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A Business Plan for Blue Carbon Offsets at Duke University

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Executive Summary

Marine ecosystems such as salt marshes, sea grasses and mangroves absorb from the atmosphere and store large amounts of carbon, both in their vegetation and in the soil beneath them. In light of rapid climate change and global warming, it is imperative that we invest in protecting and increasing the carbon and greenhouse gas sinks on our planet. Given the large quantity of carbon in coastal ecosystems relative to their area, these regions and their potential emissions are of great significance. By preserving and revitalizing coastal ecosystems, organizations can utilize this stored carbon to offset their carbon emissions. This is what the Duke Carbon Offsets Initiative is considering in North Carolina. By investing in the protection of the North Carolina shoreline, Duke University has the capacity to generate "blue carbon" Offsets to offset on campus emission. Building on existing scientific data, analysis, and available methodologies, this report presents a Business Plan for a potential blue carbon project in North Carolina and offers the following recommendations for moving this effort forward:

1. The initially proposed avoided erosion project for Ocracoke Island, NC does not appear to a viable source of blue carbon credits.
2. As an alternative, consider a project that involves preserving wetlands from avoided conversion to another land use rather than an avoided erosion project.
3. Do not engage in projects that will set the offset price above $20 per ton of carbon, as these projects are far more expensive than alternative sources of emission reduction.
4. Because blue carbon is a newly developing offset category, utilize the current methodologies for coastal ecosystems until specific guidelines become available.
5. To achieve cost effectiveness, the initial project should involve a partner organization(s). This will decrease the financial resources DCOI will need to provide the project and will utilize the skills of professionals who have years of experience with wetland preservation along the coastline.

Project Description

The purpose of this business plan is to outline a project for Duke Carbon Offset Initiative (DCOI) to engage in an innovative offset category, "blue carbon," the storage and retention of carbon in coastal ecosystems. DCOI's goal is to assist the university in meeting its 2024 objective of becoming carbon neutral. While the campus has made significant strides in reducing energy use and increasing efficiency, there are some emissions of CO_2 and other greenhouse gasses (GHG) that cannot feasibly be eliminated without incurring very high costs or severely impacting the mission of the university. For these sources, Duke University has begun exploring and developing carbon offset projects across North Carolina. Carbon offsets are reductions in emissions of carbon dioxide in order to counter an emission made elsewhere, for example emissions occurring on Duke University's campus are balanced by a reduction in emissions elsewhere. The potential carbon offset project related to this business plan will involve reducing emissions of carbon dioxide from degradation of salt marshes along the North Carolina coast and will allow DCOI to become involved in this newly identified offset sector. The strategy outlined below provides opportunities to both foster scientific advancement and decrease the university's carbon footprint.

Emission Reduction Services Provided by Blue Carbon Projects

The report continues with a brief overview of carbon sequestration in marine environments, describing the scientific parameters at play when evaluating a blue carbon project. This section will also outline the additional benefits such a project will likely have on communities and ecosystems along the North Carolina shoreline. It is important to note the difference between carbon sinks versus carbon sources in the environment. While all living organisms on earth contain carbon, the distinguishing factor between being a source and being a sink is the relative absorption and emission of carbon. If an ecosystem emits more carbon than it absorbs then it is a carbon source. Conversely, if an ecosystem absorbs more carbon than it emits, it is a carbon sink.

Carbon Sequestration

In recent years, significant attention has been directed towards carbon sinks on land, such as forests, and until quite recently little attention has been focused on marine carbon sinks, or blue carbon. Carbon sequestered in coastal ecosystems is commonly referred to as blue carbon. The living biomass above and below marine ecosystems absorbs atmospheric carbon dioxide (CO_2) through photosynthesis, transforming inorganic carbon into organic matter. This carbon could stay buried within the soil for thousands of years, providing an ongoing and long-term removal of CO_2 from the atmosphere. However, when coastal ecosystems experience degradation through disturbance, drainage, reclamation or conversion to another land use, a significant pulse of CO_2 emissions occurs due to this loss of sequestered carbon. According to a study done by Duke University's Nicholas Institute, coastal habitats are experiencing rapid conversion at a rate of 0.7% to 2% per year.[1]

Typical blue carbon repositories include mangroves, seagrass meadows, and salt marshes. The vast majority of blue carbon repositories in North Carolina are salt marshes. According to an IUCN report, each molecule of carbon sequestered in soils of marshes, wetlands, and mangroves probably has greater value than that stored in any other natural ecosystem due to the lack of production of other greenhouse gases. The presence of sulphates in salt marsh soils reduces the

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[1] Murray, B.C., L. Pendleton, W.Aaron Jenkins, and S. Sifleet. 2011. Green Payments for Blue Carbon: Economic Incentives for Protecting Threatened Coastal Habitats. Nicholas Institute for Environmental Policy Solutions, Duke University.

activity of microbes that produce methane.[2] However the research shows that these benefits occur primarily in saltwater ecosystems, therefore freshwater seagrass meadows most likely emit a larger proportion of greenhouse gases compared to their saltwater counterparts. Another aspect that contributes to the attractiveness of tidal salt marshes as carbon sinks is the impact of tidal floodwaters. Floodwaters not only contribute inorganic sediments to marsh soil, but also saturate the soil and reduce the potential for aerobic decomposition.[3] While the carbon content of soils varies across the landscape, coastal wetland soils releases 0.25 million tons of CO_2 per square kilometer (km^2) for every meter of soil lost as a global average.[4] Drainage of these coastal wetlands immediately releases carbon sequestered over recent centuries and in the years following, releases carbon that accumulated in soils over millennia.[5]

Goods and Services Provided by Estuary Ecosystems

These ecosystems provide valuable habitat for plants, birds, and fish. Communities can receive indirect economic benefits from the services and supplies marshes provide to recreational waterfowl hunters. In some parts of the U.S., native vegetation of salt marshes is harvested as fodder or simply used as natural pastures. Marsh ponds and adjacent tidal flats attract wading birds and large flocks of migratory birds that provide further recreation opportunities for bird watching. These areas also serve as an outdoor classroom to educate the public about natural history and ecology. As climate change and sea level rise become more apparent along our coastlines, marsh habitat will offer a substantial barrier. If these ecosystems are adequately vegetated, they are able to keep pace with rising sea levels and help coastal communities adapt to

