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Assessment of carbon methodologies and approaches

DEVELOPING GUIDELINES FOR A BLUE CARBON TOOLKIT

by

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Executive Summary

Blue carbon describes the carbon sequestration potential and ecosystem services associated with coastal ecosystems including mangroves, seagrasses, and salt marshes. In countries without established marine protected areas or active restoration efforts, blue carbon may serve as a mechanism for preventing coastal destruction, which increases shoreline vulnerability and negatively affects the species native to these habitats. Additional benefits of blue carbon include increased national and international climate change mitigation efforts. Blue carbon works by creating markets that shift a country's economic incentive away from destructive activities toward protecting their critical ecosystems. This paper evaluates the demand for information and current challenges facing three Global Environment Facility Blue Forests pilot projects in order to provide guidelines for the development of a blue carbon "toolkit."

A user-friendly toolkit aimed at project managers and field ecologists would help them to show various approaches to blue carbon, to determine which protocols best fit the social and political conditions of their site, and to identify field work that may be required to pursue the chosen protocol. Blue Forests demonstration projects in Abu Dhabi, Ecuador, and Madagascar, were analyzed in addition to an extensive literature review to understand the most functional approach to organizing blue carbon resources in a toolkit.

Keywords: blue carbon, coastal marine ecosystems, pilot projects, environmental policy.

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Introduction

The term *blue carbon* describes the carbon sequestration and storage potential of coastal marine ecosystems including mangroves, seagrasses, and salt marshes. Blue carbon ecosystems store carbon in their biomass and underlying sediment acting as a net carbon sink. These vegetated ecosystems can sequester 60-210 tons of carbon per $km^{-2}yr^{-1}$—two to four times the amount captured by mature tropical forest systems (Irving 2011, Murray *et al*. 2011). In addition to carbon sequestration, coastal marine ecosystems maintain important ecological value and provide a wide array of ecosystem services. Coastal marine ecosystems provide habitat, nursery ground, and food systems for aquatic species. Coastal vegetation also aids in shoreline stabilization, water purification, and resilience to sea level rise and coastal erosion (Barbier *et al*. 2012). Although the carbon potential of terrestrial ecosystems, such as forests and peat, is well documented, the carbon storage potential of marine ecosystems has been historically neglected in climate change policy (Pendleton 2012, Nelleman *et al*. 2009). Recently, however, blue carbon has emerged in scientific literature and international conversations on climate change mitigation.

The recent expansion of blue carbon literature has led to the development of blue carbon pilot projects across the globe. Funded and implemented by numerous governmental, international, and non-governmental organizations, blue carbon pilot projects help illustrate the potential for international carbon mitigation policy by demonstrating the viability of blue carbon markets and associated ecosystem services on local or regional level. Demonstration projects produce data on the amount of carbon stored, the ecosystem services available, and the feasibility for financial mechanisms for carbon, thus further promoting the development of blue carbon literature. As pilot projects are furthered and the field of blue carbon continues to evolve and grow, multiple

guidelines and protocols have been published encouraging the development of additional pilot projects. The development of pilot projects and the publication of science manuals has highlighted an imbalance between blue carbon science and policy. Although project managers have a wide variety of resources to implement the science, there is a lack of material analyzing the feasibility of blue carbon policy mechanisms based on the characteristics of the project site.

For project managers new to blue carbon, the development of a demonstration project is a daunting task. The volume of blue carbon literature, guides, and protocols is overwhelming and disorganized. In addition, blue carbon pilot projects are site specific, varying in vegetation type and availability of ecosystem services, as well as cultural and political differences. A blue carbon "toolkit" would aid project managers in the creation of a demonstration site through careful organization of blue carbon literature and methodologies in an accessible format.

In order to better understand how a toolkit should be organized, as well as the current state of science and policy in blue carbon, this paper analyzes interviews with three of the Global Environment Facility's Blue Forests projects in addition to an extensive literature review. The goal of this paper is to provide guidelines for what should be included in a blue carbon toolkit and how that information should be formatted. The blue carbon toolkit will help bridge the gap between the production of scientific information, field application, and policy implications regarding blue carbon. A blue carbon toolkit will serve as an invaluable resource aiding project managers in the creation of additional demonstration projects. An increase in demonstration projects on a global scale will lead to an expansion of the science and policy related to blue carbon, and ultimately national and international blue carbon regulation.

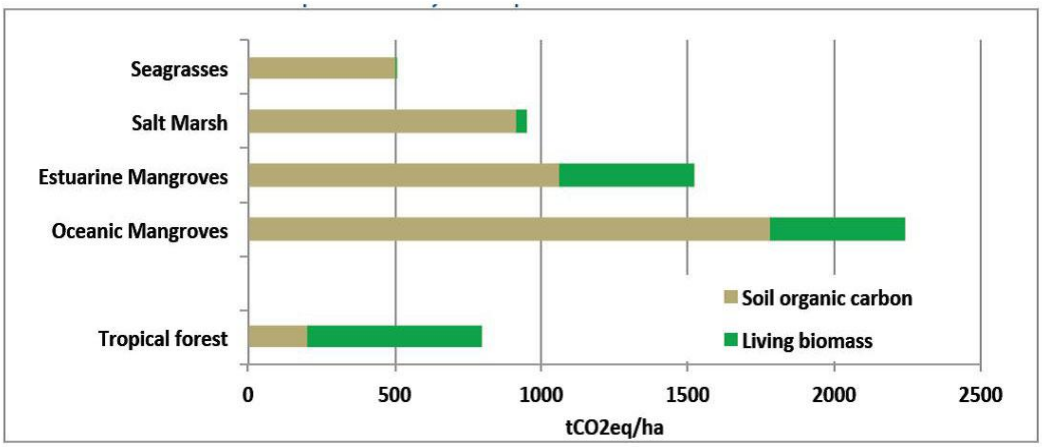
Why Blue Carbon?

The accelerated increase of carbon dioxide over the past century is primarily due to anthropogenic activity of burning fossil fuels and modifying land use for agriculture and deforestation (IPCC 2007). Land use and deforestation attribute 8-20 percent of global carbon dioxide emissions, representing the second leading source of carbon in the atmosphere (IPCC 2007, Van der Werf *et al*. 2009). Marine coastal ecosystems are threatened by deforestation, pressure for coastal development, anthropogenic pollution, and changes in land use for agriculture and aquaculture. Under these threats, blue carbon sinks are being destroyed at a rate of 0.5-3 percent annually (AGEDI 2014, Siikamaki *et al*. 2013, Pendleton *et al*. 2012, Irving 2011). The destruction of these ecosystems results in the immediate return of stored carbon into the atmosphere, while also decreasing the potential for future carbon sequestration.

When greenhouse gases are emitted they accumulate and mix in the atmosphere, in turn causing a warming effect on an international scale. Climate change is predicted to lead to shifts in temperature, oceanic changes, and an increase in the severity of weather events. More specifically, increased carbon emissions alter the chemical composition of the oceans and cause sea levels to rise (IPCC 2007). As our climate shifts due to increased carbon dioxide emissions, mitigation and adaptation strategies will be increasingly necessary. Maintaining healthy and effective blue carbon ecosystems has potential for both carbon mitigation and increased coastal resilience under the effects of climate change.

