International Blue Carbon Scientific Working Group
12th Annual Meeting & Nordic Blue Carbon Workshop

September 9th – 13th, 2019
Nordatlantens Brygge, Copenhagen, Denmark

Workshop Summary Report

the
BLUE
CARBON
initiative

Coordinating organizations:

CONSERVATION INTERNATIONAL

IUCN

United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

Workshop partner organizations:

AARHUS UNIVERSITY

Åbo Akaden University

FIU Center for Coastal Oceans Research
FLORIDA INTERNATIONAL UNIVERSITY

UN environment

GRID ARENDAL

SDU University of Southern Denmark

NIVA 60 years
Norwegian Institute for Water Research

Stockholm University

Funding organizations:

the David & Lucile Packard FOUNDATION

THE VELUX FOUNDATIONS
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Coordinating Organizations:
Conservation International
International Union for Conservation of Nature
United Nations Educational, Scientific, and Cultural Organization (UNESCO), Intergovernmental Oceanographic Commission

Workshop Partner Organizations:
Aarhus University
Åbo Akaden University
Florida International University, Center for Coastal Oceans Research
Norwegian Institute for Water Research
Stockholm University
United National Environment Programme and GRID-Arendal
University of Southern Denmark

Funding Organizations:
The David and Lucile Packard Foundation
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Nordic Blue Carbon Workshop Organizing Committee:
Mats Björk, Stockholm University
Christoffer Boström, Åbo Akademi University
Helene Frigstad, Norwegian Institute for Water Research
Marianne Holmer, University of Southern Denmark
Dorte Krause-Jensen, Aarhus University
Steven Lutz, GRID-Arendal

International Blue Carbon Initiative Scientific Working Group Chairs:
Steve Crooks, Silvestrum Climate Associates
Emily Pidgeon, Conservation International

Executive Summary

The Blue Carbon Initiative (BCI) Scientific Working Group held its 12th annual meeting in Copenhagen, Denmark, from September 9-13, 2019. The meeting was co-hosted by the Blue Carbon Initiative Scientific Working Group (BCISWG), the University of Southern Denmark, and the Florida International University, and included 77 participants from 18 countries.

The overarching goals of the IBCSWG are to advance blue carbon (BC) science, particularly as needed to facilitate climate-relevant policy and management, to expand blue carbon research collaboration, and to ensure the integration of blue carbon into international climate change actions. To that end, the meeting in Copenhagen emphasized sharing new research and specifically focused on four major areas: 1.) launching a Nordic Blue Carbon network to address the large opportunity for mitigation and adaptation represented by the region’s large blue carbon areas 2.) discussing the potential of kelp as a blue carbon ecosystem to address recent disagreement in the literature about the potential mitigation benefit of kelp aquaculture 3.) defining information needs for the inclusion of blue carbon in Nationally Determined Contributions (NDCs) under the Paris Agreement; and 4.) refining the knowledge of BC stocks and rates of sequestration through considering the implications of sea level rise, the contributions of other fluxes like methane, and lateral transfer to the coastal ocean, in order to better quantify the expected carbon sequestration and storage of blue carbon systems.

As the meeting took place in the Nordic region, which has huge kelp forests, there was a lot of discussion centered around how and whether to include macroalgae as an additional blue carbon ecosystem with climate mitigation potential. Specifically, the discussion focused on the long-term storage potential of macroalgae, given the lack of a soil carbon pool. Furthermore, the separation of the sources and sinks of the macroalgae complicates the assignment of the stocks, and any related emissions from anthropogenic activities, to individual countries. Finally, a blue carbon ecosystem must be responsive to management, and wild macroalgae may not fit this criterion, though it is possible that farmed kelp may, if the cultivation footprint does not exceed the sequestration. Current research is underway to trace the origins of organic carbon in shelf sediments using eDNA, to quantify the burial of macroalgal organic carbon, and to determine the potential sequestration impact of kelp farming. The group defined a research agenda to follow up on these questions. At least two scientific papers are being drafted based on collaborations at the meeting: first, a review of the information available on Nordic blue carbon ecosystems and a proposal for a scientific and management agenda that can support environmental policy in this area, and second, a paper on the mitigation potential of macroalgae and macroalgal farming in response to the regional interest and scientific controversy about kelp aquaculture’s blue carbon potential. Both papers will be published via an open access peer-review journal in 2020.

Another area that was discussed in detail is how to speed the integration of blue carbon into policy mechanisms governed by the United Nations (UN). For example, as part of their obligations under the Paris Agreement, countries must account for their emissions in a

greenhouse gas inventory and then create a plan of NDCs to global emissions reductions. Blue carbon is underrepresented in both the inventories and NDCs, sometimes because of a lack of awareness of its value and sometimes because there isn't enough country-level data to make it part of the NDC. Besides continuing to promote blue carbon and provide missing data, the group agreed to prioritize work that will allow for estimates of emissions beyond the IPCC Tier One, noting that we might be significantly underestimating the emissions related to the loss of blue carbon ecosystems (BCEs). In addition, BCISWG members presented a draft of a guidance document for countries looking to include blue carbon in their Nationally Determined Contributions, guidance that is adaptable for the country-specific policy priorities and available scientific information. BCISWG members went on to present the Guidance Document at the UN Climate COP 25 in Madrid.

Discussions around the presentations resulted in the identification of additional topics where more analysis or data are needed, and areas of emphasis for future initiative activities. Several speakers noted the need for the blue carbon field, now that it has matured, to avoid inconsistent use of terms and the adoption of in-group language that make it difficult for policymakers and the public to understand. Beyond the communications difficulties, the use of novel terms makes it difficult for managers and policymakers to address blue carbon within the terms of carefully negotiated international agreements. Another area where the BCI might better promote the full value of blue carbon surrounds the role of healthy, vegetated ecosystems in nitrogen capture. National and subnational governments spend significant resources reducing nitrogen inputs from agriculture to protect estuaries and coastal waters, and this means that there is an additional, measurable dollar value of these systems, in some areas, that should be reported. Seagrass researchers also presented new data describing the specific mechanisms of how blue carbon is stored in those systems, raising questions about the relative role of plant versus sediment characteristics. It may be that seagrasses differ from mangroves in that they contribute to carbon sequestration largely through encouraging sedimentation and via their relative recalcitrance to degradation, while mangroves' woody vegetation is itself a significant long-term carbon stock.

In addition to the papers and the NDC Guidance document mentioned above, the meeting resulted in major outcomes that help meet the goals of the Blue Carbon Initiative. A plan for a Nordic Blue Carbon was designed to coordinate regional blue carbon science in order to meet policy needs for integrating the blue carbon ecosystems into climate policy, and the group adopted a six-month plan of activities in order to build on the momentum of the meeting. Looking forward, one of the key tasks for the BCI Scientific Working Group in 2020 is to review the progress of the past nine years and develop a strategic plan to meet the next challenges for the field. The group will hold its 13th annual meeting in fall, 2020 in Mexico to continue those conversations.

Background on the Blue Carbon Initiative

The coastal ecosystems of mangroves, tidal marshes, and seagrass meadows provide numerous benefits and services that are essential for climate change adaptation along coasts globally, including protection from storms and sea level rise, prevention of shoreline erosion, regulation of coastal water quality, provision of habitat for commercially important fisheries and endangered marine species, and food security for many coastal communities. Additionally, these ecosystems sequester and store significant amounts of coastal "blue carbon (BC)" from the atmosphere and ocean, and are now recognized for their role in mitigating climate change.

Despite these benefits and services, coastal blue carbon ecosystems are some of the most threatened ecosystems on Earth, with an estimated 340,000 to 980,000 hectares being destroyed each year. It is estimated that up to 67% of mangroves, at least 35% of tidal marshes, and at least 29% of seagrass meadows have been lost. If these trends continue at current rates, a further 30–40% of tidal marshes and seagrasses, and nearly all unprotected mangroves could be lost in the next 100 years. When degraded or lost, these ecosystems can become significant sources of the greenhouse gas carbon dioxide and the soil carbon collected over millennia cannot be replaced on a climate-relevant timescale.

The Blue Carbon Initiative (BCI) is a global program working to mitigate climate change through the restoration and sustainable use of coastal and marine ecosystems. The BCI brings together governments, research institutions, non-governmental organizations and communities from around the world. The Initiative is coordinated by Conservation International (CI), the International Union for Conservation of Nature (IUCN), and the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific, and Cultural Organization (IOC-UNESCO).

The goals of the BCI are:

- Develop management approaches, financial incentives and policy mechanisms for ensuring the conservation, restoration and sustainable use of coastal blue carbon ecosystems;
- Engage local, national, and international governments in order to promote policies that support coastal blue carbon conservation, management and financing;
- Develop comprehensive methods for assessing blue carbon stocks and emissions;
- Implement projects around the world that demonstrate the feasibility of blue carbon accounting, management and incentive agreements; and
- Support scientific research into the role of coastal blue carbon ecosystems for climate change mitigation.

To achieve these goals, the Blue Carbon Initiative formed Science and Policy working groups in 2011. Members of both working groups routinely collaborate to ensure that qualified science forms the basis of sound policy. The International Blue Carbon Policy Working Group supports efforts to integrate blue carbon in existing international policy frameworks, such as the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD). The International Blue Carbon Scientific Working Group identifies priority research areas, synthesizes current and emerging blue carbon research, and provides the robust scientific basis for coastal carbon conservation, management, and assessment. The Working Group consists of experts in coastal carbon science, carbon assessment, remote sensing, and international climate change policy. The Working Group meets annually in blue carbon-rich countries and collaborates closely with local experts and government officials to identify or expand activities supporting the conservation and restoration of blue carbon ecosystems.

The goals of the Scientific Working Group are to:

- Describe the global relevance of coastal carbon;
- Create internationally applicable standards for quantifying and monitoring coastal carbon;
- Develop internationally acceptable standards for data collection, quality control and archiving;
- Identify and support priority research on carbon dynamics in coastal ecosystems;
- Develop coastal conservation, planning and management guidelines for coastal carbon activities; and
- Support the development of pilot projects for carbon in coastal ecosystems.

Some key contributions of the Blue Carbon Scientific Working Group include a manual for measuring blue carbon titled, “Coastal Blue Carbon: methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrass meadows.” The manual provides managers, scientists and other practitioners in the field with standardized recommendations for carbon measurements and analysis. It has been translated into Chinese, English, French and Spanish, and will soon be available in Bahasa Indonesia. Additionally, the Scientific Working Group co-founded and is supporting the “Coastal Carbon Research Coordination Network,” an effort to build tools and capacity for data-sharing, specifically focused on ecosystem processes and coastal wetland carbon cycling. Members of the BCI have consulted with the UN and national governments to integrate blue carbon science into policy: they have worked with countries on their greenhouse gas inventories; helped to write the Intergovernmental Panel on Climate Change (IPCC) 2013 Wetlands Supplement; lead the IPCC Oceans and Cryosphere report; as well as authoring many other influential reports and guidance documents.

Opening Session
Moderator: James Fourqurean, Florida International University

Marianne Holmer, University of Southern Denmark, welcomed the participants to the region on behalf of the local organizing committee of the Nordic Blue Carbon Workshop:

Marianne Holmer, University of Southern Denmark
Mats Björk, Stockholm University
Christoffer Boström, Åbo Akademi University
Dorte Krause-Jensen, Aarhus University
Helene Frigstad, Norwegian Institute for Water Research
Steven Lutz, GRID-Arendal

Jennifer Howard, Conservation International, introduced the workshop agenda and discussed expected outcomes from the meeting.

Emily Pidgeon, Conservation International, and Steve Crooks, Silvestrum Climate Associates, the co-chairs of the Scientific Working Group of the Blue Carbon Initiative, thanked the sponsors of the meeting, introduced the topic of blue carbon, and reviewed the history of the BCI. The chairs reminded the group of the essential questions that the BCI is working to answer: what is blue carbon; where is it; how can we measure it; is it recognized by international bodies; how do we encourage countries to include it in their policy, particularly NDCs; and how do we address financing of blue carbon ecosystem conservation and restoration.

The introductory session concluded with each person present introducing themselves and their reason for participating.

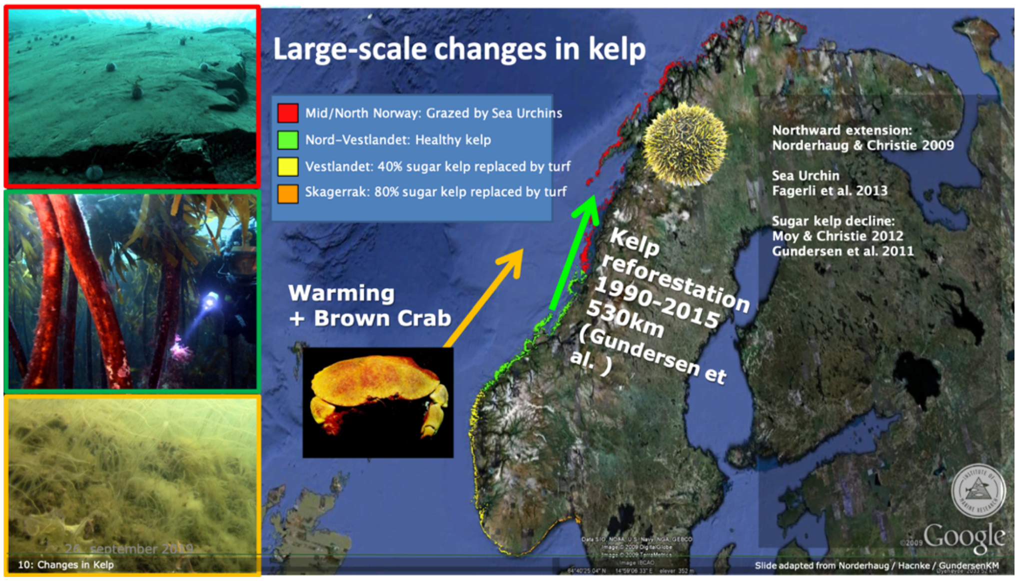
Session 1: Blue Carbon – A Nordic Perspective

Organizers: Christoffer Boström, Åbo Akademi University; Dorte Krause-Jensen, Aarhus University; James Fourqurean, Florida International University
Moderator: James Fourqurean, Florida International University

1.1 Blue forests in Norway – status and knowledge gaps

Dr. Jonas Thormar, Institute of Marine Research

Norway has salt marshes, seagrasses, and vast kelp forests. The research and management of salt marshes in Norway is shared by terrestrial and marine biology agencies, with the primary focus to date on plants and bird habitats. One estimate of the total Norwegian salt marsh area is 200 km^2, however, with a long and complex coastline and other habitats often mistakenly included, the number is very uncertain. Brown seaweeds (Fucoids) are estimated to cover about 178 km^2, based on monitoring and simplistic models, but the uncertainty is high. Rockweed is harvested commercially at a small scale. Brackish seagrass species have not been mapped systematically, but the eelgrass is relatively thoroughly mapped across the Norwegian coast and covers approximately 100 km^2. There is a time-series of eelgrass monitoring that might provide some insight into changes in the seagrass area over the past 90 years. There is one Norwegian blue carbon project in eelgrass meadows, but no sequestration rate estimates yet. The study has found that hydrodynamic exposure does affect carbon sequestration, and that sheltered organic C values are high and comparable to the highest values reported from sites in Denmark. So, the first effort to reduce the variation of blue carbon stock assessments should be to differentiate among exposure levels among sites. Sugar kelp has not been mapped in Norway, but it is registered when it is encountered during other mapping projects, so there is some information to provide a modeled estimate of approximately 2000 km^2. Sugar kelp has declined in the southern part of the country, potentially related to changes in temperature, nutrient runoff, and water clarity. Large kelp forests are mapped at about 1500 km^2, and an update to include the entire country is expected by the end of 2019. Around 2% of the kelp is harvested commercially each year. Norway has experienced large fluctuations in kelp cover. While sea urchins were responsible for eliminating kelp in many areas, with climate change, there has been significant reforestation in northern areas as the temperature affects urchin development and a predator, the brown crab, has been able to extend its range. Some key blue carbon initiatives in Norway include the Norwegian Blue Forests Network and the Nordic Blue Carbon project.