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[2] Laffoley, D.d'A. & Grimsditch, G. (eds). 2009. The management of natural coastal carbon sinks. IUCN, Gland, Switzerland. Page 7.
[3] *Ibid.*
[4] The World Bank, *Capturing and conserving natural coastal carbon: building mitigation, advancing adaptation.* November 2012.
[5] *Ibid.*

climate change and the resulting sea level rise. However, the most notable indirect benefits from marshes are storm protection and the filtering of pollutants.[6] A vegetated marsh will act as a barrier to waves during extreme storm events and protect coastal communities from damage. By up-taking nutrients from the ground water, these ecosystems help reduce nutrient enrichment that would endanger sea grass beds and marine creatures.[7]

Part of this project would involve establishing oyster beds, which can also filter water pollutants and preserve fish habitats, thereby improving biodiversity in the coastal ecosystems.[8] A living shoreline made up of oyster sills or oyster bags can also absorb wave energy and provide a buffer area for vegetation and sea-life.[9] With more wave energy being absorbed and dissipated, coastal marsh erosion is thereby controlled and carbon is retained onsite. In these ways, salt marshes provide both consumptive and non-consumptive goods and services to the communities nearby.

Strategy and Implementation

Proposed Project Site

The study site proposed for DCOI's blue carbon Pilot Project is a 122-acre preserve located on Ocracoke Island, along the outer banks of North Carolina (see Figures 1 & 2). Known as Springer's Point Preserve, this region is owned and maintained by the North Carolina Coastal Land Trust and is open to visitors year-round as a natural and cultural landmark. The preserve is

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[6] North Carolina Coastal Federation a. 2012. *Living Shorelines.* Retrieved February 26, 2012, from http://www.nccoast.org/Content.aspx?Key=76664726-1d0d-4f30-a6b0-c2702bf97ee3&title=Living+Shorelines

[7] Laffoley, D.d'A. & Grimsditch, G. (eds). The management of natural coastal carbon sinks. IUCN, Gland, Switzerland. 2009.

[8] North Carolina Coastal Federation b. 2012. *Oyster Habitat.* Retrieved February 26, 2012, from http://www.nccoast.org/Content.aspx?key=0dec568b-85f4-4e84-86d1-8a449db4055f&title=Oyster+Habitat

[9] North Carolina Coastal Federation a. 2012. *Living Shorelines.* Retrieved February 26, 2012, from http://www.nccoast.org/Content.aspx?Key=76664726-1d0d-4f30-a6b0-c2702bf97ee3&title=Living+Shorelines

boarded by a National Park Service property to the south. This section of Ocracoke is also well known for being the location of the reputed lair and hideout of the renowned pirate Blackbeard, and is thus an important historical site for many locals and visitors. The following is an excerpt from a Site Survey Report conducted by R.J. LeBlond in 2004 giving the general site characterizes of Springer's Point Preserve:

> Springer's Point Heronry[10] comprises stabilized sand dunes near Springer's Point that grade southeastward to tidal marshes and forests along Old Slough. The dunes support Maritime Evergreen while the tidelands support Tidal Red Cedar Forest, Brackish Marsh (Needlerush Subtype), and Salt Marsh (Carolinian Subtype?). The area between the Maritime Evergreen Forest and tidal habitat features low dunes and sinuous swales that support a mosaic of natural community associations that include Maritime Wet Grassland and Maritime Shrub (Corolla sand soil series area). The Maritime Evergreen Forest has been impacted by a dense covering of alien English ivy (*Hedera helix* var. *helix*) in the ground layer and 20 feet up tree trunks.[11]

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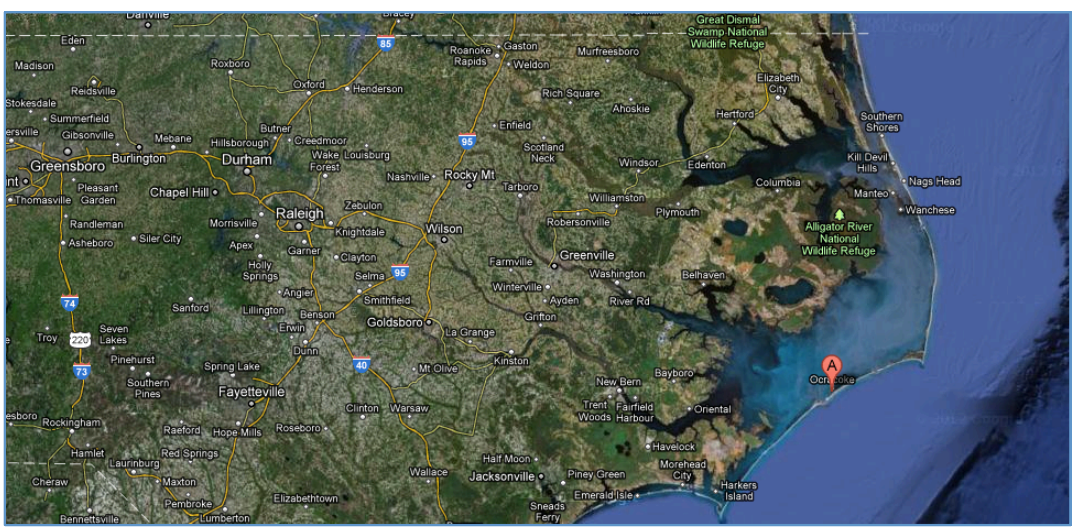
[10] Heronries: a breeding colony of herons, typically a group of trees.
[11] R.J. LeBlond, 2004, "Site Survey Report – Springer's Point Heronry." Send via email on February 9, 2012 by Janice Allen.

Figure 1 – Aerial View of Springer's Point Preserve (i.e. the study site)

Source: sent via email on February 9th, 2012, Janice Allen, North Carolina Coastal Land Trust.