Coastal ecosystems store carbon within their aboveground biomass and underlying soils. As living matter dies and decomposes, the carbon accumulates and is trapped due to low oxygen conditions (Donato *et al*. 2011). This anaerobic state is the primary difference between terrestrial

and coastal carbon systems. The low oxygen conditions allow for vertical accumulation of carbon-rich soils over decades (Howard *et al*. 2014, Chmura *et al*. 2003). When the sediment is destructed and exposed to oxygen, microbial activity increases, releasing carbon back into the atmosphere. Approximately 35 million tons of carbon, or 130 million tons of carbon dioxide, is released from the loss of mangroves each year (Siikamaki *et al*. 2013). Additionally, an estimated 9.8 million tons of carbon is emitted due to the loss of seagrass beds and 10.6 million tons of carbon is emitted due to the loss of tidal salt marshes (Siikamaki *et al*. 2013). In total, the loss of blue carbon ecosystems results in approximately 200 million tons of carbon dioxide released each year. This statistic represents an annual loss of 6 to 42 billion US dollars (UNEP and CIFOR 2014).



*Data is per unit area, where tCO2eq/ha is tons of carbon dioxide equivalents per hectare

Source: Murray, Brian, Linwood Pendleton, W. Aaron Jenkins, and Samantha Sifleet. 2011. Green Payments for Blue Carbon: Economic Incentives for Protecting Threatened Coastal Habitats. Nicholas Institute Report. NI R 11-04

Figure 1: Blue carbon sequestration potential. Coastal ecosystems may sequester three to four times more carbon than tropical forests, which are known to sequester large amounts of carbon dioxide (Pendleton *et al.* 2012). In marine ecosystems, the majority of this storage is in the underlying soil, rather than the aboveground biomass.

Incentivizing the preservation and conservation of blue carbon ecosystems is important as accelerated anthropogenic greenhouse gas emissions continue and coastal communities begin to face rising sea levels and increased frequency of extreme weather events (Arkema *et al*. 2013).

In order to protect blue carbon ecosystems their value must be recognized and policy mechanisms must be tested. The incorporation of blue carbon into climate change policies may aid the protection of such systems while also encouraging their restoration. Although blue carbon is not accounted for in climate change policies, such as national carbon inventories and international carbon payment schemes, pilot pilots have been created to demonstrate the viability of blue carbon as an economic incentive.

Development of pilot projects

Blue carbon pilot projects apply existing blue carbon science and policy literature to specific geographic locations across the globe. Pilot projects are important to test the effectiveness and viability of management strategies and scientific protocols on a local or sub-national level. Successful demonstration projects help to further define the benefits of blue carbon and advance efforts toward an international mitigation strategy. Pilot project activities also help gather support for additional blue carbon activities, provide outreach opportunities on climate mitigation and ecosystem service tools, and build relationships with coastal communities.

A demonstration project may take one of three approaches including—a policy-based approach, a management-based approach, and through a carbon finance mechanism. Policy-based demonstration projects aim to reallocate subsidies and funds to reduce greenhouse gas emissions within the country. The management-approach focuses on specific agencies and landowners within the community to change current practices and support a national strategy on reducing emissions. A carbon finance approach tests the viability of a market for carbon credit. All three involve the government, non-government organizations, and local communities.

The Phases of a Pilot Project

In general, the phases of a blue carbon project consist of scoping, planning, demonstration, and implementation (See Figure 2; AGEDI 2014). The first stage of a demonstration project is scoping, which essentially means to develop preliminary plans and develop a common understanding of both blue carbon terms and what needs to be done. Scoping establishes a project foundation, builds local interest by expanding participation, creates a setting for sectors and stakeholders to come together, and communicates with a range of governmental agencies. During the scoping phase, project managers also identify geographic areas where blue carbon ecosystems exist, establish concerns or potential causes of degradation, and evaluate any existing management strategies (including scientific capacity, national incentives, or other policy tools). The primary goal of the scoping phase is for project managers to specify the need for a potential project, gain a better understanding of the current site conditions, and outline the potential deliverables.

The project illustration leads to the second phase of a demonstration project, the planning process. Planning includes setting clear overarching goals, identifying what must be measured (i.e. which vegetation type, geographic region, soil carbon), including which protocols and methodologies will be followed. Planning also includes identifying potential project partners and sources of funding. The third phase of pilot projects is the demonstration, which includes implementing the chosen blue carbon methodologies, measuring, evaluating, and adapting the science as the project evolves. Demonstration also involves analyzing potential governance options and legal frameworks to support the project and examining potential trade-offs. Throughout the entire process the project leaders should be communicating through education

and outreach concerning their project. The demonstration phase must be flexible and able to adapt as problems arise.

The final step of a pilot project is implementation where the pilot project secures accreditation and sustainable financing. This could include a carbon market, payment for ecosystem services scheme, or international policy such as the United Nations Reducing Emissions from Deforestation and Forest Degradation program (UN-REDD+). The project should monitor and report their findings to the international blue carbon community. Throughout each stage, project managers must also consider economies of scale, high relative net greenhouse gas (GHG) benefits, financial fitness (amount of funding), low complexity/low risk attributes, improved adaptation, and maintain a workable timeline. Careful consideration of these factors helps to ensure a successful and well thought out demonstration project.

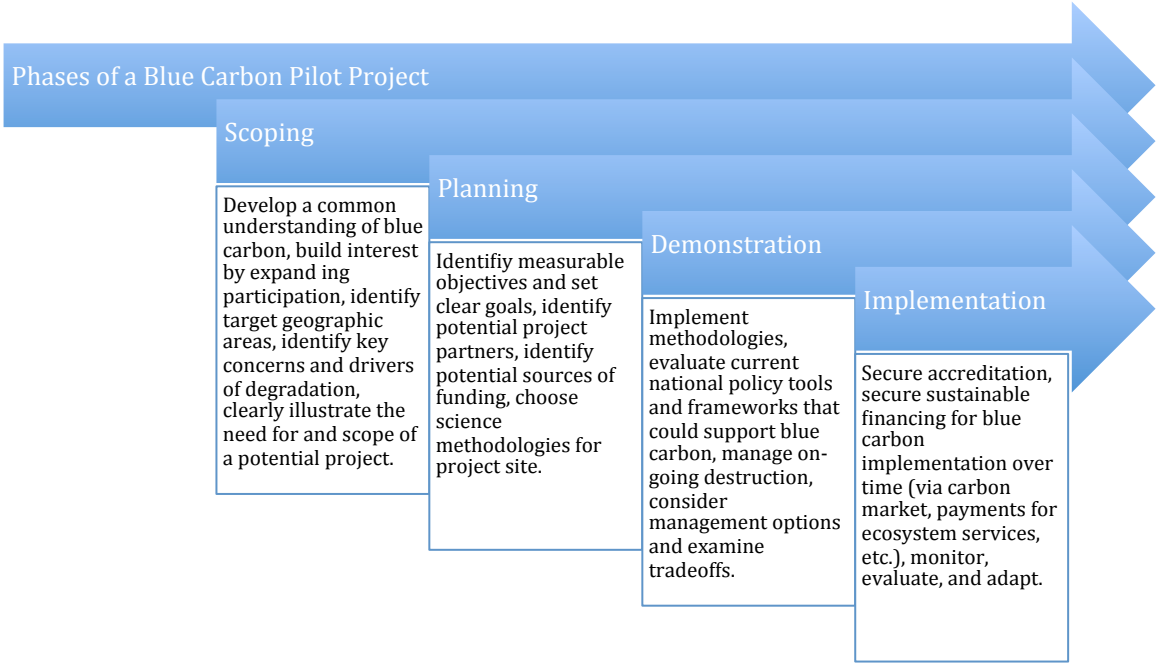


Figure 2: Phases of blue carbon pilot project (adapted from AGEDI 2014).

