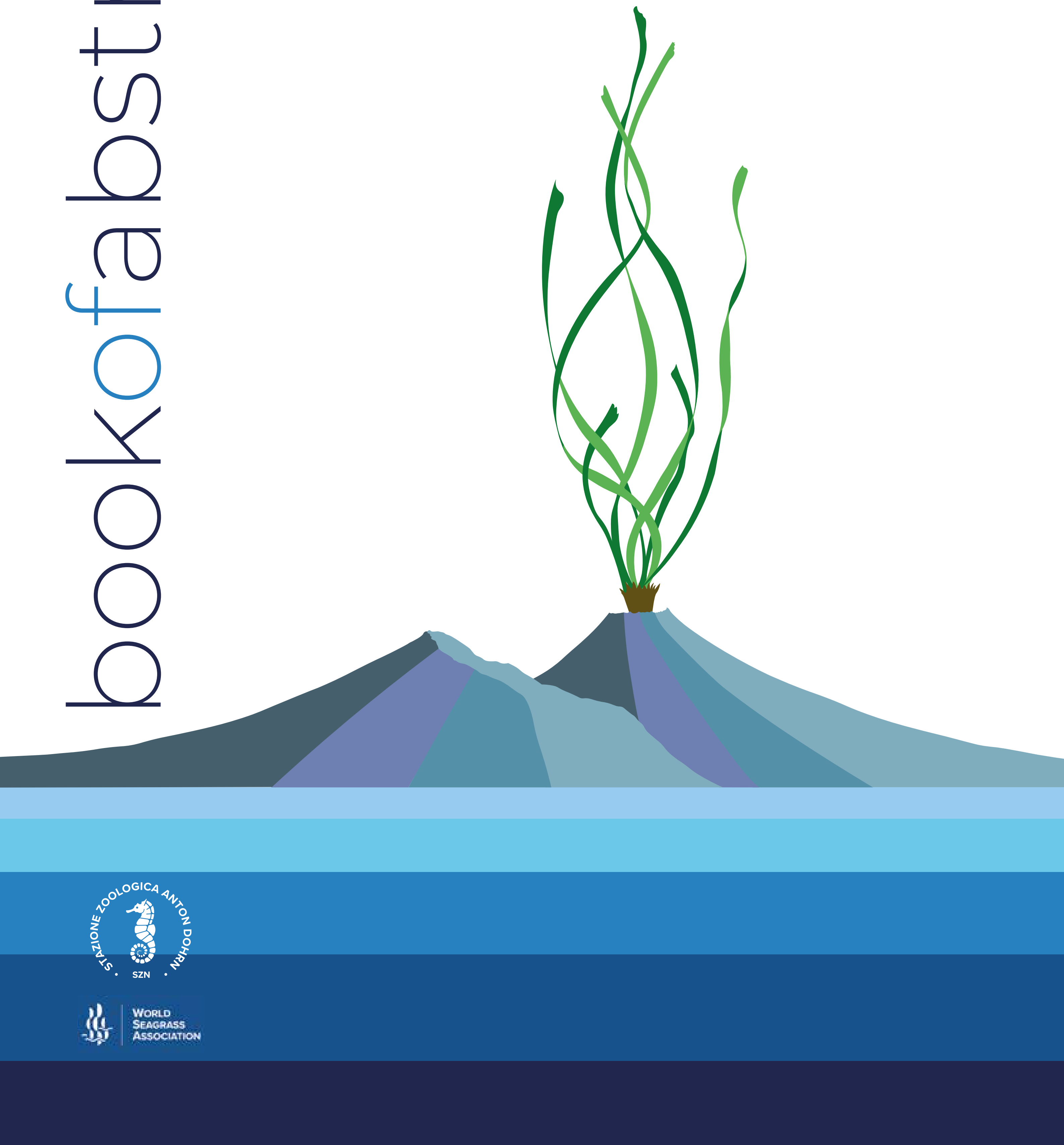
book of abstract

ISBW15 & WSC2024

NAPOLI, ITALY, JUNE 17TH TO JUNE 21ST, 2024



2024 World Seagrass Conference &
15th International Seagrass Biology Workshop
Seagrasses in the Anthropocene

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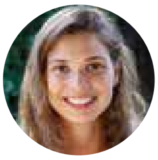

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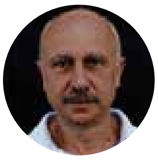

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Seagrasses in the Anthropocene

The 2024 World Seagrass Conference (WSC2024) & 15th International Seagrass Biology Workshop (ISBW15) will take place in Napoli, Italy, from June 17th to June 21st, 2024.

The theme of WSC2024 and ISBW15, Seagrasses in the Anthropocene, come from the knowledge that seagrass ecosystems are facing an accelerating human pressure at local and global scales. Environmental changes are transforming seagrass ecosystems into new configurations unlike anything observed before. Returning to past configurations is no longer an option.

The global challenge is to establish a new baseline, protect, restore, and rehabilitate the existing resource.

The key questions to address are:
To which extent species are resilient to environmental changes?
Which are the mechanisms behind that?
What can we do to ensure seagrass sustainability?
Which methodologies can we apply and/or further develop for keeping meadows functional?
How can we effectively combine socio-economic, cultural and management approaches with the basic science?

ISBW15 and WSC24 will strive to answer these questions with three themes:
– Theme 1 : Seagrass responses to environmental change
– Theme 2 : Seagrass community diversity and species interactions
– Theme 3 : Seagrass conservation, management and citizen science

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Plenary Speakers

Opening Plenary

Seagrass science in an international cooperation and policy context: A game-changer opportunity not to miss

Salvatore Aricò
PhD, CEO, International Science Council

Seagrass systems are increasingly referred to in the context of international policy processes as a promising response to inter alia climate change mitigation and adaptation. The science underpinning the contribution of seagrasses to globally agreed goals is also increasingly coordinated, and the ensuing knowledge actionable. Yet there is a disconnect between action on the needed conservation and sustainable use, and the sharing of benefits deriving from the maintenance of healthy seagrass systems, and the lack of integrated policies to ensure that seagrasses are capitalized upon as our best bet in the quest of sustainability. The 2024 World Seagrass Conference & 15th International Seagrass Biology Workshop offer an opportunity for the global voice of seagrass science to contribute to the vision of science as a global public good, in an era of global change, inequalities and polarization.

Theme Plenary

THEME 1

Thorsten Reusch
GEOMAR
Helmholtz-Centre for Ocean Research Kiel and Kiel University, Germany

A return to the sea – adaptations of seagrasses across scales

This keynote will give an overview on the breathtaking range of adaptations of seagrasses that were required to successfully return to the stressful ocean environment, but also to increasing levels of stress related to global change. Much can be learned from omic-guided approaches. For example, gene losses and gene family expansions facilitate light harvesting, hypoxic metabolism and salt tolerance across all three seagrass lineages. Population-genomic approaches permit an assessment of historical demography driven by glacial bottlenecks, allow the reconstruction of refugia, and permit the analysis genome-phenotype associations. Transcriptome profiling allows the detection of seagrass stress markers and priming effects. As clonal species, seagrasses are also ecellent examples as to how clones can diversify phenotypically through within-clone genetic and epigenetic evolution. Coupling these processes with purely ecological approaches is imperative as a basis for evolution-guided restoration measures in a rapidly changing ocean environment.

Theme Plenary

THEME 2

John J Stachowicz (Jay)
Professor, Department of Evolution and Ecology
University of California Davis (USA)

Darwin's Entangled Bank: interactions among seagrass, its associated animals, and the microbiome in a changing ocean.

Seagrasses are ecosystem engineers, but this engineering function depends on plant morphological and physiological traits, which vary among individuals and populations and with environmental change. In this talk, I will assess how genetically based and plastic variation in seagrass traits affect the diversity, composition and functioning of their associated communities. Global and local variation in seagrass form leads to predictable changes in epifaunal communities, but what are the consequences of this variation for seagrass ecosystems? Growing understanding of the role of the seagrass microbiome is revolutionizing our understanding of seagrass stress tolerance and disease ecology, but how much of plant adaptation and plasticity is microbially-based? How does the seagrass microbiome influence the better-known interactions between seagrasses and macrofauna? Integrating community and microbial ecology with our emerging understanding of seagrass trait, genetic and functional diversity can address these questions and enhance conservation and restoration of seagrass ecosystems in a changing world.

Theme Plenary

THEME 3

Jacqueline Uku
Kenya Marine and Fisheries Research Institute
Mombasa, KENYA

Seagrass conservation, management and citizen science

The degradation of seagrass meadows is prevalent in the Western Indian Ocean (WIO) region due to fishing impacts, anchor damage, sea urchin herbivory, extreme events such as cyclones and floods, and anthropogenic factors such as pollution and sediment inflows. In response to seagrass habitat degradation, there have been numerous efforts to advance the restoration of seagrass beds in several countries in the region. This presentation will focus on experimental restoration efforts in three countries of the WIO: Kenya, Tanzania and Mozambique. The conservation challenges and lessons learned will be elaborated as well as the integration of communities in citizen science initiatives.

Scientific Sessions

SS01 – Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene
Main-conveners: Marjolijn Christianen (Wageningen University, The Netherlands) – marjolijn.christianen@wur.nl

Co-conveners: Justin Cambell (Florida International University), Nicole Esteban (Swansea University), Fee Smulders (Wageningen University)

SS02 – Large scale approaches to seagrass ecology: integrating diverse approaches to produce a global view of seagrass ecosystems
Main-conveners: Jay Stachowicz (University of California Davis, USA) – jjstachowicz@ucdavis.edu

Co-conveners: Emmett Duffy (Smithsonian Institution)

SS03 – Seagrass trait-based ecology applied to seagrass responses to environmental change, biodiversity, ecosystem services, and conservation.
Main-conveners: Carmen B. de los Santos (Centre of Marine Sciences of Algarve, Portugal) – cbsantos@ualg.pt

Co-conveners: Camilla Gustafsson (Tvärminne Zoological Station, University of Helsinki) – Agustín Moreira-Saporiti (Marine Biological Laboratory)

SS04 – Seagrass genetics in the Anthropocene
Main-conveners: Patrick Larkin (Texas A&M University-Corpus Christi, USA) – patrick.larkin@tamucc.edu

Co-conveners: Paul Bologna (Montclair State University), Traci Erin Cox (University of New Orleans), Randall Hughes (Northeastern University), Ester Serrao (CCMAR), Jay Stachowicz (University of California Davis)

SS05 – Seagrasses in 'the real world': resisting and recovering from multiple stressors
Main-conveners: Hung Manh Nguyen (Ben-Gurion University of the Negev, ISR) – manhhung.hou@gmail.com; Chanelle Webster (Edith Cowan University, AU) – chanelle.webster@ecu.edu.au

Co-conveners: Kathryn McMahon (Edit Cowan University), Nicole Said (Edit Cowan University), Fiona Tomas Nash (IMEDEA), Gidon Winters (Dead Sea Arava Center)

SS06 – Ocean acidification research in seagrass ecosystems: From impacts to solutions
Main-conveners: Gema Hernan (Mediterranean Institute for Advanced Studies, Spain) – gemahernanm@gmail.com

Co-conveners: Iris Hendriks (Mediterranean Institute for Advances Studies), Aurora M Ricart (Institut de Ciències del Mar)

SS07 – Macro-micro interactions in seagrass ecosystems
Main-conveners: Ulisse Cardini (Stazione Zoologica Anton Dohrn, Italy) – ulisse.cardini@szn.it

Co-conveners: Fabio Bulleri (University of Pisa), Paul Gribben (University of New South Wales)

SS08 – Seagrass Microbe Interactions – Harnessing the Microbiome
Main-conveners: Aschwin Engelen (CCMar, Portugal) – aengelen@ualg.pt
Gina Chaput (University of California, Davis, United States) – gmchaput@ucdavis.edu

SS09 – Novel approaches to assist seagrasses in a changing environment
Main-conveners: Jessica Pazzaglia (Stazione Zoologica Anton Dohrn, Italy) – jessica.pazzaglia@szn.it

Co-conveners: Thorsten Reusch (GEOMAR, Kiel), Lázaro Marín-Guirao (CSIC-IEO, Murcia), Isabella Provera (Stazione Zoologica Anton Dohrn)

SS10 – Bird's Eye views of Seagrassscapes
Main-conveners: Dimitris Poursanidis (Foundation for Research and Technology Hellas, Greece) – dpoursanidis@iacm.forth.gr

Co-conveners: Vassilis Papathanasiou (Fisheries Research Institute, Greece) – vpapathanasiou@inale.gr

SS011 – Seagrass observing and monitoring for the future
Main-conveners: Marlene Jahnke (Gothenburg University, Sweden) – marlene.jahnke@gu.se; Lina Mtwana Nordlund (Uppsala University, Sweden) – lina.mtwana.nordlund@geo.uu.se

Co-conveners: Emmett Duffy (Smithsonian Institution), Eduardo Infantes (Gothenburg University), Per Moksnes (Gothenburg University)

SS012 – Securing resilient and just seagrass social-ecological systems
Main-conveners: Benjamin Jones (Project Seagrass) – ben@projectseagrass.org

Co-conveners: Lucy Coals (Deakin University & Project Seagrass), Leanne Cullen-Unsworth (Project Seagrass), Jennifer Rehage (Florida International University), Lina Mtwana Nordlund (Uppsala University)

SS13 – Toward better understandings and conservation of Tropical Asian Seagrasses: Succeeding the will of Prof. Miguel D. Fortes (1947-2023)
Main-conveners: Masahiro Nakaoka (Hokkaido University, Japan) – nakaoka@fsc.hokudai.ac.jp

Co-conveners: Maria Lourdes San Diego-McGlone (University of the Philippines), Wilfredo Campos (University of the Philippines)

SS14 – Seagrass restoration
Main-conveners: Agostino Tomasello (University of Palermo, IT) – agostino.tomasello@unipa.it

Co-conveners: Salvatrice Vizzini (University of Palermo), Geraldina Signa (University of Palermo), Francesco Rende (ISPRA), Leonardo Tunesi (ISPRA), Fabio Badalamenti (CNR-IAS), Monica Montefalcone (University of Genova)

SS15 – Recurring and emerging topics in the Anthropocene (open session)
Main-conveners: Irene Olivé (Stazione Zoologica Anton Dohrn, Italy) – irene.olive@szn.it

Co-conveners: Emanuela Dattolo (Stazione Zoologica Anton Dohrn), Gabriele Procaccini (Stazione Zoologica Anton Dohrn)

Abstracts are ordered following the Congress Program

SS05 – Seagrasses in 'the real world': resisting and recovering from multiple stressors

Signatures of rapid acclimation to ocean warming of the seagrass Halophila stipulacea in the Gulf of Aqaba

Hung Manh Nguyen[1,2], NetaLy Lipkin[1,3,4], Moran Kaminer[1], Beery Yaakov[2], Simon Barak[2] and Gidon Winters[1,5]

[1]Dead Sea and Arava Science Center (DSASC), Masada National Park, Mount Masada, 8698000, Israel
[2]French Associates Institute for Agriculture and Biotechnology of Dryland, The Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Sede Boqer Campus, 8499000, Israel
[3]University of Haifa 199 Aba Koushy Ave., Mount Carmel Haifa 3498838, Israel
[4]Oceanographic and Limnological Research, Haifa 3109701, Israel, [5]Eilat Campus, Ben-Gurion University of the Negev, Hatmarim Blv, Eilat, 8855630 Israel

The occurrence of extreme warming events in the Gulf of Aqaba (GoA) may prime the seagrass Halophila stipulacea to better survive future ocean changes. To verify this hypothesis, we gathered sea surface temperature (SST) data in the GoA over the last 16 years and conducted a mesocosm experiment examining single and combined effects of ocean warming (26° vs. 32°), eutrophication (2μM vs. 20μM of NO_3^-) and acidification (pH8.2 vs. pH7.6). The treatments were applied for 5 weeks on two GoA H. stipulacea populations experienced different anthropogenic levels using comprehensive measurements of plant stress response. Data showed clear rises in average SSTs and extreme warming days, especially over the last five years. For both populations, plants maintained their number of shoots, growth rates and effective quantum yield when subjected to temperature and nutrient increase (single or combined), whilst the lower pH was beneficial only under combined conditions. RNA-seq transcriptome analysis revealed similar gene expression profiles in response to single and combined stressors. The plants in this study appeared more tolerant to stresses than those from the same populations in 2017 and 2019, indicating a rapid acclimation to ocean warming, which might support the future existence of H. stipulacea in the GoA

SS05 – Seagrasses in 'the real world': resisting and recovering from multiple stressors

Marine heatwaves and light limitation independently alter the growth, productivity and leaf microbiome of the tropical seagrass Halophila ovalis

Alissa Victoria Bass[1], Laura Jane Falkenberg[1,2], Haiwei Luo[1], Benoit Thibodeau[1]

[1]The Chinese University of Hong Kong, Shatin, Hong Kong SAR, [2]University of South Australia, Australia
E-mail: alissabass@link.cuhk.edu.hk

Seagrasses are threatened by anthropogenic change, both climate and non-climate related. Two stressors which can have negative impacts on seagrasses and seagrass ecosystems globally are marine heatwaves (MHWs) and light reduction, i.e. 'coastal darkening'.
In this experiment, we exposed the tropical seagrass Halophila ovalis to a 10-day MHW and three light intensities to examine the impacts of these two stressors on the growth, productivity, elemental cycling and leaf microbiome of the seagrass. We found that both MHW and decreased light negatively impacted the growth of the seagrass, particularly the rhizome elongation rate, and the leaf growth rate, as well as increasing the rate of leaf loss. Similarly, chlorophyll concentration was altered by both stressors, with the normal adaptational responses to reduced light (i.e., increasing chlorophyll concentration) being inhibited by the MHW. Nitrogen assimilation rate also decreased under both MHW temperature and reduced light availability.
From these results, we show that MHWs can drive decreased productivity of seagrass, particularly when combined with low light availability. Furthermore, MHWs can reduce the ability of H. ovalis to adapt to lower light levels. Poor water clarity and habitat health can therefore increase the susceptibility of seagrasses to extreme climatic events.

SS05 – Seagrasses in ‘the real world’: resisting and recovering from multiple stressors

Effects of sunscreen exposure on Posidonia oceanica (L.) Delile under an increased seawater temperature scenario

Manuela Gertrudis García-Márquez[1], Sandra Muñoz Entrena[1], Cassandra Clement[1], Nona S. R. Agawin[1]

[1]Marine Ecology and Systematics (MarES), Department of Biology, University of the Balearic Islands, Cra. de Valldemossa, km 7.5., Palma de Mallorca, Spain, manuelag.garciam@uib.es

The environmental risk of coastal susnscreen pollution and ocean warming to seagrass meadows seems to be greatly intensified in the Mediterranean basin, due to its semi-enclosed nature that limits water renewal and the high influx of tourists it receives every year. Both of these stress factors could be interacting synergistically, thus, contributing to the current decline of Posidonia oceanica meadows. Our study aimed to determine the response of P. oceanica to the combined effects of elevated seawater temperature and sunscreen addition in a short-term laboratory experiment, testing an environmentally relevant sunscreen concentration in Mallorca, Spain (20 mg L^{-1}) and a control (0 mg L^{-1}) with the ambient temperature in spring (15 °C) and a worst case scenario of estimated temperature increase by 2100 (ambient + 5 °C). Sunscreen addition promoted net primary production rates in the seagrass under ambient temperature, while alkaline phosphatase activity (APA) in leaves was inhibited by the sunscreen treatment under increased temperature. Early-warning signs of the impacts of combined elevated temperature with sunscreen exposure in P. oceanica were the drastical decrease in leaf chlorophyll concentrations and nitrogen fixation associated with rhizomes (more than 50% and 100%, respectively), along with greater oxidative stress biomarkers in leaves (i.e., catalase activity and polyphenols content) and APA in roots (4-fold increase).

SS05 – Seagrasses in 'the real world': resisting and recovering from multiple stressors

Influence of warming and disease on carbon metabolism and dissolved organic carbon fluxes in eelgrass (Zostera marina) communities

RYAN S. MUELLER[1], LUIS G. EGEA[2], R. JIMÉNEZ-RAMOS[2], MARY K. ENGLISH[1], FIONA TOMAS[3]

1.Department of Microbiology, Oregon State University, 254 Nash Hall, Corvallis, 97331, Oregon, USA
2.Department of Biology, Faculty of Marine and Environmental Sciences, University of Cadiz, International Campus of Excellence of the Sea (CEI·MAR), 11510 Puerto Real, Cádiz, Spain
3.Instituto Mediterráneo de Estudios Avanzados (CSIC-UIB), C/ Miquel Marques 21, 07190, Esporles, Balearic Islands, Spain

Climate change and disease are two major challenges faced by seagrass systems, which play a critical role in carbon cycling and provide key ecosystem services to humans, including their contribution to blue carbon. Zostera marina (eelgrass) is increasingly affected by warming, and is also regularly infected by Labyrinthula zosterae, the causative agent of wasting disease. However, the effects of these stressors on carbon metabolism and dissolved organic carbon (DOC) fluxes in eelgrass remain unexplored. In a mesocosm experiment involving a simulated marine heat wave (MHW) followed by pathogen challenge with L. zosterae, we observed that the MHW decreased net production rate (NPR) (but did not change respiration) and DOC fluxes, being the released DOC more recalcitrant. Yet, Z. marina appears to be resilient to the heatwave, since metabolic rates and patterns of DOC fluxes recovered to control levels once the disturbance ceased. On the other hand, plants undergoing the pathogen challenge, which caused a significant decrease in aboveground biomass, exhibited significant decreases in both NPR and DOC fluxes. Our research highlights the capacity of Z. marina to contribute to blue carbon by producing recalcitrant DOC, and highlights how different stressors can impact eelgrass metabolism and DOC release.

SS05 – Seagrasses in 'the real world': resisting and recovering from multiple stressors

Dominance of heat vs. hypoosmotic stress in the tropical seagrass Thalassia testudinum

Katharina Csenteri[1]#, Jana Willim[1], Isabella Provera[2], Thorsten B. H. Reusch[1]#

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 # Correspondence: Katharina Csenteri, kcsenteri@geomar.de; Thorsten B.H. Reusch, treusch@geomar.de

Tropical coastlines host the world's largest seagrass meadows and face intensifying threats from marine heat waves (MHW) like the 2023 Carribean MHW, combined with freshening after precipitation extremes. Understanding the ecophysiological responses of tropical seagrasses to these interacting stressors remains limited. Here, we studied four clones of Thalassia testudinum from Bocas del Toro, Panama, propagated at GEOMAR culturing facilities since 2017. We performed a fully factorial aquarium experiment with two temperatures (control 28°C vs. HW 34°C) and two salinities (control 32 psu vs. 27 psu), fully crossed with clone affiliation. A four-week stress period preceeded a six-week recovery phase. Heat stress significantly reduced leaf growth rates (>60%), reaching a minimum at the HW end, gradually recovering to near pre-stress rates after six weeks. Leaf production shoot mortality and photosynthetic activity showed delayed minima three weeks into recovery. After six weeks two clones exhibited net shoot increase, while two faced continued net mortality, photosynthesis values recovered. Hypoosmotic stress effects were significantly smaller but added to adverse warming effects. This study emphasizes the significance of recovery time post-HW, highlighting delayed onset effects, and an interaction with clone identity. Future studies should focus on identifying resilient clones for seagrass conservation and management.

SS05 – Seagrasses in 'the real world': resisting and recovering from multiple stressors

Is tropical species Halodule wrightii persistence in temperate latitudes limited by seasonal alterations in water clarity and water temperature?

Madison Lytle[1] and Jessie Jarvis[2]

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Climate change and anthropogenic impacts are resulting in increasing water temperatures and impaired water quality, resulting in shifts in seagrasses range distributions and declines. Increasing water temperatures in the northwest Atlantic Ocean, a temperate-tropical seagrass biogeographic transition zone, are contributing to declines of temperate species Zostera marina. Currently Halodule wrightii, a tropical species found in this area, is not filling the gaps left by Z. marina. This pattern is particularly evident at the meadow's deep edge, indicating that light may be a limiting factor in the expansion of H. wrightii. To determine if H. wrightii persistence at temperate latitudes in the northwest Atlantic is limited by seasonal alterations in water clarity, water temperature or their interaction, monthly H. wrightii biomass and non-structural carbohydrate metrics were paired with continuous water temperature and light attenuation measurements for 2-years. While winter temperatures were physiologically stressful (<12°C), light limitation during warmer summer periods of maximum biomass and non-structural carbohydrate storage development also limited the ability of H. wrightii to expand into gaps left by declines in Z. marina. Therefore, expansion of tropical seagrasses into temperate locations may be limited by multiple stressors including sub-optimal water temperatures and seasonal declines in light availability.

SS05 – Seagrasses in ‘the real world’: resisting and recovering from multiple stressors

Subtidal eelgrass can tolerate high salinity fluctuations

Katrin Rehlmeyer1, Dindi Hiddink-Verberne1, Ellis Weinberg1,2, Roos van Dorp1,2, Hans van Veen1, Tjisse van der Heide1,3, Oscar Franken1,3, Laura Govers1, 3

1University of Groningen, Nijenborgh 7, 9747 AG Groningen, the Netherlands, k.rehlmeyer@rug.nl
2Van Hall Larenstein University of Applied Sciences, Agora 1, 8934 CJ Leeuwarden, the Netherlands
3Royal Netherlands Institute for Sea Research, Landsdiep 4, 1797 SZ Den Hoorn, the Netherlands

Until the 1930s, subtidal eelgrass meadows (~150 km2) thrived in the Dutch Wadden Sea but went extinct due to a wasting disease outbreak coinciding with the construction of a >30 km long dam. The dam closed off over 1800 km2 of estuary, altering hydrodynamics, tidal range, and salinity. Instead of a gradual salinity increase from estuary to sea, freshwater now enters the Wadden Sea in pulses through sluices, causing high salinity fluctuations of ~12 PSU. Donor plants are required for restoration, but the impact of the system’s light regime combined with salinity fluctuations on eelgrass is unclear. In a mesocosm study, we measured morphological and physiological responses of Danish eelgrass to five salinity levels (20; 20±6; 28; 28±6; 31 PSU) and two light levels (~70; ~200 µmol photons m-2 s-1). Salinity fluctuations showed no significant effect, but a 70% light reduction resulted in a -43% decrease in shoot numbers, -44% in leaf numbers, and -42% in aboveground biomass. Our findings suggest that the targeted donor material can tolerate high salinity fluctuations in situ but may struggle with low light conditions. We thus show that controlled experiments may help identify bottlenecks for the reintroduction of seagrass in heavily altered coastal systems.

SS05 – Seagrasses in 'the real world': resisting and recovering from multiple stressors

Expected beneficial effects of high CO2 on Posidonia oceanica are dampened by acute and chronic exposure to complex volcanic fluids in a shallow vent (Panarea Island, Aeolian Archipelago, Mediterranean Sea)

Salvatrice Vizzini1,2,3, Geraldina Signa1,2,3, Giovanna Cilluffo1,2,3, Agostino Tomasello1,2,3

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Seagrasses are expected to thrive in future acidified oceans by overcoming low CO_2 diffusion into their tissues. Much information comes from studies of naturally acidified sites such as volcanic vents. However, at such sites CO_2 emissions are often associated with toxic gases (H2S) and metal-rich fluids, allowing us to assess the response of seagrasses to complex environmental conditions. Here, we summarise the results of studies conducted at a shallow Mediterranean vent (Panarea Island, Aeolian Archipelago, Sicily, Italy) to assess the response of the long-living and slow-growing seagrass Posidonia oceanica to both acute and chronic exposure to volcanic fluids. Using a retrospective approach (i.e., lepidochronological analysis), growth performance and $\delta^{13}C$ of sheaths and rhizomes revealed a sudden and intense physiological stress following an exceptional volcanic explosion, with a complete recovery occurring after 8 years. At the same time, while persisting when exposed to chronic complex volcanic fluids, P. oceanica showed reduced performance from the leaf to the meadow level. These findings indicate that the expected beneficial effects of high CO_2 levels may be dampened by other environmental factors, and at the same time suggest the resilience and acclimatisation ability of P. oceanica under future global change scenarios.

SS05 – Seagrasses in 'the real world': resisting and recovering from multiple stressors

Assessing the effects of anthropogenic stressors on the health and biodiversity of seagrass beds in southeast Tasmania

Elisabeth MA Strain1, Kelsie Fractal1, Cailin Wise1, Jeff Wright1

1 Institute for Marine and Antarctic Science, University of Tasmania, Hobart, Tasmania, 7004, Australia
elisabeth.strain@utas.edu.au

Seagrass beds provide a range of essential ecosystem services such as sediment stabilisation, nutrient cycling, and serving as critical breeding, feeding and nursey grounds for associated taxa. However the determinantal effects of anthropogenic activities on water quality degradation remains the leading cause of seagrass habitat loss. Here we examined the effects of stormwater drains, position in the estuary and leaf characteristics on the health and biodiversity of Heterozostera nigricaulis and Zostera mulleri beds, in sites across southeast Tasmania. Our results showed distance to stormwater outfalls had a negative effect seagrass leaf length, above-ground biomass, below-ground biomass, and a positive influence on filamentous brown epiphyte cover and the abundance of sulphur reducing bacteria. The carbon and nitrogen stable isotope values in the sediment and seagrass rhizome showed greater influences of terrestrial and anthropogenic nutrient inputs at sites in the upper than lower estuary. Lower macrofaunal diversity was observed at sites with increased epiphyte algal cover and reduced structural complexity of seagrass leaves. Overall, these findings contribute valuable insights into the intricate dynamics of seagrass ecosystems in southeast Tasmania, emphasizing the need for holistic management strategies that consider both anthropogenic and natural factors to ensure the long-term health and resilience of these essential habitats.

SS05 – Seagrasses in 'the real world': resisting and recovering from multiple stressors

Insights of seagrass recovery capacity following green turtle grazing: a critical slowing down approach

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Seagrass meadows are bi-stable systems; such a system does not change visibly when approaching a critical point, but recovery is then slower after a minor disturbance, known as "critical slowing down." In the Mexican Caribbean, we studied seagrass dynamics under rotational turtle grazing. We conducted burial disturbance-recovery field experiments, and hypothesized that sustained turtle grazing (beyond normal grazing levels) would impact seagrass recovery. Experimental disturbance (10 cm burial in xx cm2 areas) in treatment plots between xx and yy m2 were applied. The treatment plots, based on time of (simulated) grazing, were: short-term (4 months of cutting), medium-term (8 months of cutting), long-term (8 months of cutting in previously grazed areas =sustained grazing). We also observed natural-recovery (for 8 months) in previously grazed areas. Recovery was highest in the unburried areas, and it diminished slightly in the buried areas of the short and medium term grazing treatments. Long-term grazing decreased recovery notoriously, and led to a significant post-disturbance loss of belowground biomass (99%). Previously grazed plots were recently abandoned by the turtles, and showed recovery, if not further disturbed. Hereby, we provide evidence of "critical slowing down" under sustained turtle grazing, and aparently, the turtles "know" when to stop grazing.

SS05 – Seagrasses in ‘the real world’: resisting and recovering from multiple stressors

Spread and impacts of Non-indigenous benthic ecosystem engineers within intertidal seagrass meadows in the context of global change

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Arcachon bay, a coastal lagoon located in southwestern France, used to shelter one of the largest intertidal Nanozsotera noltei seagrass meadow of Europe. The lagoon also hosts oyster farming activities which contributed to the introduction of numerous non-indigenous species during the last decades. Among them, benthic ecosystem engineers such as the Asian mussel Arcuatula senhousia, the sponge Celtodoryx ciocalyptoides and the macroalgae Gracilaria vermiculophylla have established durabily, colonizing N. noltei meadows. Here, we first present the results of a combination of extensive benthic monitoring surveys and aerial habitat mapping. We thereby document both spatial and temporal increases in the presence and abundances of these species, associated with pronounced impacts on benthic community structure, especially at high ecosystem engineers’ density. Futhermore, through lab experiments carried out in controlled conditions, we show that increasing densities of ecosystem engineers such as A. senhousia significantly affect benthic metabolism (oxygen and nutrient fluxes) within seagrass meadows, and that these effects are mediated by the occurrence and the intensity of atmospheric and marine heatwaves we also manipulated. These highlight the importance of understanding the interactive effects of co-occurring environmental stressors and their dependencies for a better assessment of the impacts of global change on seagrass ecosystems.

SS05 – Seagrasses in 'the real world': resisting and recovering from multiple stressors

Light and hydrogen sulfides alter the fate of inorganic carbon in the seagrass Halophila ovalis

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Seagrasses are critical global carbon sinks, yet declining at rapid pace. Phytotoxic hydrogen sulfides (H_2S) and light deprivation are known drivers of seagrass loss worldwide, however, the underlying physiological mechanisms are not well understood. To address this knowledge gap, we explored the fate of inorganic carbon (Ci) in Halophila ovalis which were exposed to either low light (88% shade), ii) sediment H_2S stress, or iii) the combination of both factors in a mesocosm setting. A ^{13}C tracer ($NaH^{13}CO_3$) was then used to investigate differences in Ci acquisition, translocation and metabolite incorporation. Ci acquisition into seagrass leaves was impacted by both H_2S and low light stress with synergistic effects occuring when both stressors were combined. Below-ground data suggest that H_2S interferes with carbon translocation from the leaf into the rhizome. Incorporation of ^{13}C into leaf sugar pools was impacted under both H_2S toxicity and light deprivation. In addition, low light affected critical intermediates of both glycolysis and the tricarboxylic acid cycle. Overall, this study suggests that it is likely a multi-level (acquisition, translocation, metabolism) disruption of the carbon budget that causes a decline in seagrass health and survival under both H_2S and low light stress.

SS05 – Seagrasses in 'the real world': resisting and recovering from multiple stressors

Eutrophication and Global Climate changes as drivers of Marine Ecosystem Regime Shifts: The Case of the Mar Menor Lagoon

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The eutrophicated Mar Menor coastal lagoon (Mediterranean, SE of Spain) suffered a intensive phytoplankton bloom in 2015-2016 inducing the collapse of dominant macrophyte communities (the seagrass Cymodcea nodosa and the macroalgae Caulerpa prolifera). We aimed to document the subsequent evolution of benthic macrophytes and to assess the potential implications of global climate change drivers in the lagoon dystrophic crisis. We assessed changes on the distribution of benthic macrophytes over time and factors potentially drove vegetation die-off (light limitation). One year of extreme turbidity was enough to promote abrupt decline of vegetation, and only the macroalgae was able to recolonize the entire lagoon bottom seven years later. To test the contribution of global climate factors, we statistically analyzed breakpoints of decadal time series of temperature, rainfall, salinity and irradiance. They revealed that increasing trends of marine heat waves and extreme rainfall events could have been involved in the sudden lagoonal regime shift and the environmental instability of the system, that experienced recurrent episodes of extreme turbidity, low salinity and anoxia. These results support the notion that the coupled loss of ecosystem services due to local pressures and global climate change could be one of the major causes of the accelerated collapse of coastal ecosystems.

SS05 – Seagrasses in 'the real world': resisting and recovering from multiple stressors

Identification of benthic light thresholds of Zostera marina transplants and implications for depth limits and restoration

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Eutrophication has resulted in a state change from eelgrass dominance to bare sediment in coastal areas in Denmark. This alternate steady state of the marine environment is difficult to reverse due to multiple stressors. Epiphyte growth, opportunistic macroalgae blooms, anoxia, deteriorated sediment conditions with increased resuspension frequency and reduced anchoring capacity, but most importantly decreased benthic light penetration as a result of increased phytoplankton production. Our recent study in Denmark aimed to quantify the benthic light and depth threshold that limits restoration of eelgrass. The study was conducted in the estuary Vejle Fjord, and used a field based approach using transplantations along depth gradients combined with benthic PAR-loggers. The depth gradients were placed at sites with varying eutrophication. Results suggest that the prevalence of stressors directly affect the benthic light requirements for eelgrass growth, resulting in different light thresholds depending on local stressor levels. This effect combined with the reduced light penetration have greatly reduced the depth limits of eelgrass, especially in esturaries close to point sources with high nutrient inputs. Furthermore, the study demonstrated that eelgrass transplantation is possible deeper than the current depth limits of natural populations (according to the Danish EPA), suggesting that natural recovery is lacking.

SS05 – Seagrasses in 'the real world': resisting and recovering from multiple stressors

First insight into the circadian regulation of the Zostera marina transcriptome under experimentally controlled light conditions

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Life on our planet is punctuated by biological rhythms that are driven by the cyclic variation of abiotic factors, including the celestial movements and many other geophysical processes and biological interactions. Organisms can either respond directly to these periodic variations or, often, anticipate them, taking advantage of endogenous oscillatory systems, called "circadian clocks". Circadian clocks regulate a wide variety of metabolic, developmental and behavioral processes ultimately providing fitness advantages.
Global climate changes and light pollution are threatening the biological rhythms of many species, including marine angiosperms, leaving some important ecological questions such as: is the thermal-photic mismatch affecting the physiology and the distribution of seagrasses? How does this impact seagrass ecosystem functioning? To answer these questions, we aim to characterize the molecular basis of the circadian clock and photoperiodism in Zostera marina. To assess the effect of light alterations on gene expression, we performed time-series experiments for 48h in light-dark and free-running continuous light and then, we evaluated the cyclic genes in our datasets by using JTK_Cycle algorithm. We observed that the oscillatory profile of genes being responsible for the regulation of rhythmic processes, such as GIGANTEA and LHY-CCA1, is lost or modified in continuous light.

SS05 – Seagrasses in 'the real world': resisting and recovering from multiple stressors

Identifying critical thresholds and effects of land-based pollution from nutrients and pharmaceuticals on seagrass habitats and fauna

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Seagrasses ecosystems are sensitive to multiple environmental stressors, including sedimentation and nutrient loading. Recent data shows that they are also vulnerable to emergent contaminants such as pharmaceuticals. Unknown is whether pharmaceuticals are present in the seagrass itself and may be a contributing factor to seagrass decline and to transfer to ecologically and economically-important seagrass fauna. Similarly, the degree to which nutrient and pharmaceutical pollution may be correlated and show similar thresholds as a function of distance from land-based pollution sources is not known. In this study, we focus on understanding the vulnerability of seagrass ecosystems to exposure to pharmaceuticals and to the combined exposure to pharmaceuticals and nutrient pollution. We tested seagrass fauna (both prey and higher order consumers), sediment and water for 95 pharmaceuticals. All samples contained pharmaceuticals, with a maximum of 16 pharmaceutials detected in a single fish and a total of 53 pharmaceuticals detected. Further, concentrations in fauna were detected at levels with a high risk to elicit pharmacological effects. Future sampling asks: is pharmaceutical exposure correlated with nutrient exposure in seagrasses? And are distance thresholds for land-based pollutant effects similar for nutrients and pharmaceuticals?

SS05 – Seagrasses in 'the real world': resisting and recovering from multiple stressors

Comparison of multi- and single-stressor event effects on Bahamian seagrass extent and health using Earth Observation

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The wide range of ecosystem services provided by seagrasses (e.g., biodiversity preservation and carbon sequestration) is under threat due to the impact of anthropogenic and climate related stressor events on habitat extent and health. The intensity and frequency of events like Marine Heatwaves and Tropical Cyclones is continuously increased by on-going climate change, causing a combination of multiple stressors to occur over relatively short periods of time. The combined effects of these multi-stressor events are difficult to predict compared to single-stressor events.

Satellite remote sensing offers consistent large-scale data of climate variables and is a powerful tool for mapping and monitoring seagrass ecosystems. To better understand the differences in effects between stressor events, we quantified and compared seagrass ecosystem extent changes within the Bahamian shallow water area after a single-stressor (Marine Heatwave) and a multi-stressor (Marine Heatwave + Tropical Cyclone) event.

For this, we created before and after event benthic habitat maps, utilising multi-temporal Sentinel-2 imagery at 10-m resolution and auxiliary bathymetry data within the cloud computing platform Google Earth Engine. Preliminary results indicate a strong correlation between seagrass density and vulnerability and a more severe decline of meadow extent after the multi-stressor event compared to the single-stressor event.

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Predicting Seagrass Responses to Multiple Stressors: A Theoretical Approach using GrassLight 3.0

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Although environmental requirements of seagrasses have been studied for years, our ability to predict seagrass response to climate change remains elusive because it is extremely difficult to separate the confounding impacts of multiple stressors through direct field observations and manipulative experiments constrained by practical limitations on treatment assortment and replication. In contrast, mechanistic models can combine observational and experimental results into a theoretical framework for efficiently exploring the simultaneous effects of multiple stressors on seagrass performance at time scales ranging from seconds to years. The numerical model GrassLight 3.0 provides an interactive computational environment for exploring impacts of the biogeochemical and physical environment on metabolic performance of seagrasses at scales ranging from whole plants to seagrass meadows distributed across the submarine landscape. By quantifying metabolic performance, the model can also quantify the density-dependent ability of seagrasses to ameliorate the impacts of ocean acidification impacts on oysters, alter water quality and promote carbon sequestration in shallow marine sediments. In addition, the theoretical insights derived from GrassLight 3.0 can be used to guide field observations, experimental manipulations involving multiple stressors and restoration efforts as we march deeper into the Anthropocene.

SS05 – Seagrasses in ‘the real world’: resisting and recovering from multiple stressors

Short-term effects of in situ nutrient enrichment and interactions between the seagrass Cymodocea nodosa and the filamentous green algae Chaetomorpha linum

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Although seagrasses and macroalgae often co-exist in shallow coastal waters, bloom-forming macroalgae can outcompete and dominate over seagrasses under eutrophic conditions. Understanding the circumstances in which the presence of macroalgae exerts an impact on seagrasses can help proactive management to prevent irreversible shifts. This study investigated the combined impact of shading induced by macroalgae Chaetomorpha linum and in situ sediment nutrient enrichment on C. nodosa's ecophysiology. The two-way factorial design included algae load addition treatments (Absence vs. 90%-100% cover by C. linum) and nutrient treatments (unfertilized vs. fertilized).

Both shading imposed by C. linum and nutrient enrichment, increased the photosynthetic pigment content of C. nodosa, with the latter's effect being accentuated in the presence of C. linum. Phenol foliar content also increased with C. linum presence. Algae load addition reduced foliar protein concentration independently of nutrient levels, while fertilization's impact was only observed in the absence of C. linum. Soluble sugar content in C. nodosa leaves significantly decreased with the interaction of high fertilization and algae load. Below-ground tissue exhibited an inverse pattern, unaffected by the two treatments' interaction.

These findings imply that combined stress from nutrient enrichment and C. linum shading triggered physiological adjustments in C. nodosa. Thus, incorporating physiological traits into the monitoring program can help prevent the decline and replacement of C. nodosa meadows in shallow coastal environments.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

Threats of poor water quality to seagrass are widespread across the British Iles

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With a growing interest in seagrass restoration its important that we protect existing seagrass first and understand the threats that these systems face so that conservation action can be taken. One everlasting and recurring threat to seagrass ecosystems is poor water quality, coastal development, and poor land use. The nutrient environment of seagrasses around the British Isles has now been assessed (during 2022 and 2023) at over 60 locations by examining the nutrient content and the stable isotope signature of the leaves. Alongside a small-scale assessment in 2015 this data conforms a widescale problem of low light availability brought about by high turbidity alongside extremely elevated nutrient levels relative to global averages. Offshore and island associated seagrasses are largely healthy, however estuarine and lagoon seagrasses are subjected to very high nutrient levels that place many of these meadows close to an ecological tipping point. We found a bright spot in West and North Scotland where nutrient content and stable isotope signatures indicate refuge with low nutrient impact, but expanding aquaculture threatens these sanctuaries. Excess nitrogen is largely of an organic origin highlighting the role of agriculture and poor sewage management in the degradation of coastal water quality in this region.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

Estimating the presence and diversity of microplastics in south african seagrass meadows

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Microplastics, plastic particles <5 mm in size, are a widespread phenomenon in marine ecosystems that threaten biota and human wellbeing. Seagrasses have been hypothesised to act as natural filters of microplastics due to their particle trapping abilities, yet little is known about the extent of microplastics within the sediment of seagrass beds. The aim of this study was to evaluate and compare microplastic accumulation in the sediments of Zostera capensis meadows with adjacent bare sediments in four South African estuaries. Sediment samples were collected from two locations containing Zostera capensis meadows in the middle reaches of each estuary. Density flotation was used to separate microplastics from sediments. Microplastics were identified using a stereomicroscope and microplastic identification guidelines. Polymer analysis was conducted using Fourier Transform Infrared (FTIR) Spectroscopy. In three of the four estuaries, significantly more microplastics were found in areas of dense seagrass coverage compared to areas of bare sediment. Fibres and fragments were found to be the dominant microplastic type while blue was revealed to be the dominant microplastic colour throughout the estuaries. This study confirms the trapping ability of seagrass meadows for microplastics and highlights the need for research into the negative effects of microplastics on seagrass health.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

Can posidonia oceanica meadows change the propagation of antropogenic noise and protect animals from this emergent pollutant?

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In seagrass meadows, oxygen release in the water column (air bubbles) during photosynthesis and habitat complexity (e.g. size and shape of the meadow, shoot density, canopy height) can influence sound speed and thus the properties of sound propagation in seawater. It is unknown if seagrass meadows attenuate anthropogenic noise and act as a natural shield/protection. We investigate the potential role of Posidonia oceanica meadows in noise attenuation, the role of oxygen production and shoot density. In autumn 2020 and summer 2021, we sampled 2 meadows and nearby bare sediment in Cote d'Azur, France. We placed recorders equipped with oxygen sensors (in seagrass only) during daytime and run standardized, linear boat transects at constant speed. Using acoustic inversion of the boat passages, we estimated linear relationships between sound pressure level of boat passages and range (boat position) for 100Hz bands between 200Hz and 1500Hz. The slope of this linear relation was used as attenuation estimate. Noise propagation was reduced in meadows between 800 and 1100Hz and this was partly related to seawater oxygen concentration. We discuss how our preliminary results could open research avenues towards the consideration of seagrass meadows as refuges against anthropogenic noise pollution.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

Accumulation of sunscreen components and the state of conservation of Posidonia oceanica seagrass meadows in a major coastal tourist destination in the Mediterranean Sea

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Coastal pollution in the anthropocence presents a challenge for seagrasses. The concern over emerging pollutants, such as organic and inorganic UV filters (UVFs) from sunscreen cosmetic products, has risen due to their potential impact on the over-all state of marine ecosystems. Their accumulation is particularly relevant in Mediterranean coasts, which are subject to a high tourism pressure during summer and can impact the health of the seagrass Posidonia oceanica, a key species in these coasts. Here, we report the accumulation of different organic and inorganic (TiO_2, ZnO) UVFs in P. oceanica meadows (water column, sediment and tissues) in Formentera (Balearic Islands, Spain) and their potential impact on P. oceanica through a correlational study of their state of conservation. Ti, Zn and organic UVFs (such as ODPABA, 2OHBP, 4MBC, BP3, EHMC, EHS, HMS and Octocrylene) were found in the water column, sediment and P. oceanica tissues. Octocrylene, BP3, HMS and ODPABA in the sediments is negatively correlated with density (at 100% cover) of P. oceanica while 4-MBC in the sediments, negatively correlated with leaf length and surface area. These results, albeit preliminary, prompt for considering management schemes to protect seagrass meadows in coasts receiving significant amounts of these emerging pollutants.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

Oil spill effects on seagrass ecosystems: a systematic review

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Oil spills have significant impacts on seagrass ecosystems worldwide, with the extent of damage influenced by factors such as duration of exposure, oil characteristics, response time, and clean-up methods that can cause significant and lasting damage to these environments, and there is a lack of consensus on how oil spills affect seagrass habitats. This systematic review focused on identifying patterns in the response of seagrass ecosystems to oil spills. After applying the eligibility criteria, 63 studies were selected that specifically focused on the effects of oil on various aspects, such as morphophysiology, population data, fauna and microbiome associated, and plants used for bioremediation. The results indicate that petrochemical contamination indirectly affects seagrasses in subtidal meadows. In contrast, intertidal meadows suffer direct effects as the plants are exposed to direct contact with the oil and indirect effects due to the cleaning methods used. In addition, oil spills disrupt the functioning of the ecosystem, causing the mortality of organisms and cascading adverse effects. In any case, seagrasses can also be considered an alternative for the bioremediation of Polycyclic Aromatic Hydrocarbons. As a general recommendation, monitoring should begin immediately after oil spills to assess the recovery rate of seagrasses and associated communities.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

Are macroalgal mats a threath to seagrass meadows? A field survey in a complex archipelago seascape

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Seagrasses are facing multiple local and global pressures. A common consequence of eutrophication is blooms of ephemeral macroalgae with mostly negative impacts on perennial seagrasses. However, it is often challenging to predict the variability in algal cover in space and time. Using dive transects we quantified the presence, coverage, thickness, biomass and species composition of benthic drifting macroalgal mats at 35 sites in the Archipelago of SW Finland. The sites differed in exposure, littoral slope, seagrass (Zostera marina) coverage, and water clarity. To assess the temporal variation in biomass and coverage, we monitored 7 sites 4-6 times throughout the season (June-October 2023). Preliminary results suggest that with the exception of the innermost archipelago sites, algal mats covered most sites visited. The mats consisted mostly of Ulva, Ectocarpus, Pylaiella and Cladophora. At 15 sites seagrass meadows was present. Using this data, we present an analysis of variables predicting the occurrence of algal mats, thus pinpointing environments where seagrass meadows may be particularly vulnerable. To conclude, a regional (250 km2) estimate of the total biomass (tonnes/ km2) of algal mats in the photic zone (0-10 m), and a conceptual model of seagrass-algal mat interactions will be presented.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

The green macroalga caulerpa prolifera constrains the natural recovery of seagrass meadows after eutrophication-induced coastal lagoon collapse

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Degradation of seagrass-based ecosystems is often associated with changes in environmental conditions that may impact on their natural recovery. Here we examine biotic and abiotic factors that may limit the natural recolonisation of Cymodocea nodosa meadows after a dramatic eutrophication-induced decline in the Mar Menor coastal lagoon. For this, we selected three meadows under different lagoon environmental conditions and used a comparative sampling approach within the surviving beds and outside them, in adjacent previously colonised bottoms. Seawater and sediment physico-chemical conditions outside the meadows are suitable for the species' growth, and surviving meadows showed full capacity to recolonise adjacent bottoms through vegetative growth and sexual reproduction. However, several years after the collapse, recolonisation is either non-existent or much slower than expected for this relatively fast-growing seagrass. The cause of this restriction is related to the large biomass the macroalga Caulerpa prolifera develops outside the meadows, as evidenced by experimental transplants with adult plants and seeds of C. nodosa. These findings are useful to inform a future restoration programme for the lagoon, currently dominated by the algae. Reducing nutrient loading and enhancing seagrass tolerance to C. prolifera canopy stress would be useful for assisted seagrass restoration in the lagoon.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

Allelopathic metabolites, caulerpin and caulerpenyne: their impact on posidonia oceanica

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Lessepsian species of green algae as Caulerpa taxifolia (M. Vahl) C. Agardh, 1817, and Caulerpa cylindracea Sonder, 1845, pose potential competition against native Posidonia oceanica (L) Delile (Bouderesque and Verlaque, 2002). The aim was to evaluate the allelopathic interaction between these species, utilizing the alkaloid caulerpin and the sesquiterpene caulerpenyne purified from algae (Carbone et al, 2008). Changes in leaf growth, chlorophyll content, and leaf protein expression of P. oceanica cuttings were evaluated over a 28-day cultivation period in mesocosm (Oliva et al, 2023). Caulerpenyne demonstrated a significant inhibition of the growth of adult leaves and the formation of new leaves, while inducing the elongation of intermediate ones and increasing the total chlorophyll content. Caulerpin did not significantly influence leaf growth and the formation of new leaves. Pathways such as stress response, nitrogen (N) metabolism, lipid metabolism and antioxidation were identified among the differentially accumulated proteins common to the two treatments. Findings suggest that the competitive interaction between algae of the Caulerpa genus and P. oceanica, observed in nature, may be influenced by the allelopathic action of these two molecules, albeit with diverse mechanisms and effects.

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SS015 – Recurring and emerging topics in the Anthropocene (open session)

Developing the potential of thalassia testudinum in the health sector in cuba following the nagoya protocol and the biodiversity conservation

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Seagrasses are highly valued for the goods and services they provide. Thalassia testudinum is the most important seagrass species in the Caribbean and Cuba. A potential for medicinal /pharmaceutical use of T. testudinum, while the lack of a proper legal and institutional framework and sustainable harvesting/management protocols could threaten this genetic resource. So the aims of this project are 1. To complete and implement the legal framework following the Nagoya Protocol and the ongoing introduction of a new economic model in the country; 2. Strengthening the national capacity to conclude the research-development phase of the pharmaceutical product from the species; 3. Gathering and analyzing essential information on seagrass conservation with an emphasis on the habitat and the associated biodiversity in the intervention sites; 4. To contribute to strengthening the local communities' capacity to manage and harvest genetic resources from marine biodiversity using environmentally sustainable practices. 5. To raise awareness in Cuban society about the importance of the conservation and sustainable use of genetic resources on a legal basis to foster an enabling environment to implement the Nagoya Protocol. Some of the main results about the biological aspects of the project will be presented.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

Zostera capensis: Nature based solution or band aid for chemical pollution in the Anthropocene?

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The advent of the Anthropocene is associated with many chemical pollutants entering water bodies. These include emerging contaminants (ECs) of concern such as organophosphate pesticides (OPP's) and heavy metals. Conventional treatment technology have proven ineffective for the complete elimination and removal of ECs, while half-life stability of metals allows for prolonged exposure in the environment. The aim of this research was to investigate the potential of the seagrass, Zostera capensis, as a nature based solution for chemical pollution. Zostera capensis was collected from the intertidal zone of Swartkops Estuary which is subject to industrial, agricultural and residential activities as well as the recipient of waste water effluent.
Extraction of OPP's followed by the QuEChERS method and were detected via GC-MS. Metal determinations followed acid digestion and detection with TXRF spectrometry. Bioaccumulation was found for most OPP's and metals analysed. Biota sediment accumulation (BSAF) of organophosphate pesticides and heavy metals occurred from sediment to roots and translocation of contaminants from roots to leaves was evident. The results highlight the potential for Z. capensis to be used in remediation as a nature base solution for contaminated estuaries however, it does not solve the ongoing pollution of the Swartkops Estuary.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

Seascape configuration and connectivity shapes blue carbon stock dynamics in coastal seagrass landscapes

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Coastal seascapes comprise intricate mosaics of productive key habitats, such as seagrass meadows and other shallow-water habitats. Coastal habitat are, however, highly constrained by cumulative environmental stressors and human-induced competion for space, which affect important ecosystem services such as natural carbon sinks. To safeguard sustainable climate governance, coastal managers therefore call for appropriate spatial conservation prioritization of seagrass meadows and other coastal vegetated habitats contributing to long-term blue carbon storage. Using a multiscale seascape ecology approach, we synthesized lessons learned from studies assessing the influence of seascape configuration and connectivity on coastal blue carbon stock dynamics in seagrass meadows within the western Indian Ocean. Our research identified large continuous seagrass meadows as blue carbon hotspots. Pronounced gradients from land to sea generated distinct patterns of seagrass carbon stock dynamics and source composition. Notably, land-use changes due to urban development, deforestation, and habitat degradation in coastal seascapes were shown to alter the supply and movement patterns of carbon stored in seagrass meadows. Our research clearly demonstrates the benefits of using a seascape approach to understand blue carbon dynamics in tropical seagrass meadows, and thereby contribute to climate change mitigation.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

Developing A Seagrass Blue Carbon Project While Supporting Shellfish Aquaculture Stakeholders

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In addition to being the location of the world's largest seagrass restoration project, the Virginia Coast Reserve also supports a thriving hard clam (Mercenaria mercenaria) aquaculture industry. This industry relieves harvest pressure on wild shellfish populations and is an important part of the local economy, with landings valued at $31.9M USD in 2021. However, there is overlap in regions of subaqueous bottom that are suitable for raising clams and areas that are suitable for seagrass restoration. This talk will outline how potential use conflicts between aquaculture stakeholders and restoration projects were taken into account and managed throughout the process of developing and registering the Virginia Coast Reserve Seagrass Blue Carbon Project. Communication with the shellfish aquaculture industry has been essential in: understanding the industry's needs in the development of regulations to permit the sale of seagrass-based carbon credits, the process of defining a carbon project area, soliciting public feedback, and following the requirements of Verra's Verified Carbon Standard. Going forward, expanding our knowledge of the interactions between shellfish aquaculture and seagrass restoration may be necessary to ensure community support for the project.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

Carbon storage potential of intertidal seagrass beds in the northern Wadden Sea – grain size matters

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The Wadden Sea comprises the largest tidal flats of the world and extensive intertidal seagrass beds occur in its northern part. However, their carbon storage potential is largely unknown. Belowground burial of carbon was assessed from different locations in 4 seagrass beds. All beds are large (76 – 441 ha), with a similar cover density (60 – 80 %), species composition (dominated by Zostera noltei) and comparable age (> 90 years). The major difference is the sediment: 3 beds have established on sandy tidal flats and 1 on mud flats. Sediment cores were taken down to 45 - 65 cm depth and organic matter was measured along vertical profiles. In the sandy sediments, the permanent carbon storage was really low, with an organic carbon content below 0.4 % (average 0.22 – 0,38 %). The low content is primarily due to Zostera noltei being the dominant species which is relatively small and input to carbon storage originates mainly from internal biomass production. However, in muddy sediment the carbon content was also low but with 1.1 % about 3 times higher. Even though all tidal flat sediments are anoxic, the sandy substrates obviously allows more microbial degradation of biomass and thus more release of carbon.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

Carbon variability in UK seagrass meadows: protecting meadows for carbon benefits

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Seagrass meadows can store large quantities of organic carbon (OC) in their sediments, however, there are numerous uncertainties regarding the capacity of most seagrass beds to act as carbon sinks. These include a lack of carbon estimates from adjacent bare sediments, and a lack of replication of carbon measurements across individual beds. This study investigates the distribution of carbon across a ~4.4Ha seagrass bed in Drake's Island (UK) with the aim of informing meadow protection practices. Ten 70 cm cores were collected using a fractal design within the seagrass bed, whilst five 70 cm cores were collected from adjacent bare sediment, with increasing distance from bed edge (20-80m). Overall, seagrass cores had significantly higher OC content than adjacent bare sediment. However, high OC variability was found across the seagrass bed, with variability highest in the centre. Highest OC values were found at the edge of the bed with minimal variation between replicates. Importantly, these high OC values extended to cores from outside of the meadow, with OC% dropping below that observed within seagrass cores only after 40 m. These findings highlight the importance of considering surrounding bare sediment and spatial variability in quantifying and protecting valuable coastal carbon stores, respectively.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

Unexplored carbon pools and fluxes in posidonia oceanica: from primary production to necromass

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Posidonia oceanica seagrass beds are among the most complex and productive marine ecosystems. The fate their production may endure is highly variable, especially considering that most of it plays a role as necromass. Ineed, the balance between primary production and remineralization governs the cycle of these ecosystems. Once being shed from the original bed, the destination of dead biomass depends on the major driving forces acting on the bed (e.g. current regime and storms). The exported necromass leads to the formation of deposits both offshore, the neglected "maceration sites", and onshore, the "banquettes". They constitute an important carbon stock and a source for detrital food webs.
In this study, we investigated the fate of the primary production in a P. oceanica bed off the Ischia Island (Southern Italy, Tyrrhenian Sea). Three different compartments were considered: (i) the living bed, (ii) the maceration site, and (iii) the banquette.
The aim was to assess and quantify the associated carbon pools ad fluxes, using ecosystem accounting. Beside the well-known importance of the living seagrass beds, results shed light on the key role of their overlooked necromass in the blue carbon cycle.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

Seagrass Species Impacts on Decomposition and Sediment Carbon Stock

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Seagrass ecosystems are lauded for storing organic carbon, but storage is highly variable. Meadows can act as carbon sinks or sources, depending on microbial processes that dictate the decomposition of carbon-rich organic matter. We investigated the impacts of seagrass species composition on decomposition. We collected two species of seagrass— the pioneer species Halodule wrightii and the climax species Thalassia testudium—from 3 sites along a natural phosphorous gradient and buried them in the sediment of a mixed seagrass meadow in Cedar Key Florida USA. There was some evidence that plants collected from a low phosphorous environment were more recalcitrant, but we found that species identiy was the largest driver of seagrass decomposition. Halodule decomposed much slower than Thalassia. Despite these mechanistic findings, when we looked at standing sediment carbon stocks in meadows around Cedar Key, Thalassia meadows or meadows with mixed species assemblages were greater. This mismatch is likely because of increased stability of meadow coverage. Meadows with the climax speices or meadows with high species diversity had were more stable, and the environmental changes due to seagrass (stabilized sediment, low oxygen) outweighed any differences in the lability of dominant source material.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

Unprecedented extended reproductive behaviour of seagrass (Posidonia oceanica) after a major heatwave

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Warming can have dramatic effects on plant phenology and reproduction, with important consequences for reproductive output, plant survivorship, or species dispersal. In seagrasses, "vegetative reproduction" through clones is generally the dominant strategy for meadow maintenance and expansion, with sexual reproduction strongly differing amongst species, being rare for some, and often associated with disturbance. Even rarer is the occurrence of pseudovivipary, an uncommon phenomenon in the plant realm, which has only been reported twice before in the marine environment as highly localized phenomena associated with environmental stress. Pseudovivipary is an asexual reproduction strategy whereby plantlets replace sexual reproductive structures, leading to the maintenance of the maternal clones. In summer of 2022 the Mediterranean Sea underwent unprecedented warming, and, associated with it, we observed pseudovivipary across numerous (>85 % of 38 sampled sites) Posidonia oceanica meadows along the Balearic Islands. This is the first time pseudovivipary is reported across so many locations in a marine angiosperm, and the fate of these plantlets is being monitored by assessing development, survivorship and dispersal through time. Considering the negative impacts that warming can have on seagrass ecosystems, the discovery of widespread pseudovivipary is a critical aspect to consider for understanding mechanisms of resilience in seagrasses.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

A new approach for spatio-temporal seagrass predictions at regional scales: coupling and adapting a probabilistic model of seagrass resilience and a regional ocean model

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Across scales, seagrass meadows interact with their environment and anthropogenic pressures. In a context of climate change and increasing pressures on coastal ecosystems, tools for seagrass prediction and management should be adjustable to include various pressures, capture feedbacks between seagrass and its environment, and provide uncertainty information.
To meet these objectives, we developp a new modelling approach that couples a probabilistic seagrass model with a regional ocean model on a shared spatial grid. The coupling of the two models allows us to represent bio-physical interactions, such as the seagrass-hydrodynamics-sediment-light feedback loop, and predict seagrass dynamics on multi-year scales with a reasonable computation time. Moreover, the probabilistic model, based on a Dynamic Bayesian Network, allows the implementation of new pressures and processes by mixing information from data and expert knowledge, and gives indication on the uncertainty associated to the predictions.
Our case study is the Arcachon Bay where the total area of Zostera noltei has declined by 44% between 1989 and 2019. We ran alternative model simulations to investigate the relative influence of environmental factors (light, temperature, hydrodynamics, ...) and ecological processes on seagrass dynamics (distribution, density and physiological status of plants) throughout the bay on seasonal and multi-year scales.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

The Ecological Beach model: towards a Mediterranean network for combining a more sustainable tourism with Posidonia banquette conservation

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The increasing tourism along Mediterranean seashores is often difficult to reconcile with the preservation of the coastal landscape. A case in point are Posidonia oceanica deposits (banquettes), representing a typical feature of Mediterranean beaches, nowadays perceived as an “obstacle” to tourist activities and thus removed as a waste with relevant environmental impacts. To support eco-sustainable practices, we implemented the ECOLOGICAL BEACH model encouraging the preservation of Posidonia banquettes and beach-dune ecosystems, together with education and communication activities to improve knowledge and acceptance.
Since 2020, guidelines for the application of the model have been published and several ecological beaches have been realized (e.g. Torre Flavia, San Felice Circeo, Favignana island, Marina di Ascea in Italy, Kerkennah and Madhia in Tunisia). Moreover, monitoring activities have been carried out to investigate banquettes. Meanwhile, through education and communication activities, we can engage the public and foster a sense of ownership and responsibility towards the conservation of these fragile ecosystems.
The creation of a Mediterranean Network of the Ecological Beaches is the next important step for this process to: i) facilitate the acceptance of Posidonia banquettes across the Mediterranean Sea ii) transfer sustainable management to Mediterranean beaches.