Figure 2 – Study Site location south of Cape Hatteras, Outer Banks, NC



Source: GoogleMaps, accessed on February 20, 2012.

The northwestern portion of the Preserve has experienced extensive wind and wave erosion that threatens its future stability. Recently, an increase of waves generated across Pamlico Sound and boat wake from a nearby navigation channel have accelerated erosion on Springer's Point. In response, both the North Carolina Coastal Land Trust and the North Carolina Coastal Federation have been working with local stakeholders to devise a plan to protect the shoreline and restore damaged habitat. This collaborative effort, titled Springer's Point Preserve Shoreline Restoration Project (here after, "the Project"), has been segmented into two phases.

- Phase One – a demonstration project that would restore 522 linear feet along Springer's Point Preserve and utilize oyster beds and a living shoreline, this will take place where the Preserve boarders Old Slough Strait
- Phase Two – the stabilization of 480 feet of sandy beach along the Pamlico Sound, north of the Phase one site.

The Land Trust expects to begin Phase one in March of 2012. This will involve breaking apart huge concrete slabs (which originally formed a jetty build shortly after World War II, see Figure 3) into smaller rocks that will better buffer wave action and mimic natural conditions. In April of this year, the Land Trust will deploy bags of oyster shell to create habitat and serve as a living breakwater. Marsh grass will be planted by volunteers in May 2012 and will thus complete Phase one. The Land Trust intends to utilize the skills of local contractors and fisherman in each of these stages.

Figure 3 - Existing Jetty between Old Slough and Pamlico Sound Shoreline

Source: sent via email on February 9th, 2012, Janice Allen, North Carolina Coastal Land Trust.

The benefits created by this Phase will go above and beyond preventing erosion. The newly planted marsh will create value for the region's fisheries by providing clean and protected fish habitat. Additionally, the Land Trust has been developing a system to allow local fisherman to harvest shellfish once the oyster sills mature. As the Project progresses, it will provide educational opportunities for students in the area to see the implementation of living shorelines first hand. Within the context of North Carolina's natural resources, this site is one of the largest and most diverse heron breeding grounds in the state, and one of only five known areas of Tidal Red Cedar Forest.[12] It is clear that this area's economic and natural benefits will be better preserved with the addition of the living shoreline and marsh preservation activities.

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[12] R.J. LeBlond, 2004, "Site Survey Report – Springer's Point Heronry." Send via email on February 9, 2012 by Janice Allen.

The primary component of this partnership would involve DCOI supplying financial resources to the Land Trust for Phase one's marsh preservation activities in exchange for the use of the carbon offset credits generated onsite, which ideally will foster an extension of this project for the activities in Phase two. Furthermore, the Land Trust maintains two inholdings alongside the Preserve that could be integrated into this project if additional financial capital became available.[13] This project aligns well with actions called for in a report conducted by various United Nation agencies; the authors called for "targeted investments in the sustainable management of coastal and marine ecosystems alongside the rehabilitation and restoration of damaged and degraded ones"[14]. This pilot project would do exactly this; by investing in Phase one DCOI would be able to support preservation and restoration efforts of critical coastal habitat. The next section provides a brief explanation of these various benefits.

Meeting Offset Market Requirements

Neither a methodology nor a market for blue carbon offsets currently exists. To fill this void in the offset sector, Restore America's Estuaries, a national non-profit dedicated to preserving America's estuarine ecosystems, is leading a technical working group that will develop requirements for quantifying and crediting the greenhouse gas benefits of several new types of wetlands conservation projects under the Verified Carbon Standard (VCS) Program.[15] Unfortunately, this methodology is still in the development and testing phase and will not be available to use for quite some time. Despite this apparent lack of a blue carbon standard, DCOI

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[13] All information in this section was provided in North Carolina Coastal Land Trust's Springer's Point Preserve Shoreline Restoration Planning and Implementation Proposal, February 28, 2011.

[14] Nellemann, C., Corcoran, E., Duarte, C. M., Valdés, L., De Young, C., Fonseca, L., Grimsditch, G. (Eds). 2009. Blue Carbon. A Rapid Response Assessment. United Nations Environment Programme, GRID-Arendal, www.grida.no

[15] Restore America's Estuaries, Climate Change & Greenhouse Gas Offset Protocol Development, accessed on March 24, 2010 at http://www.estuaries.org/climate-change/page-2.html

has chosen to pursue this offset category in an exploratory fashion. This is fitting with DCOI's mission of pursing new and innovative offset projects. Therefore, we have developed a set of interim requirements that will likely make up the key components of the forthcoming VCS blue carbon methodology. Within the scientific community of blue carbon experts, there are six key components to any project that must be present for the sequestration of CO_2 to be recognized on the offset market. These requirements are described in Table 1 below and further explained in detail in the following paragraphs.

Table 1 - Project Requirements and Terms

Key Protocol Aspects and Terms	
Real	Demonstrate that reductions have actually occurred
Additional	Confirm reduction result from activities that would not have happened in the absence of the project
Permanent	Provide procedures for assessing and managing the risk of reversal of CO_2 reductions of removals
Owned Unambiguously	Ensure that ownership of CO_2 reduction sis clearly delineated
Not Harmful	Avoid negative environmental and social impacts
Practical	Minimize project implementation barriers

Source: Restore America's Estuaries[16]

The "Real" requirement is something that should be measured at the culmination of a project, a determination of whether the project was successful in the goal or reducing CO_2 emissions. The quantification of the reductions on site involves careful calculations based on soil and tidal data. The quantity of carbon sequestered in a salt marsh is a product of the parentage of soil carbon and the overall soil bulk density (e.g., grams soil per cubic centimeter) of the soil.[17] Additional information regarding soil salinity and pH are necessary for these calculations as well.

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[16] Restore America's Estuaries, "Action Plan to Guide Protocol Development," findings of the National Blue Ribbon Panel on the Development of a Greenhouse Gas Offset Protocol for Tidal Wetlands Restoration and Management. August 2010.