Large-scale changes in kelp

- 🟥 Mid/North Norway: Grazed by Sea Urchins
- 🟩 Nord–Vestlandet: Healthy kelp
- 🟨 Vestlandet: 40% sugar kelp replaced by turf
- 🟧 Skagerrak: 80% sugar kelp replaced by turf

Warming
+ Brown Crab

Kelp reforestation 1990-2015 530km (Gundersen et al.)

Northward extension:
Norderhaug & Christie 2009

Sea Urchin
Fagerli et al. 2013

Sugar kelp decline:
Moy & Christie 2012
Gundersen et al. 2011

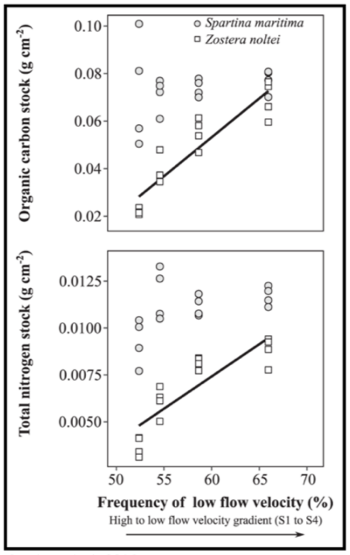
26. september 2019
10: Changes in Kelp

Slide adapted from Norderhaug / Hacnke / GundersenKM

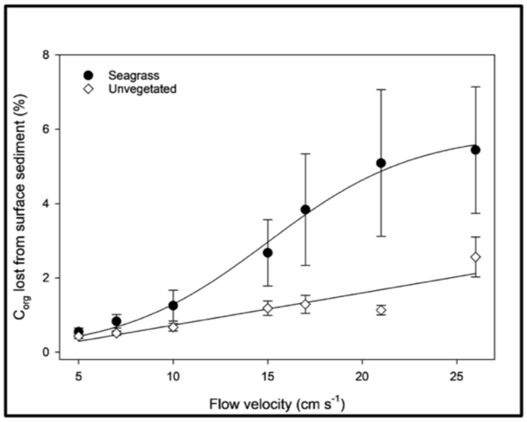
1.2 Blue forests in Sweden – status and knowledge gaps

Dr. Martin Gullström, Stockholm University

Sweden has seagrass, seaweed, and salt marsh (or salt marsh like) ecosystems. Since the coastline is unique in that it has a wide range of salinity values from ~2-31, there is widespread species diversity. Sweden is also unique in that the amount of marine protected waters (7%) is well above the global average (4.8%). In the 1930's, 90% of the seagrasses along the west coast were lost to disease, and so there have been efforts to map the seagrass beds periodically since the 1980's. There is some data on the carbon stocks of Sweden's seagrass meadows, and they show that they are much larger on the west coast than the Baltic Sea. The major drivers of carbon storage among the studied sites are hydrodynamic exposure and sediment hydro-connectivity (grain size, porosity, density). The sites also show a strong seasonal pattern in sediment carbon stocks. However, some significant knowledge gaps remain: carbon stock and accumulation rates for other seagrass species and at larger spatial and temporal scales; comprehensive blue carbon maps; and data on sink-source relationships, including greenhouse gas emissions. There is also a need for the protection of high C sink areas and inclusion in management plans, as well as the adoption of a seascape view of blue carbon ecosystems, linking them to terrestrial and oceanic areas.



Santos et al. 2019



Dahl et al. 2018

1.3 Blue forests in Finland – status and knowledge gaps

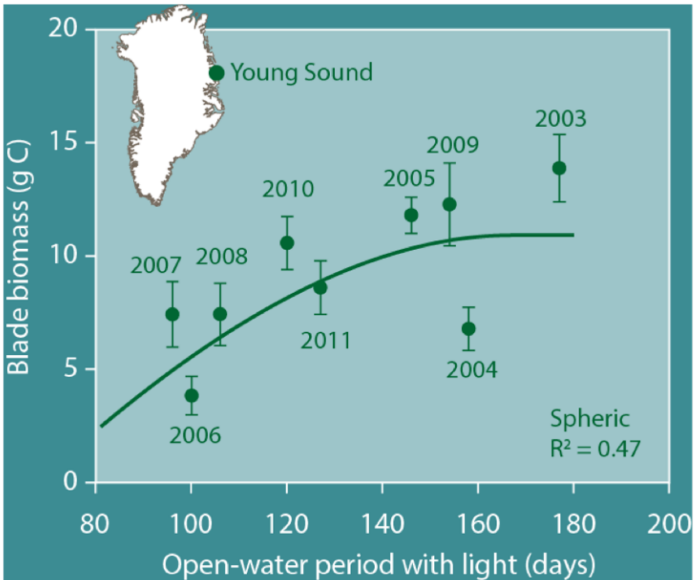
Dr. Christoffer Boström, Åbo Akademi University

Finland has many blue carbon ecosystems, including seagrass meadows, bladder wrack belts, reed belts, and mixed submerged aquatic vegetation (SAV), as well as large expanses of aquatic habitats that could store carbon, like shallow bays and coastal lagoons. Coarse mapping of the Finland coast suggests that up to 17,236 km^2 could be blue carbon ecosystem habitats, but some research suggests that seagrass habitats are being degraded. Coarse estimates of blue carbon ecosystem extent are: eelgrass may cover 6-30 km^2; bladder wrack ~239 km^2; reed belts ~330 km^2; coastal lagoons 709 km^2; mixed SAV 134 km^2, and shallow bays 867 km^2. This could mean as much as 2,292 km^2 are covered in blue carbon ecosystems, with a presently unknown total carbon stock. However, much more information is needed before blue carbon can be counted in a national inventory. Key knowledge gaps include: verifying area estimates and accounting for overlap; measurement of sediment C stocks and accumulation rates; improved modeling of POC/PON transport; and information about the area, biomass, and fate of drifting algal mats.

1.4 Blue forests in Denmark and Greenland – status and knowledge gaps

Dr. Dorte Krause-Jensen, Aarhus University

Denmark is a “hot spot” for eelgrass, due to its gently sloping, sandy coastlines in protected settings. The exact distribution area is not known, but it is estimated to constitute around 1,350 km^2, about 20% of the estimated historical extent of 6,700 km^2. With the current water clarity, the potential eelgrass area is estimated at about 2,200 km^2. Stocks of carbon, nitrogen, and phosphorus have been measured in the Danish eelgrass sediments, with the largest stocks found in protected fjords. In Greenland, eelgrass is documented only in inner, protected fjord areas of the Nuuk fjord system. There, the biomass reaches similar levels as further south, but the rate of leaf formation is much slower due to the lower temperature. Less is known about salt marshes in the two countries. Denmark has approximately 37,700 ha of salt marsh, but Greenland salt marshes have not been mapped. There have also been some site-specific studies of macroalgae in the two countries, but there is limited information on the extent of the macroalgal areas. However, with a 44,000 km coastline, Greenland has a huge macroalgal area. Notably, studies in Greenland have found that areas with longer open water periods have deeper, more productive kelp forests than areas with shorter open water periods. Arctic warming and associated melting of sea ice is, therefore, expected to lead to an expansion of the kelp forests around Greenland. Hence, it is important to ascertain whether C from the macroalgal forests is present in Greenland's sediments, whether there are latitudinal or temporal trends, and the total C-sequestration contributed by Greenland's macroalgae. More broadly in Greenland and Denmark, the areas of blue carbon habitats and their associated C-stocks and sequestration rates must be quantified country-wide, and an assessment must be made of the potential contribution of macroalgal farming to blue carbon.

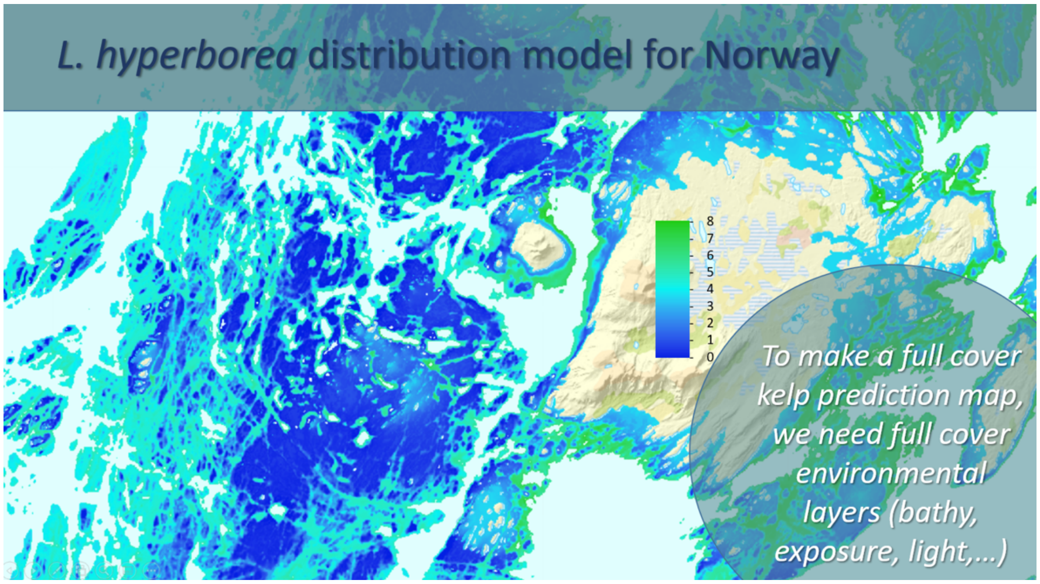


Redrawn from Krause-Jensen et al. 2012, Global Change Biology

1.5 Blue Carbon distribution mapping

Dr. Hege Gundersen, Norwegian Institute for Water Research

The Nordic Council of Ministers have funded a study of the climate adaptation, carbon uptake, and long-time storage of carbon in Nordic "blue forests." The project will: model the Nordic distribution and biomass of kelp, rockweed and eelgrass; quantify central estimates of the Nordic carbon cycle; analyze the marine carbon cycle, including uptake, export, and storage in Nordic blue forests; and identify opportunities for management measures. The Norwegian coastline is more than 100,000 km long, and much of this is rocky substrate that is potentially kelp habitat, so the best method for mapping is predictive models. Carbon stocks in the blue forests will be estimated by multiplying kelp density by region specific plant biomass and dividing by an estimated carbon content from the literature. The kelp distribution modeling work is most advanced in Norway so far, though efforts in other Nordic countries are in progress. A region-specific biomass model has shown that depth, exposure, and latitude explain 80% of the variation in kelp plant biomass. Until recently, the best available estimate of kelp biomass in Norway has been 8 Tg C (Gundersen et al. 2011), whereas the new improved distribution model suggests that this estimate has been overestimating biomass by approximately a factor of two. One ongoing data challenge is integrating high-resolution bathymetry maps for Norway (25 m) and at the Nordic level (100 m). Finally, participants were introduced to The Norwegian Blue Forests Network (NBFN.no/en), which raises awareness, performs research, and influences policy on blue forests in Norway.

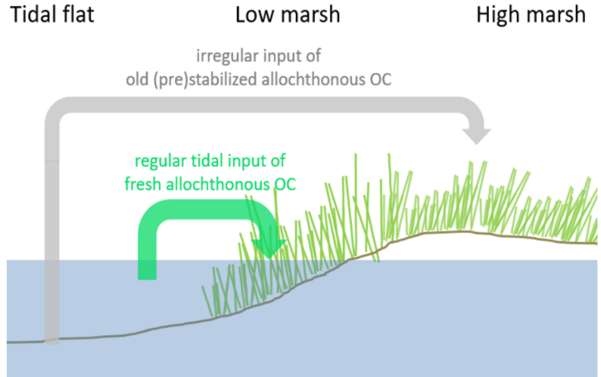

L. hyperborea distribution model for Norway

To make a full cover kelp prediction map, we need full cover environmental layers (bathy, exposure, light,…)

1.6 Carbon sequestration in the salt marshes of the northern Wadden Sea

Dr. Peter Mueller, Aarhus University

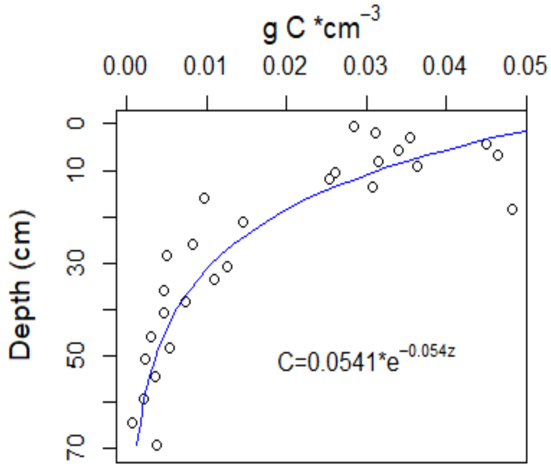
The Wadden Sea UNESCO World Heritage Site has 40,000 ha of salt marshes, with an expansion rate of about 200 ha yr^{-1}. Many of the marshes are semi-natural, with both natural features and human infrastructure related to centuries of agriculture (e.g. drainage channels, furrows, groins). In order to more precisely map and calculate the sequestration of carbon in the Wadden Sea coast, studies were conducted to compare soil carbon at tidal flat and saltmarsh areas. Saltmarsh soils had greater organic carbon density, however, a large fraction of the soil carbon contained is derived from recalcitrant allochthonous sources. Interestingly, despite being well-aerated, there were still moderate rates of C sequestration in marsh soils. C sequestration rate was found to depend on the time scale considered, since soil OC density decreases with soil depth/time.