SS015 – Recurring and emerging topics in the Anthropocene (open session)

Economic valuation of restored eelgrass at the virginia coast reserve

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The eelgrass restoration project at the Virginia Coast Reserve is the largest and most successful seagrass restoration project on the planet. The planting of 240 hectares of eelgrass has expanded into over 3,600 hectares of restored meadows, which now provide significant benefits to people and nature. This works builds upon previous valuations by Abt Associates (2014) and Kerns et al. (forthcoming) by presenting an estimate for the total economic value of the restored seagrasses based on six ecosystem service flows: commercial fisheries, biodiversity, water purification, erosion control, recreational fisheries and carbon sequestration. We estimate that the seagrass restored by this project provided benefits of $82.84 per hectare per year in 2018, and that the total economic value of the seagrass beds over 50 years could reach $22.89 million with continued expansion until the maximum available ecological niche of 10,700 hectares is filled. Although carbon sequestration has the highest monetary value, over 40% of the total value comes from non-carbon benefits, with the biggest contribution being seagrass' support to recreational fishing. These results highlight the importance of blue carbon projects beyond their carbon sequestration potential, which will be critical as we face increasingly complex resource allocation decisions in environmental conservation.

SS011 – Seagrass observing and monitoring for the future

Diverging trends of coastal ecosystem extent and condition: global seagrass monitoring highlights the need for coordinated data collection at multiple scales

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Vegetated coastal ecosystems are recognized for the services they provide but are declining globally. As a result, actions to monitor, assess, and manage these systems have been taken to ensure their continued benefit to nature and people. A variety of monitoring programs have been deployed at multiple scales of observation, from estimations of areal extent to in-situ observations of local condition (e.g., cover). However, it is rare that monitoring programs observe both scales simultaneously, and it is unclear to what extent observations from both scales can be compared, integrated, or even used interchangeably in regional and global syntheses of status and trends. Here, we analyzed data from five independent seagrass monitoring programs to test for correlation and causation between observations of areal extent and local condition. We found that, generally, trends in local condition were decoupled from changes in regional extent through time, and local condition data rarely detected changes before they manifested in areal extent observations. Our findings from seagrasses suggest that a comprehensive assessment of the status and trends of coastal ecosystems necessitates observations of both habitat extent and condition, and further highlights the need for coordinated efforts and open data sharing to support future monitoring efforts globally

SS011 – Seagrass observing and monitoring for the future

Using deep learning and aerial imagery to identify ecosystem resilience indicators from temporal and spatial patterns of seagrass meadows

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Multiple stressors have led to many tropical seagrass meadows switching from late-successional to dynamic early-successional states exhibiting widescale patchiness. Disentangling the natural seasonal dynamics to those imposed by different stressors is vital for understanding the ecosystem processes related to the patchiness and identifying indicators for when a seagrass meadow is at risk of collapsing – ecosystem resilience indicators. Integrating deep learning technologies with drone and satellite imagery has enabled us to examine both the spatial and temporal dynamics of remote Indonesian seagrass meadows over 10 years and build upon an existing mechanistic knowledge of the seagrass ecosystem. Previous experimentation displayed how a substantial turtle population intensively grazing on the seagrass meadows of the Derawan Archipelago in Indonesia stimulates meadow patchiness, which becomes further exacerbated by wave action in exposed areas. By quantifying how the spatial characteristics of meadows across Derawan have changed and the main drivers of this change, we showcase the efficacy of patchiness as an ecosystem resilience indicator for seagrass meadows. Combining a mechanistic understanding with aerial and satellite imagery, we detail how ecosystem dynamics within seagrass meadows can be disentangled to identify ecosystem resilience indicators that will aid us in protecting seagrass meadows.

SS011 – Seagrass observing and monitoring for the future

Mapping the variability in seagrass carbon stocks across the Caribbean

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Seagrasses are widely understood to provide considerable climate mitigation benefits through carbon sequestration and storage, notably in belowground biomass and sediments. However, critical science gaps remain in our understanding of seagrass carbon, and particularly around scaling up from field-data to large-scale quantification. To facilitate conservation of these ecosystems and their inclusion in policy and financial frameworks for climate mitigation, we need robust estimates of both seagrass extent and their carbon storage at national to regional scales. We attempt to address this need by mapping the variability in seagrass carbon stocks across the wider Caribbean, combining field data, high-resolution earth observation data, and machine learning. We leveraged existing high-resolution seagrass extent maps for the Caribbean by Schill et al. (2021) and training data from the Caribbean Carbon Accounting in Seagrass (CariCAS) project, supplemented by data from Smithsonian Environmental Research Center's Coastal Carbon Network. Combining the field data and expert input from the partners within the network, we identified spatially explicit environmental drivers for inclusion in our modeling. Initial predictions highlight the variability in the climate mitigation potential of seagrass ecosystems across the Caribbean, improving upon existing estimates and providing useful outputs for prioritizing conservation and natural climate solutions.

SS011 – Seagrass observing and monitoring for the future

Two decades of seagrass monitoring data show global decline with warming and regionally specific drivers

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Long-term monitoring of seagrass ecosystems over large spatial scales provides insights into drivers of environmental change. We compiled twenty years of Posidonia sinuosa seagrass monitoring data (2003-2022) from 61 sites over 3° latitude from south-western Australia, a global heatwave hotspot. As sites were in marine protected areas as well as urban and highly industrialised regions, and sampling overlapped a significant heatwave event, the relative importance of global and local processes were investigated. Spatial and temporal patterns in shoot density and key environmental drivers were assessed using Hierarchical Generalised Additive Models (HGAMs). We predicted that regions with warmer temperatures and more industrialisation would have greater declines over time. Considering all data, water depth, turbidity and ocean temperature were strong predictors of seagrass condition and there was a fluctuating downward trajectory from 2002-2017 associated with ocean temperature. However, the trajectory and important environmental drivers varied regionally. Cooler regions were stable and increased temperatures in summer were a strong driver of declines in more industrialised regions. This study reinforces that responses to future climate will vary regionally and safeguarding healthy meadows as potential climate refuge sites is a valuable strategy, as well as tailoring regionally specific management and conservation actions.

SS011 – Seagrass observing and monitoring for the future

Investigating the use of environmental dna for biomonitoring on scottish seagrass beds

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Environmental DNA (eDNA) metabarcoding is an emerging tool for the rapid detection of species using traces of DNA left by organisms in their environment and can be used to characterize the species composition and richness of habitats. As such, eDNA has been proposed as a low-cost alternative to traditional taxonomic surveys for routine biomonitoring.

This project employs eDNA metabarcoding to improve our understanding of macroinvertebrate diversity in three Scottish Zostera marina beds and compares species detected from sampling two common eDNA sources: sediment, and seawater. Additionally, the species detected using metabarcoding are benchmarked against 130 macroinvertebrate taxa collected from the same sites alongside the eDNA, enabling a direct comparison between traditional and eDNA methods for estimating species richness.

The outcomes of the project will inform best practices for future studies aiming to use eDNA metabarcoding on seagrass beds and highlight the advantages and limitations of using this method in place of traditional surveys. Furthermore, this work will support the establishment of biodiversity baselines for Scottish seagrass habitats.

SS011 – Seagrass observing and monitoring for the future

Establishing genetic monitoring of seagrass - an example from Sweden

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Monitoring is an essential tool for assessing biological diversity over contemporary time frames. Genetic diversity provides the foundation for biodiversity and is important for adaptation, resilience, and long-term survival. Genetic indicators that evaluate genetic diversity were recently developed and applied nationally in Sweden. Here, we present a baseline and framework for future temporal genetic monitoring of Swedish eelgrass. We investigated 15 eelgrass meadows along a steep salinity gradient along the Swedish coast with 2b-RAD sequencing as a cost-effective and reliable method for genotyping. We observed genetic differentiation with increasing spatial distance and a genetic separation between the east and west coasts. Eelgrass on the west coast had less clonality, higher genetic variation, and showed stronger population differentiation. In contrast, there was little genetic differentiation along the east coast, and clonal reproduction was frequent. The dominance of clones implies lower genetic variation, which likely negatively affects eelgrass meadows' long-term persistence in a changing climate. The genetic assessment can be used for prioritizing meadows for conservation and restoration and, most importantly, serve as an example for establishing temporal genetic monitoring for seagrass.

SS011 – Seagrass observing and monitoring for the future

Comparing expert opinion to the published literature for current and future practice in seagrass monitoring

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As efforts to monitor seagrass health have been increasing over the past few decades, practitioners have faced challenges with acquiring substantial seagrass health data. Many of the health indices are not comparable and too numerous to choose from when monitoring a seagrass habitat. Due to these challenges, seagrass health monitoring practices lack standardization. To work towards a consensus in health monitoring methods, we examined 500 papers from the available literature (peer-reviewed journals, dissertations, reports and presentations) to quantify the most used metrics for measuring seagrass health. Using these results and data that was collected from a workshop held at the 2023 UK Seagrass Symposium, a questionnaire was compiled and distributed globally to seagrass experts. The results were compared with those from the published literature to develop a proposed list of essential methods that provide the most robust, time-sensitive, and effective data for seagrass monitoring. From these results, the lack of reproductive data was highlighted, prompting the creation of SEAFLORA (SEAgrass FLowering Observation Recording Archive), a global database for seagrass practitioners to upload observations, data and photos on sexual reproductive events which will be used to inform restoration activities and seagrass research in a changing climate.

SS011 – Seagrass observing and monitoring for the future

Caribbean carbon accounting in seagrass (caricas) – a regional network for the assessment of seagrass carbon stocks

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The capability of some coastal vegetated ecosystems to sequester CO2 and store large organic carbon stocks is drawing increasing attention as a potential means of conservation-based climate change mitigation. Despite the fact that the Caribbean region supports large expanses of seagrass meadows, information on their status, trends, and carbon density is surprising sparse. Further, evidence of widespread declines of seagrasses across the region suggest that Caribbean seagrass blue carbon stocks are at risk to add to global warming. To address these uncertainties, the CariCAS project aims to 1) build a collaborative network of Caribbean seagrass scientists interested in blue carbon and to 2) outfit local experts from the new network to collect the data needed to construct inventories of seagrass blue carbon to a depth of 1m from 72 sites across 22 Caribbean nations to understand the range, variation, and environmental correlates of seagrass C stocks. These data are combined with seagrass mapping to generate first-order estimates of the amount of C stored in seagrasses across the region.

SS011 – Seagrass observing and monitoring for the future

Paleo-records and growth performance of three Posidonia oceanica barrier reefs in the central Mediterranean Sea

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Posidonia oceanica is an endemic Mediterranean seagrass forming dense meadows from the surface to about 40 m depth. This species can develop biogenic structures called matte - terraced formations of intertwined rhizomes, roots and sediment, which allow shoots to reach the sea surface forming barrier reefs. In this work, we report paleo-records of three barrier reefs along the south and north coasts of the island of Sicily (Italy) and estimate their age and accretion rates. We complement this information with lepidochronological reconstructions of the meadows growing at their top of the reefs, aided by reference growth charts. Our goal was to gain insights into the development and growth performance of P. oceanica barrier reefs in Sicily. The reefs dated back as far as ~1200 years, presenting differences in accretion rates as estimated by radiocarbon dating at different bathymetric depths. Growth performance was variable across years and sites, but consistent with data from other meadows in the Mediterranean Sea. We found substantial differences in primary productivity and speed of growth among the meadows, a possible proxy for different environmental conditions at the three locations. This information may help future research on P. oceanica reefs and contribute to their conservation.

SS011 – Seagrass observing and monitoring for the future

Evaluating the ecological status of posidonia oceanica meadows in calabria (south italy): a critical analysis of the prei index overestimation

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Posidonia oceanica meadows play a crucial role in supporting coastal nutrient cycles, preserving water quality, and safeguarding the region’s natural heritage. As a bioindicator for coastal marine waters, P. oceanica serves as outlined in the Water Framework Directive (2000). Italy and France have adopted the Posidonia oceanica Rapid Easy Index (PREI; Gobert et al., 2009) to monitor coastal marine environments under the Marine Strategy. A study conducted in six Special Conservation Areas (SACs) along Calabria’s Tyrrhenian and Ionian coasts revealed a concerning decline of up to 50% in shoot coverage and density compared to previous decades. Various stressors have been linked to this decline. Despite the observed decline, the analysis using PREI consistently indicated a “good ecological status,” regardless of the density classification. This emphasizes the need to incorporate diverse descriptors and indices for the effective monitoring of Posidonia oceanica. Notably, the PREI index tends to overestimate the quality of the meadows. Additionally, this study allowed for the evaluation of phenological data and epiphytic cover across different seasons. To enhance monitoring and conservation efforts, future research should prioritize updating and integrating parameters utilized by national and regional environmental agencies.

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SS011 – Seagrass observing and monitoring for the future

Mapping temperate seagrass distribution by using lidar bathymetry and optical satellite imagery: furneaux island in tasmania, australia

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Mapping seagrass meadows in temperate forests has been challenged by limitations of traditional optical imagery. Light absorption in the water column and the spectral overlap between seagrass and macroalgae make accurate identification difficult. This study addresses these challenges by combining high-resolution LiDAR bathymetry with public available (e.g. Landsat 8, Sentinel-2) and commercial (e.g. Planet SuperDove) satellite optical imagery to map seagrass presence and distribution in the western Furneaux Islands, Tasmania (2082 km^2). Expert knowledge and local observations gathered through interviews were used to create training and test datasets. These datasets were integrated into Google Earth Engine and analyzed using a Random Forest classifier. The results demonstrate that combining LiDAR and optical data significantly improves seagrass mapping accuracy compared to using either data source alone. Bathymetric variables, particularly depth and rugosity, emerged as crucial factors for accurate seagrass delineation. Notably, rugosity information enabled effective differentiation between seagrass and macroalgae. This study highlights the potential of incorporating high-resolution LiDAR bathymetry to enhance seagrass mapping in temperate waters with co-occurring macroalgae. The combined approach offers a robust and scalable method for monitoring and managing these critical ecosystems.

SS011 – Seagrass observing and monitoring for the future

Temporal population dynamics of exotic macroalgae in posidonia oceanica meadows using a two decade time-series

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Seagrass meadows are threatened by global change, including the impacts of invasive species. We quantified the presence of exotic macroalgae in seagrass meadows of Posidonia oceanica (16 sites; 23 stations) around four islands of the Balearic Sea (Cabrera, Formentera, Mallorca and Menorca) for nearly two decades (2006-2023). Five species of exotic macroalgae (Acrothamnion preissii, Asparagopsis taxiformis, Caulerpa cylindracea, Halimeda incrassata, and Lophocadia lallemandii/trichoclados) were identified in the meadows during the study period. Two of these species, Lophocadia lallemandii/trichoclados and Caulerpa cylindracea were sufficiently abundant in the meadows through space and time to run site-occupancy probability models. The population of Lophocadia lallemandii/trichoclados presented a polynomial curve shape: the population growth rate increased from 2008 to 2012 and then decreased steadily until 2022. On the other hand, the population of Caulerpa cylindracea increased from 2008 to 2022 indicating it is in an initial growing phase. Understanding the population dynamics of marine invasive species is fundamental to assess their impacts and for informing management strategies to control them.

SS011 – Seagrass observing and monitoring for the future

Keeping Our Eyes on Seagrass: A Two Prong Approach to Addressing Seagrass Loss in Florida, USA

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Florida is home to two of the largest contiguous seagrass meadows in the United States (Florida Bay, and the Nature Coast). However, the state is not immue to global trends of seagrass loss. High nutrient and sediment inputs from land run off, heat stress, and algal blooms are driving delcines in coverage statewide, including collapse of some seagrass meadows on the East coast. Regular monitoring is necessary to provide up-to-date assessments, but high costs of long-term monitoring regularly prevents seagrass conservation and restoration projects from reaching their full potential. Eyes on Seagrass proposes using citizen scientists to close data gaps, increase sampling capacity, and foster a sense of stewardship in participants. Methods executed by volunteers were designed with agency collection in mind, allowing integration with regulatory datasets. Since 2019, more than 70 sites have been surveyed annually across Florida outside of agency monitoring, a service valued nearly $100,000 USD. In addition, every participant gained knowledge of seagrass ecology and threats, with 90% implementing at least one behavior to help improve environmental conditions for seagrass meadows as a direct result of participating in surveys

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A Sentinel Watching Over Intertidal Seagrass Phenology

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Unlike subtidal seagrasses, intertidal seagrass meadows directly provide services to both marine and terrestrial ecosystems. Hence, they have been highlighted as an Essential Ocean Variable, as monitoring their occurrence, extent, condition and diversity can be used to indicate biodiversity and ecosystem health. Yet, monitoring large intertidal areas is resource intensive and often unfeasible. Current global estimates of seagrass extent and recent comprehensive seagrass reviews either ignore intertidal seagrasses and their seasonal. Here, using high-resolution Sentinel-2 satellite imagery, we demonstrate a cost effective method for consistently mapping intertidal seagrass meadows and their phenology at a continental scale; we further highlight the varying seasonal patterns across a 23 degree latitudinal range. Timings of peaks in seagrass extent varied by up to 5 months, rather than the previously assumed marginal or non-existent variation in peak timing. These results will aid management efforts by providing high-resolution spatiotemporal monitoring data to better inform seagrass conservation and restoration efforts. They also highlight the high level of variability in annual intertidal seagrass cover, meaning combination with subtidal seagrass for global assessments will likely produce misleading or incorrect estimates. These phenology patterns need to be better understood to improve calculations of blue carbon assets.

SS011 – Seagrass observing and monitoring for the future

Seagrass monitoring from space: on-going activities at the European Space Agency

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Remote sensing has emerged as a powerful tool for mapping and monitoring Seagrass ecosystems, as it allows for the repeated collection of large-scale and consistent data on their extent and health. In addition to primary measurements (e.g., spatial coverage, species composition, biomass estimation), remote sensing can be used to acquire information of environmental variables influencing those ecosystems (e.g. temperature, salinity, sea-level, currents, waves, wind, etc). The objective of this presentation is to give an overview of the main results of the current projects relevant to seagrass monitoring funded within the EO4Society programme element of the European Space Agency (ESA). In particular, in the frame of the BiCOME (Biodiversity of the Coastal Ocean: Monitoring with Earth Observation) project, Sentinel-2 data have been combined with in situ observations to map seagrass taxa extent in five coastal intertidal environments in France and Portugal, and two coastal subtidal environments in Mozambique and Indonesia. Other projects focus on developing improved satellite products of the pressures threatening these precious ecosystems, as marine heatwaves (CAREHeat), acidification (Ocean-Health-Acidification), or extreme winds (MAXSS). These products, all freely and openly available to the community, are an unique dataset allowing to further monitor seagrass ecosystems in a changing environment.

Spatially Explicit Uncertainty in Marine Remote Sensing and how to use it for model optimization

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Cloud-computing aid scientists to push the boundaries of accurate and robust Machine Learning (ML) models, processing vast spatial and temporal scales of data, and measuring Essential Ocean Variables (EOVs). However, these approaches lack spatially explicit accuracy information on their products.
By utilizing Google Earth Engine (GEE), we estimate the per pixel uncertainty (PUNC) of two ML procedures and use it for a data-driven selection of training points via bootstrapping, in an attempt to minimize the introduction of noise in the model. The ML procedures are benthic habitat classification and satellite-derived bathymetry (SDB). ESA's Sentinel-2 and Planet's PlanetScope data compose the remote sensing data of this research while the case studies are the whole optical-shallow coastal extent of Bahamas and Wakatobi (Indonesia) for the classification, and Belize for the SDB. Results indicate that the proposed method is able to slightly boost the accuracy of the procedures. In addition, User's and Producer's accuracy of seagrass class increased by at least 20%. Moreover, the insights of these produced uncertainty maps can help researchers and policy-makers in planning more effective field expeditions and decision-making, respectively.

SS011 – Seagrass observing and monitoring for the future

Long-term monitoring reveals a caribbean seagrass meadow on the verge of collapse

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Seagrasses on the Caribbean coast of Costa Rica have been monitored as part of the CARICOMP program since 1999. Over 24 years, seagrasses had periods of stability and seasonal variability. However, a marked decline in canopy complexity, biomass, and species composition has recently occurred. In 1999, seagrass canopy was dominated by the large and climax species Thalassia testudinum with mean leaf lengths of 18 cm and 10 mm widths. However, by March 2023 the canopy was instead dominated by the opportunistic species Syringodium filiforme with a length of 3 cm and width of 1 mm. Furthermore, by October 2023 the canopy was instead dominated by the pioneer species Halodule wrightii with leaf lengths of 2 cm and widths of 1 mm. Shoot density of Thalassia in 1999 was estimaated to be 1350 shoots/m2 however by 2003 it decreased to 53 shoots/m2. Biomass of Thalassia also declined from 1100 g/m2 in 1999 to only 17 g/m2 in 2023. The cause for decline at this site has been linked to excessive sea turtle grazing as opposed to a decline in water quality. This meadow is considered to be on the verge of collapse and urgent conservation and restoration efforts are needed.

SS011 – Seagrass observing and monitoring for the future

Seagrass methods videos as a path towards development of standardized protocols for seagrass essential ocean variables

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In order to bring together priority data on seagrass globally, EOVs (Essential Ocean Variables) have been developed to ensure a core set of variables are prioritized for data collection around the world. However, seagrass methodologies to collect these EOVs (seagrass occurrence, areal extent, percent cover, shoot density, canopy height) vary regionally by environmental context and objectives, and can be limited by capacity (e.g. personnel, funding). In order to build consensus around common methodologies, units of measurement and data schemas, we illustrate how the creation of training videos for seagrass methodologies can be used to co-develop generalizeable methodological approaches for data collection. Working with the Nanwakolas Council, who oversees seagrass data collection by Indigenous Guardians in British Columbia, we co-developed a process for creating training videos that are openly available for pre-field training and in-field consultation purposes. Video creation includes co-development and review of video scripts and drafts with seagrass experts and managers, and working with Guardians in the field to film videos. Video finalization includes user feedback after using them in the field. Building on this case study, we outline a framework to co-develop best practice SOP videos for seagrass methodologies nationally and globally.

SS011 – Seagrass observing and monitoring for the future

Greek Posidonia ecosystems at risk: investigating habitat loss and conservation priorities

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Despite the generally resilient state of Posidonia oceanica meadows along the Greek coasts, there are signs of decline caused by human and climate-induced stress. This study investigated case-specific degradation of Posidonia ecosystems. Employing mapping techniques and scientific diving, we closely examined the magnitude of habitat loss, meadows' fragmentation patterns, the extent of dead matte (DM) formations, and the overall conservation status. Additionally, in case-specific detailed analyses of DM formations, we measured the stocks of organic carbon in their underlying sediments. Our findings indicated that the case-studied Posidonia meadows have experienced significant decline, with losses ranging from 20 to 89 %. In most cases, the meadows were heavily fragmented, resulting in a substantial reduction in their total area (2 to 144.7 ha), indicating a conservation status ranging from poor to inadequate (CI: 0.10 – 0.45). Within the thoroughly examined DM formations, the carbon stocks ranged from 9.8 to 12.9 kg Corg m-2, being similar or even higher than those in adjacent healthy P. oceanica mattes. Understanding the condition and degradation trends within coastal “blue carbon” ecosystems is critical for formulating scientifically-sound management strategies, which properly account for the persistent contribution of DM in “blue carbon” storage.

SS011 – Seagrass observing and monitoring for the future

The Significance of Seagrass in the Girringun Traditional Use Marine Resource Agreement Area (TUMRA): Exploring Aboriginal Custodianship, Blue Carbon, and Collaborative Research Partnerships

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Aboriginal people in the Girringun Traditional Use Marine Resource Agreement Area have deep cultural aspirations that drive their sustainable management of turtles and dugongs. Our research strengthens the connection between seagrass habitats and the cultural heritage in the Girringun TUMRA.
Through an innovative lens, we explore new approaches to monitoring seagrass and dugong health and the emerging value of seagrasses in carbon sequestration, emphasising the potential for blue carbon initiatives to provide additional incentives for sustainable resource management. Our research has catalysed knowledge exchange, resource management innovation, and enhancing Indigenous custodianship practices by fostering inclusive approaches and new technology. We emphasise the importance of embracing holistic perspectives that intertwine seagrass ecosystems' ecological, cultural, and economic aspects. Our research partnership has delivered an Indigenous-led framework for the many clans in the Girringun TUMRA recognises Aboriginal custodianship as integral to protecting these ecosystems. We advocate for collaborative research partnerships that empower Aboriginal people and enable healing and connection to Country.

SS02 - Large scale approaches to seagrass ecology: integrating diverse approaches to produce a global view of seagrass ecosystems

An overview of Project SeaStore in South Africa: trans-disciplinary approaches to seagrass conservation and restoration

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In South Africa, as elsewhere globally, seagrasses face continuing anthropogenic threats, with reported declines. However, seagrasses remain poorly protected and vulnerable to changing conditions and in general there are significant gaps in knowledge around seagrass biology and management. The Cape dwarf eelgrass, Zostera capensis, is the most abundant seagrass in South Africa, where it occurs in sheltered bays and estuaries. Populations are highly fragmented and occur across a strong environmental gradient straddling two diverse ocean systems. In 2019, an inter-disciplinary team initiated Project SeaStore, with the aim of filling research gaps on the ecology, evolutionary diversity and physiology of Z. capensis in southern Africa. Since then, we have made significant leaps in detailing genomic and evolutionary patterns of population structure and diversity, as well as understanding seagrass responses to thermal stress using measures of photosynthetic efficiency, that has allowed for the identification of markers for biomonitoring and assessing in situ plant performance. In addition, we have developed novel protocols for the micropropagation and tissue culture of Z. capensis, explored transplanting as a potential tool for seagrass restoration, initiated research on the impact of glyphosates and heavy metals on seagrass fitness and extended research into estimating blue carbon stores in regional meadows. This talk provides an overview of the main aims and findings of Project SeaStore, particularly towards the aim of restoring, maintaining and conserving Z. capensis in South African estuaries and discusses future research priorities essential to the long-term persistence of seagrasses in Africa.

SS02 - Large scale approaches to seagrass ecology: integrating diverse approaches to produce a global view of seagrass ecosystems

Quantifying intertidal eelgrass exposure to thermal stress along a latitudinal gradient

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In a warming ocean, seagrass meadows are increasingly vulnerable to marine heatwaves that cause physiological stress and, in some cases, large-scale diebacks. Intertidal meadows are also vulnerable to extreme atmospheric warming events that can cause mass mortality and loss of meadow area. Thermal stress can further influence seagrass resilience to other stressors, such as disease. Yet quantifying thermal stress in intertidal meadows remains challenging; temperature records from remote sensing and long-term monitoring stations do not capture exposure to peak temperatures in intertidal flats. Additionally, seagrass populations can be adapted to temperature regimes at local and regional scales, altering responses to thermal stress exposure between meadows. Here, we integrated three years of temperature records from satellites and in situ loggers to quantify exposure to thermal stress in intertidal eelgrass meadows along 23 degrees of latitude of the northeastern Pacific coast. We compared thermal stress and relief (cooling) across spatial and temporal scales to determine the localized impact of regional heating events. Results showed sustained declines in eelgrass densities at many sites and large-scale losses of meadow area following an extreme atmospheric heatwave. These results will inform our understanding of seagrass resilience to thermal stress under climate change.

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Spatial Dynamics of Seagrass between 2004-2023 in Moreton Bay Australia, Provide Consideration For Global Scale Mapping of Seagrass

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Seagrasses have natural fluctuations and have seen decline through floods, coastal developments, and climate change at local to global scale. Local scale assessment over time and space under various environmental conditions will provide the basis to develop global mapping approaches. Here we provide an assessment of seagrass spatial dynamics from 2004-2023 14x at site and local scale and 4x regional scale to provide considerations for global mapping. Biannually (14x) seagrass species and cover maps were created for Eastern Banks (local scale). This by integrating +3000 photoquadrates collected biannually with coinciding high spatial resolution satellite imagery. Seagrass extended was mapped 4x for the Moreton Bay (regional scale) combining field data, expert knowledge and satellite image stacks. Annalysis at site, and local scale has shown change in species composition and reduction of seagrass cover over time partly related to flooding and highlighting presensce of persistent meadows. At regional scale seagrass extent were more challenged in mapping due to variation in water depth and clarity. The consistent repeated almost daily collection of satellite imagery globally in combination with field data, provide potential to map seagrass globally when considering the various conditions and temporal characteristics.

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Integrating Local Biotic and Continental Scale Environmental Drivers of Eelgrass Health and Resilience

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Eelgrass (Zostera marina) forms foundational habitats with new ecosystem values such as pathogen filtration, but is at-risk from environmental stressors, including climate warming and disease. Disease outbreaks of L. zosterae on the Pacific west coast are associated with both widescale environmental and local biotic factors. Recent, big declines in eelgrass meadows throughout the San Juan Islands, Washington in the Salish Sea are accompanied by continental scale outbreaks of warming-associated disease. Machine language learning, drone surveys and molecular diagnostics reveal climate impacts on disease levels from San Diego to Alaska and local scale work shows how biotic influences of both microbiome and herbivores may increase risk of disease. While long term surveys are valuable, we suggest one-time surveys of meadow health offer an additional metric for wider scale assessment of priority for future, widescale conservation efforts. Sites with the lowest disease levels provide an integrative proxy for sustainability and resilience to multiple stressors. Our approach of using disease as a measure of resilience to multiple stressors can be applied to other systems to guide conservation and management decisions.

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“Diving” into the macroecology of seagrasses: testing some rules

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While seagrasses have long been studied using a range of physiological, genetic, population-level and ecological metrics, classic biogeographical approaches, implemented for terrestrial plants, have been largely passed over for their marine counterparts. This has limited our macro-ecological and macro-evolutionary understanding of marine plants. Here, I first demonstrate that strong phylogenetic signal (the propensity of closely related species to resemble each other), and models of trait evolution, evidence Phylogenetic Niche Conservatism (PNC) for seagrasses, so close relatives live in comparable niches. This highlights the relevance of evolution from common ancestors and shared history underpinning large seagrass phylogenetic structuring. Secondly, I demonstrate that seagrasses have larger distribution ranges close to the equator in both hemispheres, supporting the inverse of the Rapoport’s biogeographical pattern. This may be attributed to their origins during warm geologic periods, and the subsequent longer climatic stability in tropical areas leading to climate niche conservatism constraining seagrass evolution.

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The interrelationship between seagrass ecosystem services

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There exists increasing interest in the use of credit systems to sell seagrass ecosystem services. Much of this interest relies on the assumption that these ecosystem services inter-relate in a positive and generally linear manner, however what we know from other ecosystem is that they don’t commonly have such simplistic and positive inter-relationships. There exists only a limited understanding of these concepts in seagrass, and most studies actually quantify only one or two services at once. Here we use a unique dataset from the Zostera Experimental Network to examine the inter-relationships between multiple seagrass ecosystem services across 50 sites of Zostera marina in the Northern Hemisphere. This includes data on carbon storage, nitrogen cycling and biodiversity. Our analysis shows that some linear relationships do exist between such services but these are limited. This analysis illustrates that investments in individual seagrass ecosystem services has the ability to create unintended consequences for other parts of the system function.

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Exploring the resilience of Zostera noltei meadows in Cul de Loup cove Normandy, France): a multidisciplinary investigation to grasp their ecological preferences amid a changing or declining context

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Cul-de-Loup cove , located in Normandy (Manche , France is shelter ing a Zostera noltei meadow divided into few moderate area s . Since 2008, the large st Zostera noltei is declin ing thus downgrading its water framework directive report (WFD). Since 2022, several Zostera noltei areas were discovered in the cove. Seagrass meadows face numerous threats, putting at risk the multitude of benefits they offer to both humanity and biodiversity. B etter understand interactions between anthropic activities and seagrass habitats is a key to investigate coastal resilience and recovery

To study this evolution, a pluridisciplinary project (ZAPER) was recently set up in 2023 focusing on 1) spatial distribution of Zostera noltei using drones , 2) water quality from cit ies and agriculture outlet s on a bi monthly basis and from the Channel signal using a multiparameter buoy and hourly data acquisition , 3) biogeochemistry , sedimentology and meio macrofauna analysis into Z. noltei sediments using O_2 , pH and H_2S microelectrodes followed by meiofaunal sieving , core incubation followed by macrofaunal identification and in situ sampling for the measurement of a set of biomarkers including oxidative stress responses First year results show a major faunal and biogeochemical difference s between old natural meadow and newly colonized areas. A large range of analysis and data treatment are still running to better understand th ose interactions.

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A call for nimble approaches to address inevitable surprises in seagrass ecosystems

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Global warming has seen an increase in the frequency of pulse disturbances in seagrass meadows including storms, coastal fires and floods that by their nature are unpredictable. These events may leave strong signatures on nearshore seagrass meadows, yet, typical monitoring programs, geared to track more gradual change are not designed to measure the full extent of their impact. Based on the successes and failures of attempting to evaluate two such pulse events – storm Gloria and coastal fires – I discuss strategies for research communities to collectively address these events. Critical to any effective evaluation of their impact is the ability to quickly quantify the disturbance at appropriate ecological scales, before noticeable effects dissipate. Regional networks of collaborating research and our ability to mobilise efforts is essential to respond rapidly to these events. We need to evolve nimble approaches that adapt rapidly to region-specific impacts to collectively focus energies where they are most required. These nimble approaches need to find ways to quickly develop uniform protocols, find rapid-response funding, effectively share and analyse data, and capitalize on citizen science initiatives. Nimbleness in research and action is going to be increasingly essential to respond to the inevitable surprises of our climate change reality.

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Identification and characterization of flowering genes in Zostera marina

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Eelgrass (Zostera marina) is a foundation species in coastal ecosystems and is threatened by natural and anthropogenic pressures related to climate change. Eelgrass has two methods of propagation: clonal branching and sexual reproduction via flowering. Flowering and seed production in eelgrass is considered important for resilience and contributes broadly to genetic diversity. However, the molecular mechanism of flowering in eelgrass and the environmental factors contributing to flowering are so far unknown. Flowering and seed production in the model plant Arabidopsis is achieved by the expression of a specific flowering gene (florigen) which is highly conserved in flowering plants. We have identified several candidate florigen genes in Z. marina. In field studies, we observed differing expression levels of these florigen genes in flowering and vegetative tissues collected from populations in Willapa Bay, WA.
We hypothesize that one or more of these genes can serve as a molecular marker for flowering, which may enable us to predict how climate change will affect sexual reproduction. Improving our understanding of flowering in eelgrass will give insights into how populations will respond toclimate change and help inform restoration and management strategy

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Mapping and assessing the national carbon stocks and seagrass habitat in Seychelles

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Seagrass ecosystems contribute towards climate change mitigation by sequestering carbon dioxide (CO2) from the atmosphere into long-term carbon stores. Destruction or disturbance of seagrass habitat therefore risks significant CO2 emissions. We present results from detailed satellite-based mapping of Seychelles' trained and verified usingmore than 40,000 underwater quadrats and videos. Remote sensed maps were integrated with assessments from 90 sediment cores up to 1.2m, and vegetation samples analysed using a combination of loss on ignition (LOI), elemental, and radioactive isotope techniques. Seychelles is estimated to have over 1,400 km2 of seagrass habitat comprising up to ~12 seagrass species. Meadows typically store ~118 tonnes C ha-1, yielding an estimated total stock of ~17 million tonnes COrg (~61 million tonnes CO2e). This stock is estimated as between 60 and 300 years of net carbon accumulation. Yet, the diversity and composition of seagrass meadows and their capacity of meadows to sequester and store carbon varied across anumber of environmental gradients. The work presents a pathway to include seagrass 'blue carbon' into National Greenhouse Gas Inventories (NGHGI), while emphasising the need for effective conservation and management to deliver climate mitigation and adaptation benefits and safeguarding a range of critical ecosystem services.

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Diverse approaches to produce an integrated large scale view of seagrass ecosystems

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Detailed spatial data on marine ecosystems is critical for effective conservation and management. The urgency for this is particularly pronounced in northern Australia, a region encompassing World Heritage and Indigenous Protected Areas, urban centres, remote pristine coastlines, and developed and undeveloped catchments. The area boasts globally significant seagrass habitats, crucial for their economic (fisheries, tourism), conservation and cultural values (dugong, green turtle). While spatial data on northern Australian seagrass has been collected since the early 1980s in some areas, much of the early data was poorly curated, not publicly available, or lost. To remedy this, we undertook the monumental task of compiling and making publicly accessible 40 years of historical survey data on 14 seagrass species. This extensive dataset includes >130,000 geolocated survey sites and >1700 seagrass meadows. It provides the foundation for incorporating large-scale environmental data to model species-specific habitat suitability, identify and address knowledge gaps, and emphasizes the necessity for novel approaches and technology to map and monitor seagrass in remote areas. Our efforts force a rethink of spatial management and planning for these dynamic marine systems, laying the groundwork for informed conservation and sustainable resource management.

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15 years changes of eight seagrass beds of Japan: loss of southern limit of eelgrass, earthquake, typhoon impact, decline in shallow water

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Seagrass bed surveys conducted through the long-term monitoring government project known as "Monitoring Site 1000" have been ongoing since 2008 at eight seagrass sites across six regions in Japan, spanning from sub-arctic to sub-tropical zones. We recorded seagrass coverage at sampling points, extending from the coastline to the deepest areas in each site.
This study presents a synthesis of trends in seagrass coverage over the assessment period, identifying correlated factors. A more detailed analysis explores associations between characteristic factors, including the influence of typhoons and earthquakes. Results revealed that, one study site average and 15 sampling points experienced a decrease in coverage (negative slope and R2 < 0.2). Conversely, one study site and 12 sampling points exhibited increased coverages over the 15-year trend. Points with decreased coverage were predominantly situated in shallower bathymetric zones, particularly in southern regions. At the presentation we will delve into specific site details, such as the disappearance of the southern limit of Zostera marina, the impact of heat through remote sensing comparisons using deep learning, and recovery post-Great East Japan Earthquake, comparison with herbivore distribution using species distribution modelling using eDNA data.

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A process-based modelling approach to assessing live above and below ground biomass: A non-intrusive way to compliment coverage monitoring.

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Seagrass meadows are important coastal habitats providing various ecosystem functions such as carbon storage, for which belowground biomass is a key indicator. Manual assessments of biomass are both laborious and time-consuming, while areal monitoring (drones, planes, satellite) can generally only provide accurate coverage for aboveground biomass estimations. Here, we explore the use of process-based mechanistic models in evaluating above- and belowground biomass distribution in eelgrass meadows. We conducted a feasibility study modelling eelgrass above- and belowground biomass in two modelling areas that cover a range of physical and environmental conditions – one in the Chesapeake Bay (USA) and a second in Danish waters (Denmark) using MIKE ECO Lab. This study demonstrates the capability of processed-based models in supporting traditional monitoring of eelgrass beds. The scalability and versatility of process-based models paves the way for using biogeochemical models as a faster and cost-effective approach to understanding and improving monitoring of eelgrass meadows. This is an important component that contributes towards understanding and managing eelgrass meadows.

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Overcoming barriers to seagrass restoration

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In South Australia, human activities have caused large losses of seagrass meadows between 1949 and 2002, mostly in the shallow waters of Adelaide (up to 7m depth). However, over the last two decades, more than 11,000ha of Posidonia meadows are believed to have naturally recolonised these metropolitan waters – a temporal and spatial scale never witnessed before. To date, no in-water measurements have explored the mechanisms for this unprecedented recovery, which are highly relevant information for application to restoration. In this study, a multidisciplinary approach combining genomic tools and numerical simulations, was used to investigate the role of clonal and vegetative reproduction in the recovery, and the mechanisms that enabled it. Initial field surveys indicated that areas that hadn't suffered any losses appeared to be composed of dense Posidonia spp. and Amphibolis antartica meadows; while recovery sites were characterised by monospecific meadows ranging from 20 to 90% cover, of which Posidonia sinuosa was the main representative. This initial analysis also suggests no significant differences in cover among regions but possible differences associated with depth, where particularly dense and well-established P.sinuosa meadows were found in >10m depth. The findings from the genomics and modelling outputs will facilitate insights into the modes of recovery and the potential sources of the recruits.

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Inferring seagrass meadows Blue Carbon stocks from space

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Due to their high carbon storage capacity and the risk of CO2 emissions associated to their loss, the conservation and restoration of seagrass meadows are enhanced as a way to contribute to climate change mitigation while protecting all other ecosystem services. The implementation of these (Blue Carbon) strategies is usually constrained by the lack of data on carbon stocks in seagrass meadows, added to the difficulty of monitoring the spatial and temporal trends with the accuracy needed. In this sense, remote sensing techniques could significantly increase our capacity to produce carbon inventories, report spatial and temporal variability and assess the impact of conservation and restoration projects in terms of carbon benefits. Yet, whereas remote sensing techniques have been broadly applied for terrestrial ecosystems' carbon inventories, their application for seagrass meadows is still limited. This work aimed to explore the relationship between in situ data on biomass carbon stocks from intertidal seagrass (Zostera noltti) meadows and spectral vegetation indexes derived from satellite (e.g. SENTINEL-2). This led to the development of a predictive model of seagrass biomass carbon stock that was applied to reconstruct the spatial and temporal (1985-2021) evolution of seagrass Blue Carbon in estuaries of northern Spain.

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Monitoring the Seagrass Queen of the Mediterranean: Sentinel-2 for Cloud-Based Image Processing and Blue Carbon Assessment

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Seagrass ecosystems stand out as crucial organic carbon reservoirs of our planet. The endemic Mediterranean seagrass species Posidonia oceanica has the highest C sequestration (Cseq) rate among all seagrasses, being key in climate change mitigation. The Balearic Islands' coastal waters (Spain) host expansive P. oceanica meadows that have had a 40% decline over the past six decades. Thus, spatially explicit continuous monitoring is crucial for an optimized management, both for seagrass extension and blue carbon accounting. To assess them, bathymetric data is crucial, so we first developed an interpolated 10 m bathymetry snapped to the Sentinel-2 A/B (S2) grids. Using the Google Earth Engine cloud computing platform, we generated a 7-year S2 multi-temporal composite (2016-2022), and then applied a Random Forest scalable machine learning algorithm to map benthic habitats, estimating 505,6 km2 of seagrass extent, up to 30 m depth. Integrating Tier 3 in situ measurements of P. oceanica soils Cstock, we estimated 12.27 million Mg Corg. Moreover, applying derived in situ curve trends, we mapped the annual C fixation (Cfix) and Cseq rate across depth. This information can enable the development of blue carbon strategies by providing efficient, timely, and cost-effective monitoring solutions tailored to a Tier 2 scale.

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Go large or go small? Testing the predictive importance of environmental variables for genotypic richness in eelgrass meadows

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A key goal of global conservation is to preserve biodiversity, including genetic diversity as it has been shown to maintain adaptive potential and ecosystem resilience. Sexual reproduction is an important source of genetic diversity. However, some seagrass meadows may have high levels of clonality and our understanding of the factors that promote or limit sexual reproduction is still limited. One way to study patterns of sexual reproduction is to use genotypic richness, a measure of clonality. We compiled genotypic richness data from 26 published studies on 278 meadows across the Northern hemisphere to describe patterns of genotypic richness along the distributional range of Zostera marina. Across meadows, genotypic richness was, on average, high (i.e. many different genotypes were found among the sampled individuals). However, we also found meadows where only one genotype was identified. We then examined the predictive relative importance of a range of environmental variables on genotypic richness at global and regional scales. We found that light availability and temperature were the most important predictors of genotypic richness at the global scale but not necessarily within different regions. These findings emphasize the importance of considering multi-scale approaches for a better understanding of the drivers of genetic diversity.

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The role of seagrass meadows as carbon and pollutants sinks and sediment biodiversity hotspots: a metanalysis of studies that presented paired control data

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Seagrasses are amongst the most productive marine ecosystems on Earth, providing a unique habitat opportunity for many species and key ecosystem services (ES). ES, such as carbon accumulation, water purification and biodiversity support, are widely assumed, but many biological and environmental variables can determine the degree of their provision. Furthermore, studies of seagrass ES do not always provide a comparison with unvegetated areas, making it difficult to assess the difference in service provision. Here, we aimed to estimate the effect of seagrass presence on the provision of services compared to adjacent areas of bare sediment. We conducted a systematic review of three main ES related to seagrass substrate: carbon accumulation, water purification (pollutant burial) and biodiversity support, including exclusively studies that provided paired control data. We collated 5191 comparisons
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(234 publications). Most observations were concentrated on Zostera meadows and the services of carbon accumulation and biodiversity support. The meta-analysis showed that seagrass meadows play a clear role in enhancing substrate biodiversity and water purification. However, their role as organic carbon sinks depended more on local factors and meadow species composition. Our results strengthen the need of including unvegetated areas as control samples to assess the provision of ES by seagrasses.

SS02 - Large scale approaches to seagrass ecology: integrating diverse approaches to produce a global view of seagrass ecosystems

Social-environmental drivers of change in Indo-Pacific seagrass meadows

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Seagrass meadows provide essential services for both nature and society. Following historic declines in seagrass distribution, conservation, protection and restoration efforts are becoming increasingly critical to enable the continued supply of essential ecosystem services. While in-situ data collection on seagrasses and threats is crucial, a full-spectrum analysis of threats can be both costly and time-consuming. Alternatively, open-access data for known drivers of change in seagrass ecosystems could provide a valuable resource. However, such a dataset is not readily available, especially across the Indo-Pacific. We argue that a curated dataset that acknowledges social and ecological dimensions is required to facilitate a social-ecological system perspective in seagrass research and management. This dataset would necessitate information on diverse variables, from water temperature and salinity, to human population density and marine protection. In this study, we have compiled a social-ecological dataset, with variables that describe or act as proxies for processes that drive change in Indo-Pacific meadows. By mapping variables onto the Social-Ecological Systems framework, we structure our understanding of what data is currently openly available and highlight essential gaps for future development.

SS04 - Seagrass genetics in the Anthropocene

There may be more seagrass species than we think: the case of the Zostera japonica species complex

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The distribution range of the seagrass Zostera japonica covers a broad ecological amplitude from tropical to temperate, which is highly unusual for any plant.The tropical-subtropical and temperate populations showed different life history strategies and we have found a deep divergence and secondary contact between them based on sanger sequencing and microsatellite data. Here, we tested whether or not divergent ecotypes of Z. japonica represent different cryptic species. By mapping to a newly assembled chromosome-level reference genome, we obtained 2,743,659 nuclear SNPs along with chloroplast genomes for 304 ramets from 18 populations. We identified two deeply divergent genetic clades in the north and south of the distribution range (hereafter ZJ_N and ZJ_S), with hybridization at a few intermediate locations. Hybrids were either diploid F1-crosses or were triploid, while no higher-order hydrids or backcrosses were detectable. Reproductive isolation between both cryptic Z. japonica species is likely maintained by fusion of diploid and haploid gametes leading to triploidy, which is supposed to be a dead ending for any further sexual reproduction. Using Z. marina as outgroup, a time-calibrated phylogeny including the sister species Z. noltii, revealed that ZJ_N split from the clade comprising ZJ_S and Z. noltii at 6.91 MYA, while ZJ_S and Z. noltii shared the last common ancestor at 4.41 MYA. To our knowledge, this is the first time that population genomics has revealed the existence of cryptic species in a seagrass, thus seagrasses may not be so species poor as previously assumed.

SS04 - Seagrass genetics in the Anthropocene

Transcriptomic and photophysiological responses to thermal stress in environmentally diverse seagrass populations

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Gaining insights into the transcriptional and photophysiological responses of climatic extremes, such as marine heatwaves (MHWs), is crucial to understanding the responses of foundational species. Species distributed along an environmental cline, such as the ecologically important seagrass Zostera capensis, provide an opportunity to assess key functional gene expression and photophysiological responses to temperature effects between populations. Here we exposed two genomically divergent Z. capensis populations from contrasting thermal niches within the same system, to a simulated MHW (34 °C for three days) in a common-stress garden approach. The population locally adapted to greater thermal stress showed pre-adapted phenotypic variation in response to acute warming through activation of heat-responsive genes and molecular chaperones. Both populations showed the activation of genes involved in thermal resilience including higher photosynthetic stability and respiratory acclimation. We conclude that the different intraspecific adaptive responses exhibited in gene-expression patterns during recovery provides critical information on thermal adaptation in aquatic habitats under climatic stress. In this study we identify transcriptomic mechanisms that may facilitate intrapopulation differential resilience of Z. capensis to anomalous warming events, and propose transcriptomics as an important tool to predict the tolerance of local populations to thermal stress in the face of global climatic change.

SS04 - Seagrass genetics in the Anthropocene

Forecasting Maladaptation of the Seagrass Zostera marina to Future Climates in the Baltic Sea

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Genetic diversity forms the foundation of healthy global ecosystems, but as climate change threatens these ecosystems, the ability to predict how this diversity will be impacted is crucial. To fill this gap, recently methods known as genomic offsets (GOs) have been developed, which use predictions of allele frequency variation along environmental gradients to quantify the disruption of genotype-environment associations under environmental change and thus to determine the degree of future maladaptation. This study uses GOs to characterize the degree of maladaptation of the eelgrass Zostera marina to future climates across the North Sea/Baltic Sea salinity transition zone, with the goal of predicting this species' response to climate change. Using seascape genomic data from 38 sites distributed across the Baltic, we find that future maladaptation to salinity and temperature gradients is predicted to be strongest in the Eastern Baltic. We also find that these predictions are complicated by the semi-clonal population structure observed in this species, as different treatments of clones in the data lead to large differences in the magnitude of predicted offset. Despite these differences in magnitude, these results indicate that Eastern Baltic populations of Z. marina may be at particularly high risk from the effects of climate change

SS04 - Seagrass genetics in the Anthropocene

Eelgrass population genomics informs meadow and epifaunal community response to rapid warming in the gulf of maine

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For seagrasses, accurate estimation of population connectivity is critical for determining species resilience to disturbance as well as identifying donor populations for restoration. The Gulf of Maine is warming rapidly, and recent marine heatwaves coincided with up to 50% loss of local eelgrass (Zostera marina) meadows. Here we pair population genomics analyses with field surveys and a lab-based temperature stress experiment to reveal how genetic and phenotypic differentiation in eelgrass populations might determine ecosystem response to rapid warming in the Gulf of Maine. Using 310,345 SNPs shared across 15 eelgrass populations ranging from Boston to northern Maine, ADMIXTURE analyse indicates strong regional differences in population ancestry although complex coastlines and currents contribute to both within-region inbreeding as well as surprising cross-region connectivity. Monthly field surveys conducted at six eelgrass populations captured varying meadow response to marine heatwave conditions in northern versus southern Maine, where southern Maine meadows failed to recover and epifaunal community identity shifted. Despite the persistence of northern eelgrass meadows in the field, in laboratory settings these meadows demonstrate a much greater sensitivity to high temperatures compared to southern populations. Genomic data, field monitoring, and population phenotyping can empower mangers with vital information for optimizing restoration success.

SS04 - Seagrass genetics in the Anthropocene

The sex life of seagrasses: A global synthesis of patterns in clonality and population genetic diversity in seagrasses

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Population genetic diversity, the allelic variation among individuals in a population, can contribute to more resilient ecosystems. A better understanding of the global patterns in genetic diversity provides context for diversity found in local populations, thereby informing conservation, restoration, and management actions. We assessed global patterns in the genetic diversity of seagrasses through a systematic literature review, using commonly reported clonal and genetic diversity metrics. We assessed how these diversity metrics varied across key biological attributes: family, life history strategy and reproductive mode, and across bioregions and latitude. A total of 154 articles were found with genetic diversity data from 1622 populations, of which the majority (1483 populations) used microsatellite markers. Overall, there was a range in variability across populations with weak spatial patterns, indicating that local conditions appear to strongly influence genetic diversity. There were some significant effects of biological attributes on clonal and genetic diversity metrics. This comprehensive review is the first of its kind and questions theoretical predictions for genetic patterns in seagrasses. Our findings indicate that when incorporating genetic diversity into restoration and management actions, there is a need to collect site-specific genetic data and to understand the local conditions.

SS04 - Seagrass genetics in the Anthropocene

A comprehensive assessment of flowering in Zostera marina: linking environment, phenology, and gene expression

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Sexual reproduction in Zostera marina happens seasonally. However, there is a lack of studies about its phenology, environmental drivers, and gene expression responses of populations in contrasting conditions. We took an integrative approach to address these knowledge gaps in Z. marina. We established five permanent stations in eight seagrass populations in Cape Cod between March and September 2023 (before, during and after flowering). We measured the density of reproductive shoots, environmental conditions, and sampled seagrass to study gene expression linked to flowering. Reproductive shoots started to develop in mid-to-late April when the water temperature reached 10° C, suggesting a temperature signal for the triggering of flowering. The appearance of reproductive shoots was uniform at the meadow scale. The percentage of reproductive shoots increased until mid-May, reaching a maximum of 9% of the total shoot density. Sequencing data from vegetative seagrass samples showed expression of genes leading towards flowering, and the comparison between vegetative and reproductive samples showed differential gene expression. This work sheds light on the sexual reproduction of Z. marina using a comprehensive and integrative approach, from phenology to environmental drivers to genetic apparatus, which will help to understand how flowering will be affected in a changing environment.

SS04 - Seagrass genetics in the Anthropocene

Temporal mating system variation and its effects on seed size in the eelgrass, Zostera marina: Implications for population maintenance and resilience

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Sexual recruitment is a driving force of genetic diversity in seagrass meadows, determining evolutionary potential and playing a critical role in ecological function. North Carolina hosts eelgrass (Zostera marina) at its southern range edge; warming temperatures have resulted in shifts to an annual life-history strategy in these populations, with increased sexual reproduction and decreased seed size. Because mating systems are correlated with genetic variation and subsequent phenotypic traits, understanding patterns of sexual recruitment is necessary to understand processes that shape genetic diversity and ecosystem function. To that end, we genotyped and measured developing seeds across the entirely of flowering eelgrass shoots in Topsail, NC. Using microsatellites, we examined individual-level mating system dynamics and their influence on seed size. Reliance on sexual recruitment was evident among shoots, and we detected temporal increases in self-pollination resulting in decreased seed size. Our findings reflect shifts in reproductive strategy, potentially due to heat stress and pollen limitation, and genetic influences on seed size. Given the key roles that genetic diversity and seed size play in enhancing meadow maintenance and resilience, disentangling the links between life-history, sexual reproduction, genetic structure, and phenotype will ultimately aid in informing the management and conservation of this valuable species.

SS04 - Seagrass genetics in the Anthropocene

Extreme variation in the reproductive strategy of Enhalus acoroides across islands in Southeast Asia and the Western Pacific.

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Enhalus acoroides is a dioecious, large-sized seagrass species that is widely distributed across the Indo-Pacific region. Based on its strong fruit dispersal capacity and slow rhizome growth rate, it is assumed that sexual reproduction is favoured over clonal reproduction in E. acoroides. However, significant variation in reproductive strategy has recently been detected with the occurrence of large clones in eutrophied lagoons (Dierick et al., 2021). The contribution of sexual vs. asexual reproduction plays a vital role in the resilience of seagrass beds. As a result, there is a pressing need to enhance our comprehension of the reproduction strategy and dispersal capacity of E. acoroides, and the environmental drivers that control this life history trait. Here, we investigated the clonal richness, genetic diversity, and genetic connectivity in 33 populations on contrasting island situations in the Andaman Sea (Phuket), the Gulf of Thailand (Koh Samui, Koh Phangan, Phu Quoc), the Camotes Sea (Leyte), and the Western Pacific Ocean (Guam). Our results highlight strong local and regional variability in the reproductive strategy of E. acoroides, which has major implications for conservation. Strikingly, unprecedentedly high levels of clonality are found in the Western Pacific Ocean, a phenomenon previously undocumented for E. acoroides.

SS04 - Seagrass genetics in the Anthropocene

Modes of Evolution in the Annual and Perennial Life Histories of Zostera marina (Eelgrass)

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Variation in annual and perennial life history strategies in the seagrass Zostera marina (eelgrass) is regarded as facultative and largely driven by the environment. However, we used a combination of field reciprocal transplants and population genetics analyses among annual and perennial eelgrass concurring within a single bay and found evidence for local adaptation and genetic differentiation between spatially proximate annual and perennial meadows. Because of the geographically restricted connectivity between regions where annual and perennial eelgrass coexist, it is possible that multiple evolutionary divergences have occurred between these life histories through independent and repeated selection. Here, we assessed whether parallel evolution has occurred among pairs of geographically proximate annual and perennial populations across the distribution of eelgrass using a phylogenetic framework. We aim to describe the extent to which independent lineages have arisen across the species range. Our work emphasizes the adaptive potential of life cycle variation in Z. marina, its evolutionary repeatability, and their implications for the long-term resilience of populations. These findings ultimately contribute insights into the feasibility of employing trait-based strategies (e.g. using short-lived seed-producing annuals) from locally derived populations to enhance eelgrass recovery and maintain ecosystem services in seagrass habitats.

SS04 - Seagrass genetics in the Anthropocene

Assessing the relationship between sulfide intrusion, genetic diversity, and clone size in Halodule wrightii

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Genetic diversity is positively associated with a number of traits important for the maintenance of seagrass populations, while clonal reproduction has been shown to be correlated with an increased probability of survival, especially in stressful environments. We performed a study to investigate the relationship between the intrusion of hydrogen sulfide, an environmental phytotoxin, and genotypic identity, heterozygosity, and clone size in Halodule wrightii. Isotope ratio mass spectrometry (IRMS) was used to collect sulfur isotopic ($\delta^{34}S$) data, a measure of H_2S intrusion, from 143 root, rhizome, and leaf tissue samples from three locations in the western Gulf of Mexico. A series of microsatellite markers and gridded coordinates were used for genotyping, heterozygosity (Ho), and clone size estimation. While individual genotypes varied widely for tissue $\delta^{34}S$ values, and larger clones tended to show less intrusion (root $r = 0.54$, $p < 0.01$), multivariate ANOVA confirmed location to be a more important factor. Environmental factors appear to have a more significant role than genotype, clonal size, or heterozygosity in H_2S uptake and distribution.

SS04 - Seagrass genetics in the Anthropocene

Exploring genetic diversity and connectivity of eastern mediterannean seagrass (Posidonia oceanica) meadows

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In times of global change, undertanding seagrass population dynamics provides insights into their adaptive potential and resilience. Here, we studied the genetic diversity, population structure, and connectivity of Posidonia oceanica meadows across the Eastern Mediterranean Sea (Aegean, Ionian and Cretan Seas, Greece) using 12 microsatellites and Lagrangian particle drift modelling. The strong genetic differentiation observed between the Ionian Sea populations and those in the Aegean and Cretan Seas suggests limited genetic exchange between them. Conversely, populations from the Aegean and Cretan Seas were characterized by high gene flow, indicative of a robust interconnected network. Notably, North Aegean Sea populations displayed the lowest genetic diversity and the highest clonality, differentiating from the rest of the populations. The genetic differentiation between the Ionian and Aegean/Cretan Seas aligns with the limited oceanographic connectivity based on seed dispersal probabilities. In the Aegean Sea, while Lagrangian simulations partially supported gene flow patterns, especially in the South Aegean, the distinctiveness of the North Aegean Sea populations can be attributed to historical events such as the Last Glacial Maximum. These genetic insights hold practical significance for management strategies, aiding the identification of management units and pinpointing potential donor sites in transplantation initiatives.

SS07 - Macro-micro interactions in seagrass ecosystems

Diatoms shape the Zostera marina leaf surface microbiome during early microbial colonization

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Seagrass leaves are rapidly colonized by microbial cells during formation and growth, similar to other submerged surfaces in marine environments. The resulting microbial biofilms are sites of intense microbial interactions, including seagrass-microbe interactions, which can have both positive and negative effects on the seagrass host. We investigated microbial colonization of leaves of Zostera marina using microscopy during a period of rapid leaf expansion. In combination, we analyzed leaf surface biofilms using amplicon sequencing, metagenomics and metaproteomics. Contrary to our expectations, electron microscopy revealed that diatoms (genus Cocconeis) were early colonizers, while bacterial colonization appeared delayed and concentrated around diatom cells. Network analysis identified bacterial taxa which distinctly cooccured with diatoms, leading to the hypothesis that these taxa are more closely associated to Cocconeis diatoms than to the seagrass itself. Analysis of metagenome-assembled genomes of these taxa indicated capacity for utilization of diatom-derived polysaccharides. Our findings suggest that other eukaryotes, such as epibiotic diatoms, strongly shape the seagrass microbiome in addition to the influence of the seagrass host. This has implications for our understanding of seagrass-microbe interactions, whose complexity may determine the outcome of fouling of seagrass leaves, a process leading to detrimental shading which threatens seagrass meadow ecosystems.

SS07 - Macro-micro interactions in seagrass ecosystems

Plants and animals share sulfur-oxidizing symbionts in seagrass meadows

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Host-microbe associations are essential for the health of seagrass meadows. While the seagrasses themselves host specific and benefical 'microbiomes', also symbionts of co-occurring animals can benefit the seagrass ecosystem, such as the sulfur-oxidizing Thiodiazotropha endosymbionts of lucinid clams that 'detoxify' seagrass sediments. Molecular surveys are revealing members of the genus Thiodiazotropha in root and rhizome microbiomes of seagrasses, however, their relationships to clam symbionts are unknown. We used a combination of sequencing techniques to reveal the diversity of Thiodiazotropha symbionts in co-occurring lucinids and seagrass Cymodocea nodosa. In >100 clams, within-host symbiont diversity was greater than previously observed, with multiple symbiont types co-occurring regularly. These symbionts were also identified on seagrass roots in the surrounding environment along with many other Thiodiazotropha sequence variants. The environment may therefore have a greater influence on symbiont diversity than previously thought by offering a secondary niche. Using a metacommunity model, we show that the presence of a second co-occurring host type (seagrass) can increase symbiont diversity within clams. Intimate symbionts are usually highly specialized to associate with a particular host species. Thiodiaoztropha would be the first symbiont capable of intimate associations with both a plant and an animal host.

SS07 - Macro-micro interactions in seagrass ecosystems

Diazotrophy in the seagrass rhizosphere - the potential role of rhizobia?