[17] Chmura, Gail L., "What do we need to assess the sustainability of tidal salt marsh carbon sink?" Journal of Ocean and Coastal Management, 2011.

This aspect of the project site will be discussed below in the Offset Calculation section of this report.

The “Additional” requirement has been achieved, in that this project involves avoided wetlands loss, essentially the conservation and preservation of existing wetland’s carbon stocks that would otherwise be at risk of CO_2 release by erosion and/or human impacts.[18] Furthermore, to address this component, we will attempt to display the rate and amount of erosion that is would occur at the site should the project not be undertaken and compare that loss to the expected erosion rate after the project is completed. This region of the NC coast is by no means stable, and many of the Outer Banks’ islands continue to erode on both their ocean and sound sides.[19] This dual erosion has resulted in the thinning of many islands, including Ocracoke. This thinning will only be exacerbated by future sea level rise. However, the living shoreline aspect of this project will ensure that for many years the area’s soil carbon will not be lost to erosion. Without the use of living shorelines or other stabilization techniques, this area will likely be overcome by erosion; hence the aims of this project are both important and pressing.

The “Permanent” aspect of any blue carbon project is difficult to demonstrate for coastal ecosystems are inherently dynamic and even more so now in light of global climate change. The episodic storm events that occur along the eastern coast of the United States are the largest threat to the Permanent requirement. It will be necessary to build into the offset contract various provisions related to the risk posed by hurricanes and harsh winter storms. Looking further into the future, sea level rise is real concern given current erosion trends and the gentle slope of the North Carolina’s coastline. However, much uncertainty exists as to the extent sea level rise will

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[18] Chmura, Gail L., “What do we need to assess the sustainability of tidal salt marsh carbon sink?” Journal of Ocean and Coastal Management, 2011.
[19] Pilkey, Orrin H., Tracey Monegan Rice, and William J. Neal. (2004) How to Read a North Carolina Beach. The University of North Carolina Press: Chapel Hill and London.

impact the N.C. coastal regions, and therefore this project and the coastline of Ocracoke Island. Chmura (2011) provides an excellent comparison of how changes in vertical resolution result in differences in uncertainty of land area flooded. Shown in panel (A) are lands vulnerable to a 1-meter increase of sea level, created using elevation data, and panel (B) displays a similar scenario but created by lidar elevation data. The darker blue tint represents the area at or below 1 meter in elevation, and the lighter blue tint represents the additional area in the vulnerable zone given the vertical uncertainty of the input elevation datasets. The more accurate lidar data for delineation of the vulnerable zone results in a more certain delineation.[20] This shows that caution should be applied when deciding on the lifespan of offsets generated for this project. One possible avenue for handling this uncertainty is to create an insurance account of offsets that are not utilized by DCOI but kept in case of project site damage. This scheme is similar to the Verified Carbon Standard's "buffer approach" which involves an independent risk assessment that verifies against predefined risk criteria. Based on the identified level of risk, the project is required to set aside a portion of total number of credits generated in a pooled buffer account shared by many offset projects.[21] The VCS's application of this risk account is currently situated under forestry and agriculture projects but could be expanded to include blue carbon projects. This possibility should be researched further.

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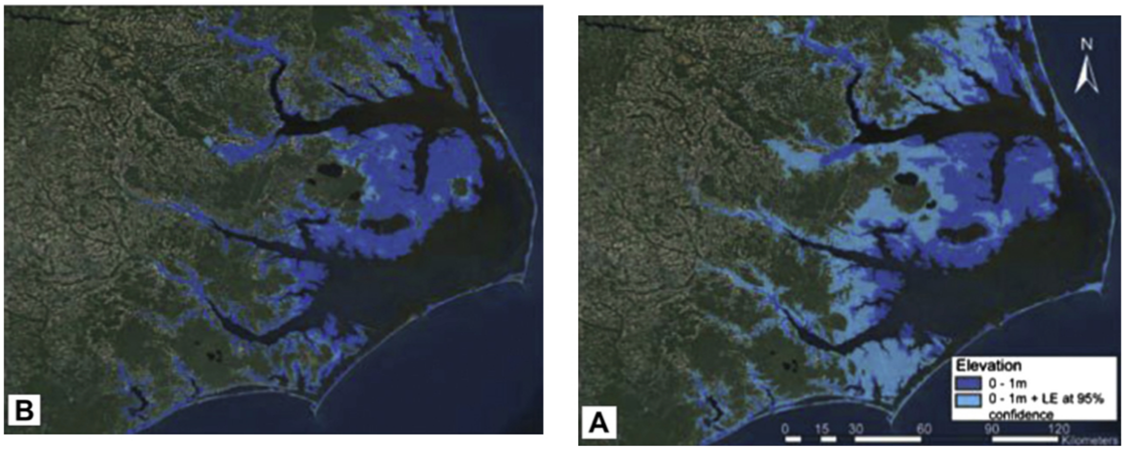
[20] Gesch, D.B., Gutierrez, B.T., Gill, S.K., 2009. Coastal elevations. In: Titus (Coordinating Lead Author), J.G., Anderson, K.E., Cahoon, D.R., Gesch, D.B., Gill, S.K., Gutierrez, B.T., Thieler, E.R., Williams (Lead Authors), S.J. (Eds.), CCSP coastal Sensitivity to Sea-level Rise: a Focus on the Mid-Atlantic Region. A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. U.S. Environmental Protection Agency, Washington D.C., USA, p. 320.

[21] Charlotte Streck, Climate Change and Forests: Emerging Policy and Market Opportunities. Bookings Institution Press, 2008.

Figure 4 - Comparison of Vertical Differences & Sea Level Rise in North Carolina



The "Owned Unambiguously" aspect of this project has yet to be fully determined but it is assumed that in future conversations with the Land Trust that these offsets will be solely owned by DCOI. This project has been show to be both "Non-Harmful" and "Practical". The environment on the Preserve is quite damaged from recent winter surges and has not been functioning in productive manner. The addition of a living shoreline will allow the marsh to regrow and become a more robust environment, capable of withstanding strong wave and wind impacts. The social component of this project is significantly beneficial; the educational, recreational, and aesthetic aspects of this project will improve the economic and social wellbeing in the region.

