International Blue Carbon Initiative Scientific Working Group Meeting

October 9 - 12, 2017
University of Balearic Islands
Ibiza, Spain

WORKSHOP REPORT

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the BLUE CARBON initiative

Coordinating organizations:

CONSERVATION INTERNATIONAL

IUCN

UNESCO
United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

Workshop partner organizations:

International Blue Carbon Initiative Scientific Working Group Meeting

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Executive Summary

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, including mangroves, tidal marshes, and seagrasses. 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 goal of the Initiative is to implement projects around the world that demonstrate the feasibility of blue carbon for climate mitigation and coastal ecosystem conservation. To achieve this goal, the Blue Carbon Initiative has formed Science and Policy working groups consisting of representatives from governments, research institutions, non-governmental organizations and communities from around the world. The International Blue Carbon Scientific Working Group (IBCSWG) 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 International Blue Carbon Policy Working Group (IBCPWG) 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) among others.

In 2017 the Scientific Working Group met in Ibiza, Spain on October 9-12. The meeting was hosted and co-organized by Dr. Núria Marbà, member of the BCI Scientific Working Group and research scientist at the Mediterranean Institute for Advanced Studies (IMEDEA, CSIC-UIB), was host and co-organize the meeting.

The objectives of the 2017 meeting were to advance the science of seagrass ecosystems as a tool for climate mitigation and expand and support the blue carbon research network throughout the European and Mediterranean region. The meeting consisted of 45 presentations by local, regional, and international blue carbon experts as well as in depth discussions on current issues and needs surrounding blue carbon science, implementation, and policy. The 75 participants included members of the IBCSWG, non-profit organizations, regional and international blue carbon policy experts, students, researchers, and collaborators traveling from 25 countries worldwide.

The regional and international blue carbon scientific community from the Mediterranean region, including the European Atlantic and Baltic coasts, highlighted the importance of the local seagrass meadows as important provisioners of mitigation and adaptation benefits to coastal areas. Various participants presented updated global carbon storage estimates based on novel research related carbon burial rates. Case studies of successful salt marsh restoration and mangrove conservation and restoration projects that increased soil accretion, and thus soil carbon stocks, were presented with examples from Europe, Latin America and the Philippines. A new restoration potential map for mangroves was presented, as well as new distribution models and sonar technologies to monitor seagrass carbon content were shared with participants. These new tools and methods will allow for more informed conservation and restoration site selection, improve carbon estimates at local and regional scales, and increase our ability to track the effects

of human disturbance in seagrass ecosystems. Local and regional policy experts from the region, showcased progress in developing blue carbon conservation projects with examples in the Balearic Islands, Andalucía, and in the Mediterranean region but emphasized that there is still a need to develop new and innovative financing mechanisms.

The meeting also focused on in depth discussions related to policy relevant science. Topics included: understanding the role of carbonates in national blue carbon inventories, clarifying the role of other marine ecosystems in the context of carbon storage and carbon cycling, and reducing the uncertainties and risks associated with blue carbon conservation projects. Discussion points and recommendations will be synthesized and presented during the 2018 IBCSWG meeting in China.

Overall the meeting accomplished its two main objectives. First, it showcased the latest scientific advancements related to seagrass monitoring and carbon analysis and highlighted seagrasses as a tool for climate mitigation throughout the European and Mediterranean region. Second, the meeting expanded the blue carbon research network and communicated with local and regional decision makers the importance of supporting policies that support the protection of blue carbon ecosystems for the benefit of ecosystem health and people's livelihoods.

Figure 1. International Blue Carbon Scientific Working Group 2017 participants in Ibiza, Spain

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Day 1. Monday 9, 2017

Session 1: Opening Remarks and Welcome

Moderated by: Dr. Jorge Ramos, *Conservation International*

1.1 Blue Carbon Initiative, International Blue Carbon Scientific Working Group

Dr. Emily Pidgeon, *Conservation International*, Dr. Steve Crooks, *Silvestrum Climate Associates*

The International Blue Carbon Scientific Working Group (IBCSWG) works to synthesize blue carbon science and create science-based user-ready tools and guidance for the policy and management community (i.e., standardized methodologies for blue carbon inventories). With many contributions from the IBCSWG, research over the last 10 years has demonstrated that blue carbon coastal ecosystems play a key role in climate mitigation strategies at local to global scales. Through the efforts of the IBCSWG, a coastal blue carbon manual for carbon measurements across all three blue carbon ecosystems (mangroves, saltmarsh, and seagrasses) has been developed and coastal wetlands are now being included in national greenhouse gas (GHG) emission inventories. The mitigation value of coastal ecosystems was included in the 2015 UNFCCC Paris Agreement. These efforts have resulted in the inclusion of blue carbon in national and international climate strategies and nationally determined contributions to the Paris Agreement. Blue carbon applications have evolved from initial scoping assessments, to many applications such as: regional climate plans, carbon market tools and green and climate bonds in coastal areas, and financial mechanisms. The BCI and the IBCSWG has partnered with the Coastal Carbon Research Coordination Network and the International Partnership for Blue Carbon to strengthen the linkage with blue carbon research and policy. For more information on the Blue Carbon Initiative please visit: http://thebluecarboninitiative.org/

1.2 Recognition of regional representatives and co-chairs of the IBCSWG

Montse Garcia, *Regidora of Environment, Ajuntament de la Ciutat d'Eivissa, Spain*
Daisee Aguilera, *Consellera of Envirnoment, Consell Insular de Formentera, Spain*
Dr. Miquel Mir, *General Director of Marine Protected Areas Biodiversity Government of the Balearic Islands, Spain*
Dr. Steve Crooks, *Silvestrum Climate Associates, co-chair of IBCSWG*
Dr. Emily Pidgeon, *Conservation International, co-chair of IBCSWG*

Figure 2. Welcome and recognition of regional policy representatives.

1.3 Blue Carbon Ocean Teacher Course
Dr. Kirsten Isensee*, Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO)*

The Ocean Teacher global academy is an online platform that hosts a digital library, open access courses, and an ocean teacher classroom. To increase capacity on the topic of blue carbon an Ocean Teacher Blue Carbon course will provide a knowledge sharing platform, build capacity in blue carbon project implementation, and drive science based international legislation of blue carbon projects with correct information. The purpose is to introduce the latest science on blue carbon ecosystems, teach the correct methods of measuring carbon stock and sequestration rates, and provide guidance on how to include blue carbon in policy relevant documents. Volunteers are needed to help develop the course modules and review the content of the course. The five module topics include: introduction to blue carbon, field and laboratory methodologies, information on science policy frameworks, design and implementation of projects, and knowledge exchange of blue carbon projects worldwide.