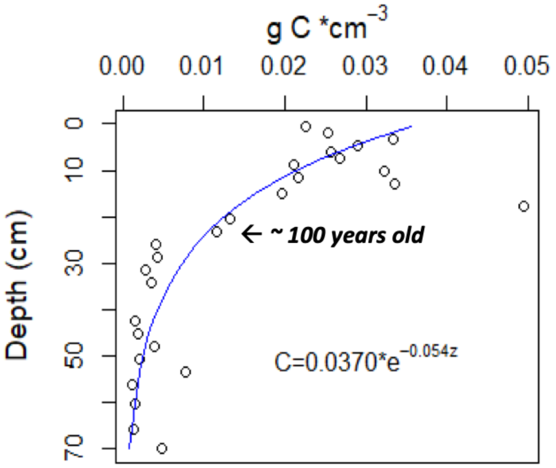
1.7 Carbon sequestration of Danish saltmarshes/meadows

Dr. Elizabeth Graversen, Aarhus University

Salt marshes and salt meadows are effective at storing organic carbon, because they have high productivity, relatively refractory detritus, oxygen-poor sediments, receive allocthonous organic matter, and the volume of their sediment increases relatively quickly over time. All continents except Antarctica have salt marshes, though the majority are found in temperate zones. The productivity of northern marshes is limited by a short growing season, and the southern marshes are limited by high salinity. The vegetation is adapted to stressful and varying conditions, like changing soil salinity, water content, anaerobic conditions, as well as wave and tidal influences. Denmark has approximately 37,700 ha of salt marshes. Cattle have grazed on the country's salt marshes for hundreds of years. The grazing affects the composition of the plant community, which in turn affects the amount of soil carbon. Danish salt marsh management is prioritizing preserving biodiversity by use of grazing livestock. Therefore, it was of interest if the management affected carbon stocks. A study of three sites showed that above ground biomass is significantly taller in non-grazed marshes as compared with grazed marshes, but that there was no significant difference in below ground biomass. There was also no significant difference in the total soil carbon stock between grazed and non-grazed areas. However, grazed areas had significantly higher C content when taking depth into account as an explanatory factor. Potentially, this difference would mean that grazed areas could be sequestering carbon at twice the rate of non-grazed areas, perhaps because of stimulated below ground production or soil compaction slowing degradation. A fraction of the C pool in the upper parts of the soil will probably not be long-term sequestered, since parts of the pool are still undergoing mineralization. The study will continue to assess sites, burial rates, the origins of buried C, and evaluate salt marsh Blue Carbon potential across Denmark.



Horsens grazed

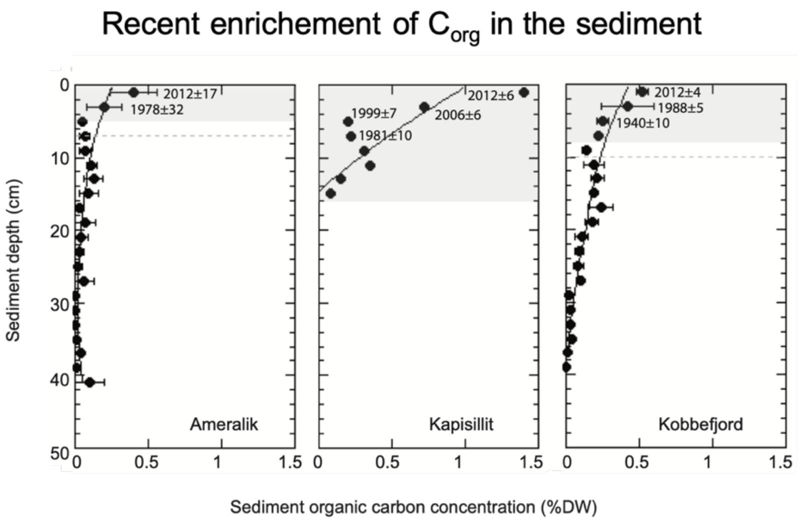


Horsens non-grazed

1.8 Expanding Greenland seagrass meadows contribute new sediment carbon sinks

Dr. Núria Marba, Instituto Mediterráneo de Estudios Avanzados

The increase in ocean temperature caused by climate change is leading to the loss of natural carbon sinks, like seagrasses, in the Mediterranean Sea and Australia. These losses may increase emissions, further exacerbating warming. Yet, there has also been a northward expansion of biota with the increase in the temperature of the Arctic. It has been hypothesized that warming and decreased ice cover will lead to more marine macrophytes in the Arctic, potentially mitigating some of the emissions related to losses in other areas. The seagrass present in the Arctic is *Zostera marina*, and it is currently limited to 70°N in Norway (where coastal areas are influenced by warm Atlantic waters) and 64°N in Iceland and Greenland. A study of three sites in Greenland show that although eelgrass has been present in Greenland for centuries, the sites are expanding: there has been organic C enrichment of the sediments traced to seagrass, the ratio of organic to inorganic C in the sediments has increased, and the burial rates have increased. Although the meadows are a relatively small stock of carbon at present, since the Greenland coast is about 12% of the total global coastline and temperatures will continue to increase, these seagrass meadows could be an important new blue carbon system requiring protection.


Recent enrichement of C_{org} in the sediment

Session 2: Blue Carbon and achieving the Paris Agreement – science needed for nationally determined contributions (NDCs), greenhouse gas inventories and actions

Organizers: Emily Pidgeon, Conservation International; Steve Crooks, Silvestrum Associates; Dorothee Herr, IUCN; Steven Lutz, GRID-Arendal
Moderator: Salvatore Aricò, IOC-UNESCO

2.1 Inclusion of blue carbon in national inventories – lessons learned and challenges ahead

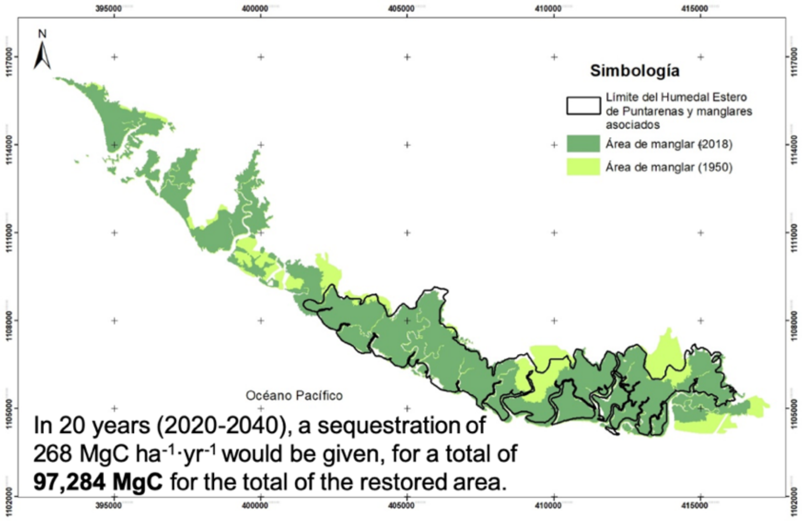
Dr. Steen Gyldenkærne, Aarhus University

Including coastal wetlands for the first time in a national inventory is a complex undertaking. The extent of the wetlands must be determined – where do the land and sea end and "wetlands" begin (see figure below)? Are they natural or created by human activity? Do humans have any control over them? Then, in determining emissions under the Paris Agreement, countries must define baseline years and a baseline area, make sure not to double count (as in including mangroves as both forests and wetlands), and determine "real, permanent and verifiable emissions reductions." Under EU rules, net-net accounting is mandatory, meaning that sequestration must be increased in the commitment year relative to the baseline years. It is important that scientists and advocates seeking to encourage the inclusion of wetlands in NDCs provide appropriate supporting info. to answer the challenges posed to people compiling the inventories: remove any effects to carbon storage that are global warming related from estimates – only human-induced effects count; don't cherry-pick sites for carbon measurement; ensure baseline values are well-supported by evidence; provide stable annual estimates of current C stock in wetland areas and include metadata about models and assumptions; and finally, help resolve questions about double-counting and other pathways of GHG in wetlands – methane, leaching etc.

2.2 Integration in payment for carbon services in Costa Rica: Blue Carbon Community Development (BCCD) model

Dr. Marco Quesada, Conservation International

Since 2012, there have been efforts in Costa Rica to pilot a blue carbon demonstration project, determine a national blue carbon budget, and develop a market for credits. The demonstration project, based in the Gulf of Nicoya, has yielded individual local mangrove management plans, a 10 year mangrove conservation strategy for the whole gulf, an assessment of ecosystem services, a carbon budget, and five years of experience for the community and the national wetlands advisory council in implementing community-based mangrove restoration. As a result, we know that the Gulf of Nicoya contains over 20,000 ha of mangroves, which provide about $408 million annually in ecosystem services, including coastal protection, fisheries, and climate mitigation. The Blue Carbon Community Development Model (BCCD) is a public-private partnership between government and local communities that includes a financial vehicle. The model will support mangrove conservation and restoration by integrating it into national policy priorities like the country's decarbonization strategy, biodiversity targets, and the blue economy policy framework. It will prioritize integration of local communities, be open and transparent within a public-sector framework, and provide financial sustainability that will enable long-term conservation. Specific intervention activities include: the prevention of deforestation, reforestation and restoration, and the reduction of wastewater and fertilizer run-off. These activities will be funded by voluntary carbon markets, REDD+ funding, and/or bilateral, results-based finance. The Costa Rican BCCD model provides a national case-study for how countries can effectively move from interest in blue carbon to action and integration of blue carbon ecosystems into their resource management and climate mitigation policies.

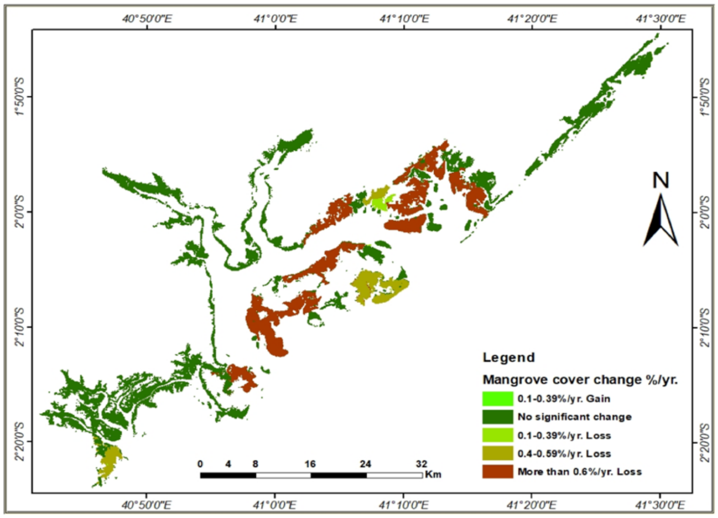


In 20 years (2020-2040), a sequestration of 268 MgC $ha^{-1} \cdot yr^{-1}$ would be given, for a total of **97,284 MgC** for the total of the restored area.

2.3 Incorporating blue carbon into Kenya's NDC

Dr. James Kairo, Kenya Marine and Fisheries Research Institute

In order for Kenya to meet its emission reduction goals, a large reduction in emissions must come from the forestry industry, via a reduction of deforestation and reforestation. Notably, when sectoral emissions in Kenya are compared to blue carbon ecosystem emissions related to degradation, the blue carbon system emissions are larger than emissions from all industries, including agriculture. This means that the reversal of degradation and the restoration of blue carbon systems can significantly help Kenya meets its goals in a way that might be easier and faster to achieve than major industrial changes. A study of mangroves in Lamu, where there are 61,000 ha of mangroves, is helping to provide information to support mainstreaming blue carbon into the national development and climate change agenda. There are nine mangrove species in Lamu, and the forests are used by communities for wood and other resources. The area was mapped using remote-sensing and the total emissions related to degradation over 1990-2019 were estimated to be ~1200 tCO_2 ha^{-1}, using IPCC protocols. The degradation was different across the Lamu area, as can be seen from the differences in mangrove size class distribution. The carbon stocks also differed, and the total stock averages 613.73 ± 115.41 Mg C ha^{-1}. The average natural regeneration of the mangroves was 7,342 juveniles ha^{-1}, which can be considered adequate to restock the forest. This detailed study shows that the Lamu mangroves have the potential to recover naturally, with management, and that they represent a large and valuable stock of C that can be used to accelerate Kenya's commitments to sustainable development goals and NDC.

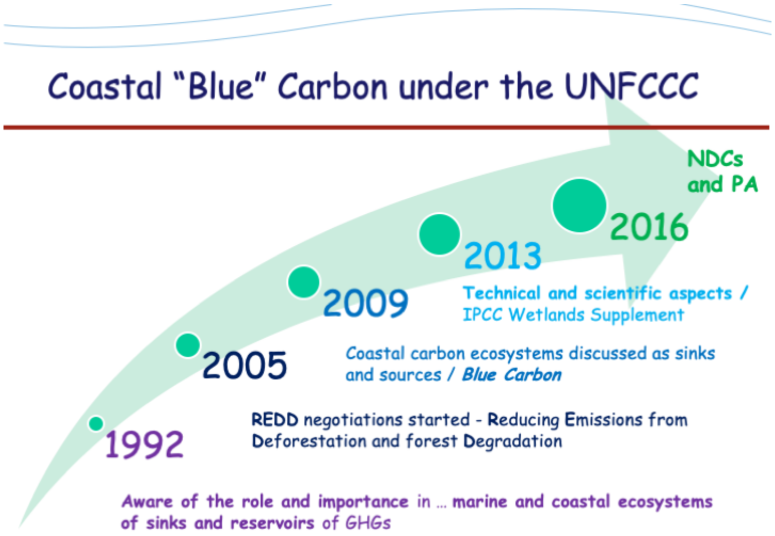


Rate of Mangrove cover loss in Lamu from **1990-2019**

2.4 New Guidelines for blue carbon in NDC, inventories and national climate change

Tamara Thomas, Conservation International

The importance of marine and coastal ecosystems as sinks of greenhouse gases was first acknowledged under the UNFCCC in 1992. Since then, the specific issue of blue carbon has emerged and the IPCC wetlands supplement in 2013 provided technical and scientific information so that countries can include these important systems in their NDC. While traditional blue carbon ecosystems like mangroves, seagrasses and salt marshes are included in the current regime, the carbon sequestration capacity of corals, kelp, and marine fauna are not currently recognized because the evidence suggests that they do not meet the definition of being consequential, verifiable, and long-term carbon sinks, with respect to the atmosphere. One hundred fifty-one countries contain at least one coastal blue carbon ecosystem, and 71 contain all three. To date, 28 countries include a reference to coastal wetlands in their NDCs and 59 include coastal ecosystems in their adaptation strategies. Since the areas are already included, there is an opportunity to advocate for including activities to conserve and restore the areas in mitigation strategies. However, it is important to keep in mind that the inclusion of coastal wetlands in NDCs depends upon: whether they are managed areas, the availability and ongoing collection of data, a commitment to permanent preservation of the C, and whether the activities are compatible with policy frameworks in terms of terminology, accounting, transparency and the country's existing mitigation and adaptation goals and targets. To successfully advocate for the inclusion on blue carbon in a country's NDCs, the project must be described in a simple, accessible way, that is compatible with how international frameworks use terms and ensure that they are clearly implementable and practical. New guidelines on how to include blue carbon in NDCs will be published in December.