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Seagrasses can enhance nutrient mobilization in their rhizosphere via complex interactions with sediment redox conditions and microbial populations. Yet, limited knowledge exists on how rhizosphere dynamics affect nitrogen cycling. Using high-resolution chemical imaging, we show that radial O2 loss (ROL) from rhizomes and roots leads to formation of redox gradients around below-ground tissues of seagrass (Zostera marina), which are co-localised with regions of high ammonium concentrations in the rhizosphere. Utilizing chemical imaging in concert with fine-scale sampling for microbial community and gene expression analyses, we showed that multiple biogeochemical pathways and microbial players contribute to the high ammonium concentration within the oxidized regions of the seagrass rhizosphere. Bradyrhizobium (symbiotic N2-fixing bacteria) were particularly abundant and expressed the diazotroph functional marker gene nifH in rhizosphere areas with high ammonium concentrations. Such potential mutualistic association between Z. marina and Bradyrhizobium can facilitate ammonium accumulation, the preferred nitrogen source for seagrasses, enhancing seagrass productivity and performance within especially nitrogen-limited environments. ROL also caused strong gradients of sulphide at oxic/anoxic interfaces in rhizosphere areas, where we found enhanced nifH transcription by sulphate-reducing bacteria. ROL from below-ground tissues of seagrass thus seems crucial for ammonium production in the rhizosphere via stimulation of multiple diazotrophic associations

SS07 - Macro-micro interactions in seagrass ecosystems

Microbial driven CO_2/CH_4 gas flux of the intertidal seagrass Zostera noltei

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Seagrass offers great potential towards global blue carbon; sediment retention and sequestration capabilities, as well as the degradation of plant material, aid the long-term carbon storage in coastal sediments. The release of labile organic material (dead plant matter) also fuels the microbial production and oxidation of methane. Both methanogenic and methanotrophic microbes are fundamental to carbon cycling, yet are overlooked in seagrass carbon budget research. The study addresses this key knowledge gap by analysing greenhouse gas flux of the intertidal seagrass Zostera noltei, in relation to the sedimentary microbiome, across a seasonal cycle in the southern North Sea, UK. Here, CO_2/CH_4 flux of Z. noltei meadows and adjacent unvegetated mudflats were measured using in-situ flow-through incubation chambers and the sediment microbial communities were quantified by qPCR analysis of both taxonomic (16S rRNA) and functional (mcrA/pmoA) genes.

Preliminary data from the autumn sampling showed significantly higher uptake of CO_2 from seagrass habitats compared to unvegetated mudflats. Moreover, whilst net CH_4 emissions were evident from both habitat types, CH_4 flux did not differ significantly between them. Further analysis is underway to link these findings to the functional microbiome. This pioneering research is of national importance to//has national implications for UK blue carbon science and natural capital markets.

SS07 - Macro-micro interactions in seagrass ecosystems

Seagrass beds as a source of methane: a novel pathway and the effects of nutrient enrichment

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Seagrass ecosystems are recognised as potentially important carbon sinks in coastal areas, helping to mitigate climate change by absorbing carbon dioxide (CO2). However, the concurrent emission of methane (CH4), a more potent greenhouse gas, could impact their climate benefits. The factors influencing methane production in seagrass ecosystems remain unclear. Methanogenic archaea produce methane through methanogenesis and utilize three main pathways: hydrogenotrophic (using CO2), acetoclastic (using acetate), and methylotrophic (using methylated compounds). Here, we investigated these pathways in seagrass ecosystems with and without nutrient enrichment - a common stressor in coastal ecosystems. Following in situ nutrient enrichment over 75 days, seagrass cores were incubated with 13C-enriched CO2 in the dark, or over a light-dark cycle. Methane production was indicated by the transfer of the 13C tracer from 13C-CO2 to 13C-CH4. Contrary to prior findings, suggesting exclusive methylotrophic methanogenesis in seagrass, we found 13C-CH4 production in dark cores, indicating hydrogenotrophic or acetoclastic methanogenesis. Nutrient-enriched seagrass exhibited increased productivity (more O2 production), and seagrass photosynthesis in the light/dark suppressed 13C-CH4 production. However, nutrient enrichment did not affect methane fluxes. Despite anthropogenic stressors potentially amplifying climate change-contributing processes like methanogenesis, our findings suggest seagrass may act as a mitigating buffer against these impacts.

SS07 - Macro-micro interactions in seagrass ecosystems

The effect of anaerobic remineralization of the seagrass Halophila stipulacea on porewater biogeochemistry in the Gulf of Aqaba

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Seagrass meadows play a pivotal role in mitigating climate change by storing over 15% of the accumulated global carbon in the ocean's sediments. Seagrasses secret oxygen from their roots, creating microenvironments with strong and complex redox gradients that greatly affect carbon mineralization rates. Threatened by local and global stressors, seagrasses are rapidly disappearing.

To examine the effects of Halophila stipulacea disappearance on key microbial processes in sediments, we conducted a series of incubation experiments. Two types of sediments from the Gulf of Aqaba were incubated with different H. stipulacea compartments (old and young leaves, rhizomes, or roots). The chemical changes in DIC, Fe2+, H2S, SO42- were measured with time and used to calculate the remineralization rate of each seagrass compartment.

Our results show that the rhizomes decomposed the fastest, followed by the young leaves, roots, and old leaves. The slow decomposition rates of the roots could indicate the preservation potential of belowground biomass. High hydrogen sulfide concentrations were observed only in the slurries containing rhizomes and young leaves. This could lead to seagrass mortality via a positive feedback loop which generates more hydrogen sulfide. Our results demonstrate the importance of understanding the biogeochemical effect on marine sediments following seagrass disappearance.

SS07 - Macro-micro interactions in seagrass ecosystems

Deciphering the habitat of shallow chemosynthetic fauna in seagrass sediments: biogeochemical changes across short spatial gradients

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Seagrasses play a pivotal role as habitats for a diverse array of marine life, including sediment macro and meiofauna engaged in chemosynthetic symbiosis with bacteria capable of driving energy from reduced compounds generated during anoxic organic matter (OM) remineralization. Despite extensive studies exploring these symbiotic relationships for insights into genetic and metabolic interactions, there remains a critical knowledge gap concerning the ecology and distribution of these associations. This study addresses this gap by investigating the habitat preferences of shallow chemosynthetic fauna within seagrass sediments, with a specific focus on biogeochemical changes across short spatial gradients. Field surveys were conducted at five sites in Calabria (Italy), spanning both the Tyrrhenian and Ionian Seas. Three Posidonia oceanica and two Cymodocea nodosa meadows were examined along horizontal (meadow, edge, and outside sites) and vertical (0, 10 and 30 cm belowground) gradients.
The study assessed the diversity and distribution patterns of chemosynthetic fauna, along with other macro- and meiofauna, at each site. In situ porewater samples were collected using MacroRhizon samplers, enabling the analysis of porewater environmental chemistry, including concentrations of dissolved inorganic and organic nutrients, as well as dissolved gases. Concurrently, sediment grain size and composition were examined. To further elucidate the contribution of various OM sources to sedimentary OM, stable isotopes analyses ($\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$) were employed. This research identifies specific biotic and abiotic factors that shape habitat suitability of chemosynthetic organisms in seagrass sediments, enhancing our understanding of their ecological preferences.

SS07 - Macro-micro interactions in seagrass ecosystems

The cyanobacterial assemblages in Posidonia oceanica leaf stratum: a functional approach

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Associations between Posidonia oceanica L. Delile and cyanobacteria may appear unfeasible, because the plant -a foundational seagrass in coastal Mediterranean ecosystems- achieves high abundances at low concentrations of dissolved inorganic nitrogen, while cyanobacteria are well adapted in eutrophic and nutrient-rich environments. However, several microbial taxa were identified associated to the seagrass environments, and they are important to nutrient cycling, including microbes capable of nitrogen fixation, ammonification and sulfur oxidation. While the host-microbe interactions are still scarcely investigated, populations of many marine macrophytes are in decline and this topic could be important to characterize key chemical interactions. To this end, 12 cyanobacteria strains were isolated from leaves of Posidonia oceanica in the Bay of Naples and cultured in axenic conditions. The strains were identified by means of a polyphasic approach. The remarkable diversity of the cyanobacterial microbiome associated to P. oceanica, here described for the first time, was related to their well-known ability to produce allochemical compounds, released in the environment to increase their competition for space. Their toxigenic power was tested on sea urchin embryos and most strains demonstrated low toxicity. This characterization explains the success of cyanobacteria in a peculiar environment characterized by high competition for space and resources.

SS07 - Macro-micro interactions in seagrass ecosystems

Microbiome dynamics in restored seagrass meadows: implications for ecosystem recovery

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Seagrass meadows harbour a unique biodiversity, with many ecosystem benefits. Global attempts to restore lost meadows in order to halt the ongoing decline in seagrass area have had variable results. Root- and sediment microbiomes and their interactions may be critical for initial restoration success and the return of ecosystem services, yet their role is largely unresolved. In the SeaStore project, we used 16S- and 18S rRNA gene amplicon sequencing to track shifts in Zostera marina meadow microbiomes, one, three, and 12 months after transplanting shoots at two newly restored- and unvegetated control sites in the German Baltic Sea. Seagrass establishment was successful at both sites; shoot densities increased 25-fold after 12 months at one site. However, we found that prokaryotic communities in restored meadow sediments still resembled those of the unvegetated sediments rather than those of natural meadows, with higher abundances of anaerobic taxa in the latter. Additonally, data from a Swedish site after 6 years of restoration showed a similar pattern. This suggests that below ground recovery in restored meadows happens on longer timescales, but that prokaryotes could serve as proxies for defining long term restoration success criteria, such as return to natural meadow sediment state.

SS07 - Macro-micro interactions in seagrass ecosystems

Seagrass – lucinid clams interactions and their role in DMSP cycling

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The antistress compound dimethyl sulfoniopropionate (DMSP) and its gaseous metabolite dimethyl sulfide (DMS) are abundant marine nutrients, signalling molecules, and essential components of the global sulfur cycle with roles in climate regulation. Seagrasses produce exceptionally high intracellular DMSP levels which can serve to recruit and feed specific microbial communities resulting in further sulfur biotransformations, e.g., to dimethylsulfoxide (DMSO). These sediments are also home to lucinid clams, which host chemosynthetic sulfur-oxidising bacteria in their gills that can respire DMSO to DMS. This study investigates the role of the interaction between seagrasses (Cymodocea nodosa and Zostera noltii), their holobiome and lucinid clams (Loripes orbiculatus) in DMSP production and cycling in vegetated coastal sediments. Samples of L. orbiculatus, C. nodosa, Z. noltii, and sediments (with their microbial communities) will be collected in Piran, Slovenia. They will then be incubated in cores with different combinations of the three partners. We will quantify DMSP standing stocks in each partner – sediment microbiota, clams, and seagrass – and evaluate the contribution of each to DMS/P production. We will relate these fluxes to the diversity of the microbiota and to sediment porewater chemistry. This study will further our understanding of DMSP cycling and DMS emissions in vegetated coastal sediments.

SS07 - Macro-micro interactions in seagrass ecosystems

Experimental manipulation of host-associated microbes to understand their effect on seagrass performance

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There is substantial evidence from a wide variety of systems, ranging from plants to humans, that microbes play crucial roles in the performance of eukaryotic hosts. Current approaches to understanding microbial effects on hosts are mostly descriptive or focus on model hosts in unrealistic conditions. To determine effects of microbes on host performance, we need experimental approaches that (i) manipulate host-associated microbiota, (ii) disentangle microbially-mediated effects on hosts from direct effects on hosts associated with the methods employed to manipulate host-microbiota and (iii) can be implemented in the field. We examined the effectiveness of different types and/or concentrations of antimicrobials (and relevant procedural controls) on disrupting bacteria associated with roots/leaves of several Australian (e.g. Zostera muelleri, Posidonia australis) and Mediterranean (Cymodocea nodosa, P. oceanica) seagrasses. We used molecular tools to determine effects of antimicrobials on bacterial assemblage structure and abundance and assessed short-term responses of hosts to treatments via measures of photosynthetic efficiency, respiration and tissue condition. Short-term exposure to iodine (few minutes) significantly disrupted seagrass-associated bacteria, with no immediate significant effects on hosts. Thus, this method may be broadly applicable and can be used to determine microbial effects on seagrass performance in laboratory and field experiments.

SS07 - Macro-micro interactions in seagrass ecosystems

The role of belowground microbes in mediating heat stress in seagrasses

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Emerging evidence shows that belowground microorganisms may play a role in the performance of seagrass under environmental stress. However, we still have limited understanding of when and where these microbes matter the most.

We determined the relative importance of root- and the bulk sediment microbes on the performance of Zostera muelleri in response to a marine heatwave, a major stressor for seagrasses. A manipulative mesocosm experiment was performed involving the separate sterilization of root and bulk sediment-associated microbial communities. We show that disruption of the root microbiome decreased leaf growth under all temperature and sediment treatments. Under a +6-degree marine heatwave scenario, leaf growth was reduced but only in the presence of an intact bulk sediment microbiome, whereas under lower temperatures seagrass growth was maintained regardless of the presence/absence of an intact bulk sediment microbial community. Importantly, even in the presence of an intact root microbiome, the growth of plants was not maintained under a +6-degree marine heatwave scenario. Analysis of root and bulk sediment microbes indicated that higher temperatures were associated with a shift in the bacterial assemblage.

These results highlight the importance of understanding the interaction between seagrasses and their belowground microbiome to predict how they will respond to future environmental changes.

SS07 - Macro-micro interactions in seagrass ecosystems

Protective ecosystem services of seagrass meadows – supporting One Health through Nature-based Solutions

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Seagrass meadows safeguard ocean health through their protective ecosystem services. Several years ago, we described that seagrass meadows remove pathogenic bacteria from seawater and thereby prevent disease on nearby coral reefs. Such a service can potentially be used to improve seawater quality, reduce risks of disease outbreaks and protect biodiversity. Here, we will provide an overview of recent progress we made in this field and the directions we are taking for future research. And we will specifically address how seagrass meadows affect the microbiome of and effectively reduce bacterial pathogen loads in nearby and associated organisms. Understanding how seagrass meadows protect organismal and ecosystem health will allow the implementation of this ecosystem service as a Nature-based Solution to protect biodiversity and valuable marine ecosystems, to support the sustainable production of safe seafood for coastal communities, and to reduce human disease risks in coastal zones. Restoring seagrass ecosystems will thus contribute to the One Health approach to find a sustainable balance between the wellbeing of people and the health of natural ecosystems.

SS07 - Macro-micro interactions in seagrass ecosystems

Quantifying blue carbon storage in Plymouth Sound seagrass beds to support development of a Carbon Code

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This study aimed to assess sediment carbon stocks and accumulation rates of UK Zostera marina seagrass beds to support the development of a UK Seagrass Carbon Code. For the first time, this study assessed seagrass sediment carbon stocks to great depth at high resolution, to gain detailed understanding of variability with depth and insight into historical patterns. Nine 3 metre cores were collected from 3 sites across Plymouth Sound, UK, using a vibrocorer in August 2022. High resolution analysis, every 1cm, was carried out for Organic Carbon content using Elemental Analysis. A subset of samples were analysed using Loss on Ignition to compare methodologies. 210Pb dating was used to estimate sediment accumulation rates. Initial results for the Drakes Island site displayed high variability in OC content between cores and with depth (average = 4.07% OC, range = 0.25-28% OC). 2 cores displayed distinct peaks in carbon, related to the presence of coal. 210Pb results provided an estimated sedimentation rate range of 0.23-0.33 cm/yr, indicating a 3 m core to date ~1200 years. This study has demonstrated the value of high resolution analysis and highlighted methodologies important for improving our understanding of seagrass carbon stocks and their role in carbon storage.

SS07 - Macro-micro interactions in seagrass ecosystems

Are macrozoobenthic communities associated with Zostera noltei meadows resistant to environmental changes ?

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Seagrasses form important coastal habitats characterised by numerous ecological functions. Arcachon Bay, a lagoon located on the Atlantic coast (France), shelters Europe's largest Zostera noltei meadows (~40 km² in 2019). This habitat underwent a strong decline over the past 20 years, with -44% of its surface lost (~70 km² in 1989). Concomittantly, changes in water nutrients concentrations, primary production and biogeochemistry fluxes were also reported.
In this context, this study aims to characterise the meadows' macrozoobenthic communities responses to seagreass decline and investigates their degree of resistance and resilience. A total of 49 stations were sampled using a hand-corer (0.045 m²) in 2002 and were revisited in 2023. Macrofauna was identified at species level, sediment was characterised and Z. noltei leaves and root biomass were measured.
In our stations, leaves and root biomass decreased from 2002 to 2023, which is consistent with the global decline of Z. noltei meadows' surface in the lagoon. Diversity estimates remained stable although changes in species composition were observed. Preliminary results suggest that the benthic community facing Z. noltei meadows decline in the bay are resistant and resilient at this timescale and question the impact of habitat fragmentation on ecosystem functioning.

SS07 - Macro-micro interactions in seagrass ecosystems

Exchange of benthic components across a diverse Zostera noltei meadow within a deteriorating or evolving ecosystem

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Seagrasses meadow s provide valuable ecosystem services play ing a key role on benthic biogeochemistry and plant sediment interactions through several biogeochemical processe s Due to large losses of seagrass meadow worldwide, studies are conducted to investigate key strateg ies for increasing coastal resilience and recovery such as restoration or natural colonization studies . In Normandy (France), Cul de Loup cove is colonized by Zostera noltei meadows , allowing us to investigate benthic biogeochemistry in two contrasted ecosystems : old and declining meadow and newly discovered The present s tudy aimed to assess how changes in seagrasses within heterogeneous Z. noltei meadow influence the spatiotemporal changes in benthic metabolism . The total benthic metabolism of the seagrass community was estimated through the total oxygen uptake (TOU) and t he effect of the presence of seagrasses on the diffusive oxygen uptake (DOU) was also assessed Cores were collected during two season s (i.e. summer and spring) and four different sites Moreover, m acro and meiofaunal analysis were conducted in the same cores allowing us to assess benthic diversity parameters. Important differences were observed based on colonization steps

SS07 - Macro-micro interactions in seagrass ecosystems

Using mutualistic interactions as a non-invasive management strategy of green turtle feeding sites

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The conservation success of the green turtle has highlighted the potentially disruptive impact of intensive grazing on seagrass-meadows. A ~5 ha meadow in Akumal Bay, Mexico has supported, for several decades, an increasing population of juvenile and sub-adult turtles that maintained feeding-ground fidelity through modification of feeding strategies, thereby bringing the meadow to the brink of collapse. An unexpected population explosion of calcareous algae (rhodoliths) discouraged turtles from feeding in areas of dense rhodoliths aggregations, allowing recovery of the climax species Thalassia testudinum, and thereby establishing a mutualistic and dynamic equilibrium among rhodoliths and turtles. In 2022, we tested whether rhodoliths can be used to control turtle feeding grounds for management purposes. Quadrants (25 & 49m2), established at sites with evidence of recent herbivory, were filled with rhodoliths that were removed from reciprocally sized plots in a mixed bed with dense rhodoliths and seagrasses. Additionally, seagrasses were clipped in another area without browsing. After five months, turtles were grazing in the rhodoliths removal and clipped plots. The turtles had stopped visiting the plots with added rhodoliths and T. testudinum was recovering. Given the expected global increase in turtles, this non-invasive method deserves attention as a conservation measure for overgrazed meadows.

SS07 - Macro-micro interactions in seagrass ecosystems

Mechanistic functioning in epi- and infaunal bivalve-seagrass communities

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Seagrasses host diverse communities and co-occur with other ecosystem engineers. Yet, we have little understanding of the complex interactions of seagrass with co-existing bivalves and their importance for habitat structure and ecosystem processes. In a 101-day-long mesocosm experiment, we investigated the individual and combined effects of epifaunal (Mytilus trossulus) and infaunal (Macoma balthica) bivalves on the performance of Zostera marina and their influence on nutrient (porewater and water-column) uptake and cycling, the impacts of Zostera presence on bivalve traits, and interactions between the two bivalves.
Macoma presence decreased Mytilus mortality, while Zostera did not influence bivalve traits. Both bivalves increased nutrient availability, with Mytilus having a stronger effect. Overall, the two bivalve species had strongly antagonistic effects on the performance of Zostera, where in co-occurrence, the positive impacts from Mytilus (shoot number, growth rate, leaf length, nutrient availability) could mitigate the negative impacts from Macoma, despite a nutrient increase.
This comprehensive study investigated multiple trait responses within the interactions of three important ecosystem engineers. The findings suggest that the performance of one ecosystem engineer largely depends on the presence but also the interaction of co-occurring engineer species, with implications for understanding ecosystem processes and changes and restoration of seagrass habitats.

SS07 - Macro-micro interactions in seagrass ecosystems

Facilitation or competition between Thalassia testudinum and Caulerpa paspaloides in a seagrass meadow?

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Interactions between seagrasses and macroalgae have been defined as competitive relationships since they use similar nutrients, space, and sunlight. The objective was to analyze the interaction between T. testudinum and C. paspaloides using population models, as well as physicochemical and photosynthetic performance indicators. The monitoring was done at "Los Petenes" Biosphere reserve in three different meadows: monospecific of T. testudinum or C. paspaloides and mixed meadows having both species. Data was taken in the dry, rainy and "nortes" seasons from 2016 to 2019. Thalassia testudinum and C. paspaloides biomass (g/m2), photosynthetic efficiency (Fv/Fm), physicochemical parameters (sediment and column water nutrients, depth, light at bottom (%) temperature, pH, salinity, type of sediment and organic matter for each meadow type. The most important factors in the PCA were depth, bottom light (%), presence of macroalgae, biomass and Fv/Fm of both species and the second component with factors temperature, pore-water phosphorous, and dissolved inorganic nitrogen (DIN). Fitness was higher in monospecific meadows for both species than in mixed meadows, due the absence of other species. However, monospecific meadows of C. paspaloides had higher mortality in the norte season. Coexistence seems to have a detrimental effect on the performance of T. testudinum.

SS07 - Macro-micro interactions in seagrass ecosystems

Characterisation of a surviving population of Pinna nobilis in tiger Posidonia meadows in the amcp of the kerkennah archipelago

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Posidonia oceanica meadows are biodiversity hotspots, providing habitat for several species. The Kerkennah archipelago (southern Tunisia) is characterised by a unique structure of Posidonia meadows, known as striped or tiger meadows, which support dense populations of Pinna nobilis. Unfortunately, over the last decade, the density of Pinna has decreased dramatically due to the destruction of its natural habitat by trawling, the presence of new predators such as the blue crab, and the epizootic. The objectives of this study, carried out as part of the PPKer project, were i) to characterize the remaining population, ii) to take measures to protect living Pinna specimens and restore the population, and iii) to highlight the importance of Posidonia meadows and Pinna through awareness raising activities with local communities. Several diving and snorkeling surveys were conducted from April to November 2023, resulting in the tagging of 8 live specimens over $2km^2$. Examination of 35 dead mussels revealed that the total height and maximum width of dead mussels ranged from 24-44 cm and 10-16 cm respectively. The age of the dead individuals ranged from 5 to 9 years. Awareness-raising workshops were held with stakeholders to ensure that they were aware of the importance of the issue.

SS08 - Seagrass Microbe Interactions – Harnessing the Microbiome

Partners for Life - Understanding Microbiome Assembly and Function Throughout Eelgrass Development and Establishment

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The microbiome is a dynamic "organ", shifting in its community composition and function as the host develops and responds to its environment. Here, we present the microbiome assembly of Zostera marina as it develops from seed to juvenile seedling and how that compares to microbiomes of established eelgrass meadows during seasonal shifts in northern CA, USA. Using 16S rRNA gene amplicon sequencing and metagenomics, we show microbial community composition and functional patterns - highlighting key microbes and their roles that are important in Z. marina development. We also present the results of laboratory experiments testing the role of bacterial volatiles in combating seagrass wasting disease and describe the usage of the EcoFAB 2.0 for lab controlled seagrass seedling microcosms. We discuss how our findings can develop microbes as indicators for eelgrass meadow health and potential tools for meadow restoration.

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Use of probiotics to stimulate the success of seagrass restoration

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Seagrass meadows are globally declining due to anthropogenic stressors. Therefore, urgent restoration efforts are required to recover and expand these crucial ecosystems. In the last decades, the role and importance of the seagrass microbiome has gained more attention. As soil bacteria have been leveraged to enhance crop productivity for many years, growth-promoting bacteria are now proposed as a tool for improving seagrass health and recovery. This project investigates the role of the microbiome in seagrass health, growth, and resilience. We aim to identify and characterize novel and known bacterial isolates to expand the list of putative beneficial microbes associated with seagrass roots. These can be used as probiotics to facilitate seed viability, stimulate the health and growth of transplanted seagrass shoots, and thus promote the success of seagrass restoration. We determined the microbial diversity on all vegetative parts of the seagrass Ruppia maritima and isolated bacteria from five marine macrophyte root systems. These bacteria were barcoded using the total 16S rRNA region. Subsequently, we performed whole genome sequencing on a selected set of isolates and tested their role in germination and early-stage development of R. maritima seeds in a laboratory experiment with Bacilli sp. increasing both germination and growth.

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Eelgrass resistance to a marine heat wave correlates with having flexible leaf microbiomes while maintaining root microbiome composition

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Microbiomes, fixed differences among individuals and plasticity all affect organism responses, but separating direct and indirect or interative effects among these factors remains a challenge. Here we examine the extent of genotype by environment interactions of Zostera's microbiome assembly to begin revealinig the potential role of a host's microbiome in mediating its response to environmental stress. We exposed paired eelgrass genotypes to either ambient temperatures or a 5-week marine heat wave for one growing season and measured eelgrass performance and characterized the root and leaf microbiome before, during and after the experimental heat wave. On the host level, marine heat wave exposure drive a shift in rank order of genotype performance indicating variation among genotypes in response to temperature. On the microbiome level, leaf and root microbial communities differ in the extent of genotype by environmental drivers of their community assembly over time. Regressing differences in host performance to changes in microbial composition across treatment reveals resilient genotypes have high leaf microbiome flexibility and constant root microbiomes while the opposite is present for low-ranking genotypes. These results suggest resilient plant genotypes may be assemblinig the appropriate microbial communities, relying on these shifts as means of coping during periods of stress.

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Role of rhizosphere microbiota in controlling seagrass response to environmental stressors

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Increasing the resilience of seagrass ecosystems and enhancing restoration outcomes requires knowledge of the processes that determine seagrass performance. Towards this end, resolving how below-ground microbial communities influence seagrass performance is acknowledged as a key knowledge gap. Molecular studies indicate the seagrass rhizosphere houses microbial taxa and functional groups that putatively benefit seagrass performance. We still, however, have little understanding of how plants control rhizosphere communities when under stress and when those microbial communities provide the most benefit to the host plant. Employing methods we developed for removing microbiota from the seagrass rhizosphere, our overall aim was to experimentally test how rhizosphere microbial communities respond to and control seagrass response to key environmental stressors. We used a combination of both field and lab experiments in which we exposed plants that had intact and disrupted microbial communities to different stressors. Overall, we showed that seagrass plants perform better with an intact microbial community, with the benefits increasing with increasing nutrient stress. We also showed that above-ground biomass removal (simulating processes such as herbivory or mechanical disturbances) can lead to changes to rhizosphere communities. Thus, seagrass rhizosphere microbial communities 1) respond to environmental stressors and 2) can control plant responses to environmental stress.

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Study of the influence of microbiomes on seed germination and development in the seagrass Cymodocea nodosa

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Marine macrophyte ecosystems are considered as a fundamental habitat throughout the world. The continuous increase in anthropogenic activity and global change pressures that seriously threaten these habitats, has led to an increased interest in assessing different factors that may promote their resilience.
In seagrasses, firsts life stages can be critical when determining the natural recovery of the ecosystem. In this sense, identifying the factors that positively influence the development and establishment of these early stages is essential for ecosystem conservation and restoration.

The study of microbiome can be a determining factor to understand their functionality and resilience, so this study aims to evaluate the influence of microbiome on C. nodosa seeds germination and development.

To test the hypothesis that the presence of certain microorganisms influences the development of seagrass, a manipulative experiment was carried out in the laboratory. Six treatments from the interaction between two factors were examined: (1) sterilization (or not) of the seeds and (2) sediment type (sediment from vege tated and non-vegetated environments and artificial sediment).

Seed germination and development was strongly influenced by the presence of the seed microbiome and sediment type (and thus soil microbiome). Also, microbial community composition differs between treatments and developmental seed stages.

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The composition and functional potential of growth Promoting bacteria within the seagrass rhizosphere

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Globally, seagrass meadows are in decline due to the combined impacts of climate change and human activities. Although current restoration of seagrasses aim to mitigate meadow decline, success rates are often low. One promising approach towards enhancing seagrass growth is the application of plant growth promoting (PGP) bacteria.
Here, we aimed to explore the potential of seagrass-associated microbes to promote plant growth. Based on work from agriculture systems and seagrass biology, we anticipated to find bacteria associated with the seagrass that promote plant health and growth by providing them with essential nutrients, detoxifying sediments, and stimulating root growth. To this end, we isolated over 400 bacteria from the rhizosphere, rhizoplane and endosphere of the seagrass Zostera marina. Using a series of physiological assays, we found that a large portion of PGP bacteria produce phytohormones, fix nitrogen, oxidize sulfur and solubilize phosphorus. Our in-depth genomic analysis enabled us to further explore the functional potential of selected PGP bacteria, including the identification of novel isolates and unknown microbial traits that likely benefit seagrass health. By isolating and characterizing these putative PGP bacteria, we have the ability to develop new microbial approaches towards enhancing plant growth and impacting the success of seagrass restoration.

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Exploring the epiphytic bacterial and fungal communities associated with the Posidonia oceanica in a changing environment

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Seagrasses and associated microbial communities constitute a functional unit, called holobiont, which responds as a whole to environmental changes. Shifts in the seagrass associated microbial communities may occur as a response to both environmental changes and to specific morphological and biochemical adjustments occuring in seagrass in response to environmental gradients, and in parallel, the ease microbial shifts can contribute to host’s health and capacity to withstand environmental changes. Integrated assessments of seagrass ecophysiology and microbial community structure can consequently help to understand the capacity of the ‘holobiont’ to persist and adapt, but also be used as an early warning indicator of seagrass stress. Posidonia oceanica is known to harbor diverse epiphytic bacterial communities, while its mycobiome still remains poorly understood.
In this study, we employed a multidisciplinary approach to investigate changes in the morphology, biochemistry and epiphytic microbial community structure (bacteria and fungi) of P. oceanica in Akrotiri bay (Cyprus, Eastern Mediterranean Sea), including: i) a coastal site close to Limassol Port, and ii) the underwater archaeological site at Amathous. The composition or structure of P. oceanica microbial communities reflected the specific biochemical or morphological condition of the meadows, providing a baseline for understanding the P. oceanica microbiome and supporting its potential use as a seagrass descriptor.

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Seed and sediment microbiomes influence the germination of seagrass seeds

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Seagrasses are the only flowering plants that produce seeds in the marine environment, forming vast meadows crucial for important ecosystem services. Over the past decades, seagrass cover has declined in many places, and re-colonization is slow. Despite clonal growth, the recruitment of seagrasses from seeds is essential for maintaining genetic diversity and facilitating dispersal. While the seed microbiome of several terrestrial plants has been shown to influence germination and seedling survival, the microbiome of seagrass seeds has received limited attention.
To investigate the effects of the microbiome on seagrass seed germination and seedling development, we manipulated the microbiome of Zostera marina seeds and sediments and conducted a germination experiment. We found three times higher germination rates for seeds with intact natural microbiomes incubated in sterilized sediments compared to sterilized seeds incubated in native sediments. By comparing microbial communities (assessed via 16S and 18S rRNA gene amplicons) in the treatments, as well as in field-sampled material, we conclude that seagrass seeds have a microbiome distinct from other plant parts, featuring several potentially plant growth-promoting taxa. This microbiome is likely critical in germination and establishment of healthy seedlings, a prerequisite for recovery and restoration of seagrass ecosystems worldwide

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Seagrass wanted dead or alive: A call for global collaboration in uncovering the diversity and pathogenic potential of phytomyxid parasites in seagrass meadows

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Phytomyxid parasites (Rhizaria: Endomyxa: Phytomyxea) are obligate intracellular biotrophic protists infamous for infecting various crops of great economic significance. They also represent one of the three groups of microorganisms generally recognized as parasites of seagrasses. Based on observations reported in the 20th century, three phytomyxid species were formerly thought to be responsible for morphological deformations in three different seagrass genera – Halophila, dwarf Zostera species and Halodule. However, our current research suggests that phytomyxid infections can be found in numerous other seagrass taxa and the diversity of these parasites is significantly greater than previously anticipated. Our molecular analyses of the rRNA phylogenetic markers show that seagrass-associated phytomyxids have likely co-evolved with their hosts and are highly host-specific. Furthermore, despite being historically perceived as extremely scarce in the marine environment, we recently revealed that phytomyxids parasitizing Zostera marina are in fact one of the most predominant eukaryotes in eelgrass beds on a global scale, and can be found in the roots of >99% of Z. marina plants. Given the clearly understudied ecological significance (and/or pathogenic potential) of Phytomyxea in seagrass meadows worldwide, we call for international collaboration aimed at uncovering the diversity of these protists – SEAGRASS WANTED!

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Carbon stocks and microbial communities from a Welsh Zostera Noltii meadow

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Studies on the microbial role in carbon cycling within seagrass sediments are still in their infancy. However, following important developments in molecular biology research, the importance of marine microbes to ocean processes has been gaining traction. This study aimed to analyse carbon sources and stocks from a Zostera noltii intertidal meadow in Porthdinllaen, on the north coast of the Llyn Peninsula in north Wales, examining stocks from seagrass sediments and leaf biomass, as well as sediment from points adjacent to the meadow. In addition, microbial communities have also been identified for all three groups, to provide a better understanding of the interaction between microbiome and carbon cycling. Seagrass seeds from this site have been harvested to be used in large seagrass restoration projects in the UK, highlighting the importance of fully understanding the mechanisms that enable these ecosystems to act as important carbon sinks.

SS09 - Novel approaches to assist seagrasses in a changing environment

Molecular signs of priming imprint in Posidonia oceanica seedlings

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Seagrasses are continuously exposed to repenting environmental changes, and exploring novel approaches to enhance stress tolerance capacity could be crucial for their survival in the future. Starting from what was already demonstrated in land plants, a thermal-priming treatment was here applyied for the first time in Posidonia oceanica seedlings. At the base of this approach, there is the potential for plants to store stress-response mechanisms, to be reactivated in the face of further stressful exposures. These mechanisms can be regulated by stress-memory, which is epigenetically modulated. In particular, DNA methylation can modify gene expression, promoting phenotypic changes that could improve stress tolerance. DNA methylation and transcriptomics profiles of primed and not-primed seedlings were explored to investigate the role of DNA methylation in mediating priming and in the regulation of thermal stress responses. Primed seedlings performed better than not-primed ones, showing the largest transcriptomic regulation. The integration of transcriptomics with DNA methylation outlined central genes and key biological processes involved in the priming acquisition in P. oceanica seedlings.

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Can microclimates foster enhanced resilience to climate change in seagrass?

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Global climate change, particularly ocean warming, can impact coastal benthic ecosystems worldwide. In the marine realm, however, little is known about how existing microclimates prime (harden/pre-select) populations and genotypes for enhanced resilience to climate change.
This research exemplifies experimental efforts across geographical scales and environmental gradients to entangle the relevance of small-scale natural microclimatic variability for the resilience of seagrass Zostera marina to warming and extreme climatic events. We combined short-term and long-term micro- and mesocosm studies with high-resolution environmental monitoring to contrast seagrass inhabiting areas with variable and stable thermal microclimates.
Despite the pronounced differences in thermal variability and underlying partial genetic differentiation between nearby seagrass meadows, we find limited support for a priming of seagrass for enhanced reliliance to long-term (1.5 years) warming and short-term warming and freshening events.
This research underscores the magnitude of thermal microclimatic differences across very small spatial scales. We equally highlight the complexity of microclimatic variability to serve as selection beds for ecosystem resilience to future climate change and, in particular, changes in variability and the occurrence of climatic extremes.

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Non-invasive assisted evolution strategies on Posidonia oceanica seedlings

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Restoring and strengthening seagrass meadows is essential to maintain their processes, functions and ecosystem services in the context of global change. This requires a redoubling of efforts to promote the acclimatisation and adaptation of the meadows to the pace at which environmental change is occurring.
This presentation illustrates different non-invasive assisted evolution approaches applied to the Mediterranean endemic seagrass Posidonia oceanica, with the potential to improve the existing genetic basis of natural populations, enhancing their ability to tolerate stressful environments (i.e. marine heatwaves) and accelerating recovery after environmental disturbances. Specifically, two assisted evolution approaches were explored. The first one aimed at identifying best performing genotypes through phenotypic screening tests on seeds and subsequent manipulative selection experiments on seedlings. The second is based on seed priming by pre-exposing seeds to mild-stress to increase their responsiveness to a subsequent stressful event, in order to unravel key aspects the induction and persistence of the priming state. The findings of these works represent an advance in the knowledge of assisted evolution strategies in P. oceanica, and are of great value and utility for improving the resilience and restoration of this valuable species.

SS09 - Novel approaches to assist seagrasses in a changing environment

Navigating the changing seascape: Epigenetic and microbiome responses in eelgrass meadows

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As the climate is changing, species will have to move, acclimatise or adapt. Sessile species with low genetic diversity may be especially vulnerable. For such species, epigenetic modifications and microbiomes may instead play an important role, and it is important to explore if such information can be useful in restoration efforts.
We sampled Zostera marina from four meadows along a 1,000 km steep salinity gradient (5-21psu) on the Swedish coast and exposed clones to current and future salinities and temperatures in a mesocosm experiment. We saw clear differences in both methylation and seagrass leaf-associated microbiomes from the same clones in the field, at the start of the experiment and at the end of the experiment. Individuals from the same meadow showed similar patterns of methylation and microbiome, but meadows differed at all time points. Survival was lower under a future scenario, and while methylation patterns and directions were highly site-dependent, we observed greater microbiome community divergence with increasing severity of treatment. This highlights the importance of studying eelgrass from several meadows with different environmental and genetic backgrounds when aiming to predict species response to a changing climate, and before such information can be used to facilitate adaptation during restoration efforts.

SS09 - Novel approaches to assist seagrasses in a changing environment

Bring on the HEAT: Helping Eelgrass Adapt to Temperature through Assisted Migration

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Eelgrass (Zostera marina) along the eastern seaboard of the United States faces multiple threats, from declining water clarity to rising sea water temperatures. Under continued warming, model predictions suggest future retraction of up to several 100 kms northward under continued warming. In 2022, The Nature Conservancy convened a group of scientists, managers, and practitioners from a range of disciplines, including terrestrial ecologists, agriculture, and industry, to propose innovative solutions to save and restore eelgrass in the face of climate change. The primary recommendation from this working group was to source thermotolerant genotypes from already heat-stressed areas and move them to areas where temperatures are expected to rise, a process known as assisted or population migration. The persistence of these transplanted genotypes should, ideally, confer climate resistance/resilience to seagrass beds and prevent further losses. A diverse team of researchers will soon embark on a preliminary implementation of assisted migration across five of the northeast US National Seashores. Here, we review our proposed design and identify regulatory and methodological hurdles still necessary to overcome, and welcome advice from those applying similar approaches.

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Trigolactone and gibberelic acid promote gemination of Zostera marina seeds

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Seagrass meadows are rapidly declining worldwide, with Zostera marina being one of the most impacted species. While successful restoration efforts are becoming more frequent, unfortunately, numerous attempts still experience low success rates and limited germination.
Seed priming has the potential to maximise the probability of germination, addressing issues related to low, slow, asynchronous germination, or dormancy. Advances in Zostera marina's genome have unveiled new insights into receptors that may modulate germination under suboptimal conditions.
In this study, we assessed the effect of priming treatments on Zostera marina seed germination. Three different phytohormones (GR24 - synthetic Strigolactone, smoke water - KAR, and GA3 - Gibberellic acid) were tested in ten different concentrations on two generations of Zostera marina seeds.
Germination rate significantly increased when seeds were exposed to GA3 and GR24. GA3 exhibited a wider efficacy at both high and low concentrations, while GR24 promoted germination at intermediate concentrations. Seed generations also influenced the outcomes, with younger generation seeds being more sensitive to the primers compared to older generation seeds. Our study suggests that hormone priming can enhance germination success and provides insights that may guide methods to increase the success of seed-based restoration projects

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Thermo-priming vs acclimation: investigating the resistance of Posidonia oceanica seedlings to heat waves

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Marine heat waves (MHWs) have been increasing in frequency, duration, and intensity as a consequence of global warming. This phenomenon is exacerbated in Mediterranean Sea and information on adaptative strategy of key species such as Posidonia oceanica is now needed. A “priming” stimulus prepares an organism for an improved response to environmental changes by triggering a memory during a lag-phase. In this study we investigated how the development of thermo-primed P. oceanica seedlings is affected by a field simulated MHW depending on the duration of the lag-phase. Results did not show evidence of a memory triggered by the priming stimulus, but the importance of an acclimation phase before the highest temperature stress was highlighted: seedlings with a lower temperature lag-phase between two heat events developed a lower number of leaves and higher leaf necrosis than seedlings that experienced a gradual increase of temperature during the experimental time. Also, regardless the priming stimulus, MHWs slowed down the development of the leaf and root length. However, although an overall resistance of P. oceanica seedlings to heat was recorded, testing different intensities of priming and length of lag-phase is now necessary to provide information about its adaptive success.

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Understanding seagrass temperature tolerance to aid in seagrass resilience and restoration efforts

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Ocean warming is having unprecedented ecological impacts on marine ecosystems, with immobile benthic habitats, such as plants, particularly vulnerable to stochastic events e.g. marine heatwaves (MHW). Understanding seagrass thermal tolerance across species provides valuable knowledge for focused restoration efforts, whilst assessing the thermal tolerance of multiple populations of a single species provide insights for thermal resilience building. We investigated thermal performance of six predominantly temperate seagrass species (Posidonia sinuosa, Posidonia australis, Amphibolis antarctica, Amphibolis griffithii, Zostera nigricaulis, and Halophila ovalis) and with four species (P. sinuosa, P. australis, A. antarctica and H. ovalis) how this varied by location along a thermal latitudinal gradient spanning 10°. We measured oxygen evolution in closed incubation chambers at temperatures ranging from 15-45°C for seagrass productivity (Pmax), optimum temperature (Topt) at which maximum photosynthesis occurred, and thermal maximum temperature (Tmax). Thermal optima (Topt) showed the greatest variation across species, differing by 10°C within the same location (e.g. 22.5°C for Z. nigricaulis to 32°C for H. ovalis). There was less variation with Tmax varying by up to 5°C across species (e.g. 35°C for Z. nigricaulis and 40°C for H.ovalis). Within each species there were differences among locations for the thermal photosynthetic performance, but this did not follow the predicted patterns along the latitudinal gradient. These findings can inform restoration approaches by identifying which species have a higher thermal tolerance and may be more resilient to ocean warming and heatwaves. There are also opportunities for resilience building within a species by transplanting populations with higher temperature tolerances.

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Evaluating and enhancing eelgrass resiliency and restoration potential in a changing climate

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In recent years, elevated water temperatures have resulted in large-scale Zostera marina diebacks of entire meadows in the lower Chesapeake Bay, Virginia, USA resulting in a conversion from historically stable, dense meadows to low-density ephemeral ones. In contrast, many Z. marina populations in Back Sound, North Carolina, USA appear to be more resilient to warming water temperatures. Structural, physiological, and genetic resiliency traits of Z. marina populations in NC and VA were compared before and after stressful summer temperatures to identify specific meadows in NC that could serve as seed donor beds for Chesapeake Bay. Reciprocal test restoration of NC and VA Z. marina seeds were used to further elucidate if greater resiliency to local stressful conditions will result in an increase in seedling survival and resilience to temperature stress outside of the local system. Z. marina restoration without considering the resiliency of the meadows to climate change no longer appears to be a viable option for long-term success. Therefore, state agencies and non-profits in both regions need species specific data to better enhance resiliency of Z. marina populations by advancing the development and implementation of ecosystem restoration strategies that mitigate current and anticipated stressors.

SS09 - Novel approaches to assist seagrasses in a changing environment

Development of axenic cultures of Zostera marina from seeds and their potential use to propagate new plants through somatic embryogenesis

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Declines in seagrass ecosystems due to local and global stressors necessitate urgent conservation efforts. While mitigating local threats can prevent habitat losses, the challenge lies in restoring seagrass without overharvesting donor populations. We are testing a pioneering approach to develop cultures of seagrasses through seeds and propagating new plants through somatic embryogenesis using explants. The first step of our study focuses on developing a standard protocol for growing cultures of Zostera marina through seed sterilization and germination. We have observed a 63% germination rate of seeds grown in a two-layered culture medium comprising basal media rhizome layer (Murshige and Skoog, MS) and a 20 ppt seawater overlayer. Seedlings were cultivated until the development of the first true leaf. Clonal plants were tested using direct organogenesis media, both solid and liquid. Secondly, we are testing the use of MS medium with varied callus-triggering hormones to induce callus formation from cotyledon, young leaf, and apical shoot explants. Our aim is optimization of callus induction and proliferation, differentiation of somatic embryos from callus, and encapsulation of single embryos to produce artificial seeds. This methodology holds promise for the propagation and enhancement of Z. marina, offering potential applications in seagrass conservation and restoration efforts.

SS09 - Novel approaches to assist seagrasses in a changing environment

Accelerated growth and low mortality of juvenile Zostera marina plants under an extreme Baltic heat wave

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Marine heat waves are increasingly threatening coastal ecosystems, including seagrass beds. Earlier ontogenetic stages may be more or less vulnerable. Here, we studied the impact of heat stress on 6-month-old Zostera marina plants to assess effects of months-long elevated temperatures (27 °C) on juvenile plants compared to controls maintained at 19 °C. Heat-exposed plants exhibited significant accelerated growth rates compared to the control group, while mortality started only after six weeks. These unexpected results contrast with prior findings where adult plants from the same region grew slower, showed decreased productivity, and revealed higher mortality at 27°C. Further research is needed to verify these differences with adult plants in the same experimental set-up, and to explore underlying physiological mechanisms driving thermal tolerance in juvenile Z. marina. This divergence underscores the complexity of temperature responses in different life stages in ecologically important species such as seagrasses. If early heat stress leads to a lasting priming effect, these plants could serve as heat-tolerant founders for new seagrass meadows. As one element of the “Assisted Evolution”-toolbox, such approaches may be promising for the sustainable restoration of seagrass ecosystems in the face of climate change.

SS12 - Securing resilient and just seagrass social-ecological systems

Securing a future for seagrass ecosystems in SE Asia – enhancing knowledge of seagrass ecosystem services (Blue Carbon) to incentivise conservation and community benefits

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Seagrasses provide many ecosystem services, including carbon sequestration, but are frequently neglected in decision-making. Seagrasses of the Indo-Pacific support up to one billion people through their provision of fisheries and provide critical habitat for many marine species. At the same time, seagrasses in the region are declining because of coastal development, unsustainable resource extraction, and environmental degradation. Limited data exists on seagrass status, their ecosystem services and value in the region, information that can incentivise seagrass conservation.

The Seagrass Ecosystem Services Project (SES project) was established to provide critical data on the state and condition of seagrass ecosystems and to promote the integration of SES into evidence-based decision-making and business models to ensure seagrass sustainability across the Indo-Pacific. The project focused on five priority sites in SE Asia and a range of SES, including carbon sequestration (Blue Carbon; BC), aiming to build capacity within NGOs to undertake BC Assessments and integrate the findings into policy, decision-making and management. Here we provide an overview of the project development and BC-related outcomes, highlighting the lessons learned to empower future similar projects and enhance their success. There is an urgent need for more projects that focus on the socialecological aspects of seagrass habitats.

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Socio-ecological modelling on seagrass ecosystems in Sangihe Islands, Indonesia

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Seagrass meadows are highly productive ecosystems that support many species, including humans. Seagrasses provide habitat and food for fish, invertebrate assemblages, and charismatic species like Dugong dugon. Seagrass systems also support human livelihood, food security, and nutrition sources in many communities. However, seagrass meadows face high global decline rates due to changing environmental conditions. In 2017, community-based (CB)-MPAs in several villages in the Indonesian Sangihe Islands were established to protect marine habitats, vulnerable species, and improve local livelihoods. This research explores the interaction between fisheries activities, seagrass ecosystems, dugong populations, and community-based MPAs, aiming to support better marine management for coastal communities. We used semi-structured household surveys to interview fishers, open-ended interviews for key informants, and intertidal-fixed transect sites from the seagrass-watch method to study the seagrass coverage. We revealed a negative correlation between fisheries activities and seagrass health. We also found that locally positive perceptions of the benefits of CB-MPAs were positively correlated to seagrass habitat protection, dugong population conservation efforts, increased fish stocks and improved local livelihoods. The authors recommend that all stakeholders and governments integrate this socio-ecological model for future coastal management and policy.

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Developing carbon emission factors to support seagrass Blue Carbon conservation and restoration projects

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Seagrass Blue Carbon (BC) is being introduced into national carbon inventories and fluxes to promote conservation and restoration actions as a natural climate solution. However, the lack of robust carbon emission factors associated with the loss or restoration of seagrass meadows is limiting BC projects and their implementation in national climate policy and strategies. Here we compiled published literature on soil carbon stock changes associated with seagrass loss and restoration to estimate carbon emission factors that could be used in policy development. The results showed that direct impacts (e.g., storms, dredging or achoring) resulted in average erosion and loss of 50 ± 29% of soil carbon stocks, whereas indirect disturbances (e.g., heatwaves and eutrophication) can cause the erosion and loss of 20 ± 22% within <1 to 55 years after disturbance. Assuming that 50% of the eroded soil carbon is remineralized, we estimated 17-202 Tg CO2eq yr-1 emissions from seagrass loss worldwide at 1.5% yr-1 loss in global extent. We modelled the exponential recovery of soil carbon stocks following seagrass restoration that can take up to 30 years. This information can facilitate the development of BC crediting schemes across multiple management activities to promote large-scale implimentation of seagrass BC projects.

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Sustenance and more: the diverse role of intertidal gleaning in the livelihood of women in coastal communities

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Coastal resources play a vital role in the well-being and livelihoods of people in coastal communities globally, with diverse uses and values that vary among individuals and across different periods. Equitable management of these resources necessitates an understanding of how people value ecosystems under varying circumstances. Intertidal gleaning, a type of small-scale fishery in the seagrass meadows and mangroves of Perigi Acheh village in the Sungai Johor estuary is conventionally portrayed as primarily focused on food security. This study explored the values of gleaning, emphasizing its non-material significance, including aesthetic, recreational, cultural, and social dimensions. Through an ethnographic case study in the Perigi Acheh village, we uncovered functional and social values that women and other gleaners attribute to this practice. Contrary to the oversimplified notion of gleaning as solely a means for sustenance, our findings highlight the diverse priorities gleaners place on activities such as socializing and connecting with the intertidal gleaning habitats. This emphasizes the importance of moving beyond simplistic understandings, signifying the evaluation of intangible values when assessing coastal ecosystem services. By recognizing the non-material roles of gleaning, we can offer more accurate portrayals of coastal livelihoods, promoting equitable management in these areas.

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Seagrass security: assessing the role of fisheries supporting and provisioning services in UK's temperate seagrass (Zostera marina) meadows

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Seagrass meadows, provide vital coastal and ecological connectivity, ecosystem services and key provision habitats that support fisheries, particularly as a nursery habitat for commercially fished species. Seagrass presence and extent are in significant decline, being altered by human pressures and a changing climate, with consequential impacts to commercial fish stock biomass, economic losses, and a changing seascape. Associated ecosystem and fishery complexities and limited understanding within these habitats means commercial valuation and natural capital assessments are often overlooked during ecosystem service review as lack of meaningful data and methodologies makes it difficult to quantify and value.
Using a Seagrass Residency Index (SRI) approach, the economic value of seagrass habitat and commercial fisheries value of supporting and provisioning services can be quantified. This study assesses the role of temperate seagrass meadows (Zostera marina) in supporting fisheries and quantifying its commercial value using SRI method approach in a UK context. Seven UK seagrass meadow case study sites were studied across varying environmental gradients, seagrass biotopes, spatial scales, and stages of restoration. This research presents a contemporary picture of the economic value of seagrass meadow provisioning services for commercial fish species in the largest assessment of its kind in the UK.

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Overcoming seagrass blindness: seruan setu – secret gardens of the sea gamelan performance for greater seagrass recognition in malaysia

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Seagrass has been described as lacking in charisma, leading to limited societal recognition of the pressing need for its conservation. While significant progress has been made in the past five years, with the global seagrass community employing science documentaries, public talks, print media, and citizen science programs, conventional science communication methods may not resonate universally—especially among those disinterested in science. In contrast, the cultural arts possess the unique ability to evoke emotions and establish a personal connection with audiences, making them a potent tool for fostering appreciation and excitement, especially for subjects deemed less-charismatic, like seagrass. This presentation introduces a Malaysian cultural arts approach to public engagement, spotlighting Seruan Setu, a gamelan music performance dedicated to seagrass ecosystems, as a case study. Seruan Setu, staged at the Kuala Lumpur Performing Arts Centre in August 2023, featured a collaboration between marine scientists and the Rhythm in Bronze gamelan orchestra. The multidisciplinary performance, encompassing gamelan music, dance, animation, and documentaries, attracted a capacity crowd, including government leaders. Audience surveys and a post-performance conference provided insights on the performance impact, which will be shared, along with video excerpts. The essential elements that contributed to Seruan Setu's success in Malaysia, such as how collaborations were formed between artistes, scientists, and communities, will be discussed.

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The cultural value of seagrass to humanity from historical to contemporary uses

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Seagrasses have been entwined with human culture for over 120,000 years, constituting a natural resource that has benefited humanity throughout this long history. Understanding the cultural value of seagrass from historical to contemporary uses can foster the valuation of these ecosystems to further encourage conservation and restoration actions. This study compiled evidence on the cultural values of seagrass around the world, showing that they have been used for spiritual and ceremonial purposes, as grounds for direct and indirect food resources, and in industrial activities including construction, clothing, fertiliser, livestock feed, and medicine. Although multiple applications of seagrass in industry have been suggested, seagrasses are a protected species and harvesting for industrial applications is prohibited, which renders seagrass farming a big challenge for the 21st century. Seagrasses are arising as a promising resource towards sustainable development goals and as a weapon against climate change despite extensive historic and current losses of seagrass ecosystems. This review can aid the development of markets around the cultural value of seagrasses to incentivize their conservation and restoration, shining light on the ancient relationships between seagrass and humanity

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Songlines and Seagrass: Cultural and biodiversity dimensions govern seagrass protection in the Gulf of Carpentaria, Australia

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We delve into the profound connection between the Yanyuwa and Marra Aboriginal people in the Gulf of Carpentaria, Australia, and seagrass ecosystems. Seagrass emerges as integral to their identity, intricately linked to their songlines and cultural heritage. The significance of protecting coastal resources becomes evident as it maintains ecosystem health and facilitates cultural connection and biodiversity protection.

Aboriginal knowledge holders reveal a deep interconnection between cultural practices, seagrass, and marine megafauna dynamics. Their Sea Country is more than an ecological reservoir, embodying living archives of lore and cultural practice across generations. This relationship reflects a profound understanding of ecology, emphasising the importance of species like turtles and dugongs and their seagrass habitats.

Recognising the importance of seagrass in cultural and ecological contexts is crucial for effective conservation strategies. We argue that a changing climate and anthropogenic threats have hastened the need for culturally sensitive and innovative approaches that equally value Indigenous and Western scientific knowledge. We emphasise the urgency for collaborative research to weave diverse knowledges, fostering conservation practices that honour the intricate web of knowing cultivated by Indigenous peoples. We present a blueprint for protecting these values as an inclusive and meaningful response to ensuring sustainability in Sea Country.

SS12 - Securing resilient and just seagrass social-ecological systems

Simple Alterations to Traditional Mooring Configurations to create the Striling Advanced Mooring System

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The Ocean Conservation Trust & Marine Conservation Society have trialled alterations to traditional mooring configurations to relieve the destructive scour of the sinker chain within seagrass meadows, on the South Devon Coast in the U.K. The moorings were installed in 2019 in collaboration with a number of local mooring holders, with the aim of firstly demonstrating Advanced Mooring Systems engineering solutions are as safe as traditional configurations, and secondly Advanced Mooring Systems safeguard seagrass recovery within the halo of the scour caused by traditional mooring. Over the past 4 years the results have been mixed, however, 2023 evidenced a strong recovery within the area of damage caused by the moorings, recording a 212% increase in seagrass cover within the mooring area. The takeaway message of this recent trial is Advanced Mooring Systems work! They safeguard vital habitats! Which, after damage can take a while to recover, and taking measures to not only restore, but to also protect these fragile habitats is an essential part of Seagrass Protection.

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Exploring the Nexus of Seagrass Ecosystems, Angler Dependency, and Conservation Concerns

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Incorporating local ecological knowledge into scientific inquiry enhances our understanding of complex ecosystems. Anglers, as avid observers of natural environments, hold valuable insight into temporal changes within coastal habitats. In particular, their experience extends into the significance of seagrass ecosystems in maintaining coastal biodiversity and providing essential ecological services to recreational fish populations. Everglades National Park (ENP), located in the southernmost region of mainland Florida, is a unique ecosystem comprised of shallow mud banks and vast seagrass meadows dominated by Thalassia testudinium, Syringodium filiforme, and Halodule writii. With high fish diversity and abundance, Florida Bay offers one of the most sought-after recreational fishing environments in the nation. It was estimated that the ENP recreational fishery generates over $1 billion annually. Of that, Florida Bay has been estimated to contribute roughly $439 million alone. In this study, we delve into the perspectives and preferences of 160 professional fishing guides, uncovering their profound concern for the loss of seagrass in Everglades National Park. As stewards of this unique ecosystem, the guides emphasize the urgency for ongoing habitat improvements, spotlighting seagrass preservation as essential for sustainable management practices to safeguard their livelihood and preserve this vital habitat for the enjoyment of future generations.

SS12 - Securing resilient and just seagrass social-ecological systems

Seagrass inclusion into climate policies

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Seagrass meadows provide a range of environmental, economic, and community benefits to our global society. They are also nature-based solutions to climate change, capable of locking away carbon into ocean sediments and providing numerous climate adaptation benefits including coastline stabilization, improving water quality, and reducing wave impacts. The management and conservation of this ecosystem can play a vital role in advancing multiple sustainable development goals, including meeting climate objectives. For example, countries can protect and restore seagrasses as part of the actions they take within the nationally determined contributions (NDC) they put forward under the Paris Agreement. There is growing momentum globally to include seagrass within NDCs, but when compared to mangroves, seagrasses are often left out of the climate dialogue. Come hear how the country of Seychelles and others in the Western Indian Ocean are overcoming research and policy barriers to include this critical ecosystem within climate policy and overall management.

SS13 - Toward better understandings and conservation of Tropical Asian Seagrasses: Succeeding the will of Prof. Miguel D. Fortes (1947-2023)

Seagrass research and conservation in southeast Asia: sir mike's outstanding achievement and contribution

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Southeast Asia is a hotspot of global seagrass diversity. However, the research and conservation efforts have been far behind those in developed regions. Professor "Sir Mike" Fortes was the pioneer and was always at the center of seagrass research and conservation in SE Asia. Above all, his enthusiasm, mentorship, and friendly personality inspired and encouraged many succeeding researchers and practitioners, not only in Asia but all over the world. By reviewing his research career and outstanding achievements, we will discuss the challenges and opportunities of current seagrass research and conservation practices in this region, and how we can develop future research and collaborations based on his legacy.

SS13 - Toward better understandings and conservation of Tropical Asian Seagrasses: Succeeding the will of Prof. Miguel D. Fortes (1947-2023)

Building capacity key to filling gaps in our understanding of seagrass ecosystem services

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Seagrass ecosystems across Southeast Asia support a rich biodiversity, but are in decline. To address these declines, decision-makers need accurate assessments of the status of and pressures on seagrass ecosystems, but these are constrained by incomplete and uneven spatial coverage. To contribute to these assessments, the IKI Seagrass Ecosystem Services project sought to deliver site-specific assessments of seagrass health, and to evaluate the ecosystem services seagrass provides. A group of six local NGOs and community groups at project sites (Indonesia, Thailand, Malaysia, Philippines and Timor-Leste) have been empowered to assess seagrass with the provision of technical tools and capacity building. Focusing primarily on biodivserity assessments we highlight how we can reduce parachute science, build capacity and fill gaps in our knowledge of seagrass ecosystems. Using an iterative proccess to effectively build capacity, we worked with partners to identify monitoring questions and aims, the key biodiversity functions and processes to monitor and the most suitable monitoring methods to do this. We then delievered training to carry out monitoring activities, manage and interpret data. We call on the scientific community to share data, knowledge and tools to ensure the accessibility, interoperability, and reporting of seagrass ecosystem services data at a global scale.

SS13 - Toward better understandings and conservation of Tropical Asian Seagrasses: Succeeding the will of Prof. Miguel D. Fortes (1947-2023)

Advancing our understanding multi-species inter-tidal seagrass meadows in the Andaman and Nicobar archipelago, India

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Seagrasses occur in all coastal waters except Antarctica, but only a fraction of this area, typically inhabiting monospecific meadows in the temperate, has formed the basis of our knowledge of seagrass ecosystems. Tropical meadows that show both monospecific and multi-species assemblages have had poor research representation. These meadows tend to be diverse and highly dynamic and depending on the seagrass species, their canopy height, density and other spatial and temporal variations, the magnitude of services are likely to vary. The shallow coastal waters of the Andaman and Nicobar archipelago of India support several multi-species intertidal and subtidal seagrass meadows. Our research group has been focussing on understanding the drivers of species assemblages and meadow dynamics, and the sociological, ecological and geophysical functions of these meadows. In this talk, I will focus on our ongoing research and some of the key findings.

SS13 - Toward better understandings and conservation of Tropical Asian Seagrasses: Succeeding the will of Prof. Miguel D. Fortes (1947-2023)

Seagrass meadows as seabird's habitats in the southern Red Sea coasts of Saudi Arabia

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Studies of seabird communities along seagrass meadows, particularly in arid environments, have remained largely limited. We studied a pristine seagrass meadows in the southern Red Sea coasts of Saudi Arabia with aims (1) to determine the diversity and distribution of seabird communities between sampling stations (S1– is a seagrass meadows; S2 – is an open coast adjacent to seagrass meadows; and S3 – is an open coast with no seagrass) and seasons (March for spring, July for summer, and November for fall); and (2) to identify the most influential climatological variables influencing the seabird communities. Bird point count survey was the sampling method used. Twenty-nine (29) seabird species from 14 families were identified throughout the study. Site S1 showed significantly higher species richness, diversity, and dominance than S2 and S3. There was a consistent downward trend in these diversity indices from S1 to S3. The multidimensional scale (MDS) and the analysis of similarity (ANOSIM) showed that seasonality has a significant influence on the heterogeneity of seabird species richness. Distance-based linear model (DISTLM) showed that air temperature is the most influential factor affecting the variability of the seabird community.

SS13 - Toward better understandings and conservation of Tropical Asian Seagrasses: Succeeding the will of Prof. Miguel D. Fortes (1947-2023)

Drastic changes to the seagrass medows in Thailand

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The seagrass meadows in Thailand provide numerous ecosystem services, however, in the recent years their decline have been observed. In this study, the changes within the last several years were recorded by various organizations within Thailand and Australia using unmanned aerial vehicles (UAVs) across many seagrass meadows along Andaman coast of Thailand. The drone images were obtained through various projects by local universities, NGOs, government staff and more recent project in the collaboration with CSIRO, Australia. In total 7 sites were revisited and mapped from 2016 to 2023. Using the drone images, it was identified that the seagrass meadows in Trang provice, have been mostly affected and suffered dramatic loss. On the other hand, seagrass meadows in Krabi and Phuket province showed smaller changes in the seagrass area. The losses of the seagrass could potentially be attributed to various factors occuring at the same time, such as increased sedimentation and other anthropogenic acctivities, climate change and herbivory pressure. The effects of the seagrass loss along Andaman coast has national importance as these meadows were one of the largest and most diversed in Thailand, which consequently has enormous effects on the decline of the ecosystem services that these meadows provided.