Day 2. Tuesday 10, 2017

Session 2. Status of blue carbon science for Mediterranean and European ecosystems

- Moderated by: Dr. Núria Marbà, IMEDEA

2.1. Effect of anthropogenic pressure on seagrass Mediterranean carbon sinks.

Dr. Núria Marbà, *IMEDEA*

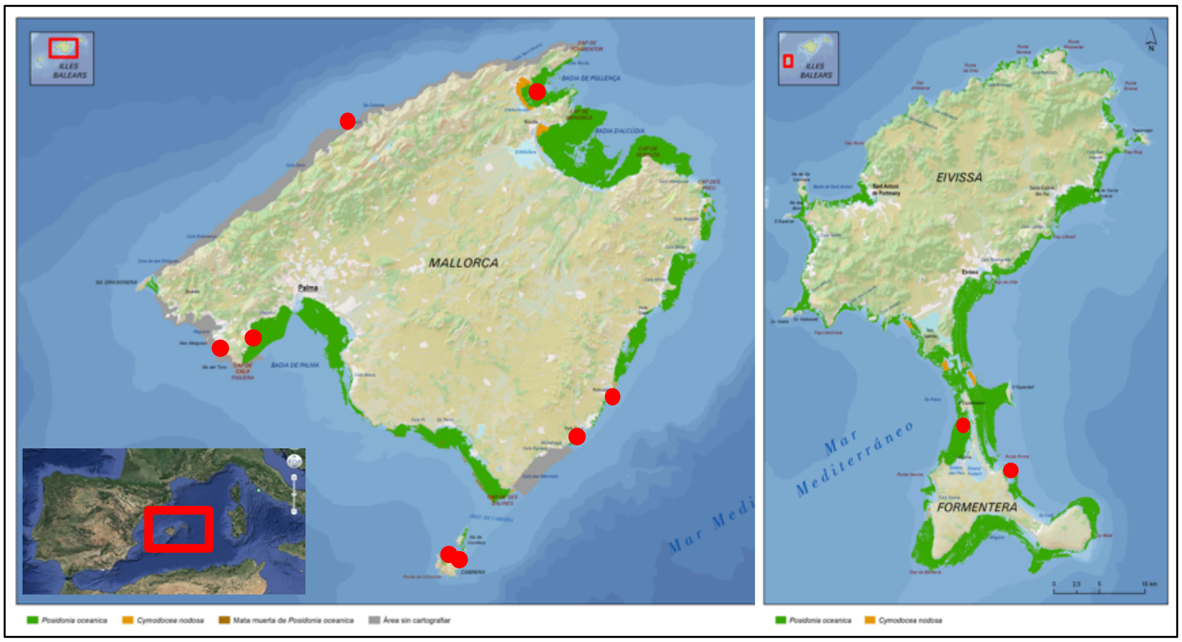

Figure 4. Extent of Posidonia oceanica seagrass meadow in the Balearic Islands in the Mediterranean region and study sites (red dots).

Figure 3. Posidonia oceanica seagrass meadow (photo credit: Manu San Felix).

Posidonia oceanica is an endemic seagrass in the Mediterranean Sea covering approximately 50,000 km^2 of the seafloor. The *P. oceanica* seagrass meadow ecosystem is reported to be the main carbon sink with burial rates ranging from 9-114 g C m^{-2} yr^{-1} at certain sites in the Mediterranean Sea. Due to coastal deterioration driven by human activities, it has been reported that between 13-38% of the total area of *P. oceanica* may have been lost since 1960. Though extent has been reduced, a study in the Balearic Islands has shown that coastal eutrophication has enhanced C_{org} burial from seston (suspended algae) in seagrass meadows of the region. Unfortunately, the recent enrichment in sestonic carbon might imply a weakening of the carbon deposits, as they may become easier to remineralize and, thus, more vulnerable to disturbances.

2.2. *Posidonia oceanica* a major Blue Carbon Ecosystem, what is being done in Corsica?
Dr. Gerard Pergent, *University of Corsica, France*

Figure 5. Posidonia oceanica in Corsica, France.

Since 2004, there is ongoing effort to assess blue carbon ecosystems of the island of Corsica, France. The process to accomplish this include developing a mapping inventory, implementing monitoring efforts, and quantifying carbon fluxes and stock within blue carbon ecosystems. Efforts have mapped 53,000 ha of *P. oceanica* in Corsica and scientists estimated at 3.5 million ha the surfaces covered in the Mediterranean Sea. With an estimated rate of carbon fixation of 1 t C ha^{-2} yr^{-1} and a sequestration of 27-30%, these ecosystems are estimated to sequester around 1 million t of C yr^{-1}in the Mediterranean Sea. These same seagrass meadows have been found to store approximately 1,190 t C ha^{-2} in the soil organic profiles. The high rates of carbon sequestration and storage has led to new studies that will address the impacts and pressures associated with climate change for Corsica and the Mediterranean Sea.

2.3 Invasion of *Halophila stipulacea* in the Mediterranean Sea: an introduced carbon reservoir?
Dr. Eugenia Apostolaki, *Hellenic Centre for Marine Research, Greece*

Figure 6. Invasive grass of Halophila stipulacea in the Mediterranean Sea (photo credits to Dr. Thanos Dailianis (HCMR).

Halophila stipulacea is an invasive seagrass slowly increasing its cover in the Mediterranean Sea. Due to a result of warming coastal waters in the Mediterranean Sea, there is an expectation of a possible faster and greater expansion of *H. stipulacea.* No evidence exists of competition interaction with native species in the region. However, negative competition effects have been recorded in the Caribbean region. Efforts to investigate its role in coastal carbon revealed that areas with *H. stipulacea* stored more carbon in the Mediterranean Sea compared to the Red Sea and had a higher burial rate of carbon than non-vegetated areas. These results show that the invasive effect of *H. stipulacea* is building a carbon reservoir as it usually only colonizes sandy habitat void of native seagrasses. More research is needed to study carbon fluxes and ecological interactions as *H. stipulacea* continues to expand its cover in the Mediterranean Sea.

2.4. Blue carbon stocks in *Zostera marina* meadows in the Baltic Sea - role of environmental settings.

Dr. Marianne Holmer; Dr. Rohr E, Boström C. *University of Southern Denmark, Denmark*

Figure 7. Zostera marina meadows in the Baltic Sea.

Zostera marina is an eelgrass with a widespread distribution in the Baltic Sea with over 6000 individual meadows covering 1500-2000 km^2. New research shows that the *Z. marina* meadows in Demark were seven times higher in carbon content and had higher variability among the sampled sites compared to Finland. Researchers discovered that variables such as soil characteristics, root:shoot ratio, and presence of seagrass help explain the organic C (C_{org}) stored in *Z. marina* meadows. Compared to other seagrasses, the C_{org} stored in *Z. marina* meadows is lower than *P. oceanica* but similar to other meadows found in Australia and Asia.