Offset Calculation

Salt marshes store carbon in anaerobic sediments where it is not oxidized into CO_2 and therefore is kept out of the atmosphere. As the tides move in and out, depositing more and more sediment into these marshes, the anaerobic materials beneath these ecosystems accumulate and with it are stored large amounts of carbon. Additionally, below ground production of roots, rhizomes, and microflora (cyanobacteria and eurkaryotic algae) that live in marsh sediment accumulates a large amount of carbon in marsh soils.[22] Figure 4 shows the above and below ground production of selected tidal salt marsh species from three different plant families in North America and Europe, demonstrating the importance of below ground production with varied plant forms. When calculating the carbon offsets from this project, it will be important to include below ground as well as above ground storage capacity and rates.

Figure 5 - Below & Above Ground Sequestration Rates

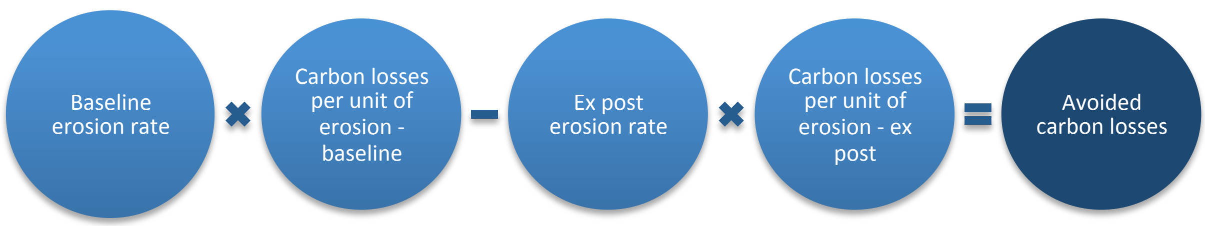
Species	Below	Above	Region	Reference
	$-$g m^{-2}	yr^{-1}$-$		
Chenopodiaceae				
Arthrocnemum macrostachyum	1260	683	Po Delta	Ibañez et al., 2000
Arthrocnemum macrostachyum	50	190	Ebre Delta	Ibañez et al., 2000
Arthrocnemum macrostachyum	340	840	Ebre Delta	Ibañez et al., 2000
Salicornia fructosia	950	580	Ebre Delta	Ibañez et al., 2000
Atriplex portulacoides	1601	598	Guadiana River	Neves et al., 2007
Plantaginaceae				
Plantago maritima	648	296	Bay of Fundy	Connor 1995
Poaceae				
Spartina patens	1113	500	Bay of Fundy	Connor 1995
Spartina patens	3300	785	Delaware Bay	Roman and Daiber 1984
Spartina alterniflora	1575	718	Bay of Fundy	Connor 1995
Spartina alterniflora	6500	1487	Delaware Bay	Roman and Daiber 1984

Source: Chmura, Gail L., 2011.

Various data go into calculating carbon sequestration potential of a site. The National Center of Ecological Analysis and Synthesis (NCEAS) is currently working on creating a modeling tool that will allow a user to determine the sequestration rate at a site by entering in various soil and wave characteristics. This model will likely be used to calculate avoided carbon losses and associated carbon gains resulting from the restoration of wetlands and may help DCOI as they pursue other project sites. For an erosion project, such as that on Ocracoke Island, the ideal method of calculating actual offset credits generated involves five key calculations outlined

[22] Chmura, Gail L., "What do we need to assess the sustainability of tidal salt marsh carbon sink?" Journal of Ocean and Coastal Management, 2011.

in the graphic below. First we must know the baseline erosion rate at the site and the associated carbon losses as a result of that erosion. Then we subtract from that initial calculation the erosion rate and carbon losses after the project has been implemented. This will then give us the avoided carbon losses, which will give us the cost per tone for the offsets based on the cost of the living shoreline project. This will be explained in more detail in the following sections.



However, the baseline erosion rates and related carbon loss rates are currently unknown and therefore we have implemented an interim calculation to predict the avoided carbon losses of this study site. Because such a tool is not yet available, we have created a meta-analysis of various studies performed on North Carolina soil, and averaged out the carbon storage levels from a total of six studies and sequestration rates from a total of five studies. The results of our analysis are presented in Table 2 (Sequestration Capacity) & Table 3 (Sequestration Rates) below. The values associated with sequestration capacity refer to the ecosystem's ability to take carbon out of the atmosphere and store it in the ground, measured in tons of carbon per hectare. The sequestration rate pertains to the rate at which the soil actively sequesters atmospheric carbon, measured in tons of carbon per hectare per year, converted to CO_2 to make consistent with other forms of GHG mitigation. The avoided carbon losses from an erosion project will be a combination of the loss in soil capacity (release of buried carbon due to erosion) and the forgone carbon sequestration into the future (loss of the marsh grass which absorbs the carbon). A more sophisticated approach is needed to provide credible estimates of the actual carbon benefits from this project, however we do not have the resources for such an endeavor at this time.

Table 2 - North Carolina Soil Carbon Capacity (top meter of soil)

Author	Craft et al. [23]					Chmura et al. [24]
Sequestration Capacity	173.65 CO_2/ha	420.79 CO_2/ha	1556.43 CO_2/ha	1957.56 CO_2/ha	2037.64 CO_2/ha	806.67 CO_2/ha
Average Capacity:				1158.79 tons CO_2/ha		

Table 3 - North Carolina Carbon Sequestration Rate

Author	Chmura et al. [25]				
Sequestration Rate	2.57 tons CO_2/ha/yr	2.16 tons CO_2/ha/yr	0.77 tons CO_2/ha/yr	5.35 tons CO_2/ha/yr	3.92 tons CO_2/ha/yr
Average Sequestration Rate:			2.95 tons CO_2/ha/yr		

When using only these data, we can hypothesize that the salt marsh at Springer's Point Preserve has a soil carbon capacity of roughly 1,158.79 t CO_2/ha and a sequestration rate of roughly 2.95 tons of CO_2/ha/yr. However the robustness of these calculations is far from satisfactory, the range for carbon capacity for these study sites is 173.65 – 2037.64 CO_2/ha and for carbon sequestration rates the range is between 0.77 – 5.35 tons CO_2/ha/yr. Both of these values are important when calculating the viability of a blue carbon project site. We will explain how these values contribute to the calculation of carbon benefits per acre in the following section.

