Understanding the Potential for Blue Carbon and it's Financial and Scientific Capabilities for Developing a Blue Economy for Small Island Developing States (SIDS)

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United Nations – The Nippon Foundation of Japan Fellowship Programme 2024

UN Office of Legal Affairs Division for Ocean Affairs and the Law of the Sea

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ABSTRACT

Small Island Developing States (SIDS) are increasingly recognizing the importance of the ocean and coastal ecosystems in fostering sustainable development, particularly through the concept of Blue Carbon. Blue Carbon refers to the carbon captured and stored by marine and coastal ecosystems such as mangroves, seagrasses, and salt marshes. These ecosystems play a critical role in mitigating climate change by sequestering large amounts of carbon dioxide. This research explores the potential of Blue Carbon to contribute to Blue Economy in SIDS, emphasizing both the financial and scientific aspects of this opportunity. The scientific understanding of Blue Carbon has advanced in recent years, highlighting the significant role that marine ecosystems can play in climate change mitigation. By protecting, restoring, and enhancing Blue Carbon ecosystems, SIDS can not only improve biodiversity and coastal resilience but also generate financial benefits through carbon credits and ecosystem-based services. This financial potential, including carbon trading mechanisms, offers a pathway for SIDS to access international climate finance while also fostering sustainable economic development. Moreover, the implementation of Blue Carbon projects in SIDS faces challenges such as limited technical capacity, lack of data, and vulnerability to climate impacts. However, with the right scientific research, policy frameworks, and partnerships, these challenges can be addressed. By leveraging international collaboration, local knowledge, and sustainable management practices, SIDS can capitalize on the emerging Blue Economy to enhance resilience, boost economic growth, and contribute to global climate goals. This paper examines the scientific foundations, financial mechanisms, and potential pathways for integrating Blue Carbon into the economies of SIDS. It also highlights the role of international cooperation, innovation, and capacity-building in empowering these nations to benefit from Blue Carbon and drive sustainable development through a thriving Blue Economy.

ACKNOWLEDGMENTS

I would like to thank the United Nations for granting me the opportunity to conduct this research and provide the resources and assistance. To the Nippon Fellowship for allowing fellows from all over the world to participate in this program and to gain so much experience, knowledge and skills. I would like to thank the fellows who participated in the 2024 program for making the experience even more remarkable. To Vanessa and Valentina, for the amazing guidance and warm assistance. My supervisor, Tim Jennerjahn for providing his expertise throughout the fellowship. A special thank you to ZMT and its personnel for additional help and assistance throughout my time in Germany. To Marver Woodley for encouraging me to pursue this research. To the Ministry of Agriculture, Lands, Fisheries and the Blue Economy for allowing me to take this opportunity. Lastly to my mother for providing never ending support through the program.

LIST OF ACRONYMS

ACR- AMERICAN CLIMATE REGISTRY

AF- ADAPTATION FUND

AFOLU- AGRICULTURE, FORESTRY AND OTHER LAND USES

A/R- AFFORESTATION/REFORESTATION

BC- BLUE CARBON

BCE- BLUE CARBON ECOSYSTEM

BCP- BLUE CARBON PROJECTS

CAR- CLIMATE ACTION RESERVE

CBD- CONVENTION ON BIOLOGICAL DIVERSITY

CCCCC- CARIBBEAN COMMUNITY CLIMATE CHANGE CENTRE

CDM- CLEAN DEVELOPMENT MECHANISM

CER- CERTIFIED EMISSION REDUCTION

COP- CONFERENCE OF PARTIES

CO_2 – CARBON DIOXIDE

CSR- CORPORATE SOCIAL RESPONSIBILITY

EBM- ECOSYSTEM BASED MANAGEMENT

ES-ECOSYSTEM SERVICE

EEZ- EXCLUSIVE ECONOMIC ZONES

FA- FOCAL AREAS

GCF- GREEN CLIMATE FUND

GDP- GROSS DOMESTIC PRODUCT

GEF- GLOBAL ENVIRONMENT FACILITY

GEF TF- GLOBAL ENVIRONMENT FACILITY TRUST FUND

GHG- GREENHOUSE GASES

INDC- INTENDED NATIONALLY DETERMINED CONTRIBUTIONS

IPCC- THE INTERCONTINENTAL PANEL ON CLIMATE CHANGE

LDC- LEAST DEVELOPED COUNTRIES

LDCF- LEAST DEVELOPED COUNTRIES FUND

LULUCF- LAND USE, LAND USE CHANGE AND FORESTRY

MPA- MARINE PROTECTED AREAS

MSP-MARINE SPATIAL PLANS

NAMA- NATIONALLY APPROPRIATE MITIGATION ACTIVITIES

NAP- NATIONAL ADAPTATION PLANS

NAPA- NATIONAL ADAPTATION PROGRAMME OF ACTION

NBS- NATURE BASE SOLUTIONS

NDC- NATIONALLY DETERMINED CONTRIBUTIONS

NGO- NON-GOVERNMENT ORGANIZATIONS

PES- PAYMENT FOR ECOSYSTEM SERVICES

RAMSAR- RAMSAR CONVENTION ON WETLANDS OF INTERNATIONAL IMPORTANCE ESPECIALLY AS WATERFOWL HABITAT IS AN INTERNATIONAL TREATY FOR THE CONSERVATION AND SUSTAINABLE USE OF WETLANDS

REDD+- REDUCING EMISSIONS FROM DEFORESTATION AND FOREST DEGRADATION

SCCF- SPECIAL CLIMATE CHANGE FUND

SDG- SUSTAINABLE DEVELOPMENT GOALS

SIDS- SMALL ISLAND DEVELOPING STATES

UNEP- UNITED NATIONS ENVIRONMENT PROGRAM

UNESCO- UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

UNFCC- UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

USD-UNITED STATES DOLLARS

VCM- VOLUNTARY CARBON MARKET

VCS- VERIFIED CARBON STANDARD

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

Countries around the world are tasked with creating climate change initiatives and action plans towards combating the adverse effects of greenhouse gases (GHG). Many Small Island Developing States (SIDS) which are regions who are mostly affected by Climate Change must also attempt to produce ways to protect and preserve their coastal resources from catastrophic impacts such as violent hurricanes and cyclones, sea level rise and drought. The race to find solutions grows every day, but effects and impacts surpass the innovative efforts produced by many states. The 1.5 to Stay Alive campaign initiated before the United Nations Framework Convention on Climate Change (UNFCC) Conference of Parties (COP) 15 Climate Change Conference held in Copenhagen in 2009 highlighted the threats that SIDS face from a global temperature increase exceeding 1.5 degrees above pre-industrial levels[1] [2] Tropical marine ecosystems and species are highly sensitive to extreme temperature changes and the concept was to promote awareness and create actions to countries with vulnerable ecosystems to not surpass this temperature. Unfortunately, due to the fast-paced nature of climate change and its impacts, the temperature has increased above 1.5 and adverse effects on the tropical environment and ecosystem can be shown through coral bleaching, harsh cyclones and fish migration.

Finding solutions has been the main issue for many SIDS. Although countries have conducted research, finding a solution to the impacts is an area that needs the upmost attention. A new approach for addressing Climate Change in SIDS is using Blue Carbon (BC). During regional and international events such as the COP and The Intercontinental Panel on Climate Change (IPCC) , BC is acknowledged as a Nature-Based Solution (NBS) and aim to protect tropical marine ecosystems, mitigate climate change, and contribute to the Gross Domestic Product (GDP) of countries that implement this strategy.[3] Many BC markets starting point arose from the role coastal ecosystems play in climate change mitigation. They aim to restore and conserve these ecosystems that can generate "credits" measured by how much carbon is captured and

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[1] Caribbean Public Health Agency (CARPHA), "CHAPTER 5 RESPONSES TO CLIMATE CHANGE AND HEALTH IN THE CARIBBEAN: STRATEGIES, ORGANISATIONS AND FINANCES ‚State of Public Health in the Caribbean Report 2017-2018" Climate and Health: Averting and Responding to an Unfolding Health Crisis, 2018, Pg.43

[2] Leon Sealey-Huggins ,"1.5°C to stay alive': climate change, imperialism and justice for the Caribbean" in Special Issue: Whatever Happened to the Idea of Imperialism? Third World Quarterly,vol. 38, John Narayan and Leon Sealey-Huggins, eds. (2444-2463, DOI: 10.1080/01436597.2017.1368013, 2017, pg. 4

[3] World Bank, "Unlocking Blue Carbon Development: Investment Readiness Framework for Governments." Washington, D.C.: World Bank.,2023, Pg.32,40

stored. [4] The IPCC describes carbon sequestration as the process of incorporating carbon-containing materials into a reservoir, such as the ocean, that can store, accumulate, or release carbon.[5] and BCEs act as deep carbon reservoirs [6] Although wetlands occupy only a small fraction of the global coastal area, they are highly productive, with a net primary production rate of 92–280 Tg C yr−1 , and they contribute up to 15 % of the total carbon accumulation in marine sediments[7] [8]As BC emerges as an innovative method for addressing climate change, economists are also focused on the timeframe of carbon sequestration since companies or nations can acquire carbon credits by capturing and safely storing carbon that would otherwise be released into, or linger in, the atmosphere."Quantifying the carbon sequestration and storage of a Blue Carbon Ecosystem (BCE) is therefore of primary importance for countries' Nationally Determined Contributions (NDC) to GHG emissions reduction and national GHG inventories as well as for voluntary emission reduction projects on the voluntary carbon market (VCM) on the other hand, so-called Blue Carbon projects (BCP). The demand for BCPs is high and increasing, however, the number of existing BCPs of 13 worldwide, all of them in mangrove ecosystems, is low."[9]

The purpose of this research is to create a guideline for BC operation for SIDS, given that the majority of SIDS contain the BCE and to also to showcase the benefits of having incorporated BC as the global climate crisis escalates and its devastating impacts is accelerating and to improve the livelihood of coastal communities and their activities within the marine space. SIDS, such as those in the Caribbean, are among the most vulnerable to climate change and its impacts. Due to their size, complex landscape and reliance on climate sensitive economic sectors such as fisheries and tourism). The Blue Economy concept creates the management of

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[4] World Bank "Unlocking Blue Carbon Development: Investment Readiness Framework for Governments" Washington, D.C.: World Bank. ,2023, Pg.9

[5] The Intercontinental Panel on Climate Change (IPCC), ".Climate Change 2013: The Physical Science Basis Working" Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, "Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA", 1535 pp., 2013, Pg.1480

[6] Claes et al. "Blue carbon: The potential of coastal and oceanic climate action" McKinsey & Company,2022, pg.2

[7] Jennerjahn T. and Ittekkot V., "Relevance of mangroves for the production and deposition of organic matter along tropical continental margins" ,Springer-Verlag, 2001, pg.4

[8] Bouillon et al., "Mangrove production and carbon sinks: A revision of global budget estimates", Global Biogeochemical Cycles,2008, pg.2

[9] Jennerjahn, T., "Analysis of existing Blue Carbon projects in the voluntary carbon market." German Environment Agency, 2023, pg. 5

one sector to linked multisector which prioritizes the responsibilities, governance and creates transparency within the sectors and highlights the coastal marine ecosystems provide crucial ecological services while serving as the fundamental part within economic development of a country. Embracing a blue economy will mean that with incorporating natural capital asset base into decision making can create effective governance over how to use the marine space and its resources and inclusive methods.

According to Damianova et al., "The blue economy concept is premised on an integrated and participatory approach that includes the sustainable use and management of marine resources for societal progress." Its origin of the blue economy started at the Rio+20 United Nations Conference on Sustainable Development, held in Rio de Janeiro in June 2012 and falls within the sustainable development principles of the United Nations Agenda 2030 and Sustainable Development Goals (SDGs). SDG 14 includes targets that countries can do to safeguard and sustainably use the ocean to which countries aimed to achieve by creating and pursing conservation efforts and having sustainable use of their marine resources [10] [11]

Highlighting Seychelles as a country who has spearheaded the success of having a prosperous blue economy and incorporating their work with BC and has been recognized as a global success in their execution of a blue economy due to its international advocacy and financing for marine conservation and sustainable fishing practices. [12] Alas, challenges and problems follow success. BCEs and their organisms are threatened and are under an immense amount of pressure to survive along with the activities and their users causing a domino effect on the ecosystem and the people who depend on them. There has been a decline of 64-71% globally in areas that contain wetland ecosystems within the twentieth centuries and are continuing at a drastic speed in current times.[13] Protecting these ecosystems that capture carbon shows great results in reducing

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[10] Damianova et al., "BLUE ECONOMY: a Path for Krasnodar Krai, The World Bank Europe and Central Asia Sustainable Development Practice Group Environment", Natural Resources and Blue Economy Global Practice, 2020,pg.15

[11] Commonwealth of Learning, "The Blue Economy: Origin and concept" https://www.col.org/news/the-blue-economy-origin-and-concept/, 2016

[12] Benzaken D, Voyer M, Pouponneau A and Hanich Q "Good governance for sustainable blue economy in small islands: Lessons learned from the Seychelles experience." Front. Polit. Sci. 4:1040318. DOI: 10.3389/fpos.2022.1040318, 2022, pg. 2-3,

[13]Li et al "Factors regulating carbon sinks in mangrove ecosystems", Global Change BiologyVolume 24, Issue 9 p. 4195-4210 https://doi.org/10.1111/gcb.14322, 2018, pg. 2, World Bank; United Nations Department of Economic and Social Affairs. 2017.

emissions. 3-19% of global deforestation can account for $US 6–42 billion annually in economic damages.[14]

In early July 2024, the Caribbean experienced 165 mph winds as category 5 hurricane Beryl swept through the region. Beryl on record, became the Atlantic's earliest forming Category 5 tropical cyclone developing rapidly and had intensifying wind speed in less than four days. This not a common behavior for cyclones this early in the Atlantic hurricane season.[15] The path of the hurricane passes over Grenada, decimating their island located on the northeastern side of the mainland [16] This was a reminder that climatic issues for SIDS are stressful and life threatening. However, having a BCP and creating a management for BCE may not be the solution to fully eradicate the problems of climate change but in a sense place a band aid on the existing effects and impacts.

Development and climate change have been a threat to coastal communities for decades. Coastal wetlands have been at a high rate over the course of time. Historically viewed as wastelands, wetlands were converted to land use for agricultural, aquaculture and industrial purposes. Since 1700, it is estimated that 87% of the world's freshwater and coastal wetlands have been lost and 35% since the 1970.[17]

In places such as North America, Europe, Africa and China for example have been converting their wetlands for centuries and millennia. Developed coastlines in Europe account for >50 % of coastlines in the Mediterranean Sea and 15,000 km2 of coastal wetlands, tidal flats, and other coastal are converted in the Wadden Sea.[18] China has at least 5,352 km2 of coastal wetlands lost

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The Potential of the Blue Economy: Increasing Long-term Benefits of the Sustainable Use of Marine Resources for Small Island Developing States and Coastal Least Developed Countries. © World Bank, Washington, DC. http://hdl.handle.net/10986/26843 License: CC BY 3.0 IGO." Pg.25

[14] Pendleton et.al, "Estimating Global "Blue Carbon" Emissions from Conversion and Degradation of Vegetated Coastal Ecosystems, 2012, pg.1

[15] National Oceanic and Atmospheric Administration (NOAA) "Hurricane Beryl: An opportunity for collaborative research", Retrieved from: https://research.noaa.gov/2024/07/24/hurricane-beryl-an-opportunity-for-collaborative-research/, 2024

[16]Smith,K., "Grenadians cope with the realities of climate change in the aftermath of Hurricane Beryl", United Nations Children's Fund (UNICEF), Retrieved from: https://www.unicef.org/easterncaribbean/stories/grenadians-cope-realities-climate-change-aftermath-hurricane-beryl, 2024

[17] Friess, Daniel A. et al. "Chapter 3 Ecosystem Services and Disservices of Mangrove Forests and Salt Marshes." Oceanography and Marine Biology, vol. 58, Taylor & Francis, 2020, Pg 22-23

[18] Friess, Daniel A. et al. "Chapter 3 Ecosystem Services and Disservices of Mangrove Forests and Salt Marshes." Oceanography and Marine Biology, vol. 58, Taylor & Francis, 2020, Pg 23

since 1978 with its remaining coastal wetlands still exposed to pollution, degradation, and overexploitation.[19] North America's coastal wetland loss both urban environments and regional for example in records shows that in Boston there has been >75 % loss of coastal wetland from the 1700 to 1800. [20] Regionally, northern Gulf of Mexico: 0.86 percent loss per year from 1955–1978 [21]

This thesis is to highlight two main topics: Blue Economy and Blue Carbon. Define them and showcase their properties, benefits and challenges, dive into and observe best practices from successful countries who may have developed and implemented initiatives and action plans as well as challenges their might have also experienced. It also will provide information on how both Blue Economy and BC are pushed by many climate focus organizations and their agenda for climate change mitigation efforts and given that many SIDS contain BCE can harness this opportunity.

Part One

Definition of the Blue Economy and Blue Carbon

The Blue Economy is an emerging sector that includes various industries reliant on ocean resources, therefore effectively managing both the users and the areas involved is crucial. Finding a balance between all areas of the marine space has been an issue for many states but with a Blue Economy, sustainable use and management of the ocean can be achieved. However, approaching a blue economy is not one size fits all solution. Defining what is a sustainable blue economy for many states needs examination and assessment to guide on what is needed and what can be done with this sector in place as well as locating gaps and challenges that essentially a blue economy can aid with.

A sustainable blue economy should safeguard its resources while offering ocean space users a strategy to harmonize their activities. A method for achieving this would be the protection, preservation, and conservation of the blue environment is BC. Climate change significantly

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[19] Meng et al. "Status of wetlands in China: A review of extent, degradation, issues and recommendations for improvement", Ocean & Coastal Management 146, 50–59.,2017, Pg.4

[20] Bromberg, K.D. & Bertness, M.D. "Reconstructing New England salt marsh losses using historical maps." Estuaries 28, 823–832.,2005, Pg.4

[21] Baumann, R.H. & Turner, R.E. "Direct impacts of outer continental shelf activities on wetland loss in the central Gulf of Mexico." Environmental Geology and Water Sciences 15, 189–198,1990, pg.1

impacts the marine ecosystem, prompting many marine sectors to seek solutions to combat climate change and protect the marine environment for future generations. The volume by Nelleman *et al.* entitled Blue Carbon. "The role of healthy oceans in binding carbon. A rapid response assessment", definition of Blue Carbon, 'Out of all the biological carbon (or green carbon) captured in the world, over half (55%) is captured by marine living organisms, not on land, hence it is called Blue Carbon".[22] Essentially protection and preservation of these ecosystems and species could have potentially positive benefits to countries experiencing the effects of Climate Change and be a tool for developing a sustainable blue economy.

Chapter 1

Blue Economy Definition

Blue Economy has many elements to become successful in SIDS, however finding the key stakeholders, analysing gaps, and creating Marine Spatial Plans (MSP) for the users of the space is a challenge presented during the implementation phase. The importance of developing the ocean economy is supported by the need for sustainability which is emphasized by initiatives and commitments such as the 17 United Nations Agenda 2030 SDGs. The ocean provides numerous services, the drivers (e.g., food security) of human activities (e.g., fisheries) result in pressures on the ocean, e.g., unsustainable extraction of fisheries resources or pollution.[23] These pressures are the factors resulting in the change in the state of a ecosystem and depending on the vulnerability frequent anthropogenic pressures trigger the risk of changes in natural systems, leading to impacts on the livelihood of humans across environmental, social, and economics aspects.

Loureiro, du Plessis and Findlay 2022, states that "changes in natural capital assets may reduce **(i)** their opportunities for continued supply, **(ii)** their use in production, **(iii)** resultant volumes of produced goods and services, and **(iv)** consequent distribution of economic benefits." and noted there is a need to emphasize sustainable approaches and methods for ocean economies to ensure that there is efficient use of resources today.[23]

[22] Lovelock CE, Duarte CM. "Dimensions of Blue Carbon and emerging perspectives." Biol. Lett. 15: 20180781.http://dx.doi.org/10.1098/rsbl.2018.0781, 2019, pg.1
[23] Loureiro, T. G., du Plessis, N., & Findlay, K., "Into the blue, The blue economy model in Operation Phakisa 'Unlocking the Ocean Economy' Programme", South African Journal of Science, 118(11), 1-4. doi:https://doi.org/10.17159/sajs.2022/14664, 2022, pg. 1

Section A

Defining a Sustainable Blue Economy and Key Sectors

The ocean connects cities and countries globally, fuelling economic activity and trade for the 38 % of the global population residing within 100 kilometres of the sea and is used every day for human activities. Some examples of activities of the blue economy are for submarine cables that to carry 90 % of the electronic traffic for communication, coastal ecosystems such as coral reefs that help protect from storm surge and wave damage, mangroves, sea grasses, and salt marshes are significant natural carbon sinks and it estimated 1 to 1.4 million species in the ocean are the source of medicines and drugs.[24] Since there are numerous definitions of the blue economy in several ways, and its roles differ among various nations; however, there is a global acknowledgment that there is minimal agreement on its definition. Patil et al. 2016, highlighted that due to the simultaneous growth of (i) the ocean economy and (ii) the current rate of change of the marine ecosystem, the concept for a 'green economy' and 'green growth' was then used for viewing the risks and opportunities in the ocean. The concept of a Blue Economy was also featured as a tool for policymaking for looking at economic and environmental policy. [25]

The Blue Economy agenda is based on development discussions and is professed to sustainably utilized the ocean resources for economic growth without degrading the health of the ecosystem services. Patil et al. 2016, also states that a Blue Economy must also consider the marine ecosystem that provide these services linked to the ocean economy as fundamental and must view invisible natural capital assets (food security, tourism, etc.), which supports the visible produced capital (machinery and structures) and intangible capital (skills, expertise etc. with which labour is applied). [25]

The concept of blue economy should include values present in these marine ecosystems without implying that their economic values are more important; instead, it should highlight the connection between the ocean's ecosystems and the economic activity and also recognize that although some activities in the ocean is dependent on the overall status of the marine ecosystem

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[24] Patil, Pawan G.; Virdin, John; Diez, Sylvia Michele; Roberts, Julian; Singh, Asha., "Toward a Blue Economy: A Promise for Sustainable Growth in the Caribbean." © World Bank, Washington, DC. http://hdl.handle.net/10986/25061 License: CC BY 3.0 IGO." 2016, pg. 18

[25] Patil, Pawan G.; Virdin, John; Diez, Sylvia Michele; Roberts, Julian; Singh, Asha., "Toward a Blue Economy: A Promise for Sustainable Growth in the Caribbean." © World Bank, Washington, DC. http://hdl.handle.net/10986/25061 License: CC BY 3.0 IGO." 2016, pg. 42- 43

and these activities could contribute to the degradation of them and thereby causing a cascading effect on the ecosystem, the economy and the livelihood of humans. With policy frameworks and industries starting to emerge it can enhance the natural and produced capital of the oceans economy to grow the blue economy.