Coastal "Blue" Carbon under the UNFCCC

NDCs and PA

2016

2013

Technical and scientific aspects / IPCC Wetlands Supplement

2009

Coastal carbon ecosystems discussed as sinks and sources / ***Blue Carbon***

2005

REDD negotiations started - Reducing Emissions from Deforestation and forest Degradation

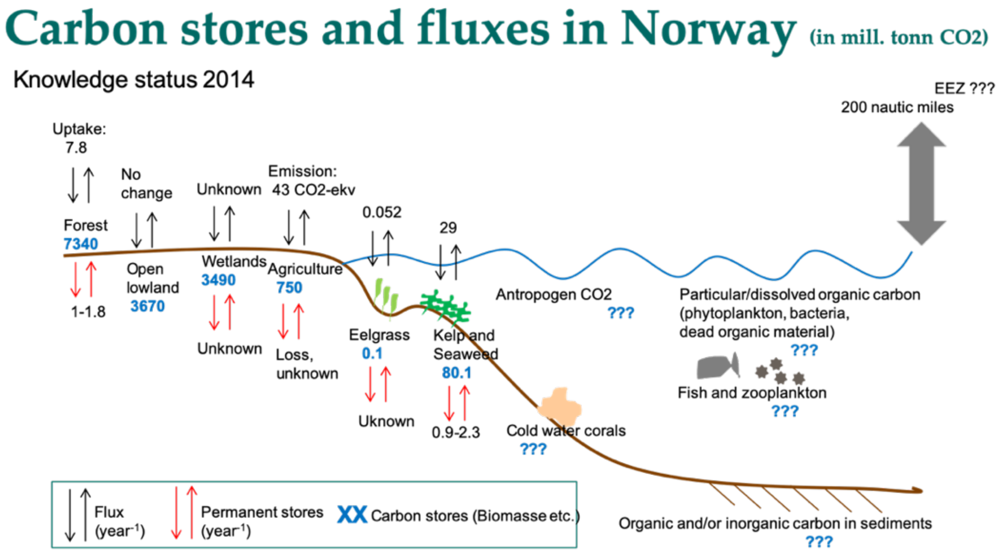
1992

Aware of the role and importance in … marine and coastal ecosystems of sinks and reservoirs of GHGs

2.5 National work on blue carbon in Norway

Dr. Åsa Pedersen, Norwegian Environment Agency

Norway is particularly interested in blue forests and blue carbon projects because it has a long coastline with significant seagrass and seaweed ecosystems, that have a sequestration potential that may be equal to the country's terrestrial systems. However, there are knowledge gaps about these systems that has resulted in blue forests and blue carbon being left out of Norway's yearly greenhouse gas inventories. In order to include them, the carbon captured by the blue carbon ecosystems must be “accountable and actionable,” so, data are needed about the full extent of the ecosystem areas, the sink capacity, and clear evidence that the sinks can be managed by specific actions to control the amount of carbon stored. Some key missing fluxes are: organic and inorganic carbon in sediments, and particulate and dissolved organic carbon. In response, the Nordic Council of Ministers, when Norway held the presidency, funded a three-year project to address, “Climate adaptation, carbon capture, and long-term storage in blue forests in the Nordic region.” The project will determine the role of Nordic blue forests in the marine carbon cycle, explore management options for securing healthy blue forests, and disseminate knowledge about blue forests and blue carbon from a sustainable development perspective. This work will enable potential future inclusion in regional NDC and national inventories. Two key remaining questions for the science and policy community are: how do we transition from knowledge to implementation, and are we able to manage carbon stores in offshore/deep sea sediments?



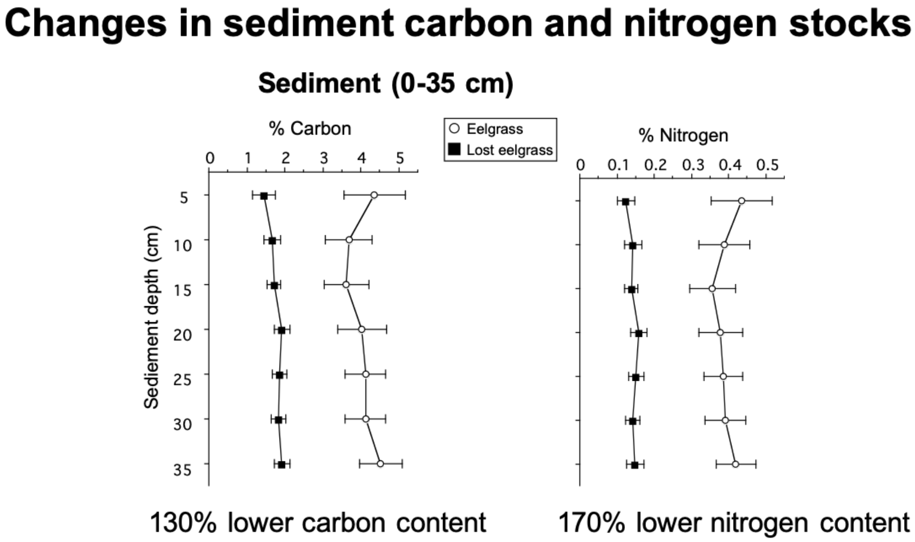
Session 3: Restoration of high latitude blue forests (seagrass, salt marsh, macroalgae)

Organizers: Steve Crooks, Silvestrum Climate Associates, Christoffer Boström, Åbo Akademi University
Moderator: Christoffer Boström, Åbo Akademi University

3.1 Losses and restoration of eelgrass in Sweden: implications for carbon and nitrogen stocks

Dr. Per-Olav Moksnes, University of Gothenburg

Eelgrass meadows are the dominant marine vegetation on shallow, soft, sediment habitats in western Sweden and the southern Baltic Sea. The meadows “engineer” the ecosystem by stabilizing the bottom, improving water quality, and providing habitat, increasing the productivity of fisheries. Since the 1980s, 60% of eelgrass in northwestern Sweden has been lost, an area of approximately 12,500 ha. It was assumed that the losses were related to eutrophication, however, even after a reduction in nutrient inputs and the restoration of good water quality, the eelgrass meadows have not naturally returned, and in fact losses have continued in new areas. Local regime shifts, like an increase in wind-driven resuspension of the unstable sediment or new drifting mats of algae, have prevented eelgrass growth by blocking light. The loss of the eelgrass has resulted in the loss of soil storage of carbon and nitrogen. Considering the loss in terms of the social cost of carbon sequestration and nitrogen abatement (Cole and Moksnes, 2016), the loss of the nitrogen results in monetary damages an order of magnitude greater than those due to the carbon loss at current pricing. We recommend the single-shoot transplantation method, which has been shown to result in the highest growth rates, with the least impact on the “donor-beds.” However, the method is labor intensive and expensive, and cannot be successfully used in areas where the water clarity will not allow seagrasses to thrive. As always, conservation results in much more robust ecosystems services and carbon storage than what can be achieved short-term through restoration. A new seagrass restoration guide for Scandinavian countries can be found at: www.gu.se/zorro.



Changes in sediment carbon and nitrogen stocks

Sediment (0-35 cm)

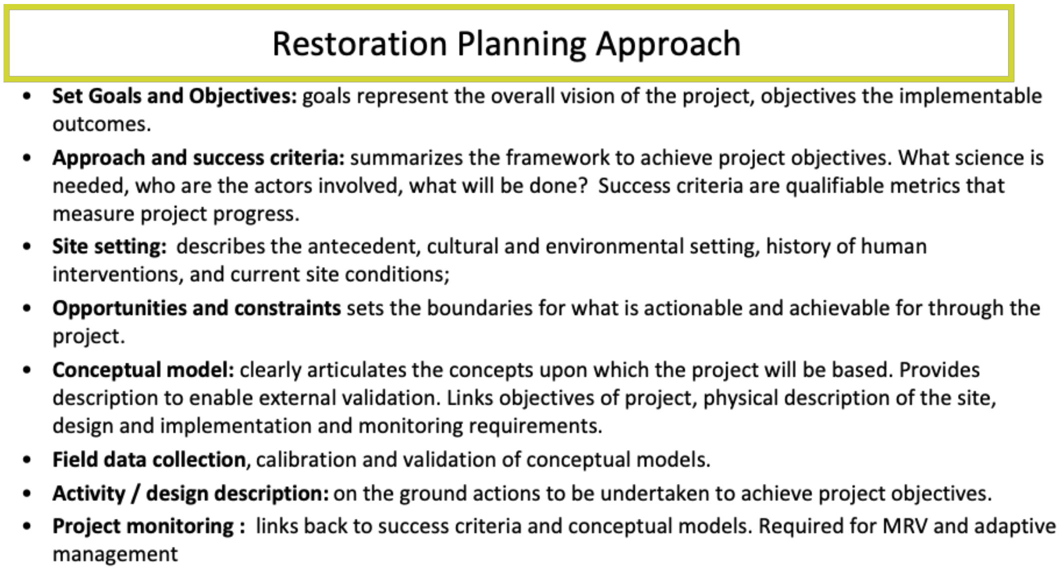
130% lower carbon content

170% lower nitrogen content

3.2 Structured planning of restoration projects: linking science to outcomes

Dr. Steve Crooks, Silvestrum Climate Associates

Integrated Coastal Management requires taking many elements into account: the state of the system to be managed, the drivers behind its condition, and current and changing pressures on the system. Additionally, as restoration proceeds, the intended goals and chosen responses must also be considered in relation to the system status and re-evaluated as the restoration progress is monitored. Errors are frequently made in designing restoration projects, both in terms of clearly stating goals, and in calculating benefits. For example, the goal of restoration efforts is not to restore the system to an idealized, pre-damaged state, but to restore it to the point where natural adaptation methods can take over, sustain the ecosystem, and protect it from future stressors. Similarly, in carbon management, the benefit is not only the sequestration that has increased from the previous baseline state, but should take into account the trend in the previous storage, which may mean that a project has even greater benefit or that the benefit is significant, even if a downward trend continues. Besides a through design of the purpose, goals, and benefits of the project, there are key elements in successful restoration projects that help ensure success. First, building public confidence and support. Second, iterating on the project: measuring progress, and then adjusting methods and goals, as necessary. Third, ensuring that the project can persist despite change over time: integrating the project into the landscape and planning for migration with climate change. Finally, we recommend adopting a "restoration planning approach" that systematizes these steps and elements and ensures a thorough analysis of what is known and unknown (Fischenich, 2008).



Restoration Planning Approach

- **Set Goals and Objectives:** goals represent the overall vision of the project, objectives the implementable outcomes.
- **Approach and success criteria:** summarizes the framework to achieve project objectives. What science is needed, who are the actors involved, what will be done? Success criteria are qualifiable metrics that measure project progress.
- **Site setting:** describes the antecedent, cultural and environmental setting, history of human interventions, and current site conditions;
- **Opportunities and constraints** sets the boundaries for what is actionable and achievable for through the project.
- **Conceptual model:** clearly articulates the concepts upon which the project will be based. Provides description to enable external validation. Links objectives of project, physical description of the site, design and implementation and monitoring requirements.
- **Field data collection**, calibration and validation of conceptual models.
- **Activity / design description:** on the ground actions to be undertaken to achieve project objectives.
- **Project monitoring :** links back to success criteria and conceptual models. Required for MRV and adaptive management

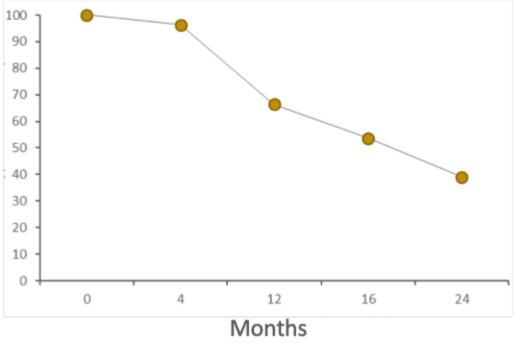
3.3 Kelp forest restoration: nudging a phase shift on a sea urchin barren

Dr. Hege Gundersen, Norwegian Institute for Water Research

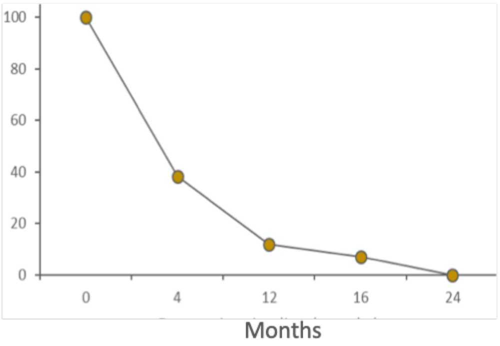
Kelp forest ecosystems and sea urchin barrens are two alternate, stable ecosystem states that depend on grazing pressure. Reversing from barren to kelp is difficult due to hysteresis effects: grazing must be reduced below the state that caused the shift and the environment may have become less hospitable to kelp forests while it was a sea urchin barren. The Marine Ecosystem Restoration in Changing European Seas (MERCES, H2020 #689518) project tested a pilot in 2017 to restore kelp on an overgrazed sea urchin barren in Norway. Adult kelp (*Laminaria hyperborea* and *Saccharina latissima*) were transplanted from three donor populations, forming a 50 km^2 patch, and sea urchins were removed to reduce the density of the population. It was hypothesized that the transplants would increase the chance of natural kelp recruitment; provide a barrier to sea urchin grazing; and re-establish habitat characteristics and predator-prey relationships that would naturally prevent over-grazing. The two kelp species differed, with *L. hyperborea* having high survival and no recruitment, and *S. lattissima* having low survival but rapid self-recruitment. In fact, *S. lattissima* propagules were also found in the *L. hyperborea* patch. The main findings of this experiment were that sea urchins are the primary obstacle to kelp recovery; the success of the transplantation technique is higher when combined with grazer removal and may differ depending on kelp species; and the transplanted patch was an effective barrier to sea urchin grazing. In conclusion, kelp restoration is possible, but the process is both time consuming and expensive.

Survival of transplants and recruitment of macroalgae and kelp

% survival of *L. hyperborea*



% survival of *S. lattissima*



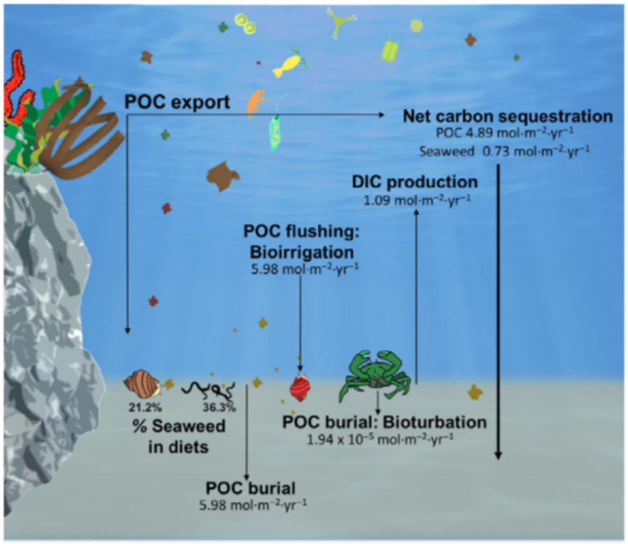
Session 4: Kelp forests and rocky shores in the Blue Carbon perspective

Organizers: ; Dorte Krause-Jensen, Aarhus University; Kasper Hancke, Norwegian Institute for Water Research; Jennifer Howard, Conservation International
Moderator: Jennifer Howard, Conservation International

4.1 Macroalgae in the blue carbon context and seaweed farming perspectives

Dr. Dorte Krause-Jensen, Aarhus University

Macroalgae differ from most blue carbon ecosystems in that they may store carbon by exporting it to sinks in shelf sediments and in the deep ocean, rather than sequestering it in the habitat. Since kelp forests are the largest and, therefore, globally most productive of the coastal vegetated habitats, this means they may naturally sequester carbon in significant amounts. To meet the definition of a blue carbon ecosystem, it must be determined that they a.) permanently sequester C from the atmosphere and b.) the process can be managed by people to either increase the natural sequestration and/or reduce emissions related to degradation of the ecosystem. As such, there is a clear research agenda for those interested in adding macroalgal systems to blue carbon programs and policy: improve mapping of macroalgae worldwide; prove that macroalgae can be managed effectively for carbon storage; fingerprint sedimentary macroalgae to trace the sources and sinks; and provide evidence of the magnitude of the C fluxes and burial rates. If and when the evidence shows that macroalgae function as BC systems, the next steps would be to: create a certification system for management and farming; include macroalgae in carbon crediting; and determine a mechanism for apportioning the macroalgal C sink between counties, since the sources and sinks are likely to span various territorial waters. To date, the science suggests that C sequestration potential in macroalgae differs according to species variation in the recalcitrance of the biomass, buoyancy, distribution area (e.g. reflected in light requirements), and productivity, meaning that some species are expected to be better candidates for C-sequestration. Additionally, the preferred habitat of the macroalgae affects the C sequestration potential, as areas with high sedimentation may bury the macroalgae quickly. Efforts are underway to better quantify the global macroalgal area, likely to be on the order of several 10^6 km^2, and the variability in area in relation to natural variation and management effort. There is evidence of successful kelp restoration in Japan, which means that it may be possible to specifically design activities to restore kelp, a key factor for a BC ecosystem. As macroalgal farming increased 8.3% yr^{-1} between 2000 and 2017, and products show potential for climate change mitigation, it could present an opportunity to maximize blue carbon sequestration, if the supporting science can be established. Finally, fingerprinting techniques, e.g. involving eDNA, are being used to track the sources and sinks of macroalgae C.