SS13 - Toward better understandings and conservation of Tropical Asian Seagrasses: Succeeding the will of Prof. Miguel D. Fortes (1947-2023)

Variation of Seagrass Community Structure and Carbon Stock in the Berau Marine Protected Area with response to land-use change

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Seagrass ecosystems increasingly receive attention due to their capacity to store high carbon. Protecting this ecosystem is the key to increasing resilience to climate change. However, in some of the Marine Protected Areas (MPAs), seagrass ecosystems are still under threats, especially from land-use change. This study aims to investigate the current condition of seagrass ecosystems in Berau MPA with response to land-use change along the Berau Watershed. We used several methods like SeagrassWatch and remote sensing, and proxies like water quality and stable isotopes. Seagrass percent cover was categorized as poor (<29,9%) and not healthy (30-59,9%). Biomass carbon was measured the highest (435 g C m-2) in the island with turbid water and low seagrass cover of 25% (Rabu Rabu island) due to the existence of one individual of a larger species E. acoroides that is known to be more persistent in extreme conditions. Meanwhile, the lower biomass carbon was obtained from the smaller and pioneer species found in the islands with clear water and higher seagrass cover of 58% (Maratua island). This study indicated that seagrasses in Berau MPA were threatened with degradation. As the threats from anthropogenic increase, there must be an increase understanding on MPA functions in seagrass carbon sequestration to avoid further loss of carbon.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

Seagrass ecosystem multifunctionality under the rise of a flagship marine megaherbivore

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Concerted conservation efforts have remarkably recovery of multiple green turtle (Chelonia mydas) populations globally, with their voracious feeding drastically reshaping tropical seagrass habitats. However, the impact of these changes on ecosystem functions and multifunctionality remains poorly understood. Through experimentally simulated grazing scenarios, we applied a novel integrated index to assess seagrass ecosystem multifunctionality, based on well-recognized measures of ecosystem functions that reflect ecosystem services. Experiments revealed that intermediate turtle grazing maximized nutrient cycling and carbon storage, while the absence of grazing led to peak sediment stabilization, decomposition rates, epifauna richness, and fish biomass. Intense grazing caused disproportionate effects, resulting in multifunctionality collapse. These findings emphasize the megaherbivores' significant influence on coastal ecosystem functions, underscoring the need for a balanced conservation approach considering key drivers like predators and habitat. Neglecting these factors may lead to overgrazing-induced multifunctionality loss. Our index proves valuable for quantifying ecosystem performance. Rapid shifts in megaherbivore abundance, whether through extinction or conservation, disrupt ecosystem functioning, compromising services countering global change effects. This highlights the urgency of an integrative ecosystem approach in environmental management to safeguard and enhance multifunctionality. The transformation of tropical habitats prompts a reevaluation of reference states and management plans for seagrass meadows.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

Temperature and herbivory drive seagrass recovery potential across the Western North Atlantic

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Marine heatwaves have been reported to lead to seagrass collapse, fueling worries about the future of this key functional group in a warming climate. Here we show that over its (sub)tropical range, seagrass has in fact higher resilience in warmer places. We assessed resilience by studying recovery rates from small-scale (0.018 m2) perturbations in which we removed all above-and below-ground biomass and applied fertilization treatments in a year-long field experiment. A total of 100 plots at ten sites in the Western Atlantic that span over 20° of latitude were monitored. We show that temperature and grazing pressure are the main driving factors impacting above-and belowground seagrass recovery. Surprisingly, ambient nutrient and light availability and fertilization treatments did not directly affect seagrass recovery. Our results suggest that while temperature extremes may still harm seagrass, resilience of this foundational species may increase in gradually warming subtropical parts of its range.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

Megaherbivory is a major force driving seagrass structure on the Great Barrier Reef

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Herbivory is a key mechanism controlling seagrass ecosystem stability, function and diversity globally. Tropical seagrass ecosystems are susceptible to large scale grazing from megaherbivores (turtles and dugongs), but research on the impact of grazing on seagrass structure and function at a regional scale is only beginning to receive attention. We established a network of megaherbivore exclusion cages at ten sites across 1200 km of the Great Barrier Reef to assess broad scale patterns and impacts of megaherbivore grazing on seagrasses. Sites covered a range of seagrass habitat types (e.g. coastal, reef top, deep-water), species and latitudes that were monitored periodically for between 2 and 15 months. Grazing impacted seagrass meadows at seven of the ten sites and there was an overall reduction in above ground biomass and canopy height. A change in seagrass species composition was detected in exclusion cages at two sites. The duration and extent of grazing impacts on seagrass structure varied across sites. These results demonstrate the broad impact of megaherbivores on regulating the structure, composition and potentially the function of seagrass meadows on the Great Barrier Reef and can inform monitoring and management of seagrasses under grazing pressure.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

Mesopredator impact on seagrass: Emerging challenges in coastal management

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Trophic cascades in coastal food webs can lead to an increase in mesopredator abundance, negatively impacting seagrasses by reducing algal mesograzers. Yet, the direct negative effects of omnivorous mesopredators on seagrasses remain less understood. In recent decades, eelgrass distribution along Koster islands, Sweden has declined, and large-scale restoration attempts have failed despite favorable environmental conditions.

To investigate potential causes behind these losses and explore effective restoration methods, a series of field experiments were conducted. In a cage experiment, eelgrass survived only in mesopredator-exclusion treatments. Uncaged treatments showed significantly lower shoot densities and lengths, of 86% and 62% respectively, regardless of location, depth or nutrient additions. Most uncaged shoots showed damage from shore crabs (Carcinus maenas), indicating crab disturbance as the main cause of losses.

Additional experiments aimed to mitigate crab damage revealed that increasing planting densities from 16 to 255 shoots m-2 increased survival from 5% to 43%. However, efforts to reduce crab densities through crab-fishing contributed to a smaller reduction ~20% in losses. These findings highlight the impact of overfishing of large predators (e.g. cod), causing tropic cascades. Consequently, an increase in mesopredators, such as shore crabs, pose unexpected new challenges to seagrass management.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

New threats for Posidonia oceanica in a changing environment. The strange case of Caulerpa prolifera along the coasts of Sardinia

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The invasion by alien macroalgae of the Caulerpa genus is among the main threats to Posidonia oceanica in the Mediterranean Sea. Till today, the two species threating the seagrass appeared to be the alien Caulerpa taxifolia and Caulerpa cylindracea. However, in the last years, a significative spread of their autochthonous congeneric C. prolifera has been observed. In Tavolara Punta Coda Cavallo Marine Protected Area (NE Sardinia), in particular, C. prolifera is colonizing large portions of the seagrass meadows. In order to acquire the first data on the expansion of C. prolifera, three photographic samplings were conducted in 2022 in a bay of TPCC MPA where its invasion is occuring. The data collected by image analysis (% cover of the substratum of the macroalga) were compaired with those collected in the same bay fife years before. The obtained results confirmed a significative expansion of C. prolifera on different substrata, among which especially P. oceanica meadows. Moreover some moprhological differences in the blades of the macroalga were noticed between 2017 and 2022 photos, thus suggesting that a new invasive variant of the macroalga could be spreading in the basin and molecular analysis are urgently needed to identify it.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

Warming may decrease seagrass resistance to herbivory; a review and meta-analysis

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Seagrass ecosystems provide unique ecological services and are widely recognized as one of the most effective carbon sinks on Earth. The interactions between seagrasses and herbivores within these ecosystems are key for sustaining ecosystem dynamics and overall health of the environment. Seagrasses have evolved resistance and tolerance strategies that protect them from herbivory. Nevertheless, climate change represents a significant threat to marine ecosystems and thus the consequences of ocean warming on defence strategies against herbivores are an ongoing subject of study. In order to elucidate these effects on a global scale, we conducted an extensive multi-level meta-analysis synthesizing data from publications ranging from 1970 to 2022. Our results reveal a negative influence of ocean warming on seagrasses' resistance strategies, while the impact on tolerance strategies against herbivory may be less pronounced. Additionally, herbivore activity may increase, rendering seagrasses even more susceptible. Although these results suggest adverse consequences of ocean warming for seagrasses, the response may not be uniform across all species. Moreover, it is crucial to consider multiple stressors arising from anthropogenic activities to achieve a more complete perspective. With this work, we enhance our understanding of the interaction between seagrasses and herbivores in a warmer ocean scenario.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

Sea turtle grazing threatens seagrass resilience in bermuda

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Over the last decade many of Bermuda's seagrass meadows have collapsed. The results of the Bermuda Department of Environment and Natural Resources (DENR) seagrass monitoring programme indicate that the rapid deterioration of seagrass was a result of overgrazing by resurgent populations of green sea turtles and not declining water quality (Fourqurean et al., 2019). Therefore, in 2020 the DENR initiated the Seagrass Restoration Project which aimed to create seagrass refuges by caging or fencing vestigial seagrass habitat, protecting it from further grazing by green turtles to allow these small areas to recover. 2,180m2 of seagrass habitat were caged and an additional 17,000m2 were fenced to exclude turtle grazing. Currently, the results range from full recovery in some locations to no recovery. Meanwhile the green turtle population around Bermuda declined substantially, most likely in response to their diminished food source, and some areas that were once seagrass meadows, particularly those that were dense Syringodium filiforme, have recovered without conservation intervention. S. filiforme is fast growing and produces hard-coated seeds that can persist in a dormant state in a seed bank, germinating when conditions are right. These characteristics may allow us to develop seed-based restoration of seagrasses.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

Implications of fragmented seagrass meadows for fish communities in a World Heritage Area

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The effects of habitat fragmententation on marine fauna are equivocal. Here we used seascape metrics to assess change in seagrass meadow composition and configuration of the globally important meadows in Shark Bay World Heritage Area in response to the 2010/11 marine heatwave (MHW). We identified a temporal lag in dense seagrass loss with greater declines apparent 6 years (1382 Ha) relative to 3 years (344 Ha) post-MHW, while the increased proportion of sparse seagrass resulted in fragmentation. We then explored the relationship between fragmentation metrics (e.g. patch area, perimeter) and community measures of small-bodied fishes (sampled via trawling) and larger more mobile fishes (surveyed by remote underwater video). Total fish abundance and biomass were greater in meadows dominated by Amphibolis antarctica compared with Posidonia australis. Furthermore, smaller bodied fishes were more common in meadows with high seagrass cover and canopy height, while larger individuals were more abundant in seagrass patches ~2 km from shore, near deep channels. These findings highlight the importance of structurally complex canopies for fish and the potential for MHW driven seagrass loss to impact larger bodied species if patches near deep channels fragment, while decreased seagrass cover could exert a greater effect on small-bodied fish.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

Assessing the influence of natural and anthropogenic-driven environmental changes on the trophic ecology of seagrass-associated macrofauna in Hong Kong

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Seagrasses are hotspots of marine biodiversity. These ecosystems are tighly regulated by natural fluctuations in environmental conditions (e.g., seasonality). However, with intensifying anthropogenic activities, seagrasses are undergoing global declines at unprecedented rates. One primary driver of this loss is eutrophication, which can alter the trophic state in these ecosystems. Our study investigated the influence of natural (i.e., seasonal) and anthropogenic-driven (i.e., eutrophication) environmental changes on the trophic ecology of seagrass-associated macrofauna in a highly urbanized coastal area. We hypothesized that the trophic interactions might change across nutrient gradients as the quality and abundance of primary producers (C/N and N content of seagrass/algae) would change with nutrient enrichment. Such trends are expected to vary between seasons (dry/wet), potentially mediated by temperature and freshwater inputs. Seasonal samples (crabs, bivalves and gastropods) were collected from two seagrass meadows with contrasting levels of nitrogen enrichment. We assessed differences in food web structures and trophic positions using stable isotopes. We found significant differences in species compositon, species richness and the basal food souces mainly influenced by nutrient enrichment. Such effects might affect the overall productivity, resistance and resilience of seagrasses in the future.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

90 years of research on Zostera capensis: Foundational science to conservation and resilience

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Cape Dwarf-eelgrass, Zostera capensis is the most abundant seagrass in South Africa, with isolated populations along the East African coastline. Providing numerous ecosystem services that support biodiversity and human wellbeing, it is endangered throughout its distribution, with several populations declining in cover in response to global change pressures. As such, the long-term persistence of Z. capensis is uncertain and novel approaches are required to reverse declines and loss of associated critical ecosystem functions. Central to this is the need to build on existing scientific knowledge, so that habitat requirements, responses to future global change pressures and the functional significance of Z. capensis from a socio-ecological perspective can be better understood. In this comprehensive review, we summarised key themes from 290 papers published between 1933 and 2023 and present a timely overview of research conducted on Z. capensis. Research has developed from foundational geographical distribution, ecology and physiology to include themes particularly relevant to ecological value and conservation in the past decade, including emerging approaches such as conservation genomics, restoration and assessing the value of seagrass meadows in the context of blue carbon. This review also identifies critical research gaps in our current understanding of Z. capensis, including impact of pollutants and sea level rise on persistence, novel techniques for mapping seagrass meadows to better understand meadow dynamics, the interaction of microbiomes and seagrass health, alternative sources for upscaling seagrass restoration and focussed management of seagrass meadows.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

Changing foundation species in the Chesapeake Bay: implications for faunal communities of two dominant seagrass species

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Climate change is accelerating shifts in the identity of foundation species, potentially altering benthic ecosystem functioning and impact faunal communities through changes to entire food webs. Seagrass meadows in Chesapeake Bay are an ideal study system to investigate these shifts because the identity of the dominant seagrass is currently shifting. As water temperatures have risen due to climate change, the once dominant Zostera marina has been declining, while Ruppia maritima has been expanding. We examined differences in faunal structure and function between Zostera and Ruppia meadows by performing quantitative surveys on epifaunal, infaunal, and nektonic communities found in each. We found that seagrass identity impacted epifaunal, infaunal, and nektonic abundance, biomass, secondary production, and diversity differently depending on trophic level. Based on current bay wide seagrass coverage, Ruppia has ~28.6% less total standing biomass of epifauna and infauna and ~22.2% less total secondary production per year than Zostera. Moreover, nektonic abundance, biomass, and richness all increased with the proportion of Zostera coverage relative to Ruppia coverage. We interpret these patterns to show that replacement of Zostera by Ruppia in Chesapeake Bay will reduce overall biomass and production of invertebrates and mobile fauna and shift invertebrate size distributions to smaller species.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

Bioturbation as a driver of tropical and temperate seagrass meadows

Nicole Esteban , Chiara Bertelli, Bettina Walter, Lowri O'Neill, Nupur Kale, Ahmed Fouad, Richard Unsworth

Seagrass meadows are typified by containing an abundance and diversity of associated animal communities. Many of these species have positive interactions with seagrass through their physical action of bioturbating the seabed, enhancing growth rates via sediment oxygenation and organic matter remineralisation. Negative effects of bioturbation include disturbance of the root-rhizome matrix preventing seedling development and stimulating leakage of 'stable' carbon. However, these interactions are commonly poorly quantified. With increasing interest in the storage of carbon in seagrass sediments knowledge of the role of these organisms in disturbing carbon has increasing importance.

Here, we report on two separate small case studies from tropical and temperate waters of burrowing organisms living within seagrass sediments that are shown to have a significant impact on the ecology of the seagrass meadow. Sedimentary surface lugworm (Arenicola marina) cast density was quantified at an Atlantic intertidal Zostera marina meadow (Porthdinllaen, Wales, UK). Carbon cores, growth rates and infaunal density were sampled in August 2023 at low, medium and high lugworm density sites. At a subtidal Red Sea seagrass meadow (Abu Dabbab, Egypt) dominated by Halophila decipiens, burrowing mound-building shrimp density and seagrass (percent cover, species, shoot length) were quantified in October 2023. Monthly abundance of green turtles (Chelonia mydas) was estimated in Abu Dabbab bay. Infaunal density correlated positively with seagrass (health, C storage) at each site.

We show how bioturbatingorganisms at increasing density can reach thresholds whereby they can become drivers of the spatial distribution of the seagrass and negatively influence its carbon storage. The distribution pattern of seagrasses vs shrimp burrows indicated that shrimps had a direct effect on seagrass health, even in the presence of a megaherbivore. This study highlights the need for greater consideration of these organisms in the context of managing seagrass meadows.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

Widespread seagrass loss leads to ecosystem-scale decrease in trophic function

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Natural and anthropogenic disturbances have led to rapid declines in the amount and quality of available habitat in many ecosystems. Many studies have focused on how habitat loss has affected the composition and configuration of habitats, but there have been less studies that investigate how this loss affects ecosystem function. We investigated how a large-scale seagrass die-off altered the distribution of energetic resources of three seagrass-associated consumers with varied resource use patterns. Using long-term benthic habitat monitoring data and resource use data from Bayesian stable isotope mixing models, we generated energetic resource landscapes (E-scapes) annually between 2007-2019. E-scapes link the resources being used by a consumer to the habitats that produce those resources to calculate a habitat resource index as a measurement of energetic quality of the landscape. Overall, our results revealed that following the die-off there was a reduction trophic function across all species in areas affected by the die-off event, but the response was species specific and dependent on resource use and recovery patterns. This study highlights how habitat loss can lead to changes in ecosystem function. Incorporating changes in ecosystem function into models of habitat loss could improve understanding of how species will respond to future change.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

Impacts of climate warming on fish assemblages in zostera marina beds of the swedish west coast

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Overfishing of top predatory fish has led to trophic shifts in eelgrass (Zostera marina) beds on the Swedish west coast. Mesopredators, benefited by warmer waters and reduced predation, now dominate these nursery grounds, and despite reduced fishing, the stocks of many commercially targeted predatory species have not recovered. We hypothesised that environmental factors related to global climate change would impact the fish assemblage structure in eelgrass beds. We sampled six sites using a beach seine in 2001 and 2022/23. We observed an increase in sea surface temperature and precipitation and a decrease in salinity in the region over the twenty-year period. While species richness was similar, the abundance of three-spined stickleback (Gasterosteidae), wrasses (Labridae), and juveniles of Atlantic cod and plaice decreased, while only gobies (Gobiidae) increased. The species composition of pipefish (Syngnathidae) changed. We found decreases in species abundance with a lower preferred range of water temperatures. As temperature and environmental variability increase, species may move deeper and change their distribution. Regional projections suggest that warming will be the most harmful pressure for the future of these coastal habitats. This study builds a baseline for monitoring and highlights species relevant for research given their potential climate sensitivity.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

Century-scale changes in Norwegian eelgrass meadows: insights from a long-term time series

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Globally, seagrass meadows have experienced a general decline over the last century. However, there is high variability in seagrass status between regions and between meadows, and recent positive trends towards recovery have been observed in several areas. Understanding the environmental and anthropogenic factors that drive both decline and recovery can inform more effective management and conservation efforts of seagrass ecosystems.

W explored a unique dataset following eelgrass (Zostera marina) cover over nearly 90 years along the Norwegian Skagerrak coast. We found that, following losses due to wasting disease in the 1930s, eelgrass populations recovered and stabilised until the 1980s, when there was a general decline, likely due to eutrophication However, following this, trends diverged in different areas. Eelgrass populations in the coastal Skagerrak recovered and continue to increase, while populations in the Oslofjord are still in decline. We link these differing trends to interacting natural environmental conditions (salinity, exposure) and anthropogenic impacts (trophic cascades, legacy impacts of eutrophication). Understanding the factors that allow for natural recovery of degraded eelgrass meadows have important implications for management and restoration efforts, as well as furthering our understanding of the drivers that promote the resilience of seagrass communities to environmental change.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

Mesoconsumer trophic linkages across reef-seagrass seascapes within Sanctuary Preservation Areas in the Florida Keys

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Tropical marine ecosystems comprise of mosaic habitats, and many fish species move across these complex seascapes for various reasons, including foraging. Sanctuary Preservation Areas (SPAs) within the Florida Keys are explicitly designed to protect fish populations but currently protect only a fraction of seagrass compared to reef and hardbottom habitats. However, many reef fish species targeted by SPA fisheries management plans have been shown to extensively forage on surrounding seagrass beds, functionally linking reef-seagrass systems. This study investigates four reef mesoconsumers trophic dynamics and examines their reliance on seagrass derived energy sources. Fin clips of four target species and basal energy sources (i.e., seagrass, macroalgae) were collected and sampled for stable isotope analysis ($\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$). These data were incorporated into Bayesian mixing models to quantify each mesoconsumers relative basal resource contribution. Further, the model's output was used for a hypervolume niche analysis to assess trophic niche properties. Determining the energy contribution of seagrass resources to reef mesoconsumers will help understand the functional connectivity between benthic habitats, which should be highlighted and incorporated into SPA designs. Further, identifying mesoconsumers niche space allows a better understanding of their resource utilization, identifying niche overlap, and inferring trophic relationships.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

Influence of Temperature on the seagrass Posidonia oceanica in the South Tyrrhenian Sea

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Rapid changes in the environment in the past decades have been influencing negatively endemic species in the Mediterranean, such as P. oceanica. The declining rate of the meadows has been alarming and increasing temperatures or heatwavesare mentioned as an important factor contributing to the decline. At 15 sites in the Tyrrhenian Sea, rangingfrom Corsica to Sicily, we recorded the change in Posidonia-cover between 2021/2022 and 2023 using line transects. We correlated the change in cover to various temperature parameters between 2021 to 2023 Locations with a higher average temperature or influenced by heat waves appear to have a bigger decrease in the P.oceanica population. At one of the sites located in a relatively warm area, no decline but even an increase was observed; this was likely due to enhanced flushing of the bay due to the proximity of a deepchannel and/or the abundance of fireworms releasing the plants from epiphyte cover. Further research will be conducted on the epiphytes found on P. oceanica organisms.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

Seagrass biophysical model of the Torres Strait

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Preserving the dispersal and connectivity of marine plants, such as seagrasses, supports the natural restoration of populations and the colonization of new habitats. We simulated dispersal and connectivity of seagrasses in the Torres Strait, Australia by using a biophysical modelling approach to combine a hydrodynamic model of water circulation with biological parameters. The simulations released millions of passive 'virtual' propagules at known sites of seagrass presence and were timed to capture variability in winds, currents and tides over five years. Simulation outputs were used in a network analysis to identify the location and intensity of connections between seagrass habitat patches and to assess changes to the structure of the seagrass network when patches were removed due to random disturbance. 'Virtual' propagules released close to the shore advected toward the coast, whilst particles released offshore travelled further and into deeper waters. Inter and intra-annual variability in dispersal was also detected. Additionally, the seagrass network was found to be densely connected, and connectivity was resilient to the random loss of habitat patches because of many redundant connections. The outputs of our analysis can inform the development of conservation strategies to protect the functioning and health of seagrass in the Torres Strait.

SS01 - Global Change and Consumer Effects – Seagrass Resilience in the Anthropocene

Incidence of herbivory of the invasive crab Percnon gibbesi on the endemic Mediterranean seagrass Posidonia oceanica

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Posidonia oceanica – a keystone endemic Mediterranean seagrass -, is under constant and increasing anthopogenic pressure, including the impact of invasive species. Percnon gibbesi is a primarily herbivorous small crab with a tropical and subtropical distribution that has established stable populations in the Mediterranean Sea. Given these two species co-occur in the same bathymetric range and environment, an experiment was set up to study their plant-herbivory interaction. Using two experiments at two different temperatures (19°C and 25°C), we assessed the incidence of herbivory on three tissues of the plant (leaves, fruits and rhizome) by the invasive crab. Fruits and rhizome were the most consumed tissues, with the leaves being the least consumed, which could be a consequence of nutrient quality and tissue structure characteristics. Temperature did not affect the grazing rates. The herbivory pressure of Percnon gibbesi on Posidonia oceanica will likely be limited to a shallow bathymetric range (0-4m), but given the large scale of the invasion, the consumption could become a relevant ecological issue in the area.

SS06 – Ocean acidification research in seagrass ecosystems: From impacts to solutions

Insights into the responses of the seagrass Posidonia oceanica to ocean acidification at CO2 vent systems along the coast of Ischia (Naples, Italy)

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We will provide an overview of recent and ongoing research into the responses of the Mediterranean seagrass Posidonia oceanica to ocean acidification. For this purpose, we use natural volcanic CO2 vent systems along the coast off Ischia (Naples, Italy). These systems cause local acidification of seawater affecting the surrounding ecosystems and are used as natural analogues to assess species and whole-ecosystem responses to future acidification conditions. We will highlight case studies in which we combine: (i) use of Unmanned Aerial Vehicles to characterize habitat confirguration of P. oceanica meadows, (ii) water carbonate chemistry and pH variability, (iii) ecological field surveys comparing the meadow structure, the epiphytic community of Posidonia, and the associated fish community; (iv) eDNA approaches to study the epiphytic community on Posidonia leaves along a CO2 gradient; and (v) sediment cores to elucidate the effects of the CO2 vents on carbon sequestration. We found higher habitat complexity (i.e. shoot density) and higher abudance of fish community and lower abundance of epiphytic calcareous species at the CO2 vents than reference sites. Interestingly, we found distinct epiphytic communities using eDNA among sampling sites. Combined, these results suggest ample opportunities to investigate P.oceanica facing today the conditions of tomorrow.

SS06 – Ocean acidification research in seagrass ecosystems: From impacts to solutions

Exploring CO2 (aq) limitation in temperate seagrass species: interspecific variability and biomass dependency

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Seagrasses are often touted for their ability to remove CO2 from the water and sequester it in the sediments as "Blue Carbon". Further, seagrasses have been hypothesized to be refugia for calcifying organisms that are sensitive to coastal acidification. However, seagrasses are also known to be carbon limited and that photosynthesis exacerbates diurnal variability in carbonate chemistry. We conducted a series of experiments to evaluate how whole plants of Zostera marina, Z. japonica, Phyllospadix torreyi and P. serrulatus change the carbonate chemistry of seawater during light saturated photosynthesis in closed 6 liter chambers. We evaluated how plant biomass (low, medium, high) influenced the carbonate chemistry over the course of 48 hours. Water column pH was measured hourly using iSAMI instruments plumbed directly into each chamber while total alkalinity (measured with Apollo auto titrator) was sampled at the beginning and end of each incubation. The rate of CO2 uptake was related to species biomass and all species were able to increase pH from about 7.9 to 9.5. There was a reduction in total alkalinity, especially in the high biomass treatments, likely because of a H+ pump associated with carbon uptake at the cellular level.

SS06 – Ocean acidification research in seagrass ecosystems: From impacts to solutions

Impact of ocean carbonation on photoprotection mechanisms in eelgrass (Zostera marina L.)

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Photorespiration, commonly viewed as a loss in photosynthetic productivity, is expected to decline with increasing atmospheric CO_2, even though photorespiration plays a key role in the oxidative stress responses for photoprotection. This study aimed to quantify the role of photorespiration and alternative photoprotection mechanisms in Zostera marina L. under increasing CO_2 conditions. Plants were grown in controlled outdoor aquaria at different $[CO_2]_{aq}$ ranging from ~55 to ~2121 μM for 13 months and compared for differences in leaf photochemistry by simultaneous measurements of O_2 flux and variable fluorescence. At ambient $[CO_2]$, photosynthesis was carbon-limited at lower light and the excess photon absorption was diverted both to photorespiration and non-photochemical quenching (NPQ). Plants grown at high $[CO_2]$ downregulated their pigment content by 30% but increased the use of NPQ at lower irradiances even at high $[CO_2]$. Therefore, phenotypic acclimation to ocean carbonation by downregulation of photosynthetic apparatus reduced the role of photorespiration but increased the role of NPQ in photoprotection. These high CO_2 acclimated plants were able to keep 4-fold higher Photosynthesis to Respiration ratios than ambient grown plants as a result of a 60% reduction in photorespiration; indicating the coupling between the regulation of photosynthetic structure and metabolic carbon demands.

SS06 – Ocean acidification research in seagrass ecosystems: From impacts to solutions

Meta-analysis on the Effects of Increased CO2 in Defense Strategies Against Herbivory in Seagrasses

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Increased ocean CO_2 and consequent ocean acidification (OA) are a main threat to coastal ecosystems. Negative effects are evident for marine life due to increased CO_2 in calcifying organisms. However, marine macrophytes such as seagrasses and algae could benefit from the increase in CO_2 available for photosynthesis, which may lead to changes in composition, abundance and distribution of marine flora. By modifying seagrass metabolism, increased CO_2 could also alter the resistance and tolerance strategies that these plants use to avoid or resist herbivory, with important consequences for trophic internactions and overall maintenance of seagrass habitats. So far, the overall magnitude and direction of OA effects on seagrass defense strategies and herbivory have not been assessed. Examining studies spanning from 1970 to 2022, our meta-analysis reconciles inconsistencies and provides a comprehensive understanding of overall patterns. The results indicate that ocean acidification could enhance the resistance and tolerance of seagrasses, while also showing a significant increase in herbivory. This work provides a broader insight into the impacts of ocean acidification on seagrasses and their defense strategies against herbivory, and highlights the importance of considering trophic interactions when examining impacts of climate change on seagrasses.

SS06 – Ocean acidification research in seagrass ecosystems: From impacts to solutions

The role of seagrass meadows as ocean acidification refugia in warming seas

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Foundation species can sustain marine biodiversity under changing climate by reducing environmental stress. We performed a mesocosm experiment to assess if the seagrass, Posidonia oceanicacould mitigate, through its metabolic activity, the negative effects of ocean acidification on the sea urchin, Paracentrotus lividus. At low pH conditions expected for the end of the century under the RCP8.5 scenario, the presence of plants reduced malformations in early-stage larvae (i.e., pluteus; 72 h post-fertilization) and enhanced the growth of final-developmental stages (i.e., echinopluteus; 30 days post-fertilization). However, another mesocosm experiment, carried out in a year characterized by a prolonged heatwave, showed that ocean acidification increased lipidic peroxidation and reduced the photosynthetic efficiency P. oceanica. Under these circumstances, seawater warming, impairing the physiological status of the seagrass, may reduce its effectiveness in buffering ocean acidification stress for calcifying species.

SS06 – Ocean acidification research in seagrass ecosystems: From impacts to solutions

Ocean acidification and nutrient effects on Zostera marina consumption by an invasive amphipod, Ampithoe valida, in San Francisco Bay, California, USA.

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Global stressors to coastal habitats, such as ocean acidification, interact with local environmental conditions to affect organisms. Urbanized estuaries are impacted by a variety of local stressors, ranging from physical disturbance to nutrient pollution. In San Francisco Bay, USA, the invasive amphipod Ampithoe valida has been observed to consume Zostera marina (eelgrass) in addition to epiphytic algae, a novel behavior for this species. This study addressed the effects of ocean acidification and nutrient pollution on eelgrass consumption by A. valida. We grew eelgrass in mesocosms under fully crossed experimental conditions for ocean acidification (ambient and reduced pH) and nutrients (ambient and increased nutrients), and exposed A. valida to the two pH conditions. We conducted a feeding assay wherein A. valida exposed to ambient or reduced pH was offered a choice of four eelgrass leaf segments corresponding to each pH/nutrient treatment combination, and measured the leaf area consumed. Preliminary results showed A. valida exposed to reduced pH conditions consumed more leaf tissue, but only when the eelgrass was grown under higher nutrient levels . Thus, multiple stressors may contribute to increased vulnerability of eelgrass to consumption by an invasive species, with local nutrient stress interacting with the invertebrate response to acidification.

SS06 – Ocean acidification research in seagrass ecosystems: From impacts to solutions

Will ocean acidification enhance fish herbivory on Posidonia oceanica meadows?

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Ocean acidification (OA) is considered one of the main threats to marine ecosystems. While there is mounting evidence on the effects of this global change driver on the autoecology of several marine species, few studies assessed if and how OA influences species interactions (e.g. consumer-producer), considering that increased pCO2 can favour primary producers. In this context, we assessed both the direct and indirect effects of the main herbivorous fish of the Western Mediterranean Sea, Sarpa salpa, on Posidonia oceanica meadows. To do so, we haphazardly collected and tagged P. oceanica shoots to perform an in situ tethering experiment (two weeks) to estimate plant productivity (as the leaves growth) and grazing rate (i.e. leaf loss rate) of S. salpa under low-pH versus ambient-pH conditions. Additionally, the biomass of S. salpa and the density of P. oceanica were estimated at each site (two vents versus two off-vent sites). In the CO2 vents, we found a higher leaf area loss due to increased abundance of S. salpa and increased fish bites (direct effects), along with increased leaf mechanical damage (indirect effects) and a following shortening of P. oceanica leaves. Overall, our results suggest the profound effects of forecasted OA on meadows' species interactions.

SS06 – Ocean acidification research in seagrass ecosystems: From impacts to solutions

Spatial and temporal variations in seawater carbonate chemistry in a seagrass-dominated coastal shallow embayment

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Ocean acidification (OA) is impacting marine communities by changing seawater carbonate chemistry. However, seagrass ecosystems influence the carbonate system through their intense metabolic activity and might modulate OA conditions in shallow coastal environments.

In this study, we investigated how warm-temperate seagrass (Cymodocea nodosa) meadows inhabiting a shallow embayment affected seawater carbonate chemistry (measured parameters pH, alkalinity, temperature, salinity, dissolved oxygen) during the low and high productivity seasons by using autonomous multiparametric sensors and incubation chambers. We compared the seawater carbonate chemistry of different habitats (seagrass patches, unvegetated areas and macroalgal beds interspersed with seagrass) and also assessed its spatial variability in seagrass patches across the embayment.

Average pH values and daily pH fluctuations for all habitats were higher during the high productivity season (~0.15 and ~0.4 pH units, respectively). For both seasons, highest pH values were shown by the seagrass patches (8.73 spring/summer, and 8.21 fall/winter) although spatial variability among patches was exhibited likely owing to its location within the embayment. A strong positive correlation between pH and dissolved oxygen concentrations pointed to the role of seagrass metabolism processes in driving pH changes.

Overall, this study highlights the need of including seasonality and spatial variability of carbonate dynamics into the assessment of the role of seagrass ecosystems in the amelioration of OA.

SS06 – Ocean acidification research in seagrass ecosystems: From impacts to solutions

Unraveling the effect of ocean acidification on seagrass decomposition and macroinvertebrate colonization: evidence from a shallow co2 volcanic vent

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Seagrass detritus, a key component in the brown food chain, plays a crucial role in nutrient cycling and ecosystem functioning. In this study, we investigated the decomposition of Posidonia oceanica detritus and the colonization of macroinvertebrates across four sites along a pH natural gradient (from 7.6 to 8.1) within a shallow volcanic CO_2 vent, conducted through a litterbag experiment. Analyses of leaf litter mass loss, carbon and nitrogen content, along with recordings of density and biomass of colonizing macroinvertebrates at intervals of 3, 6, 17, 66, 131, and 206 days, were performed. Seagrass leaf decomposition followed an exponential decay without significant differences between sites. The slow release of carbon and nitrogen content in more acidified sites was correlated with lower diversity, density and biomass of the macroinvertebrate community associated with the detritus. These findings suggest that Ocean Acidification (OA) may impact seagrass recycling by affecting detritus-associated community. Nevertheless, further research is necessary to understand the underlying mechanisms governing seagrass decomposition under OA conditions, taking into consideration the important role of seagrass detritus in the Blue Carbon global balance.

SS06 – Ocean acidification research in seagrass ecosystems: From impacts to solutions

Effects of ocean acidification on polychaetes settlement in Posidonia oceanica meadows occurring in CO2 vents off Ischia island (Italy)

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Changes in pH and carbonate water chemistry due to the increase of anthropogenic CO2 emissions (ocean acidification, OA) have severe impacts from individual species to ecosystem levels. Polychaetes, aside from calcifying taxa, appear to be robust and resilient to OA. However, recent research suggests that this trend is more complex than it seems, especially when considering the seagrass habitat, which may buffer the negative effects of OA. Here, we investigate how a decrease in seawater pH affects the settlement of polychaetes in Posidonia oceanica meadows at CO2 vents off Ischia (Italy). The experiment was conducted by installing artificial collectors in two vent systems along a pH-decreasing gradient. A total of 3247 specimens belonging to 38 taxa of polychaetes were collected. There was no significant variation in the number of species, their abundances, and diversity according to pH condition; instead, multivariate analyses revealed significant differences in polychaete composition among pH conditions, with some species (e.g., Sphaerosyllis hystrix and Syllis prolifera) increasing under acidified conditions, while others (e.g., Exogone naidina) showing an opposite pattern. This research emphasizes the resistance of polychaetes to OA during the initial phase of settlement and suggests the presence of post-settlement selection processes shaping the assemblages.

SS06 – Ocean acidification research in seagrass ecosystems: From impacts to solutions

Posidonia oceanica meadows as refugia from ocean acidification for peracarid crustaceans settled in different microhabitats

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Ocean acidification (OA) is one of the major threats to marine life, leading to a decline in biodiversity and change in ecosystems structure. Posidonia oceanica plays a fundamental role as a refuge from severe conditions associated with OA, buffering low pH through photosynthesis. The aim of this study is to assess the effects of pH variations on peracarids settled in artificial structures placed in P. oceanica meadows along a natural gradient of OA in a CO_2-vent system of Ischia Island (la Vullatura). The structures were placed at three stations: ambient pH (8.2–8.0), low pH (7.8–7.4) and extremely low pH (< 7.4), respectively, and in different microhabitats: above the seagrass canopy, near the bottom and on the dead matte without Posidonia cover. The preliminary results showed that amphipods were the most abundant and speciose group at all pH conditions. Multivariate analyses revealed significant differences in peracarids composition according to pH conditions and microhabitats (canopy, bottom, dead matte). The lowest values of diversity (H') and eveness (J') indexes were recorded on dead matte without Posidonia cover at the low and extremely low pH conditions, suggesting the role of P. oceanica meadows as OA refugia for the associated communities.

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Photorespiration in Zostera marina: Ecological Implications

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Photorespiration in plants is usually described as a wasteful process, resulting in CO_2 being released back to the surroundings while O_2 is consumed. Although most marine macrophytes repress photorespiration by possessing a well-developed CO_2-concentrating mechanism (CCM), Zostera marina has been found to photorespire under conditions of high O_2, combined with low dissolved inorganic carbon (Ci), concentrations. Such conditions can typically form in shallow bays where e.g. the widely distributed and prolific macroalga Ulva spp. can raise the seawater pH to ~10 during the day, thus lowering both CO_2 and HCO_3^- concentrations significantly. Under such high-pH conditions, the photosynthetic (and, consequently, growth) rates of Zostera marina can be significantly inhibited. (On the other hand, photorespiration can be used as a "safety valve" for dissipating excess light energy.) In summary, there is a need to take photorespiratory losses into account when modeling the photosynthetic performance and productivity of (at least) temperate seagrasses, especially when growing interactively with highly productive macroalgae.

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Unraveling the Influence of Seagrass Species on Associated Biodiversity: A Comprehensive Meta-Analysis

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The positive impact of seagrass presence on biodiversity is a widely acknowledged paradigm within marine ecosystems. However, the influence of species-specific traits on associated biodiversity and the generality of these relationships remain insufficiently explored. Here we present a comprehensive meta-analysis that delves into the global scale evaluation of species-specific differences in biodiversity enhancement by seagrasses. This expansive scope allows for an assessment of variations across diverse biogeographical regions and climate zones.
While anticipated trends, such as higher biodiversity in tropical regions compared to cold and temperate zones are perceptible, they are not significant due to the inherent variability in the dataset. Nonetheless, our findings reveal discernible disparities between geographical regions and among different seagrass species. Our analysis not only examines the overall impact of seagrass presence on biodiversity but also explores taxonomic groups of associated fauna. We highlight species-specific links between associated fauna and plants, offering insights into trait-based differences among various seagrass species.
This meta-analysis advances our understanding of the intricate relationships between seagrass species and associated biodiversity on a global scale. By elucidating these interactions, our findings contribute to the broader ecological discourse and provide valuable information for conservation efforts and sustainable management of seagrass ecosystems worldwide.

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Long-term monitoring of Zostera marina in the intertidal : phenotypic variations, environmental drivers and consequences for macrofaunal diversity

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Intertidal seagrass meadows are exposed to both marine and terrestrial environmental constraints. They are thus particularly vulnerable to climate changes in these highly dynamic and thermally stressful environments. Eight intertidal Zostera marina meadows, spread over more than 500 km of coastline, and their associated macrofaunal diversity have been monitored in Brittany (France) since 2004 as part of the REBENT programme. These long-term observations in contrasted intertidal environments allowed to 1) describe the spatial and temporal variations of density, morphology, above- and below-ground biomass and rates of clonality of Z. marina in these stressfull environments, 2) quantify the relative role of different environmental drivers in shaping these trait variations, and 3) identify trait trade-offs and eelgrass phenotypic strategies to 4) propose a theoretical response scheme of intertidal eelgrass traits under multiple stressors based on the 'stress-gradient hypothesis'. Analysis of the communities associated with these meadows further allowed to i) describe the taxonomic and functional diversity of intertidal eelgrass meadows and their spatial and temporal variability/stability, ii) explore the cascading effect of eelgrass trait variation on its associated epi- and infauna, and iii) quantify the direct and indirect effects of environmental changes on seagrass associated diversity.

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Using optical traits to assess seagrass and estuarine biodiversity in the European Atlantic coast

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The use of optical traits is a promising approach to monitor biodiversity and species distribution in extensive areas. It is essential to conduct field-based observations to assess the functional and optical diversity in situ before escalating to a larger scale. In this study we aimed to analyse the optical and biochemical traits at leaf level of Zostera noltei, Zostera marina and other estuarine species to evaluate how spectrally and functionally distinct are these species. For this purpose, two seagrasses were compared to other 12 estuarine species from North Spain. The reflectance spectrum of the fresh leaves was measured under laboratory conditions, the consistency of the traits was assessed between the species, and the frames of the spectrum that differed most were identified using multivariate analysis. The results showed that these seagrass species are composed by a set of optical and functional traits that are different from other estuarine species. The bands with the greatest variation are related to photosynthetic pigments, water content and structural proteins, around the respective wavelengths 477nm, 669nm, 1453nm, and 1935nm. These groups of optical and functional traits can be used to monitor the ecology and distribution of seagrass meadows with remote sensing platforms.

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A functional perspective on the factors underpinning carbon storage in macrophyte communities

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To date, studies on carbon storage in seagrass and other aquatic plant communities have mainly focused on mono-specific stands, typically ignoring that coastal areas can be heterogeneous, where multiple species with a range of trait characteristics may influence carbon storage differently across seasons and spatial scales. With few studies having assessed how functional traits link to carbon storage in aquatic plant communities, we sought to explore (i) the relationship between functional community composition and biomass-bound carbon stocks, (ii) the role of spatial context and (iii) how functional traits shape seasonal fluctuations of non-structural carbohydrates. We conducted multiple field surveys in the Baltic Sea, Finland, where we sampled plant communities and measured nine traits that capture the key variation in plant life-history strategies. We found that functional composition was associated with plant carbon stocks and this relationship was mediated by spatial heterogeneity. Non-structural carbohydrates varied significantly through time, with the amount stored in leaf tissue throughout winter being tied to leaf functional characteristics. Our results indicate that the underlying biological mechanisms influencing carbon storage are affected by community trait composition, underlining the importance of using functional traits as a tool to assess the role of aquatic plant biodiversity for ecosystem functioning.

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Nutrient loading weakens seagrass blue carbon potential by stimulating seagrass detritus carbon emission

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Coastal nutrient loading has been linked to a decline in the capacity of seagrass ecosystems to sequester carbon ('blue carbon'); however, the mechanisms are unclear. Here we investigated how nutrient loading can affect the contribution that seagrass plant material makes to blue carbon stocks by investigating plant quality-decomposition dynamics. Specifically, we used a combination of laboratory and field experiments to account for various changes in biogeochemical cycling from seagrass meadows, ranging from changes in leaf quality to CO2 fluxes. It was found that nutrient loading increased the 'labile' content of seagrass (i.e. increased levels of leaf nitrogen, phosphorus and soluble organic carbon (amino acid and soluble sugar content), and at the same time decreased levels of 'recalcitrant' carbon (i.e. materials that are harder for microbes to break down, such hemicellulose, cellulose and lignin contents). Nutrient-enriched leaves decomposed ~18% faster than non-enriched leaves (i.e. greater biomass loss from nutrient-affected seagrass), resulting in ~80% more CO2 emissions from nutrient-enriched seagrass. We also found that seagrass that naturally contained high levels of labile carbon at the start of the experiment were affected to a greater degree (i.e. higher CO2 emissions) by nutrients addition than seagrass that had high proportions of recalcitrant carbon to begin with. Overall, these findings suggest that nutrient loading can weaken the capacity of seagrass ecosystems to act as blue carbon sinks through its effect on seagrass leaf decomposability.

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Nutrient loading decreases the refractory dissolved organic carbon to the carbon pool in tropical seagrass beds

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Topic description, aims, methodology, main results
Seagrass ecosystems exhibit exceptionally high productivity, continuously releasing dissolved organic matter (DOC) into the ambient sewaters through both living organisms and detritus. The majority of this dissolved organic matter assumes the form of refractory dissolved organic carbon (RDOC), integrating into the blue carbon reservoirs within seagrass beds. However, escalating nearshore human activities have resulted in an augmented nutrient load on seagrass beds. The repercussions of augmented nutrient load, which primarily induced by anthropogenic influence, on the origins, composition, and carbon storage of dissolved organic carbon (DOC) within seagrass beds remain uncertain. This study endeavors to elucidate DOC composition, sources, and the impoact of nutrient loads on RDOC within seagrass beds in the South China Sea, by stable isotopes, spectroscopy, and ultra-high resolution mass spectrometry (FT ICR-MS). The DOC within tropical seagrass beds predominantly comprises organic carbon characterized by heightened reactivity, attributable to their elevated biological origins. Nevertheless, the nutrient load markedly augments DOC activity (BIX) and aromatization (MLBL) in seagrass beds, correlating with their biological transformations. The exudation from seagrass contribution 5.5 ± 4.6% to DOC, with a higher peroportion in the low nutrient loading seagrass beds. The nutrient loading heightened phytoplankton biomass, consequently amplifying the discernible contribution emanating from DOC sources from seagrass. Discovered through on-site data and indoor simulations, RDOC account near 72.0-84.2% of the bulk DOC, which could be preserved. The influx of nutrients precipitates the decomposition of recalcitrant organic compounds, notably humic substances, thereby diminishing the proportional representation of blue carbon reservoirs within seagrass beds. This study holds considerable scientific significance in advancing our comprehension of the carbon storage mechanisms inherent in DOC within seagrass beds subject to anthropogenic influence.

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Effects of herbivore on seagrass, epiphyte and sediment carbon sequestration in tropical seagrass bed

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Herbivores strongly affect the ecological structure and functioning in seagrass bed ecosystems, but may exhibit density-dependent effects on primary producers and carbon sequestration. This study examined the effects of herbivorous snail (Cerithidea rhizophorarum) density on snail intraspecific competition and diet, dominant seagrass (Thalassia hemprichii) and epiphyte growth metrics, and sediment organic carbon (SOC). The growth rates of the herbivorous snail under low density (421 ind m-2) and mid density (842 ind m-2) were almost two times of those at extremely high density (1684 ind m-2), indicating strong intraspecific competition at high density. Herbivorous snails markedly reduced the epiphyte biomass on seagrass leaves. Additionally, the seagrass contribution to herbivorous snail as food source under high density was about 1.5 times of that under low density, while the epiphyte contribution under low density was 3 times of that under high density. A moderate density of herbivorous snails enhanced leaf length, carbon, nitrogen, total phenol and flavonoid contents of seagrasses, as well as surface SOC content and activities of polyphenol oxidase and -glucosidase. However, high density of herbivorous snails decreased leaf glucose, fructose, detritus carbon, and total phenols contents of seagrasses, as well as surface SOC content and activities of polyphenol oxidase and -glucosidase. Therefore, the effects of herbivorous snail on seagrass, epiphyte and SOC were density-dependent, and moderate density of herbivorous snail could be beneficial for seagrasses to increase productivity. This provided theoretical guidance for enhancing carbon sink in seagrass bed and its better conservation.

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Uneven flowering occurrences of Posidonia oceanica along the Mediterranean Sea: insights from the 2022 event

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At the end of summer 2022, a massive flowering of Posidonia oceanica has been witnessed in the Western Mediterranean Sea. Qualitative and quantitative data have been collected from meadows across the Mediterranean Sea. Flowering intensity varied strongly across the basin, and with meadow type and water depth. The most intense flowering occurred in the northwestern Mediterranean, Balearic Islands, and Tunisia. No flowering was observed in the Adriatic and Ionian seas while low to very low flowering was observed in Tyrrhenian, Aegean, Levantine seas and south of Spain. The intensity of the 2022 flowering event in the north-western Mediterranean was comparable to those observed in 2003 (western part) and in 2010 (eastern part), implying that the massive flowering of 2022 may be attributed to the intense Marine Heat Wave (MHW) occurred in the Western Mediterranean which was not observed in the Eastern Mediterranean. However, apart from temperature rise, the frequency and intensity of massive flowering events can be attributed to other environmental factors, like solar activity, and the reproductive strategy of the plant. Therefore, a coordinated Mediterranean-scale long-term monitoring of flowering events is imperative to deepen our understanding of the dynamics associated with climate change.

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Strong summer marine heatwaves fuel flowering of seagrass (Posidonia oceanica) in the eastern Mediterranean Sea

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The intensification of Marine Heatwaves (MHWs) has impacted the ecological dynamics of various species, including the Mediterranean seagrass Posidonia oceanica. However, the limited research on Eastern Mediterranean meadows precludes understanding their response to elevated sea temperatures. Here, we used lepidochronology for reconstructing flowering patterns across 58 meadows in the Greek seas over 15 years to assess their potential link with MHWs and the effects on plant growth associated with the transition from vegetative to sexual reproduction. Our findings revealed that although flowering was sporadic in most meadows, sexual reproduction was fueled by strong (Category II) summer MHWs with a cumulative intensity exceeding 30 °C days. The years 2010 and 2021 stood out for their high flowering prevalence (> 55%) with both spatial and temporal synchrony. Flowering density was overall low (mean 11 inflorescences m-2) and exhibited no direct correlation with MHWs. Despite the latent benefits of sexual reproduction, post-flowering rhizome production decreased 1.5-fold for at least two years, signaling potential drawbacks of a future uptick in flowering frequency. This study unveils the susceptibility of Eastern Mediterranean P. oceanica meadows to MHW-induced stress, akin to the western counterparts, highlighting the complex prospects of plant growth and reproductive fitness amidst climate change.

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Effects of the intensity of a heat wave on two seagrass species : an experimental approach

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The increased frequency and intensity of extreme climatic events (ECEs) in the context of climate change have been recognised as additional pressures for seagrass habitats. Heat waves occur suddenly over a relatively short period. Their effect can be strong on species already submitted to other pressures and fluctuations. This is particularly the case for seagrasses in French Mediterranean lagoons. Our study tested experimentally the effect of a heat wave on Cymodocea nodosa and Zostera noltei shoots, two species present in French Mediterranean lagoons. After 10 days of acclimation to experimental conditions, the shoots were exposed during 20 days to three simulated heat waves of: +2, +4 and +6°C relative to control water temperature. This experiment was performed twice: in spring and in summer. We quantified the effects of simulated heat waves on growth performance, respiration, and gross primary production. For C. nodosa, its leaf growth rate increased with the intensity of the spring heat wave, whereas during the summer heat wave, leaf growth rates were homogeneous according to intensity. For Z. noltei, the spring heatwave stimulated growth up to a certain intensity (+4°C), whereas the summer heatwave had no effect, or even reduced growth at the highest intensity (+6°C). In conclusion, our experimental investigation, has unveiled nuanced responses depending on the seagrass species and seasonal variations. As we strive to comprehend and mitigate the vulnerabilities of seagrass habitats in lagoon ecosystems, our study provides valuable insights that pave the way for informed conservation strategies tailored to diverse environmental scenarios.

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Declines in local Mediterranean temperate seagrasses in parallel to the expansion of the tropical invasive Halophila stipulacea in Limassol, Cyprus- confirmation of predicted trends

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The Mediterranean is rapidly warming and becoming saltier. This tropicalization process threatens native seagrasses, notably Posidonia oceanica and Cymodocea nodosa, with predictions foreseeing more than 75% and 46%, respectively, loss of habitats by 2050. These same studies also predict that the invasive Halophila stipulacea, will expand its distribution in this basin and physically displace native species. However, field evidence for these predictions is still somewhat weak.
Aiming to understand the dynamics between invasive and invasive seagrasses in the Mediterranean, we returned in the summer of 2023 to “Dream Café”, Limassol, Cyprus, a mixed meadow (P. oceanica, C. nodosa, and H. stipulacea) site where we visited in the summer of 2017. We compared meadow characteristics (percent cover, above and below-ground biomass, shoot and apical shoot densities, internode distances, and leaf surface areas) between both visits.
Six years after our first visit, we found the disappearance of both native species, while H. stipulacea almost doubled its percent of cover, and increased its shoot density and above- and below-ground biomasses. Our study confirms previous predictions about the expected evolution in the underwater landscape of the eastern Mediterranean and sheds light on the importance of long-term monitoring of H. stipulacea in its invasive habitats.

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Trait-based responses to environment determines seagrass community assembly in intertidal mixed meadows of the Andaman Islands

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Multi-specific seagrass assemblages dominate most tropical intertidal regions. However, the mechanisms determining species co-occurrence are still uncertain. We examined the role of the fine-scale environment (aerial exposure, temperature, sedimentation) in the intertidal meadow in determining species distribution based on the species-specific trait-based responses. We conducted observational studies in the intertidal meadow of the Andaman Islands to track the phenophases and morphological traits of six seagrass species across all seasons along the environmental gradients. Additionally, we collected data on species occurrence patterns in the meadow. The distributional surveys revealed that Halodule uninervis and Cymodocea rotundata were the most dominant species in the meadow. These ubiquitous species showed a large variability in their morphological traits, which likely helped them adapt to diverse environmental conditions. C. rotundata specifically showed a similar response to flowering where the species bore flowers throughout the year but in different habitats in different seasons. These patterns in trait responses didn't translate into observed species distribution for all the species. This could be attributed to unmeasured functional strategies, environment and biotic predictors. In summary, our findings from tropical multi-species intertidal meadow suggest that local environmental gradients could override natural seasonal responses, determining species co-occurrence patterns.

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Seagrass cell wall glycoproteins act as adaptor molecules in response to salinity stress

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Arabinogalactan-proteins (AGPs) are O-glycoproteins located in the plant cell wall. They are involved in numerous processes involving biotic and abiotic stress responses. There is a proposed role as capacitors of calcium ions which were involved in salinity stress cascades. We isolated and structurally characterized Zostera marina AGPs with classical carbohydrate analytics. These molecules showed unique structural features such as high charge in the form of 1,4-linked glucuronic acids (GlcA) with methylated end groups – not known from angiosperm land plants. They showed an organ specific distribution with much higher amounts in the rhizomes compared to roots and leaves. We were able to show calcium affinity by isothermal titration calorimetry measurements and selective microscopic labelling. After widening the study to minimum two members of each seagrass family, we were able to show seagrass-specificity of these structural features. All showed similar characteristics with differing amounts of 4O-methylation and uronic acid contents. Bioinformatics search for carbohydrate-active enzymes and AGP protein backbones in seven seagrass genomes and 16 transcriptomes revealed similar patterns. Public available RNAseq data of Cymodocea nodosa and Thalassia hemprichii were re-analyzed and revealed significantly upregulated enzymes in response to elevated salinity levels. These are most likely responsible for the detected glycan modifications.

SS03 - Seagrass trait-based ecology applied to seagrass responses to environmental change, biodiversity, ecosystem services, and conservation

Leaf biomechanics and hydrodynamic forces determine seagrass species distribution along a wave gradient

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Hydrodynamic forces are a key factor for species distribution of seagrasses in wave-exposed habitats. Few studies however have established a direct correlation with biomechanical traits of seagrasses and the physical forces they are subjected to during storm conditions. To explain the observed spatial distribution of 4 large habitat–forming seagrasses (Posidonia coriacea, P. sinuosa, P, australis, Amphibolis griffithii) differing in biomechanical traits across a gradient in wave exposure on the SW Australian coast, we used a simulation of hydrodynamic forcing (numerical ocean circulation model Delft3D Flexible Mesh coupled to the phase-averaged wave model SWAN) with parameters at the peak of storm conditions (local wave height, orbital velocity, bed shear stress). Biomechanical traits of the seagrasses were measured to estimate the maximum stress they could tolerate without suffering mechanical failure. Posidonia coriacea with the highest mechanical resistance conferred by very thick leaves and arrangement of leaf fibres, occurred at the most wave-exposed sites. Amphibolis sp also occurred in high energy environments with strong wire-like stems resisting strong forces. Other Posidonia species occupied lower wave energy sites correlating with leaf traits. These studies are relevant to ecological modelling for defining the hydrodynamic boundaries of sites for large-scale seagrass restoration.

SS03 - Seagrass trait-based ecology applied to seagrass responses to environmental change, biodiversity, ecosystem services, and conservation

Intraspecific trait variation pattern of Halodule uninervis in tropical Queensland, Australia

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Intraspecific Trait Variation (ITV) significantly influences species' performance and responses to environmental change. In tropical Queensland, Australia, Halodule uninervis exhibits two distinct growth forms - narrow-leaved and wide-leaved. These two growth forms have been recorded separately but occasionally mix in one location. Despite their apparent differences, a comprehensive study on ITV in H. uninervis has not been conducted. Our research addresses this gap by analyzing H. uninervis ITV and its correlation with environmental factors. We collected samples from 12 locations and measured nine functional traits. Three distinct growth forms were found based on leaf width: at 0.3 mm, 0.7 mm, and 2.7 mm. Biomass, shoot density, and rhizome diameter followed similar patterns. Environmental covariates, particularly relative air exposure and sediment type, explained a significant portion of the trait variation, although mixed growth forms in some meadows remained unexplained. ITV observed in H. uninervis not only influences seagrass resilience against wave energy but also affects ecosystem services. Our study underscores the complexity of ITV in H. uninervis and suggests a potential role of genetic and long-term environmental factors. These insights enhance our understanding of seagrass ecology, emphasizing the need for accurate assessments of ITV to inform effective conservation strategies in tropical Queensland seagrass ecosystems.

SS03 - Seagrass trait-based ecology applied to seagrass responses to environmental change, biodiversity, ecosystem services, and conservation

Quantifying the structural complexity of Zostera marina meadows

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Seagrass meadows are ecologically important biogenic habitats, harboring diverse communities and maintaining ecosystem services. Seagrass-associated biodiversity is mainly attributed to this habitat's structural complexity. Still, there is no consensus on how to measure it. This study aims to appropriately quantify the structural complexity of Zostera marina meadows, combining spatial point pattern analysis and morphometrics for the first time. Fine-scale structural complexity and spatial arrangement of nine meadows in Brittany (France) were studied through an annual long term monitoring programme. Environmental models were used to investigate the relationships between seagrass complexity, hydodynamics, salinity, sediment characteristics and weather conditions. Shoot size, density and spatial arrangement were good descriptors of regional variability in complexity, and define it at two scales: shoot complexity increases with shoot size, while spatial complexity is a balance between shoot density and spatial arrangement. Granulometry and exposure to wind and currents were the main drivers of complexity. Complexity decreased with exposure, with higher shoot density and reduced shoot size. The most spatially complex beds were found in heterogeneous sediments, suggesting a positive feedback loop between seagrass complexity and sediment retention. Our findings evince spatial heterogeneity should be considered by studies on seagrass complexity-diversity relationships.

SS03 - Seagrass trait-based ecology applied to seagrass responses to environmental change, biodiversity, ecosystem services, and conservation

Temporal and spatial variability of Seagrass meadows in the world's hottest sea: The Arabian Gulf

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Seagrass meadows play a vital role in safeguarding coastlines and delivering essential ecosystem services, encompassing nursery habitats, water quality enhancement, and carbon sequestration. In the Arabian Gulf, seagrass meadows (6% of global extent) confront unparalleled physiological challenges, as they endure the world's highest summer sea temperatures, regularly exceeding 36°C, while plummeting to <18 °C in winter. The southern basin of the Arabian Gulf, being both the shallowest and most thermally variable, harbors substantial seagrass meadows (>80% of Gulf extent), yet these have received very limited research attention. We investigated the seasonal dynamics of seagrass meadows in the Gulf's southern basin to determine the condition of seagrass in an extreme biogeographical region and describe the enviornemental variables that determine its growth. Our study revealed variation in seagrass density, canopy height and biomass across the three study locations in Abu Dhabi, United Arab Emirates (Ras Ghurab, Saadiyat, Dhabiya) over a period of 3 years. Generelized linear modelling was performed to explore the effects of sea surface temperature, wind speed and daylength on the response variables measured at each location. Seasonality was not as marked as we thought it would and results showed some resilience to fluctuations. Through this research we aim to contribute valuable insights into the dynamics and resilience of seagrass ecosystems in the face of extreme environmental conditions in the Arabian Gulf.

SS03 - Seagrass trait-based ecology applied to seagrass responses to environmental change, biodiversity, ecosystem services, and conservation

Intraspecies and interspecies variations of primary production and benthic macrofauna across a gradient of two zosteraceae species in Venice lagoon

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Vegetated habitats play a crucial role in transitional environments, however little is known about intraspecies and interspecies adaptation strategies in microtidal environment such as Venice Lagoon. The study was conducted to evaluate morphometric, primary production (using benthic chambers) and macrobenthic communities variations across a transept of two seagrass communities (Zostera marina, L. and Zostera noltei Hornemann, 1832) at a station in May 2022. Three sods of known area were sampled at 6 points: bare sediment, dense and edge meadows of each species and a mix of the two. The net community productions were significantly higher on the vegetated sediments than on the bare one (mean±sd 24.0±6.1 vs 8.13±0.18 mmol O_2 m^{-2} h^{-1}) with higher values at higher leaf densities (dense Z. noltei and edge Z. marina: 5.00±1.35 and 5.18±1.89 leaves per shoot). Instead, macrobenthic communities seem more influenced by the sediment organic matter with higher taxa richness and number of individuals in edge Z. noltei and dense Z. marina (mean±sd: 54.0±2.8 and 6,744±124 individuals m^{-2}). Consequently, seagrass communities in Venice Lagoon do not seem affect by the edge effect, with the most abundant macrobenthic community in edge Z. noltei, while higher primary production were found in denser but shorter meadows.

SS03 - Seagrass trait-based ecology applied to seagrass responses to environmental change, biodiversity, ecosystem services, and conservation

Shining a light on the drivers of seagrass phenotypic variation to enhance restoration success

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Seagrasses display significant intraspecific phenotypic variation, allowing sub-populations to adapt to diverse environmental conditions. Identifying the drivers behind this variation has become a critical step in terrestrial flora restoration to identify target donor populations for restoration purposes. The extent of phenotypic diversity that populations exhibit may suggest either fixed traits or environmentally induced plasticity, influencing adaptability and responses to changing conditions. In Port Curtis, Central Queensland, Australia, we observed intraspecific morphological variations in four genetically distinct Zostera muelleri sub-populations, potentially linked to meadow-specific environmental conditions. To assess if observed variations, particularly in response to light availability, result from fixed traits or plasticity, a three-month mesocosm experiment was conducted across two seasons. Although all populations showed high survival rates, one population demonstrated greater plasticity across light treatments. Our results highlight the importance of examining the drivers of sub-population phenotypic variation to identify target donor populations that are more resilient to environmental variability to enhance long term resilience and persistence of restored meadows.

SS10 – Bird's Eye views of Seagrassscapes

Multi-scale remote sensing techniques for mapping seagrass extent

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In this study, we investigate the opportunities and challenges of mapping seagrass extent using multi-scale remote sensing techniques in several nearshore environments located in Jamaica, Bahamas, and Grenada. We explore the utility and limitations of various high-resolution satellite image datasets, such as Skysat and SuperDove, as well as Uncrewed Aerial Vehicles (UAV) RGB imagery, to better understand what is possible for seagrass mapping both from an extent and biophysical modeling approach. We present differences in area calculations, ideas for data integration at varying spatial resolutions, and validation methods using field datasets acquired below water. Our surface camera platform has been developed for acquiring photos that are centimeter level in accuracy, using a GNSS receiver linked to the hot shoe of the camera, and combines transducer and video capability for field data collection. We apply object-based image classification to map seagrass extent and investigate spectral correlations for detecting seagrass density, species, change using a multi-scale remote sensing approach.