2.5. Blue carbon storage in *Zostera marina* - a global survey.

Dr. Christoffer Boström, *Åbo Akademi University, Finland*

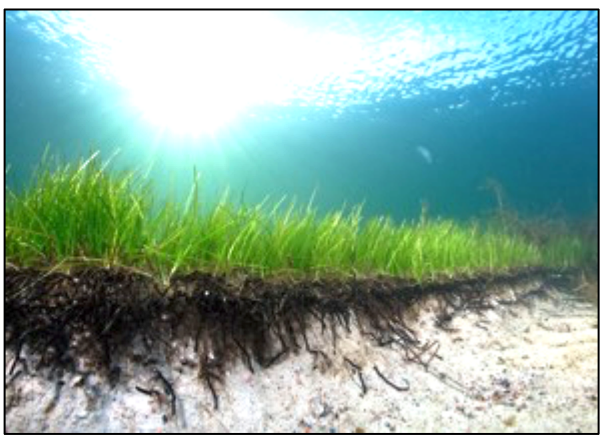

Figure 8. Zostera marina eelgrass meadow.

The Zostera Experimental Network (ZEN) was created to quantify how nutrients and grazing interactively affect biomass, production, and trophic transfer in eelgrass meadows along natural gradients. A study coordinated by ZEN sampled 162 cores from 54 meadows in 13 countries. The study found carbon stocks in *Z. marina* meadows ranged from <1 to 10 kg C_{org}. Plankton was discovered as the main contributor (42%) of carbon to these ecosystems, followed by *Z. marina* (34%) and drift algae (14%), among others. Around the world seagrasses are estimated to store approximately 120 t C ha^{-1}. This new study reveals that after *P. oceanica* (480 t C ha^{-1}), *Z. marina* (300 t C ha^{-1}) is the next most efficient seagrass species in carbon sequestration and storage.

2.6. Life Blue Natura Project: Blue carbon Science for action in the Atlantic and Mediterranean region.

Dr. Mar Otero, *IUCN-Centre for Mediterranean Cooperation*

Figure 9. The location of the project LIFE Blue Natura in Andalucía, Spain.

Andalucía is located in Southern Spain and has a significant extension of coastal marshes and seagrass meadows along the Atlantic and Mediterranean coasts. The two-year (2017-2019), LIFE Blue Natura project, will focus on understanding the role of these ecosystems have in the coastal carbon cycle and identify opportunities to support the conservation and restoration. The study will begin sampling approximately 7000 ha of seagrass meadows and 24,400 ha of salt marshes followed by public outreach and ecosystem, management workshops. The outcomes of the project will be translated into tools that will increase blue carbon awareness, blue carbon method trainings, identifying opportunities to include blue carbon in the carbon market, and integrating it in local and national level policies.

2.7. Blue carbon in southern Portugal.

Dr. Rui Santos, *Universidade do Algarve, Portugal*

The Ria Formosa lagoon in Portugal is dominated by saltmarshes (*Spartina maritima*) and below the surface of the water *Zostera noltei, Cymodocea nodosa,* and *Caulerpa prolifera* seagrass species. The region is characterized by an elevation gradient which influences sedimentation rates along seagrass communities. Allochthonous particulate organic matter (POM) was found to be the main source (>50%) of C_{org} along the elevation gradient followed by POM from *S. maritima*. The long-term storage of C_{org} was found to be greater in the *S. maritima* and *Z. noltei.* Future work will include applying new data in the InVEST tool to model ecosystem services provided by the seagrass ecosystems. The project will partner with the Environmental Education Network on Ecosystem Services (REASE) to raise awareness on ecosystem services and blue carbon. For more information on the InVEST model visit: https://www.naturalcapitalproject.org/invest/

Figure 10. Ria Formosa lagoon in Portugal and images of local saltmarshes and seagrass meadows.

2.8. Carbon stocks and fluxes across the land-sea interface.
Dr. Annette Burden, *Centre for Ecology & Hydrology, UK*


Figure 11. A natural salt-marsh (left) and a salt-marsh undergoing coastal managed realignment (right).

The Natural Environment Research Council, Centre for Ecology & Hydrology (NERC-CEH) is interested in how the environment interacts with the atmosphere and have several projects investigating carbon cycling and sequestration in the UK. For vegetation in coastal ecosystems, MultiMOVE niche model was applied to investigate sources of greenhouse gas emissions at the individual plant species' resolution. Model results showed potential for incorporation into large-scale and national greenhouse gas accounting programs. The CEH is developing other projects: 1) the use of satellite data to standardize peatland condition assessment, 2) NERC Value Nature Program, predict how key ecosystem services change when ecosystems cross tipping points, 3) UK LOCATE, address the fate of soil organic carbon in coastal areas, 4) integrating coastal wetlands in the UK national greenhouse gas emissions inventory, and 5) understanding the carbon sequestration and storage in salt marshes subject to coastal management practices. For more information on the MultiMOVE model visit:
https://catalogue.ceh.ac.uk/documents/94ae1a5a-2a28-4315-8d4b-35ae964fc3b9

2.9. Resilience of saltmarsh carbon stores in the UK.
Dr. Martin Skov, *Bangor University, UK*

Figure 12. Study was designed to study the impact of grazing on saltmarshes carbon stock in the UK.

Increasing pressures on saltmarshes from grazing, coastal erosions, and high accretion rates are driving regime shifts. Due to the reported high carbon content (~100-400 Mg C ha^{-1}) in these saltmarshes, it is important to study the resilience of these ecosystems under these pressures. Preliminary results show no detectable effect of grazing on carbon content, suggesting that saltmarsh carbon stores might be resilient to grazing. New long-term studies have shown that marshes are resilient to recent channel shifts through a shifting of marsh cover in the area. More research is needed to understand the interactive effects of these pressures on the resilience of below ground blue carbon stores and accretion rates.

2.10. Carbon sequestration in the artificial salt marshes of the European Wadden Sea
Dr. Peter Mueller, *University of Hamburg, Germany*

The Wadden Sea UNESCO World Heritage site contains 40,000 ha of salt marshes which are expanding at a rate of 200 ha yr^{-1}. Most of these salt marsh ecosystems are a result of land reclamation efforts. Preliminary research found that these created salt marsh ecosystems are sequestering carbon at 2.49 t C ha^{-1} yr^{-1} (short term) to 1.12 t C ha^{-1} yr^{-1} (long term). Livestock grazing yields the potential to enhance carbon sequestration in these ecosystems by increasing the soil fungi:bacteria ratio and slowing C turnover. Future research will investigate how salt marshes will respond to increasing temperatures in the region.

Figure 13. Majority of the Wadden Sea salt marsh ecosystems are a result of man-made restoration and land-reclamation efforts.

2.11. *Carbon sequestration and greenhouse gas emissions in Mediterranean coastal wetlands*

Dr. Carles Ibáñez, *Institut de Recerca i Tecnologia Agroalimentàries (IRTA), Catalonia, Spain*
Dr. John Callaway, *University of San Francisco, California, USA*
Dr. Siobhan Fennessy, *Kenyon College, Ohio, USA*
Dr. Maite Martínez-Eixarch, *IRTA, Catalonia, Spain*

Figure 14. The two research sites as par, Ebro Delta in Spain (left) and San Francisco Bay in USA (right).