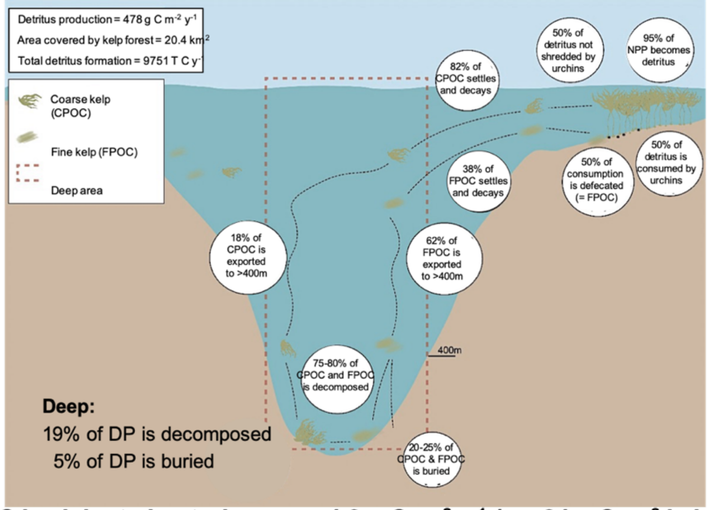


Queiros et al. 2019. Ecological Monograph (Connected macroalgal-sediment systems..)

4.2 Blue carbon from seaweeds: export and fate of seaweed detritus from coastal habitats

Dr. Morten Pedersen, Roskilde University

Blue Carbon is the sequestration of C from marine autotrophs that takes place when burial rates in sediments exceeds long-term rates of erosion and decomposition. This long-term burial depends on rates of net primary production and grazing/mineralization, and can take place within the ecosystem or via export to the coastal and deep ocean and their sediments. Currently, we lack much definitive information on the export, decomposition, and burial of macroalgae. There are several reasons that seaweeds may not be a significant part of global blue carbon sequestration: they cover a small area; are not embedded in sediments, so they lack the large soil C effect; and are heavily grazed and readily decomposed. To quantify the potential blue carbon contribution of seaweeds, researchers must collect sediment cores in sink areas, age the cores, and separate the C by origin. However, aging is often impossible because of mixing in coastal areas and the difficulty of coring in deep areas, and because it is difficult to determine the origin of the carbon. Studies of shallow, Nordic estuaries show little C export, and while seagrass does end up buried, little macroalgae is sequestered. Studies of carbon in coastal kelp forests with export show that the forests produce significant detritus, some of which is consumed by sea urchins and some of which sinks to the deep ocean. Overall, though seaweed-based ecosystems are highly productive, the detritus decomposes quickly and completely. While ephemeral seaweeds contribute little to blue carbon, some kelp may end up sequestered, yet the magnitude of this burial is much smaller than seagrasses. So, while some macroalgal systems may indeed qualify as blue carbon ecosystems, their portion of total blue carbon sequestration may not be globally significant.

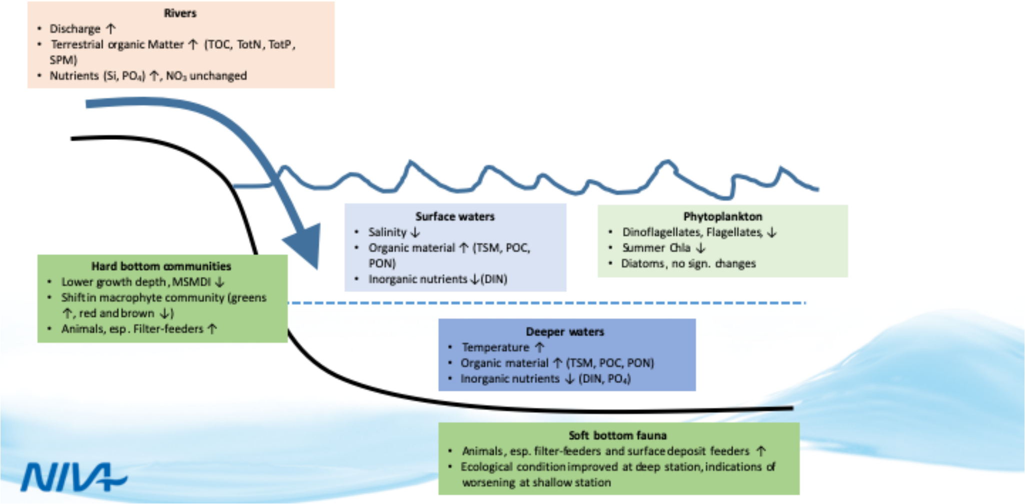


C burial rate in study area = 4.3 g C m^{-2} y^{-1} (ca. 24 g C m^{-2} kelp forest y^{-1})

4.3 Long-term changes in hard-bottom communities in Skagerrak coastal waters

Dr. Helene Frigstad, Norwegian Institute for Water Research

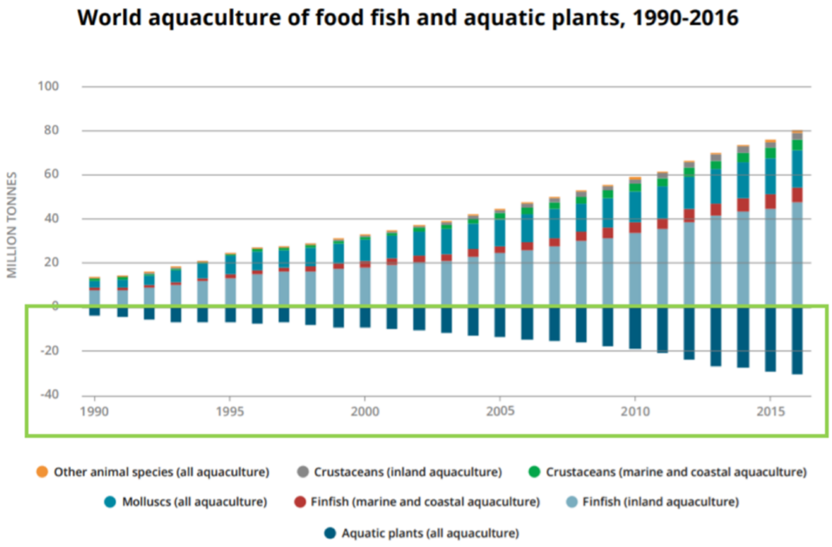
In the Skagerrak coastal waters of Norway, increased river discharge over the last three decades has reduced light penetration, due to the increase in river-borne material like cDOM and particulate organic matter. There has also been a decrease in inorganic nutrients in coastal waters, mostly due to a reduction in advected nutrient supply from the southern North Sea. There were reports of substantial reduction in sugar kelp between 1996 and 2002 in Skagerrak, including a narrowing of the depth distribution range and accompanied by historically low recruitment in key fish and zooplankton species. Using analyses of long-term time series data, it was found that there were substantial changes in hard-bottom communities since 1990, including macroalgae: reduced lower growth depth; an increase in green, rather than red and brown macrophytes; and an increase in filter feeders. The most important drivers of these changes were temperature increases, and the increases in particulate organic carbon and total suspended matter that reduce light for autotrophs. This study highlights the pressures that climate change is placing on macroalgal communities by changing their habitats and the accompanying challenges posed for restoration.



4.4 Seaweed farming in Norway – blue carbon and blue economy perspectives

Dr. Kasper Hancke, Norwegian Institute for Water Research

Seaweed is a product that can be farmed and sold for multiple purposes: food for humans, feed for animals, production of pharmaceuticals, and biofuel. Macroalgal farming accounts for more than half of total global marine agriculture production, and the majority of the industry is located in China and Indonesia (86%). Macroalgal farming is growing at an annual rate of 7-9% globally, and the industry is predicted to have a large market potential in Norway, with offshore areas having the highest potential for large biomass cultivation. While this growth represents a significant economic opportunity, it may also provide benefits for the country's efforts to mitigate climate change. First, the kelp can be used to substitute for high-C footprint products in animal feed and fuel. Second, the kelp can be used to reduce methane emissions from ruminants and to increase farming efficiency, thereby reducing high-C footprint fertilization and farming practices. Finally, kelp farms can also directly export carbon to the seabed and deep ocean (about 30-60% of production, depending on practices and efficiency), acting as blue carbon ecosystems. Since Norwegian seaweed cultivation is forecasted to be 20 million tons by 2050, the C sequestration potential from kelp farms could account for as much as 8.5% of the annual Norwegian CO_2 emissions, making kelp aquaculture a potentially important tool in managing greenhouse gases, in Norway and globally.



World aquaculture of food fish and aquatic plants, 1990-2016

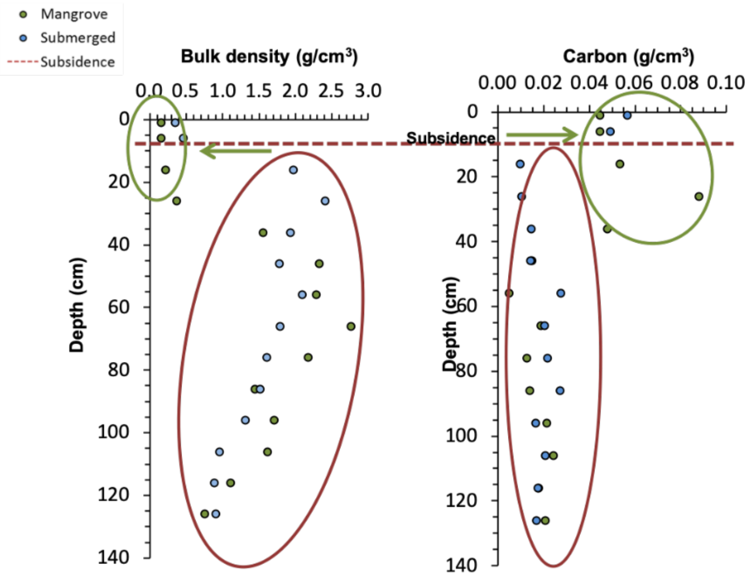
Session 5: Sea level rise and its effects on blue carbon

Organizers: Catherine Lovelock, University of Queensland; Neil Saintilan, Macquarie University; Marianne Holmer, University of Southern Denmark
Moderator: Steve Crooks, Silvestrum Climate Associates

5.1 Sea level rise and carbon stocks

Professor Neil Saintilan, Macquarie University

Global sea-level has been rising at approx. 3.4 mm per year averaged over the past three decades, nearly double the longer-term rate of 1.8 mm per year for the 20th century. The rate of sea-level rise is expected to double again before the end of the century under high emissions scenarios (IPCC, 2013). Since blue carbon ecosystems are typically low-lying and near the coastal ocean, they will be affected by sea level rise, but also by glacio-isostatic adjustment and tectonic activity, depending on geological settings. So, when considering the impact of sea level rise on blue carbon systems, we must first understand that different areas are changing at different speeds, leading to different impacts on carbon storage. Further, we must think about the ecosystem's ability to adjust to elevation changes in terms of vertical and horizontal space (the available "accommodation space"), allowing vertical accretion of sediment and organic matter, and lateral migration, the potential for which increases with sea-level rise. Water level changes drive changes to hydrology, sedimentation, and thus plant processes and soil, and so blue carbon systems under sea level rise will adapt or die depending on the local rate of sea level rise the accommodation space available, and the nature of feedbacks between inundation and vertical accretion. Recent research has shown that carbon storage is indeed controlled by changes in sea level rise, so this is an important area of inquiry for projecting future C storage (Rogers, 2019). Marshes in far field locations, away from centers of glaciation (tropics, Southern Hemisphere) have been subject to sea-level high stand for millennia, which explains the lower levels of organic carbon in wetland soils. By contrast, marshes subject to continual sea-level rise over the past few millennia have approx. 4 times the concentration of organic carbon in their soils, increasing to 10 times at 50-100 cm depth. The onset of higher rates of sea-level rise in regions of the world subject to sea-level high stand will lead to more efficient carbon storage. Since we know that sea level rise will affect the amount of carbon sequestration in blue carbon ecosystems, we must pay special attention in restoration and management projects to maintain the appropriate accommodation space to allow them to migrate and maintain their mitigation and other ecosystem functions.