SS10 – Bird's Eye views of Seagrassscapes

How hyper-spectral imaging of posidonia oceanica combined with artificial intelligence can be used to increase the speed and scale of carbon stock assessments

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Preserving and restoring seagrass meadows can significantly contribute to alleviating CO_2 emissions. The voluntary carbon market can support financing seagrass protection and restoration efforts. Methodologies to quantify net greenhouse gas emission reductions for submerged vegetation such as seagrass have been developed and approved, but these approaches provide a coarse estimate of their carbon sequestration potential. Current ways of monitoring seagrass face a trade-off between the area covered and the spatial resolution of the data. In-situ campaigns are essential to providing high quality ground-truth data, but they are labour- and time-intensive and cover relatively small areas. In contrast, airborne and spaceborne observations allow monitoring with greater spatial coverage, but at the expense of spatial resolution. Here, we introduce state-of-the-art monitoring for aquatic ecosystems, integrating underwater navigation, a high resolution RGB camera, hyperspectral imaging, and artificial intelligence to fully automate pipelines for data storage, visualization and analysis. This new technology provides insights into the health state, biomass, carbon stock and density of the seagrass and delivers results in a matter of hours. Knowing not just coverage, but also health state ensures policy makers focus where most impact can be made and adds the credibility needed to accelerate the blue carbon market.

SS10 – Bird's Eye views of Seagrassscapes

Development of an upscaled submerged aquatic vegetation leaf cover model for long-term time series analysis in Florida Bay

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Seagrass mapping using remote sensing has rapidly developed over the past 20 years, leading to better sensors as well as mapping and analytical techniques. The availability of free worldwide medium resolution satellite imagery such as LandSat and cloud-based computing platforms has enabled researchers around the world to understand seagrass dynamics using remote sensing. However, there is often a mismatch in scale between LandSat and field training data. One potential option for dealing with the scale mismatch is upscaling, the aggregation of multiple high-resolution data points into one coarser data point. In this study, we test the viability of upscaling a SAV leaf cover model developed on WorldView-2 satellite imagery for mapping SAV using LandSat imagery. Future steps for this research include testing the model's applicability to time series analysis within Florida Bay and the continuation of model development to facilitate upscaling to LandSat5. The end goal of this research is to develop a workflow for upscaling continuous SAV cover data to apply to other areas around the world and this study takes a positive first step toward that goal, proving the viability of upscaling a SAV leaf cover RF model from WV2 to LandSat.

SS10 – Bird's Eye views of Seagrassscapes

Addressing seagrass seascape multiscale responses to water quality in a subtropical estuarine lagoon

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Seagrasses form highly productive habitats in coastal areas and provide crucial ecosystem services around the globe. In Biscayne Bay, an estuarine lagoon that waters the shores of Miami (USA), seagrasses form extensive beds and support biodiversity. However, poor water quality caused by freshwater canal discharges is affecting seagrass habitats, which have experienced drastic declines across Biscayne Bay and represent a major concern for environmental managers. In a conservation framework, understanding the influence of water quality on the spatial characteristics of seagrass habitats is paramount. This study proposes a remote sensing approach to investigate how levels of eutrophication impact seagrass meadows in Biscayne Bay. Despite seagrass seascapes being influenced by biotic and environmental factors that interact across multiple scales, most ecological studies focus on a single spatial scale, limiting our understanding of seagrass habitat dynamics. To fill this gap, the present work performs a multiscale analysis of seagrass habitat distribution as a function of patterns of water quality. Our study aims to quantitatively address the appropriate spatial scale at which seagrass habitat spatial structure responds to eutrophication and to provide managers with crucial information to implement effective conservation strategies for natural resources in Biscayne Bay.

SS10 – Bird's Eye views of Seagrassscapes

Advanced seagrass monitoring using automated image processing on underwater drones

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Advances in capacity for mapping and monitoring seagrass are overcoming deficiencies in local monitoring and global distribution maps, and enabling rapid condition reporting. Along with improvements in remote sensing from satellites and aerial drones, underwater technology has advanced to the point where automated methods can monitor in more places, more often, for less cost. Underwater vehicles and drones reliably scan the seabed collecting vast amounts of imagery, operating in waters of any depth without putting divers at risk. We show how automated data extraction has overcome the processing bottleneck of manual data extraction. Using recent advances in image annotation and deep learning, we provide computer vision software that detects seagrass and records plant characteristics rapidly and reliably. Robust testing against large databases of manual records of seagrass presence and percentage cover shows high accuracy of automated measures. Seagrass presence data are ideal for detecting meadow edges and monitoring seagrass depth range. Percentage cover data can be used as one indicator of seagrass condition, paired with automated records of species or morphological type. The combination of underwater drone imagery and automated data extraction substantially increases the scale of seagrass surveys, even in deep or turbid waters, and improves reproducibility from sequential visits.

SS10 – Bird's Eye views of Seagrassscapes

Remote sensing Zostera noltei's epiphytes with hyperspectral imaging

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As with marine angiosperms, the leaves of Zostera noltei are covered with epibionts and epiphytes. Z. noltei leaves are weakly colonized compared to other species but have the characteristic of being covered by diatoms, forming a monolayer strongly adhering to the epidermis. In intertidal areas, two species, Cocconeis scutellum and Cocconeis placentula, dominate the leaf surface. The objective of this work is to test a remote sensing of epiphytic diatoms on the surface Z. noltei leaves using their spectral reflectance in the visible and near-infrared wavelengths. This constitutes an original model for the analysis of the plant-epiphyte optical properties using a hyperspectral imager. We used a hyperspectral camera Hyspex (160 spectral bands) in the laboratory to obtain spatial distribution maps of epiphytes with a pixel size of 300 µm. Absorption bands at specific wavelengths were associated with the main photosynthetic organisms. Particular attention was paid at 632 nm due to chlorophyll c characteristic of the diatom class. The presence of epiphytes was associated with a specific spectral shape in the near-infrared. We suggest this feature could be detected using satellite images such as Sentinel 2 and may become an indicator of the eutrophication of coastal areas.

SS10 – Bird's Eye views of Seagrassscapes

Merging scales and methodologies: from underwater tow Cameras to sentinel-2 imagery to assess seagrass distribution

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The implementation of large-scale seagrass monitoring programmes (e.g. EU Marine Strategy Framework Directive) requires protocols and methodologies to provide reliable and replicable habitat quality assessments over broad geographical areas. As new platforms emerge and artificial intelligence evolves, the potential of optical remote sensing to monitor seagrass cover, recognized as an Essential Ocean Variable (EOV), is undeniable. In this context, quality ground-truth observations are essential to train and validate machine learning models.

We have developed a robust methodology to capture extensive ground-truth data using underwater towed-cameras that are subsequently coupled with Sentinel-2 imagery. Seagrass species and bottom types are clearly identified in underwater recordings as the geolocated camera travels near the seabed. Georeferenced observations are extracted from the videos and combined with satellite imagery to train machine learning models and evaluate the accuracy of ensuing habitat cartographies.

This methodology was used to assess seagrass distribution in Es Freus, a Marine Protected Area in the western Mediterranean. We particularly focus on Cymodocea nodosa, a highly dynamic species with marked seasonal distribution shifts. Updated ground-truth data proved crucial for mapping this challenging species. This work is part of a wider study to evaluate this EOV (seagrass cover) in the MPA using Sentinel-2.

SS10 – Bird's Eye views of Seagrassscapes

High resolution mapping reveals hotspots of propeller scarring intensity and characterizes a range of scarring types

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In the shallow seagrass flats of the Nature Coast Aquatic Preserve, one of the least human impacted estuaries in Florida, propeller scarring is a key issue for many stakeholders. Our propeller scar mapping efforts revealed that 99.7% of scarring occurs in depths of -0.5 to -3.0ft (NAVD88), with most (93.3%) occurring in depths of -0.5 to -2.0 ft (NAVD88). We found an uneven distribution of propeller scars throughout the study area, with scarring density estimates covering two orders of magnitude from 808 linear m/ha (300 m2/ha) at the highest to 21 linear m/ha (8 m2/ha) at the lowest. Our high-resolution mapping efforts uncovered evidence of previously undescribed disturbances to hardbottom habitats generated by outboard motors/propellers, a phenomenon deserving of further study. Additionally, ~26% of total propeller impacts in seagrass beds appeared to affect only the seagrass canopy with no apparent contact with underlying sediment or rhizosphere. State agencies have policy options to address this issue, but more research is needed about spatial management zones such as pole-and-troll areas. Our team is working with stakeholders to conduct this research and make recommendations to managers about optimal seagrass protection zones that can simultaneously achieve environmental, societal, and economic objectives.

SS10 – Bird's Eye views of Seagrassscapes

THE LOST MEADOWS OF BRAZIL: how a 97% decline in a 900 hectare seagrass meadow went unnoticed

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Loss of seagrass meadows has been a critical conservation issue worldwide due to the strong dependency of many organisms on these valuable ecosystems. One-third of the global seagrass cover area is estimated to have been lost since the 19th century. However, many areas, including the Brazilian coast, are yet to be mapped, making the actual losses far greater than predicted. In this study, we quantified the loss of Halodule wrightii cover on the coast of Itamaracá Island, Northeastern Brazil. We utilized valuable local knowledge of the environmental area to infer possible causes of this loss. Area loss was calculated based on a previous map from the 1960s, combined with Landsat 7 satellite remote imagery. Semi-structured interviews were conducted with the resident population to understand local perceptions of these changes. The results show a reduction from 8,409 km^2 in the 1960s to 0.123 km^2 in 2022 in the meadow area of Halodule wrightii, with approximately 97% of the area lost in 60 years. The first registered losses by the local community were recorded in the 1980s and intensified throughout the 1990s and 2000s, with consequences for the fishing community who depend on these meadows. The main threats reported were mechanical removal and domestic and industrial waste. Here, we register the largest reported loss of a seagrass meadow in the Atlantic bioregion and emphasize the urgent need to improve global mapping efforts. These efforts will enable a better understanding of the causes of seagrass losses and help focus restoration projects and public awareness campaigns of seagrass services.

SS10 – Bird's Eye views of Seagrassscapes

A novel approach to monitor the depth limits of Posidonia oceanica meadows: seascape analysis using high-resolution underwater orthomosaics

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The deep margins of Posidonia oceanica meadows are close to the physiological thresholds of the species, making them particularly sensitive to anthropogenic pressures and climate change. Accurate monitoring of these edges is critical to assess the evolution and conservation of this valuable habitat within the EU Marine Strategy Framework Directive. Such monitoring, however, has so far been challenging due to limitations imposed by depth. Here we present a novel approach to characterize and monitor four P. oceanica deep-meadow margins (22-28 m) using an Autonomous Underwater Vehicle (AUV). The AUV was deployed at each site to record over 1,000 georeferenced images that were subsequently merged into centimeter-resolution orthomosaics covering 600 m² each. These mosaics were then classified using Random Forest, yielding seagrass distribution maps with over 80% accuracy. The resulting maps were used to analyze the spatial structure of the meadow through quantitative seascape metrics that showed strong correlation with classic descriptors of meadow structure. Results were also consistent with the conservation status of each of the meadows studied.

Findings evidence the great value of this new methodology for successfully characterizing the conservation status of deep P. oceanica margins and for accurately detecting distribution changes and fragmentation processes.

SS14 – Seagrass restoration

Combining citizen science, seahorse re-introductions and seascape restoration initiatives to accelerate the recovery of an endangered seagrass (Posidonia australis)

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Posidonia australis is a slow-growing seagrass that is declining rapidly in the most urbanised regions of eastern Australia, where it is classified as endangered. Boat moorings that scour the seafloor and remove marine vegetation are one of its major threats. This talk summarises three intitiatives that are accelerating the restoration of P. australis and associated species. Firstly, 'Operation Posidonia' enlists local citizen scientists to collect seagrass shoots that become naturally detached following storms. These shoots are then planted in old boat mooring scars in a way that avoids damaging existing meadows while also engaging communities and increasing stewardship. These methods are being used to provide a "two-for-one" method to re-stock White's Seahorse (Hippocampus whitei) populations alongside P. australis meadows in custom-built artificial reefs knowns as 'Seahorse Hotels'. Finally, 'Project Restore' is using these innovations within a multi-habitat seascape restoration initiative to re-establish ecological connectivity and lost ecosystem functions within the highly urbanised Sydney Harbour. These solutions-focused initiatives demonstrate the effectiveness of combining rigorous science and citizen science to restore marine habitats and raise awareness about the importance of seagrasses and our capacity to drive positive change.

SS14 – Seagrass restoration

LIFE Restoration of Zostera marina along the UK Southern Coast

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Ocean Conservation Trust is the lead restoration partner for the LIFE Recreation ReMEDIES project, creating England's largest subtidal seagrass restoration effort to date. This project aims to restore 8 hectares of subtidal seagrass (Zostera marina), through trialing a variety of seeding and plantlet techniques.

We will discuss two seed dispersal methods trialed, the most recent being a novel Hydro Marine Seeding (HMS) device which is used to deploy seeds into the seabed on mass (hectares at a time). The preliminary trials for this device have provided the highest germination rate of large-scale seed dispersal methods in this region. In addition to seed dispersal, we have developed proof of concept for Seed Mat Technology (SMT), allowing plantlets grown in a laboratory environment to be transplanted into the natural environment. We demonstrate high germination success (>69%) with SMT as well as promising results for in situ growth and bed formation. Here we present 4 years of cultivation and restoration effort which has led to the production of the ReMEDIES Best Practice Guide for restoring Z. marina, as well as highlighting a range of challenges for the restoration community to consider.

SS14 – Seagrass restoration

Comparison of Western Atlantic subtropical/tropical pilot seagrass program results for seagrass restoration

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Restored seagrass provide services including blue carbon, shoreline resilience, ecosystem habitats for fisheries/endangered species, &water clarity enhance human populations surrounding the restored resource. We compare our three Western Atlantic tropical/subtropical large-scale-pilot seagrass restoration investigations carried out for planning national or regional seagrass rehabilitation. The Biscayne Bay pilots occurred at 15 impacted bay areas after our successful large-scale 1973 restorations in this bay. The Matagorda Bay Texas pilot program occurred in a large partially-researched estuary (central-coastal Texas) following large-scale (100 acres) restorations in other Texas bays. The Jamaica seagrass-pilot program involved 19 variously degraded sites around the island nation with services to the public. All pilot sites tested salinity, temperature, turbidity, depth, energetics, multiple-species, restoration techniques, and pollutant types. Lessons learned: 1.) In continually-oceanic salinities, Thalassia testudinum was restored successfully; at lower salinities, Halodule wrightii was restored more successfully. 2.) Seeds had less success than plugs or sprigs. 3.) Intertidal demonstrated less success than 2-6ft depth, light-penetration dependent. 4.) Medium/course sediment demonstrated more success than fine. Details as to differences among sites and species, anmal recolonization, services reassembly will be presented. Policy and planning implications will be discussed. Operations require decision-making experts plus oversight of planting and 3-yr monitoring.

SS14 – Seagrass restoration

Best practices for the planning, implementation, and monitoring of posidonia oceanica restoration

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Posidonia oceanica (L.) seagrass meadows are in regression in various areas of the Mediterranean basin. The EU Biodiversity Strategy 2030 formulated a plan for the restoration of marine ecosystems with high potential for carbon capture and storage. Italy has invested more than other Mediterranean countries in research to restore degraded P. oceanica meadows and to compensate for damage caused by coastal works. As part of the Life SEPOSSO project, 39 Posidonia restorations carried out in Italy from 1994 to 2021 were analysed. The restorations differed in terms of technique adopted, surface, receiving substrate, bathymetry, and monitoring duration. Their performance has allowed us to select the best practices and the most efficient governance approaches for the effective P. oceanica restoration. We propose specific procedural processes for the planning, implementation and monitoring of Posidonia restoration providing the main activities and their purposes for the characterization and selection of the donor and receiving meadows and for selecting suitable restoration areas. Specific parameters and sampling frequencies are illustrated to efficiently monitor restoration performance over long periods. Our procedures refer to the restoration of degraded meadows, the reconnection of damaged portions of meadows, and the compensation of Posidonia sectors completely lost due to marine-coastal works.

SS14 – Seagrass restoration

Seed-based seagrass restoration: the challenges and advantages of scaling in the Great Barrier Reef World Heritage Area

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The largest current drivers of seagrass loss in the Great Barrier Reef (GBR) Australia are storms and flood events which, with climate change, are becoming more frequent and intense. Some meadows are lost completely during an event but recover quickly, whilst others persist but are slow to recover in terms of biomass or continuity of seagrass patches. With projected scenarios of more frequent severe storms, loss will likely increase. Proactive intervention is a necessity, as is setting up facilities and capability ahead of a major event to be ready to respond. Scientific reviews agree that successful (self-sustaining) seagrass restoration will require scaling up restoration efforts and that seed-based restoration approaches offer significant advantages for some species. Using local case studies and the outcomes of large-scale projects in the GBR we present the considerations, challenges and advantages of scaling up seed-based seagrass restoration in the Great Barrier Reef.

SS14 – Seagrass restoration

Physiological responses of zostera marina and cymodocea nodosa to different transplantation methods

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Seagrass restoration efforts have multiplied in the last years, with very diverse success rates, justifying the need for improved methodological approaches and a better understanding of the physiological responses to transplant operations. This study compares the biochemical responses of Zostera marina and Cymodocea nodosa, two subtidal seagrass species of the Ria Formosa coastal lagoon (Portugal), to different transplant methods. Z. marina was transplanted in bundles of 5 and 10 shoots and C. nodosa was transplanted in sods and single plants. Biochemical analyses focused on foliar oxidative stress, antioxidant activity, pigment content and NSC storage in leaves and rhizomes before transplant and after 4 weeks. Results reveal significant method-specific responses to transplantation stress. C. nodosa transplanted as isolated plants showed radical shifts in NSC storage and lower pigment content while sod transplantation triggered increasing antioxidant activity. Z. marina responded to transplantation by increasing foliar NSC content, antioxidant activity and chl a:b ratio. Results suggest that transplanting C. nodosa in sods is likely to be the most successful strategy for this species and Z. marina plants transplanted in bundles of 5 may have a slight advantage. This study provides insights into physiological adaptations post-transplantation and emphasizes the need for adaptable restoration strategies.

SS14 – Seagrass restoration

Zostera noltei sexual reproduction phenology and seed storage optimization: insights for intertidal seagrass seed-based restoration

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According to the global trend, seagrass abundance and species richness decreased over decades at Ria de Aveiro coastal lagoon (Northwest Portugal) and the intertidal Zostera noltei is currently the dominant species. The UN Decade on Ecosystem Restoration (2021-2030) urges to take action and several actions have been put forward at Ria to restore degraded meadows, through seagrass transplants. Seed-based methods gained attention allowing for larger-scale recovery, increasing genetic diversity and seagrass resilience. This study aimed at investigating spatial and temporal changes in Z. noltei sexual reproduction effort at Ria de Aveiro, and optimize seed storage conditions, before their deployment in situ. Spatio-temporal changes were evaluated over two flowering seasons (2 years) at 3 sites at Ria de Aveiro. In mesocosms, the most suitable temperature and salinity for seed storage were tested and assessed. Sexual effort varied in space and time, with greater spathe density in Mira and Ílhavo sites, especially during June–August. To sum up, insights into the best sites and seasons to collect spathes, and the best seed-storage conditions, crucial to establish a laboratory or mesocoms seed bank, were obtained and will foster the Z. noltei seed-based restoration actions of vulnerable intertidal seagrass beds.

SS14 – Seagrass restoration

How long will restored posidonia oceanica take to achieve reference conditions since transplanting?

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Seagrass restoration effectiveness still remains uncertain probably due to the unique features of each species, the wide range of practices and methodologies used in transplanting actions, and suitability of reference sites.
This is a space-for-time substitution to evaluate the effectiveness of Posidonia oceanica restoration, hypothesising that in successful operas the differences in functional traits between restored and local meadows will be reduced through time since transplanting. In summer 2022 and 2023 five Mediterranean sites, where restoration was conducted at different times using similar techniques, were investigated. The number of leaves, maximum leaf length and leaf growth rate per shoot of transplanted P. oceanica were compared to nearby meadows used as reference conditions. Overall, differences in P. oceanica traits between restored and reference plants were reduced in six years indicating that patches generated from transplants followed a developmental trajectory towards a plant structure similar to their local reference condition. Results suggest a positive restoration effectiveness and corroborate the need to take context into account when planning and evaluating the effects of seagrass restoration.

SS14 – Seagrass restoration

Assessment of different transplantation methods for Posidonia oceanica meadows restoration by means of physiological parameters and photogrammetric-based techniques

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The decline of Posidonia oceanica meadows in the Mediterranean Sea has become a critical concern, with a 30% reduction in the last 50 years attributed to various human activities. Among these, anchoring causes significant physical and chemical degradation due to repeated anchoring, mainly in the summer season. It is therefore crucial that we find suitable and efficient methods of restoring P. oceanica meadows and various restoration projects are being launched. Among them, the REPAIR project began in May 2022 on the site of the future eco-mooring area in Alga Bay (Calvi, Corsica). Cuttings of different origins (destructive and non-destructive harvesting) were transplanted at two depths on different biodegradable artificial substrates. The monitoring took place twice per year and focussed not only on biometric/structural parameters, but also on physiological characteristics (leaf nutrients, carbohydrates storage in rhizomes,etc) to assess the health status of the transplants and success of restoration efforts. After 17 months, the survival rate remains quite good (89%). However, challenges include inferior biometric characteristics, weight and nutrient contents compared to reference plants. Natural recolonization in the transplanting areas was monitored by photogrammetry, as this component is often understudied in restoration project but is essential to assess restoration success.

SS14 – Seagrass restoration

Restoring Posidonia oceanica seagrass meadows using seeds: the opportunity of 2022 mass flowering in northwestern Mediterranean Sea

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Following the 2022 autumnal mass flowering of Posidonia oceanica in northwestern Mediterranean Sea and the spring abundance of fruits and seeds, original restoration protocols based on the seeds collected were implemented. 18 000 seeds were settled in two dead matte sites (Marseille, Provence and Sant'Amanza, Corsica) using two methods (seeds buried in the bare matte and seeds covered by a 1-m2 square coco fiber mat), and 2 000 seeds were settled on 1-m2 patches of 2-4 cm or 5-7 cm sized rocks (only in Sant'Amanza). Harvesting and seeds installing occurred in April/May 2023. Four months later, germination rate and survival (GSR) reached in average 17.6% (matte) and 21.4% (rocks) in Sant'Amanza and 9.1% (matte) in Marseille. In Sant'Amanza, GSR was 31.2% under coco fiber mat and 4.9% on bare matte, the latter grazed by the teleost Sarpa salpa. In Marseille, GSR was 3.6% and 14.5% respectively; macroalgae (for the former) and depth might have reduced light availability. Seed density (100 and 200 seeds m-2) did not influence the GSR contrary to the size of the rocks. These results are promising but long-term monitoring is needed. These methods are likely to provide sustainable and cost-effective implementation at a larger scale.

SS14 – Seagrass restoration

Thriving together: A multi-habitat approach for coastal restoration using oysters and seagrass in Mosquito Lagoon

Carla Perscky[1,2], Angie Tasayco[2], Gabriel Benson[2], Federico Lopez-Borghesi[2], Dr. Melinda Donnelly[2], Dr. Paul Sacks[2], Dr. Linda Walters[2]

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Coastal restoration thorugh nature-based solutions enhances habitat resilience and ecosystem services. In Mosquito Lagoon, part of the Indian River Lagoon estuary, seagrass and oyster reef coverage have declined by 58% and 62%, respectively, in recent decades. Nonetheless, Halodule wrightii has persisted along restored oyster reefs edges between 2007-2020. Shoal grass, H. wrightii was co-planted along newly restored intertidal oyster reefs in Canaveral National Seashore to develop co-planting strategies with filter-feeding bivalve, Crassostrea virginica. Our research objectives include assessing the influence of co-planting and examining soil particle distribution relative to seagrass persistence. Each live (control) and restored site comprised two plots – one planted with H. wrightii, and one unplanted to track natural recruitment. Planting units (n = 12/plot) included garden staples with five shoal grass shoots. Seagrass metrics such as percent cover, shoot density and canopy height were estimated and soil samples were collected for lab analysis. Preliminary results suggest a multi-habitat approach enhances seagrass persistence at restored oyster reefs compared to controls (ANOVA: $p=0.09$). Trends indicated higher H. wrightii persistence where soil particle distribution includes very fine sand. This research informs coastal conservation by identifying positive species interactions between seagrass and oysters, offering insights for resource managers and restoration practitioners.

SS14 – Seagrass restoration

Recurring patterns in long term response of Posidonia oceanica transplantation at population and plant level

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To date, very few long-term data are available on Posidonia oceanica (L.) Delile transplantation. In this work, two Italian large-scale transplants were investigated to analyse long term response of P. oceanica transplanted on sand at population and plant level. Monitoring was performed in S. Marinella (Central Tyrrhenian Sea) and in Ischia (Southern Tyrrhenian Sea) after 14 and 10 years respectively from the transplanting activities. In each study site structural parameters (covering, shoot density, shoot micro-distribution) and functional parameters by phenological analysis (length, width, and brown senescence of the longest leaf) and lepidochronological analysis (shoot demography and growth of rhizomes) were investigated both in transplanted areas and in control areas of the neighbouring natural P. oceanica meadow. Although not all the investigated parameters highlighted signs of completely maturity if compared to natural meadows, the high allocation of resources of the plants in the hypogeum compartment allowed the plant to expand quickly and to build patch of meadow. The shoot density of the transplanted meadow was similar or higher than the natural ones after a relatively short time, as a decade. Results of this long-term monitoring may contribute to a better understanding of P. oceanica restoration.

SS14 – Seagrass restoration

The use of biodegradable geomats for the restoration of posidonia oceanica meadows of ligurian and tyrrhenian seas

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Posidonia oceanica meadows are in strong decline in several Mediterranean areas. The slow natural recolonisation capacity of the plant supported the development of transplantation techniques as an active restoration tool to promote or accelerate the recovery of the meadows. In this context, we used biodegradable geomats as substrate for P. oceanica transplanting in 8 sites, distributed from the Ligurian to the Tyrrhenian seas, for a total of 1,050 m2 of restored meadows. The transplanted plants were cuttings, with one or more shoots each, detached naturally from the surrounding meadows and beached seedlings. Monitoring results from the oldest transplantation site, carried out in April 2019 at Elba Island (Italy), revealed that after one year the survival rates were 55% for the cuttings and 80.6% for the shoots. During the following 3 years the shoots density started growing and, in September 2023, the survival rate was around 140%. The survival rate of the beached seedlings was 61.7% after the first monitoring year and, in September 2023, these plants reached a density similar to that of the surrounding natural meadow. Our transplantation technique replicated on several sites is giving encouraging results even if a longer monitoring period is needed to validate the trends observed.

SS14 – Seagrass restoration

Comparison and optimization of posidonia oceanica meadows strengthening protocols

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The strengthening of Posidonia oceanica meadows was initiated at the end of the 1970s in the Mediterranean. Several techniques (mainly transplanting) have been tested with some success but also many failures, due to the strategy chosen and the slow growth rate of this species. As part of a study carried out in Sant'Amanza Bay (Corsica), initiated in spring 2021, several protocols, based on 3 600 cuttings from the same donor meadow and 400 drifting cuttings, were settled and compared in a unique site (900 m2). Cuttings were placed on different substrates (dead matte, biodegradable net on dead matte) using different fixing techniques and planting densities. Yearly monitoring of this experiment, including the reference meadow nearby, shows significant differences in the cuttings survival rate (79.5 to 98.8 % after 2 years), their morphology (shoot number, bottom covering, leaf length) but also their carbohydrate content. The synthesis of these experiments led to the implementation of a new transplanting experiment (400 m2, spring 2023), based on an optimized and cost-effective protocol (fixing supports, absence of emersion, rapid planting, pattern of aggregation, substrate, etc.).

SS14 – Seagrass restoration

Virginia Coast Reserve Seagrass Blue Carbon Project: Why Here? Why Now?

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The largest, most successful seagrass restoration on the planet- nearly 10,000 acres of restored eelgrass meadows in Virginia's Atlantic coastal bays- is now home to the world's first registered blue carbon seagrass project.

Many important factors have contributed to the implementation of this blue carbon project: (1) the legacy of land protection across Virginia's Eastern Shore (2) an innovative restoration technique (3) long-term research through the duration of the project (4) political and state level support (5) strong partnerships among The Nature Conservancy, Virginia Institute of Marine Science, University of Virginia, and the Commonwealth of Virginia.

Registering this seagrass restoration project on the global carbon market provides a transparent process for measuring the climate mitigation value and access to carbon offset buyers. Carbon revenues will help support the cost of monitoring and managing the eelgrass meadows, which is critical to the ongoing success of the project.

This project demonstrates a "proof of concept" on how climate benefit of seagrass restoration can be quatified and how it contributes to long-term restoration and conservation. This project's success provides lessons learned and paves the way for seagrass projects across the globe, hopefully increasing the pace and scale of this critical work.

SS14 – Seagrass restoration

Restoring the largest intertidal seagrass meadow in the world

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Coastal ecosystems are rapidly degrading on a global scale, contributing to ongoing biodiversity declines. Ecological restoration provides a hopeful and positive outlook to halt and reverse these losses. However, in dynamic coastal ecosystems, seagrass restoration successes are generally low, despite increasing efforts. Hence, there is a great need to advance knowledge and develop tools that can contribute to restoration practice. Here, I will take you along on a journey where we managed to restore the (to our knowledge) the largest intertidal seagrass meadow the world in a highly altered seascape: the Dutch Wadden Sea. Continuous efforts have resulted in a restored intertidal seagrass meadow of ~1250 ha of annual Zoster marina in a relatively short time period (6y). Continued seeding efforts with a newly developed seeding method (DIS) by an interdisciplinary team of scientists, nature managers, policy makers, practitioners, consultancies and industry partners have shown consistent positive restoration successes on this site (Griend) and increased local tideflat biodiversity by about +30% Thus, we show the combined potential of high site suitability, team effort and continuous, adaptive research strategies for improving seagrass restoration successes. Our research highlights the value of linking science to practice to promote the advancement of both.

SS14 – Seagrass restoration

3D point clouds and object-based image analysis for seagrass restoration mapping and monitoring

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Seagrasses are considered one of the most important marine ecosystems in terms of goods and services. However, since the last century, they are rapidly declining due to both natural processes and human-mediated impacts. Therefore, several Posidonia oceanica transplanting experiments have been performed to mitigate the adverse effects of habitat loss. Although seagrass experimental trials and large-scale transplanting operations have been carried out, little effort has been made to define new methods to monitor the transplanted fragments over large areas remotely. Although remote sensing techniques have revolutionized ecological studies by offering valuable insights into natural phenomena, the suitability of data's spatial and temporal resolutions for ultra-fine scale ecological investigations is often limited, resulting in too general information to meet the requirements of seagrass transplantation monitoring programmes. Here, we propose a new approach for mapping seagrass transplantation based on imagery processing to create 3D point clouds using underwater photogrammetry. After image segmentation and object-based classification, we achieved a fine identification of the transplanted fragments used to restore an area of 500 m2. This method provides a new perspective for creating centimetre-level accuracy cartographic products of P. oceanica transplantation, and it could be applied to map other complex benthic habitats

SS14 – Seagrass restoration

Functional response of the fish assemblage to Posidonia oceanica restoration

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Active restoration projects are increasingly being implemented to reverse seagrass habitat degradation and recover associated biodiversity and ecosystem services. While new approaches and indicators are being developed to assess restoration performance, little attention has been paid, so far, to assessing the functional response of seagrass-associated communities. The study of functional diversity and composition can be a complementary tool based on how far the investigated indicators deviate from the desired target, thus providing a better understanding of the relationship between biotic communities and ecosystem recovery. Here we present the first results of a study carried out in Sicily (southern Italy, Mediterranean Sea) on the functional response of the fish assemblage associated with a transplanted Posidonia oceanica meadow. Functional indicators were compared with those of a pristine P. oceanica meadow, used as a reference, and an unvegetated site with dead matte. One year after transplantation, fish functional indicators showed a recovery trajectory approaching values of the reference and moving away from those of the unvegetated site. These results support the importance of taking functional indicators into account in monitoring programmes that aim to analyse the recovery of communities associated with seagrasses, even at a short time scale.

SS14 – Seagrass restoration

Help from near or far? Considering spatial scales of interaction when using infaunal bivalve facilitation in seagrass restoration

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Low historical success rates for seagrass restoration projects have led to increased interest among restoration practitioners in innovative techniques to enhance restoration success. One such technique, not widely applied to date, is co-restoration with infaunal bivalves such as venerid, lucinid, and tellinid clams. The suite of mechanisms by which infaunal bivalves may facilitate seagrass growth and survival can be broadly broken into "near" facilitation (for example, enhanced nutrient availability or decreased sulfide exposure in the seagrass root zone) and "far" facilitation (for example, increased water filtration rates that increase light availability to a seagrass bed not spatially concurrent with a bivalve bed). This mini-review highlights recent experimental work and a larger scale restoration case study to illustrate the promise of facilitative seagrass restoration approaches involving infaunal bivalves, as well as the context dependencies and data needs surrounding their effective use.

SS14 – Seagrass restoration

A trans-national comparison of Zostera noltii transplants

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Higher success rates are needed to scale up seagrass restoration to ensure the level of ocean recovery required, however most seagrass restoration experiments are small scale and localised. A means of improving knowledge is to conduct repeat experiments across a range of scales. Transplanting cores is an increasingly used method for seagrass restoration which has had high success rates. However, for a large portion of the Northeast Atlantic, core transplants remains a method that is relatively unexplored and may have the potential to unlock higher yields for future restoration.

To increase knowledge and develop best practice, a trans-national study investigating planting density and configuration was conducted. The same transplanting method and experimental design was replicated at 11 sites (across Scotland, England, France, and the Netherlands). This talk will present data across these sites. Monitoring indicates initial success of the transplants at suitable sites. Density and configuration have resulted in differences in success, but factors that reduce success have mostly been driven by environmental factors such as smothering by algal mats, bioturbation and current velocity. In the future, the partnership will continue to assess the site-specific differences and explore effective restoration methods for Z. noltii.

SS14 – Seagrass restoration

Recovering lost habitat and ecosystem function through large-scale restoration of the endangered seagrass Posidonia australis

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Nearshore marine environments are increasingly under pressure as overlaps between human activities and ecologically valuable marine habitats become more frequent. Seagrass restoration is growing in popularity as an ecological offsetting measure to compensate for developing nearshore infrastructure in urban marine environments. However, with few examples of this measure being effectively adopted over large spatial and time scales, greater understanding of the factors influencing success is crucial for guiding restoration decision-making. We used a large-scale ecological offsetting project involving restoration of the endangered seagrass Posidonia australis in a highly urbanised bay in Sydney, Australia to examine how different transplanting methods and environmental parameters affect seagrass restoration success and ecosystem function recovery through time. Here, we present findings from the first year of monitoring where we relate restored Posidonia australis density and condition to transplanting method, along with sea temperature, light, depth, and size of area restored. We also discuss how restoration can contribute to the recovery of biodiversity in previously degraded seagrass habitat. This research provides valuable real-world lessons to help shape future seagrass restoration in urban marine environments.

SS14 – Seagrass restoration

Testing habitat suitability for seagrass restoration to inform future efforts in southwestern Australia

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Cockburn Sound was declared an industrial zone and port for Western Australia in the 1950s. Rapid industrial development and uncontrolled effluent release resulted in a collapse of ecosystem functions, including the loss of 80% of seagrasses. After nutrient loads were reduced and water quality improved, large investments in seagrass restoration occurred, testing multiple methods with different outcomes. A recent review from over 50 years of restoration highlighted that present environmental conditions and processes are extremely important in determining restoration outcomes. Here, we assess the suitability of the environment for future restoration efforts of the temperate habitat-forming seagrass Posidonia australis. Working across eight sites within the industrial area we use a shoot-based seagrass restoration approach. We then investigate the influence of a wide range of environmental parameters (including sediment characteristics, light availability, and hydrodynamic variables) on restoration success. One year after planting, the average survival of P. australis transplants is 72.4% ± 4.95SE (with sites up to 97%) with majority of surviving transplants already producing new shoots. However, survival and leaf growth differ among sites. Understanding the drivers behind the restoration outcomes will contribute to identifying the most suitable areas for future efforts.

SS14 – Seagrass restoration

Lessons learned from thirty years of U.S. west coast eelgrass restoration

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Eelgrass habitats along the US west coast are threatened by human uses and global change, resulting in significant restoration and protection efforts. Despite a regional eelgrass restoration history spanning 60 years, little work has been published. Thus, we reviewed all available restoration projects from the region. Of the 82 projects included, which occurred from 1989-2020, only 6 were peer-reviewed. Despite the precedent for restoration, this lack of data availability makes assessing regional success, drivers of failure, and best practices extremely difficult.

The majority of restorations (73%) occurred for mitigation/compliance purposes, contributing to the lack of literature. While mitigation policies help maintain eelgrass structure and coverage, they don't facilitate assessments of habitat function or incentivize advancements in best practices. When we could evaluate outcomes, 32-60% of restoration plots were unsuccessful, but this was highly dependent on how success was defined. Failures were most attributed to environmental factors such as light, nutrients, or blooms, but occasionally to factors such as restoration approach. We recommend a standardized, evidence-based restoration approach, improved data sharing, and careful consideration of mitigation policies. As marine habitat restoration enters a new global stage, backed by investments, burgeoning carbon markets, and biodiversity initiatives, we must learn from past work to improve seagrass conservation and restoration success.

SS14 – Seagrass restoration

Long-term evolution of shoot density in posidonia oceanica transplants

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Two large scale Posidonia oceanica (L.) Delile transplants, which have been carried out in S. Marinella (10000 m2 in 2004) and Ischia (1600 m2 in 2009), showed that appropriate techniques make it possible to obtain, within 10-15 years of transplanting, meadows that are as dense as the surrounding natural ones and in some cases even denser. The results of long-term monitoring of shoot density these transplants, which continues today, will be presented, highlighting how different monitoring strategies have been adopted in each phase of their evolution, ranging from counting the cuttings that survived in the early stages to the detection of new shoots and from the analysis of the dynamics of shoot density to the application of methods commonly used for the study of natural meadows in mature transplanted areas. The results obtained from the monitoring of the above mentioned transplants are currently those of the longest term, at least in reference to cases that are not strictly experimental and which have generated meadows that currently still exist. Our results seem to indicate that the coefficient of variation of the shoot density tends to a constant value when the transplant is mature.

SS14 – Seagrass restoration

Succes and failures, the road to a best-practice guideline for restoration of Zostera marina in Danish waters

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Eutrophication in the marine environment has historically been the primary cause of Zostera marina loss in Denmark. Nutrient discharge has since been reduced, but the change from eelgrass dominance to bare sediment has altered our coastal ecosystems to an extend where natural recovery is absent. In this alternate stable state, restoration may be necessary to initiate positive feedback mechanisms that can stimulate natural recovery. Simultaneously, policymakers have become aware that legislation is needed to protect and restore eelgrass meadows and governmental demand for best-practice guidelines for restoration have increased in recent years.

This study presents a summary of success and failures from eelgrass restoration in Denmark, that have led to current best-practice guidelines for site selection and restoration methodology. Our current recommendation proposes a screening tool that can qualify suitable areas before initiating restoration with the following workflow: 1) analysis of a sites suitability via models coupled with geographical information systems, 2) aerial imagery analysis, 3) field inspection, 4) small-scale test trials, 5) large-scale restoration, 6) quantification of ecosystem services. More than 100 test transplantations have been carried out to qualify our approach and select sites for >20 large-scale transplantations (3,600 to 28,125 PU).

SS14 – Seagrass restoration

Seagrass restoration in Mozambique, setting the stage and existing tangible metrics

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1779.3 Km2 of seagrass were mapped in Mozambique, occurring mostly within limestone and sandstone shallow waters. The study presents an ongoing seagrass restoration initiative driven by both research needs and a will to bring back associated seagrass fisheries, highlight to dwindling macroinvertebrate fisheries mainly in NW Maputo Bay. Mozambique has experienced quite a steady degradation of seagrasses over years, with the root cause being both anthropogenic and climate related. Restoration began in 2019 in Maputo Bay, latter transformed into a demonstration project adding also Inhambane Bay, both in southern Mozambique. Three main stages of restoration were followed: preparation and design, implementation and monitoring. Manual methods, namely rod (sediment-free) and sod (with sediment-method), and plug have been tested with Oceana serrulata mixed with Thalassia hemprichii, also Zostera capensis. Four sites were restored, leading to recovery of around 7 hectares of seagrass and the potential of restoration of O. serrulata at Inhaca northern bay reach some 15-25 hectares. Multidisciplinary socio-ecological approach and actor engagement, specially with NGO and communities was crucial for tangible success (having a Quality ration > Threshold value). The restored meadows foster diversity and abundance of fauna. A third restoration initiative is being implemented in Nampula, northern Mozambique.

SS14 – Seagrass restoration

Physiological stress in Zostera marina & Zostera noltei transplantation: effects of season and donor site selection

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Seagrasses provide numerous ecosystem services, from carbon sequestration to habitat provisioning. In Ria Formosa lagoon, Portugal, seagrasses face significant threats, namely from boat traffic and clam aquaculture. Restoration may be a solution to counteract seagrass declines, but understanding the physiological effects of transplant operations is crucial before large-scale efforts are attempted. Here, we tested the effects of seasonality on the post-transplant stress physiology of Zostera marina and Zostera noltei in an experimental winter essay, using spring as control. Donor site effects were additionally tested in Z. noltei, comparing the responses of plants collected in the upper and lower limits of the species intertidal distribution. The physiological effects of the transplants were assessed in leaf and rhizome tissues through various biochemical analyses. Malondialdehyde (MDA) was quantified to measure oxidative damage, and antioxidant activity was evaluated using Total Phenolic Content (TPC), Trolox Equivalent Antioxidant Capacity (TEAC), and Oxygen Radical Absorbance Capacity (ORAC). Soluble sugars, starch, and photosynthetic pigments were also analyzed to assess overall plant condition. Preliminary results showed that one month after transplantation, plants exhibited comparable physiological parameters to the donor population, regardless of planting season or donor site. This research contributes new physiological baselines and insights for enhancing seagrass restoration.

SS14 – Seagrass restoration

The application of a nature based restoration approach for tropical atlantic seagrass meadows

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Tropical Atlantic seagrasses meadows thrive in unconsolidated sediments where most asexual reproduction and clonal growth occurs belowground. For some species, sediments are also a refuge for seed banks. Gap-forming disturbances that remove seagrasses and excavate sediments are one of the most severe disturbances in climax tropical Atlantic seagrass ecosystems where natural recovery trajectories take several years to decades. In some cases, no recovery occurs, and the disturbances expand. Here we present a series of experimental results and the practical application of a passive “nature based” fertilization method to restore physically disturbed seagrass meadows growing in phosphorus limited carbonate sediments. When properly installed, feces of birds defecating from roosting stakes provide an essential limiting nutrient, phosphorous. Roosting stakes in combination with; 1) topographical re-grading with biodegradable sediment filled tubes and 2) transplanting a fast-growing pioneer species, Halodule wrightii, accelerates recovery of physically disturbed seagrass meadows. We applied this “modified compressed succession” approach to the rehabilitation of seagrasses damaged by propeller scars, large vessel groundings, and tropical cyclones in Florida and Jobos Bay, Puerto Rico. For larger landscape-scale seagrass rehabilitation projects, this approach could be used to initiate seagrass recovery by establishing fast growing H. wrightii patches across the broader seascape.

SS14 – Seagrass restoration

Early signs of recovery of the nursery function in a restored posidonia oceanica meadow

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Seagrass meadows, structurally complex habitats, serve as essential nursery habitats for numerous fish species, ensuring the survival and growth of juveniles through shelter and food provision. However, the recovery of this function in restored meadows needs to be elucidated. This study assesses recovery of the structural complexity and nursery function in a restored Posidonia oceanica meadow in the NW Mediterranean. We evaluated habitat complexity (i.e. shoot density and leaf area index), along with juvenile fish communities (i.e. species richness, density and biomass) in the restored area, comparing them with the inner and edge sections of an adjacent undisturbed meadow. Five years after restoration, our results revealed that the restored habitat structure remains significantly lower than in the undisturbed meadow areas. Juvenile fish communities also varied among habitats, with the edge and inner meadows exhibiting significantly higher richness, density, and biomass compared to the restored area. In terms of species composition, Diplodus vulgaris dominated the edge juvenile community, while D. annularis and Symphodus tinca prevailed in the inner meadow and the restored area. These findings underscore the prolonged time needed for restoration efforts to fully recover essential ecosystem services, such as fish nursery provision, particularly in slow-growing seagrasses like P. oceanica.

SS14 – Seagrass restoration

Meadows from a random forest: analysis of Zostera marina habitat and the potential for restoration in Peconic Bay (Long Island, NY, USA)

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Seagrasses are an integral component of coastal ecosystems, providing nursery habitats for shellfish and juvenile fishes, reducing currents, and improving water quality. In Peconic Bay, Long Island (NY, USA) an >90% loss of eelgrass (Zostera marina) habitat since the 1930's prompted several, largely unsuccessful restoration attempts. In this study, we evaluated potential environmental factors limiting Z. marina distribution in the study area and created a habitat suitability model using random forest modeling to inform restoration potential. Wave exposure, proximity and direction of hardened shorelines, cumulative and sequential hours over 25 , and depth, accurately predicted Z. marina habitat with 87% accuracy. Our model highlighted several potential sites to further evaluate for possible restoration efforts, particularly on the edges of extant beds. Further, we modified our model to evaluate the potential impacts of future temperature increases and sea level rise associated with climate change. Through this modification we found that low to medium level sea level rise projections yielded an increase in potential habitat, but average temperature increases above 0.25°C decreased coverage by 95%. This study helps to understand the factors driving Z. marina distribution and increases efficiency of restoration efforts.

SS14 – Seagrass restoration

Integrated approaches to restore Hong Kong's seagrass beds

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Hong Kong's seagrass populations have experienced sharp declines in recent years as a consequence of Anthropogenic pressures. Consequently, there is an urgent need to protect and restore the seagrass beds and the ecosystem functions they provide. However, due to the different ecological characteristics of seagrass species, there is not a "jack-of-all-trades" approach that works for all. In this case, diverse approaches can facilitate the restoration success of seagrass habitats. We have tested this principle combining restoration techniques, from (i) indoor nursery systems (e.g., hydroponic cultivation of Halophila ovalis); (ii) assisted gene flow for population augmentation programs; and (iii) the probiotic approach to promote survival of transplanted seagrasses by preserving their associated microbiomes. As hypothesized, the success of these approaches is conditioned to the seagrass species and their life-history/ physiological/phenological characteristics. Here, I will discuss the importance of integration of complementary restoration approaches, highlighting the opportunities and challenges. This information is fundamental for rapid and proactive interventions aiming to buffer or reduce the extinction risk that seagrasses are rapidly experiencing, particularly in highly urbanized coastal areas.

SS14 – Seagrass restoration

Fine Scale Site Assessment for Seagrass Restoration

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As active seagrass restoration methods are developed to address global seagrass declines, the need for accurate site assessment and selection remains vital to maximise the chances of restoration success. Habitat suitability modelling is a common tool used to identify potential seagrass restoration sites. However, this approach is often restricted by coarse resolution, and largely does not address the requirements of seeds and seedlings to survive and persist in new restoration sites. In many cases, restoration sites identified by traditional methods are large (100s of metres-kilometres) and incorporate a variety of environmental conditions. This study applies a hierarchical approach to classifying these sites by assessing biological, chemical, and physical characteristics, as well as employing novel drone technologies. A suitability map was then developed by incorporating these environmental data and threshold values for Zostera muelleri to identify the most suitable areas of a potential restoration site. This suitability map was then validated by planting seagrass seeds and seedlings. Seedling survival and seed germination showed differing success rates between sites and suitability assessments indicating that fine scale environmental variation may be impacting seagrass restoration efforts.

SS14 – Seagrass restoration

Long-term nutrient and carbohydrate dynamics in posidonia oceanica transplants

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The restoration of degraded ecosystems is essential, especially when natural regeneration is insufficient. The “Bosque Marino” project (Mallorca, Spain) aims to restore two hectares of a degraded slow-growing Posidonia oceanica meadow. 12.800 drifting fragments, with one apical and at least two vertical shoots, were planted and the survival rate after 5 years is about 92%.

We present the results of nitrogen, carbon, phosphorus and carbohydrates (non-structural and structural sugars) content in different plant tissues (roots, leaves, rhizomes), measured at the beginning of planting, after 12, 20, 24, and 32 months, and compared with fragments extracted from natural meadow.

Nitrogen and phosphorus content decreased gradually in rhizomes from apical to vertical shoots while carbon content remains constant along the fragment. The trend in leaves and roots is similar but smoother. Carbon values in rhizome begin to recover quickly after planting, while nitrogen takes longer to recover and phosphorus content remains constant over time. Carbohydrates decrease after two years of transplantation but then recover to similar levels to those of undisturbed meadows. These findings show a gradual increase of reserves in transplants after planting approaching to natural fragments reserve content.

SS14 – Seagrass restoration

Donor populations for restoration

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Donor populations for seagrass restoration matter. We review quantitative and qualitative aspects of donor populations and provide a roadmap for domestication. Regarding quantitative aspects: upscaling of seagrass restoration is necessary because of (1) large losses of meadows and their ecosystem services, and (2) the need to increase success rates of restoration efforts due to (i) positive feedbacks (abiotic feedbacks, interspecific feedback, and demographic: Allee effects), (ii) bat-hatching to overcome natural variability at several scales and (iii) probably the effect of propagule pressure. Regarding qualitative aspects of donor populations: various restoration attempts have highlighted that suitability of donor populations may differ depending on the restoration sites. This is also exemplified by the reverse: a natural population may go extinct after the habitat is modified. This has implications for donor selection: the donor should be adapted not only to actual conditions, but preferably also to future conditions at the transplantion sites (for example from climate change). How can we provide sufficient donor material and get a grip on the ecotype suitability? We propose nurseries as an addition to traditional restoration, and discuss wanted or unwanted aspects of such seagrass domestication processes.

SS14 – Seagrass restoration

The restoration of Posidonia oceanica (L. Delile) and Cymodocea nodosa (Ucria) Ascherson, 1870 meadows as part of the Marine Ecosystem Restoration Project

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In the context of the European Grean Deal (2019) the proposed Nature Restoration Law (2022) sets binding targets to restore damaged ecosystems and bring nature back across Europe. Within the Italian NextGenerationEU plan, and on behalf of the Ministry of Envinment, ISPRA is launching a series of initiatives to implement active restoration on marine seagrasses habitat in five Italian sites, one related to C. nodosa and 4 to P. oceanica meadows. The aim of the activity is to restore these key benthic habitats to increase the associated ecosystem services and biodiversity, and guarantee carbon sequestration. In each site, 1000 m2 and 250 m2 of the P. oceanica and C. nodosa meadows will be restored, respectively. Each site will be protected for an extention of 10.000 m2. The restoration interventions concerning the seagrass meadows will be completed by April 2025. Moreover, protection actions and surveillance activities will be implemented in the areas subject to restoration, to minimize the pressure on restoration interventions due to recreational traffic and fishing activities. The medium-long term objective is that restored habitats will develop the same features, in terms of three-dimensionality and diversification, of natural habitats, as a signal that ecosystem services are recovered.

SS14 – Seagrass restoration

Assessing the viability of monetising seagrass carbon sequestration to support meadow restoration

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5. *Tamar Estuaries Consultative Forum*

The monetisation and sale of seagrass ecosystem services may provide an alternative and sustainable means of funding seagrass conservation and restoration, for example through the sale of 'blue' carbon credits to the voluntary carbon market, or the sale of biodiversity credits, units or tokens. This project investigated the feasibility of creating a seagrass carbon code to support a credit approach. Our multidisciplinary team used a pilot site in Plymouth Sound, UK, that includes several Zostera marina seagrass beds and seagrass restoration activity, to identify how carbon sequestration benefits of seagrass habitats could be monetised to support restoration. Due to the current economics of restoration using carbon data from this and other UK studies, and key challenges around the long-term protection of seagrass habitats, it was identified that a single ecosystem service (ES) model based on carbon was not viable. However, we identified the need to bring together a wider frame of benefits in order to support restoration, including biodiversity gain, fish stocks, water quality and more. The bundling of qualitative and quantitative benefits together underpins our proposed approach through the sale of "Plymouth Seagrass Tokens" to a range of stakeholders from corporates to local citizens.

SS14 – Seagrass restoration

Sand capping to break feedback mechanisms and promote the return of seagrass

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In NW Sweden, eelgrass recovery and restoration face challenges due to local regime shifts triggered by eelgrass loss, leading to increased sediment resuspension that prevents growth. Here we assessed if sand capping could improve conditions necessary for eelgrass restoration at historic sites.
We used pilot studies to identify a suitable area for sand capping, and high-resolution hydrodynamic models to determine the optimal location within the bay. In 2021, 1800 tons of sand were placed in a 10 cm thick layer over a one-hectare, followed by the planting of 80,000 eelgrass shoots on top of the sand. The sand capping activity showed no long-term negative effects on water quality or infauna.
The restoration resulted in a dramatic improvement of growth conditions in the bay. Light penetration within the sand capped area increased by up to one meter, resulting in a surge of eelgrass in the second year. By 2023, over 1.5 million shoots were found in the sand capped area, harboring a diverse community of invertebrates and fish. The results suggest that sand capping can break feedback mechanism on a local scale and promote the return of a seagrass dominated state with clear water and high biodiversity.

SS14 – Seagrass restoration

Seeds for snapper: scaling up seagrass restoration using community power

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Cockburn Sound near Perth, Western Australia, is a seagrass-dominated ecosystem where seagrasses have declined from 4200 ha to 967 ha between 1954 and 2017 due to poor water quality. Water quality has since improved but meadows have shown minimal recovery, thus it is imperative that seagrasses are restored at ecologically relevant scales. The most cost-effective way to conduct large scale restoration is to use seeds that are naturally produced in large quantities. In the case of Posidonia australis, millions of buoyant fruit are produced in Nov/Dec that release a single seed which sinks to the bottom after hours to days of dispersal on the sea surface. The OzFish 'Seeds for Snapper' volunteer program (2020-2023) collects fruit from reproductive shoots using SCUBA divers. Fruit are stored in circulating tanks until seeds are released. Seeds are then dispersed into restoration sites from boats. Annual seed restoration has varied from ~180 000 to over 1.2 million seeds per season in the space of four years. This simple methodology results in seedling densities of up to 46 m^{-2}, compared to 0-2 m^{-2} in naturally seeded areas after 3 months. This seed-based volunteer program demonstrates that P. australis can be restored to hectares of habitat.

SS14 – Seagrass restoration

Combining co-introduction with patch-size optimization as a novel strategy to maximize seagrass restoration

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Coastal ecosystem engineers such as corals, oysters and seagrasses, ameleaorate stressors when growing beyond a critical population size. In doing so, they provide habitat for diverse communities which can engage in reciprocal interspecific facilitation. Over the last decades, coastal ecosystems faced rapid human-induced declines, emphasizing the need for restoration. Yet, although the importance of intra- and interspecific facilitation have been confirmed, their combined potential remains untested in application-scale restoration experiments. We examined whether restoration aimed at recovery of both facilitation types increases restoration yields of the seagrass Zostera marina. We manipulated patch size to test for intraspecific facilitation and co-introduced epiphyte grazingers to investigate interspecific facilitation. We found that the effect of intraspecific facilitation on restoration yields was dependent on hydrodynamic exposure conditions. Large patches at exposed sites showed a 40% increase in seagrass restoration yield compared to small patches, while at sheltered sites, large patches performed up to 60% worse than small ones. Interspecific facilitation, on the other hand, increased success with 73% on average. Our findings are the first to show positive effects of co-introduction for seagrass restoration. Moreover, they highlight that including both facilitation types into restoration can be a powerful approach to increase coastal restoration success.

bookofabstract

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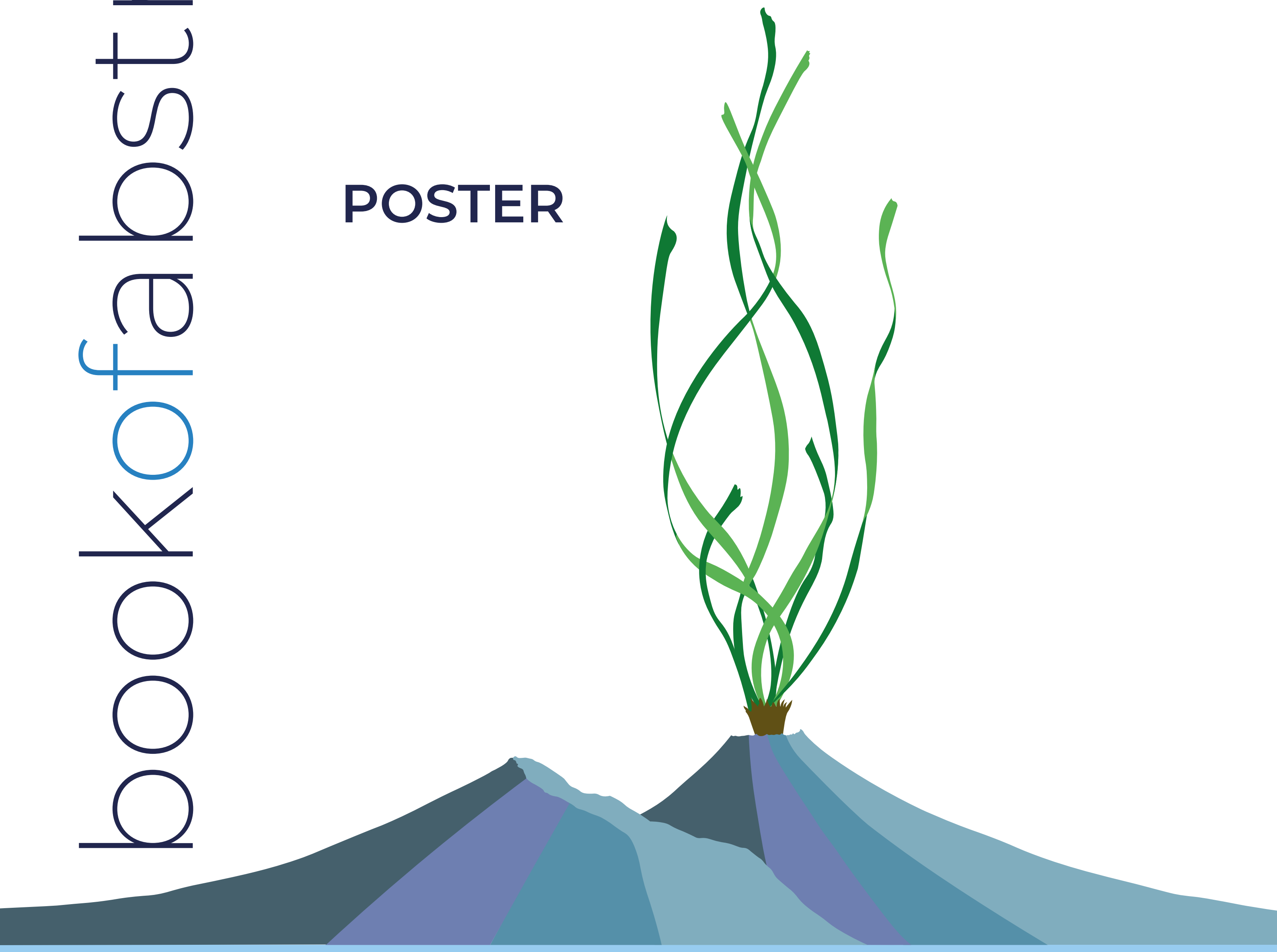
POSTER



POSTER - SS05

Multiple pressures, responses and restoration of the endangered seagrass Zostera capensis

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The endangered Zostera capensis is found in 37 South African estuaries that range from systems permanently open to the sea to estuaries that close. The highly dynamic estuary environment affects the distribution, growth and recovery of seagrass from multiple stressors. Estuary type accounts for the variability in extent of seagrass habitat. Beds are stable in estuarine bays but variable in highly dynamic closed systems. Coastal development results in numerous pressures. Water quality changes including eutrophication and macroalgal growth has caused seagrass dieback as has artificial estuary mouth breaching, bait digging and boating. These pressures including the limited intertidal habitat limit opportunities for restoration. Replanting with plugs has had variable success. As a component of Estuary Management Plan implementation, restoration should be taking place at all suitable estuaries in South Africa in an adaptive socio-ecological systems framework. Although extent has been used as the main factor for restoration prioritisation other factors to consider are biodiversity provision, socio-economic importance, political buy-in, community support, benefits or ecosystem services and the potential of the estuary to build resilience to climate change impacts. Areas for the restoration and protection of existing seagrass areas are identified to ensure the long-term survival of Z. capensis beds.

POSTER - SS05

Seagrass grows faster with experimental nitrogen enrichment in the Maldives, but sensitivity influenced by contextual disturbance

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Background. Eutrophication, caused by excessive nutrient loading – particularly nitrogen (N) – from human activities is considered a pervasive threat. In the Maldives, increased agricultural activity, poor sewerage and fertiliser management in combination with coastal realignment, mean that on some islands, seagrasses are undergoing rapid change, the drivers of which are not yet fully comprehended. This study aims to determine the impact of nutrient enrichment on seagrass growth in the Maldives.

Methodology. Here we experimentally enriched Thalassia hemprichii meadows with a N-based slow-release fertiliser at two sites (Site 1: More impacted and Site 2: Less impacted by human activity) located on seaward inter-tidal reef flat settings. Three treatment levels were used for enrichment (control; low nutrient = 600 g m^{-2} and high nutrient = 2000 g m^{-2} of NPK fertiliser). We measured the impact of the fertiliser over a 2-week period through a combination of in-situ monitoring of morphological variables, seagrass leaf-extension rates of tagged blades and new growth and the number of newly formed leaves. Elemental and isotopic analysis was used determine if and how the additional N was acquired and partitioned into the plant biomass.

Results. Growth rates of tagged leaves at Site 1 did not change significantly with the addition of N (for either treatment), however this was likely compensated for by stimulation of new leaf growth to give an overall net increase in total leaf production relative to the control plots (~16% and 23% for low-nutrient and high-nutrient respectively) and a significant increase in the leaf extension rates of new leaves ($p < 0.01$). Results at Site 1 are also broadly suggestive of latent N saturation and light limitation as a result of elevated nutrient concentrations, explaining an increase in epiphytic and cyanoacterial blue-green algal growth. At Site 2, growth rates of tagged blades significantly increased ~35% ($p<0.01$) in response to the low-nutrient fertiliser addition. Based on the growth rates of tagged leaves, we estimate a 72% increase in total leaf production (g m^{-2} day^{-1}) at Site 2 consequent on low-nutrient treatment. Isotopic signatures substantiate these findings through the significant lowering of $\delta^{15}N$ values in seagrass blades in the N-enriched plots at both sites, indicating the uptake of the fertiliser into biomass.

Conclusion. Our findings highlight that seagrass responds favourably to N enrichment through increased overall net leaf production. Additionally, sites previously experiencing, or in close proximity to coastal realignment, are likely more vulnerable or sensitive to changes in nutrient conditions. This is the first experimental study to look at the implications of nitrogen enrichment in seagrass ecosystems in the Maldives, a country that depends on healthy seagrass for sediment stabilisation and fisheries.

POSTER - SS05

Benthic environment analysis in contrasted Zostera noltei meadow s : from native to new ly col onized areas , Normandy (France)

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Seagrasses such as Zostera noltei meadows play an important ecosystem role. B ecause of their role as an indicator of the quality of coastal surface water (Water Framework Directive : WFD), s eagrass beds are habitats within the meaning of European directives. In this context, in 2019, a WFD status report downgrading the Cul de Loup cove Normandy, France) due to the decline in the surface area of the Z ostera noltei meadow since 2008. But recently, in 20 22, new meadows colonized by seagrass were discovered in the cove.