To better understand the carbon fluxes in salt marsh-tidal ecosystems, a study was designed to quantify carbon fluxes in two main deltas, Ebro Delta in Spain and San Francisco Bay in USA. Results show that carbon sequestration is not correlated to tidal ranges or local aboveground productivity. The observed variation in carbon sequestration rates in both systems is more likely to be influenced by the modified hydrology and natural sea level conditions. Additionally, results showed that rice fields emitted more methane (CH_4) than natural wetlands and that soil salinity was negatively correlated to carbon accretion and to CH_4 emissions. These results indicate that greenhouse gas emissions and C sequestration can be optimized by changing water management and farming practices.

2.12. Adaptation and mitigation co-benefits for Mediterranean and European ecosystems.
Dr. Iris E. Hendriks, *Institut Mediterrani d'Estudis Avancats (IMEDEA), Spain*

Figure 15. Salt marshes, seagrasses and mangroves provide mitigation and adaptation services.

A meta-analysis was designed to provide a quantitative basis to assess the role of vegetated coastal habitats in shoreline protection from sea level rise and storm surges and compare to sediment accretion and carbon burial. It was hypothesized that the capacity to attenuate waves is related to the density of the seagrass meadow and the salt marshes' submergence ratio (the seagrass height divided by water depth). Results showed that seagrasses contribute to wave reduction more efficiently whereas salt marshes contribute to wave attenuation, current reduction, and wave energy reduction. More research data from more ecosystems is needed to investigate the relationship between the capacity coastal vegetation to attenuate currents and their carbon sequestration capacity. Additional research needs to incorporate how increasing ocean temperatures and sea level rise will modify structural changes in vegetation and submergence ratio.

Session 3. Key questions in Blue Carbon Science

Moderated by: Dr. Carlos Duarte, *King Abdullah University of Science and Technology (KAUST)*

The number of citations per year to papers published with "blue carbon" as a topic has increased exponentially since 2004. A questionnaire was designed to survey the blue carbon scientific community to discover what are the new and most pressing questions in blue carbon scientific research. Summarizing, the top questions compiled from the survey responses addressed the following topics: cumulative impacts of changing climate and anthropogenic disturbances on carbon accumulation, the role of other ecosystems such as macroalgae in climate mitigation, improved global cover and time series maps and data of blue carbon ecosystems, role of carbonate in carbon dioxide (CO_2) fluxes, economic value of blue carbon, assessment of blue carbon coastal ecosystems interaction with the atmosphere, and best management actions to maintain and promote natural carbon sequestration. A complete summary of survey results will be will be published in a forthcoming publication.

Session 4. Seagrass ecosystems and carbon studies- A new look at seagrass ecosystems.

Moderated by: Dr. Hilary Kennedy, *Bangor University*

4.1. Modelling distribution of the seagrass *Zostera marina*.

Dr. Christoffer Boström, *Åbo Akademi University, Finland*

Figure 16. New methods are being developed to improve mapping and quantification of seagrass ecosystems.

Mapping and quantifying seagrass carbon stocks requires knowledge of seagrass distribution, though methods are extremely time consuming or underdeveloped. Rather than mapping seagrass distribution by observation, research is underway to explore ecological niche modeling to predict presence and absence of seagrasses. Different modeling methodologies are now being tested using GAM, Maxent and GAMMAX, models with very similar outcomes. All of them have the capacity to inform management and decision makers to better assess the extent of seagrasses and the effects of small scale disturbances such as turtle grazing and algal shading.

4.2. Updates on carbon in seagrass ecosystems.

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

Side scan sonar can be used to detect changes in macroalgae and seagrass as well as changes in sediment density, including human disturbance (i.e., boat propeller scars). This data is inexpensive and provides high-resolution images, requires minimal processing, and it is highly efficient in shallow coastal areas. The limitation of side scan sonar is that it requires previous local habitat knowledge to interpret results and is labor intensive in that it requires measurements be done locally and not remotely. The new parametric sonar field methods can be used to measure carbon content in seagrass beds. Preliminary results show this new technique has the capacity to estimate up to 76% of the organic carbon of one-meter soil core in a seagrass meadow.

4.3. Modern carbon burial rates in seagrass ecosystems: implications for Blue Carbon science

Ariane Arias-Ortiz, *Universidad Autonoma de Barcelona, Spain*

Globally it is estimated that in the top meter of soil, seagrasses store carbon between 4.2 and 8.4 Pg C and they have an overall carbon burial rate between 0.05 to 0.11 Pg C yr^{-1}. With an approximate global area of 600,000 km^2 and a carbon burial rate of 138 g C m^{-2} yr^{-1}, it can be estimated that seagrasses represent approximately 10% of the total C buried in the ocean. New carbon burial rate data from the last 100 years, using radiometric techniques by means of C-14 and Pb-210, estimate C burial rates in seagrass ecosystems at an average of 36 g C m^{-2} yr^{-1} (0.5-308 g C m^{-2} yr^{-1}). This is four times lower than the first global estimate (138 ± 38 g C m^{-2} yr^{-1}) and in line with value reported in the 2013 IPCC Wetlands Supplement (43 g C m^{-2} yr^{-1}). More research is needed to determine the factors of carbon burial rates such as carbon content in the sediments and sedimentation accumulation rates. Additionally, data on stocks and burial rates are missing in the southeast Pacific, tropical eastern Atlantic, western African coast and in the pacific island coasts. Compiling data from new sites with various rates of accumulation will inform blue carbon scientists and policy makers which sites are the fastest and most efficient at sequestering carbon.

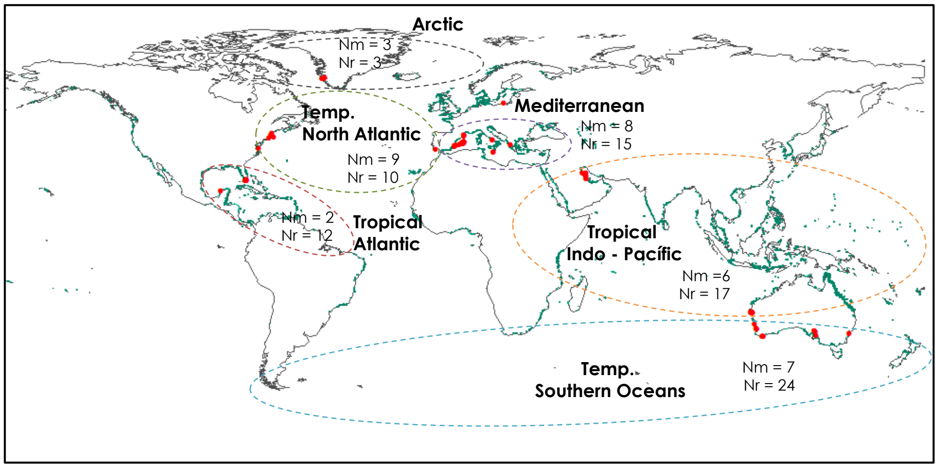

Figure 17. Distribution of seagrass meadow ecosystems and data locations on C burial rates analyzed in this study.