5.2 Estimating sea level rise effects on global mangrove carbon stocks

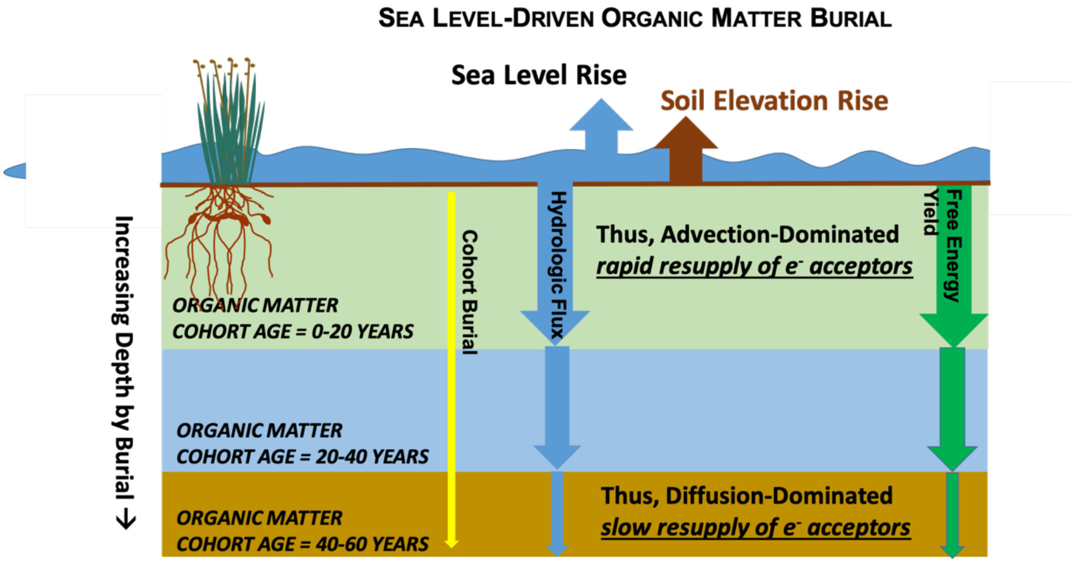
Dr. Catherine Lovelock, University of Queensland

Not all mangroves are equally vulnerable to sea level rise, because sea level rise and a range of other factors that influence vulnerability, e.g. slope of the coastal zone, subsidence, sediment supply, and exposure to extreme events and human management of the landscape, vary among locations. Models have been developed which allow us to predict the relative vulnerability and timing of risk for global mangroves. Early models of the vulnerability of mangroves to sea level rise did not consider “coastal squeeze,” which describes the loss of intertidal habitat with sea level rise due to the prevention of landward movement of coastal wetlands by fixed infrastructure (e.g. seawalls, levees, roads) and the loss of habitat on the seaward edge due to inundation. In newer models, mangroves in areas with high population density are modelled to experience acute coastal squeeze as they meet barriers to migration, preventing natural adaptation to sea level rise. Conversely, mangrove area is modelled to expand with sea level rise where coastal squeeze is low. These sea level rise models can be combined with spatial models of carbon stocks to project potential changes in biomass and soil carbon stocks in mangroves, which can be used to estimate their future role in climate change mitigation. The main results from these model compilation efforts are that carbon gains and losses in mangroves with sea level rise will be spatially variable. Coastal squeeze will strongly influence mangrove carbon stocks, with some nations predicted to lose a larger proportion of their mangrove carbon stocks than others (e.g. small island states compared to those on large continents). Some countries are likely to have a high capacity to expand mangrove areas, including Australia, Mexico, and Indonesia. Others, like Pakistan, Suriname, Vietnam and Mexico, may have the opportunity to avoid large carbon losses by managing coastal squeeze.

5.3 Biogeochemical constraints on carbon preservation

Dr. Patrick Megonigal, Smithsonian Environmental Research Center

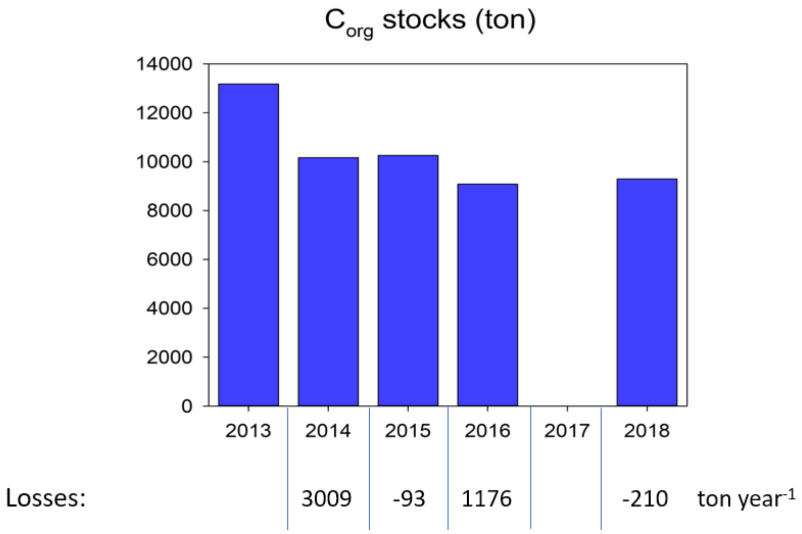
In explaining the large soil carbon pools typical of blue carbon ecosystems, we often focus equally on two explanatory factors, high rates of plant production and slow rates of decomposition of organic matter. However, data from blue carbon ecosystems suggest that plant production does not explain the size of soil carbon stocks, suggesting that it is very important to study the factors that prevent decomposition, which might be under threat from climate change. For example, studies of mangroves show that above-ground biomass does not predict the size of the soil carbon pool. Rather, it is the rate of decomposition, determined by chemical conditions in the soil, that gives a blue carbon system its ability to sequester large amounts of C. The speed of decomposition is controlled by factors like temperature, pH, the chemical composition of the organic matter, and the redox potential in the soil. Redox is in turn related to the water table depth and the amount of oxygen. In particular, this research focuses on chemical composition and redox potential, since these have been generally neglected when considering how blue carbon system functions will change with climate. The efficiency of the microbial degradation of organic matter in soil is affected by the choice of terminal electron acceptor: organic matter is more quickly and more completely broken down by aerobic respiration when oxygen is present, while it is slowly degraded when methanogenesis is the dominant respiration process. So, typically, the rate of decomposition declines with soil depth as the microbial community changes to preferentially use the less efficient processes based on the available e- acceptors. However, blue carbon research has rarely considered how changes in hydrological conditions affect the redox conditions, and consequently the oxidation of soil organic matter, with implications for overall C sequestration with accelerated sea level rise. In soils where the water flows quickly (i.e. high hydraulic conductivity) there is more rapid supply of high energy-yielding oxidants such as O_2, stimulating degradation of soil OM. Thus, in order to explain why sediment burial preserves organic matter, we need to consider the influence of burial on hydraulic conductivity and the resulting impact on redox chemistry. Second, we must consider the impact that plant roots have on increasing hydraulic conductivity and introducing oxygen into soils, while microbial decomposition reduces hydraulic conductivity. In summary, we recommend the next stage of research on blue carbon soil C stocks include an interdisciplinary approach combining marine geochemistry and ecology, and that researchers provide hydrologic metadata in their field C storage studies that will allow for better estimation of the stability of the soil stocks and future modeling under climate change.



5.4 Gyldensteen Coastal Lagoon and carbon cycling

Dr. Cintia Quintana, University of Southern Denmark

Gyldensteen Coastal Lagoon, in Denmark, is a 214 ha lagoon created by breaching dikes and letting seawater flood agricultural land, i.e. managed realignment. This is the first marine lagoon created by managed realignment in Denmark, and it allows us to consider whether and how flooded lands may develop new blue carbon storage systems. Since tidal reintroduction, careful observation of the changing chemistry (soil-air CO_2 emission, soil-water *in situ* CO_2 flux, C_{org} in the soil, and water-air CO_2 flux) has also given us insight into how similar agricultural lands might respond to sea level rise. While the soil-air CO_2 release from the soils was as high as ~12.3 tC yr^{-1} before flooding, that release dropped to ~3.2 tC yr^{-1} across the soil-water interface in the first year after flooding. However, when accounting for microalgal primary production, no net soil-water CO_2 release was documented, and the total sequestration rate of 7.6 tC yr^{-1} could be estimated by simply deducting the CO_2 uptake of the previous crops cultivated in the area from the rate of soil-air CO_2 release. The system developed a strongly diel and seasonal pattern, with soil-water CO_2 release lower in winter and fall and higher in spring and summer. The dominating anaerobic processes resulting from the seawater flooding and the residence time of about 2 days of the water table in the coastal lagoon may explain the negligible net water-air CO_2 emission measured after 4 years of flooding. There was an initial loss of 3,000 tons in the total C stock, but the soil C stock has since stabilized to about 9,300 tons. Since there were many land reclamation projects in Denmark in the late nineteenth century, there is a significant opportunity to use the management lessons learned in Gyldensteen to restore wetlands and increase carbon sequestration in Denmark. The project provides a unique laboratory to observe the chemical changes in inundated agricultural land.

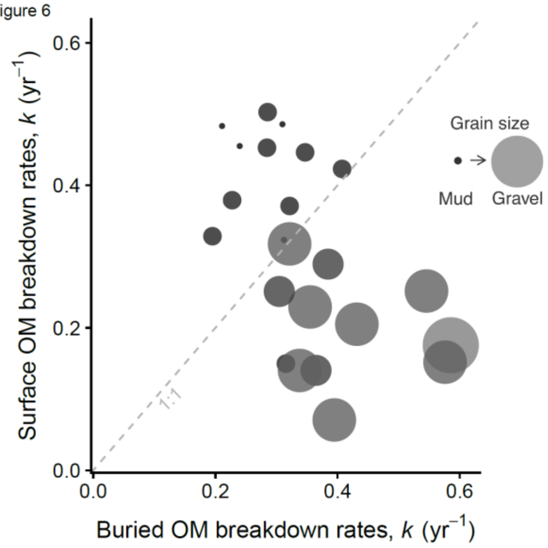


5.5 Sediment carbon early diagenesis and preservation in seagrass soils

Dr. James Fourqurean, Florida International University

There is approximately 4.2-19.8 Pg C of organic carbon stored in the top 1 m of the soil of seagrass beds worldwide. In the 20th century, about 29% of seagrasses were lost, and the rate of loss is accelerating, meaning the large pool of stored soil carbon is at risk of release to the atmosphere. The emissions related to current seagrass loss are estimated to be 63-297 Tg C y^{-1}. Yet, though we know seagrass loss leads to C release, we lack a detailed understanding of how seagrasses actually impact the sediment storage of C. In seagrass meadows, the majority of organic carbon is stored in sediments, rather than vegetation (140 Mg C ha^{-1} in sediments, 1.8 Mg C ha^{-1} belowground, and 0.8 Mg C ha^{-1} aboveground). As such, the decomposition of the stored carbon is dependent on the type of material (refractory or labile) and the deposition environment, particularly how much oxygen is available to oxidize the organic matter. Arguing from theoretical considerations, if all of the seagrass OM were deposited in oxic sediments, it would be largely remineralized within three years, so the presence of anoxic sediments is the key factor in the pool of seagrass meadow soil carbon storage. To date, we have assumed that the seagrasses influence the sediments in favor of deposition by increasing sedimentation and reducing grain size (which reduces hydrological connectivity), and causing anoxia, which slows microbial decomposition of organic matter. An experiment was conducted to test these assumptions by checking the correlation between seagrass bed density and sediment grain size and OM content; whether sediment grain size was predictive of the lability of OM; and if C burial in seagrass soils decreases decomposition and enhances preservation relative to surface deposition. Seagrass abundance was statistically correlated with sediment grain size and soil OC content, but the relationships were not highly predictive. However, the sediment grain size was a very good predictor of soil OC stock. So, while the seagrass coverage may lead to larger pools of soil OC, the degradation rates key to C sequestration are in fact more closely related to the bed characteristics, like grain size and consequently, hydrological connectivity. In a decomposition rate experiment using cellulose strips, we found that both on the surface and buried, degradation was affected by whether the sediments were muddy or sandy. In fact, though burial slows decomposition as expected in muddy sediments, it accelerates decomposition in coarse-grained sediments. In conclusion, over the landscape scale, soil organic carbon stocks were only loosely correlated with seagrass abundance; muddy soils contained more organic carbon that was more labile than carbon found in coarse-grained soils; and burial did not enhance OC preservation in all environments. These experiments make the case for refining the inventories of seagrass C storage by taking into account the sedimentary environment. They also underline the need for more mechanistic studies of how exactly blue carbon ecosystems enable C storage.

Figure 6



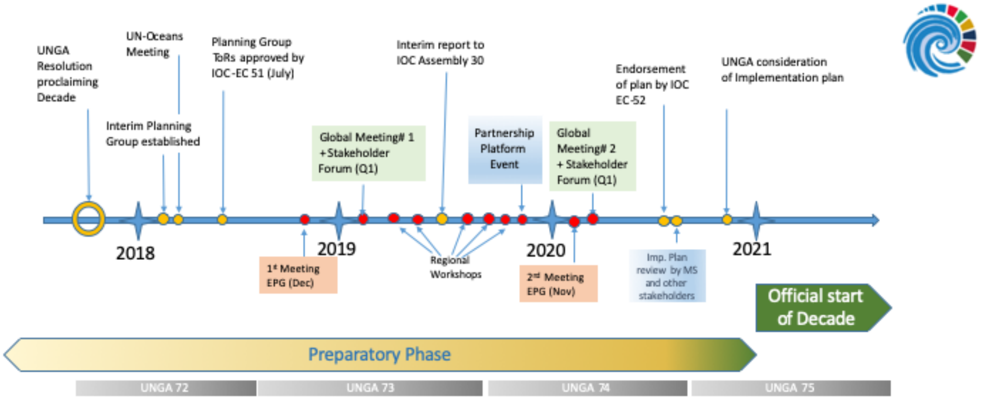
Session 6: Blue Carbon Science Updates

Organizer: Emily Pidgeon, Conservation International
Moderator: Miguel Cifuentes, Centro Agronómico Tropical de Investigación y Enseñanza

6.1 UN Decade of Ocean Science

Dr. Salvatore Aricò, IOC-UNESCO

The United Nations Decade of Ocean Science for Sustainable Development will take place from 2021-2030. As part of the original proclamation, the Intergovernmental Oceanographic Commission (IOC) was tasked with preparing an implementation plan for the decade, in consultation with the entire ocean science community. The goals of the Decade include: to radically change our understanding of the ocean's contribution to sustainable development; translate research into solutions; integrate social and natural sciences, as well as traditional knowledge; strengthen access and use of science by policymakers and citizens; promote partnership with the private sector; build and deploy new technologies; improve open access of data; increase the participation of people from underrepresented groups and regions; and maximize the resources of the UN to achieve these goals. The Decade will address both deep disciplinary understanding of ocean processes and solution-oriented research to support improved ocean management, stewardship and sustainable development. The specific societal outcomes include: a clean ocean (pollution); a healthy and resilient ocean (mapping and protection); a predicted ocean (modeling); a safe ocean (maritime safety, coastal protection, hazards); a sustainable, productive ocean (fisheries and aquaculture); and a transparent and accessible ocean (open data, participation and capacity). In the coming year, the science working group will assess research needs to meet the goals via regional meetings with stakeholders. More information can be found at: https://en.unesco.org/ocean-decade.