The Blue Economy concept aims to offer a perspective for measuring, identifying, and promoting opportunities that benefit both the ocean's economy and environment, while ensuring alignment with the principles of social equity and poverty alleviation. Like most concepts and techniques to understand the ocean and its ecosystem, blue economy takes its practices and methods from on land (green economy) as a baseline. However, this can create challenges and gaps such as clearer ownership of resources. [26]

The ocean has played an important role in economic activities. Providing food for humankind, a mode of transportation and supporting trade to and from countries and as of recently blue economy is a concept closely related to maritime resources and activities and developing economies in the ocean

Blue Economy is defined as, "economic activities" that (i) take place in the marine environment or that (ii) use sea resources as an input, as well as economic activities that (iii) are involved in the production of goods or the provision of services that will directly contribute to activities that take place in the marine environment" [27] and it includes all existing, emerging and potential economic activities that directly or indirectly depend on the ocean. A maritime Blue Economy can include diverse components, from established ocean industries such as fisheries, tourism, aquaculture, and maritime transport, to emerging activities such as offshore renewable energy, deep sea mining, and marine biotechnology; that will depend on national circumstances but will provide social and economic benefits for current and future generations and restoring and protecting the diversity, productivity, resilience and natural capital of marine ecosystems.

For SIDS, the Blue Economy often comprises most of the national economy i.e. tourism and fishing, with so many economic activities dependent on the ocean. Interactions between

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[26] Organisation for Economic Co-operation and Development(OECD), "Towards Green Growth: A Summary for Policy Makers." http://www.oecd. org/greengrowth/48012345.pdf., 2011, pg.56

[27] Commonwealth Marine Economies Programme, Maritime Blue Economy Plan. Antigua and Barbuda,2021 pg.12

economic, ecological and social interests on land and at sea, building a connection and making harder to separate. In other words, a development an activity on land/sea affects the other. Alas, definition and term Blue Economy varies. The lack of a uniform definition of a blue economy means that the term is very flexible and less critiqued by entities who reject the agenda for example, conservation non-government organizations (NGOs) [28]

Creating a blue economy, based on a countries definition, can expect their sectors to promote economic growth, improve livelihoods and social equity while including environmental sustainability and as well as improving the coastal areas that have been degraded by human activity and preserving the limited resources it provides. [29] Strategies and initiatives for a Blue Economy can enable an analysis and assessment of existing maritime sectors and creating an action plan on what needs to be done to the transition to more sustainable practices and to consider the possibilities of developing new, sustainable marine activities as well as showcasing direction and focus for the development of a sustainable Blue Economy that can also be in alignment with national issues, international targets and commitments, such as the United Nation's SDGs, and the challenges by SIDS, such as:

(i) high dependency on imports for energy

(ii) High dependency on imports for food supply

(iii) reliance on one or a few economic sectors (e.g. fishing, tourism, etc)

(iv) large ocean resource, with potential for new / emerging sector growth (e.g. biotechnology, renewable energy, minerals, etc)

(v) capacity constraints to effectively manage / exploit sustainably a large ocean area / resource - relatively small population, government, resource (e.g. navy, research / exploration capability)

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[28] Carver R., "Lessons for blue degrowth from Namibia's emerging blue economy, Blue Degrowth and the Politics of the Sea: Rethinking the Blue Economy", 2020, pg. 8

[29] Martínez-Vázquez, R. M., Milán-García, J., & de Pablo, V. J, "Challenges of the blue economy: Evidence and research trends" *Environmental Sciences Europe, 33*(1) doi:https://doi.org/10.1186/s12302-021-00502-1, 2021, pg.1

(vi) vulnerable to economic and environmental shocks (e.g. earthquakes), including those driven by climate change (e.g. hurricanes, sea level rise, ocean acidification) with low resilience / ability to recover. [30]

All elements of a SIDS economy relate to the Blue Economy due to the reliance on maritime players for importing essential equipment and exporting produce to both local and broader markets. Many SIDS contain traditional sectors which are considered as the overall starting point for having a Blue Economy. These sectors are, but not limited to tourism, fisheries, aquaculture, energy, shipping/trade and mineral/aggregate.[31] Emerging sectors such as marine biotechnology and bioprospecting, deep sea mining and offshore renewable energy and the potential inclusion of supporting activities such as ocean monitoring and surveillance, ecosystem-based management (these activities are including but not limited to carbon sequestration (BC), integrated coastal and marine area management, MSP, marine protected areas (MPA) and marine managed areas. [32]

Blue Economy Sectors: Established and Emerging

1. Established Sectors

a) **Tourism** is the most important driver of economic activity supporting 10.3% of global GDP and over 333 million jobs in 2019 [33] providing employment in the hospitality services and the construction sector. However, it is important to note that the tourism sector especially among small island states requires a healthy and resilient environment. [31] Small Island States receive high traffic of tourist from all over the world. An estimated 975 million tourists travelled internationally between January and September

[30] Commonwealth, "Commonwealth Marine Economies Programme, Maritime Blue Economy Plan." Antigua and Barbuda,2021, pg.14

[31] Commonwealth, "Commonwealth Marine Economies Programme, Maritime Blue Economy Plan." Antigua and Barbuda,2021, pg.20

[32] "World Bank, "United Nations Department of Economic and Social Affairs. The Potential of the Blue Economy: Increasing Long-term Benefits of the Sustainable Use of Marine Resources for Small Island Developing States and Coastal Least Developed Countries." World Bank, Washington, DC. http://hdl.handle.net/10986/26843 License: CC BY 3.0 IGO.", 2017, pg. 23

[33] World Travel and Tourism Council, "WTTC Cities Economic Impact", 2022, pg.7

2023, an increase of 38% over the same months of 2022, though 13% fewer than in 2019 and in that period, receipts reached over USD 1.4 trillion in 2023 [34]

b) The **fishing** sector along with tourism remains an important traditional sector that also provides employment and often serves the tourism industry and contribute more than US$270 billion annually to global GDP and as the world's population is expected to rise to 9.5 billion by 2050, food demands will also be expected to increase. [35]

c) Since **Aquaculture** supplies 58 % of fish to global markets [36], this sector can contribute to food security as well as social and economic inclusion for those living in poverty. This sector can also help to lessen the growing need for seafood and just like the previous sectors also create jobs and increase employment.

d) **Shipping, trade and maritime transport** provides transportation for the supply of materials and goods worldwide and over 80 % of trade is transported by sea and this percent is higher for most developing countries.[37]

e) The **Offshore oil and gas** sector in many states around the world has progressed in development and much information is known about the need to manage this sectors risks on the marine environment and measures taken to alleviate them.

2. Emerging Sectors

a) **Renewable marine (off-shore) energy** can play a vital role in social and economic development, as well as in climate adaptation and mitigation. Since oceans have a high renewable energy potential this sector can contribute to the decarbonization of the power sector, ensuring energy security for SID and creating employment opportunities. Forms

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[34] United Nations World Tourism Organization, "World Tourism Barometer Volume 21", Issue 4, 2023 pg. 1

[35] "World Bank, "United Nations Department of Economic and Social Affairs. The Potential of the Blue Economy: Increasing Long-term Benefits of the Sustainable Use of Marine Resources for Small Island Developing States and Coastal Least Developed Countries." World Bank, Washington, DC. http://hdl.handle.net/10986/26843 License: CC BY 3.0 IGO.", 2017, pg. 14 and 16

[36] FAO (Food and Agriculture Organization), "The State of World Fisheries and Aquaculture' Contributing to Food Security and Nutrition for All" Rome., 2016, pg.28

[37] "World Bank, "United Nations Department of Economic and Social Affairs. The Potential of the Blue Economy: Increasing Long-term Benefits of the Sustainable Use of Marine Resources for Small Island Developing States and Coastal Least Developed Countries." World Bank, Washington, DC. http://hdl.handle.net/10986/26843 License: CC BY 3.0 IGO.", 2017, pg. 21

of marine energy such as tidal and wave energy and Ocean Thermal Energy Conversion (OTEC) are still in the development phase and is not developed for a commercial scale.[37]

b) **Marine biological prospecting** includes marine genetic information and biological components that can be potentially used for the development of medicine and cosmetics.[38]

c) **Deep seabed mining** is receiving a push from governments and the private sectors for it to be an established development due to the increased demand for minerals. However, little data and information is still known these habitats, recovery potential, or the impact on these ecosystems and the wider oceans. [38]

Marine sectors (both established and emerging within the blue economy) may require tools and approaches for the management of human activities in ocean and coastal areas. Tools such as fisheries and marine species management measures, integrated marine and coastal area management, MSP, MPAs, and activities supporting carbon sequestration. One challenge remains is to connect the different management approaches for various sectors and create comprehensive and cohesive plan.[39] An analysis of the institutional framework as well as an extensive consultation with significant stakeholders is required to understand the roles played by each institution in the Blue Economy's development, and to highlight the main challenges hindering its growth.

Section B

The Blue Economy Sector: Best Practices and Challenges

Not many examples of the national adoption of a blue economy as transformational strategy for sustainable development exist but a recent analysis of blue economy being implemented and managed in some states shows a variety of plans and policies at different stages of development. Throught the analysis, it found that the Blue Economy could become successful if it developed more integrated approach to sectoral management but not enough evidence proving it was

[38] "World Bank, "United Nations Department of Economic and Social Affairs. The Potential of the Blue Economy: Increasing Long-term Benefits of the Sustainable Use of Marine Resources for Small Island Developing States and Coastal Least Developed Countries." World Bank, Washington, DC. http://hdl.handle.net/10986/26843 License: CC BY 3.0 IGO.", 2017, Pg. 17 and 18

[39] "World Bank, "United Nations Department of Economic and Social Affairs. The Potential of the Blue Economy: Increasing Long-term Benefits of the Sustainable Use of Marine Resources for Small Island Developing States and Coastal Least Developed Countries" World Bank, Washington, DC. http://hdl.handle.net/10986/26843 License: CC BY 3.0 IGO.", 2017, pg. 24

successful in integrating social, economic and environmental objectives and limited equity objectives and suggests that a blue economy may not have the potential to fulfil as a driver to integrated policy framework. Seychelles is labelled an early adopter and global leader in Blue Economy implementation is an example of its success for having a national pathway for sustainable development of the ocean space and enabling the social, economic and environmental objectives of sustainability and cross- sectoral policy through Blue Economy governance arrangements. [40] Cisneros-Montemayor et al. 2021, explains that if a country recognizes that the key factors that need to be addressed is enabling conditions (socioeconomic and governance) is an important and strategic step towards achieving a sustainable and equitable blue economy. [41] However, what kind of governance arrangements is necessary for these enabling conditions?

Due to the idea that good governance is looked at as an enabler to transition to a sustainable and equitable blue economy, effective and best governance arrangements (whether to create new ones or strengthen and update the current ones) are being discussed and considered globally. Even though these discussions are being considered and efforts being done there is no collective definition of good governance. [42]

Good governance as a model comes from development scholarship (environmental and natural resource governance scholarship aim to understand how different governance processes or policies influence desired outcomes such as preservation, conservation, livelihoods, and sustainable use or development[43]) in response to "the disjunct between aid and sustainable development and concerns related to issues of corruption" and is based on the evidence that "successful governance is dependent upon good institutions". [42]

1. <u>Diving Into Best Practices</u>

i. Seychelles

[40] Benzaken, Dominique et al. "Good Governance for Sustainable Blue Economy in Small Islands: Lessons Learned from the Seychelles Experience." *Frontiers in political science* 4,2022, pg. 2

[41] Cisneros-Montemayor et al "Enabling conditions for an equitable and sustainable blue economy." Nature 591, 396–401. doi: 10.1038/s41586-021-03327-3,2021, pg.5

[42] Benzaken, Dominique et al. "Good Governance for Sustainable Blue Economy in Small Islands: Lessons Learned from the Seychelles Experience." Frontiers in political science 4 ,2022, Pg3

[43] Partelow et al. "Environmental governance theories: a review and application to coastal systems." Ecol. Soc. 25, 1–21. doi: 10.5751/ES-12067-2 50419,2020, pg.2

Countries contributing their experience with developing a Blue Economy is a lesson that needs to be understood to replicate it for other SIDS. Since 2010, Seychelles have been one of the few that has implemented a blue economy and has been a well-known advocate of the agenda. Seychelles provides an opportunity to discover the value of having a blue economy as a policy setting for sustainable development and the role of governance enabling integration. Although the specific practices, lessons and methods from Seychelles cannot be generalized, their experience can provide suggestions and approaches for how to succeed and create solutions for challenges. [42]

An analysis by Benzaken et al. 2022, provides a summary of key takeaways for blue economy implementation from the perspective of Seychelles is listed as follows:

a) An **analysis of the effectiveness of blue economy governance arrangements** which can be done through reviews of policy and institutional arrangements and interviews.

b) An overview of **leadership and political stability**. Political leadership and commitment were seen as essential to ensuring effective blue economy integration across government sectors.

c) **Policy coherence and institutional coordination.** An analysis of available policy documents and reports to investigate the extent to which the Blue Economy was mainstreamed in national development and relevant blue economy sectoral policies.

d) **Effectiveness and institutional capacity**. Align and prioritise blue economy strategic actions across government stakeholders, developing a Blue Economy project database development, monitoring and evaluation, and media and communication.

e) **Equity and inclusiveness.** Stakeholder, both government and non-government, to be included in the design of a blue economy roadmap and the vision and social objectives.

f) **Partnerships and collaborations.** Partnerships with international organisations to secure access to finance, expertise, policy advice, and research collaborations for blue economy implementation as positive developments.[44]

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[44] Benzaken, Dominique et al. "Good Governance for Sustainable Blue Economy in Small Islands: Lessons Learned from the Seychelles Experience." Frontiers in political science 4 , 2022, Pg.11

ii. Kenya

In the case of Kenya, their blue economy is not as robust as Seychelles. However along with Antigua and Barbuda, they co-champion for the Sustainable Blue Economy agenda for the Commonwealth Blue Charter. For Kenya, developing a Blue Economy requires establishing strategic planning and management frameworks that creates good governance, appropriate and relevant policies, and investment and financing strategies. Rasowo et al. 2020 suggests that to achieve this it requires "quantifying output from Kenya's ocean economy, putting in place enabling maritime policies, legal, regulatory and institutional frameworks, identifying and investing on priority blue growth sectors, investing in management and protection of marine natural assets, knowledge sharing and collaboration, and developing a strong human resource base and marine science capability." [45] The government of Kenya has made plans to have the Blue Economy agenda in their economic pillar of the Vision 2030 development blueprint specifically to achieve the food security and manufacturing targets. [46]

Suggestions given in Rasowo et al. 2020 on how measures Kenya will use to implement blue economy will provide a summary of key takeaways from their perspective is listed as follows:

a) **Identifying and investing in priority growth sectors.** Focusing on investment efforts on selected key Blue Economy sectors with potential high economic returns and these areas in return can become the main recipients of investment resources, research and development funds, and general sectorial support.

b) **Establish enabling Governance and Legal Frameworks** which needs policy integration and proper synchronisation.

c) **Marine Spatial Planning (MSP)** delivers integrated sector planning to reduce conflict and pressure on the natural resources and defines spaces used for industrial development, shipping lanes, fishers, marine aquaculture, tourism, energy, and marine reserves that separate conservation from other uses.

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[45] Rasowo, Joseph O et al. "Harnessing Kenya's Blue Economy: Prospects and Challenges." Journal of Indian Ocean region 16.3 - 292–316. Web., 2020, pg 12

[46] Rasowo, Joseph O et al. "Harnessing Kenya's Blue Economy: Prospects and Challenges." Journal of Indian Ocean region 16.3 - 292–316. Web., 2020, pg 19

d) **Embrace collaboration and knowledge sharing.** Blue Economy requires partnerships and collaborations among countries, the national and county governments, local communities, private investors, industry, environmental organisations, academia, researchers, and global partners.

e) **Invest in developing a strong human resource base and marine science capability** [47]

Challenges in implementing a blue economy

No concept, approach and solution are without a hindrance to its success. A Blue Economy is a complex system to achieve, and it presents challenges to some states who attempt to establish it as it requires a multidisciplinary approach, and various and diverse group of stakeholders and organizations who have different agendas and priorities at a national level. [48] Collaboration is a key factor in establishing a blue economy and the main players is still unbalanced which leads to not taking advantage of opportunities for integration across stakeholders and leading to the lack of understanding of the Blue Economy concept. Also due to blue economy's multisectoral nature can create a conflict of interest. [49] Another challenge is to effectively coordinate a blue economy agenda across government players. In some countries a government can be restructured, for example, after elections, shifting the message of Blue Economy to the ministerial level can be construed depending on how drastic the restructuring is. Additionally, a lack of continuity and clear mandates of Blue Economy structures and processes for the whole of government coordination and communication. Other external threats to the Blue Economy come from events that cannot be foreseen and prevented. The InterAmerican Development Bank and the Caribbean Development Bank[50] [51] in collaboration with stakeholders have identified four key threats as listed as follows: [53]

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[47] Rasowo, Joseph O et al. "Harnessing Kenya's Blue Economy: Prospects and Challenges." Journal of Indian Ocean region 16.3 - 292–316. Web., 2020, pg 12-18

[48] Rasowo, Joseph O et al. "Harnessing Kenya's Blue Economy: Prospects and Challenges." Journal of Indian Ocean region 16.3 -292–316. Web., 2020, pg 3

[49] Rasowo, Joseph O et al. "Harnessing Kenya's Blue Economy: Prospects and Challenges." Journal of Indian Ocean region 16.3 - 292–316. Web., 2020, pg 4

[50] IDB, "Economic evaluation of the blue economy in the Caribbean. To produce an economic valuation tool of the current and potential economic activities in the Caribbean" Inter-American Development Bank Unpublished. 2020 Retrieved from: https://sustainableislands.iadb.org/projects/blue-economy-valuation

[51] CDB. "Advancing the Caribbean blue economy. Understanding risk Conference. Caribbean Development Bank." Workshop slides and notes. Unpublished. Workshop held on 28 May 2019.

a) **Climate change** is one of the largest threats to the blue economy, all blue economy sectors and has a great deal of impacts on marine ecosystems from changes in weather and extreme events, ocean acidification, sea-level rise, and changing marine ecosystems etc.

b) **Unsustainable Economic Development** damages the marine environment and threatens the provision of current and potential ocean services.

c) **Global Market Dynamic**s directly impact countries and particularly the Blue Economy sectors of tourism, oil and gas, shipping, and fisheries and the potential profit of the oil and gas sector also depends on the global market which has been increasingly volatile.

d) **The Global COVID-19 Coronavirus Pandemic** on the global economy represents a new and substantial hurdle towards the development across all blue economy sectors. As a result, the worldwide economy shrank by 3 percent in 2020,[52] Oil prices fell to a low of USD20/bbl. in May 2020 but have since increased to ~USD120/bbl. in mid-2022. Maritime trades also experienced a large negative impact, especially in ports where changes in the crew occur and mandatory quarantine periods.[53] Tourist numbers dropped significantly even further in April of 2020 due to the introduction of social distancing, a travel ban, and quarantine measures in the United States, the dominant source of tourists to the region, and by May 2020, cruise ship tourist numbers had dropped to zero for all Caribbean islands. [54]

During a consultation session with stakeholders conducted by the World Bank to view their perspective on blue economy governance in Tunisia**,** some suggestions made which can be use as a guideline to use towards creating solutions to blue economy challenges.[55]

(i) A current or updated **regulatory framework** especially regarding coastal management.

(ii) **Current governance and innovation** need to define responsibilities and overlapping mandates between different institutions intervening with coastal and marine areas.

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[52] IMF, "World Economic Outlook" Retrieved from: https://www.imf.org/en/Publications/ WEO/Issues/2020/04/14/weo-april-2020, 2020, pg.7

[53] Phang, Sui et al. "A Review of the Blue Economy, Potential, and Opportunities in Seven Caribbean Nations Pre-COVID-19." *ICES journal of marine science* 80.8: 2233–2243. Web.,2023, pg. 6

[54] Mulder, "The impact of the COVID-19 pandemic on the tourism sector in Latin America and the Caribbean, and options for a sustainable and resilient recovery" International Trade series, No. 157 (LC/TS.2020/147), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC). ,2022, pg. 20-21

[55] World Bank, "Based on the stakeholder engagement described in the World Bank background paper: World Bank. "Elaboration d'une feuille de route pour développer l'économie bleue en Tunisie: Analyse institutionnelle et des politiques en lien avec l'économie bleue." Unpublished background paper., 2023, pg.16

(iii) Proposed governance improvements through best practices from other countries, more efficient use of resources, improved legislation updates, better knowledge and specialisation in the Blue Economy field, and improved management of maritime activity authorizations for governance enhancement.