To study the temporal dynamics of seagrass meadow and their causes , a research project was recently set up in 2023 ("ZAPER project"). Within this framework, geographical and ecological approaches (macro fauna and foraminifera , bacteria, sedimentology, biogeochemistry , oxidative stress biomarkers ....) are used to study benthic habitats associated with seagrass and bare sediment . The first results leading to the ecological approach show ed marked differences in these contrasted benthic environments and oxidative stress responses in seagrass, annelids and bivalves sampled Moreover new meadows were found on the northern part of the cove where seagrasses disappeared since 2008. These results offer hope for a natural recolonization of the seagrass on a larger scale and an improvement in the cove' s environmental quality.

POSTER - SS05

Seagrass species richness and identity influence annual seagrass cover, but changes in species composition drive meadow stability

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Understanding drivers of seagrass meadow stability–or constancy of seagrass cover over time–is key to sustaining these ecosystems and the services they provide. Biodiversity-ecosystem function theory predicts that diversity promotes ecosystem functioning and stability, and previous work has shown that genetic diversity enhances resistance and resilience to disturbance in single-species meadows. However, the role of species diversity in promoting meadow stability is less clear. We investigated the effects of seagrass meadow species composition on meadow stability over time in Florida's Big Bend, a relatively undeveloped and unimpacted region that hosts extensive mixed-species meadows. We analyzed long-term (16-year) monitoring datasets that recorded annual seagrass cover at 25 sites at each of four locations. We assessed how species composition and richness affected annual cover and stability in cover over the entire monitoring period. We found that species richness and dominance by a climax species positively affected annual cover, but that changes in seagrass composition negatively impacted stability. We also found that species composition mediated changes in seagrass cover in response to disturbance events, though responses varied by site. Our findings highlight how species' tolerances to different conditions can complement one another to sustain seagrass meadow cover over time.

POSTER - SS05

Sugar and salt: how seagrass cell walls adapted to the marine habitat

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Seagrasses evolved from monocotyledonous land plants that returned to the marine habitat. This transition was accomplished by substantial changes in cell wall composition. We investigated polysaccharide composition of nine seagrass species from the Baltic, Mediterranean, Red Sea and Indian Ocean. Sequential extraction revealed a seagrass cell wall composition comparable to terrestrial angiosperms with pectins and different hemicelluloses, especially xylans and/or xyloglucans. However, the pectic fractions were characterized by high amounts of apiose, suggesting unusual apiogalacturonans are a common feature of seagrass cell walls.
Whether arabinogalactan-proteins (AGPs), important signalling molecules of land plants, are present in seagrass cell walls is of evolutionary interest. AGPs of Zostera were structurally characterised by analytical and bioinformatics methods as well as by ELISA with different anti-AGP antibodies. Although the common backbone structure of land plant AGPs is conserved in Z. marina, the glycan structures exhibit unique features, including a high degree of branching and an unusually high content of terminating 4-OMe GlcA residues. Calcium-binding of Zostera AGPs was studied by ITC and microscopy. The high Calcium-binding capacity due to the polyanionic surface is possibly involved in adaptation to the marine environment.

POSTER - SS05

Herbivory-induced facilitation increases from low to high stress: a paired observational and experimental test in Zostera marina beds

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Ecological theory expects that facilitation should strengthen under increasing environmental stress because of compounding positive interactions. Similar benefits could, however, arise from compounding negative interactions, such as competition and predation. Here, we use a model system to investigate how the top-down consumption of macrophyte competitors affects a foundational seagrass along a gradient of light limitation. We first surveyed eelgrass (Zostera marina) beds across three estuaries of Long Island, New York, USA, and established that epiphytic algae negatively impacted seagrass productivity and that epiphyte loads did not vary from shallow (high light) to deep (low light) edges of beds. Next, we employed a cageless exclusion of mesograzers at shallow and deep edges in one bay. We found that the experimental removal of mesograzers resulted in more epiphytes at greater depths than at shallow ones, leading to greater reductions in seagrass biomass and productivity. Together, these findings suggest that mediation of competitors by herbivores is more important when light, a critical resource, is already limiting, and support emerging perspectives on the interplay between environmental stress, top-down control, and facilitation.

POSTER - SS05

Weighted gene co-expression network analysis identifies molecular pathways and hub genes involved in the acclimation strategies of Cymodocea nodosa exposed to single and multiple factors

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Changes in gene expression mediate a substantial amount of organisms' acclimation to external cues. Thus, identifying regulatory gene networks involved in acclimation to single or concurrent stress factors is required to evaluate the health status and stress tolerance of seagrass populations. Many studies have described Cymodocea nodosa transcriptome changes in response to single stress factors, but the exposure to a combination of added factors could induce responses that are potentially diverse from what is known regarding the exposure to the prime factor. To test this hypothesis, we evaluated C. nodosa response to isolated increases in nutrients, CO2 and herbivore pressure and compared that with the response to double and triple combination of these potentially stressful factors. Gene expression analysis revealed that 55% of the responsive transcripts in double and triple treatment factors were not predicted from the response to the single factor's treatments. A Weighed Gene Co-expression Network Analysis (WGCNA) was applied to identify the modules of functionally related genes. From this analysis, we identified 17 modules including 34,480 genes. Four modules mainly enriched for amino acid metabolism and gene regulation, displayed significant correlation (agonistic or antagonistic) with nutrient enrichment. Overall, these data provide new insight on Cymodocea regulative mechanisms.

POSTER - SS05

The Blue Economy and Seagrass Ecosystems in the Western Indian Ocean (WIO)

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The “blue economy” has become one of the most dominant discourses within ocean/coastal governance recently. Blue economy policies in coastal states are being created, action plans drafted and activities implemented. In this context, this work analyzes multiple stressors affecting seagrasses and the potential futures for the meadows by analyzing the blue economy policies for Kenya, Tanzania and Mozambique, three major coastal states in the WIO. We create conceptual scenarios based on the blue economy ideas found in the policy documents. The future of seagrasses in the region is challenged specially by large scale projects such as port construction and oil extraction. At the same time there is important focus on small-scale fisheries, conservation, and eco-tourism, which requires preservation of healthy and productive meadows. The stressors are a complex combination of natural and man made disturbances. Three main conclusions are derived from the analysis, 1) the future of seagrasses in the region will depend on well developed and participatory spatial planning, 2) the commitment of the countries to contribute with blue carbon as a nature based solution for climate change, and 3) the level of awareness of decision makers about the value of seagrasses for fisheries production, livelihoods and human health.

POSTER - SS05

Long term seagrass meadow monitoring in the protected areas of the Adriatic Sea

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Seagrass meadows of Posidonia oceanica are distributed along the eastern coast of the Adriatic Sea. Similar to the rest of the Mediterranean, P. oceanica is an endangered and protected species. In 2011 a protocol was developed to uniform the approach to monitoring seagrass meadows across the protected areas, and has since been implemented in several National Parks and Nature Parks in Croatia. This approach identifies referent and impacted sites in relation to anchoring, as the main physical impact on the seagrass meadows.
We compared the outcomes of the monitoring carried out in the three protected areas: National Park Brijuni, Nature Park Telašćica and National Park Mljet. These are located in the north, central and south of the Adriatic Sea, respectively. Monitoring has been carried out in the sites since 2011/2012 and has been carried out until today, with varying frequency. The results indicate a clear difference between the reference sites and impacted sites across the years and locations. Rates of decline vary across the sites. To assess the drivers of this variation we assessed the differences in management practices and basic environmental factors. Impacts other than local management seem to drive the differences in decline across the sites.

POSTER - SS05

Impact of repeated disturbances on Thalassia testudinun meadows by sargassum brown tides in the mexican Caribbean

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Seagrass beds provide a wide range of valuable ecosystem services in near-shore areas. In particular, the tropical seagrass Thalassia testudinum is the climax species in Mexican Caribbean reef lagoons. Since late 2014, the Mexican Caribbean coast has experienced periodical massive influx of holopelagic Sargassum spp., resulting in build-up of decaying beach-cast material and nearshore brown waters, known as Sargassum-brown-tides (Sbt). We conducted a 3-year lasting field study assessing the effect of recurrent Sbt on patchy and continuous, T. testudinum meadows starting after the first major disturbance event in a previously lush and continuous meadow. After the second disturbance, the seagrass presence drastically decreased and a colonization of macroalgae, mainly Halimeda incrassata, occurred. Overall, density values of T. testudinum dropped off up to 98%, and the remaining seagrass showed a change in biomass distribution, with a high reduction in the above-ground portion. Density, above- below biomass and horizontal rhizome extension experimented a slight recovery after the Sbt in 2018 but, after the repeated occurrence in 2019, only continuous meadows survived and showed partial recovery. The patchy meadow was lost completely, with a horizontal rhizome mortality of 100% that highlights the importance of habitat integrity for the resilience and recovery and of seagrasses.

POSTER - SS05

Force of infection highlights rapid disease transmission in a natural eelgrass (Zostera marina) meadow

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Despite the outsized ecological impacts of marine diseases, the amount and pace of disease transmission events are poorly understood. Given the rise of climate-fueled pathogens, many of which threaten foundation species like seagrasses, there is a growing need to understand abiotic and biotic drivers of marine disease transmission. Here, we aimed to: 1) estimate the daily rate of seagrass wasting disease spread in an eelgrass (Z. marina) meadow and 2) quantify the presence of the causative agent, L. zosterae (Lz), in the water. We tracked disease development in 423 tagged eelgrass shoots in monthly trials from April – June 2022 and 2023 on San Juan Island, Washington, USA. We quantified Lz cells in seawater using quantitative polymerase chain reaction (qPCR) to detect associations between high disease levels in eelgrass and Lz concentrations. Results indicate infections accumulate rapidly in eelgrass in situ, with an average rate of lesion development of 0.79 lesions/day (or mm2/leaf/day). Disease transmission was higher early in spring, but Lz was detected in the seawater in 11 out of 19 months sampled. Importantly, this work provides early-season estimates of disease spread and of Lz propagules in situ.

POSTER - SS05

Thermal mosaics and seagrass resilience: A comprehensive exploration on a small special scale

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Seagrass ecosystems are vital in coastal marine environments, but they face global threats from climate change. The ability of seagrass to withstand these challenges relies on intraspecific trait variation influenced by genetic background and plasticity. This study investigates how thermal habitat variability contributes to intraspecific trait differences in Zostera marina on a small spatial scale and its impact on seagrass resilience to climate change-induced extremes. We conducted a common garden experiment on the west coast of Sweden, subjecting seagrass from 10 meadows to a climate change treatment with heat and desalination stress. Despite the meadows' proximity, they experienced different thermal microclimates. The climate change treatment significantly affected Z. marina, resulting in increased mortality, higher eelgrass wasting disease prevalence, reduced leaf development, and overall diminished growth. Surprisingly, varying responses occurred among meadows, unrelated to their natural thermal microclimates. We discuss the role of meadow connectivity, genetic diversity, and thermal variability in impeding intraspecific trait differences. The study underscores the importance of comprehensive habitat characterization in understanding complex effects on intraspecific trait variation and species resilience to climate extremes, particularly emphasizing the link between elevated temperatures and increased temperature variability.

POSTER - SS05

Effects of decadal long sub-lethal temperature increases on Zostera muelleri resilience to future stress events

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Estuaries are subject to high concentrations of anthropogenic stress which is exacerbated in a warming climate. These stressors can inhibit photosynthesis in seagrass and force the organism to rely upon stored carbohydrates within the rhizome to survive additional stressors. This study uses decadal long thermal outflows, which are on average approximately 2-3°C higher than ambient temperatures, as a proxy for a future climate change scenario in a large temperate Australian estuary to investigate the effects of increased temperatures on rhizome carbohydrate levels in Zostera muelleri. Samples (n=350) were collected during 2022-2023 encompassing peak growth and reproductive seasons at two different thermally affected sites and three ambient locations. HPLC was used to determine carbohydrate levels within the rhizomes by measuring sucrose and starch levels. Carbohydrates were highly variable with concentrations of sucrose and starch ranging from 5-200mg g-1 aligning with previous literature. However, there were no differences between the two treatments overall despite thermally affected sites commonly experiencing heatwaves exceeding the upper limit of Z. muelleri. This study demonstrates the resilience of temperate Z. muelleri in a real-world scenario and its capacity to acclimate to elevated temperatures which include frequent short term temperature spikes that exceed its thermal range.

POSTER - SS05

Impacts of Heat Stress on gross primary production of Small-Bodied Seagrass H. ovalis

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Seagrass meadows provide ecological services such as nitrogen cycling, increased biodiversity, and climate change mitigation and adaptation through carbon sequestration and coastal protection. They are however, vulnerable to direct anthropogenic pressures as large numbers of people live along coastlines, and indirect anthropogenic effects such as climate change and increased thermal variability associated with marine heatwaves (MHWs). Extreme heat events may threaten seagrass habitats by interfering with key physiological functions such as photosynthesis and respiration, however at present little research is available on heat stress in small-bodied seagrass. Simulated heat shock experiments can help us to understand the impacts of extreme increases in temperature on species physiology. By using Fiber optic oxygen sensors, we were able to assess how MHWs have a direct effect on gross primary productivity through photosynthesis when temperatures were rapidly increased to the maximum local summer temperature. In addition, different treatments were used to assess the effects of lesser heatwaves during different seasons. Based on the results obtained, we discuss how small-bodied seagrass will cope with rising temperatures in the future. Understanding species' ability to adapt to warming is critical to predicting future trends, therefore, the results of this study will be important for seagrass ecosystem management and conservation.

POSTER - SS05

Ecological risks of 48 trace elements detected in sediments and Thalassia testudinum from the Bay of Cartagena and in the Corales del Rosario National Park, Colombia

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This research represents the most comprehensive study to date on trace elements evaluated in Thalassia testudinum worldwide. The focus was on seagrasses from the Colombian Bolivarense Caribbean. A total of forty-seven trace elements in seagrass and sediment samples were analyzed and quantified using ICP-MS. Subsequently, pollution quality indices in sediments were determined, as well as the bioaccumulation factor to T.testudinum. The results revealed elevated concentrations in sediment samples, with Sr (4307.70 ± 11.50) > B (10.50 ± 2.26) > Zn (41.08 ± 4.39) mg/kg in the sampling zone control, corresponding to the Corales del Rosario National Park.
In contrast, in the contaminated zone, corresponding to Cartagena Bay, higher concentrations were found for Sr (1017.30 ± 638.30) > B (149.46 ± 22.88) > Ba (31.73 ± 4.96) mg/kg. Regarding T. testudinum, elevated ranges were observed in the same trace elements as in the sediments. The main elements with a bioconcentration factor greater than 1 for the control zone were Mo > Ni > Cu > W, while for the contamination zone, they were Ge > HF > Ba > Th. These results demonstrate the presence of a high number of trace elements, which, furthermore, have bioaccumulated in T. testudinum.

POSTER - SS05

Population dynamics and competition in seagrass meadows

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The drastic decrease in seagrass populations in the last decades has worrying implications for marine ecosystems. One of the major challenges is to identify and quantify the effect of local and long-range disturbances and to characterize the seagrass response to them. Besides fundamental field measurements and observations, we present a theoretical model approach able to reproduce the observed seagrass growth dynamics and the spatial organization resulting from the effect of different stressors. Such spatial patterns act as early signaling indicators of the proximity of tipping points that can be avoided or delayed through self-organization. We will analize the dependence of the mortality rate on local shoot densities, temperature and sulfide poisoning, that lead to multistability and excitability. Model outcomes have been successfully compared to field measurements of Posidonia oceanica meadows in the Mediterranean Sea and can be useful in the definition of optimal restoration strategies.

POSTER - SS05

Microplastic in tropical estuarine seagrass meadows: does seagrass size matter?

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Seagrass meadows have been recently appointed as potential microplastic (MP) hotspots, due to their capability of trapping MPs in the sediment. As seagrass species vary in size and ecosystem services provided, this study aimed to verify sedimentary MP retention in areas vegetated by small-bodied seagrass species (Halodule wrightii, Halophila decipiens, and H. baillonii) and an adjacent unvegetated area in a tropical estuary in the Brazilian coast, according to seasonality. We verified MP contamination in 80% of samples (142 ± 140 particles kg-1 dw; N = 80). No significant variation among species and the unvegetated was observed, either for seasons (dry and rainy). However, a positive correlation between MPs abundance and sediment grain size was observed (= 0.274). MPs < 1 mm (80% of particles) prevailed over larger fractions, fibers were the most abundant shape (73%) and blue the most abundant color (51%). This study presents the first records of MP contamination in seagrass meadows of the Southwestern Tropical Atlantic bioregion. Therefore, species size, sediment grain size, and local anthropogenic activities are probably crucial characteristics for the accumulation of MP in seagrass meadows. Different species and influence of seasonality should be further investigated to define regional and global patterns.

POSTER - SS05

Ecophysiological responses of the surfgrasses phyllospadix scouleri to marine heatwaves in baja california, mexico

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The seagrass Phyllospadix scouleri (also known as sufgrass) forms highly productive meadows in intertidal and subtidal rocky shores along the Pacific coast of North America. Despite their valuable socio-ecological benefits, these vital ecosystems face potential threats associated with human disturbance and climate change. This study presents a comprehensive examination of the potential effects of warming associated with marine heatwaves (MHWs) on surfgrasses from Baja California (Mexico). We examined the ecophysiological responses and growth of P. scouleri through a series of mesocosm experiments, assessing a wide range of biological traits including those related to photobiology, respiration, oxidative stress, carbohydrate and nitrogen reserves, nitrate uptake rates, and nitrogen isotopic signal. In summary, it was concluded that: i) the exposure to consecutive MHWs could lead to a progressive physiological weakening in P. scouleri; ii) P. scouleri might tolerate severe MHWs (25°C) without significant physiological disruptions, but extreme MHWs (28°C) could potentially impact its physiology to the extent of compromising its growth; and iii) important stress responses were evident after cessation of heat exposure, and therefore, recovery phases should be included in experimental studies to obtain robust insights into the thermal tolerance of these seagrasses.

POSTER - SS15

Investigating shifts in faunal communites in Norwegian Skagerrak eelgrass meadows

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Seagrass meadows are key ecosystems, providing critical ecosystem services such as nursery and habitat for numerous associated species. Seagrass areas are declining, and faunal shifts have been observed. This has been linked to human impacts such as trophic cascades and eutrophication, and could have large cascading effect on ecosystem services and functioning of seagrass ecosystems. In Norway, eelgrass (Zostera marina) is the main seagrass species, but it is relatively understudied and studies on fauna inhabiting eelgrass meadows are few and mostly several decades old.

In this study, I aim to compare eelgrass epifaunal communities that were first sampled in 1999-2001 by resampling the same sites in 2023 We collected eelgrass and fauna by scuba diving in meadows in two stations (Langerumpa and Klaua) in June and September, then counted and identified all epifauna. This work is still ongoing, but preliminary results show indications of a potential shift in epifaunal communites, particularly an increase in littorinid gastropods and a decrease in nematodes and polynoid polychaetes. Determining how the communities have changed and how these are linked to environmental drivers can help us in understanding human impacts on eelgrass ecosystem functioning and ecosystem services.

POSTER - SS15

The Meadow-Scale Trophic Effects of Detrital Kelp as a Spatial Subsidy to Seagrass-Inhabiting Mesograzers

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Seagrass meadows are connected to adjacent habitats, such as macroalgae reefs, through the exchange of fauna, detritus and nutrients which have the potential to increase seagrass productivity. Kelp is regularly eroded from reefs, and during storm events, provides a vector for nutrient transfer to seagrass meadows, where it can increase nutrient and food availability. Theoretically, kelp-derived nutrients could support increased growth of fauna in seagrass meadows, resulting in greater biomass and densities. A field experiment was completed to investigate the role of kelp in supporting seagrass meadow productivity, exploring whether its presence influences epifauna via food provision and/or habitat availability through the addition of artificial and detrital kelp. Epifauna densities (indv. 100 g seagrass-1) and biomass (g 100 g seagrass-1) were significantly higher (278.52 ± 51.45; 2.62 ± 0.72) in the presence of detrital kelp, compared to artificial kelp (146.68 ± 24.40; 1.99 ± 0.72) and controls (25.68 ± 4.84; 1.19 ± 0.23). These results underscore the dual role of kelp as a habitat and food source for epifauna within seagrass ecosystems. Our results imply seagrass epifauna could decrease as kelp declines globally. Overall, this study highlights the necessity of understanding trophic connectivity for informed coastal management, particularly in the context of climate change.

POSTER - SS15

Preliminary estimation of blue carbon associated with seagrass meadows in the insular and coastal territory of Venezuela

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Blue carbon refers to carbon sequestered and stored in the soil and biomass of mangroves, salt marshes, and seagrass meadows (SM). Blue carbon ecosystems accumulate most carbon as organic carbon (Corg) in sediment. There are no previous Corg estimations in SM in Venezuela despite these systems having a wide distribution in shallow waters. The objective of this work was a preliminary estimation of Corg in selected SM extended across the central coast and insular locations. We used reported methodologies for the indirect analysis of Corg, including a systematic sediment sampling (N=3) on a 50m transect established on each SM. The seagrass cover was also estimated. We analyzed organic matter content employing weight loss on ignition technique (LOI), and %Corg determination using reported equations. We obtained a %Corg overall 1.38±0.71(N=29) when evaluating 8 SM that differed in cover and seagrass composition, Corg values were similar to the obtained for SM in the Colombian Caribbean. We determined significant differences between PNAR and LC sites (ANOVA,$p<0.0346$) but not between meadows associated independent site (ANOVA,$p<0.2991$). Likewise, the highest %Corg values recorded were consistent with the highest cover percentage registered. Finally, this study proposes a future generation of SM blue carbon inventories in Venezuela

POSTER - SS15

Dynamics and drivers of eelgrass seed-based recovery potential along an estuarine gradient

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Seagrasses are well-adapted to survive in systems with strong gradients and dynamic changes. Yet, notable declines have been observed worldwide from an increase in anthropogenic climate change, followed by loss of ecosystem functioning and services. Sexual reproduction is critical to bed recovery after large declines. Key attributes of sexual reproduction (bed investment, seed output, and timing/duration of flowering) that contribute to recovery potential are influenced by environmental factors, yet variations in these attributes have been poorly studied at small scales. We characterized Zostera marina (eelgrass) sexual reproduction between and within beds along an estuarine gradient in South Slough National Estuarine Research Reserve (SSNERR), Oregon, USA, which suffered extensive losses of critical eelgrass habitat after one of the largest marine heatwaves (MHW) on record for the eastern Pacific. Our analyses show variation in attributes between and within sites, suggesting variable bed capacity for recovery through seeds. Physical water parameters extracted from intertidal loggers and channel stations allow us to identify environmental drivers. Determining the effects of environmental conditions on eelgrass sexual reproduction will highlight critical drivers of recovery potential and guide seed-based restoration efforts (e.g., donor site selection) for SSNERR, the US West Coast, and the larger seagrass community.

POSTER - SS15

Comparing two approaches for the quantitative assessment of blue crab commercial fishery enhancement by restored eelgrass meadows in the Eastern shore of Virginia

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The Virginia Coast Reserve hosts the largest successful seagrass restoration project on the planet, with over 3,600 hectares of restored meadows. To measure the impact of seagrass restoration on the locally important blue crab fishery, we developed estimates for the enhancement of this species by the restored meadows using two methods. First, we calculated fisheries benefits based on differences in juvenile abundances between seagrass and bare sediment and established growth and mortality rates, assuming that the presence of structured habitats acts as a limiting condition for fish production. The second method was an econometric time series analysis of the landings data, where we used Vector Error Correction models to isolate the impact of seagrass on blue crab harvest and assumed that benefits are spatially limited to the Eastern Shore of Virginia. Using the first method, we found that a hectare of eelgrass produces 330.33 kilograms of blue crab per year, while the econometric analysis found an increase of 30.84 kilograms per year, and that these benefits only occur during the first four years following restoration. The differences between these results can be attributed to the differing assumptions of the approaches, which will be further explored in the proposed talk.

POSTER - SS15

Potential loss of ecosystem services due to the removal of posidonia oceanica banquette

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The seagrass Posidonia oceanica, endemic of the Mediterranean Sea, forms extensive beds providing valuable ecosystem services (ES), such as carbon sequestration and protection from costal erosion. Significant quantities of P. oceanica dead leaves are deposited along the shores, forming heaps known as "banquettes". Their occurrence in touristic areas is perceived as a nuisance, thus leading local administrations to dispose their removal. Nonetheless, the ecological effects of banquette removal are still poorly investigated. In this study, based on the monitoring of the P. oceanica banquettes along the coastline of the Campania Region (Southern Italy), the biomass and associated concentration of chemical elements were estimated. The obtained data allowed a first estimation of the potential loss of ES due to banquette removal. Since no significant differences among the investigated sites were found, an upscale to regional level was carried out, revealing that about 40 t of C y-1 are stored in the Campania banquettes. Results highlight the key role of banquettes in the blue carbon cycle and can support policy makers for the sustainable management of P. oceanica banquettes.

POSTER - SS15

A synthesis of provision and impact in seagrass ecosystem ser-vices in the brazilian Southwest Atlantic

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The ongoing environmental crisis, driven by biodiversity loss and climate change, raises concerns about impacts on marine systems which provide crucial ecosystem services and human well-being. Seagrasses support fisheries, protect coasts, help mitigate climate change, maintain biodiversity, provide food security and enhance water quality and health. However, comprehensive assessments of seagrass ecosystem services (SESs) and their impacts are lacking. Focusing on the Brazilian Southwest Atlantic our aim is to bridge this gap and identify key research areas for improved management decisions. We screened 30351 search returns for 394 relevant documents. Research on SESs has grown over time and most research has focused on provisioning and supporting ecosystem services: 79.7% of documents mentioned at least one SES while 24.5% of the documents provided evidence of observed SESs; 31.5% only informed expected SESs. Provisioning services were most observed and expected. Coastal urbanization (54%), marine food provisioning (17%) terrestrial food and material provision (9%) and climate change (8%) were the main impacting drivers. This study provides key recommendations aimed at fostering further research and management strategies considering the complete ensemble of SESs in other bioregions to better understand the provision of and impacts to seagrass services and human well-being at the global scale.

POSTER - SS15

Blue carbon across the riverbank: Assessing carbon storage of seagrass and saltmarsh habitats in a South African Estuary

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Research on blue carbon ecosystems (BCEs) is increasing rapidly, although carbon storage variability remains understudied, and the contribution of subtidal seagrass meadows is often overlooked during carbon assessments. This study quantified carbon stock variability between three vegetation types (saltmarsh, intertidal, and subtidal seagrass), at three sites, at Olifants Estuary, South Africa. Measurements revealed organic carbon content (%Corg) differed significantly between vegetation types, with saltmarsh showing the highest, followed by intertidal, and subtidal seagrass. This study shows evidence for variability of Corg stocks between sites, with higher %Corg found within the upper sites, compared to lower sites. Variables, such as shoot density and leaf lengths within seagrass meadows, and nitrogen content (%), were also measured along with %Corg to explain carbon storage variability and it was found that nitrogen content was significantly positively correlated to carbon content, while only leaf length was significantly positively correlated to carbon content in intertidal meadows. Sediment carbon stocks were calculated for saltmarsh (10.737 ± 7.371 MgC ha-1) and intertidal seagrass (2.852 ± 1.493 Mg C ha-1) to a depth of 5 cm, and 27 cm for subtidal meadows (16.96 ± 6.70 MgC ha-1). Carbon stocks within BCEs are underestimated as a result of carbon stock, and these findings provide evidence of variability within the studied site, along with evidence that subtidal meadows of Zostera capensis, store similar amounts of %Corg to intertidal meadows. Thus, this study emphasises the importance of including subtidal meadows to carbon stocks assessments and continued protection of this endangered species.

POSTER - SS15

Carbon source matters: Species-specific methane production in anoxic seagrass sediments on the Swedish west coast

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Seagrass meadows have the capacity to capture and store large amounts of organic carbon (OC) and can therefore also be a source for methane emission. Methane is produced when the OC decomposes in anoxic sediments. The extent of the methane production is very likely related to the quality of the degrading OC. In a long-term mesocosm experiment, we studied how OC, originating from eight different macrophytes (Zostera marina, reed and various macroalgae), might affect the methane production in anoxic seagrass sediment on the Swedish west coast. Seagrass sediment was added to glass bottles with a gas-tight septa and subsequently the carbon sources were added separately to different bottles. The methane level in the air phase was measured regularly for almost a year. The results showed that the patterns of methane release from the sediment were highly dependent on the carbon source. The phylogenetic group of the macroalgae appears to be more influential than the plant structure, as evidenced by the red macroalgae exhibiting the highest methane production. The treatment with OC originating from Z. Marina generated comparatively low methane levels, indicating that carbon input from other adjacent habitats play an important role in the greenhouse gas balance of seagrass meadows.

POSTER - SS15

Modelling the colonisation of a non-indigenous mussel in seagrass meadows: the case of Arcachon bay, France

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Since the 1970's, the introduction of non-indigenous species due to oyster exchanges have been numerous. Among them, the mussel Arcuatula senhousia has colonised a large number of ecosystems worldwide and can lead to severe habitat modifications by constructing concentrated byssal mats. Often, its presence is closely linked to seagrass meadows and sometimes, the invasion leads to seagrass decline by disturbing oxygen fluxes, and eventually impacting root and rhizomes system. In Arcachon Bay (France), abundances of A. senhousia recently increased. This area hosts large areas covered by seagrass meadows, mostly Zostera marina and Zostera noltei. This study aims to determine the ecological niche of A. senhousia in the lagoon and to characterise its relation with seagrass meadows. Two extensive spatial survey at more than five hundred stations were undertaken in 2018 and 2021 to report mussel densities. We used species distribution modelling to predict zones which could be suitable for A. senhousia installation in the lagoon. For now, results showed that this species is not restricted to seagrass meadows but can spread over most of the intertidal flats. These results reveal the high colonisation potential of this species in intertidal habitats and the risk of impacts in already weakened seagrass ecosystems.

POSTER - SS15

Discovering the patterns of seagrass-associated infaunal biodiversity at multiple spatial scales

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Seagrasses are ecosystem engineering species that provide heterogeneity at the level of shoots, patches and seagrass landscapes. Benthic macroinvertebrates respond to this heterogeneity, which conditions scale-dependent patterns in their composition and functioning. The aim of this study is to characterise the biodiversity of benthic macroinvertebrates associated with Zostera spp. meadows at different spatial scales: from microhabitat (in the order of cm) to meadow (from m to 10 m) and landscape (from 10 m to km). To this end, 90 sampling stations were distributed within the seagrass meadows using a fractal design to cover five spatial scales in the order of 1, 10, 100, 1000 and 10000 metres. Sediment samples were collected from two estuaries in northern Spain and macroinvertebrate species were identified. Analyses of univariate community measures (richness; alpha, beta, gamma diversity) and species-area relationships indicate an increase in the species richness with distance. Multivariate analyses show that the community composition of seagrass-associated macroinvertebrates varies with spatial scale and is estuary-dependent. This information is essential for seagrass conservation and restoration, as it allows addressing a variety of problems, such as calculating species loss due to habitat conversion or species gain due to habitat restoration, or prioritising conservation/restoration areas and actions.

POSTER - SS15

Characterizing the retention capacity of microplastics in a seagrass meadow as a function of hydrodynamics and shoot density

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Critical ecosystem services that seagrass meadows provide include coastal sediment stabilization, and acting as carbon sinks, which are intrinsically linked to their capacity to modify coastal hydrodynamics and thus enhance particle sedimentation and trapping. Such particles, though, may include microplastics, and indeed recent research has underscored the potential role of seagrasses as “plastic sinks”. Trapping and retention are both a function of seagrass physical attributes (e.g. plant morphology, shoot density) and of the hydrodynamic conditions of they are under. We present the first investigation into the influence of waves, currents, shoot density, and their interplay on microplastic retention by Zostera marina. Wave simulations revealed high pellet retention irrespective of meadow density whereas current velocity examinations revealed that both meadow density and water depth are pivotal in influencing pellet retention. Higher pellet retention was generally observed for combinations of wave and current velocity in medium-density meadows. Given seagrass beds’ capacity to filter microplastics and facilitate their sedimentation, these findings hold significant implications for biodiversity, shaping future plastic waste management and mitigation strategies. Understanding the interplay of wave and current dynamics contributes to enhancing seagrass meadows’ role as effective barriers against microplastic pollution in coastal ecosystems.

POSTER - SS15

Exploring the function of dimethylsulfoxide (DMSO) in Posidonia oceanica: phenological, biochemical, and molecular investigations through a dose-response assay

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Posidonia oceanica is a notable producer of dimethylsulfoniopropionate (DMSP) and dimethylsulfoxide (DMSO) (Richir et al., 2021). Leaf contents vary seasonally and with tissue age, ranging from 25 to 265 μmol.gfw-1 for DMSP and 1.0 to 13.9 μmol.gfw-1 for DMSO. While DMSP and DMSO play roles in the marine sulfur cycle (Karsten et al., 1990; Pakulski, Kiene, 1992), their specific functions and its biosynthetic pathways in Posidonia remain unclear. This study aimed to evaluate the dose-response effects on growth, chlorophyll levels, and protein expression over 28 days cultivation of cuttings in a mesocosm were exposed to escalating DMSO concentrations (0.01% to 100%) compared to seawater-treated references. Across all tested concentrations, DMSO stimulated the growth of adult leaves, inhibited the growth of intermediate ones, reduced leaf blade necrosis, and increased the number of new leaves at concentrations of 0.01% and 0.1%. Chlorophyll levels dose-dependently increased, peaking at 1% DMSO. Molecular data revealed over-regulation of most proteins at 1% and 10% DMSO, spanning biogenesis, cellular renewal, energy, macromolecule metabolism, as well as nitrogen metabolism. Overall, results suggest that endogenous DMSO, like its exogenous counterpart, may play a role in cellular homeostasis and in maintaining low redox state in tissues.

POSTER - SS15

Re-casting the SeagrassNet

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Established by Drs. Fred Short, Rob Coles, Evamarie Koch and Miguel Fortes in 2000, SeagrassNet is now the oldest continually running monitoring program for seagrasses worldwide. SeagrassNet partners have generated over 100,000 on-the-ground observations at 136 locations in 35 countries and established an unparalleled global baseline for seagrass ecosystems. SeagrassNet is an important first step in assessing the state of the world’s seagrass resources and how they might be changing. With Dr. Short’s retirement, we aim to re- invigorate ongoing global monitoring efforts and will bring SeagrassNet into its next phase of life with new partners, in new locations, and with a publicly accessible data repository. We will initially focus on (1) building a reliable and easy-to-use data portal to host existing data, providing free, accessible data on seagrass health in a changing climate, (2) supporting existing partners and recruiting new teams with a shared passion for seagrass health around the world, who will be supported through training, equipment donations, regular check-ins, and an engaging community comprised of academics, NGOs, managers, and volunteers, and (3) increasing education, inclusivity, and awareness around seagrass ecosystems through outreach, sponsorships, and public events.

POSTER - SS15

Human Galectins and Plant Galactans: Will Zostera find its way into tumor therapy?

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Galectins are a group of carbohydrate binding proteins ubiquitous in the mammalian body with a variety of functions. Due to their involvement in tumor progression, human galectins-3 and -9 (Gal-3, Gal-9) are potential targets for therapeutic intervention. Plant glycans have been shown to bind to galectins and may be potential inhibitory substances addressing these targets.
Small carbohydrates can be produced by partial degradation of special cell wall glycoproteins, the arabinogalactan-proteins (AGPs). AGPs possess a variety of functions in plants and play an important role in signalling pathways.
This deconstruction results in galactose rich molecules of much smaller size (galactans), which can be used for binding analyses.
Binding capacities were tested for the galectins to the degraded AGPs of Zostera marina and Echinacea purpurea by biolayer-interferometry.
The results demonstrated binding of all galactans to Gal-3 (KD values: 0.2 – 2.2 µM). However, only the Zostera marina galactans, containing a higher branching and uronic acid content, showed an affinity to Gal-9 (KD value: 3.5 µM).
Additionally, the inhibitory impact of plant galactans on the adhesion of pancreatic tumor cells to liver endothelium cells was investigated by in-vitro assays. It was shown that this important step in the metastasis process is influenced by galectins.

POSTER - SS15

Investigation of Epiphyte Assemblages on Posidonia oceanica Leaves in Potentially Disturbed and Control Areas, Lipsi Island, Aegean Sea

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Localized eutrophication events in the Mediterranean, originating from small coastal communities, threaten the functionality of surrounding seagrass ecosystems, necessitating the reliable identification of these processes. Therefore, this study examined the suitability of epiphyte assemblages on Posidonia oceanica leaves as an indicator of anthropogenic nutrient enrichment for the first time in meadows in the eastern Aegean Sea. Seagrass biometric and meadow parameters were studied at control (CSs) and potentially affected (PAAs) sites (n=3), in addition to epiphyte community structure, during winter 2022. PAA meadows, identified using a modified Land Use Simplified Index (LUSI), exhibited decreased leaf length and shoot density, and increased epiphyte cover and biomass. Epiphyte assemblages shifted significantly, with clear differences observed in red coralline algae, filamentous brown algae, bryozoans, and annelids. Results highlighted water quality degradation from point sources, including a local sewage outlet, and tourist and agricultural activity, which strongly affected seagrass bed condition, due to substantial epiphyte cover and its direct (shading) and indirect (intensified grazing; physical leaf instability) effects. Furthermore, the study revealed that epiphyte communities, in combination with the LUSI, serve as accurate and cost-effective indicators of small-scale coastal water pollution. Regular monitoring could detect higher nutrient loading and potentially prevent long-term meadow decline.

POSTER - SS15

Human-nature relations as pathways for connecting people and seagrasses

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Worldwide, coastal areas are facing several pressures associated to human actions, which seriously compromises the functioning of these systems and the variety of ecosystem services and other nature's contributions to people they provide.
To understand the different social-ecological contexts and to drive sustainability transformations in coastal habitats, interdisciplinary cross-sectoral approaches are required together with effective communication strategies.
Here we present an initiative, started from the EuroMarine foresight workshop Pathgrass, aimed at developing and implementing social-ecological approaches in seagrass-dominated coastal systems. The Pathgrass workshop gathered a multidisciplinary research community of experts on seagrass, social-ecological systems, and social sciences to promote a collective reflection on human-seagrass connections/interactions. The Pathgrass initiative aims to i) identify (dis)connection points between human and seagrasses; ii) understand the causes of the (dis)connection; and iii) foster people-seagrasses connectedness. Further steps of this initiative will develop common conceptual frameworks and social-ecological sustainability models to be implemented in seagrass-dominated coastal systems.

POSTER - SS15

Nutrient dynamics in aquatic grass beds in Chesapeake Bay, USA

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Seagrass and aquatic grass beds are important for many ecosystem services including the ability to take up nutrients from the water column, as well as slowing water flow, that allows settling out of sediment particles. Therefore, intact grass bed ecosystems can act as important filters for anthropogenic loadings particularly in estuarine environments. One of the good news stories of the Chesapeake Bay is the resurgence of many estuarine aquatic grasses due to improved water quality. The most successful resurgence of grasses has occurred in the Susquehanna Flats region of the Upper Bay, which had been decimated by sediment deposition due to river runoff after a large hurricane in the 1970s. This now has one of the largest and most diverse grass beds in the region. Investigations of nutrient dynamics in this grass bed and interaction with nitrogen-fixing cyanobacterial mats are being undertaken, to determine whether over-growing cyanobacteria will interfere with the resilience of these grass beds. Overgrowth leads to reduced light availability and inhibits gas exchange, which ultimately decreases photosynthetic rates of the aquatic grasses and increases sediment anoxia and nutrient fluxes. Consequently, the severity of cyanobacteria coverage can be strongly related to changes in sediment biogeochemistry and seagrass loss.

POSTER - SS15

Environmental conditions of the seagrass areas of the protected natural landscape Rincón De Guanabo, Cuba

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The evaluation of the environmental conditions of seagrass ecosystems allows us to contribute to decision-making for their protection; taking into account the goods and ecosystem services they provide. The Protected Natural Landscape Rincón de Guanabo constitutes a research site for the development of a biotechnological product from Thalassia testudinum. Under this premise, the characterization of the area's waters was carried out, based on physical, chemical, microbiological, and phytoplankton indicators in the period 2021-2023. The pH and salinity values were characteristic of coastal waters with exchange with the open sea. Dissolved oxygen, COD, and sanitary hygiene quality indicators were within the permissible limits according to the Cuban standards. The concentrations of total and heterotrophic bacteria of phytoplankton showed a predominance of water oligo-mesotrophic to mesotrophic conditions, although the presence of cyanobacteria is a warning sign of possible deterioration of the ecosystem. The values of the modified FoRAM Index for seagrasses were between 3 and 4, attributed to the dominance of opportunistic foraminifera characteristic of shallow waters. In general, the waters of Rincón de Guanabo presented adequate environmental conditions for seagrasses, with a tendency to improve towards 2023.

POSTER - SS15

Orienting young scientists of Euromarine (oyster). opportunities for early career researchers in marine sciences

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EuroMarine is a network of European Marine Organizations and Research Institutions, committed to supporting early career researchers (ECR) and bottom-up science from the marine science community. The "Orienting Young Scientists of EuroMarine (OYSTER)" group was founded in early 2018 with the aim of engaging with young scientists by including a forum of 20 PhD students and post-docs from member institutions across European countries. It is an independent and self-organized group that accepts new motivated members annually. OYSTER aims to ENGAGE with and represent ECRs within the EuroMarine network, CONTRIBUTE towards the cohesive outreach and capacity building of ECRs across EuroMarine member organizations, and DEVELOP initiatives to support and integrate ECRs within the European marine landscape. To this end, OYSTER organizes a mentorship program, grants individual fellowships for training activities (24 training activities funded in 2023, 60% of success rate), funds small cooperation research project (3 projects funded since 2021) and collaborates with other ECR networks. Furthermore, OYSTER has organized workshops in several European institutions targeting topics like career paths outside academia and mental health in the early scientific stages. OYSTER has a wide community on twitter where it disseminates jobs and training opportunities regularly, as well as their own calls.

POSTER - SS15

Effects of macrophyte species richness on macrophyte resilience, invertebrate communities, and herbivore feeding decisions

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Changes in the diversity of foundation species can impact ecosystem functions and processes. Tropicalization is resulting in increased grazing pressure in subtropical regions, which can alter species richness and plant persistence. Therefore, an understanding of how seagrass species richness impacts ecosystem stability, habitat use, and herbivore feeding decisions is essential to make informed management decisions. We investigated the impact of macrophyte species richness on resilience to simlulated grazing events, herbivore feeding dicisions, and invertebrate abundance and diversity. Areas with higher macrophyte species richness exhibited better recovery of shoot density following simulated grazing events, indicating that species richness may increase resilience. Simulated grazing had the strongest negative impact on the persistent species, Thalassia testudinum, reducing T. testudinum density and dominance. Additionally, seagrass species richness positively impacted invertebrate abundance and diversity, and feeding choice trials revealed that mixed-species seagrass assemblages provided a comparable or preferred food choice to a monoculture for the sea urchin, Lytechinus variegatus. Therefore, seagrass species richness can boost ecosystem stability by allowing opportunistic species to replace species that are sensitive to a given disturbance and may positively impact secondary production by supporting large, diverse invertebrate communities and providing a desirable food choice to herbivores.

POSTER - SS15

Do some seagrass nature-based solutions approaches lead to greater carbon sequestration than others?

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To date, no comparative work evaluates the carbon offsets over time associated with seagrass NbS project approaches. Such work can guide implementation of seagrass voluntary carbon market methodologies and inform national and subnational climate models that require an understanding of how management practices affect carbon sequestration.
To address this need, we developed a mechanistic model to estimate carbon offsets over ten years associated with four theoretical seagrass NbS project approaches, selected for their prevalence and potential - 1) seeding, 2) transplanting, 3) conserving a meadow that would otherwise have been lost, 4) placing of dredge sediment prior to transplanting.
We found that in many contexts, conservation approaches can lead to overall greater carbon benefits than restoration approaches, but these benefits were more pronounced during early project stages. Our results demonstrate that seagrass restoration using dredge sediment can greatly enhance the total carbon sequestration potential of a project. Timelines for generation of carbon credits also vary greatly across project approaches. Our key findings highlight that NbS projects that can preserve existing sediment carbon stocks are more likely to serve as viable seagrass projects within the voluntary carbon market.

POSTER - SS11

Trends and interannual variations of Posidonia oceanica structural descriptors in Southeast Spain: are global variables major drivers?

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The widespread decline of Posidonia oceanica meadows caused by human activities has been widely reported, whereas the temporal dynamics of meadows without anthropogenic pressures are scarcely studied. These assessments are urgently needed in the current era of global change to identify natural factors driving the dynamics of the species. Trends in structural descriptors of undisturbed meadows are here analyzed and related to local and global environmental factors to identify the main natural drivers of P. oceanica temporal dynamics. For this purpose, generalized additive models (GAMs) fed with shoot density and meadow cover values of 12 meadows in southeastern of Spain from 2004 to 2022 were run. While deep meadows showed temporal stability during the whole period studied, trends of shallow meadows (0-10m) showed significant variations of both structural descriptors. Models showed that the main drivers of annual change rate in meadow structure are related to natural variations in light availability. In addition, climate indices such as the Western Mediterranean Oscillation index (WeMOi) also showed a strong link with interannual variations in meadow structure. Finally, contrary to expectations, the models do not identify a relevant role for variables related to extreme phenomena associated with global change, such as marine heatwaves or episodic storms.

POSTER - SS11

Advancing subtidal seagrass mapping methods for monitoring restoration

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The Ocean Conservation Trust has developed restoration techniques for transplantation and in situ seeding of Zostera marina at subtidal sites in the South West of the UK. These trials call for robust monitoring techniques that are cost-effective, accurate and repeatable at the scales associated with young plantlet growth. Additionally, it is increasingly important to address gaps in our knowledge of the extent, distribution and temporal variability of established beds as we seek to scale up restoration efforts.

Here we demonstrate two approaches to address these issues: firstly, developed with MarineSee and Sonardyne, a ROV-based system equipped with hybrid acoustic-inertial positioning to enable high resolution and accuracy photogrammetric mapping of seagrass. Secondly, a novel acoustics approach developed by Hydrosurv and University of Plymouth, deployed from a USV platform utilising machine learning to identify seagrass (94-96%) and estimate canopy height. These distinct but complementary methods offer promising solutions for monitoring subtidal Z. marina at scales commensurate with restoration, whilst also enabling increased temporal frequency to better understand annual and seasonal fluctuations of established beds. Together these represent significant advances to help inform management and planning, particularly in the context of increased restoration effort across the UK.

POSTER - SS11

Assessing Spatio-Temporal Dynamics of Nanozostera noltei in Irish Intertidal Zones using Remote Sensing technologies: Implications for Restoration

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Seagrass restoration, necessitating knowledge of site environmental conditions, appropriate planting methods, and the identification of suitable locations for seagrass growth, is the focal point of this study. The tracking of the spatio-temporal distribution of seagrasses, which is essential for pinpointing areas of persistence, loss, and recent expansion, is recognized as the initial step in determining where restoration efforts should be directed. In this study, the spatial and temporal (annual and seasonal) dynamics of Nanozostera noltei meadows in the intertidal zones of three Irish estuaries were assessed. The mapping of this seagrass was based on the use of Normalized Difference Vegetation Index derived from Sentinel-2 imagery (2016-2023). This mapping was conducted through the use of BioIntertidal Mapper software, Image True Color visualization, and field measurements, and compared with historical seagrass extents. The monitored meadows showed sizes of 25 (Killala Bay), 10 (close to Tralee Bay Nature Reserve), and 1 (South Dublin Bay Special Area of Conservation) hectares during summer 2022, with the maximum expansion reached between July and September. The results show the feasibility of low-cost remote sensing for N. noltei and underscore the importance of understanding spatio-temporal trends for restoration prioritization. Identifying suitable rehabilitation areas and evaluating persistent loss regions like South Dublin Bay are key.

POSTER - SS11

The influencing factors of seagrass distribution in Dongsha Atoll

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The seagrass of Dongsha Atoll is the largest seagrass bed in Taiwan, located on the north of the South China Sea. A twice quantitative investigations were conducted at 15 fixed stations in the atoll in 2018. The survey items include temperature, salinity, dissolve oxygen, pH, nutrients in seawater; median grain size, silt/clay content, the content of total carbon, total organic carbon and total nitrogen in substrates; species, coverage, density, and biomass in seagrass. The results revealed seagrass coverage, biomass per unit area, and average plant biomass were the highest in nearshore of island. The SIMPER analysis revealed dominant species in reef platform were Oceana serrulata, Thalassia hemprichii. In offshore of island, Halodule uninervis, O. serrulata, Syringodium isoetifolium were the dominant species. In nearshore of island, Cymodocea rotundata, T. hemprichii were the main species. The small lagoon in the island was dominated by H. uninervis, C. rotundata. Pearson correlation analysis revealed seagrass species number was significantly positive correlated with water depth, but significantly negative correlated with pH and median grain size; plant density was significantly negative correlated with median grain size; average plant biomass was significantly negative correlated with water depth, and significant positive correlation with the median grain size.

2024 World Seagrass Conference &

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Seagrasses in the Anthropocene

POSTER - SS11

Assessment of the Carbon Budget of Seagrasses in a Low-Utilization Fishing Port

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Blue carbon ecosystems, including seagrass meadows, salt marshes, and mangroves, are essential transition areas connecting land, freshwater, and the ocean, providing and supporting many ecosystem services. The seagrass areas are the largest among Taiwan's three major coastal blue carbon ecosystems. In this study, we investigated the distribution and the carbon sequestration capacity of seagrass in a low-utilization fishing port of Penghu Island, including Citou (CT), Zhenhai (ZH), and Jiangmei (JM) fishing ports in four seasons in 2023. Four research stations were established: CT1, CT2, ZH, and JM. The results indicated that seagrass bed areas exhibit great seasonal variations (Winter: 5.60 ha; Spring: 11.54 ha; Summer: 62.51 ha; Fall: 34.03 ha). Halophila ovalis dominate CT1, while CT2, JM, and ZH are dominated by Halodule uninervis. The average daily productivity of Halophila ovalis ranges from 0.04 to 0.53 g DW m-2 d-1, while Halodule uninervis ranges from 0.20 to 9.83 g DW m-2 d-1. The annual total carbon sequestration is 52.43 tons C y-1. Converted to carbon dioxide equivalent, the annual CO2 sequestration is 192.42 tons CO2e y-1.

POSTER - SS11

The plastic pollution on seagrasses worldwide: current state of knowledge

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Seagrasses, compared to other marine habitats, are little studied with regards to plastic pollution.The scientific data published in the last decade (January 2012–2023) on several seagrass species worldwide were critically analysed and relevant knowledge gaps emerged. First data appeared only in 2017, highlighting the very recent efforts dedicated to this topic. The investigated areas around the world are still limited and scattered (mostly Indian Ocean and Mediterranean Sea), despite the global distribution of seagrasses.; ii) high variability of experimental designs and limited standardised approaches have emerged, with a majority of in situ studies and only few laboratory experiments (22 vs. 5).

Most of the studies were devoted to microplastics, while limited studies were dedicated to macroplastics and nanoplastics, and the polymer physico-chemical characterization is not always provided.

To improve seagrass protection against the plastic pollution, the research efforts need to: i) explore worldwide the dynamics and effects of plastic accumulation in seagrass ecosystems at individual, population and community; ii) focus on a common model species (Z. marina potential candidate); iii) standardise the experimental designs and increase laboratory experiments but considering environmentally relevant conditions; iv) further investigate smaller (nano) size and bio-based plastics and provide accurate polymer physico-chemical characterization.

POSTER - SS11

Maps of Posidonia oceanica meadows as indicators in environmental impact assessment

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In the Mediterranean, Posidonia oceanica meadows are a seaway energy flow generated by multiple interactions between populations, trophic networks and environment. All together recognize its fundamental and ecological functions as biological indicator, in the coastal environment.
Extensive and effective monitoring of the ecological structure of the P. oceanica meadows is the basis to evaluate the changes in impact due to multiple stressors, mainly including lost and reduction in extension and productivity.
In this perspective, Remote Sensing techniques, based on the currently available multi-hyperspectral high-resolution sensors (Sentinel 2 MSI and PRISMA), on satellite in polar orbit, calibrated using innovative in situ samples acquisition/processing methods, have been successfully exploited for monitoring and mapping the P. oceanica meadows under stress, in the coastal waters of two islands, located in the Sicily Channel.
The results obtained for the P. oceanica meadows in the coastal shallow waters of Pantelleria and Lampedusa islands, allowed us to identify the effects of the anthropogenic impact as well as that from natural sea currents and waves.
In our investigations the results include maps and indicators that can be used to support the evaluation of meadow adaptation and health to suitably support the sustainable management strategy in these coastal zones.

POSTER - SS11

Discriminating Seagrass From Green Macroalgae in European Intertidal Areas using High Resolution Multispectral Drone Imagery

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Coastal areas host seagrass meadows, which offer crucial ecosystem services including erosion control and carbon sequestration. However, these areas are increasingly impacted by human activities, leading to seagrass decline and habitat fragmentation. In situ surveys, traditionally performed to monitor these ecosystems face limitations on temporal and spatial coverage, particularly in intertidal zones, prompting the use of satellite data within monitoring programs. Yet, satellite remote sensing struggles with spatial and spectral resolution, making it difficult to discriminate seagrass from other macrophytes in highly heterogenous meadows. To address these challenges, drone images acquired with multi-spectral sensors offer a promising solution. This study focuses on using drones acquisitions for mapping intertidal macrophytes, effectively discriminating between seagrass and green macroalgae. Ten drone flights were conducted at two different altitudes (12m and 120m) across diverse European habitats in France and Portugal. Low altitude flights were used to train a Deep Learning classifier based on Neural Networks to discrimintate among 5 intertidal vegetation classes. Drone mapping demonstrated an overall accuracy of 94% across all the sites and images, covering a total area of 467 000 m^2. The model exhibited an accuracy of 96.4% in identifying seagrass.

POSTER - SS11

The Lacco Ameno Posidonia oceanica long-term: learning from the past, calling to the future

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Posidonia oceanica meadows around the island of Ischia have been the subject of systematic studies since the mid-seventies of the past century. Research over years spanned from the plant properties to the associated communities as carried on by both Italian and international research groups chiefly referring to the former Benthic Ecology Lab and presently to the Ischia Marine Center of the Stazione Zoologica Anton Dohrn. The site of Lacco Ameno, located off the Northern coast of the island and hosting an extended P. oceanica meadow, has been designated as a research site in the framework of LTER (Long Term Ecological Research) network and coded IT13-002-M. It is currently being monitored for structural evolution and exposure to the climatic (thermal) environment. Changes over time in the state of the entire meadow indicate a decline in the shoot density absolute values and spatial patterns. A thorough appreciation of the long-term evolution of the meadow calls for the implementation of new tools, including those which can account for early warning signals of change.

POSTER - SS11

Multi-scale monitoring indicates impacts of low light from dredging on Posidonia sinuosa are not worsened by short-term heatwave

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Monitoring of seagrass meadows using a range of techniques is imperative for understanding biological response and informing environmental impact assessment. Here, we evaluated the response of Posidonia sinuosa to dredging during a two week heatwave by simulating low light (2 μmol m-2 day-1) and heatwave (28°C) conditions. We hypothesised that the combined effects would be worse than the effects of these factors individually. Unexpectedly, heatwave conditions had an apparent benefit on plants that manifested irrespective of the light conditions but this was limited to some indicators. For example, maximum electron transport rates (ETRMAX) were significantly higher in heatwave conditions (38.8±2.1) compared to ambient (32.1±1.5) and above ground biomass was also significantly higher following heatwave conditions (13.3±1.7 g vs. 7.8±0.9 g) but only under ambient light. Overall, we did not find strong evidence of an additive effect of low light and high temperature on P. sinuosa. These results suggest that dredging under heatwave conditions may not necessarily lead to worse outcomes provided the heatwave is short-term in duration (≤ 2 weeks). Analyses of untargeted metabolomics and proteomics data is underway and we are excited to share these insights with you in 2024.

POSTER - SS11

Indonesia seagrass mapping initiative: lesson learned

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Indonesia stands as a global hotspot for seagrass biodiversity, yet the absence of a reliable mapping framework hinders efforts to estimate the national extent of seagrass ecosystems. In alignment with the Indonesian government's ambitious goal to safeguard 30% of marine waters by 2045, the need for an accurate seagrass map has gained paramount importance. Beyond supporting conservation objectives, such a map plays a pivotal role in formulating strategies for emission reduction targets outlined in the Long-Term Strategy for Low Carbon and Climate Resilience 2050, and for the submission of Enhanced-NDC (version 3) to the UNFCCC Secretariat in 2025. Furthermore, the national seagrass mapping framework is integral to Indonesia's National Ocean Account program under the National Medium-Term Development Plan 2020-2024 and commitments to global frameworks like the Convention on Biological Diversity, Sustainable Development Goals, and the High-Level Panel for a Sustainable Ocean Economy, underscores the pivotal need for a comprehensive seagrass map. Indonesia Seagrass Mapping Initiative is a collaborative effort involves key stakeholders, including UGM, KKP, BRIN, Unhas, and UQ, supported by the David Lucile and Packard Foundation, aiming to accelerate the development of a comprehensive national seagrass map. This presentation will showcase two significant outcomes of the initiative: (1) an analysis of seagrass data governance in Indonesia, derived from focused group discussions involving diverse stakeholders—government entities, universities, NGOs, research institutes, and the military and (2) the advancements made in developing a nationwide seagrass mapping framework that ensures consistency, comparability, cost-effectiveness, and efficiency. The framework, built on open-source technology, offers a semi-automatic process with a repeatable procedure, fostering reliability in mapping efforts. Moreover, recognizing the need for sustained monitoring, we introduce a strategy leveraging citizen science. This approach, mobilizing networks encompassing the Ministry of Marine Affairs and Fisheries (KKP), universities, NGOs, and local governments, empowers local champions to collect field seagrass data. This initiative not only augments the accuracy of the map but also fosters community engagement, enhancing stewardship of Indonesia's seagrass ecosystems.

POSTER - SS02

Nested interactions in seagrass holobionts: A three-player game underpinning seagrass ecosystem health

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Seagrass beds act as global carbon sinks, achieved through a tight symbiosis between the below-ground roots and rhizomes and the microbes in and on them. Beyond the seagrass holobiont, these ecosystems rely on additional members including lucinid bivalves and their symbiotic Sedimenticolaeae microbes to counteract sulfide toxicity and possibly facilitate nitrogen fixation. Studies across seagrass, mangroves, and saltmarsh grass root systems consistently identify the bacterial group Sedimenticolaceae as a conserved symbiont. Despite this, detailed insights into their diversity, co-evolution and interactions with host plants, and roles within this ecosystem remain scarce.

Our ongoing investigation aims to unravel the functions of Sedimenticolaceae symbionts in seagrass roots and rhizomes, and in association with lucinid bivalves across 26 European coastline sites using molecular methods. As part of the TREC-EMBL expedition, we're collecting root and rhizome samples from Zostera marina, along with metadata detailing canopy height, co-existing organisms, epiphytes, seagrass bed depth, and water parameters.

This year, our sampling covered six sites, none of which housed lucinid bivalves in their sediment. We gathered 150 root and rhizome samples from Z. marina and plan to expand our sampling next year to include another 20 sites, encompassing both Posidonia oceanica and Z. marina beds along with the associated symbiotic lucinid bivalves. Consdering how widespread it is, we anticipate that Sedimenticolaceae symbiosis contributes to elemental cycling and host health within coastal ecosystems.

POSTER - SS02

Partnerships are key to large-scale assessments of seagrass ecosystems

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The vast Northern Australian coastline is geomorphologically and hydrodynamically complex, providing a range of habitats that support substantial and diverse seagrass. However, data is patchy and few large-scale mapping surveys have been undertaken. Cultural connections to dugong, turtle and fish that depend on seagrass as well as the economic and conservation values they support underscore the need to address this knowledge gap. Key to managing impacts to species in these habitats is reliable data on seagrass distribution and how it and the composition and abundance of seagrass changes over time. But northern Australia is remote and often difficult to access due to scarcity of roads and ports. Therefore, large-scale mapping and monitoring can only be achieved through partnerships including among scientists, locally based rangers, Traditional Owners, and environmental managers through co-design, participation and capacity-building. We will present on extensive areas of recently mapped seagrass habitat and planned mapping and monitoring activities. This information is crucial to custodians and environmental managers for spatial planning, Environmental Risk Assessments, the Blue Economy, and negotiation on use of resources among stakeholders. We will discuss challenges in establishing seagrass monitoring programs across northern Australia and how partnerships and the use of technologies can be used to minimise these constraints.

POSTER - SS02

A bioinformatics approach to unravel cis-elements regulation of circadian timekeeping in marine angiosperms

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The alternation of day and night is the major synchronizer of circadian rhythms. Circadian clock has evolved on life on earth as an adaptation to the 24-hour light/dark cycle. Coordinating cellular activities on the basis of circadian clock helps cellular components to optimize their performance. Molecular mechanisms by which cells maintain the clock are still under investigation, but involve a core set of clock genes that regulate large networks of gene transcription. In this context, global warming and changes in abiotic environmental conditions can disturb the biological rhythms of many species, including marine plants, which are a fundamental part of the underwater ecosystem as they provide protection and food for many types of marine organisms, as well as help to secure the sediments. Many clock genes are species-specific and diverged during the evolution and the speciation event that generated land and marine plants, and the molecular mechanisms involving them are not deciphered at all. We performed a comparative genomics analysis to better assess the core-component of the clock of seagrasses, defining a bioinformatic approach to identify and compare cis-regulatory elements in promoters of evening and day expressed genes, responsible to regulate the transcription of neighboring circadian genes.

POSTER - SS02

Zostera marina Seed Morphology and Germination Across Latitudes

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Seagrass meadows are experiencing declines in extent and shifts in species' distributions due to climate change and human impacts, but these impacts may be occurring at rates that surpass the ability of native populations to adapt to these new conditions. In response to dynamic coastal environments, effective ecosystem management needs proactive strategies that prioritize the resilience of native species. One proposed method is enhancing local resiliency by transplanting seeds from better-adapted populations; however, this relies on a nuanced understanding of intraspecific variations among populations. Within the Zostera genus, seed size is known to differ across sub-species, regions, and populations and may drive differences in seed viability. In this study, we will investigate how source location across a latitudinal gradient affects seed characteristics and how seed size impacts germination and seedling development across populations of Zostera marina. We measured average seed size, fall velocity, and carbon content from different populations across North America, and will test the relation of these metrics to germination success within populations from Eastern North America. These results will contribute to the literature needed to develop targeted conservation and restoration strategies by leveraging inter-population variation in traits related to reproduction and climate change resilience.

POSTER - SS02

Tropical seagrass bed food web identification using triple stable isotopes and fatty acid signatures

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Identifying the trophic role of primary producers is the basis of assessing seagrassbed functions but remains difficult due to the underdetermined analysis method.Here, we analyzed the multiple isotopes (δ^{13}C, δ^{15}N, and δ^{34}S values) and fatty acidmarkers of food sources and macrobenthos in a tropical seagrass bed in summerand winter, and tried to combine these indicators to resolve the limitation of δ^{13}Cand δ^{15}N values analysis. We found that the δ^{13}C and δ^{15}N values of epiphytes werelike that of seagrass and macroalgae, while the δ^{34}S values of epiphytes andmacroalgae were significantly different, and the dominant unsaturated fatty acidmarkers of seagrass (18:2n6c and 18:3n3) and epiphytes (16:1n7) were obviouslydifferent. These results suggest that the combination of multiple isotopes and fattyacid markers can effectively distinguish the complex food source. In addition, wealso found that multiple isotopes were more suitable to identify the food sourcesof polychaetes and snails with simple diets, fatty acids were more suitable toidentify the food sources of crustaceans with complex diets, but their combinationis essential in identifying the diets of macrobenthos since the wide range ofisotopic values for omnivores crustaceans and the fatty acid markerstransformation during snails and polychaetes assimilation might mislead uswhen only isotopes or fatty acid markers were used. Our findings suggest thatin tropical seagrass beds, using multiple isotopes and fatty acid markers togethercan help reduce the uncertainty caused by single markers variation and thusstrengthen the separation of food sources and the diets of differentconsumer species.