Pilot projects improve existing understanding of methodologies and approaches to blue carbon. Specifically, pilot projects have advanced blue carbon understanding through geographic analysis, carbon assessment, ecosystem services evaluation and implementation, policy and management assessment, greater communication between stakeholders, outreach to local communities, and through blue carbon viability assessments (AGEDI 2014).

Blue Forests: Case Studies

The Global Environment Facility's Blue Forests project consists of six local, sub-national demonstration sites, each with varying ecological, political, and cultural characteristics, but all implementing projects to incorporate the value of carbon and associated ecosystem services into local and national financial markets. The Global Environmental Facility (GEF), United Nations Environment Programme (UNEP), and GRID-Arendal are the primary directors of the Blue Forests demonstration projects. Each specific demonstration site is then implemented by varying organizations and institutions including Blue Ventures, Duke University, Conservation International (CI), World Wildlife Fund (WWF), the Indonesian Ministry of Affairs and Fisheries, and International Union for Conservation of Nature (IUCN).

The goal of the Blue Forests project is to improve existing knowledge of coastal management, apply and reform existing blue carbon methodologies, and explore policy strategies currently based on theoretical markets for carbon and ecosystem services. Each pilot project applies scientific reports alongside policy and economic mechanisms to better understand their viability in the field. Successful demonstration projects promote awareness of blue carbon as a feasible strategy for carbon mitigation and marine ecosystem conservation. This success may also lead to the development of additional sites, aiding efforts towards national and international blue carbon

policy. The challenges faced by pilot projects reveal key information gaps and create demand for particular research topics. In addition, the Blue Forests project aims to involve stakeholders, communities, and governments to ensure the longevity and sustainability of the demonstration projects after initial intervention.

Currently, the six Blue Forests locations include Abu Dhabi, Ecuador, Indonesia, Kenya, Madagascar, and Mozambique. This paper will focus on interviews with project managers in Abu Dhabi, Ecuador, and Madagascar. A list of questions asked during the interviews can be found in Appendix 1. The information gathered from the interviews helped shape both the organization of blue carbon literature and recommendations for toolkit design.

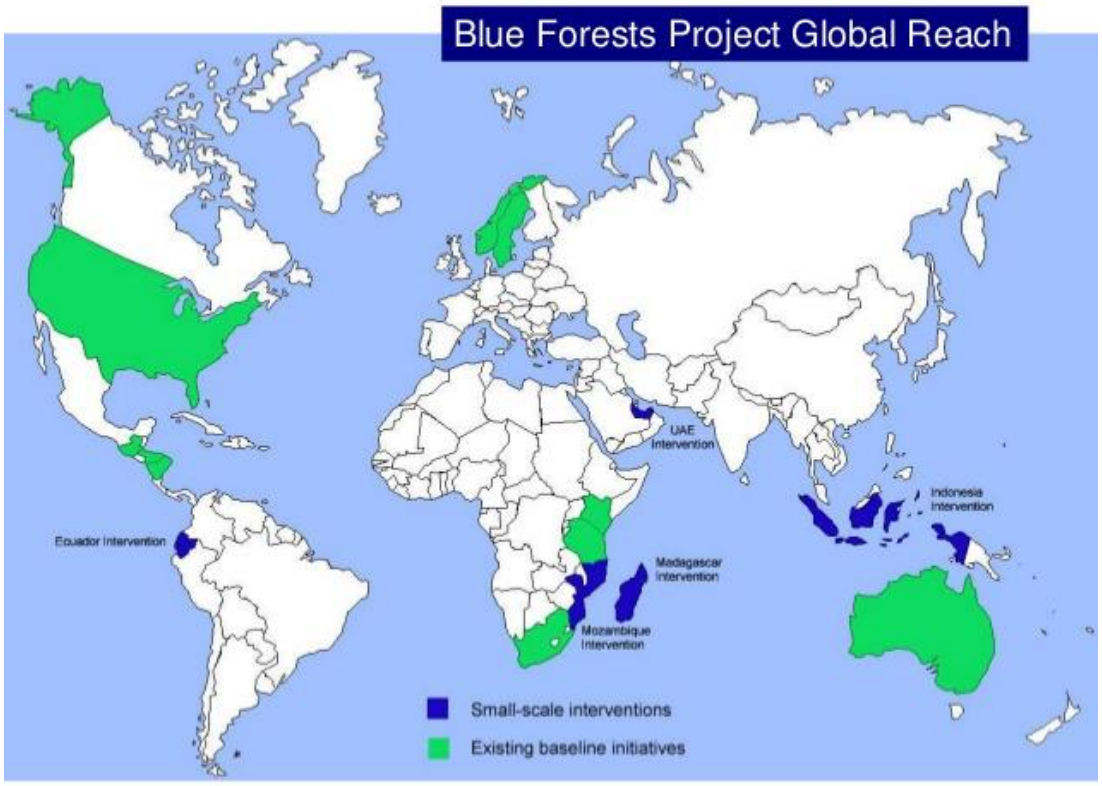


Figure 3: Distribution of GEF-Blue Forests demonstration sites (GRID-Arendal 2014). The three sites interviewed for this project included Abu Dhabi, Ecuador, and Madagascar.

Abu Dhabi – United Arab Emirates

The Abu Dhabi Blue Carbon Demonstration Project was implemented through a partnership between UNEP and the Abu Dhabi Global Environment Data Initiative (AGEDI) supported by the Environment Agency Abu Dhabi (EAD). In addition, GRID-Arendal, Forest Trends, MARES, the UNEP-World Conservation Monitoring Centre, and the International Blue Carbon Working Group helped fun and implement the one-year implementation of Phase I and subsequent development of Phase II. Phase I commenced in November 2012 and AGEDI published the final results in late 2013. The coastal ecosystems studied included mangroves, seagrass, and salt marsh, as well as two local ecosystems: intertidal cyanobacteria mats and sabkha (salt flats consisting of microorganisms). The Abu Dhabi site consists of 176,400 ha of coastal area (GEF 2015).