There are quite a few uncertainties that have been mentioned in the preceding paragraphs, a further complication arises when calculating the sequestration of carbon and its release from an erosion project. Depending on the site specifics, we must track the erosion of the marsh land separate from that of the sand simply because the erosion of sand does not release carbon dioxide. Additionally, when a marsh erodes there is a certain percentage of soil carbon that is released

[23] Craft, C. B., S. W. Broome, et al. (1988). "Nitrogen, phosphorus, and organic carbon pools in natural and transplanted marsh soils." Estuaries 11(4): 272-280
[24] Chmura, G. L., S. C. Anisfeld, et al. (2003). "Global carbon sequestration in tidal, saline wetland soils." Global Biogeochemical Cycles 17(4): 1-12
[25] *Ibid.*

into the air, the rest is kept in the ocean water and deposited as sediments on the bottom of the ocean floor. This is quite a significant complication and these percentages are almost impossible to calculate. If this project is to be pursued, DCOI must think critically about this coastal process and develop a scientifically informed methodology for quantifying these rates of release.

Calculating Offset Price of Project Site

Utilizing the results of our meta-analysis, we calculated the breakeven offset price from the Springer's Point Project in the following manner:

The total project costs to all parties involved was $70,000, and the avoided carbon loss of the site we found to be 46.90 tons of CO_2, calculated using the per acre loss estimates from the meta-analysis, which was multiplied by 0.10 because marshes only constitute of 1/10 at the project site. Therefore, the total project costs ($70,000) divided by the site's carbon sequestration capacity (46.90 tCO_2) results in the amount the DCOI would theoretically pay for each ton of carbon offset, $1,490/ton. This is much more expensive than other forms of mitigation credit that DCOI can access, which leads to our recommendation that DCOI not pursue this particular partnership with the North Carolina Coastal Land Trust. To provide a comparison (see below), the average cost of a carbon offset on the global market is roughly $6/ton of carbon sequestered. It is clear that this project would not be a viable blue carbon offset project at that price, as the carbon benefits of this project would be roughly $280, which is well below the total project cost. The next section will provide recommendations based on this outcome that would guide DCOI in selecting a new blue carbon offset project site.

Recommendations for Moving Forward

To pursue blue carbon opportunities that are likely to be more valuable than the Ocracoke example, we made recommendations on four issues to help DOOI move forward. These recommendations are summarized in the figure below and will be illustrated in detail in the following section.

Figure 6 – Recommendations for Moving Forward

Geographic Regions	Activity Types	Available Carbon Standards	Measures of Cost Effectiveness
Coastal North Carolina	Avoided emission and wetland Loss	American Carbon Registry forest carbon project standard	Break-even price maximum: 20 $/tCO2e
Tidal freshwater wetlands in Sacramento San Joaquin Delta		Verified Carbon Standard (VCS) REDD methodology	Carbon benefit per acre threshold: $9,379
Coastal wetland system in Mississippi Delta		VCS agriculture, forestry and other land Use (AFOLU) requirements	

Geographic Regions for Blue Carbon Opportunities

Coastal habitats, including mangroves, salt marshes and seagrass meadows are distributed around the globe; therefore blue carbon opportunities also exist in geographic regions other than North Carolina. Since DCOI is at the early stage of considering blue carbon payments, projects implemented in the United States would be a great place to put initial effort in. In terms of the greatest carbon sequestration potential, Restore America's Estuaries (RAE) identified coastal North Carolina, tidal freshwater wetlands in Sacramento San Joaquin Delta as well as the coastal wetland system in Mississippi Delta as the case study sites in its published Action Plan to Guide

Protocol Development.[26] Our meta-analysis shows the average sequestration rate of North Carolina soils is 2.95 tCO_2e/ha/year or 1.19 tCO_2e/acre/year, while the storage rate of California Delta is about 25 tCO_2e/acre/year.[27] The Barataria basin, which is adjacent to Mississippi Delta, can sequester carbon at a rate of 1000-4000 g C/m2/year or 4-16 tCO2e/acre/year, and Mississippi Delta had a land loss rate of 15,360 acres per year before 2005.[28] The outstanding carbon sequestration rates and alarming land loss rates indicates that these sites could serve as a starting point for DCOI to pursue blue carbon opportunities.

Project Activity Type

Wetland project activities could be generally categorized into four distinct types: avoided emissions and wetland loss, wetland restoration, wetland carbon enhancement, and wetland creation.[29] Wetland restoration covers activities restoring ecosystem services in a converted or degraded wetland; wetland carbon enhancement refers to actions increasing ecological functions provided by existing wetland; wetland creation means establishment of a new wetland ecosystem in a non-wetland habitat.[30] Erosion prevention, which is the activity type of the Ocracoke project, may have proven to be a non-starter at the beginning because the project cost far outweighs the carbon benefits. Moreover, erosion prevention has not been recognized as a major type of

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[26] Restore America's Estuaries. 2010. *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.* Restore America's Estuaries.

[27] U.S. Department of the Interior. 2009. *Carbon Storage Project.* U.S. Department of the Interior. Retrieved from http://www.doi.gov/whatwedo/climate/cop15/upload/CO2_PowerPoint_-2.pdf

[28] Batker, D., Torre, I. D., Costanza, R., Swedeen, P., Day, J., Boumans, R., & Bagstad, K. 2010. *Gaining Ground - Wetlands, Hurricanes and the Economy: The Value of Restoring the Mississippi River Delta*. Earth Economics.

[29] Crooks, S., D. Herr, J. Tamelander, D. Laffoley, and J. Vandever. 2011. *Mitigating Climate Change through Restoration and Management of Coastal Wetlands and Near-shore Marine Ecosystems: Challenges and Opportunities*. Environmental Department Paper 121, World Bank, Washington, DC.

