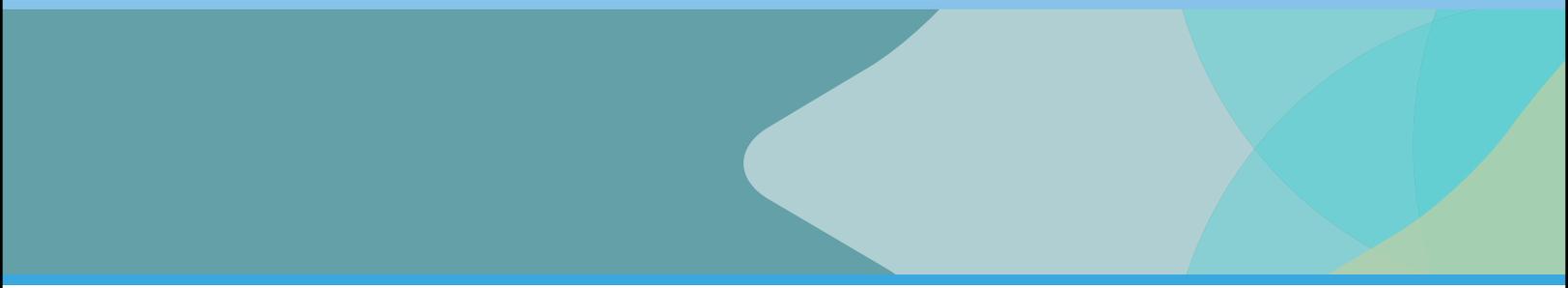




THE ABU DHABI **BLUE CARBON** DEMONSTRATION PROJECT

Blue Carbon in Abu Dhabi – Protecting our Coastal Heritage





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Published by: Abu Dhabi Global Environmental Data Initiative (AGEDI)
This publication was prepared by GRID-Arendal.

Recommended Citation:

AGEDI 2013, Blue Carbon in Abu Dhabi – Protecting our Coastal Heritage: The Abu Dhabi Blue Carbon Demonstration Project.

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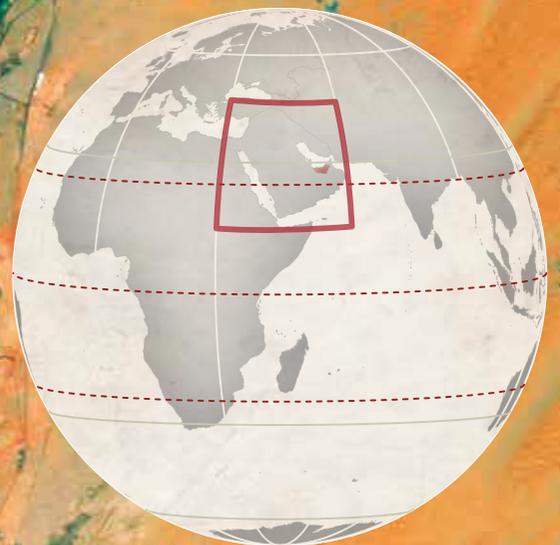
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Blue Carbon in Abu Dhabi – Protecting our Coastal Heritage

The outputs from the Abu Dhabi Blue Carbon Demonstration Project are available on the AGEDI website at www.AGEDI.ae and Blue Carbon Community Portal abudhabi.bluecarbonportal.org

Abu Dhabi is the largest and most populous of the seven United Arab Emirates, with the city of Abu Dhabi as the country's capital. Most of the Emirate is uninhabited desert land, yet the coastline is teeming with life.

Dotted with nearly 200 islands, many of which are open to visitors and tourists, Abu Dhabi's coastal environment offers a range of opportunities to enjoy nature by fishing, bird-watching, kayaking or diving.



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◆ Preface



The conservation of the marine and coastal environment of Abu Dhabi is deeply rooted in our culture. Honouring the legacy of His Highness the late Sheikh Zayed bin Sultan Al Nahyan and his bold efforts of mangrove plantations, we proudly embark on new avenues to protect our natural heritage.

Studying Blue Carbon, the role that these ecosystems play in sequestering and storing atmospheric carbon, is an exciting opportunity for Abu Dhabi to deepen our understanding of the valuable services these ecosystems provide to our Emirate and its people. Through their beauty, their important role in preventing the loss of coastlines and cleaning water, and their habitat function for fish and iconic marine species such as dugong, mangroves, salt marshes and seagrass continue to deliver an array of critical contributions to the intricate web of life and living in the Emirate.

Through targeted research and in close consultation with key actors in the Emirate, the Environment Agency – Abu Dhabi strives to support science-based decision-making that helps us to build on the value of ecosystems to people's well-being in Abu Dhabi. The Abu Dhabi Blue Carbon Demonstration project is an outstanding example of local, regional and international cooperation that will advance the science and conservation of Blue Carbon ecosystems well beyond the Emirate.

Razan Khalifa Al Mubarak
Secretary General
Environment Agency Abu Dhabi (EAD)





Mangroves are essential fish nurseries and contribute to the vitality of commercial fisheries in the Emirate. The naturally-occurring species of mangrove (*Avicennia marina*) found in Abu Dhabi, locally called 'Qurm', is the grey or white mangrove, due to the colour of the underside of its leaves.



According to legend, the City of Abu Dhabi was founded around 1760, following the discovery of a freshwater spring on the island by a Bani Yas hunting party who were following the tracks of a gazelle. Their chief, Sheikh Dhiyab bin Isa, who lived in the Liwa crescent, ordered a settlement to be established. His son and successor, Sheikh Shakhbut bin Dhiyab, moved his headquarters to Abu Dhabi around 1795, building a fort on the island that today, much enlarged, survives as the Qasr al-Hosn. The settlement became the Emirate's capital as it emerged in the 19th century, deriving its economic importance from the pearling banks offshore.

◆ Bridging the Data Gap



Bridging the gap of access to high-quality environmental information, data, expertise and capacity between developed and developing countries is an essential step in our joint struggle towards halting the loss of biodiversity and fighting climate change.

The Abu Dhabi Blue Carbon Demonstration Project has helped us in advancing the knowledge on Blue Carbon ecosystems, particularly in arid regions, and has brought together a range of experts from across the Blue Carbon community, to study ecosystems, explore new scientific ground and share experiences that will support future related projects and initiatives.

Through the project we support local and global efforts in conserving marine and coastal ecosystems. As a key partner in the Global Environment Facility's Blue Forest Project, we will continue to work with partners from around the planet to enable well-informed, science-based decision-making as a foundation for the sustainable development of our global society.

Ahmed Abdulmuttaleb Abdulla Baharoon

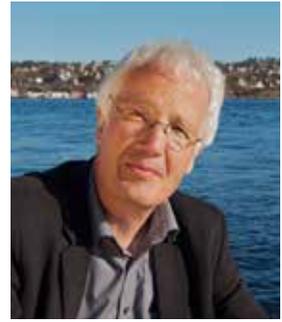
Acting Director

Abu Dhabi Global Environmental Data Initiative (AGEDI)

Environment Agency - Abu Dhabi (EAD)



◆ Foreword



Since the publication of the landmark UNEP report, *Blue Carbon - The Role of Healthy Oceans in Binding Carbon*, the Blue Carbon concept has gained considerable attention amongst marine and coastal conservation practitioners and policy-makers the world over.

Putting the vital services and functions of healthy coastal ecosystems and the associated benefits derived by people at the centre of management actions is of particular relevance for developing countries, where healthy nature is not only the wealth of the poor. Through a Blue Carbon approach inclusive of benefits such as the provision of food and material, the recognition of spiritual and cultural values, access to sustainable livelihoods and the protection from extreme weather events, we work with coastal communities to protect an environment that lies at the root of meeting their daily needs.

Working with AGEDI on the Abu Dhabi Blue Carbon Demonstration Project was an inspiring opportunity to develop cutting edge science and expertise to further serve local, regional and international efforts for the conservation of Blue Carbon ecosystems. Through our interactions with the global Blue Carbon community, and through the GEF Blue Forests Project in particular, GRID-Arendal will continue to make the findings and experiences of this success story available to support the wide application of the Blue Carbon concept for the benefit of the people, from coastal communities to our global society.

Dr. Peter Lutz Prokosch
Managing Director
GRID-Arendal, Norway





Recognising the importance of mangroves, His Highness the late Sheikh Zayed bin Sultan Al Nahyan initiated programmes of mangrove planting to maintain and expand these forests. As a result, Abu Dhabi has the oldest known mangrove restoration and afforestation initiatives anywhere in the world.

◆ Acknowledgements

The outcomes of the project have been achieved due to the willingness of stakeholders to share data and expertise. Collaboration between all stakeholders has resulted in learning opportunities for all parties and contributions from every individual involved are gratefully acknowledged.

The support the project received from the Terrestrial and Marine Biodiversity Sector, Integrated Environment Policy and Planning Sector, and the Environmental Information Science and Outreach Management Sector of the Environment Agency – Abu Dhabi (EAD) has been very valuable, as were the contributions and efforts of the field volunteers including those from Zayed University.

International Observers

Indonesian Ministry of Marine Affairs and Fisheries
Blue Ventures, Madagascar

Stakeholders

Abu Dhabi Department of Economic Development (DED)
Abu Dhabi Department of Transportation (Dot)
Abu Dhabi Marine Operating Company (ADMA-OPCO)
Abu Dhabi Motorsports Management
Abu Dhabi National Oil Company (ADNOC)
Abu Dhabi Urban Planning Council (UPC)
Abu Dhabi Tourism and Cultural Authority (TCA Abu Dhabi)
Aldar
Al Mahara Dive Centre
Critical Infrastructure and Coastal Protection Agency (CICPA)
Emirates Natural History Group (ENHG)
Emirates Wildlife Society – Wildlife for Nature (EWS-WWF)
Fujairah Municipality
Masdar
Mubadala Petroleum
New York University – Abu Dhabi (NYUAD)
Sila Connection
Tourism Development Investment Corporation (TDIC)
UAE Ministry of Environment and Water
UAE Ministry of Foreign Affairs - Department of Energy and Climate Change
UAE Ministry of International Development and Coordination
United Arab Emirates University
Zayed University



TDIC & EAD Mangrove Nursery.





The image shows a boat on a body of water during a golden hour, likely sunset or sunrise. The sky is a warm, orange-brown color. A white line graphic starts from the top right, curves down and left, then curves down and right, ending near the bottom right. The boat is on the left side of the frame, with several people visible on board. The water is calm and reflects the light from the sky.

The project undertook extensive field surveys along the coast of Abu Dhabi to sample a broad range of representative sites of Blue Carbon ecosystems.

Introduction

The Abu Dhabi Blue Carbon Demonstration Project, facilitated by the Abu Dhabi Global Environmental Data Initiative (AGEDI) was a one-year project, which commenced in November 2012.

Supportive to AGEDI's mandate and as one of the projects within the Eye on the Earth Oceans and Blue Carbon Special Initiative, the project was designed to deliver data sharing on a local level, support and encourage adaptation on a regional level and contribute to knowledge on the international stage.

Abu Dhabi was the ideal setting for such a project due to its innovative concepts and commitment to informed decision-making, in particular with regards the environment. In just over 40 years, Abu Dhabi has evolved from a small fishing community to the largest of the seven Emirates of the UAE. With the vision and direction from His Highness the late Sheikh Zayed bin Sultan Al Nahyan, the environment has become an intrinsic part of the heritage and traditions of the people of the UAE. This national affinity to the sea led to the initiation of the Abu Dhabi Blue Carbon Demonstration Project, with the aim of exploring the values coastal and marine ecosystems provide in the UAE, and to help preserve the Emirate's environment and cultural heritage.



محمية مروح البحرية MARAWAH MARINE PROTECTED AREA

According to the Emiri Decree No. 18 of 2001 it is prohibited to undertake any activity in the MPA area and the surrounding area which may have an effect on the environment of the MPA, except with the permission of the authority. Offenders are subject to the resolutions of law 23 of 1999 for the use protection and development of the living marine resources and law 24 of 1999 for the protection and development of the environment

طبقاً للمرسوم الأميري رقم ١٨ لسنة ٢٠٠١ يحظر داخل منطقة المحمية البحرية و المناطق المحاورة القيام بأية أنشطة من شأنها التأثير على بيئة المحمية إلا بتصريح من الهيئة. يتعرض المخالفون لأحكام القانون الاتحادي رقم ٢٣ لسنة ١٩٩٩ في شأن استغلال و حماية و تنمية الثروات المائية الحية و القانون الاتحادي رقم ٢٤ لسنة ١٩٩٩ في شأن حماية البيئة و تنميتها.

For more information, please contact:
The Environmental Research and Wildlife Development Agency,
P.O.Box 45580, Abu Dhabi, United Arab Emirates
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المزيد من المعلومات يرجى الاتصال على العنوان التالي:
هيئة الأبحاث و الحماة المطرية و تنميتها
ص.ب ٤٥٥٨٠ - أبو ظبي - دولة الإمارات العربية المتحدة
www.erwda.gov.ae

The Abu Dhabi Blue Carbon Demonstration Project has brought together a team of international leading experts in their academic fields.

◆ Project Overview

Project outcome

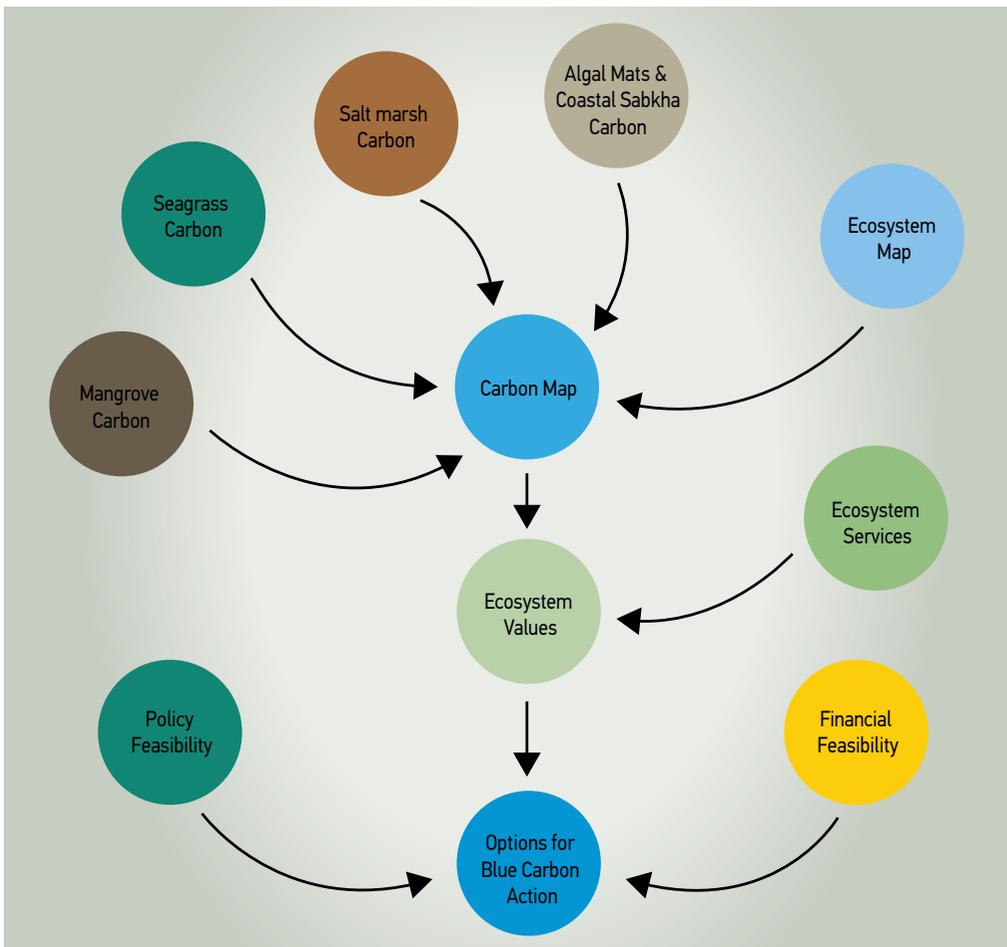
The Abu Dhabi Blue Carbon Demonstration Project has improved the understanding of carbon storage and sequestration, the extent of these “Blue Carbon” ecosystems in Abu Dhabi and the other Ecosystem Services that they provide, within the limits of a one-year long project. This scientific foundation, along with a subsequent policy and financial feasibility analysis, was then used to identify options for the incorporation of these values into policy and management, in particular in relation to sustainable ecosystem use, their appreciation in the present and the preservation of these services for current and future generations. The results highlighted the importance of access to up to the most current data and information and where such gaps were identified, recommendations were made as to priorities of how these could be filled.

Project structure

The project was comprised of five major components, each of which was delivered by leading experts. It was the first time such a variety of Blue Carbon ecosystems had been assessed and various components considered comprehensively. The result was a holistic assessment of Blue Carbon Ecosystems in Abu Dhabi.

The Abu Dhabi Blue Carbon Demonstration Project is facilitated by the Abu Dhabi Environmental Data Initiative (AGEDI) and supported by an expert team led by GRID-Arendal, including UNEP, UNEP-WCMC, Forest Trends, and a group of world-class coastal carbon scientists.

Figure 1 The relation of project components



The Project Components

Carbon baseline assessment: quantified the stocks of carbon for coastal ecosystems, and the rate of carbon sequestration associated with mangrove afforestation;

Geographic assessment: mapped Abu Dhabi's Blue Carbon ecosystems and provided a carbon analysis tool to support informed decision making;

Ecosystem services assessment: investigated the goods and services beyond carbon sequestration that Blue Carbon ecosystems provide Abu Dhabi;

Policy component: identified the most suitable options for incorporating Blue Carbon and Ecosystem Services in Abu Dhabi's policy and governance framework;

Finance feasibility assessment: recommended the most feasible options for implementing Blue Carbon initiative in Abu Dhabi on behalf of AGEDI and were ultimately responsible for the interaction and integration of the components.

◆ The importance of Demonstration Projects

Demonstration projects, by nature, aim to highlight important factors in the development and application of new concepts and help organisations to develop priorities for future focus. It is important that this is taken into consideration when reviewing project outcomes.

Blue Carbon is a relatively new global concept and this project has been particularly important in terms of:

Testing new grounds in Blue Carbon Research as it has:

- Explored the combination of a unique collective of established, candidate and associated Blue Carbon Ecosystems;
- Made significant contribution to Blue Carbon science and data, particularly as this was the first study on such scale to be undertaken in an arid region;
- Involved the collaboration between international Blue Carbon scientists, those currently implementing projects on the international stage, and local as well as international experts;
- Illustrated that the value of these ecosystems is significant when both carbon and ecosystem services are taken into account.

Providing leadership and guidance for Blue Carbon Assessment elsewhere through:

- Being the first in the region to undertake carbon stock assessments and share the outcomes of this;
- Underlining the importance of a holistic approach to marine spatial planning and that Blue Carbon ecosystems are only one component of this;
- Acknowledging that if not all the required data to make informed decisions exists, the identification of what is needed to fill these information gaps is an essential first step that can be effectively supported by considering interim management measures.

Facilitating and understanding of the international appetite for global Blue Carbon investments and mitigation by:

- Recognising the factors in addition to carbon that are of high value on a local, regional and international level;
- Determining the pre-requisites for eligibility in terms of carbon credit trading, such as the need for an inclusive national definition of forests and onus to prove additionality;
- Acknowledging that in Abu Dhabi, currently it is unlikely that Blue Carbon credits can be financially feasible; and
- Recommending locally specific and feasible financial options supporting the conservation and restoration of Blue Carbon ecosystems in Abu Dhabi.

The key to this success has been the project’s ability to regard challenges to the original concepts as learning opportunities and integrate these into the scope of the Demonstration Project.

Examples of these are expressed in Table 1.

Challenge/observation	Learning opportunity gained and how the project evolved to ensure its integration
Field surveys noted that coastal sabkha is often associated with algal mats.	As the algal mats were identified as potential Blue Carbon ecosystems, a first for the region and world, this consideration was added to the project.
The realisation that quantitative studies regarding the market and non-market values of ecosystem services previously undertaken in Abu Dhabi were limited to one or two examples.	The Ecosystem Services Assessment was based on available information and extrapolation of economic analyses from other regions. Recommendations based on best international practice and a local appreciation of ecosystem services and development pressures were made to guide future studies to comprehensively value market and non-market services.
Carbon stocks of Abu Dhabi’s Blue Carbon ecosystems are likely to be the largest of any ecosystem in the Emirate and therefore warrant protection on a local scale. On a global scale, however, per area values are relatively low.	The realisation of the importance of blended ecosystem services in which carbon is identified as one, and that collectively these are significant and merit inclusion into conservation and management and strategies. It is these blended ecosystem services that have subsequently been the main focus of the project.
Current given costs of developing carbon credits in Abu Dhabi, including opportunity costs, combined with eligibility requirements and the prevailing price for international carbon credits, their development in Abu Dhabi is not recommended.	The investigation of alternative financial approaches for the management and protection of Abu Dhabi’s Blue Carbon ecosystems were included in the Financial Feasibility Assessment. A Specialised Compensation Fund was recommended.
The presence of carbon within the coastal sabkha was found to be sourced from buried former Blue Carbon Ecosystem layers underneath. This led to the conclusion that coastal sabkha would therefore be appropriately termed an “associated Blue Carbon ecosystem” as whilst it stores carbon, it does not sequester it.	As coastal sabkha potentially “caps” other Blue Carbon deposits, it’s removal through excavation may result in the release of carbon dioxide to the atmosphere. This finding can support informed decision making on the implications of actions affecting coastal sabkha sites’ integrity, including the planting of mangroves which may result in a net loss of carbon stocks even over long time horizons.
In-field recording of ground truthing- data using traditional methods of hard copy notes could benefit from updated technological advances.	The field-testing and development of an integrated offline Ecosystem Validation Tool to support the Mapping Toolkit for the project was incorporated into Capacity Building Training sessions and the field surveys, allowing EAD scientists to continually update the extent directly from the field, and upload these into the online Validation Tool.

Table 1 Understandings that have evolved from project challenges and observations.

The Blue Carbon Concept

“Blue Carbon” refers to the ability of coastal and marine vegetation to sequester and store carbon. Blue Carbon ecosystems typically including mangrove forests, salt marshes, and seagrass beds, sequester atmospheric carbon and store it in both their biomass and sediments. When these ecosystems are destroyed, buried carbon can be released into the atmosphere as carbon dioxide (CO₂), contributing to climate change and ocean acidification. Understanding Blue Carbon resources can therefore help determine the extent to which these ecosystems can help contribute to mitigate this.

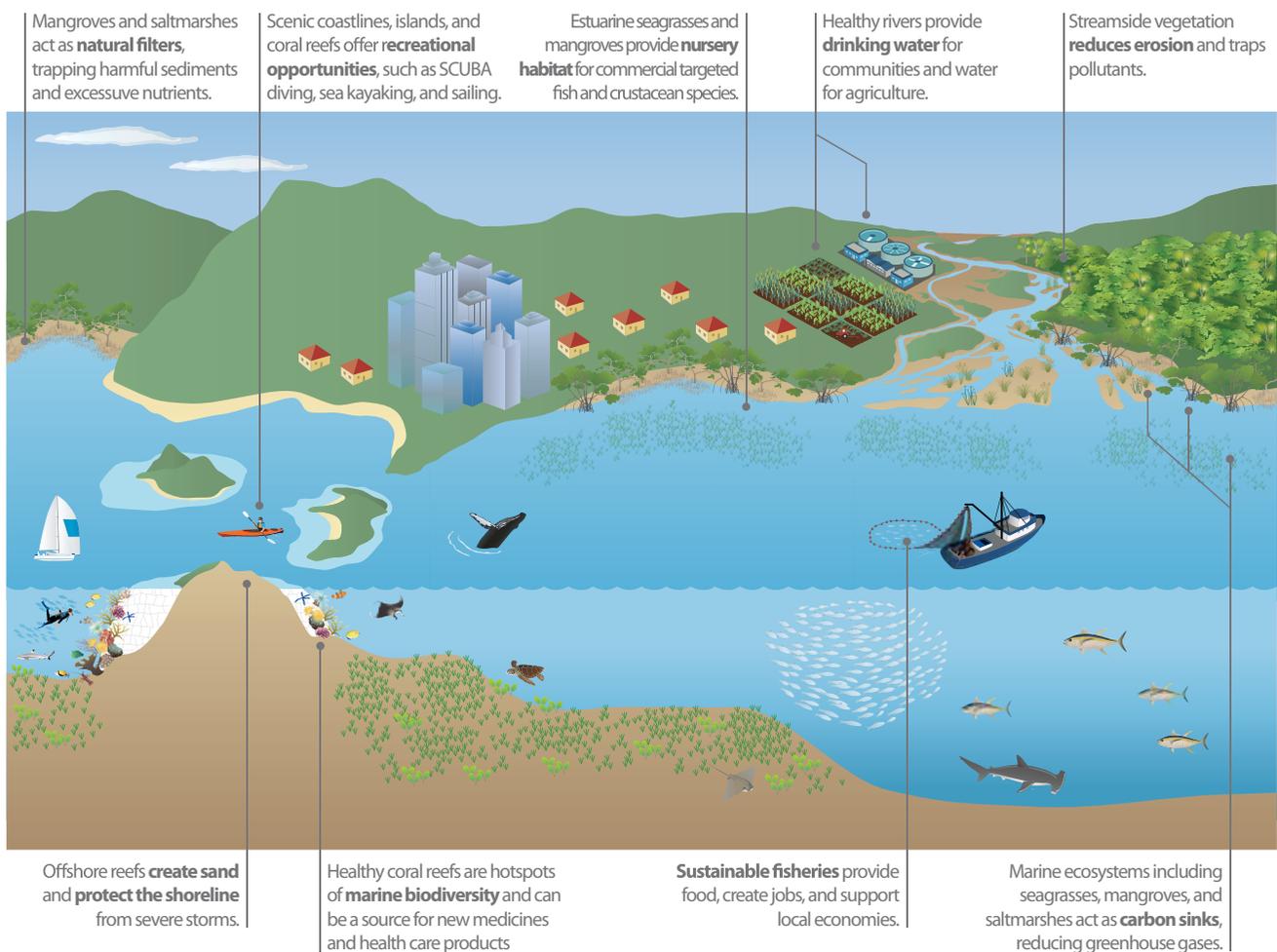


Eastern Mangroves, Abu Dhabi.

In Abu Dhabi, Blue Carbon Ecosystems are highly accessible to residents and visitors.



◆ Blue Carbon's Importance to Abu Dhabi



In addition to their climate related benefits, Blue Carbon ecosystems provide highly valuable Ecosystem Services to coastal communities. They protect shorelines, support coastal tourism and provide nursery grounds for fish and habitat for a wide range of species. They also have significant cultural and social value. In Abu Dhabi, these Blue Carbon ecosystems contribute to maintaining livelihoods, provide food and recreation and reduce vulnerabilities to sea level rise, storm events and the spread of disease. Global examples of ecosystem service delivery are illustrated in Figure 2.

The aim of the Abu Dhabi Blue Carbon Demonstration Project was to improve the understanding of carbon storage and sequestration and the other services that coastal and marine Blue Carbon ecosystems provide in Abu Dhabi. This

included determination of the existence, extent and reliability of data and information with regards to the valuation of these ecosystems, how this may be used to inform policy and management aims to lead to sustainable ecosystem use and the preservation of their services for future generations, and what future studies could be undertaken to further enhance and build upon this.

Looking globally

The Blue Carbon concept has strengthened the interest in the management and conservation of marine and coastal ecosystems, supporting climate change mitigation efforts. However, there are still gaps in our understanding of Blue Carbon, and incentives are needed to ensure more sustainable environmental management practices.

Figure 2 Scheme showing coastal and marine ecosystem services. (UNEP, 2011)



Bu Tinah Island, Abu Dhabi.

The experience and knowledge gained from the project will help guide other Blue Carbon projects and international efforts, such as the Global Environment Facility's (GEF) Blue Forests Project of which the Abu Dhabi Blue Carbon Demonstration Project is a key part. It also helps develop Blue Carbon science and data management through the testing of methodologies and the production of tools that can be utilized and up-scaled to the international arena and will enhance international Blue Carbon cooperation and training.

Why Abu Dhabi?

With the vision and direction from His Highness the late Sheikh Zayed bin Sultan Al Nahyan, the environment has become an intrinsic part of the heritage and traditions of the people of the UAE. The national affinity to the sea has led to the initiation of the Abu Dhabi Blue Carbon Demonstration project in order to explore the values, which coastal ecosystems provide the UAE, and to help preserve the environmental and cultural heritage. The project follows on from the *Blue Carbon: First level exploration of natural coastal carbon in the Arabian Peninsula - Rapid Feasibility Study, 2011* and has, through its execution, increased awareness of this concept with those who have direct interactions with and influence over these ecosystems in Abu Dhabi.

At the regional level, Abu Dhabi's Blue Carbon areas help maintain the web of life in both the Gulf and the coastal areas in countries bordering it, an increasingly critical contribution given the rapid loss of these ecosystems.

On a global scale, understanding these ecosystems in terms of the benefits they offer

and the ways they are threatened contributes to the body of worldwide knowledge. This is particularly relevant when assuming environmental conditions in the Gulf region, with its high temperatures and salinity and low precipitation, to be a potential harbinger of things to come in certain regions of the globe in a future of climate change.

Stakeholders

Reflective of the nature of this Demonstration Project, stakeholders ranged from local experts to members of the international Blue Carbon community. These stakeholders were approached to help ensure inclusion of those who support Blue Carbon through their specific expertise and guidance, and have interest in furthering the conservation of marine and coastal ecosystems in Abu Dhabi as well as regionally and internationally.

The project also incorporated stakeholder views on existing policy, market and investment frameworks, and their preferences for their application. In addition, it brought together international and locally based experts, including observers from Indonesia and Madagascar who are undertaking related projects. The sharing of information between such pioneering projects has been a great learning experience for all parties.

Blue Carbon is a relatively recent and promising approach to conserving marine and coastal ecosystems. As such its local, regional and international successes rely on stakeholders expertise, guidance and dedication to creating a future of sustainability and prosperity and sincere gratitude is expressed to all involved.

Blue Carbon Ecosystems in Abu Dhabi

This project was globally the first time such a range of ecosystems had been considered comprehensively for their Blue Carbon potential.

Traditional Blue Carbon ecosystems include intertidal mangroves and salt marsh as well as subtidal seagrass meadows. It is these ecosystems (on occasion in combination) that have been the focus of international Blue Carbon research to date.

In the Abu Dhabi context however, two further ecosystems of particular local relevance - algal mats and coastal sabkha - were studied for their Blue Carbon potential.



Blue Carbon ecosystems in Abu Dhabi build a mosaic of habitats for a range of species including dugong, sea turtles, dolphins and seabirds.



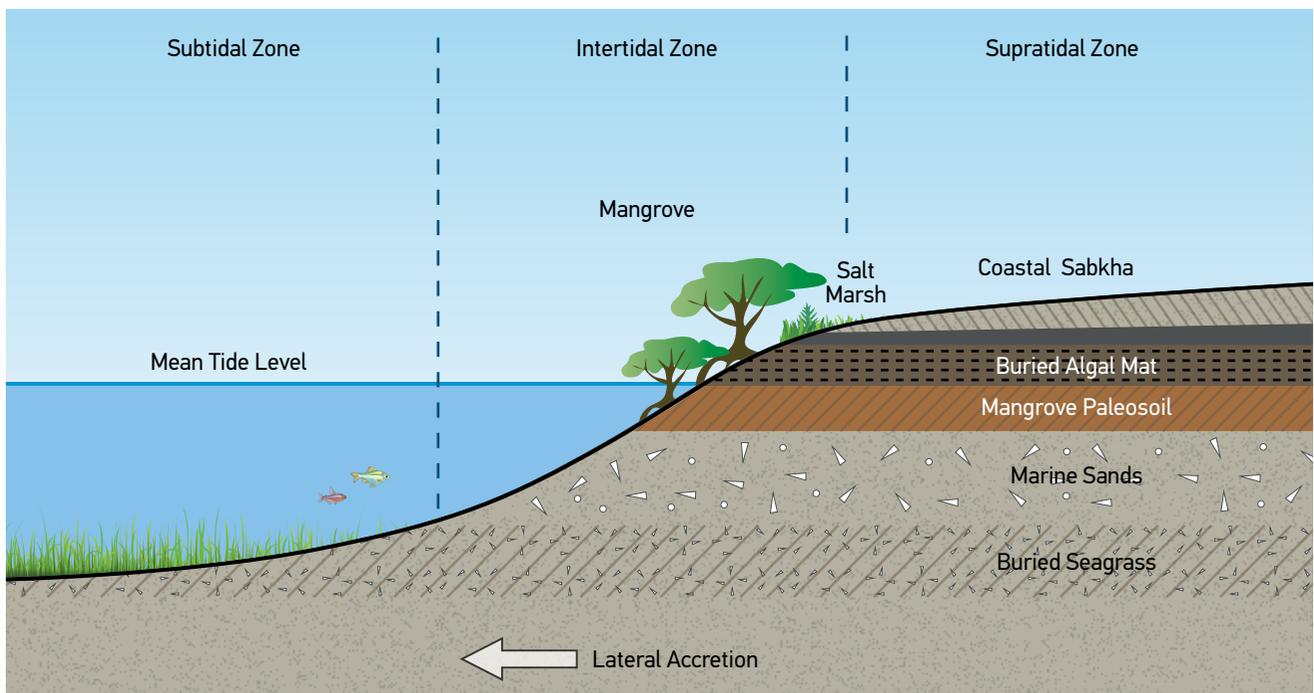
◆ Ecosystems of Interest

The *Blue Carbon: First level exploration of natural coastal carbon in the Arabian Peninsula - Rapid Feasibility Study*, 2011, the predecessor to the Abu Dhabi Blue Carbon Demonstration Project, identified coastal sabkha as expressing characteristics with the potential to sequester and store carbon. As a result, it was assessed as a candidate Blue Carbon ecosystem within the subsequent project. Through the surveys of the project however, coastal sabkha was found to not sequester carbon, but potentially to cap buried carbon, and therefore can be considered as a Blue Carbon associated ecosystem.

Algal mats (also known as cyanobacterial mats or microbial mats) can have close associations with coastal sabkha. They were found to flourish in sheltered coastal arid zone environments where vascular plants are excluded by very high soil salinities. This close relationship with coastal sabkha also prompted the hypothesis that these algal mats may have the potential to sequester and store carbon. The algal mats were therefore considered as a candidate Blue Carbon ecosystems during the assessments.

As carbon dioxide is likely to be released when areas are degraded to accommodate mangrove plantings, these should be carefully planned on a scientific basis to avoid unintended consequences. It is therefore recommended that geomorphology, connections to other marine and coastal ecosystems and the ability of mangroves to adapt to climate change-driven environmental impacts should be central considerations in future afforestation projects.

Figure 3 Illustrates the relationship between the Blue Carbon ecosystems in Abu Dhabi, the history of a shoreline shifting seaward and resulting the soil profiles. The presence of these buried former Blue Carbon ecosystems within profiles encountered has relevant implications for future development in these areas.



Mangroves

Mangroves, an iconic Blue Carbon ecosystem in Abu Dhabi, occupy an estimated 14,117 hectares. They are found in scattered locations throughout the Emirate, particularly around the margins of lagoons and mud banks behind the barrier islands near Abu Dhabi island and on the outer islands.

Recognising the importance of mangroves, His Highness the late Sheikh Zayed bin Sultan Al Nahyan initiated programmes of mangrove planting to maintain and expand these forests. As a result, Abu Dhabi has the oldest known mangrove restoration and afforestation initiatives anywhere in the world, with some stands in the Eastern Mangrove region being nearly 50 years old. More recent large-scale planting can be seen as an example at Abu Al Abyad.

Natural and planted mangroves are fringe forests of the native *Avicennia marina* (Embabi, 1993), a species able to tolerate the prevailing environmental conditions of high salinity and temperatures and limited freshwater influxes which are present in this part of the Gulf. *Rhizophoraceae* was identified in charcoal fragments dating back to between 2500 and 4000 years ago (Environmental Agency, 2006).

Most of the mangroves are small (1-3 metres) in comparison to heights in non-arid regions. However the more developed natural ecosystems, as well as the older plantations, are assumed to be delivering a number of other ecosystem services beyond carbon sequestration.

In general, mangrove afforestation in Abu Dhabi has had good success rates. Those plantations however, where saplings are planted along the same depth contour and in dense configuration, are likely to not deliver the full range of ecosystem services.

Mangroves are the most iconic Blue Carbon ecosystem in Abu Dhabi.

Photo: Bu Tinah Island, Abu Dhabi.

A photograph of a researcher in a salt marsh. The researcher is wearing a dark t-shirt, olive green cargo pants, and a backpack. He is holding a tall, silver pole with a GNSS receiver mounted on top. The marsh is filled with green, succulent vegetation. In the background, there are trees and a blue sky with white clouds. A yellow caution tape is stretched across the foreground.

Salt marsh

Salt marshes are relatively limited in extent, compared with the other Blue Carbon ecosystems, covering 4,770 hectares (equivalent to over 29 Formula 1 Yas Marina Circuits). They occur in patches along the fringe of coastal sabkha, locally on sand veneers, adjacent to channels within coastal sabkha, and amongst higher intertidal areas of mangrove stands.

The salt marshes are dominated by the succulent, halophytic shrub *Arthrocnemum macrostachyum* and subdominant species *Halocnemum strobilaceum*, *Halopeplis perfoliata*, *Suaeda vermiculata*, *Salicornia europaea*, *Limonium axillare*, *Anabasis setifera* and *Salsola* species. These species are typical of high salinity conditions and dryer, more aerated wetland soils.

Highly adapted to the extreme environments of Abu Dhabi, salt marshes play a vital role in the coastal web of life.

Seagrass

Seagrass meadows in the Gulf are one of the largest expanses in the world. In Abu Dhabi, it is estimated that they cover 158,262 hectares, accounting for 84% of the total estimated extent of Blue Carbon ecosystems in the Emirate. As this extent is based upon the amalgamation of remote sensing imagery to 3.5 metres and local expert knowledge, this is considered an underestimate of the actual extent of seagrass, as the ecosystem was found during dive surveys to be widespread beyond 10 metres. As Figure 11 illustrates, this ecosystem is subtidal whilst all other Blue Carbon ecosystems are intertidal.

Three species of seagrass exist in the region, *Halodule uninervis*, *Halophila ovalis*, and *Halophila stipulacea*. While this represents a lower species number than the eleven and seven species documented in the Red and Arabian Seas, respectively (Phillips, 2003; Lipkin *et al.*, 2003), the extent of this ecosystem is significant. Expansive areas of seagrass meadows are located between Qatar and the UAE. Within Abu Dhabi Emirate, the complex of seagrass meadows extends around the islands and along the nearshore coastal plain. In sheltered locations these meadows intermingle with algal beds (*Hormophysa*).

Seagrass is an important feeding, breeding and nursery ground for many marine species. It is estimated that over 75% of the myriad of fishery species in Abu Dhabi may rely on mangrove or seagrass or both for production (Aburto-Oropeza *et al.*, 2008). Abu Dhabi seagrass meadows, particularly those in the western region, support the world's second largest population of dugong, and also provide critical foraging habitat for sea turtle species.

In addition, seagrass supports other ecosystems of recognised value, such as the coral reefs that are the focus of Abu Dhabi's growing dive industry. Seagrass meadows can also act as a buffer to help regulate storm surges chased by shamal winds or other meteorological events.

Abu Dhabi is home to one of the largest seagrass meadows in the world.

◆ Candidate Blue Carbon Ecosystems

Algal mats

Along tidal margins of coastal sabkha where soils are consistently moist, algal mats (also known as cyanobacterial mats or microbial mats) are formed by the accumulation of cyanobacteria, regionally dominated by *Microcoleus chthonoplastes*. In total, these cover an estimated area of 10,930 hectares throughout Abu Dhabi Emirate. In these areas, cyanobacteria overlay laminae of bacteria, filamentous bacteria (salmon pink) and sulphur purple bacteria (purple-pink) (Kinsman and Park, 1976; Cardoso *et al.*, 1978).

In sheltered locations, these organisms may form a thick 'leather-like' and moist mat, with a laminated fabric centimetres to tens of centimetres in



Algal mats show unexpectedly high carbon storage.

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thickness, and can express different surface morphologies depending on location (Kendall and Skipwith, 1968). Periodic storms bring sediments to the mats, leading to layering of organic and non-organic sediment. Higher in the tidal frame where evaporation is high, and in locations subject to more regular disturbance, the algal film may only be a few millimetres in thickness, covering shelly sands (Kendall and Skipwith, 1968).

◆ Associated Ecosystems

Whilst other ecosystems associated with these coastal and marine Blue Carbon ecosystems have not specifically been included in the project, it is important that their integrity remains to support these ecosystems and prevent the release of carbon dioxide.

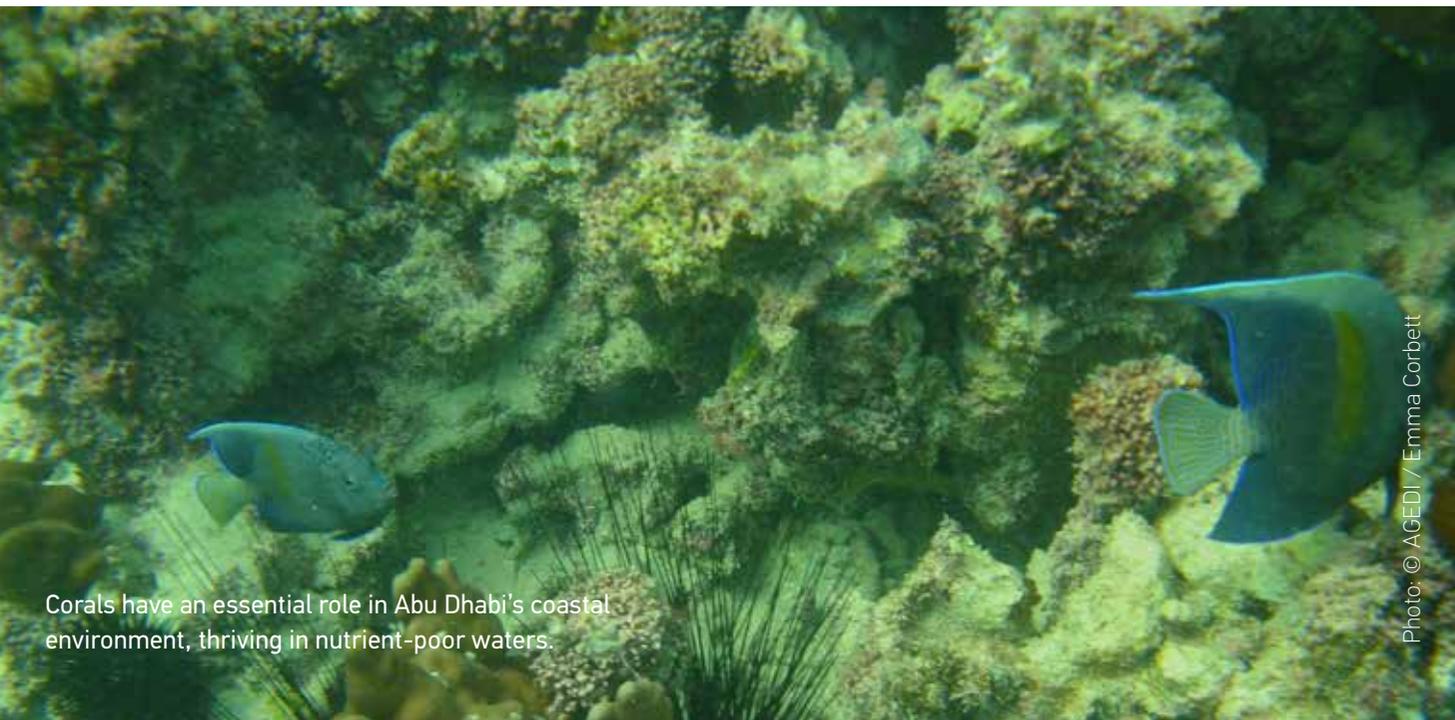
Abu Dhabi Emirate is recognised as hosting the world's largest coastal sabkha, over 300 km and extending in places more than 20 km inland (Evans and Kirkham, 2002), covering an estimated 389,331 ha. Coastal sabkha comprises the seaward part of the sabkha, which, while usually not flooded by normal astronomical tides, can be flooded several times per year when exceptionally strong shamal winds drive seawater inland. The seaward margin of the coastal sabkha dips into the intertidal environment and intermingles with patches of vegetated coastal ecosystems.

Coastal sabkha is largely devoid of vascular vegetation because of hypersalinity and long periods of dry conditions (Kendall *et al.*, 2002).

Coastal sabkha in Abu Dhabi includes the seaward part of sabkha and mostly is not flooded by normal astronomical tides but is flooded several times per year when exceptionally strong shamal winds drive seawater inland.



Sabkha is likely to play an important role in preventing soil carbon from release into the atmosphere.



Corals have an essential role in Abu Dhabi's coastal environment, thriving in nutrient-poor waters.

Photo: © AGEDI / Emma Corbett

Seaweed

The other noteworthy ecosystem is macroalgae, often referred to as seaweed. Macroalgae occur in coastal zones where there is enough light for photosynthesis and a firm attachment point from which they grow. They are an integral part of many coastal ecosystems and form one of the bases of food chains. While macroalgae photosynthesize and remove carbon dioxide from the atmosphere, they do not deposit carbon into sediments. Most excess carbon is quickly consumed by marine life, decomposed and recycled or exported out of the system. The high turnover of biomass means that carbon storage in macroalgae is basically limited to the carbon stored in their biomass, and carbon is generally not sequestered into long-term reservoirs (Reed and Brzezinski, 2009).



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Corals

Coral reefs, often associated with Blue Carbon ecosystems such as seagrass and mangroves, are some of the most diverse ecosystems in the world, harbouring an approximate 25% of all marine fish species (Spalding *et al*, 2001). Abu Dhabi hosts 34 species of hard coral, providing services that sustain livelihoods, enhance fish productivity, protect shorelines from storms and erosion, offer organisms of medicinal value and provide employment through recreational underwater activities. Coral reefs are mostly found in nutrient-poor waters with low sediments loads, a quality to which Blue Carbon ecosystems such as mangroves contribute.

The current scientific consensus is that coral reefs are net carbon dioxide emitters due to the calcification process that results in their calcium carbonate skeletons (Laffoley, D.d'A. & Grimsditch, G. 2009).

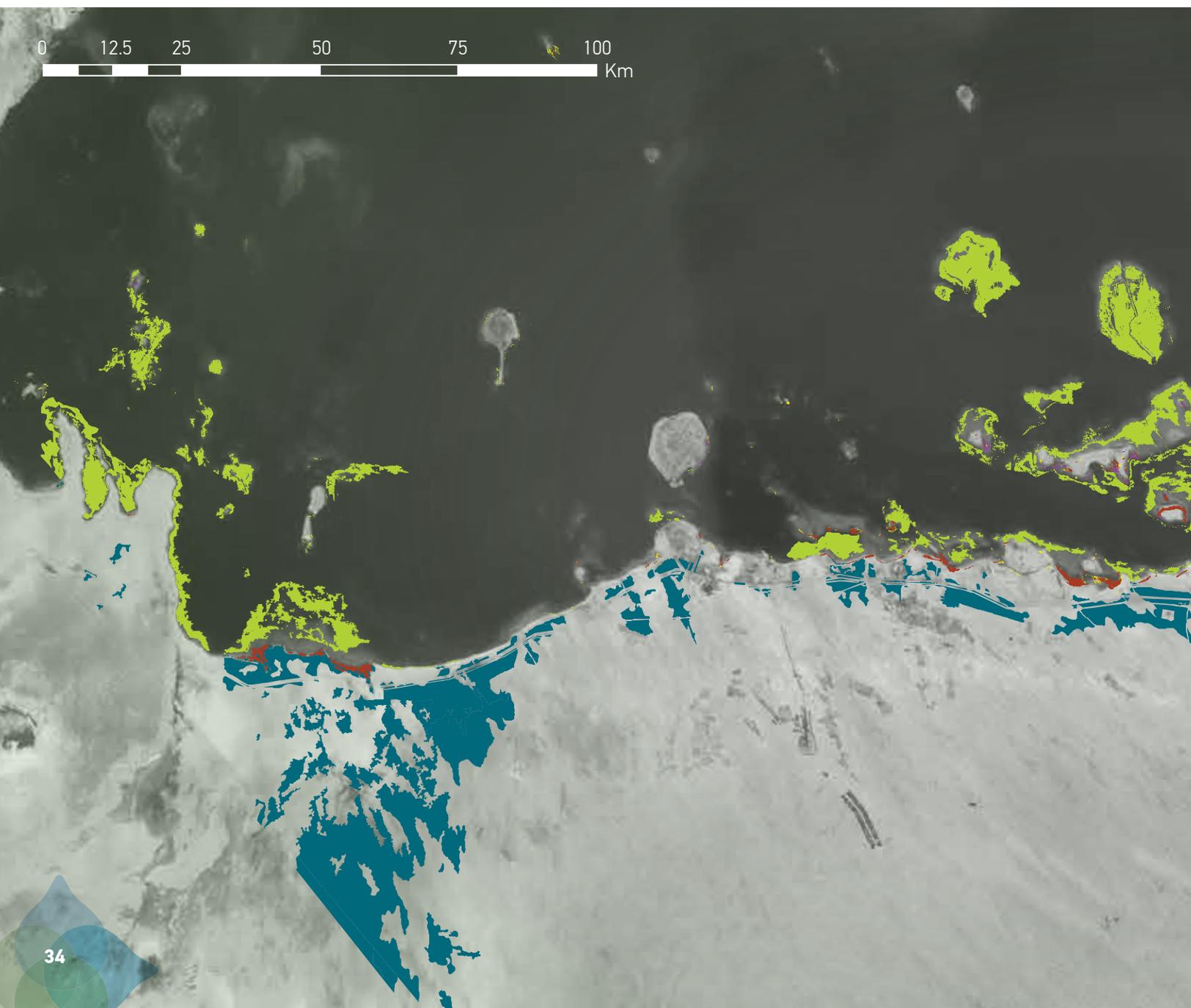
◆ The Extent of Blue Carbon Ecosystems

Determining the current extent

The extent of Blue Carbon ecosystems in Abu Dhabi were determined based on:

- EAD ecosystem layers derived from several datasets compiled in 2000 and subsequently updated and enhanced through stakeholder workshops conducted in 2012 – 2013;
- Field verifications undertaken during the Abu Dhabi Blue Carbon Demonstration Project covering 20 sampling areas and a total of 155 ground-truthing sites.

In total, the extent of mangroves (51 sites), salt marshes (25 sites), algal mats (10 sites), seagrass beds (34 sites) and coastal sabkha (18 sites) was recorded to provide an indication of the accuracy of the extent of these mapped ecosystems. The subsequent accuracy assessment undertaken concluded that coastal sabkha (83% accurate), seagrasses (77% accurate to approximately 3.5 metres depth) and mangroves (71% accurate) were mapped with

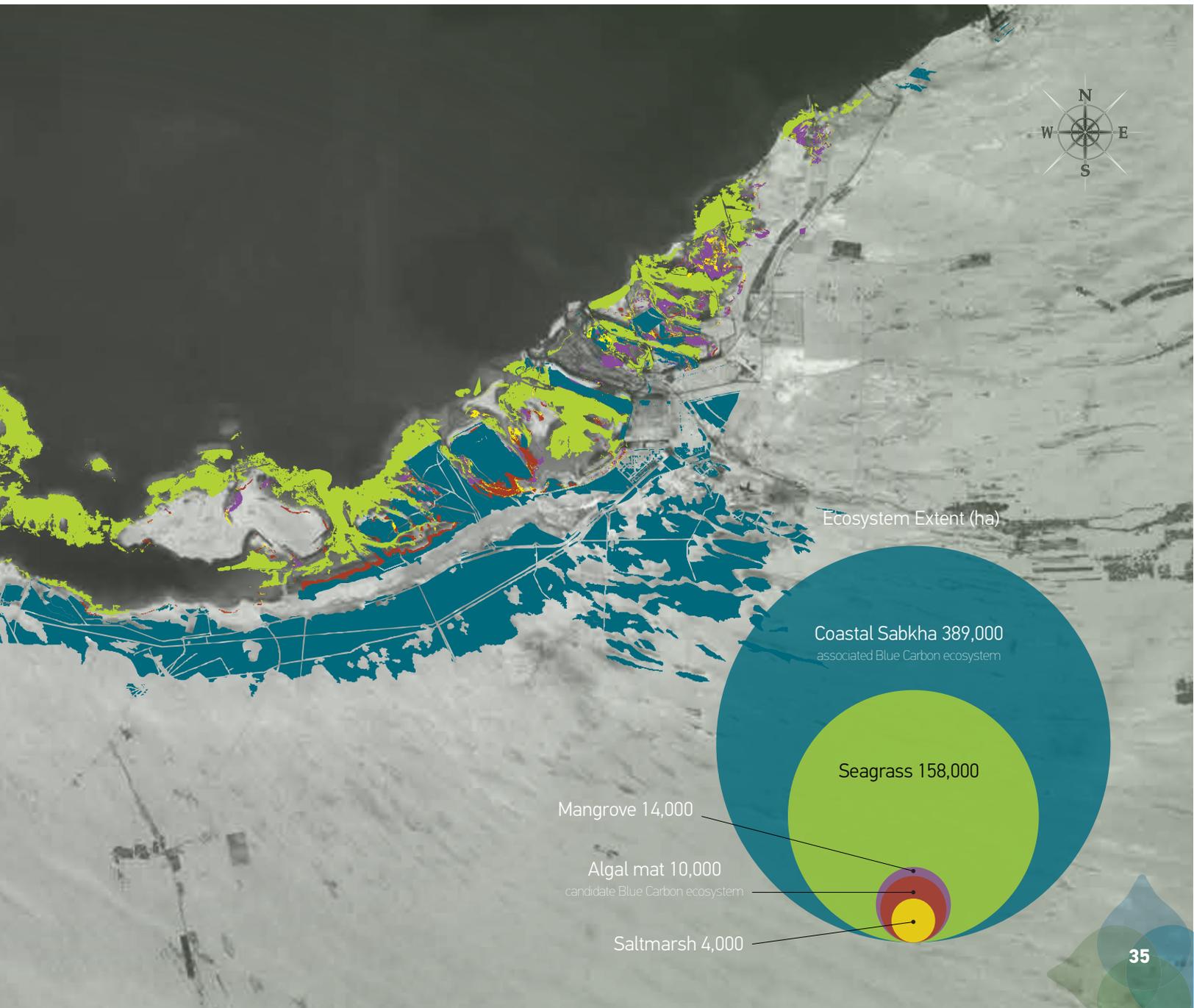


reasonable precision. Salt marsh habitats were however often misclassified (35% accurate) as mangroves, due to the very similar spectral signature given off by these habitats on satellite imagery. Algal mats (38% accurate) were also often misclassified as sabkha or salt marsh, which may reflect the natural succession of habitats over time (the imagery being from 2000 and the field-based sampling having taken place 12 years later). The overall accuracy of the maps was 40%. It is suggested that the significant time gap

between the mapping and the sampling is the main contributor to the discrepancy in remote and field based observations.

As a result of these studies, the overall extent of Blue Carbon Ecosystems in Abu Dhabi has been determined and is illustrated in Figure 4.

Figure 4 The extent of selected marine and coastal ecosystems in Abu Dhabi



Confirmation of the extent of relevant ecosystems

It is recognised that an ecosystem reclassification is currently being undertaken by EAD and that this will greatly enhance the spatial accuracy and associated carbon stock estimates. Key recommendations for areas of focus are:

- A renewed effort to map seagrass as their extent is likely to be significantly underestimated, particularly in deeper waters; and
- Additional sampling of sabkha and algal mats to improve the understanding of their contribution to carbon storage and the potential carbon lost when they are converted.

To support the need to validate existing maps through field analysis, the Abu Dhabi Blue Carbon Mapping Toolkit was developed. The Toolkit is comprised of:

1. A public online Assessment Tool allowing users to visualise the extent and associated carbon stocks of the blue carbon ecosystems of Abu Dhabi through a mapping interface;
2. An online Validation Tool (pre-approved and registered users) to remotely validate and edit the various habitat layers; and
3. An offline Validation Tool (pre-approved and registered users only) to validate and edit in situ, the various habitat layers using a tablet-based (iOS) interface.

The Abu Dhabi Blue Carbon Mapping Toolkit aims to enhance the spatial accuracy of baseline maps by providing an updatable online database and mapping platform. It further aims to support informed decision making through accessibility to important information for planning use.

This Online Assessment Tool has been designed for ease of use and provides a rapid overview of the approximate total carbon stock value and the location of Blue Carbon ecosystems in Abu Dhabi (Figure 5). By creating a polygon around an area of interest, information is provided about the ecosystem and associated carbon content within that area. Several of these areas of interest can be created and a report can be downloaded summarising the information displayed.

Figure 5 The Online Assessment Tool (www.bluecarbontoolkit.ae), one component of the Abu Dhabi Blue Carbon Mapping Toolkit, which provides users with a rapid overview of the approximate total carbon stock value and the extent of Blue Carbon ecosystems in Abu Dhabi.



The Value of Blue Carbon Ecosystems

A total of 47 sites were sampled across coastal Abu Dhabi (8 natural mangroves, 7 planted mangrove sites aged 3-15 years, 5 salt marshes, 5 intertidal coastal sabkha sites, 4 algal mats and 18 seagrass meadows), with replication at each site, to determine the carbon stock of these ecosystems.

Sampling locations (Figure 6) were selected to include the range of environment settings along the Abu Dhabi coast, from sheltered settings to offshore islands and in shallow and deep water for seagrass.



Blue Carbon ecosystems provide a myriad of valuable services to the Emirate and the well-being of its habitants.



◆ Carbon Values of Blue Carbon Ecosystems

Calculating carbon values

Replicate plots along transects were assessed for plant cover and sampled for above-ground biomass and soil carbon stocks (total, organic and inorganic) to depths up to 3 metres depending on the substrate. At intertidal sites, additional data were collected to inform a mechanistic understanding of carbon cycling including water table depth, pore-water chemistry, root zone redox potential, and soil respiration. High resolution location and elevation data were collected via Kinematic GPS and a mobile base station.

In the laboratory, above and below-ground carbon stocks were calculated through allometric equations. Carbon and nitrogen analyses were performed by an elemental analyzer.

Sampling and analysis followed scientifically recognized standards and procedures adapted to the Emirate's environmental context.

Resulting carbon values

Across the range of ecosystems studied, algal mats showed the highest combined above and below ground carbon stocks per hectare. Overall Blue Carbon stocks are estimated to be highest in seagrass, due to the large extent of the ecosystem.

Coastal sabkha, which is considered an associated ecosystem, holds significant amounts of carbon, highlighting the importance of well-informed planning of sabkha conversion.

Average total carbon stock in planted mangroves of different ages (79,92 tonnes/ha) was lower than that of natural mangroves (109,79 tonnes/ha). See figure 7 for details.

Overall, Blue Carbon ecosystems in Abu Dhabi are calculated to store over an estimated 41 million tonnes of carbon dioxide equivalent (CO₂ equivalent) within the soil and biomass, more than the Emirate's annual emissions from the oil and gas (26,4 million tonnes) or water and electricity (30,9 million tonnes) sectors¹.

¹Statistical Yearbook of Abu Dhabi 2013

Figure 6 Carbon stock sampling locations

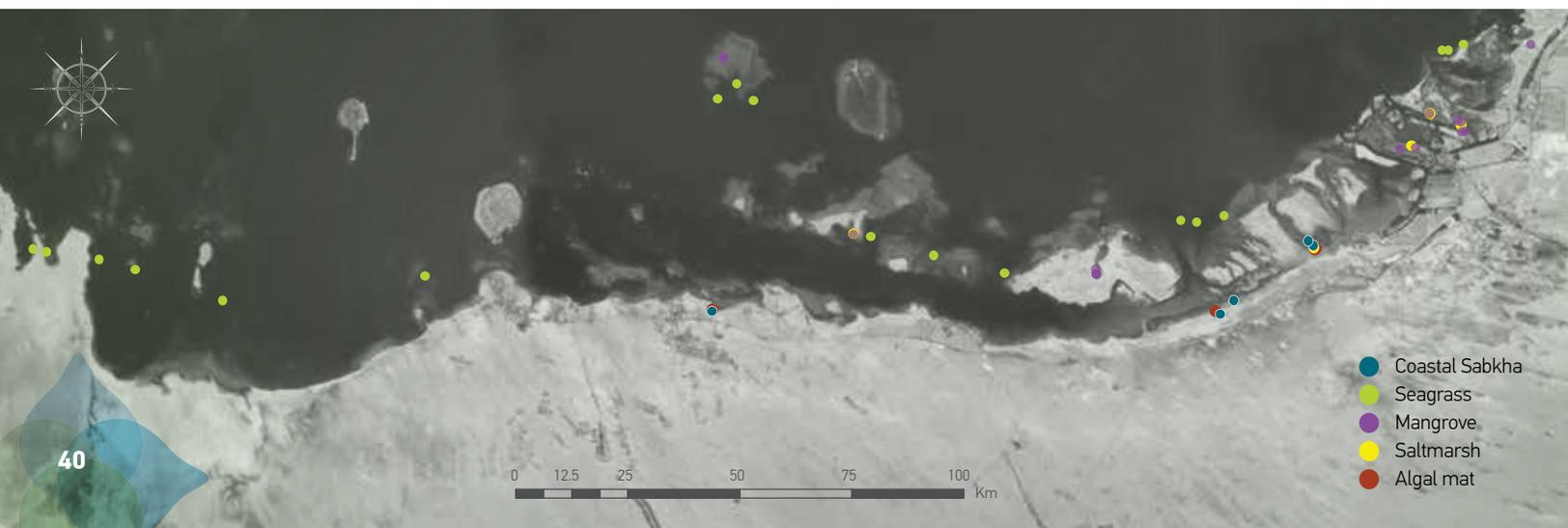




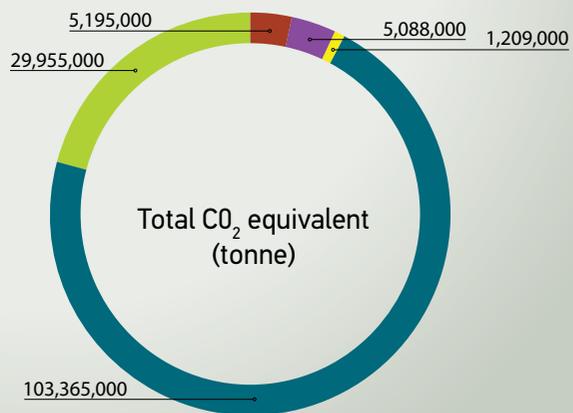
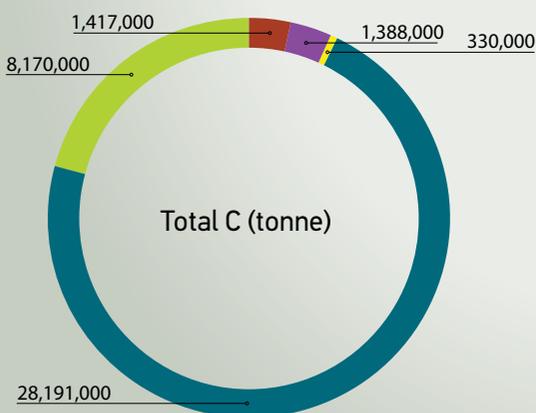
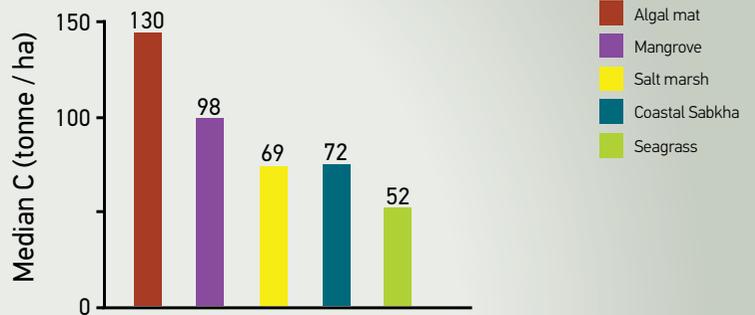
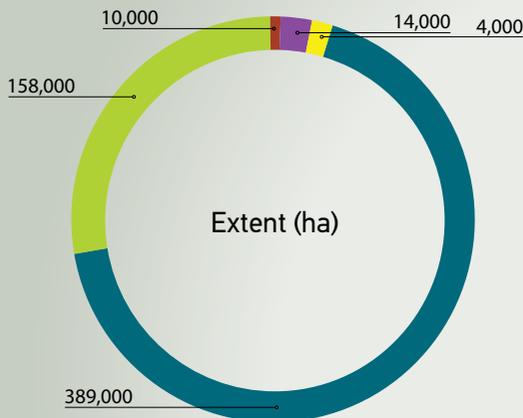
Figure 7 Total carbon stock of Abu Dhabi Blue Carbon (and candidate and associated) Ecosystems & Summary of carbon stock in Blue Carbon, candidate and associated ecosystems in Abu Dhabi.

How these values compare to non-arid regions

Compared with other dominantly non-arid regions of the world, carbon stocks per unit area in Abu Dhabi are at the low end of the range. Typical ranges for total carbon stock are

270-2,200 tonnes/ha (mangrove)	115-480 tonnes/ha (salt marsh)	50-380 tonnes/ha (seagrass)
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Although carbon values for Abu Dhabi's Blue Carbon ecosystems are at the low end of the global scale, this carbon stock is likely to be the largest of any natural ecosystem in the emirate and should these ecosystems be destroyed, significant carbon dioxide (CO₂) would be emitted.





◆ Putting a Financial Value on Blue Carbon Stocks

The Financial Feasibility Assessment of the Abu Dhabi Blue Carbon Demonstration Project provided a rapid assessment of the financial value of Blue Carbon in Abu Dhabi. Using the total extent of carbon stock estimates, Net Present Value (NPV) calculations have been used to convert the estimated future benefits and costs into current financial values. For comparative purposes discount rates² of 5% and 10% were used. Coastal sabkha and algal mats have been excluded from this analysis given the relative lack of data on these ecosystems in terms of ecosystem valuation.

The financial analysis is based on a number of critical assumptions:

- 50% of mangrove and salt marsh, and 20% of the much larger and more remote seagrass ecosystem would be protected beyond existing protected areas;
- The opportunity costs of protecting these ecosystems (US\$50,000/ha for mangroves and salt marsh, US\$50/ha for seagrass);
- The establishment and management costs of protection (US\$300/ha for all ecosystems except seagrass (US\$150/ha) for establishment and US\$100/ha/year for management);
- Mangrove afforestation is based on an average annual planting rate of 200 hectares, for a total of 5,000 hectares, over a 25-year period.

“Low”, “medium” and “high” carbon price scenarios of US\$2, US\$5 and US\$10 per metric tonne of carbon dioxide, and projections over a 25-year time horizon have also be incorporated into the analysis.

Based on these assumptions and estimations, under all the carbon price and discount rate scenarios, the net present value from the Blue Carbon ecosystems are very significantly negative, as the estimated discounted costs dramatically exceed the estimated discounted revenues. Even under the best-case scenario (US\$10 per metric tonne of carbon dioxide and a discount rate of 10%), the NPV for the protection of these ecosystems is negative US\$184 million. For mangrove afforestation, under the same best-case scenario, the estimated NPV is negative US\$58 million. The development of Blue Carbon ecosystems for financial return from developing carbon credits is therefore currently not considered as financially feasible in Abu Dhabi given prevailing market conditions.

² An interest rate used to bring future values into the present when considering the time value of money. 5% and 10% were used for the *Abu Dhabi Blue Carbon Demonstration Project*

◆ Ecosystem Services Values

Ecosystem services beyond carbon

Blue Carbon ecosystems provide valuable ecosystem services beyond carbon sequestration and storage. From a Blue Carbon perspective, these can be referred to as co-benefits to carbon.

Contributing to the beauty of the Abu Dhabi environment, these Blue Carbon ecosystems enhance human well-being in many ways at the local, regional, and global scale.

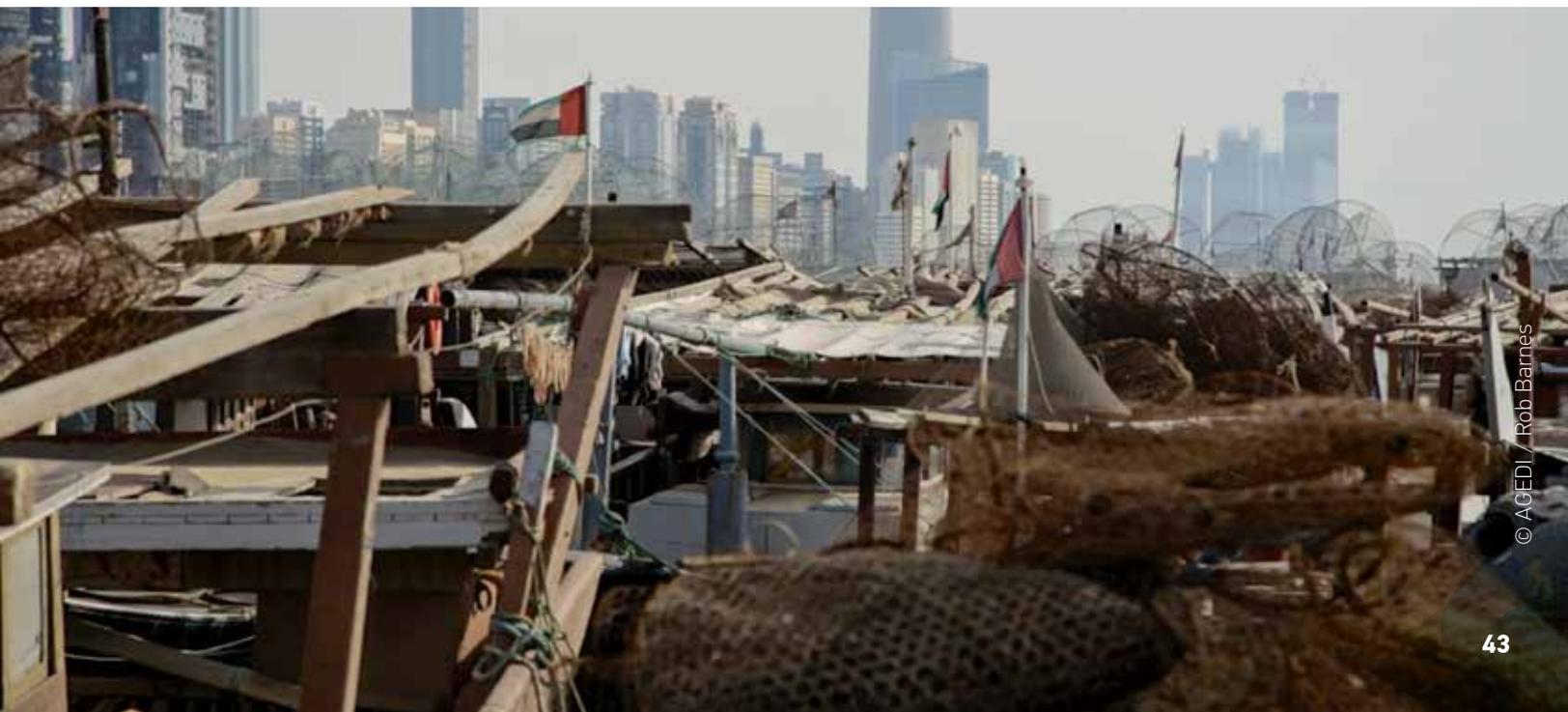
Locally, they contribute to maintaining livelihoods, providing food and recreation, reducing vulnerabilities to sea level rise, storm events and spread of disease.

At the regional level, they maintain the web of life in both the Gulf and the coastal areas in countries bordering it – an increasingly critical contribution given the rapid loss of these ecosystems.

On a global scale, understanding these ecosystems in terms of the benefits they offer and the ways they are threatened provides valuable knowledge and ground-truthing for the rest of the world.

Each of the Blue Carbon ecosystems in Abu Dhabi has a role in supporting the overall biodiversity, natural productivity and environmental health of the Emirate. Many perform pivotal roles, and their loss could create irreversible degradation and lost opportunities to take advantage of natural capital and its benefits. In particular, mangrove, seagrass, salt marsh, and to some extent algal mats play a role in maintaining coastal water quality. This in turn allows for recreational and tourism use, reduces costs of desalination, diminishes the chance for public health problems relating to exposure to toxins (via bathing or seafood) and prevents reductions in commercial fisheries.

Similarly, mangroves, seagrass, salt marsh and associated coral reefs offshore maintain shorelines and navigation channels, reduce chronic erosion and buffer land and property from storm surges. Mangrove and seagrass are particularly critical in supporting fisheries production, valued by commercial, traditional and recreational fishers alike. Collectively, Blue Carbon ecosystems play a key role in contributing to a healthy, aesthetically pleasing, and resilient coastal environment.



Calculating ecosystem services values

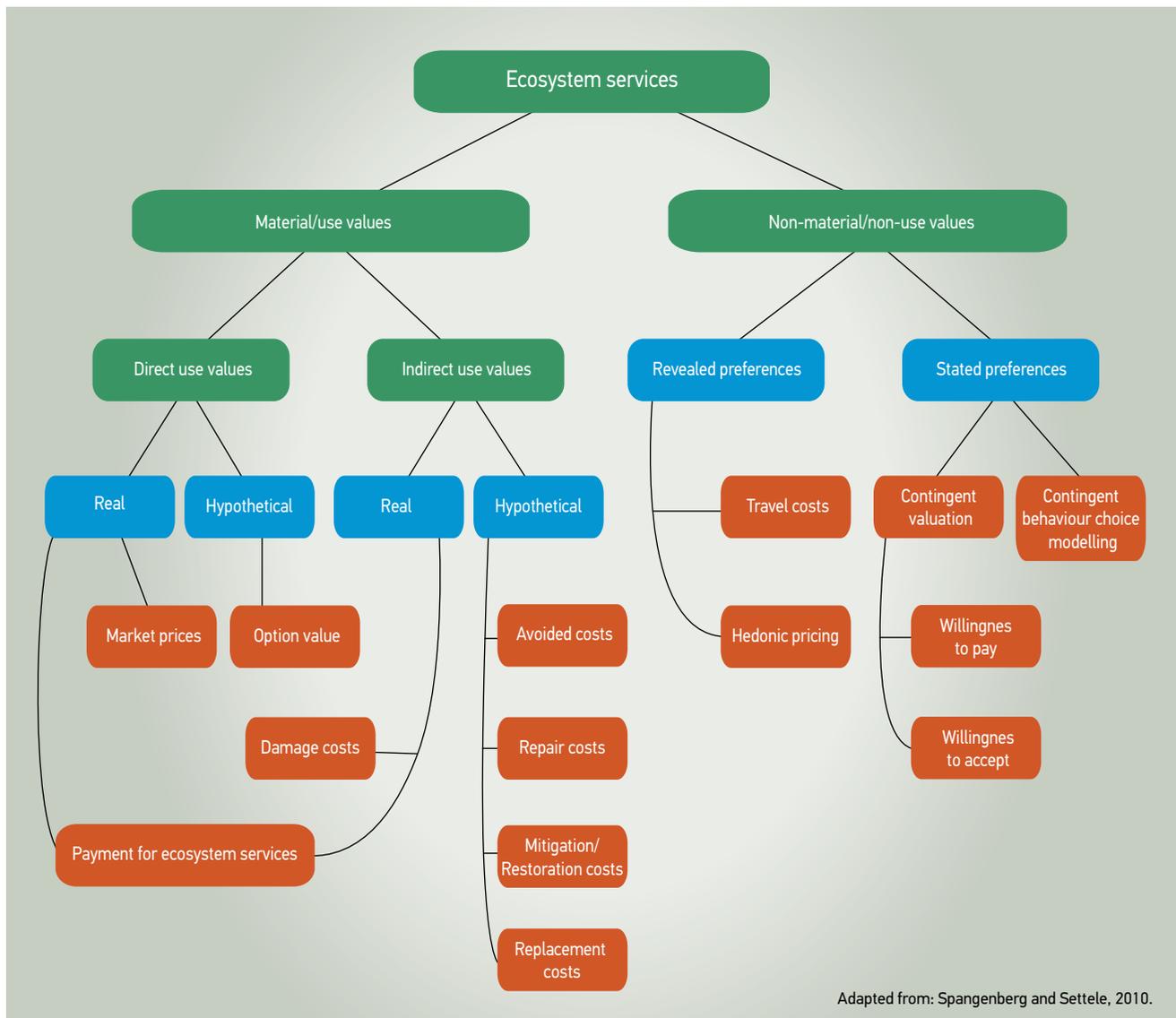
Using a rapid assessment protocol developed specifically for Abu Dhabi, the condition of a subsample of habitats within Blue Carbon ecosystems, focusing specifically on seagrass ecosystems, it was possible to identify areas of highest potential value (in terms of carbon being sequestered and other valuable benefits being provided as well).

As Figure 8 shows, values for ecosystem services can be derived that reflect either real or hypothetical value. In Abu Dhabi, as the number of valuation studies undertaken to date is limited, discussion of the value of Blue Carbon co-benefits is largely, at present, hypothetical.

Given that each Blue Carbon ecosystem and the ecological community it supports provides different services, the most valuable areas will be those that have a combination or mosaic of these ecosystems, especially those in relatively close proximity to assets of value. Five areas within Abu Dhabi possibly stand out in this regard. This is illustrated in Figure 9.

One additional and critically important consideration is that these ecosystems and the services they generate cannot be viewed in isolation (Figure 10). The delivery of goods and services from natural systems is dependent not only

Figure 8 Valuation framework (adapted from Spangenberg and Settele, 2010)



Adapted from: Spangenberg and Settele, 2010.

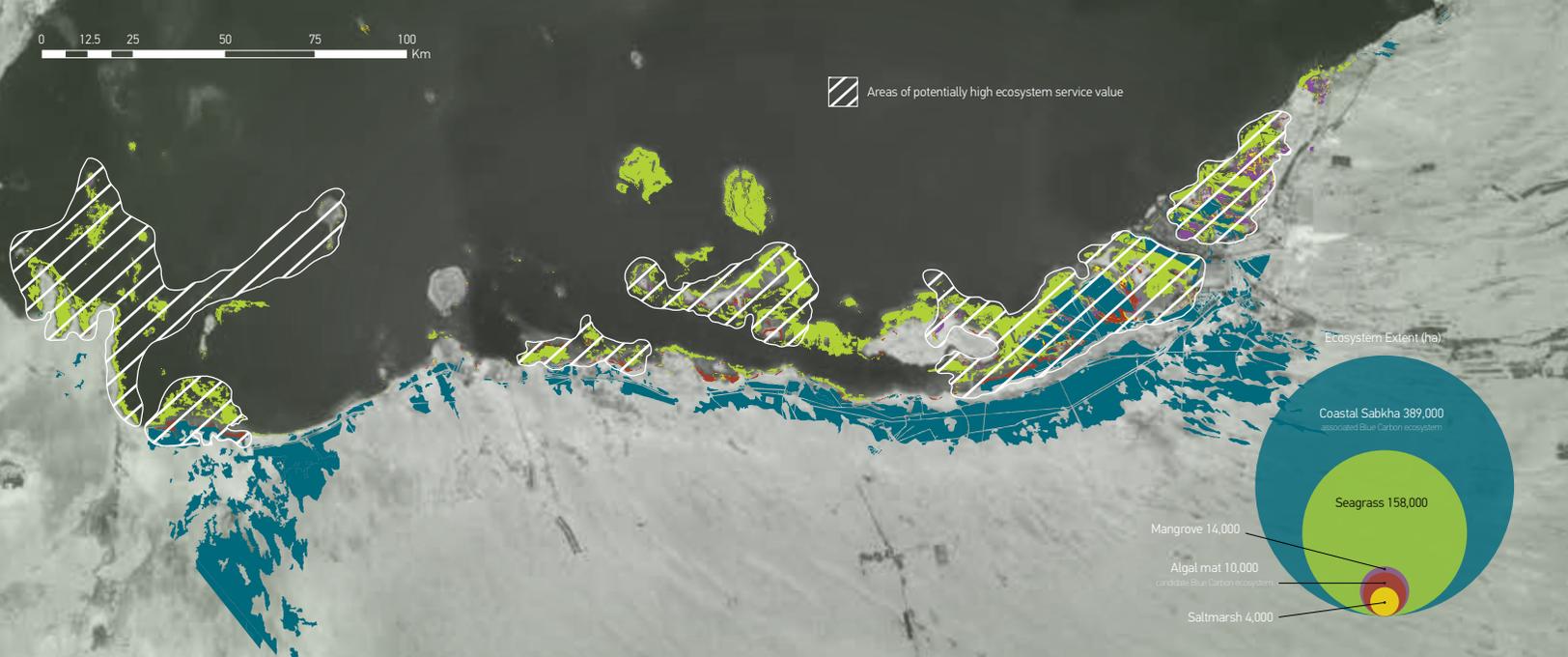


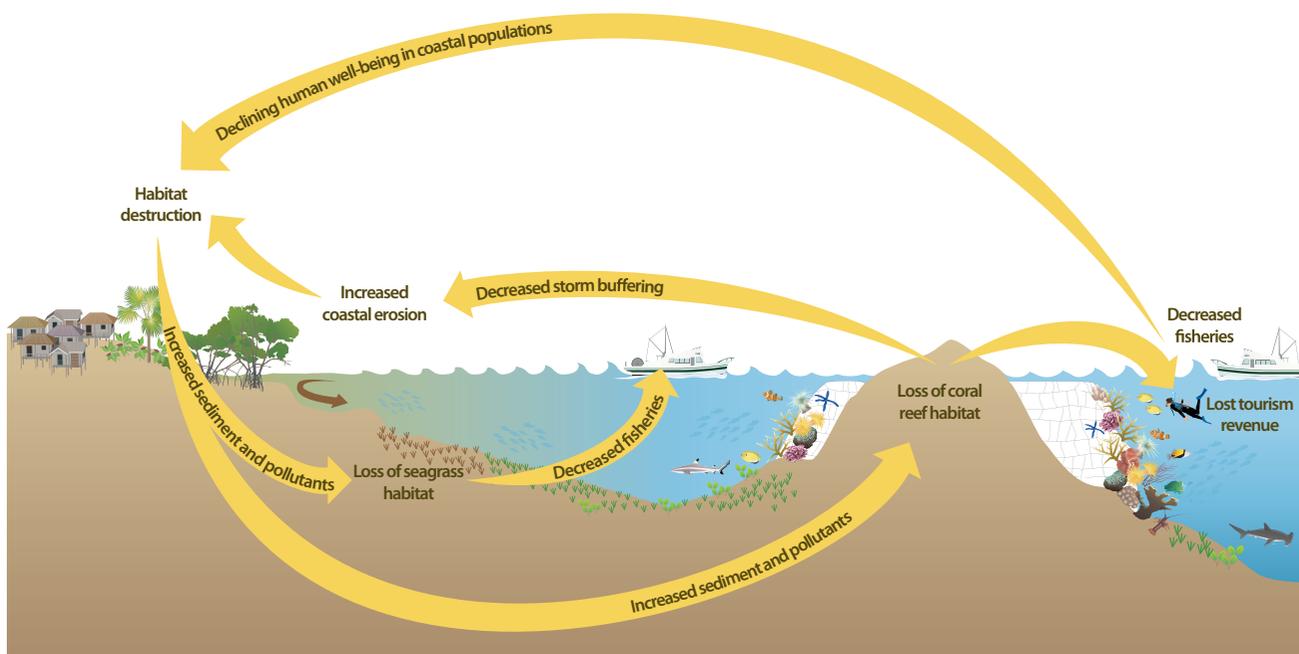
Figure 9 Estimated areas of highest concentration of Blue Carbon co-benefits arising from Blue Carbon and candidate and associated ecosystems

on the condition of the ecosystem but also its functional linkages to associated ecosystems.

For mangrove forests to continue to provide nursery grounds for commercially and recreationally important fish populations, the two-way linkages between mangrove and offshore ecosystems such as seagrass beds, coral reefs and offshore landform features must be maintained. Similarly, offshore systems such as coral reefs create the sheltered conditions necessary for inshore systems such as seagrasses to

thrive; while mangroves and salt marsh act to trap sediments and nutrients that might smother or degrade seagrasses. When marine and coastal spatial planning is undertaken or updated in Abu Dhabi, it will therefore be important to consider the full suite of services, their values, and the impacts that human activities in any sector will have on continued delivery of these services. This is especially true as climate change adds to the spectre of cumulative impacts, and threatens to undermine the resilience of all marine and coastal ecosystems, in the Emirate and in the Arabian Gulf region.





Putting a financial value on all ecosystems services

Comparing potential financial benefits with potential costs, the total economic value can be calculated. As previously discussed, financial benefits, using low end, conservative figures extrapolated from other studies from elsewhere in the world, determined the \$US value of annual per hectare service value across all ecosystem services. The costs, again in relation to carbon values, were in relation to the cost of protecting Blue Carbon ecosystems from conversion.

Studies identifying market and non-market values of some of these ecosystems (mangrove, seagrass and salt marsh in particular) helped identify what these vital areas are providing in terms of overall value.

Based on economic studies undertaken on these ecosystems in other parts of the world, the existing Blue Carbon ecosystems in Abu Dhabi likely provide services worth hundreds of millions of US dollars annually through shoreline stabilization, support to fisheries, direct recreational use, and water quality

maintenance. Other non-market values such as support to a wide array of biodiversity, regulating services that maintain planetary and regional balances, and cultural, spiritual, and aesthetic values must however also be considered.

While the true economic values of these Blue Carbon ecosystems are still being determined (and will need to be verified by future ecological and economic studies), the opportunity costs of losing these ecosystems to degradation or development are undeniably significant. This is especially true since most Blue Carbon ecosystems are difficult if not impossible to restore, with full restoration resulting in high costs over long time frames.

Encouragingly, when the associated other ecosystem services, in combination with the carbon, are accounted for, the estimated total combined NPV for these bundled ecosystem services ranges from approximately \$US1.66 billion to \$US1.71 billion, with a discount rate of 10%, and from \$US2.57 billion to \$US2.63 billion, with a discount rate of 5%, as the carbon price varies from \$US2 to \$US10 per metric ton of carbon dioxide (CO₂).

There are important caveats that must

Figure 10 Recognizing ecosystem services from Blue Carbon ecosystems needs the recognition of ecosystem connections (UNEP, 2011)

be kept in mind, however with the approach to putting a monetary value on ecosystem services. Using proxy values from other parts of the world via benefits transfer may be misleading. As a result of the extreme environmental conditions and anthropogenic impacts in the Gulf region, both biodiversity and productivity are relatively low in these ecosystems compared to other marine systems elsewhere in the world. Market values are not directly comparable to other parts of the world where fisheries are more productive, where eco-tourism is a greater factor in economic development or where coastal communities and properties are at greatest risk from flood-related inundation, storm surges caused by cyclones or hurricanes, and/or tsunamis.

Although these figures are based on numerous assumptions and studies for enhancing their robustness recommended, they do suggest that economic benefits could be quite significant.

They also highlight the prime importance of considering Blue Carbon ecosystems in a holistic manner and the central part that ecosystem services need to plan in determining environmental management priorities.



Project Outcomes

The Abu Dhabi Blue Carbon Demonstration Project shows that incorporating the values of Blue Carbon and related ecosystem services into Abu Dhabi Emirate's coastal and marine management policies is warranted and feasible and will help sustain the services Blue Carbon ecosystems provide for future generations and a growing Abu Dhabi.

The Abu Dhabi Blue Carbon Demonstration Project has enhanced local capacity to better manage Blue Carbon ecosystems and can provide lessons learned for regional and international replication and up-scaling.



Science based management will help ensure that Abu Dhabi's residents enjoy Blue Carbon ecosystems, now and in the future.



◆ Key Project Findings

- Abu Dhabi Emirate is a unique place that has developed, and continues to develop, rapidly over the last few decades. At the same time, it recognises the value of ecosystems and takes significant efforts to conserve them. As such, it can serve as an example for similarly developing places globally.
- The Emirate, with its highly saline waters, high temperatures and arid coastal environment, may provide valuable knowledge for some parts of the world in the future of climate change.
- Abu Dhabi's Blue Carbon ecosystems store significant amounts of carbon that would be emitted upon their degradation.
- Carbon stocks of Abu Dhabi Emirate's Blue Carbon ecosystems are likely to be the largest of any ecosystem in the Emirate. On a global scale, however, per area values are on the low end of the spectrum.
- Blue Carbon ecosystems in Abu Dhabi Emirate include mangroves, salt marsh, seagrass and potentially algal mats. Coastal sabkha was also explored and is considered an associated Blue Carbon ecosystem storing, albeit not sequestering, carbon. Research on algal mats and coastal sabkha has discovered unexpected results, emphasising the need for cautious action in light of science gaps, and the need to further increase knowledge on Blue Carbon ecosystems.
- Blue Carbon ecosystems and associated biodiversity provide a broad spectrum of services beyond carbon sequestration and storage, including shoreline buffering and erosion control, water quality maintenance, support to fisheries (in particular recreational fishing), tourism and recreation. Cultural values are also recognised as highly important.
- Blue Carbon stocks in Abu Dhabi are likely to be insufficient for the generation of carbon credits. Further local challenges include questions regarding additionality and opportunity costs to ecosystem conservation.
- The combined value of Blue Carbon ecosystems' services, including carbon sequestration and storage, coastline protection, habitat provision and water purification, is significant and merits inclusion into conservation and management activities and strategies, particularly for future marine spatial planning and financial planning frameworks.
- The project's engagement with Abu Dhabi stakeholders revealed the institutional and policy frameworks to be adequate to integrate and mainstream Blue Carbon conservation efforts. Opportunities for efficient implementation lie in institutional cooperation.
- The project has significantly increased knowledge in Abu Dhabi, including among stakeholders, as well as regionally and globally, particularly on Blue Carbon ecosystems in arid climates, an aspect of Blue Carbon science that has not been the emphasis of previous research. Involving local scientists as well as international observers during the project has contributed to the longevity of project's activities, particularly to the transfer of scientific knowledge.

◆ Key Recommendations Based on the Key Findings

- Further efforts should be made to map the Emirate's Blue Carbon ecosystems, and can be based on the tools developed as part of the project. This would include considerations of the Emirate's rapidly changing coastlines, improvements in remote sensing, and the project's finding that seagrass habitat extends deeper than previously indicated.
- Further research and analysis on the economic costs and benefits of protecting the Emirate's coastal and marine ecosystems would enable Abu Dhabi to determine the most cost effective allocation of funds for the protection and management of these ecosystems.
- The project has demonstrated that a scientific approach to environmental management can facilitate and shape effective policy decisions. In relation to Blue Carbon ecosystems in Abu Dhabi, the scientific findings lead the project to recommend:
 - Natural mangroves capture and store more carbon, and are likely to deliver more ecosystem services, than recently planted mangroves. Their conservation should therefore be a priority.
 - Excavation into coastal soils has the potential to release historically accumulated carbon stocks. It is recommended that potential emissions be determined within Environmental Impact Assessments undertaken for these activities, also in the context of planting mangroves.
 - The large extent of seagrass found in the Emirate is a habitat for significant populations of dugongs and sea turtles. Prior to permitting potentially detrimental activities, such as discharges to the marine environment, impacts on seagrass should be considered.
 - The continuous provision of important ecosystem services would benefit from an adoption of Ecosystem-based Management, including Marine Spatial Planning, taking into account the importance of ecosystem integrity, connectivity and resilienc. It is recommended to further strengthen the scientific basis for such approaches, particularly site-specific evaluations.
- Stakeholder engagement has shown considerable support for the establishment of a specialised "compensation fund" which developers in the coastal and marine zone would be obliged to contribute to as part of a compensation agreement and all are encouraged to contribute to as part of their Corporate Social Responsibility. The Fund would allow support to priority activities of the regulatory authority on Blue Carbon ecosystems management.
- The project has stimulated regional interest in the application of Blue Carbon and the valuation of ecosystem services, and the establishment of a regional working group on Blue Carbon is recommended. This body could further study Blue Carbon ecosystems, share experience and expertise and collectively advance the concepts' regional implementation.
- Lessons learned from the Abu Dhabi Blue Carbon Demonstration Project will be highly valuable for the international application of Blue Carbon and related ecosystem service projects. The Global Environment Facility's (GEF) Blue Forests Project, which the Abu Dhabi project is a key part of, will serve as a platform for further international uptake of the project's experiences.
- While these outcomes have been significant, they are recognised as a first step in overall ecosystem based management in Abu Dhabi. It is hoped that the success of this demonstration project subsequent be replicated in other ecosystems throughout the emirate and a holistic approach to Ecosystem-based management be pursued to the benefit of all.

These factors represent the point of departure for a policy response that aims to conserve restore and manage these ecosystems wisely for future generations. A framework for action builds upon these findings and is further shaped by Abu Dhabi's ongoing efforts to turn environmental vision into action, its institutional context for action, and its proactive stance on Blue Carbon ecosystems for the benefits of Abu Dhabi, the region, and the world.

◆ Vision Into Action

The Emirate's commitment to environmental sustainability is reflected in its vision to protect and conserve the environment for people's well-being and a better life for all. The commitment to environmental protection by His Highness the late Sheikh Zayed bin Sultan Al Nahyan is one of his enduring legacies in the UAE and the Gulf region.

The translation of this vision into action has strong links with a Blue Carbon policy. Many of the priority areas of the Abu Dhabi Environmental Strategy (2008-2012) such as environmental sustainability, biodiversity management, environmental awareness, and environmental information, have clear intersections in one way or another with priorities that would be at the centre of any Blue Carbon policy for the Emirate. This is an important point of departure in that it suggests that a basic framework is already in place for effective action to protect and sustainably manage Blue Carbon ecosystems. What is needed is to work collaboratively across Abu Dhabi institutions to effectively build upon this framework and ensure that Blue Carbon issues are integrated with current actions, and vice versa.

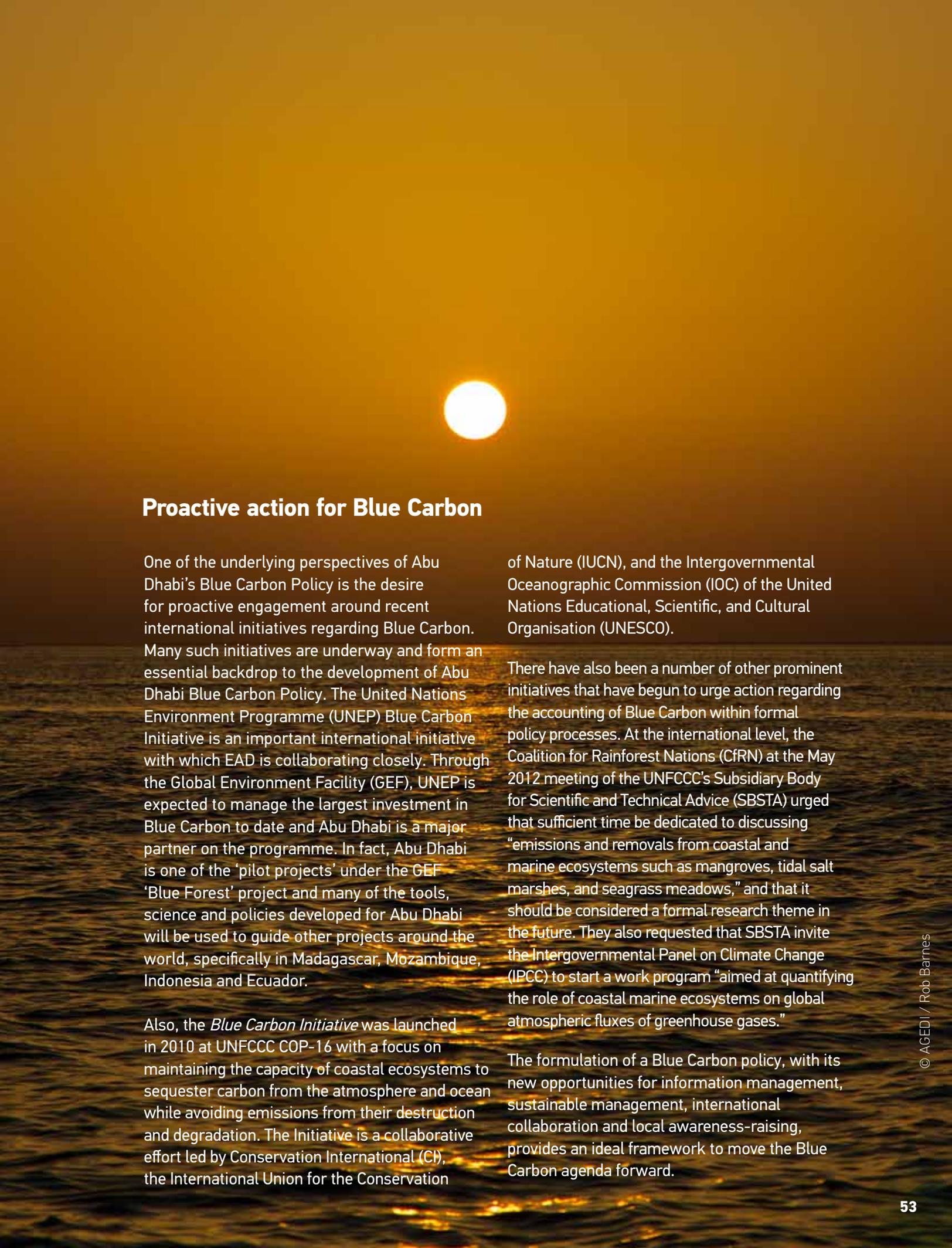
Institutional context for action

More than 10 federal laws and 20 Emir decrees relating to the marine and coastal environment have been created since 1971 (AGEDI, 2008). At the Emirate level, the Abu Dhabi Environment Strategy (2008-2012), Interim Coastal Development Guidelines, Urban Planning Vision 2030, Environment Vision 2030, and the 2009 Maritime Strategy contain policy directions that affect Blue Carbon resources.



First President of the United Arab Emirates,
the late H.H. Sheikh Zayed bin Sultan Al Nahyan

Collectively, the range of institutions and their potentially overlapping activities, roles, and responsibilities for implementing laws, decrees, and vision documents suggest that effective institutional coordination will be central to the success of any Blue Carbon policy. While this collective institutional framework offers guidance for preserving marine biodiversity, conservation of endangered species, protection of marine water quality, and sustainable management of fisheries, it does not account for the full range of ecosystem services provided by Blue Carbon resources, nor the global environmental benefits they offer. Stable institutional coordination arrangements that can accommodate an expanded focus on Blue Carbon will help to resolve potentially competing priorities that may affect the future health of Blue Carbon ecosystems.



Proactive action for Blue Carbon

One of the underlying perspectives of Abu Dhabi's Blue Carbon Policy is the desire for proactive engagement around recent international initiatives regarding Blue Carbon. Many such initiatives are underway and form an essential backdrop to the development of Abu Dhabi Blue Carbon Policy. The United Nations Environment Programme (UNEP) Blue Carbon Initiative is an important international initiative with which EAD is collaborating closely. Through the Global Environment Facility (GEF), UNEP is expected to manage the largest investment in Blue Carbon to date and Abu Dhabi is a major partner on the programme. In fact, Abu Dhabi is one of the 'pilot projects' under the GEF 'Blue Forest' project and many of the tools, science and policies developed for Abu Dhabi will be used to guide other projects around the world, specifically in Madagascar, Mozambique, Indonesia and Ecuador.

Also, the *Blue Carbon Initiative* was launched in 2010 at UNFCCC COP-16 with a focus on maintaining the capacity of coastal ecosystems to sequester carbon from the atmosphere and ocean while avoiding emissions from their destruction and degradation. The Initiative is a collaborative effort led by Conservation International (CI), the International Union for the Conservation

of Nature (IUCN), and the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific, and Cultural Organisation (UNESCO).

There have also been a number of other prominent initiatives that have begun to urge action regarding the accounting of Blue Carbon within formal policy processes. At the international level, the Coalition for Rainforest Nations (CfRN) at the May 2012 meeting of the UNFCCC's Subsidiary Body for Scientific and Technical Advice (SBSTA) urged that sufficient time be dedicated to discussing "emissions and removals from coastal and marine ecosystems such as mangroves, tidal salt marshes, and seagrass meadows," and that it should be considered a formal research theme in the future. They also requested that SBSTA invite the Intergovernmental Panel on Climate Change (IPCC) to start a work program "aimed at quantifying the role of coastal marine ecosystems on global atmospheric fluxes of greenhouse gases."

The formulation of a Blue Carbon policy, with its new opportunities for information management, sustainable management, international collaboration and local awareness-raising, provides an ideal framework to move the Blue Carbon agenda forward.

◆ Further Detail

The details of the project outcomes are presented in a series of project reports. To achieve a comprehensive understanding of the project it is recommended that all project reports be read in their entirety.

The project reports (each with its own Executive Summary) include:

- **Baseline Assessment Report**
This includes the details of how baseline Blue Carbon stock was quantified in Abu Dhabi, as well as results, analysis and recommendations for the future management and protection of these ecosystems.
- **Spatial Data Assessment Report**
This includes details and results of an assessment of spatial coverage of Blue Carbon ecosystems in Abu Dhabi, and how these can be viewed, assessed and updated through the Abu Dhabi Blue Carbon Mapping Toolkit.
- **Ecosystem Services Assessment Report**
This includes a description of the further Blue Carbon ecosystems' services, and how this relates to their condition, their potential values, the importance of ecosystems' integrity as well as present threats, which could be addressed by focused management.
- **Financial Feasibility Assessment Report**
This includes a rapid financial feasibility assessment of carbon credits and ecosystem services valuation, both individually and in combination, and a description of the financial perspective to the three recommended specific Options including a specialized compensation fund.

These reports are supported by:

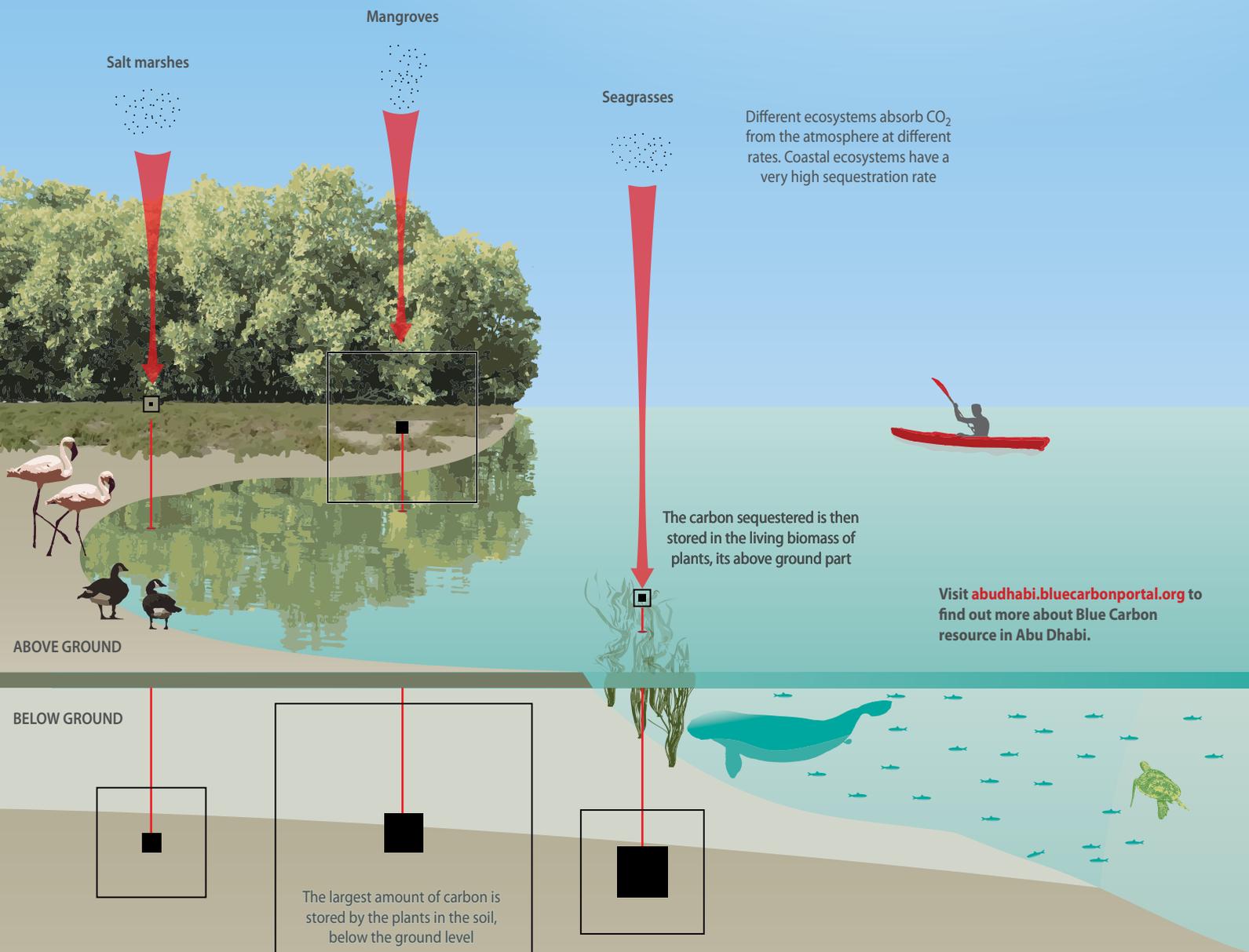
- **Abu Dhabi Blue Carbon Mapping Tool**
This includes an online assessment tool, which illustrates the latest ecosystem information and associated carbon stock data at www.bluecarbontoolkit.ae
- **Building Blue Carbon Projects – An Introductory Guide**
This outlines the approaches and components of existing Blue Carbon projects and initiatives, aiming to facilitate the development of further projects in this field.

Additional project publications include:

- **Blue Carbon Infographic:** Illustration of the relative sequestration and storage of carbon in global Blue Carbon ecosystems, and their overall value in monetary terms.
- **Edible Postcard:** A summary of the valuable services provided by Blue Carbon ecosystems.
- **Regular Newsletters:** Project updates and video footage.
- **Project Website:** Please visit: abudhabi.bluecarbonportal.org

Figure 11 Blue Carbon Infographic. Illustration of the relative sequestration and storage of carbon in global Blue Carbon ecosystems, and their overall value in monetary terms.

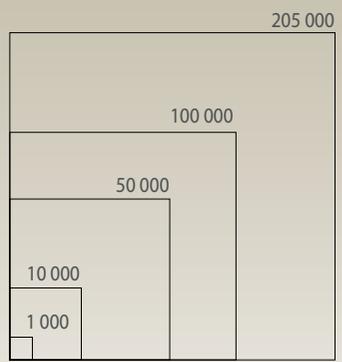
Blue Carbon ecosystems provide a highly valuable service by sequestering and storing atmospheric carbon



Visit abudhabi.bluecarbonportal.org to find out more about Blue Carbon resource in Abu Dhabi.

Organic carbon stored
Tons of Carbon per Km²

Higher estimate
Lower estimate



Ecosystem service value Thousand US Dollars per hectare per year



Sources: Schile, L., *et al.*, in preparation, Carbon stocks in arid coastal environments. For submission into *Ecosystems*; Murray, B., C., *et al.*, Green Payments for Blue Carbon Economic Incentives for Protecting Threatened Coastal Habitats, Nikolas Institute, Duke University, 2011.

Policies and Practices for Blue Carbon Ecosystems

Using the key management priorities as a foundation, and taking into consideration the framework for action, the Abu Dhabi Blue Carbon Demonstration Project explored various ways in which this could be achieved including: the management and policy frameworks and the generation of funds from carbon offsets.



Recognising the value of Blue Carbon ecosystems for Abu Dhabi's well-being has important implication for planning a future Emirate.



◆ Recommended Priority Options

The improved understanding of carbon storage and sequestration, the extent of these ecosystems in Abu Dhabi and the other ecosystem services that they provide, as well as the respective values of these, as a result of the Abu Dhabi Blue Carbon Demonstration Project forms the basis of recommended Abu Dhabi Blue Carbon Policy Actions. It also represents a broad range of views taken from the Emirate-wide stakeholder consultative process that took place from April to September 2013. Collectively, these have provided clear direction regarding the dominant themes that should characterize the Policy.

At the broadest level, the purpose of the Policy is to build conservation of Blue Carbon ecosystems into the daily business of the Emirate, within the broader framework of environmental management. It seeks to provide those responsible for administering relevant activities with clear guidelines and policy direction to ensure that Blue Carbon ecosystems in Abu Dhabi including

mangroves, seagrasses, salt marshes and algal mats as well as associated Blue Carbon ecosystems including coastal sabkha, are managed in a way that accounts for their local and global environmental benefits.

Ten Blue Carbon Policy Actions were recommended to increase and sustain the productivity and integrity of Blue Carbon ecosystems within the Emirate of Abu Dhabi and beyond, through supporting the management of Blue Carbon ecosystems in Abu Dhabi through activities that improve management practices, develop enhanced knowledge networks, promote coordinated action across emirate-level institutions, build local capacity, and support global actions. These Policy Actions recommended will take some time to implement fully. As the need for the management of these Blue Carbon ecosystems is immediate and the rate of development in the Emirate high, three non-exclusive options are suggested for implementation to ensure the integrity of these ecosystems in the interim.



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Three main options for supporting Blue Carbon ecosystems

1. The development of a Specialised Fund

A Specialised Fund is recommended to help streamline existing environmental permitting and compensation requirements, improve economic linkages, and enhance stakeholder engagement. At present, for example, the existing compensation policy requires twice the area of mangroves that are removed by development activities to be planted with mangrove seedlings. The Abu Dhabi Blue Carbon Demonstration Project has determined that, based on science, this may need further consideration as:

- Mature mangroves sequester and store relatively more carbon than planted mangroves, and during their excavation carbon dioxide would be released;
- Overall Blue Carbon ecosystem service value provision is assumed to increase in parallel with carbon.

It is proposed that developers would pay a compensation fee into a Specialised Fund. This would allow the regulatory authority to prioritise marine and coastal conservation and restoration activities and seek to optimize the outcomes. In the future the Specialised Fund could also be developed to include the support for the concepts of habitat banking, biodiversity offsets, and system benefits change models.

It is also recommended that the design of the Specialised Fund be flexible in order to integrate other forms of support or additional finance in the future.

These include the potential for obtaining such support from Corporate Social Responsibility (CSR) and philanthropic contributions, and potentially also from the legal system where fines or other financially punitive actions taken against those who violate environmental legislation could be provided to the Fund.

Ultimately however, it will be important that this Specialised Fund extend beyond Blue carbon ecosystems to include all ecosystems in Abu Dhabi. If this approach is not taken there is an inherent risk that some ecosystems may be protected in favour of others, and as a result the fine balance between, and the integrity of, the environment could be compromised.

In recognition of the evolving understanding of the importance of Blue Carbon ecosystems, *Abu Dhabi's Blue Carbon Policy* aims to provide those responsible for administering relevant activities with clear guidelines and processes to ensure that mangroves, salt marshes, seagrasses, and algal mats in coastal sabkha areas are managed in a way that also accounts for their global and local environmental benefits within the context of the Specialised Fund.

Moving forward, one of the most important considerations is that the key stakeholders regarding the proposed analysis, design, establishment and management of the Specialised Fund itself, are fully engaged in the process within an effective collaborative approach and working group to move the process forward.

2. Strengthening local Ecosystem-based Management to support Ecosystem Services including Blue Carbon

To fully capitalise on these findings and ensure that important ecosystem services are enhanced and protected, it is recommended that Abu Dhabi undertake four important lines of research:

1. Confirm the potentially most valuable areas as a priority, and eventually focus planning and conservation efforts to them, safeguard valuable ecosystem services from impacts, and to start on a systematic assessment of ecosystem service 'hotspots'.
2. Fully determine the condition of Blue Carbon ecosystems, using widespread application of the Ecosystem Services Assessment protocol under a statistically robust sampling regime. The purpose of this would be to better understand which Blue Carbon ecosystems are delivering maximum services, and for those Blue Carbon ecosystems that are degraded, allow identification of the root causes or drivers behind threats.
3. Enhance the understanding of the hydrology and oceanography of Abu Dhabi's nearshore waters and coastal systems, including flows through mangrove channels, sea level changes, and patterns of inundation. This is necessary to be able to model responses to climate change, as well as predicted outcomes resulting from restoration, protection, or – alternatively – ecosystem loss. It is suggested that such applied research be focused first and foremost on the areas estimated to support the greatest concentration of ecosystem services (as identified in the ecosystem services assessment).
4. Survey stakeholders and the populace of Abu Dhabi to appraise the perceived value of marine goods and services, including recreational and cultural values attached to coastal landscapes/seascapes, the value of hazard risk minimisation for developers, insurers, and investors, and the public health values associated with maintaining ecosystem health and minimising disease.

Improving the robustness of information relating to ecosystem services in this way will facilitate enhanced planning, in which trade-offs can be evaluated and outcomes predicted. Reliable ecosystem services information will also allow bona fide adaptive management, through which natural capital can be optimally safeguarded (Figure 12). Such adaptive management will both increase efficiency and reduce costs of management and, importantly allow for greater resilience in the face of climate change and other global scale variability to come (Beatley, 2009).



Present

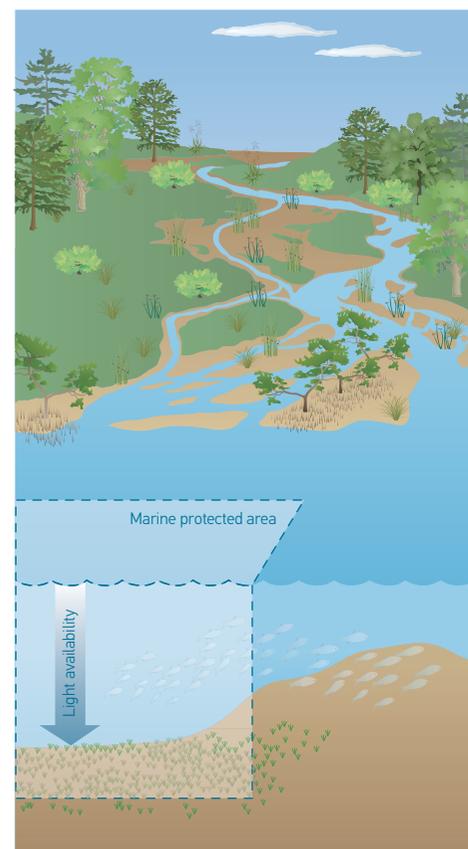


Figure 12 Valuation framework (UNEP, 2011)



3. International Voluntary Reporting

Reporting Greenhouse Gas (GHG) emissions is part of the UAE's international commitment under the United Nations Framework Convention on Climate Change (UNFCCC).

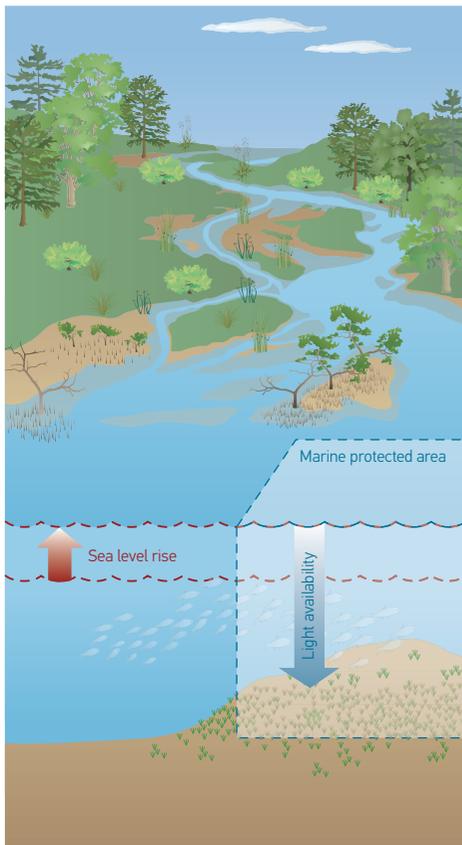
Blue Carbon inventory development is important because it represents the starting point for any subsequent quantification of the carbon benefits associated with potential mitigation actions. These actions may include, for example, reducing emissions from Blue Carbon habitat loss/ degradation, protection/conservation of Blue Carbon biomass stocks, sustainable management of Blue Carbon ecosystems, and enhancement of carbon stocks

The 2006 IPCC Guidelines for National GHG Inventories do not provide specific guidance for the estimation and reporting of anthropogenic GHG emissions from land use change in mangrove forests, salt marshes, seagrasses, or other Blue Carbon ecosystems. However, UNFCCC SBSTA 39 encourages Annex 1 countries to use the "2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (Wetlands Supplement)" in preparing national inventories for 2015.

Specifically, this recommendation (also a Policy Action recommendation) aims to develop a user-friendly GHG emission tool that can be applied to Blue Carbon ecosystems for periodic GHG emission estimation and reporting for Abu Dhabi. A key feature of the tool is for its design to be compatible with potential follow-on Nationally Appropriate Mitigation Actions (NAMA) activities under the UNFCCC, such as baseline establishment, demonstration of additionality, leakage, and permanence of emissions reductions. The tool will codify the emerging methodological guidance in the IPCC's 2013 Supplement and should be linked to the information products of the Policy Action on Blue Carbon observation system. The use of this tool enables Abu Dhabi to better understand the GHG emission implications associated with past and current coastal development activities affecting Blue Carbon ecosystems.

While it is recognised that it is likely that this would not result in any other carbon payments to Abu Dhabi/UAE post Kyoto, it would encourage a pioneering approach in international reporting, ensure that estimations are at a "macro" rather than project level and avoid definitional and eligibility issues for Blue Carbon at a local and national level.

Future



The Future

Through its collective efforts to turn environmental vision into action, establish a robust institutional context for action, and a proactive perspective in accounting for Blue Carbon's potential, Abu Dhabi has already taken important steps in recognising and promoting the importance of Blue Carbon ecosystems locally and internationally. With the development of a Blue Carbon policy, Abu Dhabi is poised to build on these efforts and assuming a leading role in the international Blue Carbon-related efforts.

Abu Dhabi already stands much to gain from the Blue Carbon Demonstration Project, as it has shed light on ongoing efforts to recognize, capture, and safeguard important values being provided by this rich mosaic of coastal ecosystems. The world stands much to gain as well, as Abu Dhabi provides leadership in this cutting edge and important field.

Abu Dhabi faces an exciting future. With good information about natural capital and the benefits it provides, and with an improved understanding of how these ecosystems function, the Emirate will be able to anticipate and accommodate change, and grow more sustainably. Blue Carbon ecosystems will be a crucial component of that growth.





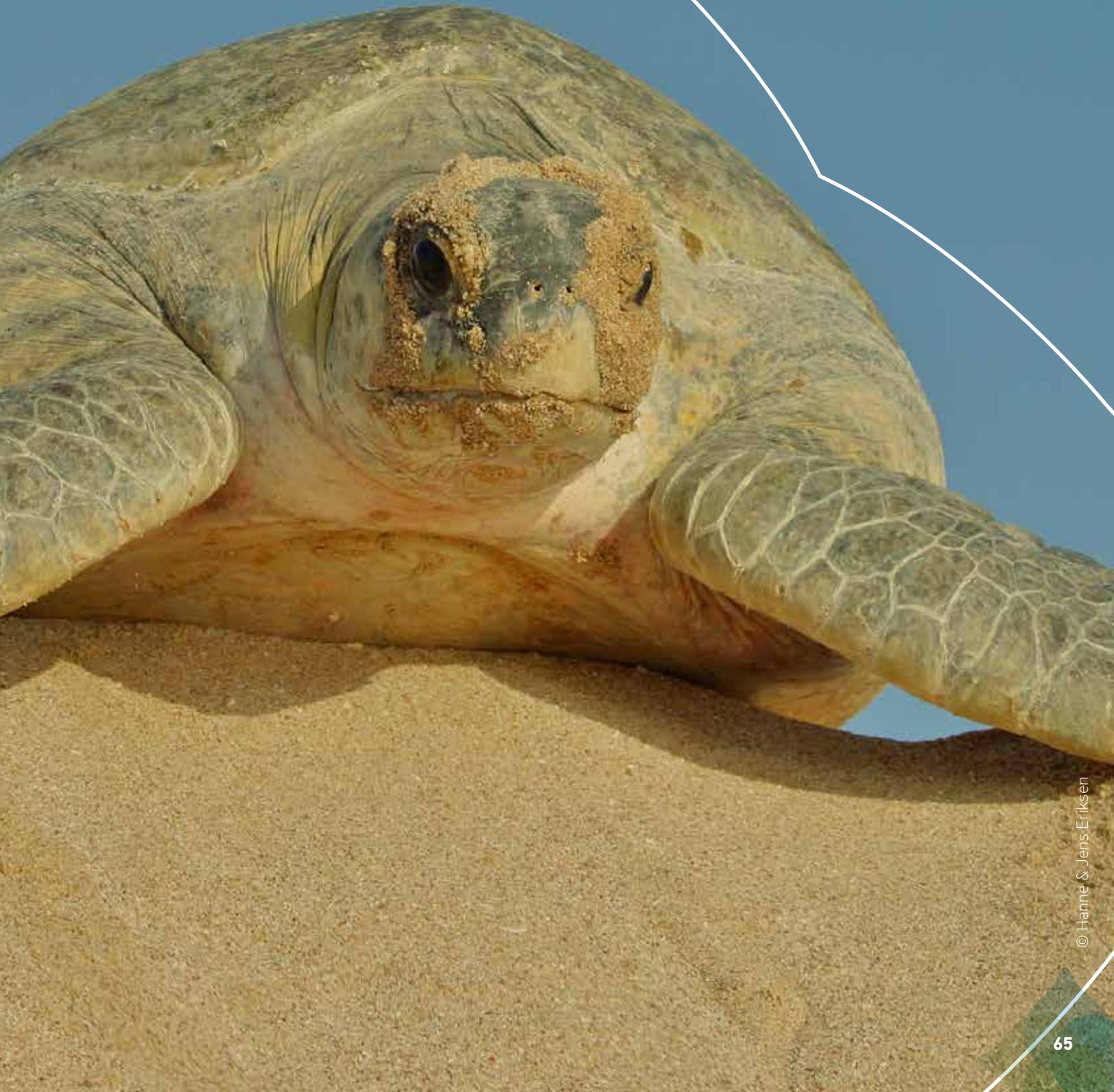
"We cherish our environment because it is an integral part of our country, our history and our heritage. On land and in the sea, our forefathers lived and survived in this environment. They were able to do so only because they recognized the need to conserve it, to take from it only what they needed to live and to preserve it for succeeding generations."

The late H.H. Sheikh Zayed bin Sultan Al Nahyan

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Scientific knowledge is the first step to make effective decisions to protect the diversity of life in our coasts and oceans.



◆ Glossary

Blue Carbon Credits: A Carbon Credit is a financial instrument equivalent to either the right to emit 1 metric ton of CO₂ or an equivalent GHG (i.e. an allowance) or the reduction or sequestration of 1 metric ton of the same (i.e. an offset). Carbon credits are either generated by projects that operate under one of the UNFCCC approved mechanisms such as the Clean Development Mechanism, or by projects that are accredited to independent international standards. Blue Carbon Credits are those associated with the sequestration or avoided emission of carbon from Blue Carbon ecosystems.

Carbon Stock: The quantity of carbon contained in a “pool”, meaning a reservoir or system, which has the capacity to accumulate or release carbon.

Carbon Sequestration: The removal and storage of carbon from the atmosphere in carbon sinks (such as oceans, forests or soils) through physical or biological processes, such as photosynthesis.

Ground-truthing: A field assessment of the accuracy of mapping.

Ecosystem: A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.

Ecosystem Services: The benefits people obtain from ecosystems. These include four different categories, namely provisioning services such as food, water, timber, and fibre; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling.

Ecosystem-based Management: In ecosystem-based management, the associated human population and economic/social systems are seen as integral parts of the ecosystem. Ecosystem-based management is concerned with the processes of change within living systems and sustaining the services that healthy ecosystems produce. Ecosystem-based management is therefore designed and executed as an adaptive, learning-based process that applies the principles of the scientific method to the processes of management.

Ecosystem Integrity: The capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having species composition, diversity and functional organisation comparable to that of natural ecosystems of the region.

Ecosystem Resilience: The capacity of a system to absorb disturbance and reorganise while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks.

Greenhouse Gas: Those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and re-emit infrared radiation.

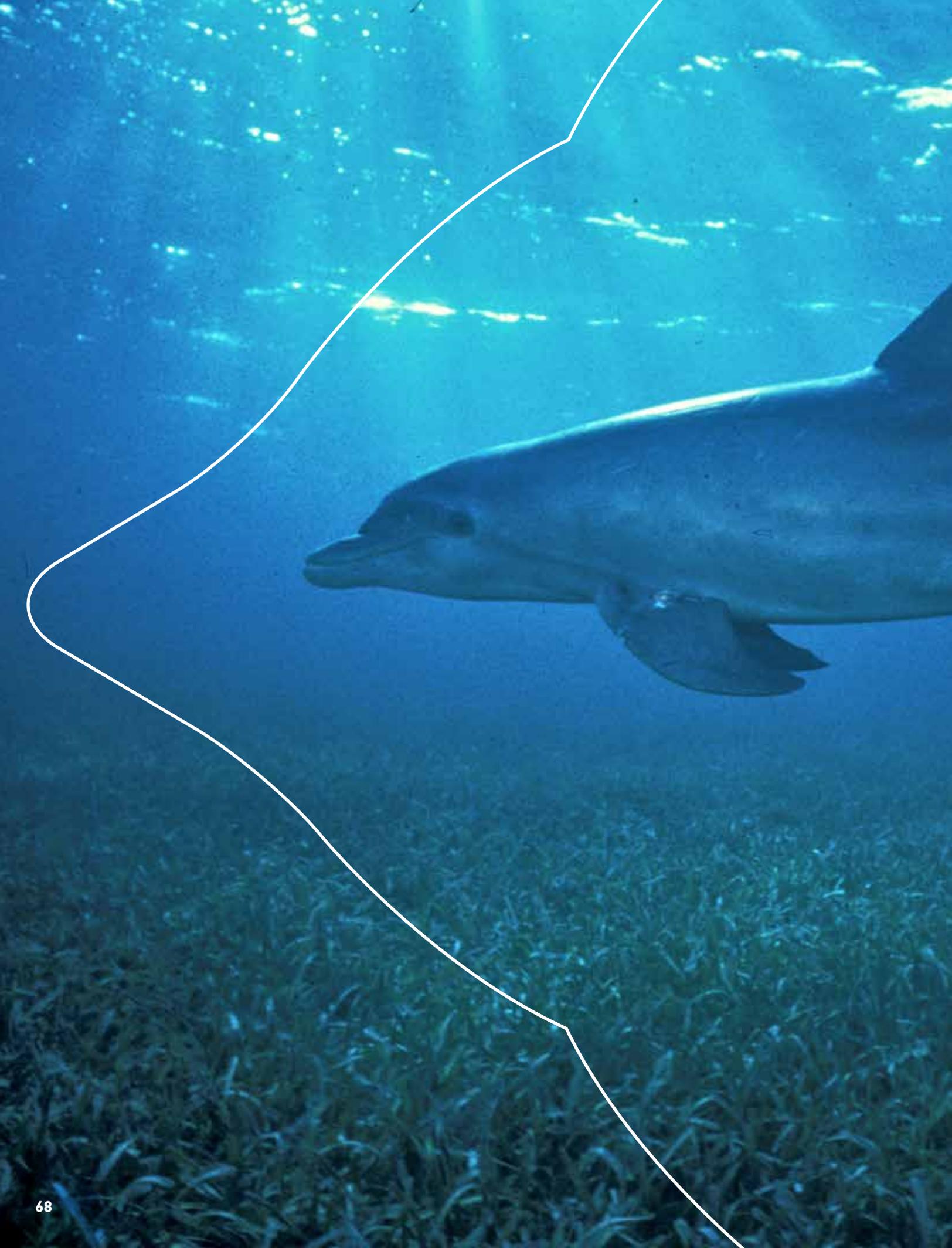
Eligibility: To be eligible for certification as a project generating carbon credits, a project must fulfil certain criteria. To be certified under the CDM mechanism, GHG reductions must be additional to any that would otherwise occur in the absence of the certified project activity. Other criteria include a net-positive contribution to the economic, environmental and social welfare of the local population that hosts it.

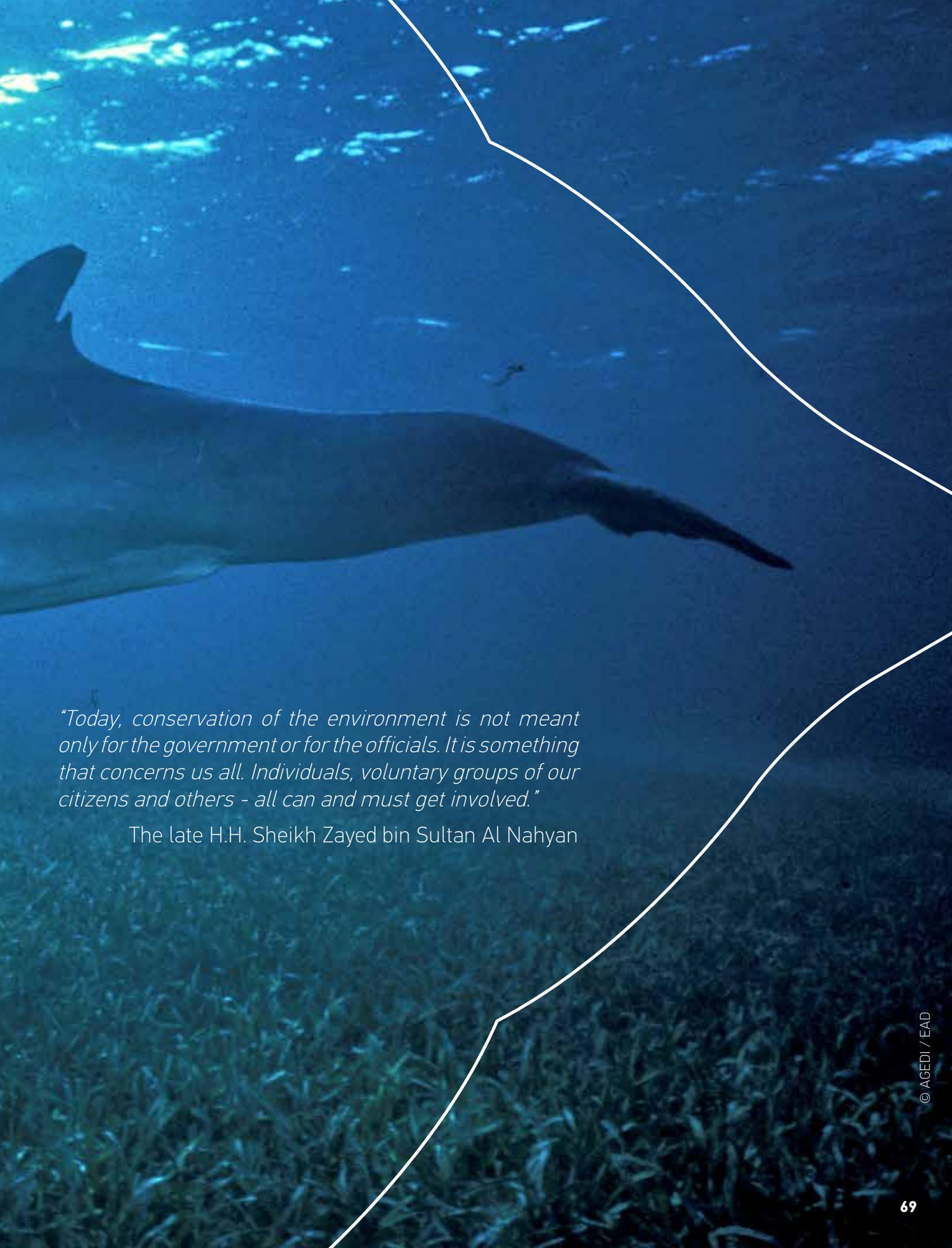
Marine Spatial Planning: This is a framework which provides a means for improving decision-making as it relates to the use of marine resources and space. It is based on principles of the ecosystem approach and ecosystem-based management. It is also temporal, utilising forecasting methods and fully taking into account seasonal dimensions. Marine spatial planning builds on related approaches such as integrated coastal zone management or integrated marine and coastal area management, and includes efforts to establish marine protected areas.

Natural Capital: Natural capital are natural assets in their role of providing natural resource inputs and environmental services for economic production.

Acronyms

AGEDI	Abu Dhabi Global Environmental Data Initiative
CO ₂	Carbon Dioxide
COP	Conference of Parties
EAD	Environment Agency Abu Dhabi
Ha	hectare (10,000 m ² = 0.01 km ²)
GHG	Greenhouse Gas
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
NPV	Net Present Value
SBSTA	Subsidiary Board of Scientific and Technological Advice
UAE	United Arab Emirates
UNFCCC	United Nations Framework Convention on Climate Change
UNEP	United Nations Environment Programme



An underwater photograph showing a large shark swimming horizontally across the middle of the frame. Below the shark is a dense field of seagrass. The water is a deep blue color. A white, wavy line graphic runs across the page, starting from the top right and curving down towards the bottom left.

"Today, conservation of the environment is not meant only for the government or for the officials. It is something that concerns us all. Individuals, voluntary groups of our citizens and others - all can and must get involved."

The late H.H. Sheikh Zayed bin Sultan Al Nahyan

◆ About AGEDI

The Abu Dhabi Global Environmental Data Initiative (AGEDI) was launched under the guidance and patronage of His Highness Sheikh Khalifa bin Zayed Al Nahyan, President of the United Arab Emirates, and was formed at the United Nations World Summit for Sustainable Development in Johannesburg in 2002 to address the local, regional and global responses to the critical need for readily accessible, accurate environmental data and information for all those who need it. Supported by Environment Agency – Abu Dhabi (EAD) on a local level, and championed by United Nations Environment Programme (UNEP), regionally and internationally.



AGEDI works to bridge the environmental data and information gap between developed and developing countries. AGEDI works closely with international networks to facilitate and enhance information exchange enabling more effective, accurate environmental decision-making.

AGEDI facilitated the implementation and engagement on the Abu Dhabi Blue Carbon Demonstration Project . For more information, visit www.AGEDI.ae

◆ About the Environment Agency-Abu Dhabi

The Environment Agency – Abu Dhabi (EAD) was established in 1996 to preserve Abu Dhabi's natural heritage, protect our future, and raise awareness about environmental issues. EAD is Abu Dhabi's environmental regulator and advises the government on environmental policy. It works to create sustainable communities, and protect and conserve wildlife and natural resources. EAD also works to ensure integrated and sustainable water resources management, to ensure clean air and minimise climate change and its impacts.



For more information, visit www.EAD.ae

All reports are available for download at AGEDI.ae

◆ About GRID-Arendal

GRID-Arendal is a centre collaborating with the United Nations Environment Programme (UNEP), supporting informed decision making and awareness-raising through:



- Environmental information management and assessment;
- Capacity building services;
- Outreach and communication tools, methodologies and products.

For more information, visit: www.grida.no

◆ About the Specialist Team

GRID-Arendal led the implementation services and coordination of experts from:

- Climate Change Research Group
- Environmental Science Associates
- Florida International University
- Forest Trends
- Oregon State University
- UNEP, with support from the Climate Change Research Group
- UNEP-WCMC
- Smithsonian Environmental Research Center



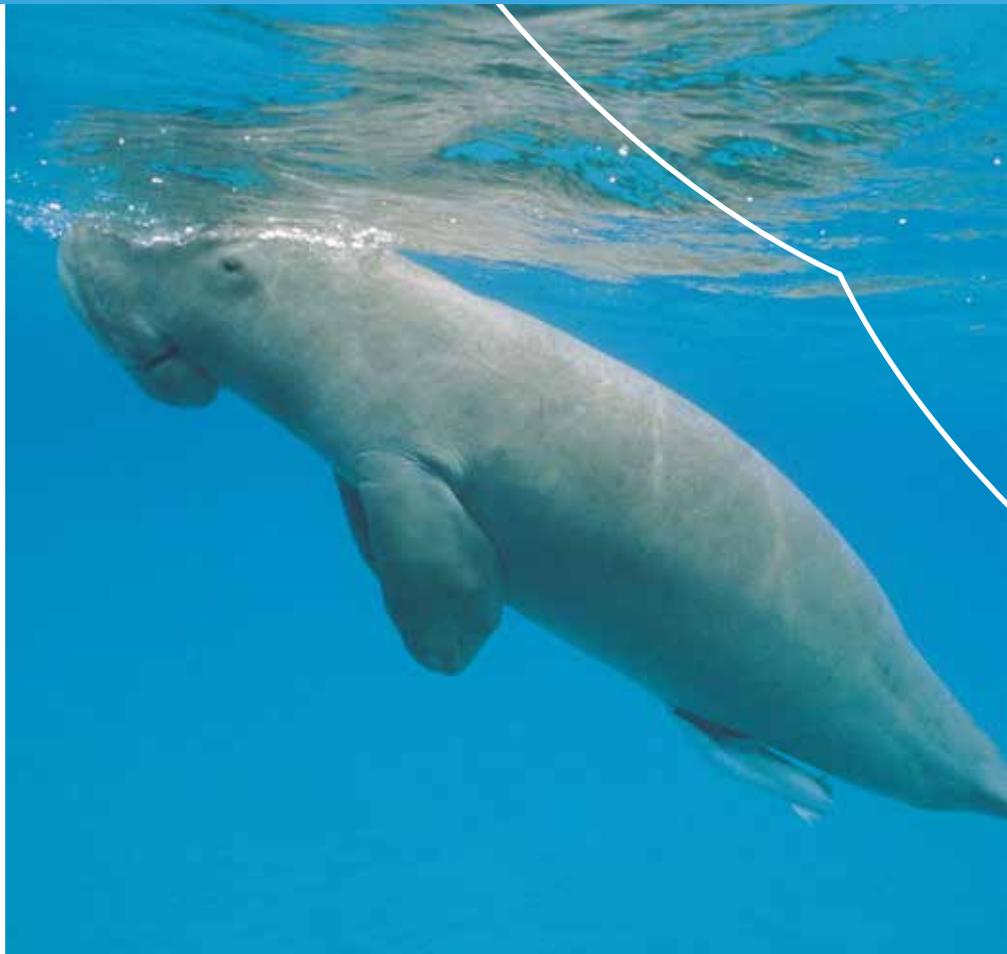


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