4.4. Drivers of CH_4 and N_2O emission rates in tropical seagrasses - ongoing studies from the Western Indian Ocean.

Mats Björk, *Stockholm University, Sweden*

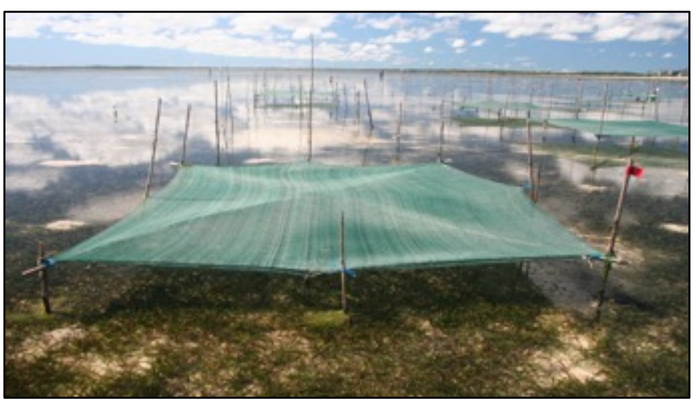

Figure 18. Experimental shading of seagrass meadows in Tanzania.

Carbon dioxide (CO_2) is the greenhouse gas most commonly considered in climate change discussions and greenhouse gas mitigation planning efforts. Similarly, the blue carbon scientific community has focused in CO_2 as the primary greenhouse gas linked to carbon source/sink dynamics in coastal ecosystems. However other gases such as methane (CH_4) and nitrous oxide (N_2O) are important and should be studied. Along a gradient of increasing anthropogenic pressure on seagrass meadows in Tanzania, CH_4 and N_2O emission rates increased along an urban development. Further, higher emission rates of CH_4 and N_2O were observed from the seagrass meadows experimentally exposed to higher levels of disturbances, such as shading and clipping. Experiments revealed that higher CH_4 and N_2O

emission rates from seagrasses will be influenced primarily by disturbances directly modifying physiological processes, followed by slow biomass degradation of the ecosystem.

4.5. Seagrass Deposits as Time Capsules of the Human Past.
Dr. Dorte Krause-Jensen*, Århus University, Denmark*

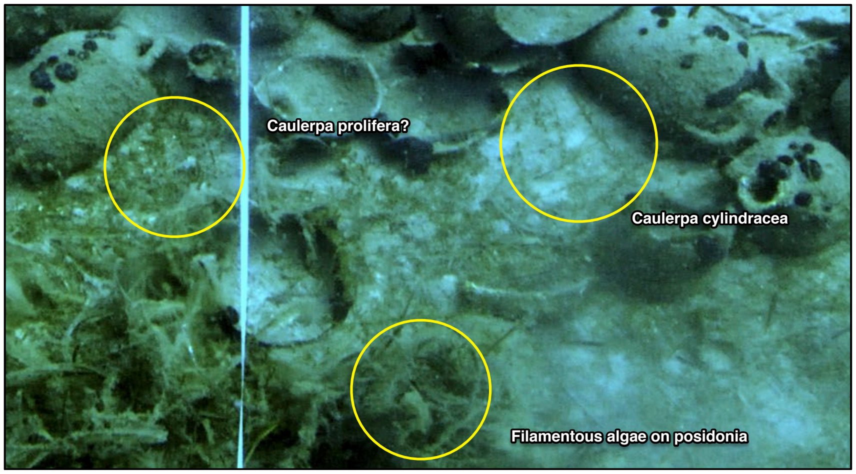

Figure 19.Archeological items from a shipwreck in the Aegean Sea, Greece surrounded and protected by seagrass ecosystems.

Seagrasses provide and number of ecosystem services that can be listed alongside carbon sequestration and greenhouse gas mitigation. Cultural services from seagrasses have been understudied and have been predetermined by others as low providers of cultural services. For example, an overlooked service is the ability these ecosystems to protect submarine archaeological heritage sites. For example, *Posidonia* meadows have protected and preserved ancient Italian pottery and Greek ships and artifacts. Research valuing ecosystem services must start to investigate the significance of the cultural ecosystem services provided by seagrasses as they may provide additional impetus for conservation and restoration.

Session 5. Seagrass ecosystems and carbon studies - The role that carbonates play in blue carbon inventories.

Dr. James Fourqurean, *Florida International University, USA*

Blue carbon science and policy have focused primarily on the relationship between organic carbon (from living and dead plant material) and CO_2. The CO_2 sequestered as organic carbon in blue carbon coastal ecosystems can be linked to less CO_2 in the water column and atmosphere. Inorganic carbon, in the form of solid carbonates, has been overlooked in blue carbon discussions but make up the soil matrix of many seagrass ecosystems. The creation of this solid inorganic carbon (calcification) acts as CO_2 source and with more calcification, more CO_2 could be emitted to the ocean water and atmosphere. Organic and inorganic processes may need to be considered for a complete understanding of CO_2 sequestration and production in seagrasses and other blue carbon ecosystems. Further topics of discussion included: role of the organic/inorganic ratios to determine their sink/source dynamics; management strategies that can promote sequestration of CO_2 from the water; temporal scale differences between inorganic and organic carbon processes; quantification of direct CO_2 emissions from blue carbon ecosystems; and challenges with the "0.6 rule" (ratio of CO_2 produced to solid carbonate formed). The complete summary from these discussions will be provided in a forthcoming report.

Day 4. Wednesday 11, 2017

Session 6. Considering Other Coastal Ecosystems, Carbon Cycling vs. Carbon Storage

Moderated by Dr. Emily Pidgeon, *Conservation International*

Mangroves, tidal marshes, and seagrass meadows meet the key criteria to be included in climate mitigation policy frameworks. The key criteria include: 1) high carbon sequestration potential; 2) there is a clear ownership/governance of the ecosystem; 3) management activities can be applied to enhance climate mitigation purposes; and 4) policy frameworks and funding mechanisms exist that can be applied for the conservation and restoration of these ecosystems. Other ecosystems such as coral, kelp, phytoplankton, and other marine fauna currently do not meet all of these key criteria. The following presentations explore other coastal ecosystems, their role in carbon cycling and sequestration, and challenges in meeting the blue carbon key criteria.

6.1. The role of macroalgae in C-sequestration.

Dr. Dorte Krause-Jensen, *Aarhus University*, and Dr. Carlos Duarte, *KAUST*

Figure 20. Macroalgal forests are being explored as potential blue carbon ecosystems but additional long-term carbon sequestration data is needed.

Macroalgal forests have a current extent of 3.4 (1.4-6.8) km^2 worldwide, are highly productive and provide a wide range of ecosystem services. Their role as carbon sinks has been explored over the past years but the fate of their exported carbon is still unclear. Most macroalgal beds grow in rocky environments, hence they do not accumulate and build rich organic deposits underneath them. This growing structure determines that macroalgae have a very low proportion of their carbon buried compared to the very high proportion of their carbon exported. Some studies have found evidence of macroalgae presence in the deep sea, suggesting that biomass from macroalgae can be exported to the deep-sea floor. New studies have estimated a global rate of 173 (61-268) Tg C yr^{-1} of total carbon sequestration from macroalgae ecosystems. This new information offers an opportunity to begin exploring a pathway for macroalgae ecosystems to be considered a blue carbon ecosystem. Next steps should include the collection of additional C export flux data from macroalgae ecosystems and an investigation of long-term carbon sequestration potential.