The primary goal of the Abu Dhabi demonstration project was to better understand the carbon and ecosystem services available and the potential for climate mitigation. During Phase I a baseline carbon assessment was conducted through satellite imagery of the coast and field sampling to test the quantity of carbon for each vegetation type (AGEDI 2013). The results of the study showed low carbon values, but the potential for marine ecosystem conservation focused on ecosystem services such as shoreline stabilization, fisheries, and water quality. Water quality, in particular, may be particularly useful to incentivize the conservation of these ecosystems, as poor water quality influences tourism and recreation in the area. Additionally, due to high salinity and high water temperatures during the day, the extreme conditions of the site may be viewed as a test bed for what coastal ecosystems may look like under the on going effects of climate change.

Phase II of the project extends the baseline assessment of carbon stocks to the Northern Emirates, including a geographic assessment of current coastal vegetation. Learning from Phase I of the project, the focus of Phase II is on establishing community support and capacity for ecosystem services surrounding mangroves, rather than carbon storage potential.

Ecuador

Conservation International will implement the Blue Forests project in Ecuador, with help provided by GRID-Arendal. The project, consisting of 41,000 ha of mangrove ecosystem, will focus on understanding the effect policy tools have on mangroves. This goal differs from other Blue Forests projects because Ecuador has already established a carbon baseline for the mangroves. In 2008, the Ministry of Environment implemented the Socio Bosque Program, a national policy that incentivizes communities to protect and conserve local forests. Socio-Manglares, one part of Socio-Bosque, focuses on the protection, conservation, and sustainable use of local mangrove forests. In exchange for conserving and using mangroves in a sustainable way, families participating in Socio-Manglares receive annual payments for the forest they are protecting. The concession is based on the amount of mangroves they have received measured in hectares. The agreement is accompanied by a plan for how the mangroves are to be used and managed. In addition to Socio-Manglares, the Ministry of the Environment began mapping where deforestation of mangroves has taken place and began a national forest assessment. In 2009, Ecuador joined the United Nations REDD+ program and is now developing a national implementation framework.

The goal of the current Blue Forests project is to assess the current state of mangrove policy in Ecuador and evaluate how well current initiatives are working. Under national policy, the

Ministry of the Environment can place restrictions on land use and implement penalties for improper use of mangroves such as slash and burning for shrimp aquaculture. The goal of the pilot project will be to better understand how these penalties are working. At the time of this interview, the pilot project was awaiting confirmation of their agreement with GRID-Arendal and planned to begin efforts in January 2015.

Madagascar

The Madagascar Blue Forests Project is lead by Blue Ventures, in addition to GRID-Arendal. The project consists of two mangrove areas—one located in the northwest region of Ambaro-Ambanja Bays and one in the southwest region of Belo sur Mar and Ambondrolava. The goal of each site is to apply and evaluate current mangrove methodologies and approaches for valuing carbon and the associated ecosystem services. In addition, the demonstration project aims to increase the capacity of local communities to participate in REDD+ projects. This includes teaching local communities skills in forest management, carbon stock measurement, and helping individuals gain legal rights to protect the ecosystem.

The project in the Ambaro-Ambanja Bay location is approximately two years into the development of a Verified Carbon Standard (VCS) project. In the southwest regions of Belo sur Mar and Ambondrolava, project leaders have submitted a proposal for Plan Vivo Certification. This proposal included carbon surveys in the above ground biomass, rather than the soil. Both financial mechanisms incentivize the conservation of coastal ecosystems and promote the development of ecosystem services. In particular, sustainable fisheries management has been a viable ecosystem service in Madagascar.

Challenges for Blue Carbon Pilot Projects

During the interviews, the three sites communicated unique challenges and specific needs to further their projects. Despite ecological and cultural differences, the need for a synthesized and accessible place to find blue carbon information was apparent. The history of wetland carbon science is extensive and methods to quantify carbon in the soil and biomass of these ecosystems exist, however, the connection between science and policy in this field is not well developed. Scientific protocols for calculating the amount of carbon in the soil and biomass are available, but the wide range of policy options makes the next step in the project harder to refine. Since an international policy on blue carbon does not currently exist, pilot projects may choose to advocate a voluntary, regulatory, or international policy tool. This may include developing a carbon market with the Verified Carbon Standard or Plan Vivo, or working with existing systems such as REDD+, a nationally appropriate mitigation action (NAMA), or under the Clean Development Mechanism (CDM), to name a few.

In addition to the wide variety of policy mechanisms to choose from, information about these mechanisms and how to implement the policy is spread out among the literature. Some manuals explore blue carbon by vegetation type while others focus on potential financial options. This poses a challenge to project leaders whose specific geography, political, and cultural characteristics require unique blue carbon plans. Currently, there is not a straightforward way to establish a project based on the characteristics of the site, making it harder for managers new to blue carbon.

The first questions project managers will ask include: What type of coastal vegetation do I have? How many hectares are available? What is the available data? How will I receive funding? From

this initial sequence two challenges arise. The first is that project managers must be able to localize a methodology to a specific demonstration site, while still creating results that can be comparable and viable on an international level. Each site and country will vary immensely. The protocols must be tailored to fit the site, yet the results must be comparable in order to unite the pilot projects and encourage the expansion of demonstration sites. The project development protocol must also allow for flexibility based on what information is already known and what information is needed.

The second initial challenge is that project leaders must be able to communicate the potential benefits from the science to policy makers before all the data is collected. Project managers must be able to answer hard questions about the potential benefits under uncertainty. The current state of blue carbon literature does not provide guidance on effective communication strategies at the initial stage of a blue carbon pilot project. This is in part because there is not a comprehensive database for current pilot projects to communicate best practices and difficulties with implementation.

Accessibility to the literature was noted as a potential challenge for blue carbon newcomers. Access to manuals and guidebooks published by NGOs was easier to achieve than access to primary scientific literature. The accessibility of literature is an aspect to consider when creating a blue carbon toolkit. The toolkit should focus on distilling the information from public guides, protocols, and manuals. In addition, summaries of the scientific literature or saved versions of the papers could be added to the site.

The project leaders also discussed lessons learned from their sites. The Abu Dhabi demonstration site resulted in low carbon sequestration values, but the potential benefits from ecosystem

services. This finding is applicable to a blue carbon toolkit for two reasons. This is important because project researchers now have a better understanding of which ecosystem services are more important in the area, such as the role mangroves play in water purification and its importance for tourism and recreation. The second is that although the baseline carbon found in Phase 1 of the project found low carbon, the project has adapted Phase II to focus on the potential for ecosystem services. The ability to adapt the project to fit the site characteristics is crucial to the success of the project.

There was also an incredible amount of support from Abu Dhabi because of the late president Sheikh Zayed bin Sultan Al Nahyan's efforts to restore mangroves and the importance he placed on them. However, expanding the efforts of Abu Dhabi's demonstration project is challenging because the other Emirates are not as advanced in the intrinsic value placed on the coastal ecosystems. For all pilot projects, community involvement and on the ground prep is important before the implementation of the project. This is important to sustain the project in the long term and also to discover the key drivers of forest degradation in the area. It is helpful to note that an intervention alone will not stop the drivers of coastal degradation immediately. There must be ground development and support before the project begins. Starting a discussion with stakeholders, community members, and governments early in project development helps with this part of the process.

Another challenge for pilot projects is the ability to find local experts. The global nature of blue carbon projects makes it difficult to find regional experts in the field to spearhead projects without an organization or NGO's involvement.