POSTER - SS02

Flore associée aux herbiers de Posidonie de la côte Algérienne

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The Algerian coast is considered a hot spot of Mediterranean marine biodiversity. Posidonia oceanica is among the most remarkable and structuring habitats of marine biodiversity in this region. Despite its ecological and economic importance, the distribution and characterization of these meadows have been little documented in Algeria.

We carried out this work to contribute to the national database on marine biodiversity of the Algerian coast "BANBIOM". We present the inventory to the Posidonia herbaria of the Algerian coast with a focus on Rhodophytes.

POSTER - SS02

Habitat structural complexity drives fish recruitment enhancement in submerged aquatic vegetation: a meta-analysis

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The importance of submerged aquatic vegetation (SAV) as fish nursery grounds is well established, yet knowledge gaps remain regarding how biotic and abiotic factors influence the function. Here, we conducted a meta-analysis (76 studies and 1043 responses) to evaluate important drivers of fish recruitment enhancement (RE) – defined as a relative increase in young of year fish abundance in vegetated vs. unstructured bottom – in SAV across North America. Overall, SAV enhanced fish recruitment by ~ 236% compared to unstructured bottom. SAV augmented benthic invertebrates or fish and benthopelagic fish but not pelagic fish. Structural complexity of SAV (shoot % cover and biomass) strongly enhanced fish recruitment, with RE up to 520% higher in dense (~80% shoot cover) vs. sparse (~20%) habitats, whereas patch area and edge effect had weak effects. RE did not vary with mean annual temperature but was higher in subtidal and oligohaline environment. Multi-model inference analyses incorporating fish, habitat, and environment-related variables revealed fish guild and structural complexity as the two most important predictors of RE. Our study reveal important commonalities among drivers of nursery habitat use in SAV across a broad geographic scale and call for explicit consideration of habitat quality management and fish life histories in its conservation and restoration.

POSTER - SS02

Synthesizing research trends for the Zostera genus: a global systematic review of seagrass stressors, response variables, and study design

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Seagrass meadows are ecologically significant habitats experiencing losses estimated above 50%. Thus, there is increased interest in the conservation of these meadows as they face possible global depletion. For our systematic review, the main objectives were to [A] qualitatively assess the state of literature focused on seagrasses within the Zostera genus; [B] utilize data from full-text articles to identify frequencies of stressors, response variables, and study designs; and [C] map the distribution, type, and number of these studies globally. We used an online screening tool, colandrapp.com, for our review. We conducted a Web of Science search, followed by a standardized review and data extraction protocol. We screened 7,331 abstracts and extracted data from 1,098 full-text articles. We found nutrients, temperature, and light were the most studied stressors. The United States produced the most studies, followed by Australia. Zostera marina was the most frequently studied species. We identified knowledge gaps in geography, stressors, and species. Undertaking a review of global studies allowed us to synthesize study trends related to the Zostera genus. This centralized knowledge base is a vital information source for seagrass research and management efforts, while existing as an open access data source for continued public use.

POSTER - SS02

Topic modelling analyses on seagrass ecological science: temporal trends, connectedness of recurrent themes and perspectives for future research

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Seagrass ecosystems support an impressive biodiversity and greatly contribute for the resilience of coastal oceans and human livelihoods. Yet, seagrass habitats are rapidly decreasing owing to several anthropogenic stressors, demanding urgent and original science capable to bridge the gaps of current knowledge on seagrass ecology worldwide. By conducting topic modelling analyses on a collection of 8529 documents, published from 1878 to 2020, we found that the relative share of documents on seagrass population dynamics / productivity along with shoreline processes / impacts is declining, while attention to other research areas, i.e. conservation / management, remote sensing and biotechnology, is on the rise. Despite growing interest and potential for collaborative work on their interfaces, those latter topics have been largely dealt with separately. We also report strong functional and geographic biases. Many more studies focused larger seagrasses, widely distributed in North America, the Caribbean, Australia or the Mediterranean regions, compared to smaller species, restricted to smaller geographic ranges in other regions of the world. We conclude that advances on fundamental science should more readily support technological applications, and that broader scientific networks should aim a more equitable understanding of seagrass systems across ecoregions, and also improved guidelines for their sustainable management.

POSTER - SS04

Broad-scale genetic diversity and biogeography of Seagrass Wasting Disease

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Seagrasses are considered ecosystem engineers, creating meadows that provide vertical habitat for organisms, preventing erosion, and serves as a carbon sink. Worldwide, meadows are quickly vanishing due to environmental factors such as eutrophication, sedimentation, temperature, and disease outbreaks. The seagrass native to the west coast of North America, Zostera marina, has shown signs of decline related to disease, specifically due to an opportunistic pathogen Labyrinthula zosterae (Lz). Lz, is a marine slime mold that causes eelgrass wasting disease (EWD), characterized by dark lesions on the blades that eventually progresses to necrotic tissue. Although we are beginning to understand that there are different strains and species of Labyrinthula based on culture-based sequencing, little is known about the broad- scale genetic diversity and biogeography of the pathogen(s). To explore this, we collected seagrass samples from sites across the west coast of North America including: Alaska, British Columbia, Washington, Oregon, Northern California, and Sothern California. We extracted DNA from seagrass blades and targeted the Internal transcribed spacer (ITS1) and 18S gene using amplicon-based high throughput sequencing (Illumina MiSeq 2X250 bp). Sequencing both genes allows for higher resolution and potential detection of different strains found in the environment. We are developing a phylogeny of Lz which can provide information on strain variation within eelgrass blades and allow for development of more specific diagnostic assays. We expect to detect large scale spatial variation in strains between locations. Additionally, a new suspected strain characterized by a crescent shaped lesion will likely differentiate itself from other strains. By exploring the broad-scale spatial genetic diversity of Lz using molecular analysis, we can improve our understanding of this pathogen and provide data that can help prevent future epizootics and improve overall health of meadows.

POSTER - SS04

High clonality in urban Thalassia hemprichii seagrass meadows

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Dispersal is necessary for seagrass populations to maintain connectivity and genetic diversity, which help promote their resilience over time. The genetic diversity within a population depends on a variety of factors including life history of the species, environmental drivers, hydrodynamics, and physical disturbance. Understanding how such local processes shape seagrass populations is crucial to formulating conservation strategies for this critical coastal habitat, particularly in urban areas where they need to be resilient against a multitude of stressors. In this study, we examined the genetic diversity, connectivity and population structure of six impacted Thalassia hemprichii meadows across the Singapore and Western Johor Straits using nine microsatellite loci. We found high genetic diversity and three distinct population groups even at such a small scale. These could be remnant sites that represent a proportion of the total genetic diversity that once existed in the area. We also identified identical multi-locus genoytpes (MLGs) in four pairs of sites, indicating successful dispersal by vegetative fragments (as opposed to sexual propagules). This is particularly significant for a newly reclaimed site, Tanah Merah, which had two such MLGs, constituting half its genetic richness. We recommend prioritising protection for the two most extensive and genetically diverse meadows, Pulau Semakau and Cyrene Reef, to serve as a source of genetic material for current and future meadows.

2024 World Seagrass Conference &

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Seagrasses in the Anthropocene

POSTER - SS04

Changes in Halodule wrightii genotypic diversity over a six-year time span (2017-23)

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Genetic diversity in seagrass populations is associated with many positive traits, such as resistance to, and recovery from disturbance. While genetic diversity features have been assayed in a number of seagrass populations, data is lacking on the maintenance of these attributes over time. We used a series of microsatellite loci to assess changes in Halodule wrightii genotypic diversity attributes (clonal richness (R), evenness (ED), and architecture (Ac)), mean heterozygosity (Ho), and clonal size over a six-year time span (2017-23) that included a major disturbance (freeze) event. While one genotype always dominated the population, it’s prominence fluctuated and did not exclude the recruitment of new genotypes. Clonal richness increased over time (R: 0.20 0.29), although most new clones were small and tended to be lost at a higher rate than larger ones. Our results indicate that genetic diversity and clone size remain fairly stable over extended periods of time, and can recover quickly after a major disturbance event.

POSTER - SS07

Impacts of salinity and epiphyte cover on light absorption and photosynthetic properties of Zostera marina meadows in western Ireland

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Seagrasses are unique marine angiosperms that fulfill many key ecosystems functions in coastal waters. The eelgrass Zostera marina L. is the dominant seagrass species in the Northern Hemisphere with a remarkable resilience to varying salinities and temperatures, which is considered a key factor contributing to its wide distribution. Seagrass meadows experience additional environmental stressors, such as aerial exposure and changes in light availability, and anthropogenic pressures including eutrophication - all of which impact on seagrass physiology, in particular photosynthesis, and ultimately carbon uptake and sequestration.
As part of the wider BlueC.ie project which assesses the carbon storage potential of seagrass habitats in Ireland, this particular study aimed to assess spatial variation in seagrass productivity and physiology across environmental gradients. Specifically, it characterised spatial variation of epiphytic algal density and biodiversity, and its effect on Z. marina light absorption properties, and examined the impacts of salinity, in situ and following lab exposure, on (i) chlorophyll fluorescence (using rapid light curves), and (ii) biochemical compounds (e.g. Chl a). Results highlight significant impacts of salinity and epiphyte cover on light absorption properties which contribute to the highly variability productivity rates observed along natural environmental gradients along the Irish west coast.

POSTER - SS07

Beyond brine: Unravelling the legacy of brine discharge on the life history traits of seagrass communities

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In an 18-year study comparing a seagrass community affected by a brine discharge from the San Pedro desalination plant (Spain) with an unaffected site, the research aims to assess the lasting effects on the surrounding ecosystems. The methodology involves collecting data such as sediment analysis, quantifying the abundance and diversity of benthic organisms, and biannually measuringand and physico-chemical parameters at both sites. Significant disparities in seagrass community structure, diversity, and associated organisms are evident between the affected and unaffected sites. Despite mitigation efforts since 2010, substantial impacts on sediment composition and benthic community structure persist, particularly affecting functional groups related to feeding modes. The study highlights the continued vulnerability of suspensivorous or detritivorous families with low mobility, while carnivorous or highly mobile families show greater resilience to increased salinity. This underlines the importance of long-term monitoring and integrated approaches to assess the ecological resilience of seagrass-associated ecosystems under anthropogenic stress. Understanding variations in feeding modes over 18 years is critical, highlighting the importance of maintaining organisms with a suspensivorous diet for ecological stability and resilience. Such organisms contribute to species diversity, enhancing the ecosystem's ability to withstand disturbance and reinforcing the study's relevance for informed long-term conservation and management strategies.

POSTER - SS07

2D imaging combination of planar optode and DET 2D: application in Zostera marina seagrass

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The intense biogeochemical activity in sediment, submerged soil or wetlands is often characterized by steep gradients of various physical and chemical parameters over submillimeter distances. In aquatic environments, mineralization of organic carbon induces strong changes in redox potential and the lability of several solutes in sediment. Moreover, animal-induced sediment reworking and bioirrigation as well as exudates from seagrass below-ground biomass can play a major role for carbon mineralization in marine sediments e.g. by affecting the oxygenation and distribution of labile carbon in deeper sediment layers and by inducing spatial and temporal heterogeneity in terms of redox conditions. A precise mapping of chemical gradients and their spatio-temporal dynamics in sediments is thus essential for understanding links between sediment biogeochemistry and marine organisms inhabiting/colonizing such sediments. In this context, we developed new multi-parameter chemical imaging techniques by combining luminescence-based optical sensor foils (planar optodes) with 2D-diffusional equilibrium in thin-film (DET) hydrogels enabling simultaneous sensing of pO2, dissolved iron, phosphate, nitrite/nitrate, sulfide, ammonium, manganese or pH.
A first application was used in Zostera marina meadow to better understand biogeochemical interactions between the seagrass rhizosphere and the surrounding sediment. Nitrate/ nitrite, dissolved iron, oxygen and pH were analyzed in parallel in a rhizobox system showing clear codistributions in front of root systems.

POSTER - SS07

Tipping the Balance: Global Change Stressors Impact Carbon Dynamics in Seagrass (Posidonia oceanica) Ecosystems

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Seagrasses are key carbon sinks in the biosphere and, hence, promising nature-based solutions for climate change mitigation. Unfortunately, they are also experiencing major anthropogenic pressures that can lead to seagrass degradation or even result in difficult-to-reverse abrupt shifts (i.e. tipping point responses) to complete cover loss. Although the possibility of tipping point responses in seagrass ecological dynamics has been addressed, the potential cascading effect of tipping points on biogeochemical dynamics, shifting seagrass ecosystems from carbon sinks to carbon sources remains largely unexplored. In this context, we developed a mechanistic model coupling ecological and biogeochemical dynamics to assess the effects of global change stressors on the carbon storage capacity of seagrass ecosystems. After parameterising our model for Mediterranean Posidonia ecosystems, we explored different stress scenarios to identify the processes and the most critical parameters that can cause ecological tipping points leading to changes in biogeochemical dynamics. We then quantified the uncertainty and the magnitude of the cascading effects of abrupt carbon release.Our results highlight that the probability of potential tipping points from increased carbon sequestration to sudden carbon loss can have implications for the role of seagrass ecosystems as nature-based solutions for climate mitigation in the long-run.

POSTER - SS07

Exploring the functional diversity of Posidonia oceanica isopods: traits that matter

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Crustacean isopods constitute a common component of the epifauna associated to Posidonia oceanica. Three main attributes seem crucial in determining the successful response of isopod assemblages to the extreme complexity of P. oceanica systems. These are the great variety of body plans, the choosy generalism towards the wide range of trophic resources and the flexible use of microhabitats. However, traits specific to individual taxa modulate the taxocene role within this general frame. Thus, an effort was made to obtain a high-resolution picture of isopods' functional spectrum based on observational data and published research pertaining to feeding behaviour, body size and morphology and motility/dispersal potential of the species associated to P. oceanica. One result is the recognition of the high diversity of trophic habits among species ranging from micropredation and microdetritivory to phyllophagy and endophagy. Alongside, the diverse morphological types recorded point to a differential use of sub-habitats within the structural context of P. oceanica beds as also related to the displacement abilities shown by several species or stages. Altogether, reconstructing the mosaic formed by the morphological and behavioural traits of individual species is instrumental in appreciating the interactive potential of the isopod taxocene as a whole in P. oceanica systems.

POSTER - SS07

Update on the co-occurrence patterns of angiosperms and charophytes in the northern Baltic Sea

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The low-salinity northern Baltic Sea is inhabited by euryhaline macrophytes of both freshwater and marine origin. Several species, with generally similar biological traits, coexist in this region. The distribution data of 11 soft substrate charophyte and angiosperm species were analyzed with aim to elucidate the co-occurrence patterns among these sympatric macrophyte species and quantify their distribution areas. The benthos biomass dataset, covering the whole extent of the Estonian sea area, with a set of 13 environmental variables was used to test the potential niche separation and demonstrate the co-occurrence patterns between regionally coexisting charophytes and angiosperms. Depth, salinity, and duration of ice were the most influential environmental gradients that discerned the environmental niches of the species. Comparison of the breadths of the environmental niche spaces, occupied by the studied species, showed highly species-specific results. Within the studied species, Zannichellia palustris and Zostera marina had the lowest niche specialization, and Chara connivens had the highest. The most extensive distribution overlap was observed between Chara aspera and Chara canescens, while Zostera marina exhibited the least overlap with the other species. The mean number of co-occurring species was the highest in Chara baltica while Z. marina had the largest share of single-species occurrences.

POSTER - SS07

Seawater microbiome in seagrass meadows: Patterns of pathogen prevalence

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Seagrass meadows mitigate pathogen abundance with ramifications for human health and mariculture, but the mechanisms by which pathogen abundance is reduced remains elusive. Understanding how seagrasses reduce the burden of pathogens will elucidate the opportunity costs of losing seagrass meadows on human health and mariculture and support better accounting of ecosystem services rendered by seagrass meadows. We hypothesise that the a-diversity of bacterial communities is higher in sites with seagrass meadows, and that pathogen abundance is suppressed by biotic resistance. Eight seagrass habitats in Singapore were surveyed to investigate the relationship between bacterial a-diversity and enterococcus abundance. Seagrass richness and density were described, and paired with seawater samples that were collected from a seagrass meadow, and at an adjacent site without seagrass. We use 16s rRNA sequencing and the DADA2 pipeline to characterise bacterial communities, and a GLM to predict enterococcus abundance. We found no significant differences in the a-diversity between sites with and without seagrass, and found no correlation between enterococcus abundance and bacterial a-diversity. However, the abundance of vibrio and tenacibaculum were significantly inversely correlated across all sites. Results suggest that identifying the prevalence of specific traits in a bacterial community could be useful in determining pathogen abundance.

POSTER - SS07

Spatial and temporal models of functional bioconnectivity of fishes with seascape suitability near the mangrove in "Los Petenes" Biosphere Reserve, Campeche, México

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Integral functional bioconnectivity encompasses the relationships between biological communities and their environment, emphasizing landscape structures and their link to fauna. This study aimed to assess this connectivity for solitary and shool fishes with landscape suitability in the Los Petenes Biosphere Reserve (LPBR), Campeche, Mexico. Landscape suitability incorporated cobertures from submerged aquatic vegetation (SAV) habitats like seagrass and macroalgae, mangroves, waterbodies and urban land uses areas. Landscape metrics and depth via remote sensing were considered, as well. This study evaluates the bioconnectivity with fish and food sources from sediment and vegetation leaves. We analyze fish dynamics during seasonal period 2013-2023 using hidroacustics. Results show that solitary fish occupied more space and preferred shallow mangrove landscapes, facing higher movement costs. On the contrary, fish schools occupied less space in SAV habitat and had fewer interactions with mangroves arguably, constrained by depth. Seasonal differences impacted fish density between rainfall and dry season from 2013-2023. Seascapes near seagrass and fish-bearing mangroves exhibited high bioconnectivity potential in the border between wetlands. Ultimately, the RBLP remains well-preserved, displaying robust bioconnectivity in its wetland ecosystems. This information is key as a baseline for proposing local seascape and landscape management, prioritizing wildlife corridors and conservation of biological elements.

POSTER - SS07

Ammonium loss microbiologically mediated by Fe(III) and Mn(IV) reduction along a coastal lagoon system dominated by seagrasses

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In this study, we determined the potential Feammox and Mnammox rates as well as the related abundances of dissimilatory metal-reducing bacteria (Acidomicrobiaceae A6 and Geobacteraceae) in subtidal coastal sediments using the 15N isotope-tracing technique and molecular analyses. We collected sediment samples at four different depths (at 5 cm intervals) across three sectors (inlet, transition, and inner) in a coastal lagoon system dominated by seagrass meadows. The positive relationship between 30N2 production rates and dissimilatory Fe and Mn reduction provided evidence for Feammox's and Mnammox's co-occurrence. Measured rates ranged from 0.04 to 0.71 μg N g−1 day-1, and the process was generally higher in vegetated bottoms than in the adjacent bare sediments. Sediment organic carbon and microbiologically reducible Fe(III) and Mn(IV) showed evident positive relationships with Feammox and Mnammox rates. The abundance of dissimilatory metal-reducing bacteria significantly influenced the spatial variability of the Feammox and Mnammox process. An annual loss of 32.3±3.6 t N was estimated to be associated with these Feammox and Mnammox pathways within the investigated area, accounting for 2.9–4.7% of the gross total import of reactive N from the ocean into the Bahia de San Quintin. This study improves our understanding of the coupling between N and trace metal cycles in coastal environments.

POSTER - SS08

Disentangling the effect of the whole rhizosphere microbiome on seagrass species interactions and performance

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There is emerging evidence that seagrasses, like terrestrial plants, have significant relationships with both their aboveground and belowground microbial communities and that these communities can have key roles in plant health (e.g., stress resilience, growth). However, despite characterisation of seagrass microbial communities across species and under different environmental conditions, we have limited methods available to experimentally test when these microbial communities matter most for seagrasses. Here, we developed a method of disrupting the rhizosphere microbial community of the seagrass Halophila minor using 10% povidone-iodine solution. Our method successfully reduced bacteria abundance in the plant rhizosphere sediment compared to that of untreated plants, whilst not having adverse effects on plant growth or survival. We then applied this method to determine whether the rhizosphere microbial community has a role in interactions between two seagrass species, Halophila minor and Zostera muelleri. This new method therefore can help disentangle key ecological processes such as interspecific interactions and will help expand our understanding of when the rhizosphere microbial community most strongly influences host plant survival (e.g., under increasing environmental stress)

POSTER - SS09

Unravelling Posidonia oceanica sensitivity to desalination brine discharges: the role of shoot apical meristems

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Seagrasses are angiosperms that have undergone a complex set of evolutionary processes to develop a submerged lifestyle in seawater, being salinity adaptation one of the most difficult challenges they have faced. Desalination industry development have raised concerns as their high salinity brines may affect sensitive seagrasses such as the Mediterranean Posidonia oceanica. Most studies on hypersalinity and seagrasses have focused on leaf sampling, although shoot apical meristems (SAMs) could be used as reliable bioindicator organs. To test the role and bioindicator potential of P. oceanica SAMs compared to leaves, 2 different experiments (mesocosm and field) at different brine exposures (+2 to +6 psu). Hydrogen peroxide (H_2O_2), thiobarbituric acid reactive substances (TBARS) and ascorbate were measured to determine oxidative damage and antioxidant defences, and relative expression of genes related to osmotic and oxidative response was also measured. H_2O_2 and TBARS were more responsive to brine influence in SAMs. Overall, relative gene expression was higher in SAMs than in leaves and increased with the influence of brine, indicating a more active metabolic response in this organ. These findings indicated that SAMs might play an essential role in P. oceanica salinity tolerance and have potential as early warning indicator organ for brine stress.

POSTER - SS09

Indoor cultivation of the Arabian Gulf’s seagrass species in controlled aquaponic systems

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An aquaculture system has been designed to support the development of optimum indoor cultivation methodologies of the Arabian Gulf’s seagrass species. The Recirculatory Aquaculture System is based on aquaponic principles with water from large fish tanks feeding into the seagrass raceways. Temperature and salinity are controlled in the fish tanks while lighting, water depth and currents are adjustable in the raceways. Nutrient inputs are monitored and controlled with the density of fish maintained in the fish tanks. Seagrass samples are collected using a core device specifically designed and built for seagrass collection, allowing a clean cut of the rhizomes and its surrounding sediments. Samples from monospecific meadows of Halodule uninervis as well as from mixed meadows with Halophila stipulacea and H. ovalis have been successfully maintained in this aquaculture system since their collection in winter time.The ability to control the water quality, the photoperiod as well as the light spectrum and intensity distributed over the seagrass raceways is critical to define the species growth optimums. As no natural flowering is observed in the Gulf, trials are being developped to pinpoint environmental conditions that would trigger the sexual reproduction of the seagrass species in this indoor cultivation setting.

POSTER - SS09

Could Zostera marina be the new cereal for the future? Previous results and future perspectives

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The Eelgrass Zostera marina has been cultivated experimentally by the Chef of the Sea Gastronomic Research Lab (Aponiente – Ángel León) since 2018 at three different locations in the Bay of Cadiz, SW Spain. Although controlled cultivation was successful already twice, it was impossible to maintain viable populations throughout the years, without regular transplants. After these initial attempts and with the support of the Costa Cruciere Foundation an ambitious project is starting to finally achieve a viable controlled eelgrass population that could be sustained perennially in order to obtain seeds destinated at human consumption, foster its wild populations and look for a new hope restoring abandoned traditional saltpans.

Our project will focus on the environmental restoration of abandoned traditional saltpans and its adaptation to eelgrass controled cultivation by redisigning specific cultivation channels that could ensure optimal ecological conditions for the long-term survival of the plantation. The parameters of this adaptation will be determined by the hits and misses of our previous experience as well as by the knowledge obtained from other projects of restoration of natural seagrass beds. Future perspectives for the controlled cultivation of the “marine cereal” as a food as well as a socioeconomical resource will be discussed.

POSTER - SS12

An ecological method using palm tree for Posidonia oceanica restoration in Kerkennah archipelogo, south Tunisia

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Due to the loss of seagrass habitats, restoration has become an integral part of coastal management. In the Mediterranean, Posidonia oceanica forms a complex social-ecological system. Understanding and conserving Posidonia meadows requires a new approach that integrates the ‘human dimension’. Here we present a citizen science project in the futur MCPA of Kerkennah Archipelago, South Tunisia, which provides new opportunities for citizens, civil society organisations, MCPA managers and volunteers to participate in seagrass restoration alongside scientists. Our project involves collecting historical data on seagrass loss and site selection for Posidonia transplantation with fishermen in the future MCPA of the Kerkennah Archipelago. We then developed an ecological model for transplanting P. oceanica using natural fibres with local artisans, creating a new source of economic income and training volunteers and managers in Posidonia restoration and monitoring. This initiative provides a unique experiential learning opportunity to rehabilitate degraded Posidonia meadows, particularly in threatened areas such as ‘tiger meadows’. We have restored 100m^2 using natural detached cuttings of P. oceanica attached to the ecological model. Our work focuses on helping researchers to integrate scientific and local knowledge, and engaging communities to implement conservation and restoration measures through a participatory approach.

POSTER - SS12

Smart MPA, an ICT tool to facilitate the management and governance of Posidonia oceanica in M arine P rotected A reas

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Marine protected areas are essential tools for the conservation of marine ecosystems.
However, many studies found that their creation has not led to effective protection for their conservation, mainly due to a lack of adequate budget, lack of coordination between management bodies or lack of participation of key actors in the conservation of these marine ecosystems.
Under this context, digitalization can provide useful tools to manage, govern and conserve marine ecosystems in protected areas in a more efficient, effective, and participatory way. Through ICT tools, different sources of information (from historical monitoring, sensors or citizen science) can be integrated and converted into services for the managers and users of marine protected areas, which can then be directed and processed for improving de cision making process in the management and conservation of these marine habitats and species.
In this sense, the research presented is the development of an ICT tool, called Smart MPA, which integrates an analytical framework created to evaluate the management and governance of Posidonia oceanica (through 12 indicators) in the marine natural park of Sierra Helada in Alicante (Spain). The Smart MPA tool with the analytical framework has been tested with the managers of the natural park with the aim of being used to carry out an adaptive management for the long term conservation of Posidonia oceanica.
At the same time, an analysis of perceptions on the usability of the ICT tool and a semi structured interview with the contents of the analytical framework addressed to managers of Sierra Helada was carried out. In conclusion, it can be stated that the combination of the Smart MPA Tool and the management and governance analytical framework are instruments that facilitate the management of Posidonia oceanica in Sierra Helada and increase citizen participation and collaboration between actors in conservation tasks and environmental governance processes. Finally, it should be noted that the management and governance of Posidonia oceanica in the Sierra Helada marine natural park is efficient in general terms, the limiting factor being the lack of adequate funding for the management of Posidonia oceanica.

POSTER - SS12

Bridging dimensions for holistic water quality evaluation: Integrating physiological, ecological, and socio-ecological metrics in the Ebro Delta coastal ecosystems based on the seagrass Cymodocea nodosa

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Coastal environments are vital for human well-being and demand careful management strategies. We evaluated the water quality of two bays in the Ebro Delta using the seagrass Cymodocea nodosa as a bioindicator through the CYMOX index. While suitable for water quality evaluation, this index is biased towards physiological metrics. Our study aimed to address this by incorporating ecosystem-level metrics and a socio-ecological perspective, often overlooked in water quality assessments.
We examined the physiological and ecosystem-level indicators in eight C. nodosa meadows and gathered social perceptions through online questionnaires and in-person interviews. We used Principal Component Analysis to summarise the different metrics in the CYMOX and a redefined more balanced index.
Results revealed a robust connection among physiological, ecological, and social metrics. Physiological metrics responded promptly to disturbances, while ecological indicators proved valuable in linking water quality to ecosystem services delivery, as perceived by society. Strong ties between local communities and ecosystems, rooted in cultural and emotional factors, underscored a profound sense of belonging.
In summary, our study provides a comprehensive understanding of water quality by balancing physiological and ecological metrics and incorporating a socio-ecological perspective, emphasizing the interdependence between human well-being and coastal ecosystems.

POSTER - SS12

Engaging Stakeholders in Co-Design and Implementation of Nature-Based Coastal Protection in Tunisia-A case study from ORIENTATE Project

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Nature-based solutions (NbS) are increasingly recognized as effective alternatives to hard engineering methods for addressing coastal vulnerability. These approaches, characterized as nature-inspired solutions, offer numerous co-benefits and contribute to sustainable development goals. The interdisciplinary nature of NbS suggests that involving various stakeholders through collaborative approaches and dialogues is essential for successful planning, design, and implementation.
To explore the potential of NbS in coastal erosion prevention, ORIENTATE project (Oceanographic and Ecological Data for Nature-based Coastal Protection) was conceived with two primary objectives: (i) Establishing a dynamic co-design laboratory that brings together stakeholders from diverse backgrounds. This collaborative environment aims to collectively brainstorm strategies for ensuring the success and long-term sustainability of NbS. (ii) Establishing a pilot site in a marine ecosystem to assess ideal conditions for seagrass transplantation also evaluates its effectiveness as a nature-based solution for protecting Djerba Island's coast from erosion.
Within this project, we present two key aspects:(i) Stakeholder Perceptions, Preferences, and Perspectives, and (ii) Analyzing the participation process involves examining challenges, opportunities, motivations, and collaborative governance structures
Our findings indicate that a bottom-up, stakeholder-led approach is the most suitable identified method for involving stakeholders. Collaborative planning is crucial for engaging stakeholders and fostering knowledge about NbS among stakeholders involved in the process.

POSTER - SS12

The Sunrise project and the public perception of the seagrass Posidonia oceanica

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Nature-based environmental education is crucial to improve the public awareness towards the benefits generated by protecting biodiversity locally. Seagrasses, from this perspective, support a rich biodiversity and deliver important ecosystem services, but they remain poorly known.

Aims: within the "Sunrise" project, we assessed the public knowledge/perception about the seagrass Posidonia oceanica (L.) and its beach-cast accumulations (called "banquettes"), contributing to spread the notion about the importance of "marine naturalness, biodiversity and ecosystem services" in the context of the Genoa City (Italy, NW Mediterranean).

Methodology: we administered a questionnaire to 250 pupils (aged 11-17) of 14 school classes then showing 'in the field' what we discussed in the classrooms. Elderly people, also, were involved to collect their memories about P. oceanica and banquettes in the past.

Main results: only 14% of pupils recognizes P. oceanica as a "marine plant" and 68% perceives the presence of the banquettes along the beaches as a "noise". Elderly reported a vivid memory of the past presence of P. oceanica and banquettes, without any negative perception as it was 'natural'.
Results stress the urgent need i) to systematically include (marine) ecological concepts in school programmes and ii) to promote inter-generational exchanges about environmental perceptions.

POSTER - SS12

Caribbean island under sargassum landings. Early stakeholder involvement using Group Model Building to identify ecological research questions and nature management options

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Caribbean coastal ecosystems are increasingly exposed to human pressures related to tourism, fisheries or land use. Recently, they face major threats from massive sargassum landings. We developed a flexible, practical procedure to involve stakeholders in an early stage of a five-year ecological research project, (i) to map the Social-Ecological System (SES) in our case study Lac Bay, Bonaire island, Dutch Caribbean, (ii) to identify and prioritize ecological research questions, and (iii) to make an inventory and prioritization of nature management options. The procedure consisted of a desk study, interviews and three stakeholder sessions. We used the Group Model Building (GMB) methodology - a diagnostic participative tool, for identifying drivers, key variables and feedback loops in this SES.
The GMB sessions have clarified that nature and tourism in Lac Bay are tightly connected and made clear that sargassum influx is a newly identified threat to both. The underlying mechanisms of driving feedbacks in the socioeconomic (viz. tourism) as well as the ecological system (viz. seagrass-mangrove) were revealed and shared during these sessions. For Lac Bay we have come up with topical ecological research questions for the conservation of seagrass beds and mangrove forests and practical measures for nature management. Both were used in follow-up scientific research and nature management plans, illustrating the applicability and effectivity of our procedure for early science-stakeholder interaction

POSTER - SS12

Seagrasses as nature-based solution for watershed pollution in Zanzibar, Tanzania: First insights from the SOMWAT project

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Deteriorating water quality poses a global threat to coastal ecosystems, impacting human livelihoods, health, and recreational activities. In Zanzibar, coastal waters near urban areas have consistently shown harmful levels of nutrients and pathogenic bacteria, compromising marine ecosystems, public swimming and mariculture. Seagrass meadows are considered natural filters for watershed pollution, potentially facilitating coastal habitats and associated livelihoods. The SOMWAT project, endorsed by the UN Ocean Decade, investigates the role and local perception of seagrasses in reducing anthropogenic nutrient and pathogen loads, and their use as monitoring tool in South Africa and Tanzania. Crucially, the project assesses their impact on associated and adjacent ecological communities, as well as sponge and seaweed aquaculture farms. Preliminary findings reveal elevated macrofauna (e.g. sea urchins) diversity and abundance in seagrass meadows, as well as pathogenic bacteria (e.g. E. coli) and phosphate concentrations compared to bare sediments along pollution gradients. Importantly, our results indicate the potential benefits of seagrasses for subsistence sponge aquaculture, showcasing elevated growth rates in sponge farms. Algae farms, however, experienced increased urchin predation in the seagrass meadows. Subsistence farming will be further investigated in and around seagrass meadows to provide best farming practices to the local communities.

POSTER - SS12

Formalizing Creole Names for Seagrasses in Seychelles: adding value to a resource

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Historically most Seychellois call both seagrass and seaweeds "gomon" which translates to "slimy and plantlike". Our project objective was to raise awareness and appreciation for critically important Seychelles seagrass ecosystems. But how can people value a resource without a name?

We undertook to formalize Creole names for seagrass in general and each of five life forms that we identified amongst 12 seagrass species by: identifying old Creole names already in use; engaging the public to devise new names for un-named seagrass life forms; and gaining official recognition for old and new seagrass names identified by our project.

To engage the geneal public we used interviews, social media platforms, websites, newspapes, TV and radio interviews. We specifically targeted fishermen, and conducted multiple surveys asking the public to vote for favorite names to create short-lists. Across all categories 876 candidate names were submitted by 141 participants, including 43 fishermen.

The final names were officially approved by Lakademi Kreol and will be incorporated along with their definitions into the next edition of the national Seychellois-Creole Dictionary. The result has been noticeably higher awareness amongst the general public. The Creole names are also proving to be a useful training tool for native Creole speakers.

POSTER - SS12

Community-Led Seagrass Conservation and Blue Carbon Financing

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Seagrass meadows in the Western Indian Ocean (WIO) region are an invaluable resource for food security and subsistence for millions of coastal communities. Unfortunately, seagrass meadows are amongst the most rapidly declining of all global ecosystems, with destructive fishing the primary cause of threat in Africa. This is a case study of establishing a community-led seagrass locally managed marine area (LMMA) in Vanga Bay located in Southcoast, Kenya, focused on seagrass conservation and linked to blue carbon and biodiversity funding. The LMMA is a first of its kind and will protect approximately 225 ha of critically important seagrass beds, co-managed by local Beach Management Units. A benefits sharing structure has been agreed by the community that will ensure proportionate rewards to approximately 2,000 households. The LMMA should bring both environmental and social benefits to the local community. Here, we discuss the main barriers – community perceptions, financial and governance – to establishing community-led blue carbon projects based on seagrass conservation and describe how these barriers have been overcome in this project. Lessons learnt from this process are of major importance in championing for the conservation of seagrasses and can be used in the implementation of similar projects.

POSTER - SS12

Blue carbon stock of tropical seagrass on the northwest coast of Sri Lanka

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Protection and restoration of seagrass ecosystems is a promising contribution to climate change mitigation because of the large quantities of organic carbon stored in their soils. However, uncertainties about carbon stocks hamper development of policies and frameworks, especially within tropical seagrass ecosystems. This study focused on quantify in the blue carbon stocks of the Vedathtaltivu Nature Reserve, Sri Lanka. Three dominant species which included Enhalus acoroides, Cymodocea serrulata, and Halophila minor were sampled for soil organic carbon (SOC) stock to a depth of 1m. In addition, organic carbon in living above- and below- ground biomass were measured within 0.25m2 quadrats.

There was little variation in SOC ($p>0.05$) between species, but the highest average SOC stock was observed for H. minor (130.8 ± 40.5 Mg C ha-1), while C. serrulata showed the lowest values (62.8 ± 29.6 Mg C ha-1). Total average organic carbon in above- and below-ground biomass varied, with E. acoroides yielding the highest (1.8 ± 0.12 Mg C ha−1) and H. minor the lowest values (0.1 ± 0.03 Mg C ha−1).

The results of this study provide important baseline data species conservation and informed decision making at Vedathtaltivu Nature Reserve and in other seagrass meadows across Sri Lanka. Furthermore, these findings are fundamental for developing effective policies and providing essential baseline information for future research.

POSTER - SS13

Very High-Resolution Mapping of Coastal Nature-based Climate Solution: A case study seagrass site from Singapore

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Seagrass meadows are greatly threatened by anthropogenic pressures ranging from pollution to land-use change. It is thus crucial to map existing seagrass ecosystems accurately in order to understand the baseline and monitor changes in seagrass extent as well as inform policymakers and practitioners. The use of UAVs to map these ecosystems allows for more flexibility and the development of very high-resolution maps. In this paper, UAV flights and ground truthing were conducted at Eagle Bay, located in the Southern Islands of Singapore. This site is a coastal sandy shore, a modified shoreline which is a habitat type understudied and poorly represented in current literature. Over May-July 2023, a Fixed Wing WingtraOne Gen II drone with Sony RX1R II RGB Camera, Micasense Rededge-P Multispectral Sensor and a multirotor DJI 3M was flown over the site at low tide. Imagery was processed in Pix4D photogrammetry software to produce georectified orthomosiacs which were then further segmented and classified using Rstudio and ArcGIS. Two main classification methods were compared: Object-based Image Analysis with supervised classification and unsupervised K-means classification. For these methods, a comparison of which image classification algorithm and number of classes is discussed. For assessing the accuracy of the classification of seagrass, we employ two methods: first, comparing the accuracy of seagrass coverage percentage and second looking at cover class. Seagrass coverage percentage estimates take the root mean square error of seagrass coverage between predicted and observed (ground truthing). In contrast, the cover class assessment looks at the agreement of predicted against observed benthic classes. The assessment accuracy is then also reported in terms of seagrass on bare sediment versus in the water. Overall, the paper evaluates the accuracies of the various methodologies to derive a map of the seagrass ecosystem at Eagle Bay. Findings also suggest that Eagle Bay offers sufficient shelter for persistent species, such as Enhalus Acordies to survive, underscoring its possible potential as a restoration site. Ultimately, the poster seeks to offer handles for important considerations in developing high resolution maps of seagrass in a more heterogeneous environmental setting. Given the challenging nature of mapping seagrass ecosystems compared to terrestrial ecosystems, we believe this is a case study of importance to push mapping practice in coastal applications.

POSTER - SS01

Informing the recovery and restoration of tropical seagrasses using a biophysical modelling approach

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Coastal and catchment management and restoration projects have been implemented to mitigate the impacts of human stressors on seagrasses. However, their success rate is highly variable. A comprehensive understanding of seagrass dynamics, especially in tropical regions like the Great Barrier Reef (GBR) in Australia, is critical to inform effective mitigation and management approaches. This study focuses on assessing seagrass dispersal and connectivity over the entire GBR, using a high-resolution biophysical modeling approach. A sensitivity analysis will be performed to refine input parameters of GBR biophysical models, such as the impact of vegetation drag coefficient on tropical seagrass dispersal. This refined model will identify metapopulations and source-sink dynamics over decadal time scales. The outputs of this study will inform the evidence base for seagrass management and restoration in the GBR and tropical ecosystems globally by producing new information on dispersal and connectivity processes that influence natural recovery. This information includes identification of suitable meadows for natural recovery, assess isolated and at-risk areas, and identify key contributors to the seagrass network.

POSTER - SS01

Evaluation of decadal predictability of seagrass growth over southern Taiwan through the Pacific meridional mode

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While the decal predictability is one of the key information demands on marine management and conservation endeavors, the lacking of the long-term persistent observed record and complex climate variability causes the challenge. Seagrass beds are not only important blue carbon sinks but also crucial habitats and feeding grounds for diverse marine organisms. It is essential to document how seagrasses are impacted by climate variability. In this study, the in-situ observed data from 2001 to 2021 is used to investigate the primary decadal environmental control, Pacific meridional mode (PMM), on the growth of seagrass in southern Taiwan. We examined two primary seagrass metrics: aboveground biomass and cover, using a range of environmental and meteorological data sources. Initial findings showcased a prominent correlation between PMM and seagrass growth, where a negative correlation was observed with aboveground biomass, while cover exhibited a weaker positive association. An exploration into regional climate dynamics revealed significant shifts in surface solar radiation, temperature, and rainfall in relation to seagrass metrics. Specifically, increased aboveground biomass corresponded to a reduction in solar radiation in southern Taiwan, paired with rising temperatures and declining rainfall – indicative of a negative PMM-like pattern. This pattern points to the sensitivity of aboveground biomass to large-scale climatic fluctuations across the Pacific basin. Conversely, while seagrass cover also displayed increased solar radiation and similar temperature and rainfall patterns as aboveground biomass, its growth was found to be influenced by a broader set of factors, manifesting a more nonlinear response. In essence, our research underscores the vital role of PMM and regional climate conditions in shaping tropical seagrass growth, offering crucial insights for marine conservation efforts.

POSTER - SS01

Inconsistent change in ecological status of urban seagrass meadows 18 years apart

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Anthropogenic pressures on marine ecosystems are affecting water quality and seafloor integrity. The meadows of the Mediterranean seagrass Posidonia oceanica are considered a priority habitat under the European Directive 92/43/CEE, recognizing its ecological and economic significance, and its role as an indicator of environmental quality. A study in 2005 assessed the ecological status of five P. oceanica meadows facing the waterfront of Genoa city (Ligurian Sea, NW Mediterranean). The same meadows, located within an urban area subjected to multifarious human pressures, were revisited in 2023 and surveyed using the same methods as in 2005. The Conservation Index CI (at 10 m and 20 m depth) and the lower limit depth were adopted as synthetic ecological indices to assess change in the meadows status eighteen years apart. CI showed an overall improvement of the ecological status, especially at 10 m and in the most urbanized areas; this might be the outcome of the recent regulations for anchoring and beach replenishment. On the other hand, the lower limit depth regressed in the most anthropized areas, suggesting an increased level of water turbidity. These inconsistent results highlight the persistent need to manage the challenges faced by P. oceanica meadows in urban settings.

POSTER - SS01

Contrasting epifauna and oxygen dynamics in seagrass and perennial algal mats along the Swedish west coast

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Along the Swedish west coast, large mats of perennial drift algae have replaced seagrass meadows in many areas following extensive losses of eelgrass, and are presently preventing natural seagrass recovery and restoration. However, little is known about this mobile habitat and the functions it may provide to coastal ecosystems. By comparing the epifaunal diversity and oxygen conditions between algal mats and seagrass habitats, our research aims to understand the dynamics of drift algae and elucidate the ecological implications of this ecosystem shift.

Field sampling, population genomics, and five-year remote sensing data reveal that the algal mats are dominated by Furcellaria lumbricalis which forms relatively stable dense expanses exceeding 50 hectares in shallow bays, which are genetically distinct from conspecifics growing on nearby hard substrates.

We collected epifauna from perennial drift algae (F. lumbricalis and Fucus), seagrass (Ruppia maritima and Zostera marina) and bare sediment at two sites over two years, spanning early and late summer. Oxygen loggers were deployed in each habitat. Preliminary results suggest comparable species richness between the drift algae and seagrass, but a two- to three-fold higher abundance in the seagrass. This increase is predominantly attributed to amphipods, which are sensitive to anoxia.

POSTER - SS01

Maximising research impacts and bridging gaps through the Norwegian Blue Forests Network

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We need to bridge the gap between science and policy in order to successfully and sufficiently protect and restore marine habitats.

The Norwegian Blue Forests Network (NBFN) is a collaboration of marine science and policy institutions in Norway. We synthesise and share latest knowledge about blue forests, including seagrass, in order to raise awareness, offer solutions, and inspire ecosystem-based policymaking. We produce everything from synthesis reports and policy briefs to editorials, blogs, videos, and infographics. We also run a series of digital events. Though based in Norway, our reach is global.

The network draws on the expertise of researchers from around the world. We are eager to collaborate with like-minded organisations, and to act as a platform for individuals that wish to share their research and experience with our audience, which consists of policymakers, practitioners, media, and the public, as well as scientists.

The purpose of this poster is to raise awareness about NBFN and to get in touch with researchers who would like to enhance the outreach and impact of their work by collaborating with us, in order to improve seagrass management, conservation, and restoration actions.

POSTER - SS06

Evaluating the ability of seagrass Posidonia oceanica to locally mitigate the effects of ocean acidification: insights from a mesocosms experiment

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Ocean acidification (OA) is a critical issue worldwide. While OA is conventionally seen as harmful to marine calcifying organisms, at a local scale, seagrass ecosystems can induce changes in carbonate chemistry via photosynthesis and respiration cycles that might mitigate OA effects, potentially serving as chemical refugia (i.e., ambients with higher pH and calcium carbonate saturarion state, Ω) for benthic calcifying organisms. We undertook a mesocosms experiment combining acidified vs ambient treatments with seagrass Posidonia oceanica (present vs absent), and two life stages (juvenile and adult) of urchins Paracentrotus lividus and mussels Mytilus galloprovincialis. We investigated whether the seagrass presence would have positive effects on the growth of the two species, and if these effects would be maintained under OA conditions. Our results showed an increase in average pH during the day, in the presence of seagrass, that was higher than the nighttime average pH decrease. In addition, seagrass presence enhanced juvenile mussels' growth. However, we did not observe significant varying trends for sea urchins' growth among treatments. Thus, the effects of OA in ambients with seawater chemistry modulated by the presence of seagrass may be more complex than initially expected and may depend on the calcifying species and life stages.

POSTER - SS06

Status of Posidonia oceanica beds in the marine protected area off ischia, procida and vivara (Gulf of Naples, Italy): historical data and recent monitoring

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The Marine Protected Area of “Regno di Nettuno”, includes the Phlaegrean islands of Ischia, Procida and Vivara (Gulf of Naples, Italy), and was instituted in 2008 mainly due to the occurrence of vast Posidonia oceanica meadows extended for ~20 km 2. These seagrass beds have been intensively studied, since the mid ‘70s, and here we report a general overview and synthesis on their distribution and ecological status based on historical data as well as on a recent monitoring survey. The monitoring project, conducted in November 2021, considered 6 beds distributed around Ischia and Procida submitted to different levels of impacts, evaluating several variables, from shoot density to morphological parameters and lepidochronology by collecting shoots at 15 m depth in all beds, and at 5 m and along the deep, lower limits in some of the meadows.

The results highlight a good status (accoding with the European Marine Strategy) of various meadows, located far from coastal urban settlement (e.g., Cava dell’isola, San Pancrazio), while others seem to suffer from various anthropogenic disturbances (e.g., anchoring damages; Lacco Ameno, Corricella-Procida). A dense flowering events was documented in 3 of the meadows studied. Data of the survey were compared to previous historical knowledge available in each of the site considered.

POSTER - SS06

Effects of seagrass (Zostera marina) on oyster (Crassostrea gigas) calcification in ambient and ocean acidification conditions

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Ocean acidification is a substantial threat to marine calcifiers, including shellfish that serve important roles in ecosystem habitat formation and aquaculture. Recent literature has suggested that marine macrophytes could provide refugia for shellfish by modifying seawater chemistry through photosynthesis, thus mitigating the effects of ocean acidification. Our study aimed to test the hypothesis that the presence of seagrass will result in higher calcification of oysters in both ambient and elevated CO2 seawater conditions. The Pacific oyster Crassostrea gigas was incubated in laboratory chambers in the presence and absence of the seagrass Zostera marina. Incubations were conducted with both ambient and elevated CO2 and ran in both light and dark periods. Rates of calcification for oysters were measured using changes in seawater total alkalinity. We observed a sevenfold and twofold increase in calification rates for the ambient and elevated CO2 treatments respectively when seagrass was present. This suggests that seagrass photosynthetic activity can induce seawater chemistry changes that are beneficial to oyster calcification even under ocean acidification conditions. These findings enhance our understanding of how seagrasses can influence the performance of calcifying organisms in the context of future climate change, with implications for the management of seagrass ecosystems and sustainable aquaculture.

POSTER - SS06

Preliminary assessment of soil organic carbon stocks in seagrass meadows of Kerkennah archipelago, Tunisia: implications for blue carbon storage and climate change mitigation

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Seagrass meadows play a critical role in supporting global efforts to reduce greenhouse gas emissions and build resilience to climate change. Preserving and restoring these meadows is considered a key nature-based solution for climate change mitigation. While Tunisia hosts more than a third of the total extent of Posidonia meadows in the Mediterranean, the lack of data on blue carbon storage in these meadows introduces uncertainty into current estimates reported for the Mediterranean region. Here, we provide the first direct estimate of soil organic carbon stocks and accumulation rates for Posidonia oceanica and Cymodocea nodosa seagrass meadows in the Kerkennah Archipelago (southern Tunisia). Posidonia meadows stored on average 159.93±42.02 MgCorgha-1 at a rate of 0.356±0.007 MgCorgha-1yr-1, whereas Cymodocea meadows stored 127.63±44.77 MgCorgha-1 at a rate of 0.121±0.002 MgCorgha-1yr-1. The similar sediment carbon stocks of both seagrass species could be explained by the establishment of C. nodosa on dead P. oceanica meadows. The up to 2.4-fold higher C sequestration in the seagrass compared to the adjacent bare sand confirms the role of seagrass in enhancing C sequestration. Overall, this study highlights the importance of maintaining and restoring seagrass meadows, particularly in the context of climate change mitigation.

POSTER - SS03

Quantifying the blue carbon potential of Ireland’s seagrass meadows along environmental gradients at local scale

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Seagrass ecosystems provide important ecosystem services such as habitat creation, nutrient cycling, and carbon sequestration, but they are currently under threat globally. Ireland’s seagrass meadows are characterised by Zostera noltii and Z. marina, usually occupying intertidal and subtidal zones, respectively.
This study aims to assess the carbon storage potential of seven subtidal seagrass meadows in western Ireland along environmental gradients, such as sediment type or sedimentation rate, among others. In each location, sediment cores were taken within meadows and from adjacent non-vegetated areas. Cores were then processed and analysed for CHN ratios, C and N isotopes, 210Pb, LOI, and grain size to quantify (i) the organic carbon content, and (ii) carbon sedimentation rates over the last centuries. In parallel, seagrass traits including morphology, productivity, and population descriptors were measured. Collectively, results will provide insights into the current status of seagrass traits, environmental dynamics, and the long-term accumulation of organic carbon.
As part of the BlueC.ie project, this research investigates carbon dynamics in Irish seagrass systems, exploring their potential for climate action and ecosystem services. This pioneer study on Irish seagrasses as carbon sequestration systems will inform management and policy decisions, supporting Ireland’s Climate Action Plan for 2030 targets.

POSTER - SS03

SeagrassTraitDB: the global database of curated seagrass traits

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Trait-based ecology in the study of seagrasses continues to lag behind that of terrestrial plants, despite being an approach that has proven to be key to understanding how plant functional diversity influences their response to environmental factors and their effects on ecosystem properties and services. In the Anthropocene, theoretical and quantitative approaches such as trait-based ecology are increasingly necessary to understand the changes that seagrasses are currently undergoing and will undergo in the future, and how these changes will influence associated biodiversity, ecosystem service provision and conservation actions. As has been demonstrated in terrestrial ecology with the existence of the TRY Plant Trait Database, large databases of trait data are essential to facilitate and drive research in trait-based ecology. SeagrassTraitDB is a global database of curated seagrass traits that has been created to integrate seagrass trait data from around the world in a consistent format, based on datasets contributed by seagrass scientists (https://seagrasses.ccmar.ualg.pt/). We expect SeagrassTraitDB to facilitate high quality data for ecological research studies that use a trait-based approach to understand seagrass responses to environmental change, how their functional structure influences ecosystem functions and services, and how this can be applied to seagrass conservation.

POSTER - SS03

Escarpments within Mediterranean seagrass Posidonia oceanica meadows enhance habitat structural complexity and fish diversity and biomass

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The erosion of millenary deposits of intertwined roots and rhizomes of seagrass Posidonia oceanica results in the formation of 3D structures named escarpments. The natural history of seagrass escarpments including their formation processes and their role as habitat for reef fauna and flora remains poorly understood. This research located and characterized Posidonia oceanica escarpments in Menorca (Balearic Islands) and compared habitat structural complexity and fish assemblages among seagrass escarpments, seagrass meadows, rocky substrates and bare sand to understand the natural history of seagrass escarpments with emphasis on its role as habitat and shelter for typically rocky fish. Fish abundance and biomass were similar between seagrass escarpments and rocky substrates ($P > 0.05$), but significantly lower in seagrass meadows ($P < 0.05$). The large number of caves found along seagrass escarpments provide shelter to fish, including species that typically only inhabit rocky substrates. We found a positive correlation between habitat structural complexity and fish diversity. Seagrass meadows form a rather homogenous habitat within their canopy, but the presence of seagrass escarpments enhances habitat complexity at the seascape level and thereby fish abundance and biomass. This study adds on a new-fangled ecosystem service provided by seagrass meadows, evidencing that further research is needed to understand the ecological importance of escarpments.

POSTER - SS03

Exploring root systems: root traits of halophila ovalis in varying below-ground environments

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Seagrasses have extensive root and rhizome systems that provide anchorage and facilitate nutrient absorption and transport. Rapid changes in below-ground environments due to excessive sedimentation and eutrophication may negatively impact seagrass root system traits and functionality, leading to the decline of seagrasses and potential problems for seagrass restoration. This study aims to explore the relationship between root system traits of the tropical seagrass, Halophila ovalis, with sediment physicochemical properties, sediment nutrients and belowground interspecies interaction at intertidal sites in Johor, Malaysia. Roots collected across a gradient of below-ground environments were analysed using WinRhizo Pro to measure parameters such as root length, root diameter, root volume, specific root length (SRL), root length ratio (RLR) and root mass ratio (RMR). Analysis of sediment and nutrient contents in porewater complemented the root analysis, and regression models were applied to characterise relationships between root system traits and their belowground environments. Knowledge obtained from this study can be applied to predict the responses of seagrass root system traits towards future climate change scenarios or local anthropogenic change. Such findings could also serve as a basis for selecting suitable sites with optimal below-ground conditions for seagrass transplants to survive and succeed in restoration.

POSTER - SS03

Impact of Storm Gloria on carbon storage in Posidonia oceanica meadows

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Global climate change is expected to affect the frequency, intensity and ditribution of temperate storms. These events can strongly impact the carbon sink capacity of temperate seagrass meadows, compromising the permanence of sequestered carbon in the meadow and enhancing the risk of shifting to sources of CO_2 emissions. In January 2020 an extreme and erosive storm (Gloria) hit the Spanish Mediterranean coast impacting severely its seagrass (Posidonia oceanica) meadows. We evaluated the climate-induced change of carbon stocks in P. oceanica meadows using three before-after comparisons: long-term shoot ligula burial/unburial monitoring, long-term sediment accretion measurements on fixed bars, and ^{210}Pb-dated sediment cores. We investigated the potential influence of environmental factors such as storm intensity, meadow depth, and exposure were explored in carbon stocks changes. The findings from our before-after comparisons reveal significant carbon losses due to erosion at numerous locations along the storm's path, accounting for decades of carbon sequestration. Particularly exposed meadows experienced substantial carbon losses. This study highlight the vulnerability of millennial Mediterranean seagrass meadows to the increasing intensity and frequency of extreme temperate storms. The observed carbon losses suggest a potential compromise of the carbon storage capacities within these ecosystems, amplifying the overall impact of climate change.

POSTER - SS03

Summertime dynamics of eelgrass (Zostera marina), from meadow-scale to tissue-scale in the St-Lawrence Estuary

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Zostera marina is a prominent macrophyte in the temperate North Atlantic. Eelgrasses consolidate seabed, attenuate wave energy, and provide a nursery and shelter habitat for many species. They are common coastal ecosystems along the St-Lawrence Estuary and spread north, where intense winters shorten the growing season. In this study, we investigated the dynamics of eelgrass meadow phenology during the ice-free growing season to understand the adaptations enabling their survival over winter. Fieldwork was conducted monthly (June to October), on intertidal eelgrass meadows in Rimouski. Sampling and measurements were carried out in the western part of the meadow under the Rimouski River's influence, the eastern part of the meadow, and a small meadow in Pointe-au-Père disconnected from the Rimouski meadow. Preliminary results showed that the local environmental conditions affected the seasonal dynamics of each meadow. They suggest that light conditions influenced productivity and differed among sites. Overall, biomasses peaked in July, while shoot densities were stable throughout summer. Leaf surface and Fv/Fm values suggested a lower energy investment into the photosynthetic apparatus during spring to benefit shoot growth. The following steps, involving the analysis of photosynthetic pigments, might lead to a better understanding of meadow phenology at a high spatial resolution.

POSTER - SS03

Seagrass meadows contribution to local fisheries: the role of epigeal structural complexity and economic valuation

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Seagrass meadows support local fisheries worldwide. Their leaves offer refuge and nourish (directly or indirectly) for multitude of fish species of commercial interest (FSoCI). Yet, while this function has been widely described, less attention has been paid to identifying the traits that favor it.

Here we studied the contribution of an intermediate-sized seagrass species to local fisheries, the role of its epigeal structural-complexity in mediating this function, and the economic valuation of such contribution. Two replicated meadow structural-complexity levels (high-HC, low-LC) were assessed in natural meadows (Canary Islands). FSoCI abundance was determined from visual census transects. The economic valuation was estimated using production values estimations and standard local market prices for each species.

We registered a total of 17 FSoCI. Fish abundance in HC meadows significantly exceeded that of LC ones. Biomass of FSoCI was more than 700-fold greater in HC than LC meadows.The economic value regarding this function was more than 100-fold greater in HC than LC meadows, peaking up to 2777 €·ha-1 in the highest structurally-complex meadow. Our results confirm the contribution of the studied seagrass species to local fisheries, that its epigeal structural-complexity mediate this function, and that the economic valuation of this contribution is considerable.

POSTER - SS03

Comprehensive Assessment of Seagrass Ecosystems along the Saudi Arabian Coast of the Red Sea: Implications for Conservation and Management

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The study focuses on the underexplored seagrass ecosystems along the Saudi Arabian coast of the Red Sea, aiming to address the significant knowledge gaps in species composition, distribution, and ecology, particularly in the face of increasing anthropogenic pressures. The primary objectives include conducting a comprehensive survey of over 200 sites, spanning latitudes 18°N to 28°N, utilizing the SeagrassWatch 'Fixed Point Site' methodology. The study also seeks to understand the potential impact of the 2023 heatwave, as recorded by NOAA, on the seagrass distribution.

Following the SeagrassWatch methodology, surveys were conducted in both subtidal and intertidal environments using SCUBA, snorkeling, and on-foot methods. Visual assessments determined survey suitability, and GPS points were recorded for each site, employing weighted floats or snorkelers as needed.

Halophila stipulacea emerged as the predominant species in the Farasan Bank bioregion, while Halophila decipiens and Halophila ovalis exhibited the highest percentage cover in the Farasan Island bioregion. These findings underscore the urgency of continuous monitoring, and the implementation of effective management and conservation plans for the vulnerable Red Sea coastal reef ecosystems in the face of escalating anthropogenic threats.

POSTER - SS03

Reference models for the ecological evaluation of Posidonia oceanica meadows along the spanish mediterranean coastal waters

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Posidonia oceanica meadows are recognised as a key habitat in the conservation and management of Mediterranean coastal areas due to their biological and ecological importance. Structural descriptors of P. oceanica meadows (i.e. shoot density and meadow cover) are widely used as indicators of their ecological status despite unavailability of suitable reference values. Therefore, a proper assessment of these descriptors in undisturbed meadows across large areas and biogeographic regions is needed for the correct assessment of this valuable habitat. The aim of this work was (i) to gather comprehensive data on shoot density and meadow cover of pristine P. oceanica meadows, and (ii) to develop structural reference models of P. oceanica meadows. Exhaustive sampling was performed by divers covering the entire geographic and depth distribution of the habitat along the Spanish Mediterranean coast. Meadows were grouped into environmental units and independent models of shoot density and meadow cover were developed for each unit. The models resulting from this study constitute an essential tool for the rapid and accurate assessment of the ecological status of Spanish P. oceanica meadows.

POSTER - SS03

Eelgrass (Zostera marina L.) potential as a natural biofilter for oyster aquaculture

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Oyster farming often overlaps with eelgrass (Zostera marina) meadows in estuaries and coastal lagoons along the North American Pacific coast. We used benthic chambers and labeled 15N to measure in situ leaf ammonium uptake rates and internal N recycling of eelgrass shoots growing near oyster farming long-lines in a coastal lagoon located in Baja California, Mexico. We compared these N uptake/retention capacities with reference shoots not influenced by oyster aquaculture. Shoot productivity was also compared between sites. Shoots at the oyster site exhibited higher ammonium uptake rates (33.1 mmol N m–2 day–1) compared to those not exposed to oyster cultures (25.6 mmol N m–2 day–1). Similarly, photosynthesis and growth were greater in shoots at the oyster site. Moreover, these shoots were more efficient in re-utilizing internal nitrogen for the growth of new leaf tissues or for translocating it to belowground tissues. Our results showed that even a small portion of eelgrass beds can absorb all the ammonium excreted by the oysters (5.2 × 106 mmol N day–1). This demonstrates the potential of eelgrass to act as a natural biofilter for ammonium in oyster aquaculture.

POSTER - SS03

Changes in seagrass distribution and carbon contents in seagrass and sediment in Hiroshima Bay

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Seagrass bed is important as a blue carbon ecosystem that absorbs carbon dioxide. However, the distribution of seagrass has been decreasing worldwide for various reasons. Therefore, it is important to observe the distribution of seagrass over the long term. It is also important to analyze changes in the amount of carbon in seagrass and sediment. In this study, we mesured changes in the distribution of seagrass beds in Hiroshima Bay using UAV, and also tracked changes in the carbon content of Zostera marina and sediment.
Although there were seasonal changes in the carbon content in Zostera marina and sediment, there were almost no annual changes. On the other hand, there were no major changes in the distribution of eelgrass at the outer edge, but bare area was expanding. As a result, the carbon content captured in seagrass beds was decreasing.

POSTER - SS03

Unveiling the carbon stock potential of uk seagrass meadows

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Seagrass meadows, highly productive ecosystems, are pivotal in providing global ecosystem benefits, including carbon sequestration - a crucial factor in mitigating climate change. In the face of escalating global temperatures and legislative pressures on businesses to reduce emissions, studies examining the significance of seagrass ecosystems' role as carbon sinks become imperative. While global estimates of seagrass carbon stocks exist, research on UK meadows is scarce. This study addresses this gap by focusing on the carbon stock analysis of North Wales's largest intertidal seagrass meadow. By examining seagrass and sediment samples from this meadow, and adjacent sample points, for carbon content and particle size, our research establishes that UK seagrass meadows are significant carbon stocks. The findings underscore the potential of UK seagrass meadows as valuable nature-based solution assets for businesses seeking to offset emissions. The study highlights that the decline of UK seagrass could have severe socio-economic consequences. The results advocate for the incorporation of UK seagrass into climate change mitigation strategies, emphasizing their role in offsetting emissions and preserving vital ecosystem services. The efforts of this study prove the significance of local research in contributing to the broader understanding of seagrass ecosystems and their potential in climate change mitigation.