6.2. Kelp in Nordic Blue Carbon Systems
Dr. Sindre Langaas, *Norwegian Institute of Water Research (NIVA)*

Figure 21. Global distribution of kelp forests.

The Norwegian Blue Forests Network was founded to mobilize the Norwegian expertise to promote the sustainable management of the blue forests in Norway and abroad. Research has focused on mapping global distribution, species, trends and the ecosystem services of kelp forests. Recent estimates quantify the carbon sequestered by kelp forests to exceed the carbon sequestered in seagrasses, tidal saltmarshes and/or mangroves. More research is needed to investigate its potential to effectively sequester and store carbon from oceans and atmosphere. The NBFN is leading more than ten projects studying the role of kelps as C sinks, aiming to increase knowledge of carbon cycling in blue forests.

6.3. Blue Carbon: Recognizing the importance of long term C storage.
Dr. Peter Ralph, *University of Technology, Sydney*

Macroalgae ecosystems are an essential coastal marine ecosystem that provide critical ecosystem services to our coasts and oceans. There are a number of increasing opportunities to integrate macroalgae into a market in the evolving blue economy sector. It is a highly productive system with significant amounts of CO_2 uptake, but the fate of its biomass is still unclear. A recent study identified several challenges for the macroalgae ecosystem to be considered a blue carbon ecosystem: 1) grows in hard substrate; 2) fate of detached thallus is poorly understood; 3) recalcitrance of its carbon biomass is unknown; 4) organic rich detritus contributes to the allochthonous components of other habitats; and 5) important to establish provenance. The scientific community agrees that because macroalgae ecosystems grow on hard substrate it mostly provides allochthonous carbon to other habitats, serving more like a blue carbon donor. Issues that still need to be addressed include developing accurate measurements of C accumulation in the deep ocean, ownership and management of deep ocean carbon, possible integration to greenhouse gas inventories and potential use as biofuels and other macroalgal products.

6.4. An IPCC context for Ocean Carbon Storage.
Dr. Hilary Kennedy, *Bangor University*

Currently the guidance (2013 IPCC wetlands supplement) is available only for estimating and reporting anthropogenic greenhouse gas (GHG) emissions and removals from managed coastal wetlands, vegetated by vascular plants. GHG emissions or removals are only reported for activities where the anthropogenic contribution dominates over natural emissions and removals. Emissions/removals from coastal wetlands that are not part of the total land area (e.g. seagrass meadows) are reported separately and the associated areas excluded from the total land area. The UNFCCC and the IPCC would determine whether additional methodological guidance would allow for more accurate country specific GHG accounting. For inclusion of other blue carbon coastal ecosystems, derivation of default greenhouse gas (GHG) emission factors need sufficient data to support representative values of emissions or removals associated with specific management activities using appropriate methodologies, of which the starting point is the availability of appropriate peer-review literature. This first step is the scientific community's responsibility and it is also the scientific community's role to always continue exploring new blue carbon ecosystems.

6.5. Concluding remarks

Dr. Steve Crooks, *Silvestrum Climate Associates*

There is still a lack of clarity among the wider community as to which coastal ecosystems are included as blue carbon ecosystems. Recent papers such as that by Howard et al. (2107), have put forth a perspective with a set of criteria that defines what coastal ecosystems are considered as blue carbon and their contribution to climate mitigation potential. There is still an interest among the scientific community for a definition speaking to the role of coastal and marine ecosystems in the global carbon cycle, irrespective of whether there is a climate mitigation opportunity through management that exists with current policy and technology. The complete summary from this discussion will be provided in a forthcoming report.

Session 7. Blue Carbon Member and Partner Updates

Moderated by Dr. Jorge Ramos, *Conservation International*

7.1. Global Science and Data Network for Coastal Blue Carbon

Dr. Pat Megonigal, *Smithsonian Environmental Research Center*

Figure 22. The Coastal Wetland Carbon Research Coordination Network will accelerate scientific discovery, advance science-informed policy, and improve coastal ecosystem management

The Coastal Carbon Research Coordination Network is building a community of practice in support of Blue Carbon science, policy, and management goals. Funded by a five-year grant from the US National Science Foundation, the Network is building tools and capacity for data sharing specifically focused on ecosystem processes and coastal wetland carbon cycling. Ongoing activities include building an open data library, developing data analysis and coding tools, organizing data synthesis workshops, holding town halls with scientists and practitioners, and developing communication materials. The effort is international in scope. Currently, more than 1,000 blue carbon soil profiles have been collected for mangroves and saltmarshes. Future engagements include participation in the American Geophysical Union meetings, launch of the database in 2018, and international webinars.

7.2. The Nature Conservancy's Blue Carbon Projects.

Dr. Mark Spalding and Ms. Emily Landis, *The Nature Conservancy*

The Nature Conservancy proposed to analyze the potential of Natural Climate Solutions, such as conservation, restoration, and improved land management actions to increase carbon storage and avoid greenhouse gas emissions from forests, wetlands, grasslands, and agricultural lands. Analysis showed that NCS can provide around 40% of CO_2 mitigation needed to hold warming below 2 °C by 2030. Additional TNC projects include constructing a global map of mangrove forest soil carbon and developing a global map that delineates potential restoration habitat for mangroves. Additional blue carbon projects are being developed in Mexico, Indonesia, Papua New Guinea, and TNC is collaborating with the International Partnership for Blue Carbon. For more information on the mangrove forest soil carbon paper visit: https://iopscience.iop.org/article/10.1088/1748-9326/aabe1c/pdf

7.3. Baseline of the blue carbon in Mexico
Dr. Jorge A. Herrera-Silveira, *CINVESTAV-IPN, Merida, Mexico*

Figure 23. Mexico's current extent of mangroves, seagrasses, and salt marshes.

Mexico coastal areas have all three blue carbon coastal ecosystems: mangroves (7,700 km^2), salt marshes (150 km^2), and seagrasses (9,200 km^2). With support from United Nations Development Programme, Mexico committed to synthesizing current blue carbon data, policies, and carbon market status for the country. Preliminary data show an average carbon in mangroves of 450 ± 90 Mg C ha^{-1} and 104 ± 23 Mg C ha^{-1} in seagrasses. Ecological restoration projects have successfully promoted vegetation growth, carbon sequestration and sediment accretion. The restoration projects have also recovered the microtopography of the ecosystem, allowing mangroves to adapt to sea level rise. More research is needed to complete mapping of seagrasses and salt marshes, expand blue carbon sites to understudied regions, and investigate other biogeochemical process that influence carbon fluxes.