The need for a toolkit

A blue carbon toolkit focused on pilot project development would alleviate the challenges faced by project managers through the creation of a one-stop-shop database. The toolkit will act as a portal for information relating to blue carbon and sort the literature into specific baskets of information. This organization makes it easier for a project manager who is just starting out to compare their site characteristics to specific protocols and sections of manuals. In addition, the blue carbon toolkit will document information on current blue carbon pilot projects. Implementing a web-based format will allow pilot projects to continually update their information and concerns as the project continues to evolve.

Blue Carbon Literature

In addition to interviews with pilot project managers, a blue carbon literature review was performed. The goal of the literature review was to lay the foundation for the web-based toolkit by considering key challenges faced demonstration sites that were communicated during the interviews. The literature review included scientific papers, protocols, methodologies, reviews, and manuals on both the science and policy aspects of blue carbon. Blue carbon resources were first separated into two overarching categories—accessible resources and scientific literature. Accessible resources included any reviews, guides, protocols, or manuals that were public and easily accessible. Government organizations, NGOs, and private firms working on blue carbon primarily published the accessible literature. It was important to note a difference between accessible and scientific literature because the scientific journals require subscriptions or special access. For many project managers, this resource may not be an immediate option, so the toolkit

should focus on organizing the information stemming from the public resources, in addition to summarizing scientific literature.

The blue carbon resources were then organized into four categories—assessment, project development, policy framework, and financial mechanism. Financial mechanism resources were also separated into three subcategories—voluntary, regulated, or other. The four categories were chosen based on conversations with project managers and were organized from a policy perspective, rather than sorted by project stage. This difference is important to note because the contents of a project stage may vary with the specific characteristics of the demonstration site and any existing data. For Ecuador, the initial stage does not include a carbon baseline assessment because the country has already established the carbon sequestration and storage potential through existing national policies. For Abu Dhabi and Madagascar, stage one did consist of a carbon baseline assessment. Organizing the literature in these four buckets allows project managers using the toolkit more flexibility when designing their project.

In addition to classifying each document as accessible or scientific literature and then within the four categories, each resource was also labeled based on ecosystem type (mangroves, seagrasses, salt marsh, and wetland). For larger manuals or reviews, chapters are sorted between the four primary categories and also in regard to ecosystem type. Grouping the information into these specific baskets helps organize the information in an assessable format for project managers.

The excel charts generated from this project will be used as an organizing tool for the blue carbon toolkit. In addition, this literature review highlights gaps in blue carbon literature and an imbalance between blue carbon science and policy. Key results from this literature organization include a significant amount of resources that relate to assessment, and limited resources relating

to policy framework. This is important moving forward, as additional policy resources are necessary to better the pilot project efforts and goal of international blue carbon policy.

Assessment

Assessment was defined as literature that would be helpful in calculating the carbon sequestration and storage potential, modeling techniques to quantify the flux of greenhouse gases, and valuing the associated ecosystem services provided by blue carbon. In addition, assessment included scientific methodologies and protocols for each coastal ecosystem. Appendix 2 displays the accessible literature categorized as assessment and Appendix 3 highlights the scientific literature categorized as assessment. The majority of literature analyzed, including both accessible and scientific literature, was labeled as assessment. The availability and prominence of assessment resources, which apply to the initial stages of a demonstration project, was supported through discussions with project managers. The quantity of blue carbon resources labeled as assessment highlight the imbalance between blue carbon science and policy.

Assessment resources focus on the science of blue carbon and how a project manager would calculate the amount of carbon stored. The availability of blue carbon science resources is not surprisingly give that the field of blue carbon is relatively new. The challenge now remains in how to connect the science with the policy application in the field. A blue carbon toolkit may aid in bridging the gap between blue carbon science and policy by providing an outline and guide for a new project manager to create a demonstration project. In addition to providing updates from pilot projects on what policy measures are being used, and the challenges for each. Understanding how a pilot project works is an important step in understanding which policy tools may be utilized. Further, as additional pilot projects are implemented, scientists and

mangers will gain a better understanding of which policy tools work best under specific conditions.

Project Development

Project Develop includes information and recommendations for the construction and planning of a demonstration site. This includes step-by-step protocols and guides that relate to the implementation of both the science and policy of a blue carbon pilot project. In addition, project development includes information surrounding on the ground development and prep work. Seven manuals and guides were classified as project development, but there were no scientific articles concerning project development (Appendix 4). The majority or resources categorized as project development are accessible resources, which is beneficial for project managers that have limited access to scientific journals. The limited amount of guides on project development, however, may nod to the fact that blue carbon is a newer field and project development may not be intrinsically linked in the scientific realm.

Policy Framework

Policy framework was defined as literature on blue carbon policy and legal recommendations, future steps, and overarching policy guidelines. There were three public resources that were included under policy framework and one scientific paper, found in Appendix 5 and Appendix 6 respectively. The Blue Carbon Policy Working Group produced two key reports that are listed under policy framework. These include the Blue Carbon Policy Framework and the Blue Carbon Policy Framework 2.0—both based on discussions of the International Blue Carbon Policy Working Group. The International Blue Carbon Working Group was created in 2011 to develop strategies for international and national blue carbon policy. The working group was developed

because the science was established enough to begin implementing these tools in the field. The fact that there was only one scientific article categorized as policy framework highlights blue carbon as a newer realm of study and opens an opportunity for scientists to provide key insight to how the policy framework and discussion should be formatted.

Financial Mechanisms

The Financial Mechanism category is broken into three subcategories including voluntary, regulated, and other market systems (Appendix 7). All of the blue carbon literatures classified as financial mechanism were accessible resources. This is beneficial for project managers who are starting out in the field. Financial mechanism includes any policy tool that provides an economic incentive for countries or communities to conserve or preserve coastal resources.

Voluntary financial mechanisms include any elected carbon market such as the Verified Carbon Standard and Plan Vivo. Regulated mechanisms include national cap and trade programs and international policies such as UN-REDD+ incentives, CDM, and NAMAs. Other mechanisms include payment for ecosystem services schemes and valuation techniques.

The Blue Carbon Toolkit

In order to establish national and international blue carbon policy, the feasibility of incentivizing blue carbon must first be demonstrated in the field. Blue carbon pilot projects are important to explore the challenges in managing coastal ecosystems and alter the policy framework to include the value of blue carbon. A blue carbon toolkit will help overcome challenges facing the development of pilot projects through the creation of an accessible comprehensive website that takes a holistic approach to blue carbon. The following guidelines will aid the development of a

blue carbon toolkit. The final toolkit will implement the literature organization produced by this paper alongside these recommendations.

Guidelines for the toolkit

1. Making the format accessible for new project managers

In order to maximize the toolkit's use and accessibility, the toolkit should be an online resource that provides a holistic approach to blue carbon and acts as a comprehensive guide to aid in the creation of a demonstration site. The web-based toolkit should be organized based on the four primary sections outlined in this paper; assessment, project development, policy framework, and financial mechanism. These sections were developed through conversations with project managers and analyzing the frequency and content of existing literature. Each section should include subsections with resources for ecosystem type—mangrove, salt marsh, and seagrass. A project manager viewing the toolkit must understand where they are in the pilot project development process, what information they need to attain, and what information they already have. The toolkit will help establish a project concept, define a project market, and plan the project activities.