Preparing for the Decade: Next Steps

6.2 Blue Carbon Manual, Volume 2

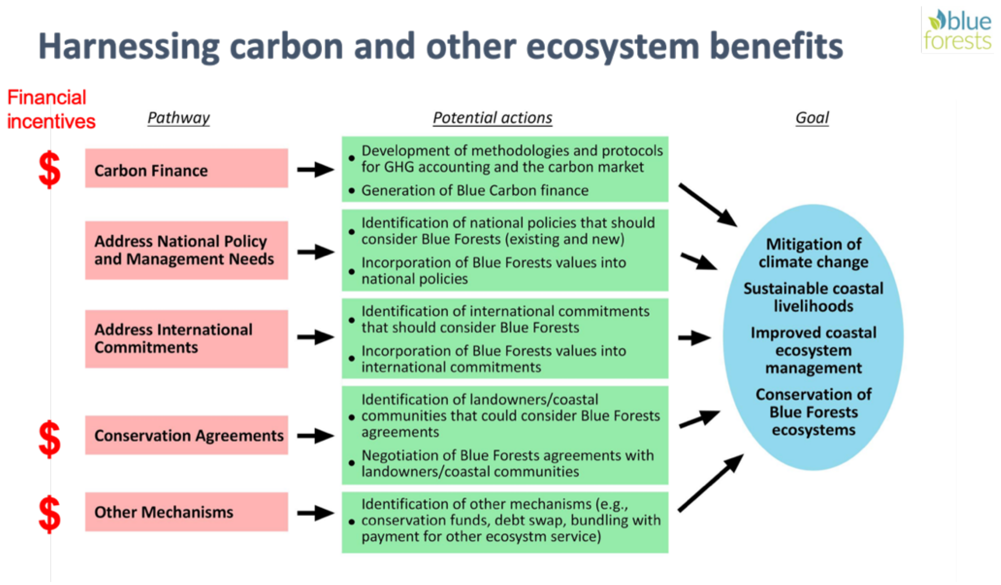
Dr. Jean Brodeur, Conservation International

Six years ago, the Blue Carbon Initiative Scientific Working Group identified a need: greater integration of blue carbon science into policy. The group also saw that there was an important barrier to addressing that need: not enough global blue carbon data, nor any guidance about how to collect it. So, the BCI created a comprehensive, practical guide that would describe a scientifically robust approach to collecting blue carbon data, from design to execution and data analysis. The protocols came from the work of several group members, including Boone Kauffman (mangroves), Jim Fourqurean and Nuria Marba (seagrass), and Pat Megonigal (salt marsh), among others. Today, the original manual is available online in Chinese, English, and Spanish (www.thebluecarboninitiative.org/manual), and is downloaded up to 10 times a day. It has been used across the world and even as a college text. The working group identified several changes that can be made to the existing manual: add lessons learned from worldwide experience in applying the method; explain how the field sampling data fits into the IPCC wetlands supplement carbon pools; include more detail about adapting the methods for specific sites (carbonate in seagrasses, soil accumulation rate sampling); update the remote sensing information; and add information about data management and how to contribute to databases like the Coastal Carbon Research Coordination Network. However, the group discussed that it might be necessary to make a second volume that includes new information and practices, as an addition to the original manual, rather than focusing on updating the first edition. Another idea was to focus on migrating the manual to an online version that includes videos demonstrating the methods. Finally, it was suggested that the manual or the online resources should include a flow diagram that explains how to apply the information for carbon accounting in policy. The group felt that a user survey might help to guide decision-making around how to update the original and what kind of new resources to provide. Several members volunteered to assist with the updates.

6.3 The Blue Forests Economy – harnessing carbon and other coastal and marine ecosystem benefits

Dr. Steven Lutz, GRID-Arendal

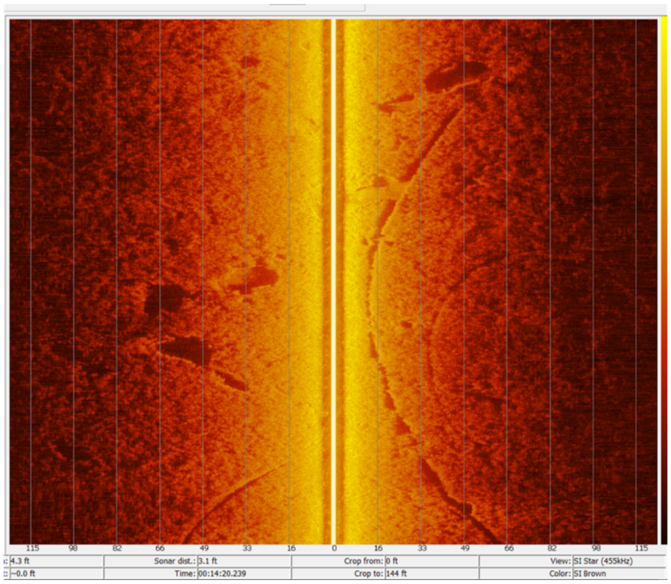
Blue Forests projects improve ecosystem management through harnessing blue carbon and other ecosystem services. Current blue forests efforts span the globe, and include a demonstration project in the UAE leading to the inclusion of blue carbon in the country's NDC. There are several pathways to conserve these forests: carbon financing, incorporation into national policy, incorporation into international commitments, conservation agreements, and other novel financial instruments. Within each pathway, there are specific actions that can be taken to meet the overall goals of conservation, sustainable livelihoods, climate mitigation and improved management (see figure below). Considering blue forests in economic terms shows that they have significant value beyond climate mitigation (fisheries, coastal protection, energy, recreation, pollution abatement, etc.) that can be leveraged for conservation. In fact, coastal wetland ecosystem services have been recognized in NDCs. Yet, can the implementation of sustainable NDC goals and blue carbon be supported by nature-based employment opportunities? An upcoming report will provide greater detail on this question. However, there are several examples of the strength of the blue forest economy, like: carbon finance in Kenya, sustainable fisheries in Ecuador, eco-tourism in Vietnam, mangrove honey in Thailand, mangrove ink in the Pacific islands, seaweed and kelp products in Norway, and seaweed packaging material in the UK. Taking into account the many ways that blue carbon ecosystems can provide sustainable economic value to their communities is a critical tool in the protection of these systems and their sequestered carbon.



6.4 Novel acoustic remote sensing methods for estimating aboveground biomass and sediment organic carbon of seagrass meadows

Dr. Faiz Rahman, University of Texas, Rio Grande Valley

To date, the calculation of the global seagrass carbon stocks and their spatio-temporal changes have been challenged by three major problems: global maps of seagrass areas are low resolution, there are no disturbance maps of major seagrass beds to refine estimates, and sediment carbon estimation is difficult and expensive. A mapping project of seagrass beds on the Gulf Coast of Texas proved that side scan sonar can be used to develop accurate maps of large areas of seagrass using low cost, commercially available technology. Furthermore, neural networks were used with the maps to identify, localize, and classify disturbances in the seagrass beds, like boat scars (see image below). This information could inform management of the seagrass beds and help with enforcement of environmental protections. The model's algorithms were found to be robust to both image noise and minor distortions. Another study experimented with an ultrasonic method to measure seagrass soil carbon in cores. The ultrasonic and traditionally measured total organic carbon values were strongly correlated. The next steps will be to develop a probe that can measure values *in situ*, without the need for cumbersome collection and processing of sediment cores. Other potential applications of acoustic technology include observations of above-ground productivity and foliar density within seagrass beds.



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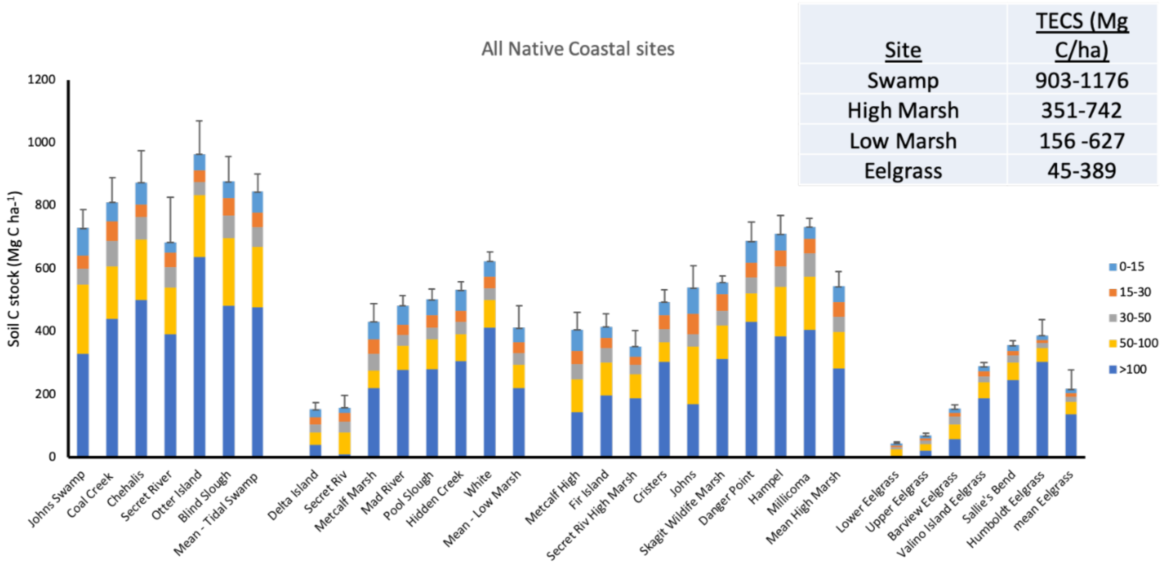
Color: SI Brown

6.5 Blue carbon stocks of coastal ecosystems of the Pacific Northwest, USA

Dr. Boone Kauffman, Oregon State University

Salt marsh carbon sequestration rates vary across the United States coast. The Pacific Northwest Carbon Stocks and Blue Carbon Database Project (2016-19) was created to provide more information about the specific sequestration values in National Estuarine Research Reserves on the coasts of Washington, Oregon and northern California. Some key research questions from the project were: what are the carbon stocks of the dominant coastal wetlands of the Pacific Northwest; how does land use affect the carbon stocks and what are the potential emissions from land cover change; how do the carbon stocks relate to other environmental variables; and can we develop cost-effective approaches to quantification and monitoring of stocks. The wetlands in the study vary widely in terms of dominant plants, typical conditions, soil characteristics, etc. Final results from the study are in review for publication, but a main finding is that the coastal wetlands of the Pacific Northwest are important carbon stocks similar to or greater than the stocks in the region’s forests, which have typically received more attention and protection.



Site	TECS (Mg C/ha)
Swamp	903-1176
High Marsh	351-742
Low Marsh	156 -627
Eelgrass	45-389

Session 7: Methane and nitrous oxide emissions

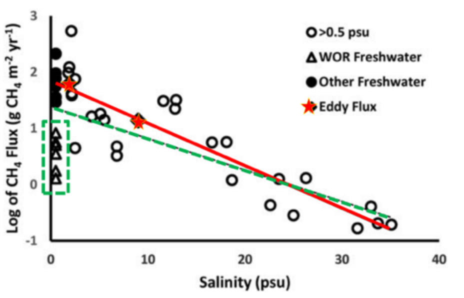
Organizers: Patrick Megonigal, Smithsonian Environmental Research Center; Mats Björk, Stockholm University
Moderator: Dorothee Herr, International Union for Conservation of Nature

7.1 Methane and Nitrous Oxide: Friend, Foe, or Indifferent?

Dr. Patrick Megonigal, Smithsonian Environmental Research Center

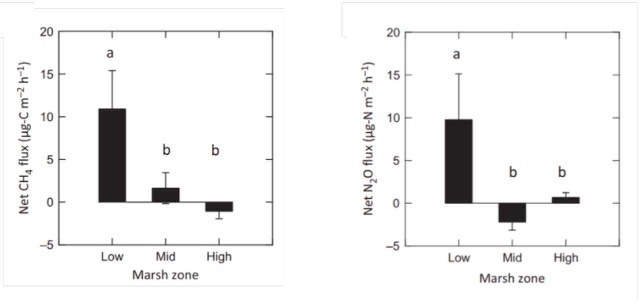
Excluding water vapor, the “big three” greenhouse gases (GHG) are carbon dioxide (CO_2), which contributes to 56% of the greenhouse effect, methane (CH_4, 18%), and nitrous oxide (N_2O, 6%). While CO_2 is frequently considered in Blue Carbon science, methane and nitrous oxide have been largely neglected. Depending on the conditions within a blue carbon ecosystem, this can be a significant oversight. Within the soil of a given blue carbon ecosystem, organic carbon (OC) is respired or stored based on the chemical conditions, namely the redox state of the system and the mix of available electron acceptors, which affect the rate at which organic carbon is degraded. For example, an oxic system degrades OC much more quickly than one which relies upon a lower energy e- acceptor like those that yield methane, the process that results in the slowest rate of decay. Generally speaking, the more carbon stored in the system, the more methane is released via microbial decay. There are many challenges to quantifying CH_4 and N_2O fluxes in Blue Carbon systems because gases do not accumulate, but instead flux out of the system, varying widely at fine spatial and temporal scales. Thus, besides the pathway of photosynthesis to burial that we use for soil carbon sequestration, we must also account for methane degassing, and the export of methane, particulate OC, dissolved OC, and dissolved inorganic carbon in water. One important proxy for understanding the relative importance of methane emissions across sites is salinity, as CH_4 flux decreases predictably with increasing salinity. A second proxy is elevation: low marshes emit much more CH_4 and N_2O than mid- or high marshes. These proxies have allowed us to model methane and nitrous oxide emissions so that they can be accounted for when considering blue carbon ecosystem emissions. Furthermore, the proxies reveal several management options for reducing the flux of these powerful GHGs, like reintroducing tidal hydrology, preventing the conversion of mangroves to rice fields, and restoring seagrasses.

PROXIES: SALINITY PREDICTS METHANE EMISSIONS ACROSS SITES



Holm et al. (2016) *Wetlands*
Poffenbarger et al. (2011) *Wetlands*

PROXIES: ELEVATION PREDICTS METHANE AND N_2O EMISSIONS

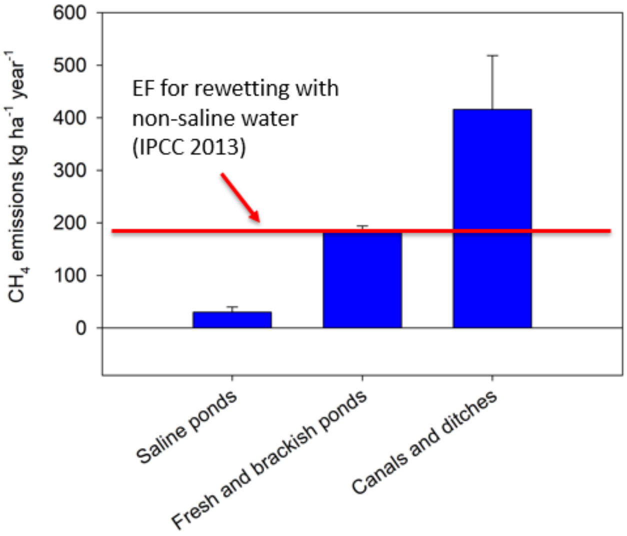


Yang and Silver 2016 *Global Change Biology*

7.2 2019 Refinement of the 2006 IPCC guidelines for national greenhouse gas inventories

Catherine Lovelock, The University of Queensland

There are three key documents for calculating GHG inventories for coastal wetlands: the 2006 IPCC guidelines, the 2013 IPCC Wetland Supplement to the IPCC 2006 Guidelines, and the new 2019 Refinement of the 2006 Guidelines. Notably, the 2019 Refinement does not modify the 2013 Wetlands Supplement. However, it does include new guidance for "flooded land," which previously existed only in the appendix of the IPCC 2006 Guidelines. The flooded land is divided into two categories: reservoirs and other constructed water bodies, including waterbodies like agricultural ponds and ditches. The guidance provides information for a Tier 1 estimate of non-CO_2 emissions, as well as explanations of how to estimate emissions more accurately at Tiers 2 and 3 using country-specific values and/or models. The 2019 Refinement builds on the approach of the 2013 Wetland Supplement by including a method whereby a methane emissions factor (EF) is applied for constructed water bodies, including aquaculture ponds. The EF for saline ponds is low, but non-zero, and the EF for fresh, linear water bodies (canals and ditches) is high, similar to reservoirs, and potentially substantial in countries with extensive construction of ditches. Further research is needed to map the area of ponds, as well as to differentiate emissions for different pond management regimes and variance in other site characteristics like soil type, nutrient inputs, aeration, etc. Remote sensing methods can be used to distinguish between inactive and actively managed ponds and methods, are emerging to support more accurate Tier 2 and 3 approaches to estimating these important sources of methane emissions.