7.4. Updates on Blue Carbon work in the Philippines
Dr. Nicholas Hill, *Zoological Society of London*

Zoological Society of London has been active in mangrove and beach forest protection and rehabilitation in the Philippines since 2008. For the last 10 years, ZSL has been working through the Western Visayas region and training thousands of community members and local people in mangrove rehabilitation practices and re-planting activities. Mangrove restoration work has reverted more than 60 ha of abandoned fishponds back to mangrove areas. Future work includes refining the

Figure 24. Mangrove restoration work has expanded to rehabilitation and as reverted more than 60 ha of abandoned fishponds back to restored mangrove areas.

science and synchronized restoration practices of mangrove and seagrass ecosystems. Blue carbon is an optional financial mechanism that can bring additional resources and improve the livelihoods these communities. A pilot blue carbon project in the three bay-scapes in Northern Panay in the Philippines includes community mangrove-based projects in marine protected areas (MPAs), understanding of land ownership, tenure and rights, develop a conservation business model of which blue carbon is a component, and ultimately create financially sustainable community based-MPAs.

7.5. Intergovernmental Panel on Climate Change (IPCC) Ocean and Cryosphere Review
Dr. James Kairo, Kenya *Marine and Fisheries Research Institute*

The new IPCC Special Report on the Ocean and Cryosphere in a Changing Climate will include assessing ecosystems such as high mountain areas, polar regions, low lying islands, coasts, and addressing the impacts of climate change in oceans, marine ecosystems, and ocean dependent communities. Dr. Miguel Cifuentes is contributing lead author (CLA) of Chapter 4: Sea Level Rise and Implications for Low Lying Islands, Coasts and Communities, which will address future projections of sea level rise, socioeconomic factors, and implications to build resilience for coastal communities. Dr. James Kairo, CLA of Chapter 5: Changing Ocean, Marine Ecosystems, and Dependent Communities, will summarize the observed changes in oceans, biodiversity, marine ecosystem services and human well-being, and offer governance pathways to solutions. Others interested in serving as contributing authors, please contact the CLAs of the chapter to sign up. The deadline for published peer-reviewed literature to be considered for the review is October 15, 2018 and the reviews final draft is due May 31, 2019.

7.6. International Partnership for Blue Carbon
Mr. Karl Haby, *Department of the Environment and Energy, Government of Australia*

Figure 25. The IPBC brings together governments, NGOs, research institutions, international organizations.

The International Partnership for Blue Carbon (IPBC) was established at the 2015 COP 21 Paris Climate Change. The IPBC provides a voluntary forum for countries and organizations to benefit from the experience and expertise of the global community through building awareness, sharing knowledge, and accelerating practical action. These efforts and activities are guided by the international frameworks of the UNFCCC (Kyoto Protocol, Cancun and Paris Agreement), REDD+, IPCC, Ramsar Convention, SDGs, and CBD. Future projects include developing a roadmap with concepts and activities that will primarily guide the use of narratives, examples and tools on how to incorporate blue carbon into NDCs, exploring blue carbon finance and access resources for blue carbon projects.

Session 8. Policy Challenges of Blue Carbon Projects in the Region

- Moderated by Ms. Dorothée Herr, *IUCN* and Dr. Maria del Mar Otero, *IUCN-Centre for Mediterranean Cooperation*

8.1. Reinforcing protection legal framework for Posidonia in the Balearic Islands.
Jorge Moreno, *Balearic Islands Wildlife Protection Service, Government of the Balearic Islands.*

The Balearic Islands have the largest perimeter of coastal areas and have 40% of the *Posidonia oceanica* seagrass meadows of Spain. The islands are also a popular boating tourist destination that constantly degrade and destroy seagrass habitats due to the anchoring of large yachts. A policy developed in 2007, prohibits the disturbing of seagrass meadows and regulates the anchoring activities within *P. oceanica* habitats. However, the policy lacks strict enforcing, and ecosystems are still threatened. To efficiently protect these ecosystems, awareness of all of the benefits associated with blue carbon coastal ecosystems need to be communicated to all stakeholders. A final draft of a new law that recognizes the importance of biodiversity in coastal blue carbon ecosystems is moving forward and will be linked to national and intergovernmental policies.

8.2. Andalusian Law of Climate Change and the future market on Blue Carbon offset
Susana Álvarez Peláez, *Andalusian Environment and Water Agency*

The Government of Andalucía is expected to pass its new Climate Change Law in the fall of 2017. The new Andalusian Climate Action Plan (PAAC) will include three instruments: mitigation, adaptation, and communication programs. These will respectively include assessments of current, historical trends and projections of greenhouse gas emissions (mitigation component), strategies to prevent future climate change impacts (adaptation), and results from participatory input from the community. The PAAC allows for Andalucía to commit to reduce emissions by 18% by the year 2030. Blue carbon coastal ecosystems can be included within the Andalusian Offset Emission System (SACE) under the PAAC mitigation instrument. The SACE allows for the creation of offset projects in public property lands, including activities of restoration or conservation actions in wetlands, marine meadows or another similar environment. A collaborating project, Life Blue Nature, will develop a blue carbon standard which will include principles and concepts (e.g. additionality, transparency), methodologies, and verification and certification requirements. These steps will allow for the Andalusian Environment Department to include blue carbon projects in the SACE registry and be included in the catalogue of offset projects available for companies to choose and buy blue carbon units.

8.3. Market opportunities for coastal blue carbon offsets.
Dorothée Herr, *IUCN*

Potential buyers of carbon offsets include the public sector (e.g. governments, multilateral funds), private companies, buyers of credits for trading purposes and investors, NGOs, and individuals. Currently, the carbon offsets are available through compliance markets and voluntary markets but not all buyers are interested in offsets that follow specific compliances. Generally, the most important key factor that motivates a buyer to purchase carbon offsets is the carbon content (including costs, risks, discount and time). The motivations of buyers to purchase carbon offsets range from reselling credits at a profit, governments meeting reduction commitments, to philanthropy and personal responsibilities. However, there are still many risks associated with carbon offsets that could be addressed by increasing capacity at national offices, implementation agencies, and local communities; raising awareness and training on blue carbon methodologies; and addressing the quality and stability of blue carbon coastal ecosystems under the impacts of climate change. Future programs should exhibit a diverse portfolio of blue carbon projects that contain examples on how to reduce risks, include the blue carbon within the supply chain management, and keep integrating blue carbon in national and international frameworks such as Sustainable Development Goals and nationally determined contributions.

8.4. Tools and Incentives for engaging the private sector in the conservation of Blue Carbon ecosystems

Dr. Mar Otero, *IUCN-Centre for Mediterranean Cooperation*

Engaging investments from private sector in projects that enhance carbon stocks and sequestration, incentives need to be considered. Market based instruments (MBI), are the policy instruments that use markets, price, and other economic variables that provide incentives to reduce or eliminate negative environmental externalities. Examples of MBI include: taxes, tradable schemes, property rights, voluntary mechanisms, certification, among others. Projects exist using MBIs around the world, the USA Conservation Stewardship Program, USA Wetland Mitigation Banking, Seychelles Conservation, Climate Adaptation Trust, and conservation easements. Creating multi-stakeholder partnerships have ability to link policy and technical expertise to raise awareness about a project and test pilot studies but are not financially stable and partners can withdraw at any time they choose.