[30] *Ibid.*

activities protecting wetland and coastal ecosystems, and therefore experiences and methodologies developed from this activity may not be expanded to other types of actions.

Given the fact that the capacity of storing greenhouse gas in coastal and wetland habitats is enormous on a per area basis and these ecosystems are being destroyed at an alarming rate in some areas, avoided emission and wetland loss turns out to be a reasonable option for DCOI to start pursuing blue carbon opportunities. Nicholas Institute's study on green payments for blue carbon also suggests that blue carbon payments for avoided conversion projects can exceed project costs in some areas without accounting for ecosystem service values.[31] For the other wetland project activity types, however, there is little scientific analysis of their economic viability. Combined with the suggestions on available geographic regions, we recommend DCOI to consider avoided emission and wetland loss projects in Sacramento San Joaquin Delta, Mississippi Delta and coastal North Carolina as a starter in its search for blue carbon offsets suppliers.

Availability of Blue Carbon Protocols and Standards

One great challenge to quantify blue carbon offsets is the absence of a specific and well-developed protocol or standard accounting for blue carbon offsets. Nicholas Institute's study on blue carbon financing options indicates that existing REDD standards can be used to verify blue carbon offsets, at least in the case of mangroves.[32] Scrutiny of all the major protocols and standards currently utilized in the voluntary carbon offset market reveals that American Carbon Registry (ACR) and Verified Carbon Standard (VCS) are relatively applicable to blue carbon

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[31] Murray, B.C., L. Pendleton, W. Aaron Jenkins, and S. Sifleet. 2011. *Green Payments for Blue Carbon: Economic Incentives for Protecting Threatened Coastal Habitats*. Nicholas Institute for Environmental Policy Solutions, Duke University.

[32] Gordon, D., B.C. Murray, L. Pendleton, and B. Victor. 2011. *Financing Options for Blue Carbon: Opportunities and Lessons from the REDD+ Experience*. Nicholas Institute for Environmental Policy Solutions, Duke University.

projects in that they incorporate certain types of blue carbon in REDD projects and are inclined to develop innovative carbon offset types.

American Carbon Registry

The most updated version of ACR forest carbon project standard defines activities such as "avoiding conversion of a peatland or wetland" under the category of REDD project.[33] Among all the current ACR-approved methodologies, the methodology for Restoration of Degraded Deltaic Wetlands of the Mississippi Delta is to some extent related to blue carbon project. This innovative methodology also has the potential to be generalized to other wetland restoration project types in broader geographic regions in the future.[34] Additionally, modifications on existing ACR-approved methodologies without weakening their consistency to determine carbon offsets and additionality are acceptable if original approaches are not directly applicable.[35] Therefore, ACR forest carbon project standard as well as the aforementioned methodology can be considered as an appropriate approach for DCOI to quantify blue carbon offsets, particularly offsets generated from wetland restoration projects.

Verified Carbon Standard

Carbon offset projects developed on forested wetlands without peat are likely eligible for the REDD methodology in VCS, while projects implemented on wetlands containing peat are separately covered by the latest version of the VCS Agriculture, Forestry and Other Land Use (AFOLU) Requirements, which categorize peatland rewetting and conservation into AFOLU

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[33] American Carbon Registry. 2010. *The American Carbon Registry Forest Carbon Project Standard*. American Carbon Registry.
[34] American Carbon Registry. 2012. *Restoration of Degraded Deltaic Wetlands of the Mississippi Delta*. American Carbon Registry.
[35] American Carbon Registry. 2010. *The American Carbon Registry Standard*. American Carbon Registry.

project types.[36][37] Although VCS has partially accounted for the wetland conservation practices, standards and requirements that can credit a broader range of wetland project types are currently being designed under the VCS program. RAE has been leading the National Blue Ribbon panel since 2010 to develop an innovative and comprehensive carbon offset requirement for tidal wetland management, including avoided wetland loss and wetlands restoration.[38] According to RAE's proposal of developing wetland project requirements, eligible project types are likely to include certain typical blue carbon repositories, such as mangroves and salt marshes, and the final version of wetland requirement have been submitted to VCS for approval.[39]

In all, ACR standard and VCS could be directly applicable to wetland restoration projects, particularly projects on mangrove forests and peatlands. In terms of restoration projects in other coastal ecosystems and other project activity types, appropriate modifications on existing standards and methodologies are required and allowable but would need the approval of ACR. Moreover, it is entirely possible that the pending wetland requirements developed by RAE will soon be approved by VCS program. Once this requirement is officially approved, DCOI can assess whether they should utilize the specific requirement to credit various types of coastal and wetland projects.

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[36] Verified Carbon Standard. 2012. *Agriculture, Forestry and Other Land Use (AFOLU) Requirements*. Verified Carbon Standard.
[37] Verified Carbon Standard. 2010. *Approved VCS Methodology VM0007 Version 1.1: REDD Methodology Module REDD Methodology Framework (REDD-MF) Sectoral Scope 14*. Verified Carbon Standard.
[38] Restore America's Estuaries. 2010. *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.* Restore America's Estuaries.
[39] Restore America's Estuaries. 2011. *Proposal to Develop Wetlands Requirements for VCS Submitted by Restore America's Estuaries*. Verified Carbon Standard.

Measures of Cost Effectiveness

At this stage, DCOI is interested in developing blue carbon projects by financing or co-financing projects. The cost-effectiveness of a project is therefore a very significant factor to determine whether this project deserves investment. In the following section, we will illustrate two measures of cost effectiveness – break-even price and carbon benefit per acre.