(iv) Challenges for the coordinating body. Effective communication with other institutions involved in the Blue Economy, legitimacy among other institutions and citizens, understanding and commitment to sustainability, addressing perceptions of being an "obstructive" institution, creating a conducive climate for planning, and the ability to conduct or oversee high-quality technical studies, such as environmental impact assessments, are some of the challenges the coordinating body would need to overcome. [56]

Chapter 2

Blue Carbon Definition

The term BC refers to the carbon captured in oceans and coastal ecosystems and BCEs such as tidal marshes, mangroves, and seagrass meadows can sequester carbon more than five times the amount in their soils compared to terrestrial habitats (tropical forests) and are an important ecosystem that has the opportunity to be used for ecosystem-based climate mitigation which can also preserves the ES of these habitats. [57] [58] ES are nature's way of providing benefits to humans and coastal ecosystems can improve the livelihood of coastal communities and provide food security and employment. ES also provide protection from storm, cyclones, coastal erosion and a nursery and protection for numerous wetland species.

[56] "World Bank, "Beyond the Shoreline - Towards a Blue and Resilient Future for Tunisia", Washington, DC: World Bank. http://hdl.handle.net/10986/41614 License: CC BY-NC 3.0 IGO.",2024, pg. 16

[57] "World Bank United Nations Department of Economic and Social Affairs, "The Potential of the Blue Economy: Increasing Long-term Benefits of the Sustainable Use of Marine Resources for Small Island Developing States and Coastal Least Developed Countries" World Bank, Washington, DC. http://hdl.handle.net/10986/26843 License: CC BY 3.0 IGO.",2017, pg. 25

[58] FAO, Global Blue Growth Initiative and Small Island Developing States, 2014, pg.6

Section A

Define Blue Carbon

The term BC was coined in 2009 [59] during the COP session in Copenhagen highlighting its potential to sequester large capacities of carbon in coastal ecosystems [60] and since then the term has started the wave for the development of programs and policies aimed to preserve and restore these highly threatened coastal ecosystems for climate change adaptation and mitigation. However, much like the Blue Economy, the term BC has varied. BC as previously mentioned is referred to as the process in which carbon is captured by coastal vegetated ecosystems and BCEs have high sediment carbon burial rates are hotspots in the global carbon cycle and preserving and restoring these habitats has been used to sequester anthropogenic carbon from the atmosphere making them a useful tool to achieving climate change actions.[61]

In Lovelock and Duarte 2019, "BC has multiple meanings which reflect the original descriptions of the concept including (1) all organic matter captured by marine organisms, and (2) how marine ecosystems could be managed to reduce greenhouse gas emissions and thereby contribute to climate change mitigation and conservation. Since the term was coined, knowledge about BC sequestration has rapidly evolved." [59] Researchers have studied BC storage by determining ecosystem carbon stocks and potential CO_2 emissions caused by habitat degradation and loss.[62] Now more research is done to quantify long term carbon storage in BCES to have an estimate of national and global sediment carbon estimate.[63] Despite terrestrial and marine ecosystems have the capability to sequester carbon, coastal wetlands can hold carbon in it's soil for long periods of time (centuries to millennia) resulting in very large carbon stocks[64] and although coastal wetlands range is smaller in comparison to terrestrial ecosystems they can capture and bury

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[59] Lovelock Catherine E., Duarte Carlos M. "Dimensions of Blue Carbon and emerging perspectives." 2019 Biol. Lett.1520180781,2019, pg.1

31 Nellemann et al., "Blue Carbon - the Role of Healthy Oceans in Binding Carbon.", 2009, pg.15

[61] Isaac et al., "The renaissance of Odum's outwelling hypothesis in 'Blue Carbon' science" Estuarine, Coastal and Shelf Science, Volume 255, 2021, 107361, ISSN 0272, 2021, pg.1

[62] Kauffman et al., "Total ecosystem carbon stocks of mangroves across broad global environmental and physical gradients." Ecol. Monogr. 90, e01405,2020, pg.2

[63] Wang et al. "Global blue carbon accumulation in tidal wetlands increases with climate change." Natl. Sci. Rev., 2021, pg.1

[64] Duarte, C.M., Middelburg, J.J. & Caraco, N, "Major role of marine vegetation on the oceanic carbon cycle." Biogeosciences 2, 1–8., 2005, pg.1

carbon at a faster pace and store it at the highest rate per unit area .[65] This could be because soil carbon accumulation in terrestrial ecosystems is limited by high availability of oxygen, creating an environment for anaerobic microbial carbon oxidation which is then release into the atmosphere versus in BCEs where the soil is constantly waterlogged keeping it in an anaerobic state which then accretes vertically at high rates resulting over time in a continuous build-up of carbon.[66]

BCEs are considered established ecosystems. Mangroves, seagrass meadows and salt marshes are considered established as these ecosystems often have high carbon stocks, have long-term carbon storage capacities, have the potential to manage GHG emissions and support adaptation policies. Other ecosystems such as coral reefs do not fit the criteria to become established within the Blue Carbon framework and others have either gap in scientific understanding of carbon stocks or GHG fluxes or limited potential for management or accounting for carbon sequestration such as macroalgae and phytoplankton. However, if they gaps are addressed these ecosystems and species may be considered and established BCEs over time.[59]

	criteria for inclusion as actionable Blue Carbon ecosystems					
	scale of GHG removals or emissions are significant	long-term storage of fixed CO_2	undesirable anthropogenic impacts on the ecosystem	management is practical/possible to maintain/ enhance C stocks and reduce GHG emissions	interventions have no social or environmental harm	alignment with other policies: mitigation and adaptation
mangrove	yes[1,2]	yes[3]	yes[4,5]	yes[6,7]	?	yes[8]
tidal marsh	yes[1,9]	yes[9]	yes[10]	yes[11,12]	?	yes[13]
seagrass	yes[1,14]	yes[15]	yes[16]	yes[17]	yes	yes[18]
salt flats (sabkhas)	?	?	yes[19]	?	?	?
freshwater tidal forest	?	yes[20]	yes[21]	yes[22]	?	?
macroalgae	yes[23]	?[23]	yes[24]	yes[25]	?	yes[26]
phytoplankton	yes[27]	?[28]	?	?	?	no
coral reef	no[29]	no	yes[30]	no	?	yes[31]
marine fauna (fish)	no[29]	no	yes[32]	no	?	no
oyster reefs	no[29]	?	yes[33]	no	yes	yes[34]
mud flats	?[35]	?	yes[36]	?	yes	yes[36]

[65] Pendleton et al. "Estimating Global "Blue Carbon" Emissions from Conversion and Degradation of Vegetated Coastal Ecosystems" PLOS One, doi: https://doi.org/10.1371/journal.pone.0043542, 2012, pg.1

[66] The Blue Carbon Initiative, "Coastal Blue Carbon methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrass meadows", 2014, pg. 18

Table 1. Taken from Lovelock and Duarte, 2019 [67] shows an assessment of whether coastal ecosystems meet the Blue Carbon criteria. Question marks indicate where additional investigations of the science or policy are needed. Green shading indicates strong evidence for meeting the criteria, yellow indicates some evidence or inference, grey indicates that the criteria are not met.

Macroalgae/Kelp Forest have potential to be also included within the BC framework as the have high primary productivity rates could possibly sequester large amounts of carbon compared to the established BCEs.[68] However they do not have high local sedimentation rates, and which makes it harder to quantify to be included in the blue carbon framework and in order to qualify for the inclusion large amounts of carbon would need to be outwelled and sequestered into the deeper parts of the ocean or dissolved. Nonetheless, there is still a lot of research that needs to be done on how to include other ecosystem types and carbon burials.[69]

When BC was first introduced, it's aim was to create awareness about reversing the ongoing degradation of BCEs and now BC has become a global interest, in management, scientific, and policy settings to reference ES and SDGs objectives and targets and tropical states praising their BCEs and its potential to be used in mitigating climate change.

<u>Characteristics of Blue Carbon Ecosystems (BCE's)</u>

Coastal ecosystems are the most economically and environmentally valuable environments. And if protected they support millions of livelihoods, provide natural protection from sea level rise, cyclones, erosion, are home to various and numerous plant and animal species and a use to fight against climate change. However, when degraded or destroyed, their stored carbon is released and contributes to the global climate change. As previously mentioned, established BCEs meet a criteria standard of scientific understanding and implementation potential, and these solutions need to offer scientifically verifiable levels of carbon abatement such that they can be described

[67] Lovelock Catherine E., Duarte Carlos M. "Dimensions of Blue Carbon and emerging perspectives." Biol. Lett.1520180781,2019, pg.2

[68] Filbee-Dexter, K., and Wernberg, T., "Substantial blue carbon in overlooked Australian kelp forests." Sci. Rep. 10, 12341.,2020, Pg.11

[69] Filbee-Dexter et al., "Movement of pulsed resource subsidies from kelp forests to deep fjords." Oecologia 187, 291–304.,2018, Pg.1

by methodologies that qualify them for VCMs. These approaches are focused on coastal BCEs specifically mangroves, salt marshes, and seagrass meadows. [6]

(i) Mangroves

Mangroves are salt tolerant trees which often are located at the coast connecting between land and sea are one of the most carbon-rich tropical forests and can found worldwide in coastal ecosystems within tropical and subtropical latitudes.[70] These carbon-rich tropical forests are complex and have a high primary productivity rate with efficient biological nutrient recycling and a permanent exchange with terrestrial and marine ecosystems[71] and is estimated that can store 6 to 8 megagrams CO_2 equivalent per hectare (Mg CO_2e ha $^{-}$1) per year along with salt marshes[70] A study by Chandra et al. 2010 shows that 15 countries represent roughly 75 % of the global mangrove area[72] and the Global Mangrove Watch mapped out in 2020 the area of mangrove habitat in the world at 147,358.99 km^2 [73]

(ii) Seagrass Meadows

Unsworth et al. 2022 defines seagrasses as a unique group of submarine flowering plants[74] and distribution are based on species assemblages, but their regions range tropical to temperate zones.[75] Seagrasses play a role in supporting food security, improving biodiversity, purifying and filtering water and protecting coastlines. They can be found in estuaries and bays and have an estimated cover area between 16 million to 60 million ha. [76] The World Atlas of Seagrass 2003,

[70] World Bank, "Unlocking Blue Carbon Development: Investment Readiness Framework for Governments." Washington, D.C.: World Bank., 2023, Pg.7

[71] Jennerjahn, T. "Relevance and magnitude of 'Blue Carbon' storage in mangrove sediments: Carbon accumulation rates vs. stocks, sources vs. sinks", 2021 , pg.1

[72] Chandra et al., "Status and distribution of mangrove forest of the world using earth observation satellite data", Global Ecology and Biogeography,2010, pg. 4

[73] The Global Mangrove "Watch, Mangrove Habitat Extent:", Retrieved from: https://www.globalmangrovewatch.org/?active-widgets=[%22mangrove_habitat_extent%22,%22mangrove_net_change%22,%22mangrove_habitat_change%22,%22mangrove_alerts%22,%22mangrove_species_location%22,%22mangrove_species_distribution%22,%22mangrove_species_threatened%22,%22widgets_deck_tool%22], 2020

[74] Unsworth et al., "The planetary role of seagrass conservation Richard", Science 377, 609–613, 2022, pg. 1

[75] Short et al., "Global seagrass distribution and diversity: A bioregional model.", Journal of Experimental Marine Biology and Ecology, 2007 pg.1

[76] World Bank, "Unlocking Blue Carbon Development: Investment Readiness Framework for Governments." Washington, D.C.: World Bank., 2023, Pg.9

lists Australia as having the most extensive areas (9.63 million ha), followed by Indonesia (3 million ha) and the Gulf of Mexico (1.94 million ha).[77]

(iii) Salt Marshes

Salt marshes are lush, intertidal grasslands[78] and formed by accumulation of mineral sediments and organic material and are flooded with salt water at high tide. The extent of salt marshes globally is not currently mapped but and it has an estimate of 5,495,089 ha and their distribution can be found in countries outside the tropics such as the United States, Canada, Europe, Australia, Argentina, and Russia, Southern Brazil and Uruguay.[79]

Emerging Blue Carbon Ecosystems

(i) Benthic sediments

Benthic sediments can contain approximately 1.25 × 1022 g of organic carbon[80] and store nearly twice as much carbon as the top meter of terrestrial soils [81] More carbon is stored in benthic sediments found within the 200 nautical mile area from the coast or the Exclusive Economic Zones (EEZ) than in the high seas.[82] Not many maps on the global distribution of benthic sediment exist but some studies have to starting using advance technology to map the seafloor carbon stocks as well as to quantify them.[83]

(ii) Coastal Mudflats

Coastal Mudflats or tidal flats, compared to coastal wetlands have a higher carbon sequestration rate and are formed by the slow accumulation of sediment left behind by rivers and tides.

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[77] Green, E. P., & Short, F. T., “World Atlas of Seagrasses.” Univ of California Press. Retrieved from http://environmentalunit.com/Documentation/04%20 Resources%20at%20Risk/World%20Seagrass%20atlas.pdf, 2003

[78] Silliman, B. R., “Salt Marshes” Current Biology, Volume 24, Issue 9, R348 - R350 Retrieved from https://www.cell.com/current-biology/fulltext/S0960-9822(14)00256-5, 2014 pg.1

[79] World Bank, “Unlocking Blue Carbon Development: Investment Readiness Framework for Governments.” Washington, D.C.: World Bank., 2023, Pg.11

[80] Estes et al., “Persistent Organic Matter in Oxic Subseafloor Sediment.” *Nature Geoscience* 12 126–131. Retrieved from https://www.nature.com/articles/s41561- 018-0291-5#citeas., 2019, pg.1

[81] Atwood et al., “Global Patterns in Marine Sediment Carbon Stocks.” *Front. Mar. Sci.* Retrieved from https://www.frontiersin.org/articles/10.3389/ fmars.2020.00165/full, 2020, pg.1

[82] Atwood et al., “Global Patterns in Marine Sediment Carbon Stocks.” *Front. Mar. Sci.* Retrieved from https://www.frontiersin.org/articles/10.3389/ fmars.2020.00165/full, 2020, pg.4

[83] World Bank, “Unlocking Blue Carbon Development: Investment Readiness Framework for Governments.” Washington, D.C.: World Bank., 2023, Pg.13

Mudflats can be found on the coastline in areas such as lagoons, estuaries, and bays and their global area cover is approximately 127 thousand km^2 and have a wide latitudinal range with nearly 70 % in Asia, North America, and South America.[84] Even though they can sequester carbon, mudflats lose 4.8 Tg of carbon annually due to habitat degradation and loss and climate change[85] and there is no current information on emission reductions through conservation or restoration as to date.

(iii) Macroalgae: Kelp Forests and Seaweeds

Macroalgae are found in the intertidal zone across coastlines and kelp forests and seaweed use the process of photosynthesis to store carbon in their living tissues. [86] When macroalgae die, they sink to the bottom of ocean floor where the cold temperatures at deeper depths and lack of oxygen promote potentially long-term carbon sequestration.[87] The global estimates of macroalgae distribution are still uncertain but research is being carried out to understand their extent and using refined distribution models (which predict the occurrence of macroalgal extent) to predict their regional extent but not the global scales as yet . [86]

<u>Section B</u>

Benefits of Blue Carbon Ecosystems on SIDS

Looking beyond the potential of BC, BCEs, especially when protected and conserved, is extremely beneficial for many coastal countries who have these ecosystems and can be used to strengthen climate resilience. BCEs provide numerous ESs from being biodiversity hotspots and coastal protection to providing employment and supporting the livelihood of local communities.

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[84] World Bank, "Unlocking Blue Carbon Development: Investment Readiness Framework for Governments." Washington, D.C.: World Bank., 2023, Pg.14

[85] Chen Z.L. and Lee S.Y. "Tidal Flats as a Significant Carbon Reservoir in Global Coastal Ecosystems", Front. Mar. Sci., 2022, pg.7

[86] World Bank, "Unlocking Blue Carbon Development: Investment Readiness Framework for Governments." Washington, D.C.: World Bank., 2023, Pg.15

[87] Duarte et al. "Global estimates of the extent and production of macroalgal forests", Global Ecol. Biogeogr. 2022; 00:1–18. ,2022 pg.12

An estimated 4.1 million small -scale fishers rely on mangroves worldwide for fishing.[88] This is mostly due to mangroves role in being a nursery for many commercial fish and shellfish.[89]

BCEs services can be grouped into environmental, social and economic benefits and are linked together because of the many different roles they play.

Benefits of BCE: Environmentally

Nursery and Habitat Functions

As mentioned previously many species that are important to commercial fisheries use wetlands for food, shelter, and safety. Mangroves can support a vast number of juvenile species as their complex root and stem structures provide sufficient food and shelter for them[90] creating a nursery ecosystem service. Since many juvenile species are found in these habitats, it contributes to the fishing industry and supporting food security.[91] Apart from marine species, mangroves have a high biodiversity with birds with a third of species being migratory. [92] Seagrass meadows are also act as a nursey, foraging area and a safe ground for many different species of juveniles.

Coastal protection

Coastal wetlands provide protection by buffering the impact of storm surges and coastal flooding. Mangrove forests and salt marshes can reduce wave energy through reflection and dissipation which is the friction generated by the physical structure and roughness of vegetation (including pneumatophores, aerial roots, trunks, and stems). [93] It was thought that mangroves can

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[88] Ermgassen et al. "Fishers who rely on mangroves: Modelling and mapping the global intensity of mangrove-associated fisheries." Estuar. Coast. Shelf Sci. 248, 107159,2021, pg.6

[89] Beers, L., Crooks, S., May, C., and Mak, M. "Setting the foundations for zero net loss of the mangroves that underpin human wellbeing in the North Brazil Shelf LME: Blue Carbon Feasibility Assessment." Report by Conservation International and Silvestrum Climate Associates.,2019, Pg 13

[90] Verweij et al., "Structure, food and shade attract juvenile coral reef fish to mangrove and seagrass habitats: A field experiment" Marine Ecology Progress Series 306, 257–268.,2006, Pg.9

[91] Nagelkerken, I. "Evaluation of nursery function of mangroves and seagrass beds for tropical decapods and reef fishes: Patterns and underlying mechanisms" In Ecological Connectivity Among Tropical Coastal Ecosystems. I. Nagelkerken (ed.). Dordrecht, Netherlands: Springer, 357–399.,2009, Pg.1

[92] Beers et al. "Setting the foundations for zero net loss of the mangroves that underpin human wellbeing in the North Brazil Shelf LME: Blue Carbon Feasibility Assessment." Report by Conservation International and Silvestrum Climate Associates.,2019, Pg.14

[93] Mazda et al., "Wave reduction in a mangrove forest dominated by Sonneratia sp." Wetlands Ecology and Management 14, 365–378. McCauley, D.J., Selling out on nature. Nature 443, 27–28., 2006, pg.10

also protect against tsunamis however information on this is limited.[94] Salt marshes have been showed to reduce as much as 82 % wave energy compared to 29 % for unvegetated tidal flats.[95]

Coastal stabilisation

Mangroves and salt marshes can mitigate coastal erosion and reduce the vulnerability of people and property in coastal areas by stabilizing sediments. Mangrove roots and shoots resist and slow the flow of water causing the deposition of suspended sediment and inhibiting its resuspension[96] The sediments mix with organic matter and then become solid within interlocking belowground roots. Another process binds the sediments and slows rates of erosion by preventing sediments from being picked up and lost by near-bed currents.[97] This process results the vertical and lateral build-up of land through accretion over time[98]

Seagrass meadows are also coastal stabilizers as their leaves slow down water-currents which increases sedimentation, and their roots and rhizomes stabilise the seabed.[99]

Marine Protected Areas (MPAs)

There is potential for BCEs to be considered for MPAs designation and management as MPAs are areas that are managed for protection and conservation. An MPAs can be used along other measures such as zoning and fisheries management which then can be used to create a balance between the user and the marine space and its resources. For example, strict conservation MPAs can be used to restore depleted fish stocks for areas outside the MPAs and reinvigorate the local fishing industry.[100]

Benefits of BCE: Socially

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[94] D. M. Alongi, “Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change.” Estuar. Coast. Shelf Sci. 76, 1–13, 2008, Pg.1

[95] Möller et al., “Wave transformation over salt marshes: A field and numerical modelling study from North Norfolk,” England. Estuarine, Coastal and Shelf Science 49, 411–426, 1999, pg.1

[96] Christiansen, T., Wiberg, P.L. & Milligan, T.G., “Flow and sediment transport on a tidal salt marsh surface.” Estuarine, Coastal and Shelf Science 50, 315–e1331., , Furukawa, K. & Wolanski, E. 1996. “Sedimentation in Mangrove forests” Mangroves and Salt Marshes 1, 3–110, 2000, pg.1
Gedan, K.B., Crain, C.M. & Bertness, M.D. “Small-mammal herbivore control of secondary succession in New England tidal marshes” Ecology 90, 430–440.,2009, Pg.1

[97] Feagin et al., “Does vegetation prevent wave erosion of salt marsh edges?” Proceedings of the National Academy of Sciences 106, 10109–10113.,2009, pg.3

[98] Alongi, D.M., “Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change.” Estuarine, Coastal and Shelf Science 76, 1–13.,2008, pg.1

[99] Arthur et al., “Ecosystem engineering by annual intertidal seagrass beds: Sediment accretion and modification” Estuarine, Coastal and Shelf Science, Volume 74, Issues 1–2, Pages 344-348, ISSN 0272-7714, https://doi.org/10.1016/j.ecss.2007.04.006.,2007, Pg.1

[100] World Bank. “Unlocking Blue Carbon Development: Investment Readiness Framework for Governments” Washington, D.C.: World Bank.,2023, Pg.84

Wetlands have been known to improve the livelihood of coastal communities and provide commercial uses such as harvesting for honey and crab, poles made from mangrove tree used for fishing and fencing, grazing of livestock, fuel, and bark used for tanning. [101]

Food from coastal wetland organisms

Coastal communities depend on wetlands for food and is their main source of dietary protein and [102] since wetlands are vital spawning ground and nursery, it provides a diverse array of species marine species which supports a highly productive food source.[103]

Construction materials

Mangroves are durable and are resistant to rotting and pest which makes it an important source of material especially the *Rhizophora spp.* It is use for the construction of houses, fencing and boats in some coastal countries.[104] The *Rhizophora spp.* is used mostly in South and Southeast Asia and South America,[105] *Heritiera fomes, Excoecaria agallocha* were historically used in the Sundarbans of Bangladesh and India,[106] *Avicennia spp*., *Xylocarpus spp*., and *Barringtonia asiatica* are preferred in the Pacific islands,[107] and *Sonneratia alba* is preferred in Madagascar.[108] Mangrove-associated and many salt marsh species such as *Juncus kraussii, Spartina alterniflora, and Phragmites spp*. has also been used in the construction of farmhouses and homes.[109] The

[101] Beers et al. "Setting the foundations for zero net loss of the mangroves that underpin human wellbeing in the North Brazil Shelf LME: Blue Carbon Feasibility Assessment." Report by Conservation International and Silvestrum Climate Associates.,2019, Pg.15

[102] Carney, J.A., "Shellfish collection in Senegambian mangroves: A female knowledge system in a priority conservation region." Journal of Ethnobiology 37, 440–458.,2017, Pg.2

[103] Friess, D.A., "Ecosystem services and disservices of mangrove forests: Insights from historical observations." Forests 7, 183., 2016, pg.9

[104]Friess, D.A., "Ecosystem services and disservices of mangrove forests: Insights from historical observations." Forests 7, 183., 2016, pg.5

[105]Bandaranayake, W.M., "Traditional and medicinal uses of mangroves." Mangroves and Salt Marshes 2, 133–148.,1998, pg.1

[106]Bandaranayake, W.M., "Traditional and medicinal uses of mangroves." Mangroves and Salt Marshes 2, 133–148.,1998, pg.3

[107]Bandaranayake, W.M., "Traditional and medicinal uses of mangroves." Mangroves and Salt Marshes 2, 133–148.,1998, pg.4

[108]Rasolofo, M.V., "Use of mangroves by traditional fishermen in Madagascar" Mangroves and Salt Marshes 1: 243–253,1997, pg.9

[109] Cunningham, A.B., "Wetlands and people's wellbeing: Basic needs, food security and medicinal properties." In Wetlands and Human Health. C.M. Finlayson et al. (eds). Dordrecht, Netherlands: Springer, 31–44. Daily, G.C. (ed.) Nature's Services: Societal Dependence on Natural Ecosystems. Washington, DC, United States of America, Island Press.,1997, pg.1

Nypa fruticans are a common roofing material in Indonesia and Malaysia [110] and wood from mangroves is still used today often for fencing posts and charcoal .[104]

Fuel

The *Rhizophora spp.* are high in calories and are slow burning generating a lot of heat while producing little smoke and because of this most used as a source of fuel and charcoal [104] [111] Historically, mangroves were used as fuel for trade ships travelling between European and Asian markets and naval fleets in Latin America. [104] [112] In recent times, there is small scale commercial charcoal production that can have negative impacts on local mangroves if not regulated effectively.[113]

Benefits of BCE: Economically

BCEs are valued at over $190 billion in U.S. dollars per year[114] and can be estimated to reduce costs associated with impacts such as flooding by over USD $65 billion annually.[115]

Pharmaceuticals and natural compounds

Medicinal use of wetland organisms is commonly used in Asia, Africa, Latin America and the Caribbean and are used to treat ailments such as asthma, skin diseases, diabetes, cancer treatments, inflammation, tumours, viruses, ulcers, and animal venom. [116] The leaves, fruits, flowers and seeds found in wetlands can contain the medicinal properties which are also used to treat ailments however extracting biomolecules from microbes, fungi, algae, insects, and

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[110]Baba, S., Chan, H.T. & Aksornkoae, S., "Useful Products from Mangrove and Other Coastal Plants." H.T. Chan (ed.). ISME Mangrove Educational Book Series No. 3. Okinawa, Japan: International Society for Mangrove Ecosystems (ISME), and Yokohama, Japan: International Tropical Timber Organization (ITTO).,2013, pg.29

[111] Walters et al., "Ethnobiology, socioeconomics and management of mangrove forests: A review." Aquatic Botany 89, 220–236,2008, pg. 3

[112] López-Angarita et al. "Mangroves and people: Lessons from a history of use and abuse in four Latin American countries." Forest Ecology and Management 368, 151–162.,2016, Pg.2)

[113] Buchbaum, R. "Coastal marsh management." In Applied Wetlands Science and Technology. 2nd ed. D.M. Kent (ed.). New York: Lewis Publishers, 324–346.,2021, Pg.1

[114] Bertram et al., "The blue carbon wealth of nations." Nat. Clim. Chang. 11, 704–709Retrieved from: https://doi.org/10.1038/s41558-021-01089-4, 2021, pg.2

[115] Leal, Maricé and Spalding, Mark D. (editors), "The State of the World's Mangroves 2022." Global Mangrove Alliance. Retrieved from: https://www.wetlands.org/publications/the-state-of-theworlds- mangroves-2022/.,2022, Pg.9

[116] Friess, Daniel A. "Chapter 3 Ecosystem Services and Disservices of Mangrove Forests and Salt Marshes." Place of publication not identified: Taylor & Francis, 2020, Pg 10

herpetofauna have also been identified as a source of medicine. [117] Some examples of species and their medicinal uses Extracts from *Bruguiera* spp. are used in the treatment of tumours and viral infections,[118] *Xylocarpus* spp., *Ceriops spp*., and *Rhizophora* spp. extracts have also been used in the treatment of diarrhoea and haemorrhaging,[119] the HIV-1 inhibitors have been from the mangrove associate, *Calophyllum inophyllum*[120] and the *Avicennia spp.* has been identified to have anti-viral, analgesic, and anti-parasite biomolecules used in the treatment of leprosy, hepatitis, and smallpox.[117]

Not much is known about the medicinal properties of salt marsh species, however some studies have shown that there is potential. *Salicornia herbacea* extracts have potential as an antibacterial, antidiabetic, antiproliferative, antioxidant, anti-inflammatory, and in diabetes treatments.[121] This species has traditionally been used to treat gastrointestinal ailments and obesity.[122] Another species, *Suaeda fruticose,* has also been looked at as an antioxidant, anti-inflammatory, and anti-cancer compounds.[123]

Recreation and tourism

Recreation and tourism are major benefit to the people of coastal communities and contributes to the local economy. There are two types of wetland recreation: non-extractive such as walking, photography, bird watching, social gatherings, and extractive such as ecotourism such as fishing and [124] hunting [125] One example is the Codrington lagoon situated in the island of Barbuda (sister island to Antigua) is recognized as a RAMSAR (Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat is an international treaty for the conservation and sustainable use of Wetlands). This site is a diverse wetland ecosystem

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[117] Friess, Daniel A. "Chapter 3 Ecosystem Services and Disservices of Mangrove Forests and Salt Marshes." Place of publication not identified: Taylor & Francis, 2020, Pg 11

[118] Knox, G. & Miyabara, T., "Coastal Zone Resource Development and Conservation in Southeast Asia with Special Reference to Indonesia. Jakarta, Indonesia," UNESCO.,1984

[119] Bandaranayake, W.M., "Traditional and medicinal uses of mangroves." Mangroves and Salt Marshes 2, 133–148.,1998, pg.10

[120] Patil, A.D.et al., "The Inophyllums, novel inhibitors of HIV-1 reverse transcriptase isolated from the Malaysian tree, Calophyllum inophyllum Linn." Journal of Medicinal Chemistry 36, 4131–4138.,1993

[121] Patel, S., "Salicornia: Evaluating the halophytic extremophile as a food and a pharmaceutical candidate." 3 Biotech 6, e104.,2016 pg.1

[122] Rhee, M.H., Park, H.J. & Cho, J.Y. , "Salicornia herbacea: Botanical, chemical and pharmacological review of halophyte marsh plant." Journal of Medicinal Plants Research 3, 548–555.,2009, pg.1

[123] Oueslati, S., "Phenolic content, antioxidant, anti-inflammatory and anticancer activities of the edible halophyte Suaeda fruticosa Forssk." Food Chemistry 132, 943–947,2012

[124] Friess, Daniel A. *Chapter 3 Ecosystem Services and Disservices of Mangrove Forests and Salt Marshes*. Place of publication not identified: Taylor & Francis, 2020, Pg 15

[125] Kelleway, J.J. et al.,. "Review of the ecosystem service implications of mangrove encroachment into salt marshes". Global Change Biology 23, 3967–3983.,2017, pg.1

containing mangroves, seagrass beds, algal mats, tidal and mud flats, beaches and coral reefs with numerous species of marine organisms such as lobster, reef fish, sea turtles and marine mammals and includes an abundance of seabirds. Due to its highly diverse ecosystems, it is one of the island's greatest economic assets as it is home to one of the biggest colonies of frigate birds to which tourist visit the island to witness [126] Another example is The Sundarbans mangrove has a rich biodiversity of plants and animals and is home to the endangered Royal Bengal Tiger. [127] The wetlands are recognised as a UNESCO World Heritage Site[128] and the Tiger Reserve is a major tourist attraction brought in over 174,000 visitors and permits in 2015.[129] This brought a large economic benefit and promoted community management.[130] Salt marshes and mudflats also have a high biodiversity in the area and commonly visited by tourist as well.[131] Migratory and resident birds can be found in these salt marshes and attracted birders while the low marsh is prime habitat for recreational fishing activities.[132]

Part Two

Unlocking Blue Carbon and its Blueprint for SIDS

With BC garnering global interest to combat climate change, SIDS with large carbon stocks is becoming a suitable solution as small island states can approximately hold 1806–2892 Tg. of BC. However, only 23% of these states have quantitative and measurable BC targets in their

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[126] Ramsar, Information Sheet on Ramsar Wetlands (RIS): Antigua and Barbuda,2006 (Giosan et al., 2014)

[127] Bhattacharyya, S., Raha, A.K. & Mitra, A, "Ecotourism revenue in Sunderban Tiger Reserve" Techno International Journal of Health, Engineering, Management and Science 2, 29–34,2018, pg.1

[128] Salam, M.A., Lindsay, G.R. & Beveridge, M.C. "Eco-tourism to protect the reserve mangrove forest the Sundarbans and its flora and fauna" Anatolia 11, 56–66.,2000, Pg.1

[129] Bhattacharyya, S., Raha, A.K. & Mitra, A, "Ecotourism revenue in Sunderban Tiger Reserve" Techno International Journal of Health, Engineering, Management and Science 2, 29–34,2018, pg.6 (Bhattacharyya, Raha, & Mitra, 2018)

[130] Uddin, M.S., van Steveninck, E.D.R., Stuip, M. & Shah, M.A.R. 2013. Economic valuation of provisioning and cultural services of a protected mangrove ecosystem: A case study on Sundarbans Reserve Forest, Bangladesh. Ecosystem Services 5, 88–93.,2013, Pg. 3

[131] Myatt, L.B., Scrimshaw, M.D. & Lester, J.N. , "Public perceptions and attitudes towards a current managed realignment scheme: Brancaster West Marsh, North Norfolk", UK. Journal of Coastal Research 19, 278–286, 2003, pg.5

[132] Feagin et al., "Salt marsh zonal migration and ecosystem service change in response to global sea level rise: A case study from an urban region." Ecology and Society 15, 14., 2010, pg.1

NDCs and 36% have none.[133] This is now a goal for climate-determined organizations to implement BC targets and actions in many SIDS.

BC has also attracted interest from policymakers[134] and the financial industry[135]. Countries with large BC resources such as Indonesia, Australia, and the USA contributing the most to the world's BC wealth [136]and have established robust frameworks for BC conservation and restoration. For example, Indonesia has recently enacted several new BC policies and has established a new agency responsible for mangrove restoration, with a target of 600,000 ha by 2024,[137] The Australian Government has produced a method for estimating the climate change mitigation benefits of national BC restoration projects[138] and the bipartisan 'Blue Carbon for Our Planet Act' has been discussed by the United States Government to provide direct support for BC activities and initiate pilot projects[139]

Chapter 1

Efforts to conserve and restore coastal wetlands have been ongoing for over a century aiming goal to preserve biodiversity and provide benefits to local communities and various funding sources have been used to support these efforts. As the recognition of the value for carbon storage and sequestration coastal wetlands have, there needs to be an acknowledgement of the emissions released if these ecosystems are degraded and loss through development. Wetland management is now looking into funding options for climate change mitigation and adaptation.

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[133] Daniel A Friess, "The potential for mangrove and seagrass blue carbon in Small Island States", Current Opinion in Environmental Sustainability, Volume 64, 101324, ISSN 1877-3435,2023 https://doi.org/10.1016/j.cosust.2023.101324. (https://www.sciencedirect.com/science/article/pii/S1877343523000714),2023, pg. 1

[134]IUCN & Conservation International. "International policy framework for blue carbon ecosystems: Recommendations to align actions across international policy processes for the conservation and restoration of coastal blue carbon ecosystems." Gland, Switzerland: IUCN and Arlington, VA, United States: Conservation International, 2023.Pg21

[135] Friess D.A. et al., "Capitalizing on the global financial interest in blue carbon", PLoS Clim 2022, 1:0000061.,2022, Pg. 3

[136] Bertram C et al., "The blue carbon wealth of nations", Nat Clim Change 11:704-709.,2021, Pg. 1

[137] Sidik F. et al., "Blue carbon: a new paradigm of mangrove conservation and management in Indonesia". Mar Policy 2023, 147:105388. Pg.3

[138] Lovelock C.E.et al., "An Australian blue carbon method to estimate climate change mitigation benefits of coastal wetland restoration." Restoration Ecology, 2023, Pg.2

[139] US Congress, "US Congress: **S3245 Blue Carbon for Our Planet Act;** United States Congress:" 2022. ⟨https://www.congress.gov/bill/117th-congress/senate-bill/3245/text⟩ (US Congress, 2022)

Section A

The Blue Carbon Economy

The VCM is expected to be worth approximately 50 billion dollars by 2030 as natural climate solutions are seen as contributions to corporate net-zero ambitions in the financial sector[140] and is expected to increase as quality standards cause the retirement of other carbon credit types. BC is a small section of the carbon market however, potential within the BC finance in the VCM is large. For example, approximately 20% of the world's mangrove extent (approximately 2.6 million ha) could potentially generate 1.1 billion USD per year.[141] The interest in BC is now strong enough that investors are identifying BC fund opportunities and multiple structures and partnerships are now being put incorporated to facilitate the development of BCPs are. Some of these examples include: a major bank recently announced the launch of two natural capital funds that are expected to raise a combined investment capital of up to US$2 billion, with BCEs as a key focus.[142] Carbon project developers are working together with investors and other stakeholders to establish structures to facilitate BCP development such as the Blue Carbon Facility.[143] The Blue Natural Capital Financing Facility and Blue Carbon Accelerator Fund were established to help facilitate a cooperation between stakeholders who are financiers, technology providers, and in academia. [144] [145]

The UNFCCC has established the overall framework for measures to reduce GHG emissions, offers technical aid and dedicated funding to support various climate mitigation efforts, especially those relating to carbon in wetlands. Wetland carbon activities aimed at addressing climate change under the UNFCCC can start as a standalone project or be a part of a larger

[140] Taskforce on Scaling the Voluntary Carbon Market (TFSVCM), "Taskforce on Scaling the Voluntary Carbon Market Final Report." Taskforce on Scaling the Voluntary Carbon Market". 2021. Pg. 68

[141] Zeng Y. et al. "Global potential and limits of mangrove blue carbon for climate change mitigation." Curr Biol.; 31: 1737–1743 pmid:33600768, 2021, pg. 3-4

[142] HSBC. "HSBC Global Asset Management & Pollination launch partnership to create world's largest natural capital manager". Retrieved from: www.assetmanagement.hsbc.com.sg/en/institutional-client/news-and-insights/climateassetmanagement-sg,2020, pg. 1

[143] Mirova. "Call for early-stage Blue Carbon Project Proposals." 2021, Retrieved from https://www.mirova.com/en/news/call-early-stage-blue-carbon-project-proposals

[144] IUCN. "Blue Natural Capital Financing Facility: Our Partners", 2021, Retrieved from: https://iucn.org/our-work/projects/blue-natural-capital-financing-facility-bncff. IUCN. New Blue Carbon

[145] IUCN, "Accelerator Fund to support blue carbon entrepreneurs and leverage private sector finance." 2021. Retrieved from: www.iucn.org/news/marine-and-polar/202111/new-blue-carbon-accelerator-fund-support-blue-carbon-entrepreneurs-and-leverage-private-sector-finance

national or sub-national initiative. There is a difference between projects and national or subnational programs and for the specific type of activity there are funds and financial mechanisms for each. Herr et al. 2014 states that when identifying the activities and the funding sources two things to remember:

1. "Some countries include emissions and removals from wetlands in their national GHG inventories submitted to the UNFCCC, while others do not. If both carbons offset projects and a national wetlands accounting scheme are in place (or being developed), there is a risk of double counting the GHG benefits. Addressing the potential conflict between project-level crediting and country-level crediting is necessary to prevent GHG benefits from being counted twice within the system.
2. A balance between specific mitigation and adaptation solutions is prominent in agriculture, forestry, and rural land use sectors. Similar synergies can be found in coastal management, where in addition to coastal protection and carbon sequestration, they offer various ecosystem services and job opportunities for local and global communities. There is significant potential for developing synergies between climate change mitigation and adaptation, and it is important to consider several adaptation-oriented funds." [146]

1. **Funding Sources: National or Subnational Programs and Compliance Voluntary Carbon Market**

- **National or subnational programs**

National or sub-national programs are large-scale initiatives aimed at improving the management of wetland areas at either the national or sub-national level and are grouped into climate mitigation and climate adaptation mechanisms. Climate mitigation mechanisms are Nationally Appropriate Mitigation Activities (NAMAs) and Reducing Emissions from Deforestation and forest Degradation (REDD+) and climate adaptation mechanisms the National Adaptation Programme of Action (NAPAs) and the National Adaptation Plans (NAPs). [146]

- **Nationally Appropriate Mitigation Activities (NAMAs)**

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[146] Herr, D. et al. "Keep it Fresh or Salty An introductory guide to financing wetland carbon programs and projects",2014, pg 15

NAMAs are activities use to reduce emissions in developing countries and are usually developed and by the national government with the aim to secure funding for developing nations and offer flexibility to prioritize and carry out the project activities based on their capabilities. To qualify for NAMAs support, the program reduces their GHG emissions as well as include factors for economic and social development to alleviate poverty. NAMAs can be funded by countries with additional financial assistance and the UNFCCC can offer to connect NAMAs with funding opportunities. [147]

- **Reducing Emissions from Deforestation and forest Degradation (REDD+)**

REDD+ aim is to address climate change by reducing and eliminating GHG emissions through forest management in developing nations. REDD+ supports the preservation, sustainable management, and enhancement of forest carbon stocks to boost GHG removal which supports countries' efforts to reduce emissions from deforestation and forest degradation. One thing to note is that each participating country in REDD+ has the freedom to define "forest" according to their preferences. [147]

- **National Adaptation Programme of Action (NAPAs)**

NAPAs provide aid to Least Developed Countries (LDCs) and are short term assistance programs that address the countries' needs for adaptation, discuss their issues, problems and gaps and cost for adaptation in the future. [148]

- **National Adaptation Plans (NAPs)**

Like NAPAs (which only focuses on LDCs), NAPs are used to identify the medium and long-term adaptation needs and aids in developing and implementing strategies for those needs and is designed for all developing countries. Wetlands can be included in NAPs which presents a valuable opportunity for states with wetlands to participate in NAPs and access related funding.[149]

2. Coastal wetland carbon projects funded via the Compliance Market

[147] Herr, D. et al. "Keep it Fresh or Salty An introductory guide to financing wetland carbon programs and projects",2014, pg. 17
[148] Herr, D. et al. "Keep it Fresh or Salty An introductory guide to financing wetland carbon programs and projects",2014, pg. 18
[149] McGray, H., "Clarifying the UNFCCC National Adaptation Plan Process", 2014, Retrieved from: https://www.wri.org/insights/clarifying-unfccc-national-adaptation-plan-process

Wetland carbon projects such as restoration includes specific initiatives for the reduction of GHG emissions. The Clean Development Mechanism (CDM) was created to assist with countries activities at the project level and helping them reduce emissions for sustainable development which overall contributes to achieving their objectives and targets under the UNFCCC and provide support to developing countries who have BC and create Certified Emission Reduction (CER) units, with each unit representing one tonne of CO_2 which can be exchanged on carbon markets. Activities related to wetland carbon to for development and implementation such as capacity building, technical guidance, and policy analysis reports are mostly carried out by NGOs.[150]

3. UNFCCC financial mechanisms

Under the UNFCC there are various climate funding sources for coastal wetland carbon mitigation and adaptation efforts. These sources include The Global Environment Facility (GEF) which serves as a financial mechanism. Under GEF is the GEF Trust Fund (GEF TF), its Focal Areas (FA), the Special Climate Change Fund (SCCF), and the Least Developed Countries Fund (LDCF). Apart from the GEF, the UNFCCC has established other funds that support wetland carbon activities like the Green Climate Fund (GCF) and the Adaptation Fund (AF).[151]

- **GEF Trust Fund**

The GEF TF funds GEF which supports projects in seven key Focal Areas (FA), such as biodiversity, climate change (both mitigation and adaptation), chemicals, international waters, land degradation, sustainable forest management/ REDD+, and Ozone layer depletion. [151]

- **Special Climate Change Fund (SCCF)**

The SCCF which funds capacity building, adaptation, technology transfer, and climate change mitigation and economic diversification programs for countries that mainly rely on revenue from fossil fuels. Within in this funding source are two ongoing funding opportunities: the SCCF-A for Adaptation and SCCF-B for Technology Transfer. [152]

[150] Herr, D. et al. “Coastal “blue” carbon. A revised guide to supporting coastal wetland programs and projects using climate finance and other financial mechanisms.” Gland, Switzerland: IUCN., 2015, pg.19

[151] Herr, D. et al. “Keep it Fresh or Salty An introductory guide to financing wetland carbon programs and projects”,2014, pg. 22

[152] Herr, D. et al. “Keep it Fresh or Salty An introductory guide to financing wetland carbon programs and projects”,2014, pg. 23

- **Least Developed Countries Fund (LDCF)**

Another funding source under the GEF is the LDCF which aims to address the requirements of the 48 Least Developed Countries (LDCs) and has $2.0 billion for activities and is also supported by GEF operated fund to involve the creation and execution of NAPAs to recognize the immediate needs of LDCs for adapting to climate change. [153] [154]

- **The Green Climate Fund (GCF)**

The Green Climate Fund (GCF) is governed by the GCF Board and was established in 2010 as a finance mechanism under the UNFCCC serving to transfer funds from developed countries to developing countries. The aim of this funding source is to aid developing countries in implementing adaptation and mitigation measures to combat climate change. [153]

- **Adaptation Fund (AF)**

The Adaptation Fund (AF) has allocated approximately US$ 120.4 million since 2010 towards adaptation measures in coastal areas, with US$82.3 million currently designated for approved or ongoing projects that focuses on flood defence and resilience. [155] To qualify for funding from the AF the general eligibility criteria for countries are:

1) Party to the Kyoto Protocol.
2) Particularly vulnerable to the adverse effects of climate change which includes low-lying coastal and other small island countries, and countries with fragile mountainous ecosystems, arid and semiarid areas, and areas susceptible to floods, drought and desertification. [156]

4. **Coastal wetland carbon projects funded via the voluntary carbon market**

Voluntary carbon markets

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[153] Herr, D. et al. "Coastal "blue" carbon. A revised guide to supporting coastal wetland programs and projects using climate finance and other financial mechanisms." Gland, Switzerland: IUCN., 2015, pg.24

[154] GEF "GEF Programming Strategy on Adaptation to Climate Change for the Least Developed Countries Fund and the Special Climate change Fund for the GEF-8 Period of July 1, 2022, to June 30, 2026, and Operational Improvements" 2022, pg.10

[155] World Bank, "Unlocking Blue Carbon Development: Investment Readiness Framework for Governments". Washington, D.C.: World Bank. 2023 Pg.48

[156] Herr, D. et al. "Coastal "blue" carbon. A revised guide to supporting coastal wetland programs and projects using climate finance and other financial mechanisms." Gland, Switzerland: IUCN., 2015, pg.25

In contrast to the CDM, where verified CERs are traded through a UN regulated market, VCM allow carbon emitters to offset their inevitable emissions by purchasing carbon credits emitted by projects targeted at removing or reducing GHG from the atmosphere. Credits can be used by a company and other emitting entities to pay for the emission of carbon they emit, and they comply with their own Corporate Social Responsibility (CSR) or Good Stewardship, to establish themselves as environmentally friendly.[157] Notably carbon crediting programs are Verra, American Climate Registry (ACR), Climate Action Reserve, Plan Vivo, Gold Standard, Climate Forward and Global Carbon Council[158] and Blue Carbon projects registries are only under Verra Verified Carbon Standard (VCS), Climate Action Reserve (CAR) and Plan Vivo.

Section B

Current Blue Carbon Projects

BCPs within the VCM or any other funding source at a smaller scale has been shown to have a higher success potential than the UNFCCC mechanisms. Even though the UNFCCC are more practical, a VCM project requirements are easier and simpler to develop compared.[159] As awareness of the benefits provided by BCEs grows and different alternative methods for supporting projects are being developed, more countries, institutions and organizations are likely to respond and adapt to climate change impacts by reducing their carbon footprint. Projects developed within the VCM testing ground can help with discussing the global climate mitigation policy since looking into best practices are still currently being done for implementing REDD+, CDM, and AMA projects, with the expectation of being able to facilitate the incorporation of more BCPs in the future. [159]

Blue Carbon Projects

[157] Herr, D. et al. "Coastal "blue" carbon. A revised guide to supporting coastal wetland programs and projects using climate finance and other financial mechanisms." Gland, Switzerland: IUCN., 2015, pg.27

[158] Medium, "Carbon Credits — Path to Net-Zero or Diversion from Emission Cuts?", 2023 Retrieved from: https://medium.com/@malikmanisha04/carbon-credits-path-to-net-zero-or-diversion-from-emission-cuts-de6bd9b07ebb

[159] Wylie, L., Sutton-Grier,A.E., Moore A., "Keys to successful blue carbon projects: Lessons learned from global case studies", Marine Policy, Volume 65, Pages 76-84, ISSN 0308-597X, https://doi.org/10.1016/j.marpol.2015.12.020, 2016, pg. 8

Although many BCP are situated in mangroves, it is important to note it is recommended that all three BCEs be included in future projects to take advantage of the carbon storage services they provide. Things to note for this section is several of these initiatives are in the early stages of development or lack readily accessible recent information and these projects are utilized or attempt to utilize carbon markets, specifically UNFCCC mechanisms as well as the VCM.

- **Blue Carbon NAMA, Dominican Republic**

The Dominican Republic has submitted the first Blue Carbon NAMA under the UNFCCC's NAMA mechanism, and this signifies the government's commitment to reducing GHG emissions in alignment with national development goals and capacity. This project aims to:

1. Integrates mangrove conservation, restoration, and sustainable use practices into existing international policy and financing processes
2. serve as a transformative tool for effective national natural carbon management [160]

This project is currently in its early phase of development but aims to quantify the carbon sink capacity of Mangroves in the Dominican Republic which will then contribute to generating emission allowances, emission credits, and other types of CO_2 compensation certificates, build national and local institutional capacity to assess the CO_2 sequester capacity of mangroves in the Dominican Republic, facilitate national dialogue on how to leverage carbon credits to promote greater competitiveness for small and medium-sized businesses through policies and financial mechanisms ,develop national strategies to restore and reforest mangrove systems around the Dominican Republic, and establish a Blue Carbon NAMA Knowledge Toolkit. [161]

Mikoko Pamoja, Kenya

The Mikoko Pamoja community led project focuses on restoring and reforesting mangroves in Gazi Bay, Kenya.[162] The aim of this project is to restore the mangrove ecosystem, as a major threat to their mangroves is deforestation mostly for wood for construction, enhance ecosystem

[160] Herr et al., "Coastal "blue" carbon: A revised guide to supporting coastal wetland programs and projects using climate finance and other financial mechanisms", 2015, pg.23

[161] Commonwealth, "Case study: Community-led Mangrove Restoration and Conservation in Gazi Bay, Kenya - Lessons From Early Blue Carbon Projects (on-going)",2020, Retrieved: https://thecommonwealth.org/case-study/case-study-community-led-mangrove-restoration-and-conservation-gazi-bay-kenya-lessons

[162] Global Mangrove Alliance, "Mikoko Pamoja: A Business Case for Carbon Credit in Gazi-Kwale County, Kenya", Retrieved from: https://www.mangrovealliance.org/mikoko-pamoja/ n.d.

services, encourage sustainable income from mangroves, and serve as a model for future projects.[163] This projects is in involved in a Payment for Ecosystem Services (PES) agreement with Plan Vivo, the credit manager, and five-year research on carbon storage potential has been conducted.[164] The project did meet its target in 2014 of improving the livelihood of the local communities who generated income from the mangroves activities such as beekeeping and ecotourism and the profits were used to enhance and develop their education system as well as provide running water to the communities. The project also created a solution to the major treat of deforestation in the mangrove forest by finding alternative sources of wood from terrestrial forests.[165] The management of these projects is carried out by Gazi women, who have benefited from participating in alternative livelihoods that are opportunities not given to women.[166]

The project did face some challenges such as the fluctuating price of carbon credit due to an uncertain market and the small size of the project, finding funds for a watchtower to prevent illegal mangrove cutting, changing rainfall patterns and turnover in the project coordinator position[167] nonetheless the project has successfully met its goals despite the challenges and the success of the Mikoko Pamoja project can be attributed to the local community actively supporting and participating in the project.

<u>India Sundarbans mangrove restoration project</u>

The Sundarbans, India to southern Bangladesh is home to the largest mangrove forest in the world as is currently impacted by human activities such as population growth, ecosystem disruption, and prawn harvesting.[168] These mangroves provide ecosystem services to approximately five million locals,[169] serving as natural defences for a man-made embankment

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163 Wylie, L., Sutton-Grier,A.E., Moore A., "Keys to successful blue carbon projects: Lessons learned from global case studies", Marine Policy, Volume 65, Pages 76-84, ISSN 0308-597X, https://doi.org/10.1016/j.marpol.2015.12.020, 2016 pg.3

164 Abdalla S. L.N.A., Kairo J.A., Huxham M., "2013-2014 Plan Vivo Annual Report: Mikoko Pamoja", 2014. Pg. 17

165 Wylie, L., Sutton-Grier,A.E., Moore A., "Keys to successful blue carbon projects: Lessons learned from global case studies", Marine Policy, Volume 65, Pages 76-84, ISSN 0308-597X, https://doi.org/10.1016/j.marpol.2015.12.020, 2016, pg.4

166 Abdalla S. L.N.A., Kairo J.A., Huxham M., "2013-2014 Plan Vivo Annual Report: Mikoko Pamoja", 2014. Pg. 26

167 Abdalla S. L.N.A., Kairo J.A., Huxham M., "2013-2014 Plan Vivo Annual Report: Mikoko Pamoja", 2014. Pg. 14

168 Dey A., Kar A., "Scaling of mangrove afforestation with carbon finance to create significant impact on the biodiversity – a new paradigm in biodiversity conservation models." Field Action Science Reports (FACTS),2012, pp.1–15 pg.6

169 Ranjan R., "Optimal mangrove restoration through community engagement on coastal lands facing climatic risks: The case of Sundarbans region in India" *Environmental Sciences, Faculty of Science and Engineering, Macquarie University Sydney, 2109, Australia,*2019, pg.1

that was built for flood and storm protection and shielding the community from daily tidal fluctuations of up to 20 feet.[170] The India Sundarbans Mangrove Restoration project is a Verra grouped project (combined multiple project activity instances into a single, combined project that adds new instances over time) and aims to plant 6000 ha of mangroves over a span of three years, engage with locals during the implementation process and contribute to the Danone carbon offset strategy and collect carbon credits.[171] Like the Mikoko Pamoja, this project has local women heavily involved and have been trained in mangrove planting and providing employment opportunities them in an area where much of the population lives below the poverty line.[172]

Blue Forests, Madagascar

Approximately 2% of the world's mangrove forests can be found in Madagascar and these mangroves ecosystems play a crucial role in supporting their coastal communities by providing fisheries, timber, and protection against storms and erosion.[170] The Blue Ventures' Blue Forests initiative collaborates with local communities to implement carbon financing projects aimed at conserving mangrove forests to support sustainable communities. [173] The initiative aims to integrate mangrove conservation and restoration projects into Madagascar's national REDD+ strategy and implement mangrove conservation projects using VCM standards (Plan Vivo) across several project sites as well as research into quantifying GHG emissions and analysing the drivers of wetland loss and modelling to forecast future wetland changes. The projects also seek to identify alternative sources of livelihood and analysing user rights of mangrove forests. In Madagascar, the Blue Forests effort aims to integrate mangrove conservation and restoration

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[170] Wylie, L., Sutton-Grier,A.E., Moore A., "Keys to successful blue carbon projects: Lessons learned from global case studies", Marine Policy, Volume 65, Pages 76-84, ISSN 0308-597X, https://doi.org/10.1016/j.marpol.2015.12.020, 2016, pg.6

[171] Dey A., Kar A., "Scaling of mangrove afforestation with carbon finance to create significant impact on the biodiversity – a new paradigm in biodiversity conservation models." Field Action Science Reports (FACTS),2012, pp.1–15 pg.3

[172] Dey A., Kar A., "Scaling of mangrove afforestation with carbon finance to create significant impact on the biodiversity – a new paradigm in biodiversity conservation models." Field Action Science Reports (FACTS),2012, pp.1–15,2013, pg.12

[173] GEF, "Greening the blue: championing coastal climate solutions",2019, Retrieved from: https://www.thegef.org/news/greening-blue-championing-coastal-climate-solutions

projects into the country's national REDD+ strategy[174] and implement mangrove conservation projects using VCM standards across several project sites.[175]

Chapter 2

Blue Carbon Opportunities and Challenges

Organizations, Institutions, government entities and local communities globally are showing an interest in restoring and conserving coastal wetlands as climate change mitigation strategy and have mentioned these ecosystems importance in their Intended Nationally Determined Contributions (INDCs) submitted before the new international climate agreement was created by the COP of the UNFCCC in Paris, France 2015.[176] When the management of carbon in a coastal wetland is properly managed it will boost carbon sequestration which will then prevent GHG emissions and bring numerous advantages to local communities and biodiversity and there is an emerging support to conserve and restore these ecosystems through financial mechanisms for climate change mitigation. However, finding a suitable funding source is still a challenge.

Section A - Blue Carbon in Climate Change

Coastal countries have an interest in BC specific commitments and actions, both adaptation and mitigation and climate organizations have initiatives to help aid these communities with support such as the Blue Carbon Initiative of the UN Environment Program (UNEP) advocates for Ecosystem Based Management (EBM) and creative financing mechanisms to support the rehabilitation, conservation, and sustainable management of deteriorated BCEs to ensure the preservation of their carbon sequestration and storage capabilities.[177] These coastal BCEs have the capacity to alleviate climate change and assist nations in fulfilling their global climate, restoration, and biodiversity obligations and with the support and aid of international climate

[174] Food and Agriculture Organization of the United Nations, "Blue forests: Community-led mangrove management to protect coastal eco-systems and livelihoods." London, UK: Blue Ventures. Retrieved from: https://blueventures.org/wp-content/uploads/2021/03/BV-Blue-Forests-Factsheet-2015.pdf, 2015, pg.3

[175] Food and Agriculture Organization of the United Nations, "Blue forests: Community-led mangrove management to protect coastal eco-systems and livelihoods." London, UK: Blue Ventures. Retrieved from: https://blueventures.org/wp-content/uploads/2021/03/BV-Blue-Forests-Factsheet-2015.pdf, 2015, pg.4

[176] Herr et al., "Coastal "blue" carbon: A revised guide to supporting coastal wetland programs and projects using climate finance and other financial mechanisms", 2015, pg 11

[177] Delacámara et al., "Ecosystem-Based Management: Moving from Concept to Practice" Springer Nature, pp 39–60, 2020, pg.1

organizations and agencies to help share and enhance knowledge, improve datasets and secure funding can create a platform for establishing a successful BC action for coastal communities.

Establishing a Policy and Institutional Framework for Blue Carbon

The conservation and restoration of forests have been recognized by the UNFCCC as crucial for mitigating climate change through the REDD+ mechanism.[178] Expanding these efforts to include other natural systems, such as BCEs, could aid in reducing emissions from the degradation and loss of these areas as well. According to Article 4.1(d) of the UNFCCC has urged for the sustainable management, conservation, and enhancement of "sinks and reservoirs of all greenhouse gases not controlled by the Montreal Protocol including …oceans as well as … other coastal and marine ecosystems." Therefore, there is potential to incorporate coastal ecosystems into existing UNFCCC mechanisms, although this has not yet occurred.[179] Parties were asked to provide information on the extent and coverage of their mitigation and adaptation efforts, as well as on methodological approaches, including those for estimating and accounting for anthropogenic GHG emissions and removals.[180]

The INDCs submitted by a country during COP21 will automatically serve as its first NDC when the country ratifies the Paris Agreement, unless decided otherwise. [181]Parties are now obligated to regularly submit updated NDCs every 5 years, with a review process intended to progressively increase ambition. [182] Although the current NDCs represent a significant contribution, the existing commitments will not achieve the 2°C target required to address climate change.

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[178] Herr, D., E. Pidgeon, and D. Laffoley (eds.) "Blue Carbon Policy Framework: Based on the discussion of the International Blue Carbon Policy Working Group". Gland, Switzerland: International Union for Conservation of Nature and Arlington, Virginia: Conservation International,2012, pg.13

[179] Herr, D., E. Pidgeon, and D. Laffoley (eds.) "Blue Carbon Policy Framework: Based on the discussion of the International Blue Carbon Policy Working Group." Gland, Switzerland: International Union for Conservation of Nature and Arlington, Virginia: Conservation International,2012, pg.7

[180] UNFCCC Decision, "Report of the Conference of the Parties on its twentieth session, held in Lima from 1 to 14 December 2014." Decision 1/CP.20, 2014, Retrieved from: http://unfccc.int/resource/docs/2014/cop20/ eng/10a01.pdf#page=2 , 2014, pg. 14

[181] UNFCC, "Intended Nationally Determined Contributions (INDCs)", Retrieved from: https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs/indcs, n.d.

[182] UNFCC, "Nationally Determined Contributions (NDCs)", Retrieved from: https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs, n.d.

Scientists have determined that collectively, the NDCs will reduce GHG emissions but will still result in a warming of 2.6–3.1 °C by 2100.[183]

Leveraging natural solutions to aid in climate change mitigation and adaptation.

Effectively managing the extraction of natural resources and agricultural lands in a sustainable manner, as well as restoring natural or modified ecosystems and preserving intact systems, present opportunities to tackle the challenges posed by climate change. One significant nature-based solution originates from the Land Use, Land Use Change and Forestry (LULUCF) sector. Specifically, within the LULUCF sector as part of the UNFCCC, the potential of coastal and marine ecosystems for climate mitigation, particularly mangroves, has been highlighted in recent years.[184]

The Inclusion of Coastal wetlands as part of LULUCF commitments

Human activities in BCEs for example shrimp farms need to be in included in a country's climate change mitigation efforts and national GHG reports. Mangroves may be considered part of a country's overall forestry-related activities, such as Afforestation/Reforestation (A/R) or REDD+, depending on the national definition of "forests." Typically, countries focus on "forests" as part of natural climate solutions for mitigation and not having to specify activities for individual forest types. [185] LULUCF serves as a sector in a country's GHG inventory to quantify and account for the emissions and removals of GHG from terrestrial lands, which may include coastal wetlands based on a country's definition of land.[186] The IPCC has provided guidance on including coastal wetlands, although it is not mandatory. While many countries address LULUCF and REDD+ activities in their NDCs, it is not always clear from these submissions whether coastal wetlands are included, unless a country specifies the ecosystem.[187]

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[183] Rogelj, J. et al., "Paris Agreement climate proposals need a boost to keep warming well below 2°C" Nature 534, 631-639. , Nature, http://dx.doi.org/10.1038/nature18307, 2016, pg. 1

[184] Herr, D., E. Pidgeon, and D. Laffoley (eds.) "Blue Carbon Policy Framework: Based on the discussion of the International Blue Carbon Policy Working Group." Gland, Switzerland: International Union for Conservation of Nature and Arlington, Virginia: Conservation International,2012, pg.17

[185] Herr D., E. Landis, "Coastal blue carbon ecosystems Opportunities for Nationally Determined Contributions." United Nations Environment Programme (UNEP), 2016, Policy brief. Pg.11

[186] Herr D., E. Landis, "Coastal blue carbon ecosystems Opportunities for Nationally Determined Contributions." United Nations Environment Programme (UNEP), 2016, Policy brief. Pg.11-13

[187] Herr D., E. Landis, "Coastal blue carbon ecosystems Opportunities for Nationally Determined Contributions." United Nations Environment Programme (UNEP), 2016, Policy brief. Pg.13

The potential contributions of BC to Small Island States

Macreadie P.I. et al states that SIDS are estimated to have BCEs covering 36–185 million ha.,[188] but these estimates may be conservative due to the difficulty in mapping small habitat patches using global satellite datasets. Various aboveground biomass and soil carbon models calculate national-level blue carbon stocks, indicating that collectively, SIDS hold 1806–2892 Tg of BC.[189] An approach originally adopted by Taillardat et al.[190] to estimate the carbon sequestration of existing mangrove forests in a country, emissions from deforestation, and the potential sequestration foregone by deforested mangroves was used by Friess 2023, to estimate the potential climate change mitigation benefits from mangrove carbon sequestration in SIDS. The approach use (which can be shown in Table 2 and 3) "Offsetting potential was estimated for 1) stable mangroves (the carbon sequestration of existing mangrove forests in a country); 2) avoided deforestation (emissions from deforestation and potential sequestration foregone by deforested mangroves only); and 3) the net balance of sequestration and emissions (the carbon sequestration of existing mangrove forests in a country, minus any emissions from deforestation and sequestration potential foregone by deforested mangroves)." [191]

[188] Macreadie P.I. et al., "Blue carbon as a natural climate solution", *Nat Rev Earth Environ*, **2**:826-839., 2021, Pg.20

[189] Friess D., "The potential for mangrove and seagrass blue carbon in Small Island States, Current Opinion in Environmental Sustainability", Volume 64,2023,101324, ISSN 1877 3435, https://doi.org/10.1016/j.cosust.2023.101324.n Retrieved from: (https://www.sciencedirect.com/science/article/pii/S1877343523000714),2023, pg.2

[190] Taillardat P, Friess DA, Lupascu M "Mangrove blue carbon strategies for climate change mitigation are most effective at the national scale" Biol Lett., 14:20180251.,2018, Pg.2

[191] Friess D., "The potential for mangrove and seagrass blue carbon in Small Island States, Current Opinion in Environmental Sustainability", Volume 64,2023,101324, ISSN 1877 3435, https://doi.org/10.1016/j.cosust.2023.101324.n Retrieved from: (https://www.sciencedirect.com/science/article/pii/S1877343523000714),2023, pg.3

Table 1

Offsetting potential for (a) carbon sequestration for existing mangroves; (b) potential avoided deforestation offsetting; and (c) net balance of mangroves against AFOLU.

Countries	E_{AFOLU} in 2019 (TgC yr^{-1})[a]	(a) Existing mangrove contribution			(b) Avoided deforestation contribution					(c) Net balance contribution	
		Surface area in 2019 (km^2)[b]	$S_{mangrove}$ in 2019 (TgC yr^{-1})[c]	Potential of stable mangroves to offset AFOLU emissions (%)	Mangrove change 2019–2020 (km^2 yr^{-1})[b]	$E_{mangrove}$ 2019–2020 (TgC yr^{-1})[d]	$S_{mangrove\_foregone}$ (TgC yr^{-1})[c]	$E_{mangrove}$ + $S_{mangrove\_foregone}$ (TgC yr^{-1})	Potential of avoided deforestation to offset AFOLU emissions (%)	$S_{mangrove}$ - ($E_{mangrove}$ + $S_{mangrove\_foregone}$) (TgC yr^{-1})	Mangrove potential to offset AFOLU emissions (%)
Antigua and Barbuda	0.006	8.77	0.001	24.0	-0.08	0.005	< 0.001	0.005	85.9	-0.004	-61.7
Bahamas*	0.004	1517.49	0.255	5897.2	23.72	-1.861	n/a	-1.861	-43048.1	2.116	48945.3
Barbados	0.013	0.1	< 0.001	0.1	0.01	-0.001	n/a	-0.001	-7.0	0.001	7.1
Belize	0.096	530.43	0.089	93.2	-1.74	0.085	< 0.001	0.085	88.8	0.004	4.4
Comoros	0.055	0.98	< 0.001	0.3	-0.01	< 0.001	< 0.001	0.001	1.7	-0.001	-1.4
Cook Islands	0.002	0.03	< 0.001	0.3	0.00	0.000	0.000	0.000	0.0	< 0.001	0.3
Cuba	3.532	3599.72	0.605	17.1	-2.78	0.203	< 0.001	0.203	5.7	0.402	11.4
Dominica	0.010	0.01	< 0.001	0.0	0.00	0.000	0.000	0.000	0.0	< 0.001	0.0
Dominican Republic	2.762	191.47	0.032	1.2	0.37	-0.022	n/a	-0.022	-0.8	0.054	2.0
Federated States of Micronesia	0.012	88.18	0.015	120.8	-0.24	0.006	< 0.001	0.007	53.1	0.008	67.8
Fiji	0.104	488.71	0.082	79.3	-0.57	0.025	< 0.001	0.025	24.0	0.057	55.4
Grenada	0.004	1.93	< 0.001	7.9	0.00	0.000	0.000	0.000	0.0	< 0.001	7.9
Guinea Bissau	0.493	2707.08	0.455	92.2	-18.76	0.985	0.003	0.988	200.4	-0.533	-108.1
Guyana	0.763	290.42	0.049	6.4	-1.83	0.114	< 0.001	0.114	15.0	-0.066	-8.6
Haiti	1.180	154.17	0.026	2.2	-0.16	0.011	< 0.001	0.011	0.9	0.015	1.3
Jamaica	0.146	99.42	0.017	11.4	0.03	-0.002	n/a	-0.002	-1.3	0.019	12.7
Kiribati	0.002	1.46	< 0.001	12.2	0.00	0.000	0.000	0.000	0.0	< 0.001	12.2
Maldives	< 0.001	0.97	< 0.001	172.0	0.00	0.000	0.000	0.000	0.0	< 0.001	172.0
Mauritius	0.031	4.27	< 0.001	2.3	0.05	0.000	n/a	0.000	-1.0	0.001	3.4
Papua New Guinea	0.199	4535.62	0.762	382.8	-10.88	0.830	0.002	0.832	418.1	-0.070	-35.3
Saint Kitts and Nevis	0.002	0.34	< 0.001	2.3	0.01	-0.001	n/a	-0.001	-40.4	0.001	42.7
Saint Lucia	0.011	1.63	< 0.001	2.6	-0.01	0.001	< 0.001	0.001	6.8	< 0.001	-4.2
Saint Vincent and the Grenadines	0.004	0.32	< 0.001	1.2	0.01	0.000	n/a	0.000	-11.0	0.001	12.2
Samoa	0.051	2.31	< 0.001	0.8	0.01	0.000	n/a	0.000	-0.3	0.001	1.0
Sao Tome and Principe	0.004	0.48	< 0.001	1.8	0.00	0.000	0.000	0.000	0.0	< 0.001	1.8
Seychelles	0.001	3.83	0.001	74.3	0.00	0.000	0.000	0.000	0.0	0.001	74.3
Singapore	0.005	7.3	0.001	24.3	0.00	0.000	0.000	0.000	0.0	0.001	24.3
Solomon Islands	0.020	527.5	0.089	433.5	-0.99	0.087	< 0.001	0.088	428.1	0.001	5.4
Suriname	0.168	808.3	0.136	80.8	-7.86	0.404	0.001	0.405	241.1	-0.269	-160.3
Timor Leste	0.266	10.52	0.002	0.7	-0.02	0.002	< 0.001	0.002	0.6	< 0.001	0.1
Tonga	0.0213	10.58	0.002	8.3	-0.15	0.001	< 0.001	0.001	6.5	< 0.001	1.8
Trinidad and Tobago	0.062	83.45	0.014	22.6	-1.22	0.066	< 0.001	0.066	106.2	-0.052	-83.6
Tuvalu	0.001	0.09	< 0.001	1.9	0.00	0.000	0.000	0.000	0.0	< 0.001	1.9
Vanuatu	0.127	16.35	0.003	2.1	-0.51	0.045	< 0.001	0.045	35.5	-0.042	-33.4

The net carbon balance of mangroves is estimated for stable mangroves by calculating the carbon sequestration of existing mangroves ($S_{mangrove}$) versus emissions from mangrove loss ($E_{mangrove}$) and foregone carbon sequestration opportunity ($S_{mangrove\_foregone}$).

[a] Minx et al. [41].

[b] Bunting et al. [34].

[c] Using an average sequestration value estimated by Taillardart et al. [2];

[d] Based on estimates of national carbon stocks provided by Macreadie et. al [5]; Note that Cabo Verde, Nauru, Niue, Palau and the Republic of the Marshall Islands are not included in this analysis due to no presence of mangroves, or insufficient data on mangrove extent or AFOLU emissions.

* Values for the Bahamas are high due to low reported E_{AFOLU} and a large reported increase in mangrove extent.

Table 2 and 3: Showcasing the offsetting potential for SIDS estimate the potential climate change mitigation benefits from mangrove carbon sequestration.[192]

The general emissions were then compared with the emissions from the countries mangrove deforestation, which falls under the UNFCCC's land use category of Agriculture, Forestry and Other Land Uses (AFOLU) and the estimation was based on the availability of continuous global data on mangrove area change. [191] In the Friess 2023 analysis, it shows that in 2020, mangrove sequestration in sixteen countries offset more than 10% of AFOLU emissions. While in some countries with low AFOLU emissions, such as the Federated States of Micronesia, Seychelles, and Singapore, as well as countries with relatively large mangrove areas like Belize, Cuba, and Papua New Guinea, reported significant offsetting potential. Possibilities of avoided deforestation strategies may have contributed to 11 countries to offset more than 10% of their AFOLU emissions in 2020. On the other hand, countries with high rates of mangrove deforestation, such as Guinea Bissau and Papua New Guinea, had the greatest offset potential and countries with negligible offset potentials for avoided deforestation, such as Cook Islands, Kiribati, Maldives, Singapore, and Tuvalu, were experiencing little to no mangrove deforestation. 8 SIDS, including Bahamas, Barbados, the Dominican Republic, Jamaica, Mauritius, Saint Kitts and Nevis, Saint Vincent and the Grenadines, and Samoa, had a negative offsetting potential for avoided deforestation due to an expansion in mangrove area between 2019 and 2020. 11 other countries had mangrove carbon balances already in place that could compensate for 1% to 10% of their national AFOLU emissions, while 3 countries had a minimal potential for compensation, ranging from 0% to 1%. 9 countries (Antigua and Barbuda, Comoros, Guinea Bissau, Guyana, Papua New Guinea, Saint Lucia, Suriname, Trinidad and Tobago, and Vanuatu) showed a negative potential for compensation, indicating that their mangroves emitted more than they sequestered in 2020. Friess 2023 states that these countries present a significant opportunity for climate change mitigation and suggests that if deforestation can be halted the remaining mangroves could still contribute to offsetting AFOLU emissions.[191] The decrease of wetland degradation can be done to achieve reduce emissions, but emphasis must be made that this potential only applies to areas suitable for restoration from a biophysical

[192] Friess D., "The potential for mangrove and seagrass blue carbon in Small Island States, Current Opinion in Environmental Sustainability", Volume 64,2023,101324, ISSN 1877 3435, https://doi.org/10.1016/j.cosust.2023.101324.n Retrieved from: (https://www.sciencedirect.com/science/article/pii/S1877343523000714),2023, pg.4-5

perspective and does not account for the various socioeconomic and governance factors that will significantly limit the feasible restoration area.[193] Some mangrove forests can take up to 40 years to reach maturity and achieving these carbon stock values will also require substantial time[194] while soil carbon stocks are expected to take even longer.[195] In an analysis done by Bourgeois C. et al, 40-year-old planted mangroves reached 75% on carbon stocks in planted mangrove forests.[196] Unfortunately, there are currently no global estimates of restoration potential and sequestration rates for seagrasses or tidal marshes.

Table 2

A non-exhaustive summary of current plans and actions around blue carbon for climate change mitigation in Small Island States, based on the publicly available information (See Table S1 for full information and references).

Country	Summary of blue carbon plans and actions	Quantitative targets?	Integrated into National GHG Inventory?
Antigua and Barbuda	Mangrove and seagrass conservation	✓	X
Bahamas	Mangrove conservation and restoration, considering blue carbon credits	X	X
Barbados	No identifiable blue carbon actions can be found	X	X
Belize	Mangrove conservation and restoration, including calculation of blue carbon benefits, considering blue carbon credits	✓	**Commitment for next NDC**
Cabo Verde	Seagrass conservation	X	X
Comoros	No identifiable blue carbon actions can be found	X	X
Cook Islands	No identifiable blue carbon actions can be found	X	X
Cuba	No identifiable blue carbon actions can be found	X	X
Dominica	No identifiable blue carbon actions can be found	X	X
Dominican Republic	Mangrove conservation and restoration	X	X
Federated States of Micronesia	No identifiable blue carbon actions can be found	X	X
Fiji	Mangrove and seagrass conservation and restoration	X	X
Grenada	Mangrove and seagrass conservation	X	X
Guinea Bissau	Mangroves in National Greenhouse Gas Inventory	X	✓
Guyana	Mangrove conservation and restoration	X	X
Haiti	Mangrove conservation and restoration	✓	X
Jamaica	Mangrove restoration project established	X	X
Kiribati	Mangrove and seagrass conservation and restoration	✓	✓
Maldives	No identifiable blue carbon actions can be found	X	X
Mauritius	Mangrove and seagrass restoration	X	X
Nauru	No identifiable blue carbon actions can be found	X	X
Niue	No identifiable blue carbon actions can be found	X	X
Palau	Offsetting emissions using blue carbon	X	X
Papua New Guinea	Committed to incorporating blue carbon into the National Greenhouse Gas Inventory	X	**Commitment** for **next NDC**
Republic of the Marshall Islands	No identifiable blue carbon actions can be found	X	X
Saint Kitts and Nevis	No identifiable blue carbon actions can be found	X	X
Saint Lucia	Conducting a blue carbon stock assessment	X	X
Saint Vincent and the Grenadines	No identifiable blue carbon actions can be found	X	X
Samoa	Mangrove restoration	✓	X
Sao Tome and Principe	No identifiable blue carbon actions can be found	X	X
Seychelles	Mangrove and seagrass conservation	✓	X
Singapore	Mangroves incorporated into the National Greenhouse Gas Inventory	X	✓
Solomon Islands	Mangrove conservation	X	X
Suriname	Mangroves in Forest Reference Emissions Level	✓	✓
Timor Leste	Mangrove restoration	X	X
Tonga	Mangroves may have been incorporated into the National Greenhouse Gas Inventory	X	X
Trinidad and Tobago	Mangroves incorporated into the National Greenhouse Gas Inventory	✓	✓
Tuvalu	No identifiable blue carbon actions can be found	X	X

Table 4: shows summary of current plans and actions around blue carbon for climate change mitigation in Small Island States [197]

Existing BC actions in SIDS present a mixed outlook for climate change mitigation as seen in the analysis in Friess et al. 2023 and most of these actions communicated through a nation's NDC to the Paris Agreement,[198] along with associated NAMAs and National Greenhouse Gas

[193] Zeng, Y., et al, "Economic and social constraints on reforestation for climate mitigation in Southeast Asia". Nat. Clim. Chang. **10**, 842–844 https://doi.org/10.1038/s41558-020-0856-3, 2020, pg.1

[194] Sillanpää M, Vantellingen J, Friess D.A. "Vegetation regeneration in a sustainably harvested mangrove forest in West Papua, Indonesia." Ecol Manag*,* 390:137-146.,2017, Pg.9

[195] Wang G et al., "The potential of mature Sonneratia apetala plantations to enhance carbon stocks in the Zhanjiang Mangrove National Nature Reserve." Ecol Indic, **133**:108415., 2021, Pg.1

[196] Bourgeois C. et al. "Four decades of data indicate that planted mangroves stored up to 75% of the carbon stocks found in intact mature stands" , Sci. Adv. 10, eadk5430,2024, pg.6

[197] Friess D., "The potential for mangrove and seagrass blue carbon in Small Island States, Current Opinion in Environmental Sustainability", Volume 64,2023,101324, ISSN 1877 3435, https://doi.org/10.1016/j.cosust.2023.101324.n Retrieved from: (https://www.sciencedirect.com/science/article/pii/S1877343523000714),2023, pg.6

[198] Vanderklift M.A. et al "A guide to international climate mitigation policy and finance frameworks relevant to the protection and restoration of blue carbon ecosystems." Front Mar Sci, **9**:872064., 2022, Pg.4

Inventories. As previously mentioned, only 23% of SIDS have specific and measurable BC targets in their NDCs, and just 4 countries (Guinea-Bissau, Kiribati, Suriname, Trinidad and Tobago) have explicitly included BC in their National Greenhouse Gas Inventories or Forest Reference Emissions Levels. 41% of SIDS mention BC or express goals without quantitative targets. Despite this, it shows that SIDS are understanding the role BCEs play in mitigating climate change and how necessary it is to have measurable targets that showcases the impact of BC management and to provide incentives when integrating BC into national policies. 36% of SIDS did not have identifiable plans or actions related to BC but majority of these countries did reference BCEs in their NDCs under climate change adaptation.[199]

Section B – Challenges When Developing a Blue Carbon Projects

Since the 19th century, wetlands have seen a drastic decline in size mostly for agriculture purposes. Not much knowledge was known about their importance to coastal communities and the vibrant ecosystems they contain. Due to the lack knowledge and understanding of their importance, these wetlands are threatened by rising sea levels, coastal erosion, climate change and acidification. A few restoration projects helped maintained their numbers in some areas but still saw a decline in the post 2000 and it is crucial to work towards restoring these ecosystems and halt their decline. [200]

1. Threats to Wetland Ecosystem

- **Climate Change**

The average global sea level is expected to keep rising throughout the 21st century, with almost 20% anticipated regional sea level increase along about two-thirds of the world's coastlines. By 2100, the global mean sea level rise could reach levels above the likely range of nearly 2 meters, and it may exceed 15 meters by the year 2300.[201] Example of this can be mostly found in the

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[199] Friess D., “The potential for mangrove and seagrass blue carbon in Smalv l Island States, Current Opinion in Environmental Sustainability”, Volume 64,2023,101324, ISSN 1877 3435, https://doi.org/10.1016/j.cosust.2023.101324.n Retrieved from: (https://www.sciencedirect.com/science/article/pii/S1877343523000714),2023, pg.7

[200] Li X., et al., “Coastal wetland loss, consequences, and challenges for restoration”, https://doi.org/10.1139/anc-2017-0001,2018, pg.1-2

[201] IPCC, “2023: Sections. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change”, Core Writing Team, H. Lee and J. Romero (eds.). IPCC, Geneva, Switzerland, pp. 35-115, doi: 10.59327/IPCC/AR6-9789291691647,2023, pg.43

Pacific Island SIDS where a spatial analysis from 1961-2003 has demonstrated the seaward edge retreat of mangroves in American Samoa due to relative sea level rise and long-term mangrove zone retreat landward has been observed in the tectonically subsiding coastlines of Southwest Papua and Tikina Wai, Fiji. Additionally, Micronesian mangrove substrates cannot catch up to increase sea level rise.[202]

- **Storms and harsh cyclones**

The IPCC Forth Assessment report 2007, anticipated that there will likely be an escalation in peak wind intensities of tropical cyclones and an increase in mean and peak precipitation intensities in certain regions due to global climate change and [203] also projected that storm surge heights will rise if there is an increase in the occurrence of strong winds and low pressures and due to climate change can become more frequent or severe due climate change.[204] The Caribbean countries and foreign territories were severely impacted by Hurricanes Irma and Maria which caused extensive damage to Barbuda, from September 5 to 9, 2017.[205] Hurricane Irma seriously damaged or destroyed approximately 95%[206] of the structures on Barbuda, while the mainland island of Antigua was mostly unaffected.[98] An estimated 1,400 residents of Barbuda were completely evacuated, with most seeking shelter on Antigua. The governor general of Antigua and Barbuda has approximated that the rebuilding of Barbuda could cost around $300 million.[207]

- **Temperature**

The global surface temperature was at 0.99 °C during the period of 1850–1900. Since 1970, the rate of increase in global surface temperature has been more rapid than during any other 50-year

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[202] Ellison J., "Effects of Climate Change on Mangroves Relevant to the Pacific Islands", Pacific Marine Climate Change Report Card, Science Review *2018: pp 99-111,* 2018, pg. 8

[203] Solomon, S., et.al., Miller, H.L. (Eds.), "Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change." Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.,2007, Pg.915

[204] Solomon, S., et.al., Miller, H.L. (Eds.), "Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change." Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.,2007, Pg.916

[205] Sullivan M.P., "Hurricanes Irma and Maria: Impact on Caribbean Countries and Foreign Territories" Retrieved from: https://apps.dtic.mil/sti/citations/trecms/AD1172110, Library of Congress Washington DC,2017, pg.1

[206] deGrandpre A., BeverL., "The tiny islands ravaged by Irma are in trouble as Hurricane Jose looms" The Washington Post, 2017, Retrieved from: https://www.washingtonpost.com/news/worldviews/wp/2017/09/07/the-tiny-islands-ravaged-by-hurricane-irma-are-in-trouble-and-begging-for-help/

[207] Freidman L., "Islands Seek International Funding for Hurricane Recovery", 2017, Retrieved from: https://www.nytimes.com/2017/09/19/climate/united-nations-caribbean-hurricane-relief-money.html?mcubz=0

stretch in at least the past 2000 years. The likely range for the overall rise in global surface temperature attributed to human activities from 1850–1900 to 2010–2019 is between 0.8°C and 1.3°C, with an optimal estimate of 1.07°C.[208]

- **Development**

Since the early 1900s, it appears that the rate of deforestation has decreased from over 2 percent annually to a still significant 0.4%. The majority of current emissions stem from Southeast Asia, although areas of intense deforestation can be found in Latin America and Africa [209] There is a natural process in mangrove ecosystems that causes both loss through erosion and gain through sedimentation. However, due to human activities such as deforestation, mining and agriculture, these processes are heightened.[210] Policies aimed to protect coastal wetlands are very important in preventing their loss and through these policies, governments can establish rules and objectives to protect natural resources from developing activities. However, economic development policies often conflict with environmental goals which leads to competition among various stakeholders. The complexity of decision-making in this governance structure is evident as multiple actors with different interests competing for access to and use of natural resources.[211]

2. **Challenges for blue carbon implementation in Small Island Developing States**

Successful examples of managing and setting targets for BC in SIDS exists, countries still find it a challenge to bridge the gap between BC potential and implementation. BC strategies have obstacles related to the environment, economy, and governance, such as securing funding, access to land, and community involvement,[212] causing a hindrance in their global application.

Aside from these general limitations, SIDS are likely to face specific barriers due to their distinct environmental, socioeconomic, and political contexts. These limitations concise of:

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[208] IPCC, "2023: Sections. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change" [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 35-115, doi: 10.59327/IPCC/AR6-9789291691647,2023, pg.8

[209] World Bank, "Unlocking Blue Carbon Development: Investment Readiness Framework for Governments", Washington, D.C.: World Bank.,2023, pg.24

[210] Bunting et al. "Global Mangrove Extent Change 1996–2020: Global Mangrove Watch Version 3.0. Remote Sens", 14, 3657. https://doi.org/10.3390/rs141536572 , 2022, pg.22

[211] Friess, D.A. et al., "Policy challenges and approaches for the conservation of mangrove forests in Southeast Asia." Conserv. Biol. 30 (5), 933–949. http://dx.doi. org/10.1111/cobi.12784.,2016, pg.1

[212] Macreadie P.I. et al, "Operationalizing marketable blue carbon", One Earth, Volume 5, Issue 5, Pages 485-492, ISSN 2590-3322, https://doi.org/10.1016/j.oneear.2022.04.005,2022, pg.2

- **Limited baseline data and information.**

Baseline data to quantify BC contributions is important and needed to integrate into National Greenhouse Gas Inventories. Some studies have provided data on national BC stocks for countries like Belize[213] and the Bahamas[214] but baseline data on carbon stocks needs to also be the focus of research. Nevertheless, the absence of this information should not exclude BC from NDCs and national GHG inventories.

- **Limited scientific and policy capacity.**

Many NDCs proposed actions require external technical expertise as well as local expertise to meet the targets and goals. Stakeholders indicate that those lacking relevant expertise might find it challenging to meet the stringent accounting requirements of BC strategies.[215]

- **Integrating Seagrass and Salt Marshes into Plans and Actions.**

Current knowledge about BC predominantly revolves around mangrove forests[216], and only about 21% of SIDS have mentioned seagrasses in their BC plans and actions.[217] The uneven attention given to mangroves partly stems from more readily available research within mangrove ecosystems.[218] There is also a misconception that seagrasses and tidal marshes are harder to include in national greenhouse gas inventories as mangroves can be categorized within the Forests category, as seen in the NDCs of SIDS such as Singapore and Suriname.[219]

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[213] Arkema K.K. et al., "Evidence- based target setting informs blue carbon strategies for nationally determined contributions." Nat Ecol. Evol., **7**:1045-1059.,2023, Pg.2

[214] Blume A. et al., "Seagrass extent and blue carbon accounting using earth observation." Front Mar Sci, **10**:1058460, 2023, Pg.1

[215] Strong A.L., Ardoin N.M. "Barriers to incorporating ecosystem services in coastal conservation practice: the case of blue carbon." Ecol Soc, 26:40, 2021, Pg.1

[216] de Paula Costa MD, Macreadie P.I., "The evolution of blue carbon science." Wetlands, 42:109. A summary of blue carbon science and its trajectory,2022, pg. 1

[217] Friess D., "The potential for mangrove and seagrass blue carbon in Small Island States, Current Opinion in Environmental Sustainability", Volume 64,2023,101324, ISSN 1877 3435, https://doi.org/10.1016/j.cosust.2023.101324.n Retrieved from: (https://www.sciencedirect.com/science/article/pii/S1877343523000714),2023, pg.6

[218] Duarte C.M. et al., "The charisma of coastal ecosystems: addressing the imbalance." Estuaries Coasts, 31:233-238.,2008, pg.1

[219] Friess D., "The potential for mangrove and seagrass blue carbon in Small Island States, Current Opinion in Environmental Sustainability", Volume 64,2023,101324, ISSN 1877 3435, https://doi.org/10.1016/j.cosust.2023.101324.n Retrieved from: (https://www.sciencedirect.com/science/article/pii/S1877343523000714),2023, pg.8

However, according to the IPCCs Wetland Supplement 2013, seagrasses are included in three of nine CO_2 emissions and removal activities[220] and can thus be included in GHG inventories.

- **Limited understanding of calcium carbonate geochemistry.**

The carbon emissions from geochemical processes in karstic systems can sometimes surpass the rates of BC sequestration.[221] Additionally, the presence of calcifying algae in certain seagrass systems may contribute to these emissions.[222] Inorganic carbon is overlooked in BC accounting methods and including them can be very important for future global research especially for SIDS with karstic geologies.

- **Lack of Funding**

Many NDCs stated that proposed BC actions require a range of funding sources. This is particularly an issue because BCPs can be substantially more expensive than equivalent projects in terrestrial ecosystems.[223] Some BCPs in SIDS have been funded by development loans, such as a 1600 ha mangrove restoration project in Jamaica supported by the Inter- American Development Bank.[224] Financial instruments such as Blue Bonds have been launched or proposed for several SIDS, however it has some criticism for unclear metrics of impact and poor transparency.[225] Therefore, multiple funding sources exist, and SIDS may ultimately require a blended finance approach to incorporate multiple public and private funding streams. For example, the governments of Fiji, Papua New Guinea, and Seychelles are members of the International Partnership for Blue Carbon, alongside intergovernmental organizations such as the Pacific Island Development Forum and the Pacific Islands Forum Secretariat.[226]

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[220] IPCC, "2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands." Intergov. Panel Clim Change. The Intergovernmental Panel on Climate Change,2013, Pg.277

[221] Van Dam B.R.et al., "Calcification-driven CO_2 emissions exceed "Blue Carbon" sequestration in a carbonate seagrass meadow." Sci Adv., 7:eabj1372.,2021, Pg.1

[222] Raven J., "Blue carbon: past, present and future, with emphasis on macroalgae." Biol. Lett., 14:20180336.,2018, Pg.1

[223] Bayraktarov E., et al., "The cost and feasibility of marine coastal restoration." Ecol. Appl., 26:1055-1074.,2016, pg.13

[224] IADB, "JA-T1169: Blue carbon restoration in southern Clarendon." Jamaica. Inter-American Development Bank, 2020, Retrieved from ⟨https://www.iadb.org/en/project/JA-T1169⟩.

[225] Thompson B.S., "Blue bonds for marine conservation and a sustainable ocean economy: status, trends, and insights from green bonds." Mar Policy, 144:105219.,2022, Pg.6

[226] Friess D., "The potential for mangrove and seagrass blue carbon in Small Island States, Current Opinion in Environmental Sustainability", Volume 64,2023,101324, ISSN 1877 3435, https://doi.org/10.1016/j.cosust.2023.101324.n Retrieved from: (https://www.sciencedirect.com/science/article/pii/S1877343523000714),2023, pg.8-9

3. **Consequences of coastal wetland loss**

Lossing wetland area can result in reducing or eliminating the ecological benefits and services these ecosystems provide. The land remaining would only be beneficial for aquaculture practices and other land use activities. [227] Other land use from reduction wetland areas will lead to serious alterations and will result in damages such as flooding.[228] Biodiversity will also be heavily effected and can lead to deteriorating important coastal ecosystem functions such as fishing, purification and detoxification processes (which can affect the water quality and increase harmful algal blooms) and the loss of a vital nursery ground for marine and bird species.

4. Challenges for coastal wetland restoration

There are still knowledge gaps in the successful restoration of coastal wetlands. The areas where coastal wetlands can form are complex, ranging from high tidal zones to lowlands, lagoons, and tidal creeks. These areas are constantly changing due to human activities and natural processes, and there is not enough real-time monitoring for important processes like water and sediment redistribution, subsidence, and ecosystem dynamics[229] When restoring vegetation in the tidal zone, it's important to consider how the ecosystem will interact with the physical environment. Different species will redistribute and attenuate waves and sediments in varied ways based on their density and biomass, impacting landforms and subsequently affecting vegetation diversity and distribution.[230] There is limited information on the bio-morphological interaction mechanism of these specific sites within the wetlands, such as tidal ranges, wave energy, salinity gradients, suspended sediment contents, morphological conditions, and species structure.

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[227] Li X., et al., "Coastal wetland loss, consequences, and challenges for restoration", Springer Nature,2018, pg.6

[228] Worm, B. et al., "Impacts of biodiversity loss on ocean ecosystem services." Science, 314: 787–790. doi: 10.1126/science.1132294. PMID: 17082450.,2006, Yang, S.L., "The role of Scirpus marsh in attenuation of hydrodynamics and retention of fine-grained sediment in the Yangtze Estuary." Estuar. Coast. Shelf Sci. 47: 227–233. doi: 10.1006/ecss.1998.0348.,2006,1998, pg.1

[229] Giosan L. et al., "Climate change: protect the world's deltas." Nature, 516(7529): 31–33. doi: 10.1038/516031a. PMID: 25471866 ,2014, pg.2

[230] Leonard L.A., and Croft A.L., "The effect of standing biomass on flow velocity and turbulence in Spartina alterniflora canopies." Estuar. Coast. Shelf Sci. 69: 325–336. doi: 10.1016/j.ecss.2006.05.004., 2006, pg.12

Conclusion

Throughout this research it shows that Blue Carbon can still be considered an emerging concept in the world of adaptation and mitigation and requires more in depth and thorough research to achieve its possibilities. Nonetheless, there are numerous actions being done to make so that it can be implemented and become a very useful tool to alleviate the impacts of climate change. Impacts of climate change grow stronger and stronger every year and new events such as increased and stronger hurricanes and cyclones appearing earlier within the season are occurring, droughts are experiencing longer periods and global temperature is rising expeditiously This thesis purpose is to act as a guideline for SIDS and how we can aim to help improve our environment and in the long run our livelihood and future as many SIDS depend heavily on support and aid from developed countries. Documenting best practices from countries who have successfully created both operations and have found a harmonious balance between their ocean space with a blue economy and improving their BCEs is what can be the best option for SIDS to incorporate and replicate these actions. When looking at the relations between Blue Carbon and Blue Economy, both concepts aim to find a balance within the ocean space, create opportunities for climate change adaptation and mitigation and contribute to the country's GDP. However, they both present challenges of gaps in policies, lack of stakeholder engagements, and an overall push for their agendas. It is evident that some of these problems lie within the political system of the countries. Many of the challenges found within these concepts stems from the lack of support from the countries decision makers who have the final say on whether both these concepts are implemented and are made a high priority. But the question that needs to be addressed is what is the priority for these SIDS?

Many SIDS main industries are tourism and make up most of their GDP and the ocean has been a major player in boosting the country's economy and providing for the necessities for its people,[231] but this comes with a price of development which is one of the major threats to SIDS. BCE are the most threatened ecosystems.[232] It is estimated that the annual release of CO_2 from

[231] Sun et al. "Tourism in Small Island Developing States" Retrieved from: https://ssrn.com/abstract=4634270 or http://dx.doi.org/10.2139/ssrn.4634270, 2019, pg.1

[232] Steven, A. D. L., Vanderklift, M. A., & Bohler-Muller, N., "A new narrative for the Blue Economy and Blue Carbon" Journal of the Indian Ocean Region, 15(2), 123–128. https://doi.org/10.1080/19480881.2019.1625215, 2019, pg.4

degraded or lost wetlands is equal to the yearly emissions of the United Kingdom.[233] As it is shown, losing these ecosystems also poses significant risks of serious flooding and coastal erosion, thereby increasing the vulnerability of millions of people living along the world's coastlines. Therefore, it is crucial and urgent that we safeguard and rehabilitate the world's BCEs.

Over time, shifts in political leadership resulted in a decrease in backing for the blue economy as a top national priority, which in turn undermined government processes as a whole and strengthened the perception that the blue economy was advancing an international agenda and encroaching upon existing ministerial responsibilities. The relocation of the blue economy portfolio to various ministries additionally eroded its significance as a national policy framework and the credibility of structures and processes for coordination. Strengthening policies and enforcement for wetland protection is also very crucial for implementation within SIDS. States who have policies, legislations and regulations surrounding the protection, conservation and preservation of their wetlands give them a fighting chance in not only safeguarding their coastal environment but present many opportunities to create sustainable projects within the space. Since much development takes place in and near wetlands, first policies regarding coastal management need to be considered when development projects are about to be conducted. However, wetlands are overseen within development mitigation plans and therefore efforts to either protect them or even restore them are very limited. An approach to this is creating Nature-based Solutions which aims tackle societal issues by implementing actions aimed at safeguarding, sustainably managing, and restoring both natural and altered ecosystems, which in turn provide benefits for both people and nature simultaneously.   Some examples of some countries NbS policies referenced in their enhanced NDCS can be found in Cuba's State Plan to Confront Climate Change "Tarea Vida" (2017) which they state to "Including measures for coastal protection of cities, integral recovery of beaches, mangroves and other natural protective ecosystems, hydraulic and coastal engineering works, among others." Belize's Forests (Protection of Mangroves) Regulations (2018) to "Established a permitting system that aims to safeguard mangroves and their many ecosystem services from deforestation and degradation." The

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233 Pendleton L. et al., "Estimating Global "Blue Carbon" Emissions from Conversion and Degradation of Vegetated Coastal Ecosystems." PloS one 7(9). Retrieved from: http://dx.doi.org/10.1371/journal. pone.0043542, 2012, pg.4-5

Bahamas Master Plan for The Bahamas National Protected Area System (2012) states that "Through this Master Plan the Government of The Bahamas has identified targets for expanding protected areas for terrestrial and marine ecosystems in order to meet its obligations under the Convention on Biological Diversity (CBD)." [234]

Recommendations

Further Recommendations for implementing Blue Carbon

Some suggestions to implement effective strategies to further the development of BC and the role it plays in climate change mitigations and adaptation and future BCP.

1. Local Community Engagement

Throughout this thesis, a common challenge between both blue economy and BC is local engagement of community members. In most SIDS, the community is the one to have the most knowledge about the area they reside and/or work in and creating a space and a platform for them to actively be involved in decision making, plans and development and overall policies and legislations and allowing them to voice their opinions and expertise should be pushed and to prevent any injustice. Local engagement during the development of a blue economy has been ignored in the past and incorporating their knowledge will be a step forward towards transformative change and promote social equity and opportunities. However, the approach, methodologies and process of engagement of locals is still recognised as a challenge. But there are chances to align incentives from BC credits with other benefits like sustainable tourism ventures and improve ecosystem delivery, allowing local communities to benefit from BC development, either as partial beneficiaries or through predetermined commitments to enhance the livelihoods of local communities which can be done through education, employment opportunities, or infrastructure development).

2. Valuing Blue Carbon Stocks

[234] Gautreau S., Correa V. "Blue Economies and Nature-based Solutions for Enhanced Climate Action in Latin America and Caribbean Small Island Developing States", UNDP, 2023, pg.39

Little is known about the science behind carbon stocks and limited information on it's potential for managing or accounting for carbon sequestration from soil or plant carbon. A carbon inventory is crucially needed to further the valuation and operationalization of BC resources.

3. Centralized Accounting Institution or Organisation

There are no international recognized institutions for carbon accounting. It is important to have a standardized assessment of these resources as it can be beneficial for calculating a nation's carbon inventory to contribute to NDCs and carbon offsets, potentially aiding in the decarbonization of industries. Having an internationally recognized institution could enhance the credibility of estimates through their reputation and scientific methodologies as well as providing ground truthing for accurate verification of BC estimates. This institution can offer quality assurance to stakeholders and is crucial for the implementation of BCPs. Additionally, a single centralized organization using standardized accounting methodologies for a nation's BC assessments promotes consistency and simplifies the valuation of different BC systems within the nation.

4. Continuous Monitoring of Blue Carbon Systems

Continuously monitoring of the distribution of BCEs and the associated carbon fluxes over the long term is highly important. Reliable and trustworthy monitoring is essential to make informed decisions regarding carbon offsets and NDC contributions.

5. Operationalizing Blue Carbon

There are various challenges and uncertainties when it comes to implementing BC from the social, governmental, financial, and technical and scientific aspects. However, from this research suggests and steps can be taken to promote the operationalization of BC. Having an equal and fair distribution of benefits, laws to help assist with the carbon trading system, continuous monitoring of BCEs and strong stakeholder engagement. Integrating these suggestions into transdisciplinary research and development can aid the creation of a functional market for BC and attracting investment opportunities. Consensus on principles and practices for fair benefits offers an overarching value proposition and an outlook for stakeholders engaged in BC programs.

With many projects, research and efforts done globally to reduce the effects of climate change and creating initiatives and projects to help countries who suffer from its impact. Using BC is a new concept to many SIDS and to understand it and its potentials requires a push and made a priority. It has the greatest potential and benefits in decreasing the ever-growing effects of climate change and a chance to relieve coastal countries of impacts that are currently detrimental to the environment, its people and future generations.

BIBLIOGRAPHY

Abdalla, S., Kairo, J., & Huxham, M. (2014). *2013-2014 Plan Vivo Annual Report: Mikoko Pamoja.*

Alongi, D. (2008). Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. *Estuarine, Coastal and Shelf Science 76*, 1-13.

Arkema et al. (2013). Coastal habitats shield people and property from sea-level rise and storms. *Nature Climate Change 3*, 913-918.

Arkema et al. (2023). Evidence- based target setting informs blue carbon strategies for nationally determined contributions. *Nat.Ecol.*, 1045-1059.

Arthur et al. (2007). Ecosystem engineering by annual intertidal seagrass beds: Sediment accretion and modification. *Estuarine, Coastal and Shelf Science*, 344-348.

Atwood et al. (2020). Global Patterns in Marine Sediment Carbon Stocks. *Frontiers in Marine Science*.

Baba, S., Chan, H., & Aksornkoae, S. (2013). Useful Products from Mangrove and Other Coastal Plants. In *ISME Mangrove Educational Book Series No.3.* Okinawa: Japan: International Society for Mangrove Ecosystems (ISME), and Yokohama, Japan: International Tropical Timber Organization (ITTO).

Bandaranayake, W. (1998). Traditional and medicinal uses of mangroves. *Mangrove and Salt Marshes 2*, 133-148.

Baumann, R., & Turner, R. (1990). Direct impacts of outer continental shelf activities on wetland loss in the central Gulf of Mexico. *Environmental Geology and Water Sciences*, 189-198.

Bavraktarov. (2016). The cost and feasibility of marine coastal restoration. *Ecol. Appl.*, 1055-1074.

Beer, L., Crooks, S., & Mak, M. (2019). *Setting the foundations for zero net loss of the mangroves that underpin human wellbeing in the North Brazil Shelf LME: Blue Carbon Feasibility Assessment.* Conservation International and Silvestrum Climate Associates.

Benzaken et al. (2022). Good governance for sustainable blue economy in small islands: Lessons learned from the Seychelles experience. *Frontiers in Politcal Science*, 2,3, 16-17.

Bertram et al. (2021). The blue carbon wealth of nations. *Nat. Clim. Change* , 704-709.

Bertram et al. (2021). The blue carbon wealth of nations. *Nat.Clim.Change*, 704-709.

Bhattacharyya, S., Raha, A., & Mitra, A. (2018). Ecotourism revenue in Sunderban Tiger Reserve. *Techno International Journal of Health, Engineering, Managment and Science* , 29-34.

Bhattacharyya, S., Raha, A., & Mitra, A. (2018). Ecotourism revenue in Sunderban Tiger Reserve. Techno International Journal of Health, Engineering. *Managment and Science*, 29-34.

Biswas et al. (2018). Do invasive plants threaten the Sundarbans mangrove forest of Bangladesh? *Forest Ecology and Managment*, 1-9.

Blume et al. (2023). Seagrass extent and blue carbon accounting using earth observation. *Mar.Sci.*

Bouillon et al. (2001). Mangrove production and carbon sinks: A revision of global budget estimates. *Springer-Verlag*.

Bourgeois et al. (2024). Four decades of data indicate that planted mangroves stored up to 75% of the carbon stocks found in intact mature stands. *Sci.Adv.*

Bromberg, K., & Bertness, M. (2005). Reconstructing New England salt marsh losses using historical maps. *Estuaries*, 823-832.

Buchbaum, R. (2021). Coastal marsh management. *Applied Wetlands Science and Technology* , 324-346.

Bunting et al. (2022). *Global Mangrove ExtentChange 1996–2020: Global Man4grove Watch Version 3.0. Remote Sens.*

The Blue Carbon Initiatives. (2014). *Coastal Blue Carbon methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrass meadows.* The Blue Carbon Initiatives.

Caribbean Public Health Agency. (2018). CHAPTER 5 RESPONSES TO CLIMATE CHANGE AND HEALTH IN THE CARIBBEAN: STRATEGIES, ORGANISATIONS AND FINANCES ,State of Public Health in the Caribbean Report 2017-2018. In *State of Public Health in the Caribbean 2019* (p. 14). Port of Spain: Healthy Ageing in the Caribbean.

Carney, J. (2017). Shellfish collection in Senegambian mangroves: A female knowledge system in a priority conservation region. *Journey of Ethnobiology*, 440-458.

Carver, R. (2020). *Lessons for blue degrowth from Namibia's emerging blue economy Blue Degrowth and the Politics of the Sea: Rethinking the Blue Economy.*

CBD. (2019). *Advancing the Caribbean blue economy. Understanding risk Conference. Caribbean Development Bank.*

CCCCC), C. C. (2012). *2012 1.5 Stay to Alive Education Initiative*. Retrieved from Caribbean Community Climate Change Centre (CCCCC): https://www.caribbeanclimate.bz/education/2012-1-5%CB%9A-stay-to-alive-education-initiative/

Chandra et al. (2010). Status and distribution of mangrove forest of the world using earth observation satellite data. *Global Ecology and Biogeography*. Retrieved from Global.

Chen, Z., & Lee, S. (2022). Tidal Flats as a Significant Carbon Reservoir in Global Coastal Ecosystems. *Frontier Marine Science*.

Christiansen, T., Wiberg, P., & Milligan, T. (2000). Flow and sediment transport on a tidal salt marsh surface." . *Estuarine, Coastal and Shelf Science 50*, 315-e1331.

Christiansen, T., Wiberg, P., & Milligen, T. (2000). Flow and sediment transport on a tidal salt marsh surface. *Estuarine, Coastal and Shelf Science*.

Cisneros-Montemayor et al. (2021). Enabling conditions for an equitable and sustainable blue economy. *Nature*, 396-401.

Claes et al.,. (2022). *The potential of coastal and oceanic climate action.* McKinsey & Company.

Clarke et al. (2021). The Caribbean and 1.5 C: Is SRMan Option? *Atmosphere*.

Clean Globe Initiative . (2023). *Carbon Credits — Path to Net-Zero or Diversion from Emission Cuts?* Retrieved from Medium: https://medium.com/@malikmanisha04/carbon-credits-path-to-net-zero-or-diversion-from-emission-cuts-de6bd9b07ebb

Commonwealth. (2021). *Commonwealth Marine Economies Programme, Maritime Blue Economy Plan.*

Conservation International. (2023). *Impact Report: Ocean Cimate Soloutions 2020-2022.*

Cunningham, A. (2005). Wetlands and people's wellbeing: Basic needs, food security and medicinal properties. *Springer*.

Damianova et al. (2020). *Blue Economy: A Path for Krasnodar Krai.* Washington D.C.: Work Bank .

Danielsen et al. (2005). The Asian tsunami: A protective role for vegetation. *Science 310*, 643.

Davidson et al. (2017). Livestock grazing alters multiple ecosystem properties and services in salt marshes: A meta-analysis. *Journal of Applied Ecology*, 1395-1405.

de Paula Costa, M., & Macreadie, P. (2022). The evolution of blue carbon science. *Wetlands*.

deGrandpre, A., & Bever, L. (2017, September 7). *The tiny islands ravaged by Irma are in trouble as Hurricane Jose looms*. Retrieved from Washington Post: https://www.washingtonpost.com/news/worldviews/wp/2017/09/07/the-tiny-islands-ravaged-by-hurricane-irma-are-in-trouble-and-begging-for-help/

Delacámara et al. (2020). Ecosystem-Based Management: Moving from Concept to Practice. *Springer Nature*, 39-60.

Dey, A., & Kar, A. (2013). Scaling of mangrove afforestation with carbon finance to create significant impact on the biodiversity – a new paradigm in biodiversity conservation models. *Field Action Science Reports*, 1-15.

Duarte et al. (2008). The charisma of coastal ecosystems: addressing the imbalance. *Estuaries Coasts*, 233-238.

Duarte et al. (2022). Global estimates of the extent and production of macroalgal forests. *Global Ecol.Biogeogr.*, 1-18.

Duarte, C., Middelburg, J., & Caraco, N. (2005). Major role of marine vegetation on the oceanic carbon cycle. *Biogeosciences 2*, 1-8.

Duarte, C., Middelburg, J., & Caraco, N. (2005). Major role of marine vegetation on the oceanic carbon cycle. *Biogeoscience*, 1-8.

Ellison, J. (2018). Effects of Climate Change on Mangroves Relevant to the Pacific Islands. *Pacific Marine Climate Change Report Card , Science Review*, 99-111.

Ermgassen et al. (2021). Fishers who rely on mangroves: Modelling and mapping the global intensity of mangrove-associated fisheries. *Estuar.Coast. Shelf Sci.*

Estes et al. (2019). Persistent Organic Matter in Oxic Subseafloor Sediment. *Nature Geoscience 12*, 126-131.

FAO. (2014). *Global Blue Growth Initiative and Small Island Developing States.* FAO.

FAO. (2015). *Blue forests: Community-led mangrove management to protect coastal eco-systems and livelihoods.* London: Blue Ventures.

FAO. (2016). *The State of World Fisheries and Aquaculture' Contributing to Food Security and Nutrition for Al.* Rome: FAO.

Feagin et al. (2009). Does vegetation prevent wave erosion of salt marsh edges? *Proceedings of the National Academy of Sciences 106*, 10109-10113.

Feagin et al. (2010). Salt marsh zonal migration and ecosystem service change in response to global sea level rise: A case study from an urban region. *Ecology and Society* .

Filbee-Dexter et al. (2018). Movement of pulsed resource subsidies from kelp forests to deep fjords. *Oecologia*, 291-304.

Filbee-Dexter,K.;Wernberg,T. (2020). Substantial blue carbon in overlooked Australian kelp forests. *Sci.Rep.*

Freidman. (2017, September 19). *Islands Seek International Funding for Hurricane Recovery*. Retrieved from NY Times: https://www.nytimes.com/2017/09/19/climate/united-nations-caribbean-hurricane-relief-money.html?mcubz=0

Friess et al. (2020). Chapter 3 Ecosystem Services and Disservices of Mangrove Forests and Salt Marshes. In *Oceaography and Marine Biology.* Taylor & Francis.

Friess et al. (2016). Policy challenges and approaches for the conservation of mangrove forests in Southeast Asia. *Conservation Biol.*, 933-949.

Friess et al. (2022). Capitalizing on the global financial interest in blue carbon. *PLoS Clim.*, 3.

Friess, D. (2016). Ecosystem services and disservices of mangrove forests: Insights from historical observations. *Forest*.

Friess, D. (2023). The Potiential for mangrove and seagrass blue carbon in Small Island States. *Current Opinion in Environmental Sustainablity* , 1.

Furukawa, K., & Wolanski, E. (1996). Sedimentation in Mangrove forests. *Mangrove and Salt Marshes*, 3-110.

Gautreau, S., & Correa, V. (2023). *Blue Economies and Nature-based Solutions for Enhanced Climate Action in Latin America and Caribbean Small Island Developing States.* UNDP.

Gedan, K., Crain, C., & Bertness, M. (2009). Small-mammal herbivore control of secondary succession in New England tidal marshes. *Ecology*, 430-440.

GEF. (2019, December 3). *Greening the blue: championing coastal climate solutions*. Retrieved from GEF: https://www.thegef.org/news/greening-blue-championing-coastal-climate-solutions

GEF. (2022). *GEF Programming Strategy on Adaptation to Climate Change for the Least Developed Countries Fund and the Special Climate change Fund for the GEF-8 Period of July 1, 2022, to June 30, 2026, and Operational Improvements.* GEF.

Giosan et al. (2014). Climate change: protect the world's deltas. *Nature*, 31-33.

Global Mangrove Alliance. (n.d.). *Mikoko Pamoja: A Business Case for Carbon Credit in Gazi-Kwale County, Kenya*. Retrieved from Mangrove Alliance: https://www.mangrovealliance.org/mikoko-pamoja/

Green, E., & Short, F. (2003). *World Atlas of Seagrasses.* Univ of California Press.

Guannel et al. (2016). The power of three: Coral reefs, seagrasses and mangroves protect coastal regions and increase their resilience. In N. Gurran, *The turning tide: Amenity migration in coastal Australia* (p. e0158094). International Planning Studies.

Herr et al. (2014). *Keep it Fresh or Salty An introductory guide to financing wetland carbon programs and projects.* IUCN.

Herr, D., & Landis, E. (2016). *Coastal blue carbon ecosystems Opportunities for Nationally Determined Contributions.* UNEP.

Herr, D., Pidgeon, E., & Laffoley, D. (2012). *Blue Carbon Policy Framework: Based on the discussion of the International Blue Carbon Policy Working Group.* Gland: IUCN.

Himes-Cornell, A., Pendleton, L., & Atiyah, P. (2018). Valuing ecosystem services from blue forests: A systematic review of the valuation of salt marshes, sea grass beds and mangrove forests. *Ecosystems Services 30*, 36-48.

Hochard, J., Hamilton, S., & Barbier, E. (2019). Mangroves shelter coastal economic activities from cyclones. *National Academy of Science*, 12232-12237.

HSBC. (2020). *Global Asset Management & Pollination launch partnership to create world's largest natural capital manager.*

IADB. (2020). *Blue carbon restoration in southern Clarendon, Jamaica*. Retrieved from Inter-American Development Bank: https://www.iadb.org/en/project/JA-T1169

IDB. (n.d.). *Economic evaluation of the blue economy in the Caribbean. To produce an economic valuation tool of the current and potential economic activities in the Caribbean*. Retrieved from Sustainable Islands: https://sustainableislands.iadb.org/projects/blue-economy-valuation

IMF. (2020). *World Economic Outlook.*

IPCC. (2013). *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands.* IPCC.

IPCC. (2013). *Climate Change 2013: The Physical Science Basis Working" Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate*

Change, "Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Cambridge, New York.

IPCC. (2023). *2023: Sections. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Geneva: IPCC.

Isaac et al. (2021). The renaissance of Odum's outwelling hypothesis in 'Blue Carbon' science. *Estuarine, Coastal and Shelf Science*.

Ito et al. (2000). Chemical constituents of Avicennia alba. Isolation and structural elucidation of new naphthoquinones and their analogues. *Chemical and Pharmaceutical Bullentin*, 339-343.

IUCN & Conservation International. (2023). *International policy framework for blue carbon ecosystems: Recommendations to align actions across international policy processes for the conservation and restoration of coastal blue carbon ecosystems.* Arlington VA: IUCN.

IUCN. (2021, November 11). *Accelerator Fund to support blue carbon entrepreneurs and leverage private sector finance*. Retrieved from IUCN: https://iucn.org/news/marine-and-polar/202111/new-blue-carbon-accelerator-fund-support-blue-carbon-entrepreneurs-and-leverage-private-sector-finance

IUCN. (2021). *Blue Natural Capital Financing Facility: Our Partners*. Retrieved from IUCN: https://iucn.org/our-work/projects/blue-natural-capital-financing-facility-bncff

Jennerjahn, T. (2023). *Analysis of existing Blue Carbon projects in the voluntary carbon market.* German Environment Agency.

Jennerjahn, T., & Ittekkot, V. (2021). Relevance and magnitude of 'Blue Carbon' storage in mangrove sediments: Carbon accumulation rates vs. stocks,sources vs. sinks.

Kauffman et al. (2020). Total ecosystem carbon stocks of mangroves across broad global environmental and physical gradients. *Ecol.Monogr.*

Kelleway et al. (2017). Review of the ecosystem service implications of mangrove encroachment into salt marshes. *Global Change Biology*, 39673983.

Knox, G., & Miyabara, T. (1984). *Coastal Zone Resource Development and Conservation in Southeast Asia With Special Reference to Indonesia. Jakarta, Indonesia.* UNESCO.

Leal, Maricé, & Spalding. (2022). *The State of the World's Mangroves 2022.* Global Mangrove Alliance.

Leon, S.-H. (2012). 1.5 C to stay alive:climate change, imperialism and justice for the Caribbean. *Third World Quarterly*.

Leonard, L., & Croft, A. (2006). The effect of standing biomass on flow velocity and turbulence in Spartina alterniflora canopies. *Estuar.Coast Shelf Sci.*, 325-336.

Li et al. (2018). Coastal wetland loss, consequences, and challenges for restoration. *Springer Nature*, 1-15.

Li et al. (2018). Factors regulating carbon sinks in mangrove ecosystems. *Global Change Biology*, 4195-4210.

López-Angarita et al. (2016). Mangroves and people: Lessons from a history of use and abuse in four Latin American countries. *Forest Ecology and Managment*, 151-162.

Loureiro, T., du Plessis, N., & Findlay, K. (2022). Into the blue - the blue economy model in operation phakisa 'unlocking the ocean economy' programme. *South African Journal of Science*, 1-4.

Loureiro, T., duPlessis, N., & Findlay, K. (2022). Into the blue, The blue economy model in Operation Phakisa 'Unlocking the Ocean Economy' Programme. *South African Journal of Science* , 1-4.

Lovelock et al. (2023). An Australian blue carbon method to estimate climate change mitigation benefits of coastal wetland restoration. *Restoration Ecology*.

Lovelock et al. (2023). An Australian blue carbon method to estimate climate change mitigation benefits of coastal wetland restoration. *Restoration Ecology*, 9.

Lovelock, C., & Duarte, C. (2019). *Dimensions of Blue Carbon and emerging perspectives.* Biology Letters.

Lovelock,C.E.,;Duarte, C.M.,;. (2019). Dimensions of Blue Carbon and emerging perspectives. *Biology Letter*.

Macreadie et al. (2021). Blue carbon as a natural climate solution. *Nat.Rev. Earth Environ.*, 826-839.

Macreadie et al. (2022). Operationalizing marketable blue carbon. *One Earth*, 485-492.

Martinez-Vazquez, R., Milan-Garcia, J., & de Pablo, V. (2021). Challenges of the blue economy: Evidence and research trends. *Environmental Sciences Europe*, 1.

Mazda et al. (2006). Wave reduction in a mangrove forest dominated by Sonneratia sp. *Wetlands Ecology and Managment*, 365-378.

McGray, H. (2014, June 11). *Clarifying the UNFCCC National Adaptation Plan Process*. Retrieved from World Resource Institute : https://www.wri.org/insights/clarifying-unfccc-national-adaptation-plan-process

Meng et al. (2017). Status of wetlands in China: A review of extent, degradation, issues and recommendations for improvement. *Oceana and Coastal Managment*, 50-59.

Mirova. (2021). *Call for early-stage Blue Carbon Project Proposals*. Retrieved from Mirova: https://www.mirova.com/en/news/call-early-stage-blue-carbon-project-proposals

Möller et al. (1999). Wave transformation over salt marshes: A field and numerical modelling study from North Norfolk, England. *Estuarine, Coastal and Shelf Science 49*, 411-426

Mulder. (2022). *The impact of the COVID-19 pandemic on the tourism sector in Latin America and the Caribbean, and options for a sustainable and resilient recovery.* Santiago: Economic Commission for Latin America and the Caribbean (ECLAC).

Myatt, L., Scrimshaw, M., & Lester, J. (2003). Public perceptions and attitudes towards a current managed realignment scheme: Brancaster West Marsh, North Norfolk. *Journal of Coastal Research*, 278-286.

Nagelkerken, I. (2009). Evaluation of nursery function of mangroves and seagrass beds for tropical decapods and reef fishes: Patterns and underlying mechanisms. *Springer*, 357-399.

National Oceanic and Atmospheric Administration (NOAA). (2024, July 24). *Hurricane Beryl: An opportunity for collaborative research*. Retrieved from NOAA:

https://research.noaa.gov/2024/07/24/hurricane-beryl-an-opportunity-for-collaborative-research/

Nellemann et al. (2009). Blue Carbon - the Role of Healthy Oceans in Binding Carbon.

OECD. (2011). *Towards Green Growth: A Summary for Policy Makers.*

Oreska et al. (2018). *Seagrass Mapping: A survey of the Recent Seagrass Distribution Literature.* CRC Press.

Oueslati, S. (2012). Phenolic content, antioxidant, anti-inflammatory and anticancer activities of the edible halophyte Suaeda fruticosa Forssk. *Food Chemistry*, 943-947.

Partelow. (2020). Environmental governance theories: a review and application to coastal systems. *Ecol.Soc.*

Patel, S. (2016). Salicornia: Evaluating the halophytic extremophile as a food and a pharmaceutical candidate. *Biotech 6*, e104.

Patil el al. (1993). The Inophyllums, novel inhibitors of HIV-1 reverse transcriptase isolated from the Malaysian tree, Calophyllum inophyllum Linn. *Journal of Medical Chemistry*, 4131-4138.

Patil et al. (2016). *Toward a Blue Economy: A Promise for Sustainable Growth in the Caribbean.* Washington D.C.: World Bank.

Pendleton et al. (2012). Estimating global "blue carbon" emissions from conversion and degradation of vegetated coastal ecosystems. *PLoS ONE*, 1-7.

Phang et al. (2023). A Review of the Blue Economy, Potential, and Opportunities in Seven Caribbean Nations Pre-COVID-19. *ICES Journal of Marine Science*, 2233-2243.

Pirog, R. (2008). *Seagrass : Ecology, Uses and Threats.* Nova Science Publshers.

Programme, C. M. (2021). *Marine Blue Economy Plan, Antigua and Barbuda.* Commonwealth Secretariat .

Quiros et al. (2009). Blue Carbon Ecosystem Services Through a Vulnerability Lens: Opportunities to Reduce Social Vulnerability in Fishing Communities. *Frontiers in Marine Science 8*.

Ramsar. (2006). *Information Sheet on Ramsar Wetlands (RIS):* . Antigua and Barbuda.

Ranjan, R. (2019). Optimal mangrove restoration through community engagement on coastal lands facing climatic risks: The case of Sundarbans region in India. *Environmental Science*.

Rasolofo, M. (1997). Use of mangroves by traditional fishermen in Madagascar. *Mangrove and Salt Marshes*, 243-253.

Rasowo et al. (2020). Harnessing Kenya's Blue Economy: Prospects and Challenges. *Journal of Indian Ocean Region*, 292-316.

Raven, J. (2018). Blue carbon: past, present and future, with emphasis on macroalgae. *Biol.Lett.*

Rhee, M., Park, H., & Cho, J. (2009). Salicornia herbacea: Botanical, chemical and pharmacological review of halophyte marsh plant. *Journal of Medical Plants Research*, 548-555.

Robinson et al. (2014). Mechanisms of microbial carbon sequestration in the ocean. *Biogeosciences*.

Rogelj et al. (2016). Paris Agreement climate proposals need a boost to keep warming well below 2°C. *Nature*, 631-639.

Rosanna, C. (2020). Lessons for blue degrowth from Namibia's emerging blue economy. *Sustainability Science*, 131-143.

Salam, M., Lindsay, G., & M.C., B. (2000). Eco-tourism to protect the reserve mangrove forest the Sundarbans and its flora and fauna. 56-66.

Short et al. (2007). Global seagrass distribution and diversity: A bioregional model. *Experimental Marine Bilogy and Ecology* , 3-20.

Sidik et al. (2023). Blue carbon: a new paradigm of mangrove conservation and management in Indonesia. *Mar.Policy*, 3.

Sidik et al. (2023). Blue carbon: a new paradigm of mangrove conservation and management in Indonesia. *Mar.Policy*.

Sillanpää, M., Vantellingen, J., & Friess, D. (2017). Vegetation regeneration in a sustainably harvested mangrove forest in West Papua, Indonesia. *Ecol.Manag*, 137-146.

Silliman, B. (2014). *Salt Marshes.* Current Biology.

Siswanto, N., & Rosdaniah, S. (2023). Driving Blue Economy for Sustainable Development: A Case of Stakeholder Collaboration Platform Development. *Earth and Environmental Science*.

Smith, K. (2024, July 19). *Grenadians cope with the realities of climate change in the aftermath of Hurricane Beryl", United Nations Children's Fund (UNICEF)*. Retrieved from United Nations Children's Fund (UNICEF): https://www.unicef.org/easterncaribbean/stories/grenadians-cope-realities-climate-change-aftermath-hurricane-beryl

Solomon et al. (2007). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press.

Steven, A., & Vanderklift, M.-M. (2019). A new narrative for the Blue Economy and Blue Carbon. *Journal of the Indian Ocean Region*, 123-128.

Strong, A., & Ardoin, N. (2021). Barriers to incorporating ecosystem services in coastal conservation practice: the case of blue carbon. *Ecol.Soc*.

Sudhakar et al. (2023). Chapter 9 - Blue economy and blue carbon materials applications in various fields with respect to marine algae. In *In Developments in Applied Microbiology and Biotechnolgy* (pp. 157-165). Academic Press.

Sullivan. (2017, September 28). *Hurricanes Irma and Maria: Impact on Caribbean Countries and Foreign Territories.* Retrieved from DTIC: https://apps.dtic.mil/sti/citations/trecms/AD1172110

Sun et al. (2019). Tourism in Small Island Developing States. *SSRN.*

Taillardat, P., Friess, D., & Lupascu, M. (2018). Mangrove blue carbon strategies for climate change mitigation are most effective at the national scale. *Biol.Lett.*

TFSVCM. (2021). *Taskforce on Scaling the Voluntary Carbon Market Final Report.*

The Commonwealth. (2020). *Case study: Community-led Mangrove Restoration and Conservation in Gazi Bay, Kenya - Lessons From Early Blue Carbon Projects (on-going)*. Retrieved from The Commonwealth: https://thecommonwealth.org/case-study/case-study-community-led-mangrove-restoration-and-conservation-gazi-bay-kenya-lessons

The Commonwealth of Learning. (2016, June 6). *The Blue Economy: Origin and concept*. Retrieved from The Commonwealth of Learning: https://www.col.org/news/the-blue-economy-origin-and-concept/

The Global Mangreove Watch. (2020). *Mangrove Habitat Extent*. Retrieved from Global Mangrove Watch : https://www.globalmangrovewatch.org/?active-widgets=[%22mangrove_habitat_extent%22,%22mangrove_net_change%22,%22mangrove_habitat_change%22,%22mangrove_alerts%22,%22mangrove_species_location%22,%22mangrove_species_distribution%22,%22mangrove_species_threat

The Intercontinental Panel on Climate Change (IPCC). (2013). *Climate Change 2013: The Physical Science Basis Working" Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press.

Thompson, B. (2022). Blue bonds for marine conservation and a sustainable ocean economy: status, trends, and insights from green bonds. *Marine Policy*.

Twilley, R., Chen, R., & Hargis, T. (1992). Carbon sinks in mangroves and their implications to carbon budget of tropical coastal ecosystems. *Springer*, 265-288.

Uddin et al. (2013). Economic valuation of provisioning and cultural services of a protected mangrove ecosystem: A case study on Sundarbans Reserve Forest, Bangladesh. *Ecosystem Services*, 88-93.

UNFCC Decision. (2014). Report of the Conference of the Parties on its twentieth session, held in Lima from 1 to 14 December 2014.

UNFCC. (n.d.). *Intended Nationally Determined Contributions (INDCs)*. Retrieved from UNFCC: https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs/indcs

UNFCC. (n.d.). *Nationally Determined Contributions (NDCs)*. Retrieved from UNFCC: https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs n.d.

Unsworth et al. (2022). The planetary role of seagrass conservation. *Science 377*, 609-613.

UNWTO. (2023). *World Tourism Barometer Volume 21.*

US Congress. (2022). S3245 Blue Carbon for Our Planet Act; .

US Congress. (2022). US Congress: S3245 Blue Carbon for Our Planet Act; United States Congress.

VanDam et al. (2021). Calcification-driven CO_2 emissions exceed "Blue Carbon. *Sci.Adv.*

Vanderklift et al. (2022). A guide to international climate mitigation policy and finance frameworks relevant to the protection and restoration of blue carbon ecosystems. *Front. Mar. Sci.*

Verweij et al. (2006). Structure, food and shade attract juvenile coral reef fish to mangrove and seagrass habitats: A field experiment. *Marine Ecology Progress Series*, 257-268.

Walters et al. (2008). Ethnobiology, socioeconomics and management of mangrove forests: A review. *Aquatic Ecology*, 220-236.

Wang et al. (2021). Global blue carbon accumulation in tidal wetlands increases with climate change. *Natural Science*.

Wang et al. (2021). The potential of mature Sonneratia apetala plantations to enhance carbon stocks in the Zhanjiang Mangrove National Nature Reserve. *Ecol.Indic.*

Whitfield, A. (2017). The role of seagrass meadows, mangrove forests, salt marshes and reed beds as nursery areas and food sources for fishes in estuaries. *Rev Fish Biology Fisheries*, 75-110.

World Bank. (2017). *The Potential of the Blue Economy: Increasing Long-term Benefits of the Sustainable Use of Marine Resources for Small Island Developing States and Coastal Least Developed Countries.* Washington D.C.: World Bank .

World Bank. (2023). *Based on the stakeholder engagement described in the World Bank background paper: World Bank. "Elaboration d'une feuille de route pour développer l'économie bleue en Tunisie: Analyse institutionnelle et des politiques en lien avec l'économie bleue.*

World Bank. (2024). *Beyond the Shoreline - Towards a Blue and Resilient Future for Tunisia.* Washington: World Bank.

World Bank. (2024). *Beyond the Shoreline - Towards a Blue and Resilient Future for Tunisia.* Washington D.C.: World Bank.

WorldBank. (2023). *Unlcoking Blue Carbon Development:Investment Readiness Framework for Governments.* Washington D.C.: Work Bank Group.

Worm et al. (2006). Impacts of biodiversity loss on ocean ecosystem services. *Science*, 787-790.

WTTC. (2022). *WTTC Cities Economic Impact.*

Wylie, L., Sutton-Grier, A., & Moore, A. (2016). Keys to successful blue carbon projects: Lessons learned from global case studies. *Marine Policy*, 76-84.

Yang,S.L. (2006). The role of Scirpus marsh in attenuation of hydrodynamics and retention of fine-grained sediment in the Yangtze Estuary. *Estuar.Coast Shelf Sci.*, 227-233.

Zeng et al. (2020). Economic and social constraints on reforestation for climate mitigation in Southeast Asia. *Nat.Clim.*, 842-844.

Zeng et al. (2021). Global potential and limits of mangrove blue carbon for climate change mitigation. *Curr Biol.*