A web-based format allows for information to be adapted and evolve as the field of blue carbon expands. In addition, the web-based format allows for direct links to materials, videos and images of protocols, and potential access to current pilot project resources. Visual aids such as videos and photos of blue carbon protocols help overcome language barriers between countries and may make complex ideas easier to interpret. Abu Dhabi's demonstration site has already started to take videos of protocols in the field, in addition to a wide range of photos.

A list of current pilot projects, links to their websites, and their published documents is useful to include as a separate tab. If a project manager is able to search pilot projects based on similar site characteristics, habitat type, or climate, they would able to view protocols and methodologies that are already in place. Altering current methodologies and applied frameworks, instead of creating methodologies without the support from other projects, allows project managers to advocate to governing organizations that the protocol works through real-life examples. Help from existing pilot projects also provides a foundation to build their project on and allows project managers to preview all of the tools they may need before they begin.

The online format provides flexibility for project managers, with varying scientific and policy backgrounds, to explore blue carbon topics they are less familiar with. This format ensures that blue carbon resources are accessible to newcomers in the field. The majority of scientific literature requires a journal subscription or payment to view the information. The toolkit should focus on the best way to present public accessible resources, the majority of public resources consisting of blue carbon manuals and guides. Understanding what other project teams are working on and the challenges facing their projects also helps strengthen the development of new projects.

In addition, the blue carbon toolkit should be incorporated with the existing Blue Carbon Portal. The Blue Carbon Portal is a current website that provides updates on blue carbon news, events, and information. However, the Blue Carbon Portal is targeted at general audiences and has a broader view of blue carbon. Digging through the literature and updates will provide a rough sense of the tools needed to create a demonstration project, but is not enough to ease the process

of project development. A toolkit should expand or work with the Blue Carbon Portal to target project managers specifically.

2. Filling in knowledge gaps

Understanding the information generated by existing pilot projects will help coastal managers, scientists, and policymakers to target information gaps. An example of this, is the field of blue carbon is in need of further expansion on quantification of the flux of greenhouse gases such as CO_2, CH_4, and N_2O. This is especially true for greenhouse gas release and storage in degraded or rebuilding coastal ecosystems. This information will be highlighted through the development of a pilot project section within the toolkit. Currently, there is no single portal for all pilot projects and it is difficult to find information on the activities of current projects. This is due to the geographic distances between projects and the wide array of organizations involved in the funding and implementation of demonstration sites. Listing each pilot project and allowing each to update their information will help new project leaders compare their sites. Understanding what policy tools and scientific methods each project is using provides a launch pad or starting place for managers developing their own project.

In addition, understanding the concerns and challenges that other projects face will allow researchers to focus on certain policy regimes and then practice those policy options in the field. The toolkit will be an important tool as continual reporting from pilot projects is added to the website. Appendix 8 provides a sense of the number of publications that have appeared overtime. The majority of literature was published in 2011 and the majority of this information was scientific literature. The most recent blue carbon resources have been public manuals and guides

that have expanded the scientific literature. As the field of blue carbon evolves, the next step should be pilot projects publishing their results, findings, and recommendations.

3. Community support, outreach, and training

In order to implement a successful blue carbon pilot project there must be community support, interest, and trust. The most important aspect of community support is providing an understanding of the benefits of blue carbon—including the ecosystem services they may provide. There is a need to invest in pre-project community capacity building, capacity within the government (national and subnational support), train local individuals to ensure the longevity of the project, and emphasize stakeholder communication. Creating long lasting relationships with local people is important to decrease current deforestation and degradation of these ecosystems, and also provide economic incentive to alter this practice.

Including this section within the toolkit will spark conversation on how to incorporate community action and prep-work before site implementation. Currently, there is limited literature surrounding best practices for community support for blue carbon projects. This section will allow current project managers to provide information on how to involve stakeholders and communication strategies from the project inception.

4. Financial Considerations

From a project manager perspective, financial considerations including how to get funding for a project, how to lease the land associated with the project, and the logistics of financial mechanisms is important. Currently, there are several documents that explore the financial mechanisms that can be used to incentive the preservation and conservation of coastal ecosystems, but there is not a document describing how to structure the financial considerations

of a demonstration project. There is a need to continue research on this topic and including a section on financial considerations in the toolkit is important to start the conversation between project managers, scientists, and policymakers.

Conclusions

As our climate changes, policymakers and scientists search for mitigation and adaptive solutions. Coastal marine ecosystems, termed blue carbon, may serve as one such mitigation strategy. Blue carbon ecosystems act a net carbon sinks, trapping carbon dioxide in the biomass and underlying sediment. In addition, blue carbon systems maintain ecological and economic value, protecting against coastal erosion and creating resilient coastlines. The science of blue carbon sequestration has been developed and potential policy tools have been theorized. The next step towards an international blue carbon strategy is to test the feasibility of blue carbon in the field. Pilot projects help demonstrate the feasibility of blue carbon sequestration and test incentives for marine ecosystem protection.

The current challenge for project leaders is to understand what information exists and how to incorporate this information into their own project. A blue carbon toolkit, aimed at project managers and ecologists, can help increase the amount of successful demonstration sites. This project analyzed three GEF Blue Forests demonstration sites, in addition to an extensive literature review, in order to provide guidelines for the development of a toolkit. The toolkit will help project managers design and implement demonstration sites based specific characteristics of their site, current literature, and the experiences of past pilot projects. The toolkit will be developed following the publication of this report by a subsequent Masters Project. The

recommendations provided in this report are accompanied by a re-organization of blue carbon resources in an accessible format.

Appendix 1: Interview questions asked to current project managers.

1. What is your role in the project?
2. Could you tell me how your project began?
3. What kinds of vegetation does the project include?
1. Was there community support for your project?
2. What are the associated ecosystem services?
3. What is the financial basis for your project?
4. What have the successes of the project been?
5. What do you see as challenges to your pilot project?
6. What do you think the state of blue carbon science is?
7. What do you think the state of blue carbon policy is?
8. What does a blue carbon toolkit mean to you?
9. What would you like to see in a blue carbon toolkit?
10. What format should the toolkit be in?
11. What do you see as the future of blue carbon?