Session 9. Uncertainties associated with blue carbon/coastal ecosystems

Moderated by Dr. Catherine Lovelock, *The University of Queensland*

Information is needed to address how do risks to blue carbon coastal ecosystems compare to risks associated to terrestrial system's carbon. For example, there is much more information available on the occurrence and impacts of fire, an agent of disturbance in terrestrial systems, and the process of recovery and risk reduction strategies. The blue carbon community should strengthen its knowledge on the agents of disturbances, impacts, steps of recovery, and investigate the ways we can reduce risks (risk reversal) in blue carbon coastal ecosystems.
The discussion listed several agents of disturbance such as storms, droughts, overgrazing, disease, hypoxia, sea-level rise, mooring, dredging, ocean acidification, thermal stress, eutrophication, and synergistic impacts associated with these (ocean acidification and thermal stress). Other discussion components included: having baseline information of carbon stock and baseline of disturbance level of the system; increase research on the mechanisms of carbon remineralization; and interactions with fauna as disturbance; and examine the interactions between disturbance intensity, size, and rate of return and the blue carbon ecosystems. The advantages of carbon stock stored in blue carbon ecosystems compared to terrestrial systems need to be clearly communicated and linked to opportunities of a market-based insurance program for blue carbon coastal ecosystems.

Session 10. Ecological Succession of Blue Carbon in Coastal Ecosystems

Dr. Jorge Ramos, *Conservation International*

Figure 26. More information on stocks and fluxes associated with recovery from various disturbances from blue carbon coastal ecosystem restoration and reforestation practices are needed

Currently, most of blue carbon coastal ecosystem data includes static measurement of carbon stocks and carbon sequestration rates mostly from mature ecosystems. More research is needed to fill data gaps of carbon stocks and associated carbon fluxes (including CH_4 and N_2O) within blue carbon coastal ecosystems, at different stages of ecological succession, and from more geographies. Chapter 4 of the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands includes methodologies for estimating emissions during management practices, extraction, rewetting/revegetation, and drainage. However, the rewetting/revegetation value assumes one value for both mangroves and salt marshes and for only one point in the rewetting process. Many restoration efforts associated with initiatives, partnerships, and the increasing interest to invest in the blue carbon market, is driving a need for more information on stocks and fluxes associated with disturbance and recovery of blue carbon ecosystems. The Blue Carbon Initiative will lead the efforts to compile data, received feedback and updates, summarize and publish results.

Session 11. Concluding Remarks

Moderated by Dr. Núria Marbà, *IMEDEA*

11.1. Introducing the Blue Carbon Initiative Early Career Fellowship

Dr. Emily Pidgeon, *Conservation International*

The Blue Carbon Initiative (BCI) is pleased to announce the launch of the BCI Early Career Fellowship. The fellowship has been created to support the development of the next generation of scientific leaders from around the world in the rapidly expanding field of blue carbon. The BCI Fellowship will be awarded to scientists and professionals whose future contributions to the field of blue carbon will be significantly enhanced by the support and resources provided through the fellowship. The Blue Carbon Early Career Fellowship will include for the fellow (1) a stipend to design and produce a collaborative cutting-edge research project that will advance the field of blue carbon science, (2) travel to two International Blue Carbon Scientific Working Group workshops to present their project, (3) be an active participant in the BCI, building relationships with leaders in the field from across a range of disciplines and around the world, and (4) develop and refine new professional development skills in areas such as policy, leadership, and science communication and outreach.

11.2. Blue Carbon Initiative 2018 partnership with State Oceanic Administration (SOA), China.

Dr. Guangcheng Chen**,** *Third Institute of Oceanography, SOA*

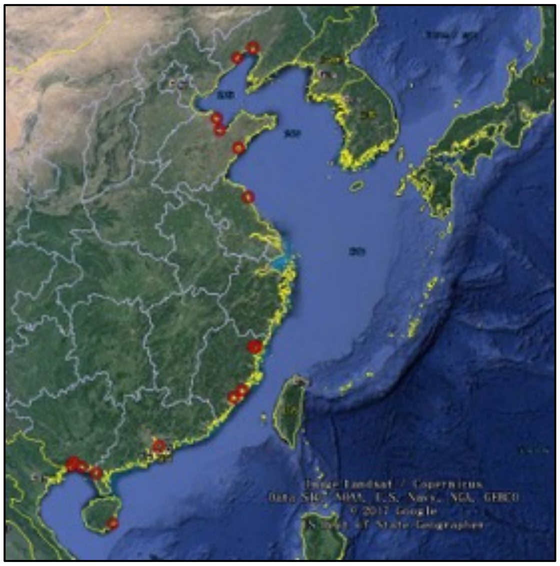

Figure 27. Ecological restorations of coastal wetlands supported by SOA since 2010.

All three blue carbon coastal ecosystems can be found in China's coastlines with approximate extents of 34,000 ha of mangroves, 120,600 ha of salt marshes, and 25,000 ha of seagrass meadows. Mangrove ecosystems in China are estimated to store about 6.91 Tg of C with an approximate average of 355 Mg C ha^{-1}. Recent studies have shown a rate of 1-90 mm yr^{-1} soil organic carbon burial rates in mangrove ecosystems. Additional efforts will start to record greenhouse gas flux emissions (CO_2, CH_4, and N_2O) from mangroves, salt marshes, and aquaculture fish ponds. SOA is also exploring the storage mechanisms of other ecosystems such as shellfish, seaweed aquaculture, and the marine carbonate system. SOA supports and will continuously support the blue carbon field by assisting in the strategy development for blue carbon development in China, increase blue carbon research, build a blue carbon network, construct demonstration projects, and include social and economic components to blue carbon projects.

Session 12. Closing Events

Figure 28. International Blue Carbon Scientific Working Group 2017 participants in Ibiza, Spain.

Figure 29. Tour of historical downtown Ibiza and closing reception hosted by the local government at the Sala Capitular del Ayuntamiento de Ibiza (photo credit Jorge Ramos).

Day 5. Thursday 12, 2017

Field Trip to Formentera Island

Formentera is the smallest inhabited island in the Balearic Islands, Spain and was declared a UNESCO World Heritage site in 1999. Participants of the IBCSWG workshop participated in a scuba diving and snorkeling expedition to explore the *Posidonia oceanica* seagrass meadows. The participants were also invited to attend the "Save Posidonia" festival during the visit to Formentera. The festival's goal was to promote sustainability, respect for the environment and to involve all stakeholders in taking actions to conserve *Posidonia oceanica* seagrass meadows in the Balearic Islands.

Figure 30. Posidonia oceanica diving and snorkeling expeditions and participants attending the Save Posidonia event in Formentera Island, Spain (photo credits Jing Wang and Jorge Ramos).