POSTER - SS03

Expansion of temperate intertidal seagrass meadows without intervention: what are the blue carbon ramifications?

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Intertidal seagrass is recovering across many parts of Europe, often without human intervention, including southwest England. Since 2015, we have documented colonisation of bare intertidal mudflat by the seagrass Zostera marina and establishment of two annually stable meadows (25 ha total) in Tamar Estuary locations with no historic records of seagrass.
We examined spatiotemporal variability in organic carbon (OC) stocks of these newly-established beds, pre-existing Nanozostera noltei meadows and unvegetated mudflats. Between 2021 and 2023, 70 cores (50 cm depth) were collected across the habitats, and the OC profile of each core (5 cm intervals) was examined using a CHN analyser.
OC stocks in the top 50 cm were higher in newly-established Z. marina meadows (Meadow1: 69.28 ± 5.32 MgCha-1; Meadow2: 74.63 ± 7.65 MgCha-1) than an older pre-existing Z. noltei meadow (53.46 ± 4.03 MgCha-1), but lower than adjacent unvegetated mudflats (76.83 ± 5.51 MgCha-1). We recorded significant seasonal variation in carbon stocks between sampled meadows.
These findings show that, under favourable conditions, intertidal seagrass can successfully expand into unvegetated sediments without direct intervention, contributing to local OC storage. However, wider patterns and drivers of OC storage in temperate seagrass meadows and unvegetated mudflats require further investigation.

POSTER - SS03

Where the Seagrass Grows: A Study of Key Drivers for Southeast Asian Seagrass Distribution

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Seagrass is highly dynamic, with distributional extent that changes with shifts in its surrounding environmental conditions making it hard to quantify the variability and extent of its distribution. Across Southeast Asia, the extent of seagrass distribution is still largely underestimated. Coupled with increasing pressure from both natural and anthropogenic causes, the vulnerability of the seagrass ecosystem has become more prominent with their accelerated decline. This study made use of existing datasets from the occurrences of seagrass species and the environmental gradients in which it occurs. Generalized additive models (GAMs) were used to identify the main influencing variable in driving the species distribution of 2 seagrass types across Southeast Asia. Comparing the requirements of larger climax species with smaller colonizing species in how the seagrass are characterized by their ecological constraints from the extent of light availability, water quality, seasonal influence, and hydrological flow of the water along the coastline. This paints a clear depiction of what tropical seagrass species prioritize across the coastal waters of Southeast Asia and how it shapes their distribution thus, aids in informing future conservation and restoration efforts and decision makings.

POSTER - SS03

The seagrass Zostera marina takes a deep breath when exposed to a heat wave

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Elevated ocean temperatures from global warming threaten seagrass populations in coastal waters worldwide, particularly in the Baltic Sea, where frequent summer heat waves contribute to observed seagrass die-offs. One neglected source of indirect warming effects is the increased draw-down of oxygen as a combination of enhanced metabolism and reduced O2-availability in sediments. We hypothesized that aerenchyma, the morphological adaptation of many seagrasses to secure oxygenated below-ground structure, expand upon warming stress. Leaf samples were collected in $2m^3$ tanks of the Kiel Outdoor Benthocosms, which simulate summer heat waves under ambient conditions and heat treatments above ambient temperature in the Kiel Fjord, with maximum temperatures of 28°C. We examined aerenchyma parameters that are crucial for gas exchange between leaves and rhizomes using 200x magnification and staining with Astra and Toluidine blue. We found a significant enlargement of aerenchyma surface (and volume) under heat stress, particularly in those plants that revealed disintegrating meristems, indicating proceeding mortality. In plants collected in 2023, additional histological samples from juvenile and adult plants are currently analyzed, focusing on parameters including leaf width, thickness, epidermal width, and surface area of vascular bundles. Collectively our findings point to an additional, easily examinable parameter of heat stress in seagrasses.

POSTER - SS10

Sentinel-2 and Unmanned Aerial Vehicles (UAVs) for mapping seagrass habitats in Southern Mozambique

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The lack of detailed information on seagrass mapping, hinders our ability to protect and manage them in the face of climate change and anthropogenic impacts. This study, integrated data from satellite imagery from Sentinel- 2 and Unmanned Aerial Vehicles (UAV) using machine-learning to provide a consistent classification approach for monitoring seagrass in southern Mozambique. Sentinel- 2 imagery was used to map changes in seagrass in mesoscale in Maputo Bay. Microscale mapping was performed using UAV systems to map seagrass at species level and biomass. Out of the three algorithms tested (SVM, RTC and MLC), all of them were capable of detecting seagrass with high producer accuracy and Kappa coefficient. SVM obtained the best score in both Sentinel-2 and UAV imagery. Overall, the area of seagrasses in Maputo Bay decreased by 33% between 1991 and 2023, with a decreasing trend of 0.48 km 2/yr. Oceana serrulata and Zostera capensis were mapped from the UAV imagery. The biomasses of O. serrulata and Z. capensis were 315 g DW.m-2 and 213 g DW.m-2 respectively. The results of this study will guide implementation of combined satellite and UAV imagery technologies in seagrass monitoring.

POSTER - SS10

Mapping Stuckenia pectinata distribution in Lagoonal Ecosystems: Assessing Seasonal Trends, Abiotic Correlations, and Spatial Patterns

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Sentinel-2 data, which are available with a frequent revisit time (<5 days) and a high spatial resolution (10m pixel size) can be used to map grassbeds at the surface or slightly below the surface of permanent lagoons, hence enabling the characterization of its seasonal dynamics, which was not possible with previous remote-sensing tools. We have proved the feasibility of such a method in the natural reserve of the Bagnas (Herault, France) where Stuckenia pectinata coverage can be tracked thanks to Sentinel-2 images, machine learning methods and field work. Inter-annual dynamics (seasonal growth and senescence) as well as time series from January 2017 to December 2022 are mapped at 10m resolution. Correlations of these time series with abiotic parameters such as temperature, salinity, and water depth are shown to be significant even during recent very hot summers. The study also allows us to extract spatial patterns for preferential occupancy of the grassbeds over each year. Such data will gain to be understood more deeply by taking into account growth, death and colonisation processes, and will be discussed accordingly

POSTER - SS10

Transdisciplinary seagrass mapping towards place-based restoration planning in Sanday, Orkney, Scotland

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Conservation and restoration are priorities to sustain seagrasses' various critical functions within socio-ecological systems (SES). Socio-cultural knowledge supports optimal, just, and equitable restoration design, but remains a 'missing layer' in marine spatial planning (MSP). The 'missing layer' of human activities and values at-sea, alongside place-based knowledge, helps identify socially and ecologically important habitats, places, and human-ocean connections. To bridge this gap, we applied a transdisciplinary approach integrating remote sensing and participatory mapping to understand 'space' and 'place' of seagrass extent, maritime activities, and coastal values in Sanday, Orkney, Scotland, generating restoration priority sites. Coupling participatory mapping and drone surveys, we mapped seagrass (Zostera marina) distribution, human activities, and place values, using place-based knowledge to inform restoration planning. Local ecological knowledge helped prioritise in-situ surveys and revealed historical meadows beyond geotechnologies' ability, co-producing Sanday's first scientific seagrass records. We found two meadows and highlighted activities (notably shellfisheries) and place values (humanistic and scientific) corresponding spatially with seagrass. Enriched SES understanding, capturing space and place, can inform equitable restoration planning and meaningfully embed local perspectives. Our approach enabled the integration of diverse worldviews and filled the missing layer, enabling a shift towards participatory, MSP-compatible seagrass knowledge production in a restoration planning context.

POSTER - SS10

Rapid And Broad Area Detection, Classification and Localization of Seagrasses in Very Shallow Waters Using a Phase-Measuring Sidescan Sonar

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A phase-measuring sidescan sonar (PMSS) has been used in very shallow waters (0-5 m) to map many types of submerged aquatic vegetation (SAV). These sonars are designed and optimized for nearshore water depths thus the operating frequencies are high, typically ranging from 400-1800 kHz. They are mounted onto a vessel of opportunity, rather than towed, as they also collect co-located, three-dimensional swath bathymetry. This yields high-resolution (~0.10m) sidescan data with an absolute localization of ~0.30m and bathymetric data of similar resolution and localization. Due to the presence of air lacunae in its leaves, eelgrass (Zostera marina) has a distinct acoustic signature and as such can be differentiated from other types of SAV in sidescan sonar data. The combined sidescan and bathymetric datasets are ideal for detecting (presence/absence) and quantitatively classifying SAV coverage, spatial heterogeneity, canopy height and for a first approximation of above ground biomass in surveyed areas, which can be mapped at a rate of 1km2 for every 3-4 survey hours in shallow waters. These instruments are designed for rapid and broad area mapping in shallow waters and are ideal for the detection, classifcation, and localization of seagrasses in coastal waters.

POSTER - SS10

Multi- and hyperspectral classification of intertidal vegetation using a spectral library for coastal biodiversity remote sensing

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Monitoring coastal biodiversity is critical. Coastal areas are exposed to many pressures owing to increased population density. Traditional monitoring methods do not provide datasets with full coverage in a timely manner, and the use of remote sensing (RS) is becoming more common. Remote sensing of important habitats, such as seagrass beds, is well documented. However, the ability for multispectral RS to distinguish between classes of vegetation with similar pigment composition, such as seagrass and green algae, has proved difficult, thus challenging large-scale mapping. A machine learning approach was used to differentiate between soft-bottom intertidal vegetation classes, comparing 6 different multi- and hyperspectral remote and in situ sensors. For the library of 366 spectra, collected across Northern Europe, high accuracy (>80%) was found across all spectral resolutions. While a higher spectral resolution resulted in higher accuracy, there was no discernible increase in accuracy above 10 spectral bands. This work highlights the ability of multispectral RS to discriminate intertidal vegetation types, while also showing the most important wavelengths, giving spectral recommendations for future satellite missions. The ability for multispectral RS to aid in accurate and rapid intertidal vegetation classification could be a significant contribution for future sustainable and effective ecosystem management.

POSTER - SS10

Seagrass mapping using 3D sensing and underwater drones: A case study for a giantic Zostera asiatica in eastern Hokkaido, Japan

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Remote sensing using satellites and drones is commonly used for seagrass mapping, but seagrass at deep depths may not be detectable depending on the water transparency. We are developing a new mapping method using underwater drones and high-resolution stereo cameras to visualize deep seagrass meadows that cannot be seen with airborne remote sensing. For the self-positioning, acoustic positioning is common because GPS cannot be used in underwater due to severe electromagnetic wave attenuation. In waters where tall seagrass forms canopy, however, acoustic positioning may not work correctly due to the effect of multipath caused by reflections. We have developed a 3D sensing system based on stereo camera technology that works even in environments with floating particles and image distortion which are unique in underwater, and enabled underwater navigation by using Visual-SLAM. A preliminary survey were conducted in 2023 at Akkeshi Bay, eastern Hokkaido where Zostera asiatica forms high canopy of 2-3 m from the sea floor. We created a recognizer for the seagrass using images from the 3D sensing system, and successfully mapped the seagrass meadow of the survey area.

POSTER - SS10

Mapping the national seagrass extent of Venezuela

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Owing to the threats faced by seagrasses in many parts of the world and the knowledge gaps in seagrass extent globally, there is an urgent need to map the global seagrass extent. Venezuela is no exception.In the Caribbean, Wabnitz et al. (2009) had mapped its regional seagrass extent based on Landsat imagery. However, these are not available or accessible. For Venezuela, the available seagrass data on UNEP-WCMC consists only of point data and the extent maps of two islands, including the Los Rosque Archipelago National Park. Faced with the pressure of the invasive seagrass Halophila stipulacea, it is crucial to know where Venezuela's seagrasses are, before trying to distinguish where the local and invasive seagrasses are found.We use an established multitemporal composite approach on Google Earth Engine and Sentinel-2 imagery to map the Venezuelan seagrasses. Reference data were obtained from a mix of ground truth and historical data, curated by expert knowledge. The reference data were split using a 70:30 ratio to obtain 797 training data points and 329 validation data points. Our initial classification achieved an overall accuracy of 76%, which shows the potential of this approach to produce a national extent of seagrasses for Venezuela.

POSTER - SS10

Estimation of eelgrass above-ground carbon from remote sensing multispectral imagery along the coast of the estuary and Gulf of St. Lawrence

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The intertidal and littoral vegetation present in salt marshes and seagrass beds contributes significantly to the primary production and carbon sequestration in coastal ecosystems. Recently, coastal habitats have been mapped at fine scale (1 m) along the Estuary and Gulf of St. Lawrence (ESGL), but above-ground biomass of vegetation has only been quantified sporadically. While the importance of biomass has been recognized and extensively studied for decades, more research is needed to quantify above-ground carbon and biomass. Our objective is to develop regional algorithms to quantify the above-ground carbon along the EGSL coast. Here we reported in situ data of above-ground biomass, Leaf area index, plant allometry and multispectral imagery of a few eelgrass (Zostera marina L.) in the northern EGSL. Low tide Sentinel-2 images acquired over the Port-Cartier and Kegaska from April to October 2023 were selected and atmospherically corrected. The eelgrass beds were delimited using an object-based algorithm. Different published vegetation indexes were tested to estimate the eelgrass biomass.

POSTER - SS10

Advanced Seagrass Mapping for Restoration and Blue Carbon Assessment: The Plastic-i Initiative

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Plastic-i, an innovative start-up, has pioneered a tool for monitoring seagrass distribution across western Europe, focusing on the UK and France. This tool integrates high-resolution satellite imagery from Sentinel-2 and Planet with advanced deep learning algorithms and satellite derived bathymetry, offering unprecedented insights into the location, condition and temporal evolution of seagrass meadows. To date we have successfully mapped Zostera meadows along the UK and French Atlantic coast, and Posidonia meadows on the French Mediterranean shoreline.
This tool's primary objective is to support seagrass restoration projects by providing marine biologists with precise, up-to-date data. It serves as a scalable model for future global seagrass mapping endeavours. Furthermore, this mapping is a foundational step in developing methodologies to quantify the carbon storage capacity of seagrass meadows worldwide, thereby contributing to the burgeoning blue carbon sector.
Our presentation will highlight the tool's potential in aiding the conservation and management of seagrass ecosystems, addressing key conference themes such as environmental change response, community diversity, and innovative conservation strategies. By harnessing technology for ecological monitoring, Plastic-i aims to drive forward the sustainable management and restoration of vital seagrass habitats.

POSTER - SS10

Estimating change in seagrass meadows: the value of old maps

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Seagrass meadows are key marine ecosystems in coastal areas, but are declining worldwide due to both global and local human-related pressures. Availability of cartographic data series on their distribution and extent can be pivotal to quantify their regression and to assess the effectiveness of conservation efforts for their recovery. In the Ligurian Sea, the Mediterranean endemic seagrass Posidonia oceanica has suffered more than 50% reduction over the past 150 years. Until the 1980s the only available maps reporting its presence were those for fishery, while thematic maps purposely dedicated to illustrate its distribution become available only in the last decades. In this study, we compared historical maps of three P. oceanica meadows since the 1930s on a GIS platform. The meadows of Monterosso and Bergeggi have been included in Marine Protected Areas (MPAs) since 1997 and 2007, respectively, while the meadow of Cogoleto has never been protected. All meadows exhibited a comparable trend, with an initial decline followed by some recovery since the 2000s. Our study showed that old maps can be valuable sources, but caution should be exercised when using quantitative data, which are susceptible to errors; on the contrary, qualitative data, such as presence/absence, can provide reliable information.

POSTER - SS10

Co-development of a regional roadmap for the management, conservation, restoration, and monitoring of coastal wetlands including seagrasses in the Mesoamerican Reef Region

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Coastal wetlands are critical ecosystems that provide a range of ecosystem services that promote biodiversity, support livelihoods, mitigate climate change, and build climate resilience. With an increased recognition of these services, countries throughout the Latin American and Caribbean region are increasing management interventions that protect and restore these important ecosystems. This is being achieved through national policies, which are included within global commitments such as the Global Biodiversity Framework within the Convention on Biological Diversity, and Nationally Determined Contributions within the Paris Climate Agreement. With each country setting ambitious goals to increase and improve coastal wetlands management, it will be critical that the enabling conditions are in place which allow equitable and fair interventions to be implemented that provide benefits to both people and nature.

Building on the success of the Regional Strategy for Mangrove Management, Conservation, Restoration and Monitoring in the Mesoamerican Reef 2020-2025, we propose the co-development of a roadmap to support and facilitate national coastal wetland protection and restoration goals by a range of stakeholders and enabling multi-sector collaborations. This version will include both mangroves and seagrasses to provide a more holistic seascape approach to their management, understanding that these ecosystems are highly connected and inherently transboundary.

POSTER - SS10

How to combine spatial and spectral details: Satellite-based Seagrass Mapping at Sub-Meter Scale

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Seagrass mapping is crucial for understanding, managing, and conserving benthic habitats. Traditional cost and labour-intensive monitoring methods, however, become impractical at large spatial scales. Instead, earth observation has emerged as a cost-effective solution to identify spatial patterns or temporal trends.
The increasing availability of sensors with very high resolution (footprint ≤ 2 m) offer new monitoring possibilities for small-scale habitat structures. For an effective seagrass mapping, however, there is a trade-off between footprint, spectral resolution and signal-to-noise ratio, which is particularly critical in turbid waters.
To compensate for this trade-off, we propose a data fusion approach by combining the detailed spatial information from pan-sharpened Pléiades data (0.5 m footprint, 4 bands) with enhanced spectral information from Sentinel-2 MSI (10-60 m footprint, 12 bands). For this, we employed a convolutional neural network for binary classification of Pléiades data and refined the results with an MSI-based random forest model. We demonstrate our approach along a ~250 km long section of the German Baltic Sea coast. Our approach is able to discern seagrass, bare sand and mixed substrates with high spatial detailing and accuracy, opening up new opportunities for management and conservation of coastal environments

POSTER - SS10

Mapping seagrass blue carbon potential using Seagrass Mapper

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The Northwest Pacific Region Environmental Cooperation Center is designated as the Special Monitoring and Environment Assessment Regional Activity Centre of the Northwest Pacific Action Plan (NOWPAP) of the United Nations Environmental Program. Established in 1994 by China, Japan, Korea, and Russia, NOWPAP aims to ensure the wise use, development and management of the coastal and marine environment so as to obtain the utmost long-term benefits for the human populations of the region, while protecting human health, ecological integrity and the region's sustainability for future generations". Conservation of seagrass habitats is acknowledged as a prioritized issues within the NOWPAP framework.

In collaboration between NOWPAP and the UNESCO IOC Sub-Commission for the Western Pacific (IOC-WESTPAC) Ocean Remote Sensing Project, the Seagrass Mapper was developed as a cloud-based tool for mapping seagrass distribution, utilizing both satellite imagery and field-based information. Using the Seagrass Mapper, case studies to estimate blue carbon potential in seagrass ecosystems were conducted in selected sea areas in China, Japan, Korea, and Russia. The upcoming demonstration of the Seagrass Mapper and the subsequent presentation of case study results will highlight the current status of seagrass ecosystems, importance of blue carbon they hold and effectiveness of its mapping capabilities.

POSTER - SS14

Posidonia oceanica (L.) seedlings from beach-cast fruits to restore small anchoring damage to meadows

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In the Mediterranean Sea, the endemic seagrass Posidonia oceanica suffers mechanical damages from different sources. In some areas heavily frequented by boaters, anchoring has caused frequent impacts under the form of scars of a few m2 in dimention on the seagrass bed.
In 2016 an experimental transplantation project started on the Island of Favignana (Marine Protected Area, Egadi Island, Western Sicily) to assess whether P. oceanica seedlings produced from beach-cast fruits and grown indoor can be used to restore small, mechanical damaged, portion of the seagrass bed.
A total of 18 grids with three different seedling densities (40, 100, 200 seedlings/m2) were deployed at two randomly chosen sites at a depth of 10 m. After 6 years, all grids were removed, and seedling counts and biometrical measurements were carried out. No significative differences were found for densities and sites, in terms of surviving seedlings and growth performance. The highest percentage of surviving seedlings was recorded at the intermediate density (100 seedlings/m2) with a peak of about 80%, while the overall survival rate was about 40%. The best growth performance was recorded in grids with intermediate density that doubled the number of shoots through vegetative growth.

POSTER - SS14

Extreme storms as a chalenge in seagrass restoration

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Seagrass meadows are important habitats on shallow soft bottom providing a number of goods and services to the ecosystem. However, today they are exposed to many pressures and a lot of effort is directed to their protection and restoration. Within EU Horizon 2000 MERCES project (http://www.merces-project.eu) in 2017 we performed a test of a seagrass restoration technique involving Posidonia oceanica transplantation in biodegradable BESE structures, placed above and below ground. Selected site harboured autochthonous Posidonia oceanica meadow on Dugi Otok Island, central Adriatic (Mediterranean Sea), exposed to the south-east. Overall, our experiment persisted for at least 24 months, until the extreme storm in November 2019 wiped it out completely. During stated period, seagrass survival was higher within BESE than controls, but no shoot expansion was observed in this slow-growing species Today, when we aim to return habitats to the good state with restoration actions, more frequent and intense storms as a consequence of climate change could pose an increasing challenge, by annulating ongoing restoration efforts and causing extra damage to the existing natural seagrass habitats. This in turn may perpetuate the need for restoration actions which adopt more resistent techniques and use donor shoots uprooted by the extreme storms.

POSTER - SS14

ReSOW – Restoring Seagrass for Ocean Wealth

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ReSOW – Restoring Seagrass for Ocean Wealth, is a multidisciplinary project which intends to apply a holistic, systems-based approach which integrates understanding of environmental functioning with the various priorities of those who use, or benefit from, the coast. The UK Government has recognised the need for nature-based solutions to climate change as part of the UK's target of reaching Net Zero emissions by 2050. Seagrass meadows create a highly efficient and long-term store of carbon in their marine sediments; and providing habitat to a wide range of species enhancing biodiversity; and so their restoration allows them to become a key contributor to these solutions. The final outcome is to produce the 'Coastal Ecosystem Enhancement Decision Support' or CEEDS tool which will help inform stakeholders of the best locations to restore seagrass. My role within ReSOW is to conduct habitat suitability models (HSM) to identify locations suitable for restoration based upon environmental predictors. HSMs are being increasingly used for purposes such as species reintroduction, species management, and restoration projects. More recently these models have been used to forecast the likely responses to future disturbances and climate change, including changes in temperature, ocean acidification and sea level rise. Success of HSM depends upon the data available. Better predictions can be made if existing seagrass presence is known with accurate geo-referenced data for this as well as environmental variables. The inclusion of higher resolution data where available, such as wave height, power from waves etc. can drastically affect model performance and improve outcomes. Case studies show that when fine-scale wave modelled and other hydrodynamic data was used, model outputs were vastly improved with significantly larger areas of suitable habitat conditions identified in some cases when compared to the use of low-resolution wave energy data.

POSTER - SS14

Advancing dwarf eelgrass (Zostera noltii) restoration methods

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Over the course of the twentieth century, dwarf eelgrass (Zostera noltii) has drastically declined in the Dutch Wadden Sea and natural recovery has been limited. Active restoration is therefore required to restore dwarf eelgrass in this area. During a four-year restoration project, we aim to 1) gain insight into the factors driving restoration site suitability and 2) optimize techniques for the local and global upscaling of dwarf eelgrass restoration, using an experimental approach. By comparing different restoration methods (dispenser injection seeding (DIS) and cores) across different locations, we found that method suitability depends on local environmental conditions. In addition, we found that natural seed germination of dwarf eelgrass restoration is relatively low compared to intertidal common eelgrass (Zostera marina). Combined with high seed collection efforts, this challenges the use of seed-based methods to upscale dwarf eelgrass restoration. However, we have developed a novel method to optimize seed germination by exposing seeds to scarification and freshwater, leading up to 17x higher germination rates than untreated seeds. This pre-treatment will allow us to use seeds more efficiently. These preliminary results are promising and contribute to advancing the restoration of one of Europe’s four seagrass species.

POSTER - SS14

Challenges for subtidal eelgrass restoration in the Dutch Wadden Sea

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Extensive subtidal eelgrass (Zostera marina) meadows once covered up to 120-150 km2 of the seafloor of the Dutch Wadden Sea. Besides providing ecosystem services, these meadows also sustained an industry of seagrass farming. However, these meadows disappeared due to the wasting disease and large-scale morphological changes and have never recovered. Due to their ecological importance and European policy, policy makers have determined a conservation target of 10 km2 with >5% cover (subtidal + intertidal). Therefore, active restoration strategies need to be developed to actively restore subtidal eelgrass meadows in the Dutch Wadden Sea. Previous research suggests that while intertidal eelgrass restoration has been successful in the Dutch Wadden Sea, subtidal restoration is lagging behind due to the dynamic and turbid nature of the Wadden Sea. Previous small-scale restoration trials have shown that bottlenecks include finding suitable restoration sites, high current velocities and low light conditions. Building upon this knowledge, we aim to restore subtidal eelgrass in a seascape context to overcome current bottlenecks and to benefit from co-functions that build stability and resilience, when multiple habitats are restored. To understand what is required to restore the extensive Dutch eelgrass meadows we aim to: 1) subject eelgrass in flume experiments simulating the Wadden Sea and test co-restoration of artificial reefs to mitigate flow velocities, 2) testing donor material from different sites and 3) optimising methodologies. This project will provide a unique insight into seascape restoration in a highly dynamic coastal system and provide policy makers with the knowledge as to what is required for successful subtidal seagrass restoration in the Wadden Sea.

POSTER - SS14

Learning from setbacks and successes in seagrass restoration

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Seagrass restoration is increasingly highlighted as a way to respond to global seagrass decline. However, seagrass restoration success is highly variable and low performance appears frequent. Despite this, published information on the factors causing project success and failure is sparse, both within peer-reviewed and grey literature. Acknowledging and sharing failures is crucial for conservation and restoration, yet such information largely remains as expert knowledge with individuals conducting restoration activities. This study seeks to explore how individuals associated with seagrass restoration learn from failure, identify drivers of project success and failure, and highlight lessons learned. Social surveys, in the form of key informant interviews were used to explore experiences from seagrass restoration researchers and practitioners across the globe. Surveys were used to elicit information on projects which have, in particular, not met with the intended goals, or where information remains unpublished. This research reveals how learning from setbacks and successes can inform future restoration and serves as a critical step in bringing information on failures to the forefront of seagrass restoration practice. By initiating conversations about failure in seagrass restoration, we demonstrate how learning from other disciplines can further future restoration endeavours.

POSTER - SS14

Mitigate hydrodynamic in order to restaure Z.noltei using Roseliere device – Small to large scale méthodology

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The Zostera seagrass beds in the Arcachon Bay have experienced a decline of approximately 50% over the past thirty years. Cognat (2019) demonstrated that the hydrodynamic consequences of this regression have resulted in large areas unsuitable for the spontaneous recovery of seagrass beds. As part of the PROSPERE projects (in collaboration with the Marine Natural Park of Arcachon Bay) and REST-COAST (a European H2020 project), the company Seaboost is deploying artificial seagrass beds (called Roselière) to mitigate currents and facilitate the restoration of seagrass beds. The objective of the poster is to present the overall methodology combining these two projects:

1. Assess the hydrodynamic performance of the Roselière device.
2. Assess the spatial variability of seagrass in sediment carbon storage.
3. Optimization of the deployment pattern of Roselières through modeling using Swash.
4. Deployment a one-hectare pilot and implementation of transplantation and seeding.
5. Hydrodynamic, morphodynamic, and biological monitoring.
6. Basin-scale modeling at a detailed level to provide potential restoration scenarios (MARS model).
7. Large-scale and long-term numerical modeling (DEFT) to evaluate ecosystem services (carbon storage, attenuation of erosion and submersion, water quality) induced by a potential future large-scale restoration facilitated by the Roselière device.

POSTER - SS14

Testing seeding method using Zostera noltii seeds, in a recently nourished area of the Romanian Black Sea coast

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To increase the conservation value of seagrass habitat within coastal protection works carried out in the south of the Romanian Black Sea coast, Zostera noltii rehabilitation of numerous hectares is a requirement in the project. To fulfill the requirements, two restoration methods, perfomed for the first time in Romania, are identified: 1) transplantation using cores, 2) seeding by Dispenser Injector Seeding (DIS). As it is known, seed-based restoration is considered suitable for scaling up to hectares, it is desired to investigate whether this technique has potential for seagrass rehabilitation within these coastal protection works. All known Romanian Z. noltii meadows are investigated on seed availability in August 2023. Flowering is observed in one area and approximately 1103 bundles are collected. The seed bundles are left for several weeks in a tank of aerated seawater to fall down. Approximately 1000 seeds are stored at 6˚C in artificial, aerated seawater until planting. The seeds will be planted in an artificially nourished beach cell in Spring 2024, using DIS methods. If this technique is successful, further studies on sustainable seed collection are needed. This approach could provide important information for future seagrass restorations on the Romanian Black Sea coast. The first results will be presented during the conference.

POSTER - SS14

Storm-shoots: a collaborative effort to carry out a pilot study to replant Posidonia oceanica shoots uprooted by storms

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This pilot study was conducted in the Natura 2000 site of l'Albera, where SUBMON has a marine stewardship agreement with the local administration of Llançà and the Government of Catalonia. The initiative consisted of replanting Neptune seagrass shoots with the collaboration of the fishermen's guild and the local community. This action aimed to restore meadow areas previously affected by illegal mooring systems historically installed in the area.

The replanting was done following a non-destructive methodology, using shoots naturally uprooted by storms. Furthermore, the material used to fix the shoots into the seabed was biodegradable, avoiding the generation of marine litter. A total of 236 shoots were replanted, having a survival rate of 74% after a year.

The collaboration of citizens and the fishing sector was crucial: people walking along the beach would recover the uprooted shoots found along their walk and would take them to the fishing harbour, where specific tanks with seawater were installed to preserve the shoots until the replanting actions could happen. Different information talks were organized throughout the project to achieve this collaboration, explaining the role of local citizens and raising awareness of the importance of seagrass meadows.

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Restoration of a Posidonia oceanica meadow through plants harvested from a meadow to be destroyed by harbour extension works

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In the Mediterranean Sea, restoration of marine habitats has mostly focused on the endemic seagrass Posidonia oceanica. Although many transplanting experiments have been performed, large-scale projects are rare and their success is poor. The present work describes a restoration project of a large degraded area in northern Sardinia using plants harvested from a donor meadow to be destroyed due to harbour extension works. Plants were manually uprooted from the harbour area and cuttings (rhizome fragments of about 20 cm with 1-3 shoots) were selected and transplanted within 24 h by environmental engineering techniques. The cuttings were transplanted onto degradable mats of natural coconut nets coupled with a double-twist steel mesh and fixed on the bottom. Overall, 7000 plots with 20 cuttings each were transplanted in three periods: July 2022, October/November 2022 and February/March 2023. One year after the restoration all the plots were in situ, the overall survival rate of cuttings was 58% and the mean number of shoots per plot was 14.8±0.4. Results are comparable to those of previous small-scale projects carried out with the same technique and endorse its suitability.

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Garden Bed Installation for Seagrass Restoration

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In response to the severe seagrass loss (> 75%) in Cockburn Sound, Western Australia, multiple projects occurred to improve water quality and restore the seagrass meadows. Recent research has implicated the sediments and their legacy of pollution as a primary cause of poor growth of local seagrasses. In August 2023, The University of Western Australia (UWA) launched an experimental restoration project to address the impact of sediment contaminants on seagrass survival and growth, while investigating the potential of using dredged material for seagrass restoration. Additionally, the project seeks to evaluate the feasibility of using underwater garden bed in mitigating these challenges. With the help of O2 Marine commercial divers, the team installed twenty garden beds (3450mm diameter each) and deployed approximately 3 ton of sediment obtained from dredging activities outside Cockburn Sound into each structure. The deployment process spanned multiple days, including barge anchoring, sediment bag deployment, and precise positioning by divers. Seagrass sprigs were then transplanted and site checks and ongoing monitoring are conducted by the UWA team. Preliminary results indicate the successful installation of garden beds, which remained intact after six months, despite severe storms. This underscores the resilience and effectiveness of these structures in challenging marine environment, offering promising prospects for seagrass restoration efforts contending with sediment-related challenges.

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“Restoration of Posidonia oceanica meadows through metal stake technique and naturally detached cuttings in the “a sea forest to save the planet” campaign.

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Mediterranean seagrass meadows have experienced a significant regression in recent decades and several restoration actions have been undertaken to ensure their persistence. This study is part of the “A Sea Forest to Save the Planet” campaign, aimend at recovering the priority habitat 1120* Posidonia oceanica beds of the EU Habitats Directive.
Restoration actions were implemented through transplanting P. oceanica cuttings in two Marine Protected Areas in Sardinia (Italy, Western Mediterranean). Several patches of dead matte, probably caused by mechanical impacts of fishing gears or anchoring, were identified within two well-structured meadows. Cuttings were obtained from naturally detached plants collected from nearby areas and manually fixed to the dead matte using metal stakes. Over 300 m2 (12 cuttings per m2) were transplanted for each MPA.
After two years, monitoring indicates a very low loss of transplanting plots and a survival of cuttings of around 80%.
The results are encouraging and indicate the feasibility of this restoration approach even for large-scale projects. This method enabled the restoration of highly fragmented meadow, in a relatively short time without expensive equipment. Moreover, the post-rooting removal of stakes ensures a substrate devoid of unnatural materials, highlighting the sustainability of this technique compared to other.

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Evaluating the effects of auxin application on the transplantation of rhizome fragments of Posidonia oceanica in the marine environment

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Establishing root systems in rhizome fragments of Posidonia oceanica presents a significant challenge for its restoration. Rhizome fragments of this slow-growing seagrass requires robust rooting for successful anchorage and nutrient absorption from the environment. Controlled experiments demonstrated that applying 5 mg/l of the auxins -naphthaleneacetic acid (NAA) and indole-3-butyric acid (IBA) for 24 hours stimulates rooting in P. oceanica cuttings. However, this effect is untested in a marine environment. In this study, rhizome fragments were exposed to varying NAA and IBA concentrations (3, 5, 10, 20 mg/l) for 24 hours before transplanting into a dead matte area in the Bay of Pollensa (Mallorca, Spain). After one year, all fragments survived, but contrary to expectations, no significant differences emerged in the growth and biomass of roots, rhizomes (orthotropic and plagiotropic), and leaves between treated and untreated fragments. This implies that applying auxins on P. oceanica rhizome fragments could not offer an advantage when rooting transplants in the marine environment. Future studies should explore how environmental conditions interact with auxin effects over time and determine whether different hormones, concentrations, or exposure times are necessary to enhance rhizome fragments rooting post-transplantation.

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Sands of Time: Sowing the Future for Upscaling Seed-Based Seagrass Restoration

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Seagrasses have faced significant global decline in the last century prompting the development of numerous restoration attempts and techniques. However, seagrass restoration remains challenging, and success rates are generally low, particularly when conducted on small scales or in unsuitable restoration sites. Seagrass restoration on silty sediments is sometimes preceded by placing a layer of sand (sand-capping) to enhance suitability of the site. Spanning across three years, we will investigate the mechanical, biological, and ecological challenges associated with integrating seagrass seeds into sand nourishments, to develop a technique for large-scale restoration.
In phase 1, the settling behaviour of sediment-seed mixtures were investigated to determine the most suitable installation method for optimal seed distribution within the capped layer. In upcoming phase 2, the impact of the developed sand-capping method will be evaluated regarding the damage, germination, and survival of Zostera marina, Zostera noltii, and Ruppia maritima in a laboratory setting. In the final phase, we will apply the lessons learned in previous phases to strategically ‘lace’ marine top-soil’s with optimal seed densities for restoration. With this research, Van Oord aims to contribute valuable insights to the future of large-scale, seagrass ecosystem restoration and translate scientific findings towards full-scale implementation in marine infrastructure.

POSTER - SS14

Subtidal eelgrass restoration in lake Grevelingen, The Netherlands

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Extensive seagrass (Zostera marina) meadows once covered up to 4600 hectares of the seafloor of Lake Grevelingen, the Netherlands. However, due to human coastline alterations, leading to extreme salinity changes, eelgrass completely disappeared in the 1990s. Due to the closed nature of Lake Grevelingen, no natural recolonization can occur. We are therefore developing a knowledge base for large-scale restoration of subtidal eelgrass in this area using an iterative, experimental approach. Previous research (2017-2021) has shown that reintroduction of eelgrass is arduous. Main challenges include site selection, long-term survival, up scalability of methods and biotic bottlenecks due to major food web alterations. Building upon this knowledge, we are currently (2022-2027) focusing on upscaling restoration attempts to meet policy targets (~5 ha restored) using a combined modeling and experimental field-based approach. Our current aims include 1) finding suitable locations for both survival and expansion, 2) testing methods (cores vs. shoot-based transplant units), and 3) optimizing transplant design by testing scale and density-dependency. First results from a 2022 field experiment, where we tested two transplant scales (4 vs 36 m planted), are promising, showing a 500% increase in shoot densities within 13 months with no detected scale-dependency. Next steps include identification of promising transplant sites based on historical presence and a newly developed habitat suitability map and identification of bottlenecks for long term survival. This project provides unique insights in the challenges met - and how to solve them - when attempting seagrass restoration in highly altered coastal ecosystems.

POSTER - SS14

Optimising Seed-based Seagrass Restoration in Nursery Conditions

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In terrestrial restoration, the use of nurseries has been highly successful and are crucial for providing the material for restoration programs. Similar approaches are now being used for generating material for assisting with seagrass restoration. For the majority of seagrass species, there are still many knowledge gaps that need to be overcome, to enable large-scale nursery cultivation. Determining optimal nursery conditions to maximise seagrass seedling establishment, and subsequent survival in the field, is vital for the success of seagrass restoration programs. My research has focused on optimising nursery conditions to produce robust seedlings that can survive once transplanted into the marine environment. This includes conditioning seedlings during the rearing process to prepare them for conditions in the natural marine environment. Specifically, my research has focused on optimising the intertidal and turbid light conditions of Zostera muelleri seedlings in the nursery to prepare them prior to being transplanted into the field. This will make an important contribution to establishing successful restoration programs for this species in Australia and the knowledge has important implications for similar programs globally.

POSTER - SS14

Seagrass restoration trade-offs: comparing survival from beach-cast salvaged restoration materials to translocated fragments of Posidonia australis

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Restoration of Posidona australis is increasingly needed to combat the species decline in eastern Australia, but is limited by low availability of local donor material. A solution to this consists of salvaging ‘beach-cast’ fragments that naturally wash up from meadows to use in restoration. This method is currently being used in the context of offsetting seagrass damage and medium-scale restoration in Sydney, Australia. Here we quantify the efficacy of using beach-cast fragments for restoration by comparing their survival with fragments translocated from nearby meadows. Both fragment types have been planted into bare sand patches within fragmented Posidonia australis meadows, and had their survival and condition monitored for six months. It is expected that the stress experienced by beach-cast fragments will result in lower survival. For restoration, this means greater effort and resources are needed when using beach-cast fragments compared to fragments translocated from existing meadows. This study is the first to quantify this trade-off, helping to inform restoration planning.

POSTER - SS14

Planning restoration to ensure maximum shoot survival in Zostera marina

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Common eelgrass (Zostera marina) is a globally declining keystone species. Given its importance for the habitat and the ecosystem services provided, its restoration is essential. In our case, when we transplanted individual shoots in the German Baltic Sea, we lost about 38% of them in the first days after planting. To identify thresholds of hydrodynamic forces likely responsible for the shoot loss and avoid them in future restoration plans, we i) carried out an experiment in a wave channel to test the shoot survival rates against the typical German Baltic Sea's hydrodynamic forces during the established restoration timeframe (mid May-mid June); ii) we mapped hydrodynamic forces using linear wave theories and open-access wave parameters for four spatiotemporal scenarios within the restoration timeframe; iii) we employed the experimental results to predict and map the survival rates for the four scenarios; and iv) we compared the scenarios and selected the 2nd week June as the optimal to ensure the highest shoot survival rate. In summary, we recommend the use of open-access products, such as the 10-days wave forecast available in the Copernicus Hub, for time-planning shoot transplants and substantially improve restoration outcomes

POSTER - SS14

The Seagrass Consortium - a unique partnership between scientists, social entrepreneurs, tech firms and government officials to accelerate the scale and impact of seagrass restoration in Europe

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With seagrass restoration methods still in development globally, setting new scientific, training and logistical standards is necessary to create a blueprint for testing and validating large-scale restoration techniques (current restoration practices are confined to hectare-scale projects, these must ambitiously expand to cover kilometers).
Innovation and collaboration can significantly increase the scale of global seagrass restoration. Achieving pre-industrial levels of seagrass coverage necessitates a paradigm shift in our approach, moving from small-scale, localized efforts to extensive, kilometer-scale restorations.
The Seagrass Consortium was founded in 2022 by seagrass and data scientists, government officials and social entrepreneurs to accelerate large-scale seagrass restoration in Europe. The new consortium, which includes the science lead of one of the most successful European restoration programmes to date, has set out a realistic work programme to develop and validate the necessary blueprint and implement enablers that make restoration possible at scale.
Here we introduce the the consortium's approach. During the first phase (2023-2026) restoration methods are being developed, researched and validated for all four native European species at four European sites – Oosterschelde (Netherlands) Bassin d'Arcachon (France), Étang de Berre (France) and in Mallorca (Spain). Our ambition is to scale up the restoration in the second phase from 2027.

POSTER - SS14

Early seed development and seedling survival under different seed-based restoration methods of the seagrass posidonia australis and posidonia sinuosa

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Seagrass seed-based restorations have been developed and implemented in several places worldwide. Nevertheless, a significant loss during the recruitment process has been limiting the success of restoration endeavours. Understanding seagrass early-life transition and seedling survival under different techniques is crucial in developing successful restoration strategies. Here, we aimed to investigate the early seed development of Posidonia australis and Posidonia sinuosa and quantify the variation in their seedling survival and growth under different seed-based restoration methods. We documented the early seed development in a lab-scale observation for two weeks since dehiscence. The effects of differing treatments on seedling survival and growth over eight weeks were determined using a factorial design—2 seagrass species x 3 treatments (broadcast seeding, seed burial and a hessian bag utilisation). The preliminary results showed that both species developed second leaf and adhesive root hairs for anchoring after the first week. Additionally, survival rates of P. australis and P. sinuosa under all treatments after two weeks were 100% and 98%, respectively. Seedlings under seed burial and hessian bag utilisation treatments exhibited faster growth and development than those under broadcast seeding. The findings of this study can assist in developing effective restoration strategies for Australian Posidonia.

2024 World Seagrass Conference &
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Seagrasses in the Anthropocene

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A systematic quick scoping review: the state of knowledge regarding zostera spp. Restoration

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Seagrass meadows are suffering a global decline as a result of local and worldwide anthropogenic pressures. Ecological restoration activities are considered crucial to boost the recovery of ecosystem functioning and services. In the case of Zostera spp. spp. considerable progress has been made since the 70s, being Zostera marina the most studied species of all marine macrophytes including seaweeds and macroalgae. However, the knowledge, methodologies, and techniques to develop large-scale restoration actions are limited in comparison with other terrestrial macrophytes. Overall, the great variety of practices and methodologies used in Zostera spp. restoration provides a wide range of available information on the subject. A rigorous assessment is required to fill the identified knowledge gaps. Here, previous experimental efforts and human-mediated active restoration actions of the genus Zostera have been collated through a literature systematic review. Different factors have been analysed to determine those that allow success in transplantation experiments, and the main constraints limiting the development of seagrass restoration have been identified.
From our world-wide systematic review, we describe general features and best practices for Zostera spp. restoration, to develop a unified protocol according to the type of transplant, location, and specific scenario.

POSTER - SS14

Investigating the potential for seed based restoration with Zostera marina in the German Baltic Sea

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Seagrass restoration through shoot transplantation is a successful, but time-consuming and small-scale technique, requiring professional divers. With the goal of upscaling, reducing costs, enhancing genetic diversity, and greater stakeholder involvement we experimented with seed-based restoration, learning valuable lessons on harvesting, storing, and out planting Z. marina seeds over a three-year period. Bottlenecks arose in the creation of adequate overwintering conditions in the lab and improving germination rates in the field. Germination success and seedling establishment was documented in multi-factorial (temp, salinity) mesocosm experiments, as well as in parallel field experiments. Outplanted seeds were sown in the field at three timepoints and the effect of lugworm bioturbation and seed morphology (3 colours) on germination rates were considered. Grey seeds were found to have the highest germination success of all morphologies, both in the field and lab. All seeds performed best when out planted in late spring (April or March, not February) and lugworm numbers had no significant effect on germination success. In the lab, the highest germination success was found in salinity 19 psu combined with temperature 10°C. An unresolved bottleneck is how to collect sufficient seeds from wild populations (>1 mio) to enable hectare-scale seed-based restoration.

POSTER - SS14

Sowing the Seeds of Tomorrow: Scaling up Seagrass Restoration

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The importance of seagrasses is unequivocal, with seagrass meadows being one of the most widespread ecosystems in the world that provide habitat, nurseries, food, water filtration, coastal protection, and carbon sequestration. In response to local losses, many restoration projects have occurred - and worked - but they have been operating at square metre to hectare-scales. However, with ~110 km2 of seagrass meadows disappearing each year, or ~30 ha per day, we can no longer afford to be working at such scales. Modern technology and innovative restoration methods can enable the global scale-up that is required. Individual pieces of this puzzle have come on leaps and bounds in recent years. The integration of advanced mechanised planting, improved approaches to site selection and automated approaches to seagrass seed collection are some of the options we have at our disposal to transform the narrative of our seagrass meadows from gradual loss to rapid restoration. It is also time for researchers, environmentalists, policymakers, communities and the private sector to unite, and push for a step change in restoration efforts. By aligning their goals, this collaboration should foster innovation and place paramount priority on ocean health. Nothing less than the future of our oceans is at stake.

POSTER - SS14

Enhancing seagrass meadow resilience using seed-based restoration techniques

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Seagrass meadows are rapidly degrading along coastlines worldwide, largely due to anthropogenic activities. Seed-based seagrass restoration can facilitate the recovery of seagrass meadows, enhance resilience to future disturbances, and increase the scale at which meadows can be restored relative to transplantation. Zostera muelleri is a species of interest in seed-based restoration due to its capacity to produce a large number of seeds annually, and reports of extensive losses in aerial extent. We tested three seed dispersal methods including broadcasting (by hand), dispenser injection seeding (DIS), and seed balls using Z. muelleri seeds in a highly fragmented intertidal seagrass meadow in Queensland, Australia. Total seagrass cover, Z. muelleri cover and shoot density, and meadow fragmentation were monitored along transects three- and six-months post-seeding. The results of this experimental trial will highlight the most effective dispersal method for Z. muelleri seeds to assist in meadow recovery at the target site, and will inform the experimental design of a future large-scale seagrass restoration trial that aims to recover 20 hectares of seagrass. Ultimately, identifying the best seed dispersal methods for target seagrass species and restoration sites can help facilitate more successful large-scale seagrass restoration outcomes.

POSTER - SS14

Enabling authorities to grant seagrass restoration activities

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Seagrass restoration, be it voluntarily or as mandatory damage control for human activities, requires steering through authorities. In the federal structure of Germany this involves multiple administrative bodies with some of them having little knowledge of seagrass ecosystems and restoration approaches. To enable decisions that enhance restoration success, we developed a restoration guide based on experiences made during the SeaStore project. The guide covers how to select sites via an online interactive map, the permit application process, how to harvest donor plants in a maximally least harmful manner, a planting method to optimize restoration success, conducting a final validation of the planted meadow, and logging relevant information about the restored area and donor meadow. The guide comprises of a set of short and concise documents targeted to (i) authorities, (ii) citizen scientists (e.g. volunteer SCUBA divers) and (iii) managers planning human activities leading to seagrass disturbance (e.g. underwater construction). These are backed up by in depth online information on the restoration method most suitable for the German Baltic Sea. This presentation will outline the development of the guide's initial version and report on first application examples. Subsequently, the guide will be updated based on scientific progress and practical experiences.

POSTER - SS14

Growth of Posidonia oceanica seeds in mesocosms: ultrastructural analysis of early roots and associated microbial biofilms

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Posidonia oceanica seeds were grown on sterilized sand in a mesocosm filled with sterilized seawater until complete root germination and leaf development. The times of germination of primary roots and formation of adventitious roots were monitored. Here we show the rhizosphere of seedlings. The rhizosphere of seagrasses, including Posidonia oceanica, are known to be metabolically active matrices, accumulating carbohydrates and metabolites from associated microbes. These compounds are used by a wide range of nitrogen-fixing and sulfate-reducing bacteria, which constitute a key group in the rhizospheres of seagrasses. Plants and microorganisms also contribute to producing extracellular polymeric substances (EPS), which play a fundamental role in the growth and adhesion of the microbial community to substrates; furthermore, EPS can be a site of ion accumulation and also a site of mineral formation biomediated by microbes, and consequently could have a role in the mechanisms of root development and fixation on mineral substrates.The main objective of this study is to examine the microbial population and EPS associated with the first roots developed from Posidonia oceanica seeds. The methods are based on electron microscopy (TEM, SEM) and microanalysis techniques, which have proven to be powerful tools for this purpose.

POSTER - SS14

Success story of a seagrass restoration: the importance of appropriate design and stakeholder engagement

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Seagrass meadows have been declining globally due to a range of pressures. To compensate for the decline, seagrass restoration is one of the possible efforts to re-establish ecosystem function and sustain ecosystem services. Amidst seagrass degradation in Indonesia, an effective practice of seagrass restoration has yet to be developed. We assumed that developing a seagrass restoration framework might enhance seagrass restoration success. The framework involves not only seagrass transplantation activity but also stakeholder engagement. We implemented the framework at Pari Island in May 2021, comprising 1) restoration site selection, 2) measuring environmental conditions, 3) transplantation with methods that may increase survival rates, and 4) monitoring activities. Following an engagement session with local stakeholders, we determined restoration sites in the southwest and northwest of Pari Island. Different seagrass transplant methods did not have a significant effect on the success of the restoration. We found that seagrass density fluctuates during the first five months, yet following a two-year restoration period, the density was seven times higher than the initial density. Our study showed that appropriate planning and stakeholder engagement can support seagrass restoration success on Pari Island. Further testing of such an approach may enhance seagrass restoration, aligning with the goals of the Indonesian National Medium-Term Development Plan for 2020–2024.

POSTER - SS14

Seagrass transplantation success after a quarter of century in the Ligurian Sea (NW Mediterranean)

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Seagrass meadows are important coastal ecosystems playing valuable ecological functions. They experienced an alarming decline worldwide, with Posidonia oceanica meadows being particularly affected in the Mediterranean Sea by the increasing anthropogenic pressures along the coastline. Restoration projects have thus been developed to mitigate the impact of human activities and to promote natural recolonization by restoring degraded meadows. In 1996, an experimental transplantation of P. oceanica was successfully carried out in the Ligurian Sea (NW Mediterranean Sea), making it one of the earliest reported cases. The transplanted meadow was mapped and the shoot density was measured in 2019 and in 2023. Despite the high level of anthropogenic pressures in the area, the restored plants survived and the meadow expanded twenty-seven years apart. The good health of this experimental transplant is also supported by the high shoot density. “Historical” restoration interventions are extremely rare in the Mediterranean Sea, monitoring them over time can serve as a valuable benchmark for evaluating the success of future restoration efforts.

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Comparison of adult transplantation techniques for the Mediterranean seagrass Posidonia oceanica

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Considering widespread degradation of seagrass ecosystems and within the context of the UN's Decade on Ecosystem Restoration, there is an increasing interests in seagrass restoration, and many initiatives have been developed worldwide. Nevertheless, appropriate methods for many species have not been tested, obtained or contrasted, but such comparisons are needed to provide the most useful and efficient techniques for interested stakeholders. In the Mediterranean Sea, restoration has focused on Posidonia oceanica, being the transplant of plagiothropic fragments a widely-accepted method. Surprisingly though, while several techniques have been proposed, there is a lack of studies that compare efficiencies and costs of those techniques and that consider context-dependency. Here we provide an in situ comparison of three different transplant techniques, two already accepted and used by the scientific and the NGO communities (bee-waxed-covered iron staples, bamboo sticks) and a third one developed by our team (garden stakes) across two sites in Mallorca, Balearic Islands. When considering transplant success, logistics, and associated costs (environmental, economic), the garden stake technique emerges as the most optimal at both sites. This work highlights the importance of providing useful comparable assessments that consider multiple aspects of seagrass restoration in order to optimize success.

POSTER - SS14

Biodiversity recolonisation following restoration of Zostera marina seagrass meadows in the German Baltic Sea

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Seagrasses are responsible for a wide range of ecosystem functions and services, for example enhancing biodiversity, regulating hydrodynamics, and carbon storage. Global losses have driven a rise in restoration attempts One example is the SeaStore project , which carried out restoration with Zostera marina at three location s in the German Baltic, chosen for their variation in hydrodynamic conditions, sediment type and proximity to a natural meadow. We assess ed colonization rates of in and epifaunal species, comparing the influence of biotic and abiotic site condition s on the success of restoration works. We contrast the changing community composition with healthy reference meadows as well as bare sediment sites , evaluat ing if and when colonization of restored sites reach levels similar to that of a natural meadow. Differences found between sites indicated colonization being highly influenced by biotic conditions, such as the distance from a natural meadow and proximity to other natural habitats (mussel beds, algal mats). Initial plant survival immediately following restoration (varying from 30 86%) as well as original planting density also play a role. Our results confirm a rapid recovery time for Z. marina associated fauna in the German Baltic Sea and highlight the potential positive impacts on biodiversity through restoration in German waters.

POSTER - SS14

When and where: how seascape context and site maturity influences animals in restored seagrass

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Understanding the drivers of how restoration actions benefit animals can inform future projects. Seagrass is often restored to provide habitat for animals. At the same time, these animals play vital roles in maintaining ecosystem persistence, so their presence is critical to restoration success. Multi-habitat restoration and consideration of the seascape could benefit outcomes, but empirical examinations of how these concepts affect animals are scarce. We surveyed animals within 132 sites in Vejle fjord, Denmark that were within natural seagrass, on bare sand, and in restored seagrass transplanted 1, 2, 3, or 4 years ago. Sites also varied in terms of their distance to a nearby restored boulder reef and restored mussel beds. Diversity abruptly changed after 1 year post-restoration, and despite seagrass cover differences, was similar among the older sites. Community metrics were also related to seascape metrics, with sites closer to restored mussel areas harbouring more diverse communities. Effects on abundance were highly species-spefic, with clear influences of nearby restored reefs. We, however, found little difference in the condition of individuals, with Fulton's K, scaled-mass-index, and metabolite concentrations similar across sites. Our findings show that restored seagrass is quickly inhabited and that consideration of seascape connectivity may enhance outcomes.

POSTER - SS14

Posidonia oceanica (L.) Delile restoration habitat in the Marine Protected Area Gaiola Underwather Park

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This work concerns the habitat restoration project of Posidonia oceanica (L.) Delile realized in the Marine Protected Area (MPA) Gaiola Underwater Park (Napoli, Italy), which falls in the Special Area of Conservation, IT8030041 “Gaiola and Nisida Seabeds”. The planting of the cuttings was preceded by preliminary phase of study and mapping of the distribution of dead matte areas along the coast.
Therefore, 3 different sperimental areas for the restoration on dead matte were selected, located at -15, -9 and -4 metres depth.
Only cuttings that had already been dig out were used for the restoration. These cuttings, with orthotropic and plagiotropic rhizomes, were found in the C Zone of the MPA Regno di Nettuno.
For the restoration, two different ground fixing strategies were adopted to study the best grip: bio mats in “R.E.C.S.® - Cocco” (Reinforced Erosion Control System) and metallic pegs, covering 200m2 in total with more than 3000 restored cuttings.
The project is managed by the MPA Gaiola Underwater Park, in collaboration with the International School for Scientific Diving.
It is the first habitat restoration project of Posidonia oceanica in the City of Naples, and it was realized thanks to the contribution of MASAF (1.40 Measure/ FEAMP 2014-2020).

POSTER - SS14

Transplantation of Zostera noltii sods to establish seagrass meadows on newly nourished sediments as part of coastal development works in Romania

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To enhance ecosystem resilience and Natura 2000 habitats, the Romanian government and private sector integrate a strategy to support the recovery of Zostera noltii in the Romanian Black Sea. Coastal development projects aim to establish favourable conditions for Z. noltii over 2.8 ha within the project. A numerical model was developed to include suitable conditions of depth, erosion/sedimentation, and flow/orbital velocities into the design. Post-construction, site suitability was monitored on sediment stability and light penetration from January to May 2023. Subsequently, 468 Z. noltii sods (approximately 3.7 m2) were collected with 10 cm cores from nearby meadows and transplanted into the constructed beachcell in June 2023. Three different planting patterns were incorporated: single sods, clustered sods and spaced clustered sods, exploring the effectiveness of clustering and spacing for stimulation of self-sustaining feedback mechanisms and optimal use of donor material for future upscaling. Drone-imagery from October 2023 revealed the restored seagrass area expanded to approximately 160 m2. Field-monitoring results to demonstrate the effects of winter storm events on different planting patterns, will be presented one year post-transplantation. The project demonstrates the potential for large-scale restoration of socio-economic important habitats during coastal development works, through incorporating requirements and creating suitable abiotic conditions.

POSTER - SS14

The influence of turbulent coherent structures on transport of Amphibolis antarctica seedlings accellerating seagrass restoration efforts

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Seagrasses play a critical role in maintaining the delicate balance of the coastal environment. Seagrass meadows are declining across the globe, making restoration efforts crucial. This study explores a combination of restoration methods to enhance acreage and thus aid in rapid revegetation and settlement of seagrass seedlings
The dispersal ability of Amphibolis antarctica seedlings is highly dependent on the available coastal currents and hydrodynamics. Research concerning hydrodynamics and water flow within seagrass meadows suggest that the structure of the seagrass meadow affects surrounding water flow, with a major variation in flow from the top of the canopy to the substrate. The areas just above the canopy and close to the seabed, where A. antarctica lacks leaves, show the highest rates of water flow. The lowest rates flow rates tended to be within the leafy meadow. This can be linked to the evidence that seedlings are negatively buoyant and it is likely that the increased flow at the base of the meadow aids in dispersal when and where the seedlings are detached.
The study aims to enhance restoration methods by understanding the dispersal strategy of Amphibolis antarctica and its impact on seedling settlement/attachment and detachment in view of local flow rates.

POSTER - SS14

Developing knowledge and tools to upscale european seagrass restoration – insights of Zostera noltii transplantations at the Eastern Scheldt, Netherlands

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To counteract global seagrass losses, active seagrass restoration is currently considered a viable management tool with increasingly better outcomes. However, despite recent advancement, local seagrass restoration remains challenging. Current restoration methods are laborious, influencing upscaling capacity. In this project, we aim to develop the knowledgebase for a more standardized approach to European seagrass restoration using 4 demonstrator sites across Europe. Furthermore, we are training young people in marine conservation through the involvement of the Sea Rangers. We highlight the first steps that have been taken to kickstart restoration of dwarf eelgrass (Zostera noltii) in the highly modified Eastern Scheldt lagoon (NL). Transplanting cores across 13 sites followed by extensive monitoring not only identified current bottlenecks to seagrass survival, but also suitable locations to upscale future restoration attempts. The end goal is to develop a toolkit that links both general knowledge and site-specific restoration practice while building restoration capacity

POSTER - SS14

Investigating perennial & annual eelgrass (Zostera marina L.) in Padilla Bay as potential donor sources for seed-based restoration

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This research explores eelgrass (Zostera marina L.) meadow recovery at Joe Leary in Padilla Bay, Washington. Goals include mapping perennial and annual Z. marina distribution, studying flowering shoot density, seed production variation, and comparing flowering shoot phenology. Field methods, like presence/absence transect and quadrat-based counts, were used during the flowering stage in summer. The study revealed spatial and temporal variations in perennial and annual population distribution, density, and phenology. Annuals shared an intertidal range with perennials but showed differences due to potential stress indicators like proximity to the slough, algal mats, or elevation.

Quadrat-based monitoring found annual shoots higher in the intertidal than the perennial population. Phenology data showed perennial shoots flowering a month earlier. Despite low perennial shoot densities, the study emphasized Joe Leary's potential as a donor site for flowering annuals in seed-based restoration. Caution was advised to avoid introducing non-native species. The research concludes with recommendations for refining delineation methods, understanding eelgrass population dynamics, and optimizing seed collection for resilient restoration amid climate change.

POSTER - SS14

Assessing techniques to improve germination of Zosteraceae species

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Seagrasses are some of the most important coastal marine habitats yet have seen significant global losses to date prompting the development and increased demand for active seagrass restoration. Although a relatively new field of research, seagrass restoration is advancing at a rapid rate with new approaches and tools being developed for different species. However, with ambitious restoration targets set globally, there are still several limitations common to many restoration programs, including the need to source material from donor meadows and the low survival of seeds sowed directly into restoration sites. The emerging practice of cultivating seagrass seedlings in nurseries provides the opportunity to overcome some of these limitations. Nursery based experiments were conducted in Wales, UK and Victoria, Australia investigating seed viability and germination triggers for Zosteraceae species (Zostera marina, Zostera muelleri and Heterozostera nigricaulis). This research sought to investigate how different indicators of seed viability reflect germination success and survival rates, alongside investigating the temporal influence of germination triggers across species on germination success. Here we present the outputs from this research to facilitate the provisioning of nursery cultivate plants, improving seagrass restoration success by maximising germination rates during initial developmental stages.

POSTER - SS14

Assessment of seagrass restoration methods at northern and Southern European coasts

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Over the last decades, seagrass meadows along the European Atlantic coast have experienced a notable reduction in extent. These meadows play a crucial role in climate resilience, making their reintroduction to coastal regions vital for climate change mitigation. In this context, the EU-funded CLIMAREST project focuses on ecosystem restoration and monitoring in Atlantic coastal habitats. Our research includes detailed experimentation on small-scale seagrass meadow restoration in Ireland and Southern Spain, specifically targeting Zostera marina and Nanozostera noltei species. In Ireland, four estuaries were carefully chosen for both providing donor meadows and serving as recipient sites, with stakeholder input playing a key role in site selection. The rate of carbon burial in successfully restored meadows will be also evaluated over the long term. Distinct transplantation and seeding methods are being assessed in donor sites and receiving sites. Notably, ballasted transplants in donor areas are showing higher survival rates than unballasted transplants, over a 4-month observation period. These preliminary results revealed the importance of site selection. Our experience in Southern Spain is also revealing other important constrains when the number of suitable donor meadows is limited related with the lack of genetic information, the presence of alien species, or administrative issues

POSTER - SS14

Understanding the best medium for planting eelgrass seeds

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Seagrasses are increasingly being grown in artificial environments for propagule and seed production to support restoration. Understanding optimal growth conditions is key to increase the success of methods. In this proposed talk, we present data from a number of separate trials examining the use of a range of substrates and additions, such as nutrients, to determine the most effective methods.
Our research so far focuses on optimising germination success, seedling survival, and growth of Zostera marina. Plants grown in initial trials were transplanted into the two most successful substrates with slow-release fertiliser applied. Plant development was monitored over a six-month period. We observed that the addition of fertiliser led to an increase in biomass, plants grown without additional nutrients instead invested in sexual reproduction, producing our first harvest of seeds. We also present evidence of the benefits of using Kettering loam as a substrate.