Break-even Price

Break-even price is the carbon offset price at which carbon benefits are equal to the project costs. In our analysis, carbon benefits only refer to the values of generated carbon offsets. Ecosystem services values or other non-market values are not accounted for. From a blue carbon project developer's perspective, break-even price is the minimum price that the developer would be willing to charge for the carbon offsets. For a project investor or pure offset purchaser such as DCOI, break-even price of a potential blue carbon project is also meaningful to determine future investments or payments. Generally, blue carbon projects with break-even prices significantly exceeding market price or DCOI's expectation for payments should not be considered, in that the carbon benefits actually acquired cannot cover the payments. Although the existing voluntary carbon market does not incorporate blue carbon and price for blue carbon offsets is therefore unknown, reasonable estimations of blue carbon offset price could be made based on the offset prices in general voluntary market. Because wetland projects and forest projects are to some extent similar and some types of blue carbon activities could be categorized into REDD projects, offset prices in forest carbon market can also shed light on future payments for blue carbon.[40]

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[40] Gordon, D., B.C. Murray, L. Pendleton, and B. Victor. 2011. *Financing Options for Blue Carbon: Opportunities and Lessons from the REDD+ Experience*. Nicholas Institute for Environmental Policy Solutions, Duke University.

Table 4 - Carbon Prices in Voluntary Markets (2010)

Market	Price ($\$/tCO_2e$)	Comment	Source
Voluntary market	6	Average price of global over-the-counter (OTC) market in 2010. OTC market is currently the largest component of voluntary carbon market. Since Chicago Climate Exchange effectively stopped operating in 2010, it is excluded from voluntary market in this report.	Peters-Stanley, M., K.Hamilton, T. Marcello, and M. Sjardin. 2011. *Back to the Future: State of the Voluntary Carbon Markets 2011*. Ecosystem Marketplace & Bloomberg New Energy Finance.
U.S. voluntary market	4.9	Average price of U.S. OTC market in 2010. U.S OTC market refers to all transacted offsets generated from projects implemented in the United States.	
VCS market section	6	Average price for carbon offsets from projects credited by VCS program in 2010. The price range of VCS market section is from less than 1 $\$/tCO_2e$ to more than 20 $\$/tCO_2e$.	
ACR market section	< 3	Average price for carbon offsets from projects credited by ACR standard	
DCOI's expectation	10-15	DCOI expects the offsets to be priced between 10 $\$/tCO_2e$ to 15 $\$/tCO_2e$. Since blue carbon offset is a new type of offset, prices slightly exceeding 15 $\$/tCO_2e$ could also be acceptable.	Client meeting with David Cooley on March 19, 2012
Voluntary forest carbon market	5.6	Average price for carbon offsets generated from forest projects in the OTC market in 2010	Diaz, D., K. Hamilton, and E. Johnson. 2011. *State of Forest Carbon Markets 2011*. Ecosystem Marketplace
Voluntary REDD market	4.9	Average price for carbon offsets from REDD projects in the OTC market in 2010	
VCS forest carbon market	4	Average price for carbon offsets from forest carbon projects credited by VCS program in 2010. The price is approximately ranged from 1 $\$/tCO_2e$ to 17 $\$/tCO_2e$.	

Comparison of carbon prices in the overall voluntary carbon market and its distinct market sections reveals that prices for general offsets and forest carbon offsets are averaged between less than 3 $/t$CO_2$e to 6 $/t$CO_2$e, and the general offset prices under VCS program can range from 1 $/t$CO_2$e to 20 $/t$CO_2$e. Our client DCOI is willing to pay 10-15 $ for each unit of carbon offset based on its previous payments. Because DCOI is at the early stage of developing blue carbon projects, blue carbon offsets with prices slightly over 15 $/tCO2 will also be considered. According to the summary of different market prices and our client's expectations, we recommend an economically reasonable blue carbon offset price should not exceed 20 $/tCO2e. In another word, this is the largest price that DCOI would be willing to pay in order to be cost effective. Hence, if the break-even price of a potential blue carbon projects surpasses 20 $/tCO2e, it would not be cost effective to finance this project, and vice versa.

Carbon Benefit per Acre

Cost effectiveness of a blue carbon project can also be measured by comparing carbon benefit per acre with project cost per acre. Carbon benefit per acre is the product of project carbon reduction benefit and market offset price, while project cost per acre is the general project cost divided by project site size. Generally, projects with cost per acre lower than carbon benefit per acre would be deemed as cost effective and attractive to finance.

According to the meta-analysis of North Carolina soil performed above, the average carbon sequestration capacity, which could also be viewed as the project carbon reduction benefit in the case of avoided conversion, is 1158.79 tCO_2e per hectare or 468.96 tCO_2e per acre. At an offset price of $20/t$CO_2$e, the carbon benefits per acre are roughly $9,379 (See Figure 6 for calculation overview). Since the carbon price we utilized in the calculation is the largest economically reasonable price, we recommend DCOI to consider $9,379 as a threshold value of carbon benefits per acre it can acquire by making payments. In other words, this is the maximum value that DCOI will invest in each acre of wetland in order to achieve cost-effectiveness. If the project cost per acre is less than 9,379 $/acre, then the project as a whole is cost effective and could be considered as a potential blue carbon offset supplier.

Figure 6 - Calculating a Carbon Benefits per Acre Threshold

Three aspects need to be paid special attention to when using this method to determine future payments. First, this threshold value mainly applies to projects implemented in North Carolina as we utilized average carbon sequestration capacity of North Carolina soils in the calculation. For projects in other geographic regions, the threshold value of carbon benefits per acre needs to be adjusted by using the average carbon sequestration capacity of that specific area. Second, since the carbon sequestration capacity of 468.96 tCO_2e per acre is the average level of North Carolina soils and the specific values may vary greatly across differing project sites and habitat types, the threshold value of $9,379/acre should not be taken as a determinant in blue carbon payments. For example, it is entirely possible that a project of which the cost surpasses $9,379/acre is actually economic viable if the carbon sequestration capacity is much higher than 468.96 tCO_2e per acre. Third, given the fact that blue carbon projects have not been well developed and blue carbon offset market still doesn't exist, we used a relatively high offset price of $20/tCO2e in our calculation. However, along with the gradual incorporation of blue carbon into overall carbon market, the economic reasonable blue carbon price is expected to get closer to the average market price. Hence, the threshold value of carbon benefit per acre is expected to decline in the future.

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