Appendix 2: Accessible Manuals and Guides – Categorized as Assessment

Author	Title	Year	Publisher	Mangroves	Seagrass	Saltmarsh	Wetlands
AGEDI	Abu Dhabi Global Environmental Data Initiative (AGEDI) – Baseline Assessment Report: Coastal Ecosystem Carbon Stocks	2014	AGEDI, GRID Arendal Environmental Agency Abu Dhabi	X			
Crooks, S., Herr, D., Tamelander, J., Laffoley, D., Vandever, J.	Mitigating Climate Change through Restoration and Management of Coastal Wetlands and Near-shore Marine Ecosystems: Challenges and Opportunities	2011	World Bank, IUCN, ESA, PWA	X	X	X	
Crooks, S., Orr, M., Brew, D. Findsen, J., Igusky, K.	Greenhouse Gas Mitigation Typology Issues Paper - Tidal Wetlands Resoration	2009	PWA, SAIC				X
Crooks, S., Orr, M., Emmer, I., von Unger, M., Brown, B.	Guiding Principles for Delivering Coastal Wetland Carbon Projects	2014	UNEP, CIFOR	X	X	X	
Howard, J., Hoyt, S., Isensee, K., Telszewski, M., Pidgeon, E.	Coastal Blue Carbon	2014	The Blue Carbon Initiative, Conservation International, IUCN, IOC-UNESCO	X	X	X	
Kauffman, J.B., Donato, D.C.	Protocols for the measurement, monitoring, and reporting of structure, biomass, and carbon stocks in mangrove forests	2012	CIFOR	X			
Laffoley, D., Grimsditch, G.D.	The Management of Natural Coastal Carbon	2009	IUCN	X	X	X	

	Sinks					
Lutz, S.J., Neumann, C., Bredbenner, A.	Building Blue Carbon Projects – An Introductory Guide	2014	AGEDI	X	X	X
Murray, B., Pendleton, L., Jenkins, W.A., Sifleet, S.	Green Payments for Blue Carbon – Economic Incentives for Protecting Threatened Coastal Habitat	2011	Nicholas Institute for Environmental Policy Solutions, Duke University	X	X	X
Murray, B.C., Vegh, T.	Incorporating blue carbon as a mitigation action under the United Nations Framework Convention on Climate Change: technical issues to address	2012	Nicholas Institute for Environmental Policy Solutions, Duke University	X	X	X
Nellemann, C., Corocan, E., Duarte, C.M., Valdés, L., De Young, C., Fonseca, L.,	Blue Carbon - The role of healthy oceans in binding carbon	2009	UNEP, FAO, IOC/UNESCO, IUCN	X	X	X
Sifleet, S., Pendleton, L., Murray, B.	State of Science on Coastal Blue Carbon	2011	Nicholas Institute for Environmental Policy Solutions, Duke University	X	X	X
Siikamaki, J., Sanchirico, J.N., Jardine, S., McLaughlin, D., Morris, D.	Blue carbon: Coastal ecosystems, their carbon storage, and potential for reducing emissions	2013	Resources for the Future	X	X	X

Appendix 3: Scientific Literature – Categorized as Assessment

Author	Title	Year	Journal	Mangroves	Seagrass	Saltmarsh	Wetlands
Alongi, D.M.	Carbon sequestration in mangrove forests	2012	*Carbon Management*	X			
Arkema, K.K., Guannel, G., Verutes, G., Wood, S.A., Guerry, A., Ruckelshaus, M., Karieva, P., Lacayo, M., Silver, M.J.	Coastal habitats sheild people and property from sea level rise and storms	2013	*Nature Climate Change*	X	X	X	X
Bell, J., Lovelock, C.	Insuring mangrove forests for their role in mittigating coastal erosion and storm-surge: An Australian case study	2013	*Wetlands*	X			
Bianchi, T.S., Allison, M.A., Zhao, J., Li, X., Comeaux, R.S., Feagin, R.A., Kulawardhana, R.W.	Historical reconstruction of mangrove expansion in the Gulf of Mexico: linking climate change with carbon sequestration in coastal wetlands	2013	*Estuarine, Coastal and Shelf Science*	X			
Chmura, G.L.	What will we need to assess the sustainability of the tidal salt marsh carbon sink?	2011	*Ocean and Coastal Management*			X	
Donato, D.C., Kauffman, J.B., Murdiyarso, D.	Mangroves among the most carbon-rich forests in the tropics	2011	*Nature*	X			

Duarte, C.M., Kennedy, H., Marba, N., Hendriks, I.	Assessing the capacity of seagrass meadows for carbon burial: current limitations and future strategies	2011	*Ocean and Coastal Management*		X	
Fourqurean, J.W., Duarte, C.M., Kennedy, H., Marba, N., Holmer, M., Angel Mateo, M., Apostolaki, E.T. et al.	Seagrass ecosystems as a globally significant carbon stock	2012	*Nature Geoscience*		X	
Irving, A.D., Connell, S.D., Russell, B.D.	Restoring coastal plants to improve global carbon storage: reaping what we sow	2011	*Plos ONE*	X	X	X
Lovelock, C.E., Ruess, R.W., Feller, I.C.	CO2 efflux from cleared mangrove peat	2011	*Plos ONE*	X		
Luisetti, T., Jackson, E.L., Turner, R.K.	Valuing the European 'coastal blue carbon' storage benefit	2013	*Marine Pollution Bulletin*	X	X	X
Mcleod, E., Chmura, G.L., Bouillon, S., Salm, R., Bjork, M.,Duarte, C.M., Lovelock, C. E., Schlesinger, H., Silliman, B.R.	A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2	2011	*Frontiers in Ecology and the Enivronment*	X	X	X
Mudd, S.M., Howell, M.	Impact of dynamic feedbacks between sedimentations, sea-level rise, and biomass production on near surface marsh stratigraphy and	2009	*Estuarine, Coastal and Shelf Science*			X

	carbon accumulation					
Pendleton, L., Donato, D.C., Murray, B.C., Crooks, S., Jenkins, W.A., et al.	Estimating global blue carbon emissions from conversion and degration of vegetated coastal ecosystems	2012	*Plos ONE*	X	X	X
Thomas, S.	Blue carbon: knowledge gaps, critical issues, and novel approaches	2014	*Ecological Economics*	X	X	X

Appendix 4: Accessible Manuals and Guides – Categorized as Project Development

Author	Title	Year	Publisher	Mangroves	Seagrass	Saltmarsh	Wetlands
AGEDI	Abu Dhabi Global Environmental Data Initiative (AGEDI) - Baseline Assessment Report: Coastal ecosystem carbon stocks	2014	AGEDI, GRID Arendal, Environmental Agency Abu Dhabi	X			
Crooks, S., Emmett-Mattox, S., Findsen, J.	Findings of the National Blue Ribbon Panel on the Development of a Greenhouse Gas Offset Protocol for Tidal Wetlands Restoration and Management: Action Plan to Guide Protocol Development	2010	RAE, PWA, SAIC				X
Crooks, S., Orr, M., Emmer, I., von Unger, M., Brown, B.	Guiding principles for delivering coastal wetland carbon projects	2014	UNEP, CIFOR	X	X	X	
Howard, J., Hoyt, S., Isensee, K., Telszewski, M., Pidgeon, E.	Coastal Blue Carbon	2014	The Blue Carbon Initiative, Conservation International, IUCN, IOC-UNESCO	X	X	X	
Lutz, S.J., Neumann, C., Bredbenner, A.	Building Blue Carbon Projects - An introductory guide	2014	AGEDI	X	X	X	
Murray, B.C., Vegh, T.	Incorporating blue carbon as a mitigation action under the United Nations Framework Convention on Climate Change: Technical issues to	2012	Nicholas Institute for Environmental Policy Solutions, Duke University	X	X	X	

	address					
O'Sullivan, R., Chagas, T., Burns, D., Pearson, T.	Blue Carbon Policy Options Assessment	2011	Climate Focus, The Linden Trust for Conservation	X	X	X

Appendix 5: Accessible Manuals and Guides – Categorized as Policy Framework

Author	Title	Year	Publisher	Mangroves	Seagrass	Saltmarsh	Wetlands
Herr, D., Pidgeon, E., Laffoley, D.	Blue Carbon Policy Framework: based on the first workshop of the International Blue Carbon Policy Working Group	2011	Conservation International, IUCN	X			
Herr, D., Pidgeon, E., Laffoley, D.	Blue Carbon Policy Framework 2.0: based on the discussions of the International Blue Carbon Policy Working Group	2012	Conservation International, IUCN				X
Lutz, S.J., Neumann, C., Bredbenner, A.	Building Blue Carbon Projects - An introductory guide	2014	AGEDI	X	X	X	
Siikamaki, J., Sanchirico, J.N., Jardine, S., McLaughlin, D., Morris, D.	Blue carbon: coastal ecosystems, their carbon storage, and potential for reducing emissions	2013	Resources for the Future	X	X	X	

Appendix 6: Scientific Literature – Categorized as Policy Framework

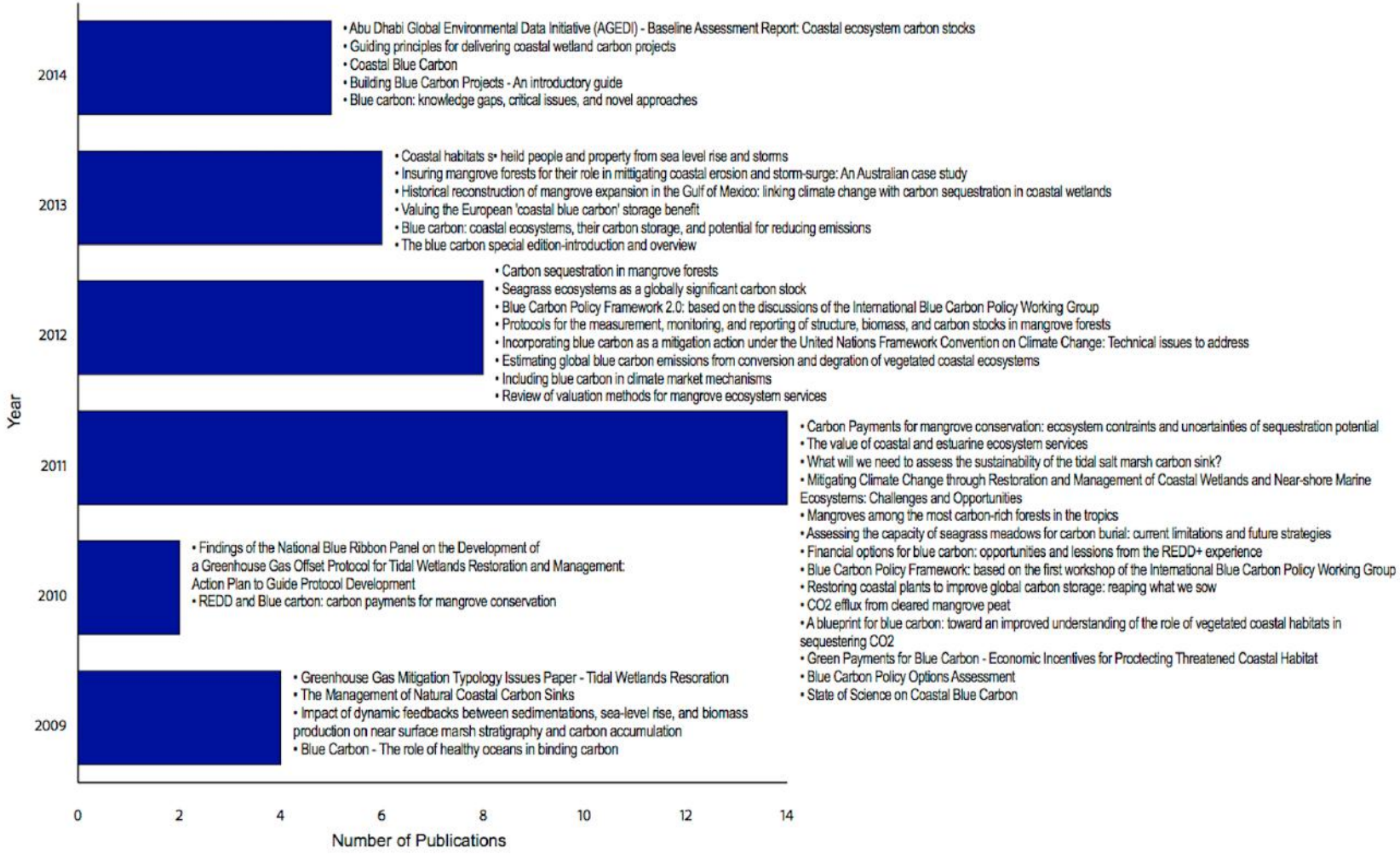
Author	Title	Year	Journal	Mangroves	Seagrass	Saltmarsh	Wetlands
Ullman, R.,Bilbao-Bastida, V., Grimsditch, G.	Including blue carbon in climate market mechanisms	2012	*Ocean and Coastal Management*	X	X	X	

Appendix 7: Accessible Manuals and Guides – Categorized as Financial Mechanism

Author	Title	Year	Publisher	Mangroves	Seagrass	Saltmarsh	Wetlands
AGEDI	Abu Dhabi Global Environmental Data Initiative (AGEDI) - Baseline Assessment Report: Coastal ecosystem carbon stocks	2014	AGEDI, GRID Arendal, Environmental Agency Abu Dhabi	X			
Crooks, S., Emmett-Mattox, S., Findsen, J.	Findings of the National Blue Ribbon Panel on the Development of a Greenhouse Gas Offset Protocol for Tidal Wetlands Restoration and Management: Action Plan to Guide Protocol Development	2010	RAE, PWA, SAIC				X
Crooks, S., Orr, M., Emmer, I., von Unger, M., Brown, B.	Guiding principles for delivering coastal wetland carbon projects	2014	UNEP, CIFOR	X	X	X	
Howard, J., Hoyt, S., Isensee, K., Telszewski, M., Pidgeon, E.	Coastal Blue Carbon	2014	The Blue Carbon Initiative, Conservation International, IUCN, IOC-UNESCO	X	X	X	
Lutz, S.J., Neumann, C., Bredbenner, A.	Building Blue Carbon Projects - An introductory guide	2014	AGEDI	X	X	X	
Murray, B.C., Vegh, T.	Incorporating blue carbon as a mitigation action under the United Nations Framework Convention on Climate Change: Technical issues to	2012	Nicholas Institute for Environmental Policy Solutions, Duke University	X	X	X	

	address					
O'Sullivan, R., Chagas, T., Burns, D., Pearson, T.	Blue Carbon Policy Options Assessment	2011	Climate Focus, The Linden Trust for Conservation	X	X	X

Appendix 8: Blue carbon resources and publications organized by year.



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