7.3 Effects of tidal marsh elevation on methane and nitrous oxide emissions

Peter Mueller, Aarhus University

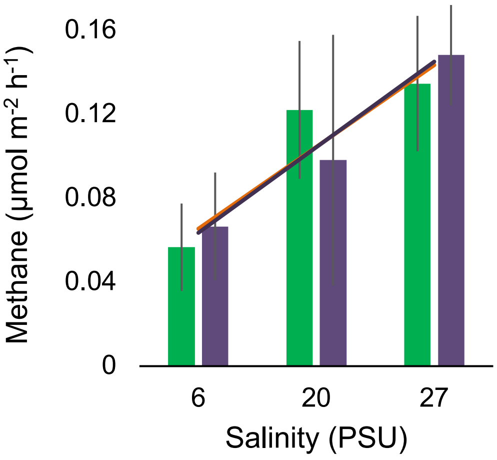
Why study methane emissions along elevation gradients? Such studies allow us to understand the effects of accelerated sea-level rise and can explain variation in emissions among marsh sites. Two recent studies have been conducted to reveal insight into this topic. In the MERIT experiment (Marsh Ecosystem Response to Increased Temperature) on the German North Sea coast, *in situ* instrumentation is used to directly measure salt marsh greenhouse-gas emissions in response to increasing temperature and marsh elevation (Fuß and Kutzbach, Universität Hamburg, unpublished data). Methane fluxes at ambient temperatures were low and generally restricted to the most frequently flooded pioneer zone. Nitrous oxide emissions were largely restricted to the high marsh and these emissions were greater in magnitude than the methane emissions. The second study, a marsh-organ experiment on Chesapeake Bay, US, assessed the methane emissions of native and invasive plants in relation to surface elevation (and thus flooding frequency) and atmospheric CO_2 concentrations (Megonigal lab, Smithsonian Environmental Research Center, unpublished data). Methane emissions were found to increase with flooding frequency, likely driven by increasingly reducing soil conditions. However, plant species composition had a greater impact on methane emissions than flooding frequency. Further, elevated atmospheric CO_2 resulted in greater methane emissions at all elevations, setting up a feedback loop that could increase methane emissions with increasing anthropogenic CO_2 emissions. The variations uncovered in these comprehensive experiments will allow for better modeling of emissions in marsh ecosystems and, consequently, better prediction of how they will change with climate change and human activity.

The flooded pioneer zone of Hamburg University's MERIT experiment.
Photo: P. Mueller

7.4 Methane emissions in Nordic seagrass meadows

Mats Björk, Stockholm University

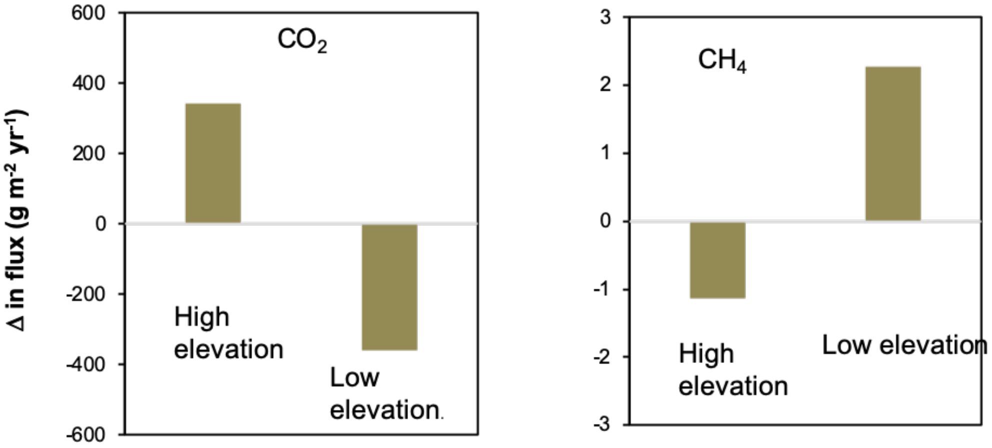
Our previous work in tropical areas have shown a significant flux of methane from seagrass meadows. This emission rate increased with organic carbon content, and was lowered by the presence of a vegetation cover. In order to estimate the blue carbon capacity of Nordic seagrass meadows, we must also determine the methane flux in these systems. Experiments were performed in *Zostera marina* meadows in Finland, Sweden, and Denmark. The data are still being analysed, but a preliminary evaluation of the results show that the total CH_4 flux was found to be low, much lower than in tropical seagrass meadows. The emissions were similar in both vegetated and un-vegetated systems, and the un-vegetated system had only a slightly lower soil OC content. Among the three country sites, the methane flux was highest in Sweden and Denmark, and much lower in Finland. Notably, the flux from the un-vegetated sediment was slightly greater than the vegetated area in both Sweden and Finland, but lower in Denmark. Methane flux appeared to increase with salinity and OC content, yet, these differences were not significant.



7.5 Methane emissions after tidal reintroduction in an Australian salt marsh

Neil Saintilan, Macquarie University

The Australian Government's Emissions Reduction Fund is being used to support the restoration of blue carbon ecosystems. In mangroves and tidal marshes, projects have been funded to reintroduce tidal flow, value the avoided disturbance of soil, and develop land-use plans for sea level rise. In seagrass meadows, the fund is being used to value the avoidance of physical disturbance, and to improve water quality or conduct revegetation work. However, studies of emissions at these sites demonstrate the importance of marsh site selection for restoration projects to ensure a GHG benefit. Typically, the restoration of tidal flow is expected to reduce methane emissions in salt marshes. Studies of several restoration projects in Australia do confirm that there was an overall GHG benefit achieved, and at the Tomago wetland on the Hunter River there was a significant reduction in CO_2 emission in a site converted from vegetated to open water habitat following tidal reinstatement. However, the methane flux will not be high if the site is exposed to saline intrusion from groundwater prior to tidal reintroduction. This means that tidal reinstatement will not achieve methane reductions if benchmark salinities are higher than 18 parts per thousand. Measures should be taken if salinity or electrical conductivity prior to the planning of tidal reinstatement if emission reduction in an intended outcome. Even so, tidal flooding also significantly changed the bacterial community in the lower elevation impacted sites, with higher representation of sulfur-reducing bacteria. This suggests that tidal restoration may quickly restore the biogeochemical conditions suitable for methane gas reduction. Finally, extreme changes to precipitation levels (whether flood or drought) were still shown to exert a strong influence on carbon flux following tidal re-instatement. So, determining the methane emissions impact of the restoration of tidal flow in a marsh requires careful attention to the variation among sites and the variation in climatic conditions at the site.



Negandhi, K., et al. (2019). *Scientific reports*, *9*(1), 4368.

Session 8: Designing a Nordic Roadmap for Blue Carbon

Organizers: Marianne Holmer, University of Southern Denmark; Mats Björk, Stockholm University; Christoffer Boström, Åbo Akademi University; Dorte Krause- Jensen, Aarhus University; Helene Frigstad, NIVA; Steven Lutz, GRID-Arendal; Jim Fourqurean, Florida International University

Moderators: Marianne Holmer, University of Southern Denmark, and Emily Pidgeon, Conservation International

The session began with an exercise where participants were asked to write down why BC is important for Nordic countries and why they are interested in creating a blue carbon network. The answers were wide-ranging and cited both the climate mitigation and adaptation benefits of the ecosystems as well as their inherent value. The network was important to participants because it will allow for scientific exchange and identify the most important questions; facilitate better connection between science and policy to protect and restore the ecosystems; raise the profile of BC in the region, including for the public; and stimulate investment in BC research and projects.

Then, the group brainstormed action items in four categories that cover the proposed goals for the network: improve Nordic BC science and scientific collaboration, particularly around preparing data for policy; raise regional awareness of the importance of BC; develop and advocate for policies that conserve and restore BCEs for climate mitigation and adaptation; and collaborate on restoration and conservation projects:

Improve Nordic BC Science and Scientific Collaboration

- Identify research questions
- Place BC in larger ecosystem valuation frameworks
- Define natural flux, stock info. to help get other BC systems in GHG framework
- Write a white paper for inventory person/team, perhaps using the emission factor database or Tier One values, to determine managed wetlands extent, impact of conversion activities
- Collaborate on proposals to support the network and salt marsh mapping
- Integrate BC data into other data systems already prepped for inventory, like forests

Raise Awareness of BC

- Form a Nordic BC network – like existing seagrass network, but with policy, joint research and shared management knowledge, translation into policy, possible advisory board of managers and politicians
- Define common ground for Nordic countries – marshes in NDCs could be a first step before tackling kelp, as they are mappable (though little data available), possibly broaden out to other systems

- Create a communications platform to encourage social mobilization, not just awareness
- Target inventory teams, given that BC is sometimes a small fraction of land and gets neglected, consult with forestry people for feedback on science priorities
- Engage public, civil society, policymakers – provide recommendations to Nordic council ministers, define step two for policy awareness
- Use citizen science as a tool for building a common public language for B.C. issues, examples are UK salt marsh app, WWF Guillemot bird cam, other cams possibly in seagrass beds, ghost net fishing app, adopt a seagrass meadow like adopt a tree concept, generate stories about individual organisms/places
- Connect with regional environmental NGOs, community organizations
- Provide forum for connection of different climate and ocean policy groups, using the strategy of UP, IN, OUT: UP - policy, IN - scientists, OUT – public
- Cultivate champions within specific ministries
- Be real about B.C. not being the ultimate climate solution, but playing a role for many priorities, have scientific integrity in comms to build credibility

Develop and Advocate for BC Conservation and Restoration Policies

- Support science-based policy
- Provide info. for GHG inventories, emissions-based, possible product of Nordic B.C. network, but still need to figure out where macroalgae/kelp fits so it can be integrated
- Integrate BC data into other data systems already prepped for inventory like forests, engage forestry community
- EU – look for a way to get BC ecosystem funding
- Engage International Partnership for Blue Carbon – government to government, add Nordic Countries

Collaborate on Conservation and Restoration

- Provide technical advice for projects to reintroduce tidal flows

Finally, the group worked on a proposed six-month workplan for the Nordic Working Group that would capture the momentum of the meeting, make progress on BC issues in the region, and build the connections that the participants hoped to secure.

SIX MONTH PLAN

Objective 1: Form Nordic Blue Carbon Network

The first task in forming a new Nordic Blue Carbon Network is to determine the participants. The group felt that it was important to include representation from each Nordic country and to have a sub-group to coordinate the work. Volunteers for the coordination sub-group included: Steven Lutz, Mats Bjork, Dorte Krause-Jensen, and Christoffer Bostrom. It was decided that the network needs an increase in salt marsh expert representation, and that the coordinating sub-group should also include a policy expert or policy-experienced scientist.

Some of the goals of the network will be: promote consistent messaging; promote data sharing and scientific coordination to make sure all of the key questions are answered; stimulate research collaboration across the region; and establish the network as a thought-leader to create vision, coordination and momentum for BC in Nordic countries.

Various participants mentioned some key resources that may help the network: partnership with the Nordic Oceans and Climate counselors' group; use of the Coastal Carbon Research Coordination Network and its Coastal Carbon Atlas as a place to upload and aggregate regional data; and a student coordinator, potentially funded via one of the coordinating sub-group's university labs.

Specific Tasks Identified:

- Hold an initial meeting of the coordinating sub-group at a regional blue carbon science meeting in November

Objective 2: Establish policy connections

In order to further the ability of the network to influence regional national blue carbon policy, the group felt that the first step was to build key relationships with policymakers, and subsequently identify champions to cultivate and from whom to learn about the policy context. They also noted that climate, aquaculture and fisheries policy sectors might be good partners for future work.

Specific Tasks Identified:

- Encourage Nordic countries to join the International Partnership for Blue Carbon, a government to government partnership
- The coordinating sub-group should start making a network map of the relevant managers of BCEs in each country and build relationships with them
- Schedule introductory meetings with policymakers using materials from this workshop
- Connect with Stockholm University Baltic Science Center (Mats Bjork's research group) to draft a two-pager for scientists from policymakers about their needs and perspective and share in the region

Objective 3: Produce scientific outputs

The group identified several specific scientific outputs for the network to fill critical knowledge gaps. Participants agreed that it was important to consider the place of BC in other larger-scale ocean projects and research. They also discussed the importance of further general research about BC and seascape management; quantifying how BC serves multiple policy priorities; and how BC can fit into various spatial and temporal scales of management and science.

Specific Tasks Identified:

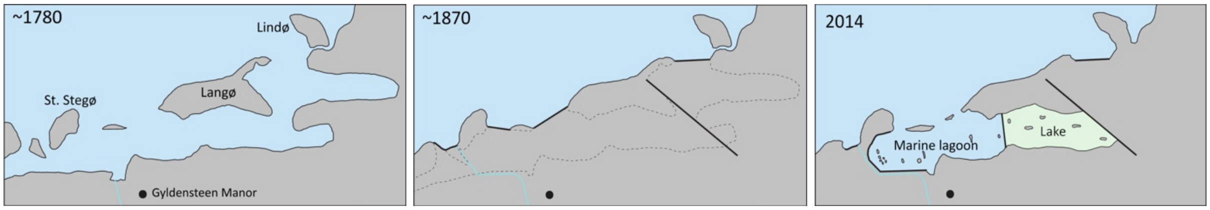
- Dorte Krause-Jensen will lead a paper reviewing the information available on Nordic BCEs and what is still needed for policy applications.
- A paper, potentially to be led by Peter Ralph, will address the controversy around the potential of macroalgae as BCEs, which is especially important in the Nordic region with the massive growth of kelp farming and the industry has proposed that it may produce climate mitigation benefits.
- Gary Banta volunteered to coordinate salt marsh proposals and collaborations to expand the available data.
- Collaborate with the Coastal Carbon Research Coordination Network to upload BC data into the Coastal Carbon Atlas: https://ccrcn.shinyapps.io/CoastalCarbonAtlas/. BCI Scientific Working Group Member Patrick Megonigal is a PI on the project, and can provide assistance with any questions or technical issues.

Field Trip

The group divided in two for field visits on Thursday, September 12. One group took a canal tour of Copenhagen. The second group visited a research site outside of the city.

The research site is located in Gyldensteen Strand, a large nature reserve in the northern part of Funen, Denmark. The “Glydensteen Coastal Lagoon” is part of the reserve, and was created by deliberately breaching the dikes to an old agricultural field, with the goal of restoring biodiversity and to provide a model for how restoration projects can serve as climate adaptation and mitigation resources. Dr. Cintia Quintana, University of Southern Denmark, hosted the visit, and led the participants in various activities, including: wading in the lagoon, hiking around the property, and climbing a former mill to observe the project. The group discussed preliminary findings from biogeochemical studies of the site since tidal reintroduction. More information about the results of the project can be found in the summary of Dr. Quintana’s Session 5 presentation.

These maps show the changes in the project area from before reclamation, after reclamation for agriculture, and after the managed realignment:



This is an aerial view of the site in May, 2014, after tidal reintroduction:

Here are pictures of the working group meeting participants exploring the site:

And some pictures of historic dikes and a mill: