Regional Organization for the Protection of the Marine Environment (ROPME)

Blue Carbon Inventory for the ROPME Sea Area





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This Report is a review of the current scientific evidence of the extent and carbon sequestration potential of blue carbon ecosystems in the ROPME Sea Area, which encompasses the territorial waters of the eight Member States of ROPME: Kingdom of Bahrain, Islamic Republic of Iran, Republic of Iraq, State of Kuwait, Sultanate of Oman, State of Qatar, Kingdom of Saudi Arabia and the United Arab Emirates

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Prepared by:

Lisa Benson, Silke Kröger, Ella Howes, William Procter, Roi Martinez and Will Le Quesne, International ClimateChange Centre (iMC[3])**,** CEFAS, Lowestoft Laboratory, United Kingdom (www.cefas.co.uk)

The Regional Organization for the Protection of the Marine Environment (ROPME)
ROPME Secretariat, Jamal Abdul Nasser Street, Garnada, P.O. Box 26388, Safat,13124 State of Kuwait. www.ropme.org

Reviewed by:

Alanoud Al-Ragum - Kuwait Institute for Scientific Research, Kuwait
Aziza Said Humaid Al Adhasbi - Ministry of Environment & Climate Affairs (MECA), Sultanate of Oman
Cecilia Martin – King Abdullah University of Science and Technology, Kingdom of Saudi Arabia
Daniel Mateos-Molina - Emirates Nature - WWF, United Arab Emirates
Mohammad Reza Shokri – Shahid Beheshti University, Islamic Republic of Iran
Simon Wilson - Five Oceans Environmental Services L.L.C, Sultanate of Oman
Thamer Salim Ali Al-Dawood - Arabian Gulf University, Kingdom of Bahrain

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Executive Summary

A Regional Blue Carbon Inventory for the ROPME Sea Area and review of threats to these habitats across the Region was prepared to support Member States best evaluate and manage coastal and marine habitats to support climate change mitigation.

This was conducted as part of the ROPME work plan on marine climate change adaptation and mitigation.

The Inventory was prepared through an expert lead review of existing Global and Regional blue carbon ecosystem extent maps, and by compiling available existing data on carbon stocks and sequestration rates, with an emphasis on studies that had been conducted within the Region.

The analysis considered widely recognised blue carbon ecosystems in the Region – mangroves, saltmarsh and seagrass – as well as newly considered ecosystems such as sabkha and microbial mats.

Across the whole ROPME Sea Area the recognised blue carbon ecosystems are estimated to cover 7,398 km^2 and to sequester 70.3 $x10^9$ g of carbon per year. The total carbon stored within these habitats is estimated to be 49.3 $x10^{12}$ g.

The newly considered ecosystems are estimated to cover a further 7,612 km^2.

The analysis was based on best available data but recognises there are ongoing knowledge gaps regarding ecosystem extent and the carbon sequestration rates and storage by different blue carbon ecosystems in the Region.

Of the recognised blue carbon habitats, seagrass has the largest spatial extent, but mangroves providethe largest contribution of carbon sequestration and storage.

The annual accumulation rates of blue carbon habitats across the RSA are relatively small compared to current total annual emissions by the ROPME Member States. However, the importance of these habitats should also be considered in terms of (i) the greater proportion of emissions they would account for once total emissions have been significantly reduced, (ii) the total carbon stored, and (iii) the important wider ecosystem services delivered by these ecosystems.

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Abbreviations

ABFWG	Arabian Blue Forest Working Group
AGEDI	Abu Dhabi Global Environmental Data Initiative
GHG	Greenhouse Gas
GMW	Global Mangrove Watch
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel for Climate Change
NbS	Nature Based Solutions
NDCs	Nationally Determined Contributions
NGO	Non-Governmental Organisations
ROPME	Regional Organization for the Protection of the Marine Environment
RSA	ROPME Sea Area
SAR	Synthetic Aperture Radar
SDGs	Sustainable Development Goals
SOMER	State of the Marine Environment Report
TPHs	Total Petroleum Hydrocarbons
UAE	United Arab Emirates

1 Introduction

It is now well-recognised that increasing concentrations of gases such as carbon dioxide, nitrous oxide and methane in the atmosphere have led to a global increase in temperature, known as global warming, and is associated with many negative effects on ecosystems. Human activities since the industrial revolution have greatly contributed to this effect and global action is required to halt this trend. In the face of this human-induced climate change, an increasing focus is being placed on the development of climate mitigation strategies to limit warming to the 2ºC goal of the 2015 Paris Agreement. Nationally determined contributions (NDCs) define nations' climate goals and action plans. NDCs detail efforts to adapt to the consequences of climate change, to avoid further increases in greenhouse gas emissions, to advance towards low carbon emissions systems and to achieve developmental, environmental, social, and economic priorities under the framework of sustainable development.

Climate change mitigation actions towards NDCs can be supported through so-called Nature-Based Solutions (NbS). NbS involve the protection, restoration and improved land management practises that avoid greenhouse gas (GHG) emissions and/or increase carbon sequestration. They are regarded as a win-win solution to protect and sustainably manage ecosystems for the benefit of nature and humans (Seddon *et al.,* 2020).

Climate change mitigation strategies can involve reduction of emissions as well as management of carbon fluxes in and out of terrestrial and marine ecosystems. The marine environment has been shown to act as a sink for carbon dioxide (DeVries *et al.,* 2019), this is commonly referred to as blue carbon. Carbon dioxide is transformed, through primary production, into organic carbon that can be used or stored, in parts for extended periods of time. Some of the processes that control the flow of carbon to and from atmosphere to water column and vegetated ecosystems, and the subsequent storage of carbon within these systems can be influenced by human activities and thus are potentially manageable. Management can either maintain the integrity of the natural stores, thus decreasing the risk of releasing greenhouse gases, or actively enhance the sequestration potential of the system. Vegetated coastal ecosystems (mangroves, seagrass and saltmarsh grass), in particular, can sequester and store significant amounts of carbon, prompting increased interest of these ecosystems in mitigation strategies.

1.1 The ROPME Sea Area

ROPME is the Regional Organization for the Protection of the Marine Environment. The ROPME Sea Area (RSA) encompasses the territorial waters of the eight ROPME Member States. These are the Kingdom of Bahrain, Islamic Republic of Iran, Republic of Iraq, State of Kuwait, Sultanate of Oman, State of Qatar, Kingdom of Saudi Arabia, and the United Arab Emirates. Located in the northwest corner of the Indian Ocean, this Region is known for its oil production.

With the diminishing influence of the northernmost Indian Ocean moving further into the RSA, the area can be divided into three distinct zones (Figure 1). The Outer ROPME Sea Area

(O-RSA) lies in the north of the Indian Ocean (along the southern Omani coast), has a temperature range from 22 to 26°C and a typically monsoonal climate. April brings the summer monsoon, which typically lasts through until September, bringing strong winds from the southwest, high rainfall and producing strong upwelling. The Middle ROPME Sea Area (M-RSA) extends northwards and westwards from the Indian Ocean (along the eastern Omani coast) to connect with the Inner ROPME Sea Area (I-RSA) through the Strait of Hormuz. The I-RSA is a shallow, semi-enclosed sea that experiences the greatest environmental extremes of the RSA. Sea surface temperatures ranges from 13 to 35°C and salinity reaches up to 70 PSU.

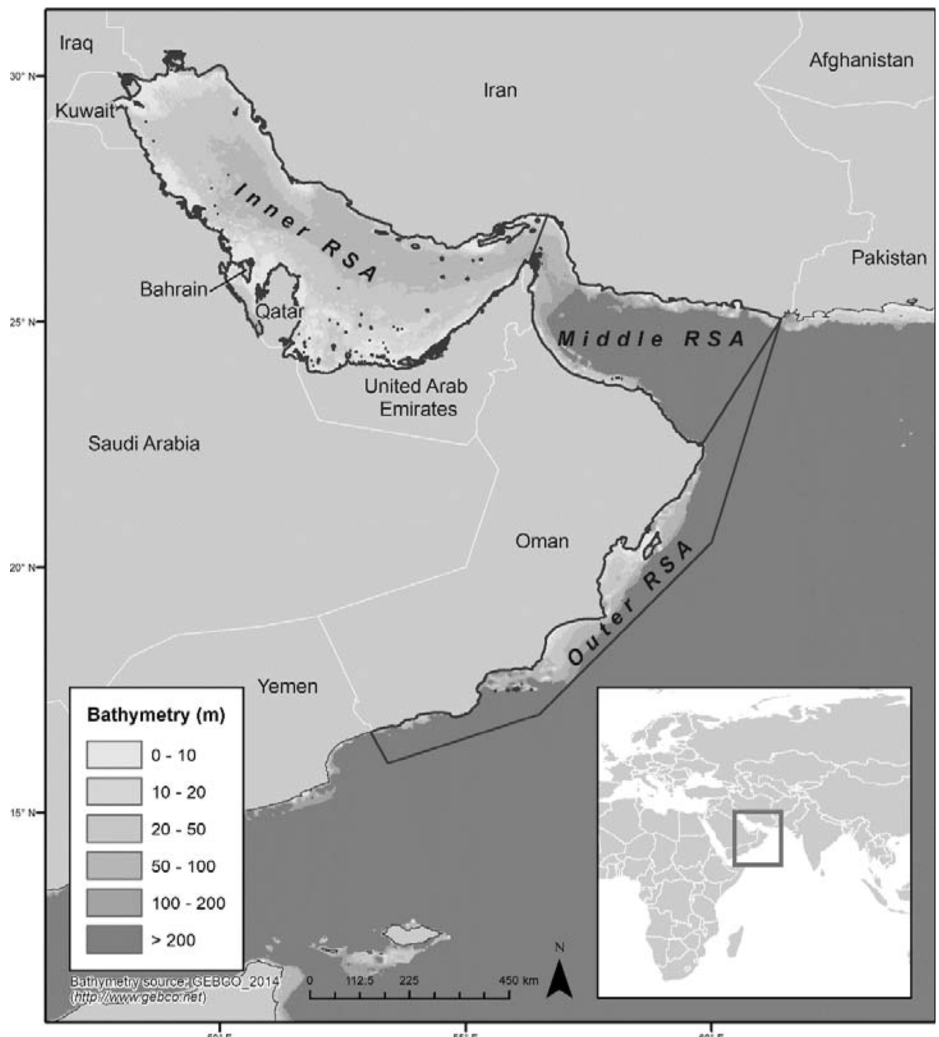

Figure 1: The coverage of the ROPME Sea Area (RSA) including geographical divisions. The RSA is boundedin the south by the rhumb lines 16° 39'N, 53° 3'30'E; 16° 00'N, 53°25'E; 17°00'N, 56° 30'E; 20° 30'N; 60° 00'E; 25° 04'N; 61° 25'E, comprising three geographically and environmentally distinct parts: The Inner RSA (I-RSA), the Middle RSA (M-RSA) and the Outer RSA (O-RSA).

The coastlines of the RSA consist of a mosaic of highly productive ecosystems, including coastal sabkhas, mudflats, mangroves, saltmarshes and seagrasses, that provide food and habitat for diverse ecological communities and represent important stores of blue carbon. In recent years there has been accelerating loss and degradation of these ecosystems and this

Region is now considered among the most degraded marine eco-regions in the world (Burt 2014). It is therefore, of great importance to take an overview of the existing habitats, account for the carbon stocks they hold and consider management options.

1.2 Purpose and scope

The 2013 ROPME 'State of the Marine Environment Report' (SOMER) highlighted a need to undertake more detailed examination of climate change risks, to raise public awareness of these risks and review the capacity of the Region to respond (ROPME, 2013). The SOMER recommended that RSA Member States should agree on action plans and work with the International Community to mitigate climate change and adapt to impacts.

The work programme to develop a "Regional Marine Climate Change Adaptation and Mitigation Strategy" for the RSA was launched in 2019. This Strategy supports ROPME Member States' commitments to International agreements on climate change and biodiversity, including UNFCCC, UN Convention on Biological Diversity, and UN Sustainable Development Goals (SDGs). The UNFCCC requires that all signatory countries report regularly on how they are addressing climate change by publishing 'Nationally Determined Contributions' (NDCs) documents. All ROPME Member States have submitted either their NDC or intended-NDC (INDC) to the UNFCCC. These INDCs and NDCs provide an update on the RSA Member States' efforts to: i) adapt to the consequences of climate change; ii) avoid further increases in greenhouse gas emissions; iii) advance towards low carbon emissions systems; and iv) achieve developmental, environmental, social and economic priorities under the framework of the UN SDGs.

To support Member States best evaluate and manage coastal and marine habitats to support climate change mitigation this Report presents the first Regional Blue Carbon Inventory for the RSA along with a review of carbon storage and sequestration rates by blue carbon ecosystems in the Region and a review of the threats to these ecosystems in the Region.

Despite increased interest in the potential of so-called 'blue carbon' in supporting climate change mitigation strategies, to date, studies have been disproportionately focussed on tropical areas (Fourqurean *et al.,* 2012; Adame *et al.,* 2013; Griscom *et al.,* 2020; Kauffman *et al.,* 2020). Similar works in arid regions of the world, where habitats endure extreme temperatures and low rainfall can affect productivity, are scarce.

For the purposes of greenhouse gas accounting the Intergovernmental Panel for Climate Change (IPCC) has published guidelines and default values to quantify and report stocks and emissions arising from land-use change in coastal wetlands (IPCC, 2014). However, while generic values of carbon storage and sequestration potential exist, coastal blue carbon ecosystems have been shown to be highly variable across environmental and physical gradients (Campbell *et al.,* 2015; Kauffman *et al.,* 2020). Therefore, the accuracy of Regional level carbon accounting is improved by the use of available Regional data.

To date, only a limited number of studies have attempted to measure the carbon stored in blue carbon ecosystems within the RSA or to accurately map their extent. To fill this knowledge gap, as part of the ROPME work plan on marine climate change a Regional Workshop was organised to conduct an expert-led review of available carbon data and ecosystem spatial extent information to compile the first Regional evaluation of the climate mitigation potential of blue carbon in the RSA.

The Inventory Report collated organic carbon stocks and accumulation rate data within the current widely accepted blue carbon ecosystem types (saltmarsh, seagrass and mangroves), while highlighting ecosystem types that may be incorporated in future inventories (coastal sabkhas, microbial mats andsediments).

1.3 Inventory Assessment Methods

1.3.1 Expert Workshop

As part of the ROPME Regional Action Plan on Marine Climate Change a Regional Technical Support Group (TSG) for blue carbon was established in January 2020. This group consists of experts in blue carbon from across the ROPME Member States, including members of the Arabian Blue Forest Working Group (ABFWG).

A workshop of the TSG was hosted by the Oman Ministry of Environment and Climate Affairs on 21st-22nd January 2020 in Muscat, Oman. The workshop was attended by 23 experts from seven of the ROPME Member States (Appendix 1). The workshop was led by Cefas and included presentations from member of the TSG on national initiatives on blue carbon and collaborative working sessions.

The primary objective of the workshop was to prepare a Regional Blue Carbon Inventory of the RSA. This was conducted through:

- an expert lead review of existing global and Regional blue carbon ecosystem extent maps.
- compiling available existing data on carbon stocks and sequestration rates, with an emphasison studies that had been conducted within the Region.

The workshop also provided an opportunity to summarise Regional activities related to the management of blue carbon stores in the RSA.

1.3.2 Mapping

While discrete coastal habitat mapping efforts have been carried out within the RSA (e.g., Mateos - Molina *et al.,* 2020, Lamine *et al.,* 2020) the availability of spatial datasets is limited. During the workshop participants reviewed existing spatial data from Regional and Global datasets for each blue carbon ecosystem (Green and Short, 2003; Mcowen *et al.,* 2017; Bunting *et al.,* 2018; UNEP-WCMC, 2020). Experts reviewed the ecosystem types and countries that related to their specific expertise. Where the Regional experts considered it necessary, they made manual adjustments to the starting ecosystem map data layers based on their local knowledge.

The edited shapefile was the result of the changes made to existing spatial data during and following the workshop. Four types of alterations were applied to the existing data to produce the final edited product: add, remove, extend and reduce. Where existing polygons were to be reduced in extent, a clip function was performed to remove extraneous data from the polygon. Where the existing polygons were to be extended, a union between existing and new overlapping polygons was performed to increase the size of the existing area. Polygons that were found to be wrongly classified were erased from the shapefile and areas that were identified during the workshop to be a blue carbon ecosystem, but were not identified by the existing datasets, were drawn into the shapefile aspolygons.

Extent (km^2) was calculated for each polygon within the original and edited shapefiles. The total area of each ecosystem and the extent of each ecosystem within each Member State was calculated and differences in ecosystem extent between datasets were also evaluated.

1.3.3 Carbon data collation

Participants spent time reviewing available literature about the Region to ensure all data pertaining to blue carbon stocks and sequestration rates were captured as part of the Report. All related studies were evaluated and recorded, and relevant data were extracted either from the text or supplementary materials. Data collated included sediment depth, sediment bulk density, % sediment organic matter,sediment organic carbon density and sediment mass as well as carbon accumulation rates. Where applicable, above and below ground carbon data were also extracted. Metadata included the Member State, survey site, habitat type and condition and any relevant management interventions.

Carbon related variables were summarised for each habitat type. Where the extracted data were presented as mean values, the standard error of the summarised data were calculated based on the propagation of errors of the underlying data points.

2 Defining Blue Carbon

2.1 Blue Carbon

The term “blue carbon” was first used in a rapid response assessment report edited by Nelleman *et al.,* (2009) as part of the United Nations Environment Programme. Here, it took a broad meaning, in the following statement: 'Out of all the biological carbon (or green carbon) captured in the world, over half (55%) is captured by marine living organisms—not on land—hence it is called Blue Carbon'.

Soon after, Laffoley and Grimsditch (2009) focussed particularly on carbon stored in the marine environment that could be managed to reduce emissions of greenhouse gases (GHGs) or enhance sequestration, thereby contributing to climate change mitigation and the conservation of marine ecosystems.

In the decade proceeding these two influential reports, the concept of blue carbon has sparked multidisciplinary collaboration and research: crossing biochemical and physical sciences, socio-economics, conservation and policy. The focus of these efforts has, in the most part, been on the potential for the conservation and restoration of coastal ecosystems to contribute to the mitigation of greenhouse gas emissions and the promotion of climate change adaptation.

However, the diverging blue carbon definitions contained in the early reports along with a flourish of interest in the concept has led to growing debate over the definition of blue carbon.

Most recently the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate refined the blue carbon definition to “All biologically-driven carbon fluxes and storage in marine systems that are amenable to management can be considered as blue carbon (IPCC, 2019). Coastal blue carbon focuses on rooted vegetation in the coastal zone, such as tidal marshes, mangroves and seagrasses. These ecosystems have high carbon burial rates on a per unit area basis and accumulate carbon in their soils and sediments. They provide many non-climatic benefits and can contribute to ecosystem-based adaptation. If degraded or lost, coastal blue carbon ecosystems are likely to release most of their carbon back to the atmosphere. There is current debate regarding the application of the blue carbon concept to other coastal and non-coastal processes and ecosystems, including the open ocean.”

This definition highlights the important features of coastal blue carbon that have accelerated the volume of work being carried out on the topic. Furthermore, it introduces the growing interest and uncertainty of applications of the concept beyond vegetated coastal blue carbon ecosystems.

While improved understanding of the marine carbon cycle is important, it is just one element of the blue carbon concept. This Report focuses on blue carbon in the context of its potential for actionable climate change mitigation in the RSA.

2.2 Blue Carbon Ecosystems

In order for ecosystems to be included in actionable blue carbon projects and considered ‘blue carbon ecosystems’ they must meet a range of criteria (Lovelock and Duarte 2019). These criteria are that:

- the scale at which they remove or emit GHGs is significant;
- they provide long-term storage for fixed CO_2;
- the ecosystems are negatively impacted by anthropogenic activities;
- it must be possible to manage the ecosystem in order to maintain and/or enhance C stocksand reduce GHG emissions;
- interventions must not cause social or environmental harm;
- management activities can be aligned with existing or developing international policy andnational commitments to address climate change.

GHG accounting guidance from the IPCC allows for the inclusion of actionable blue carbon ecosystemsdue to them falling within the definition of 'wetlands'. This inclusion in policy frameworks is essentialfor the development of actionable interventions. Where mangroves fall under the definition of 'forests' there may be opportunities to include them in national GHG reduction schemes.

Coastal blue carbon ecosystems provide a wide range of ecosystem services, which also makes them important for biodiversity conservation and building climate change resilience and adaptation. Therefore, following the Paris Agreement these ecosystems can be included in both climate adaptation and mitigation interventions.

However, despite meeting these key criteria a number of barriers to the successful development of blue carbon projects remain (Herr *et al.,* 2017, Lovelock and Duarte 2019). These include uncertainties surrounding land tenure and land-sea jurisdictional boundaries as well as high variability in the carbon stored and potential emissions from anthropogenic activities.

Several different habitats form the blue carbon ecosystems of the RSA, meeting the above criteria, specifically mangroves, seagrasses and saltmarshes. These ecosystems vary in extent, carbon burial efficiency and sensitivity to stressors. In addition to their carbon storage, they provide a range of other ecosystem services such as coastal protection, supporting biodiversity and acting as nursery grounds for broad-scale finfish and shellfish species.

2.3 Emerging blue carbon ecosystems

The criteria required for actionable blue carbon ecosystems can be used as a guide for research into other marine ecosystems that may be considered blue carbon ecosystems in the future.

Coastal sabkhas, and adjacent microbial mats are extensive in arid environments and have been considered as emerging blue carbon ecosystems for the purpose of this Report. Early research has indicated that they may be significant carbon stores, however, more studies are needed to determinetheir sequestration potential and the scale of emissions when they are disturbed. Their role in climate change adaptation is also not well documented.

Wider considerations should also include mudflats and marine sediments, where often carbon is buried for extended periods of time.

In order to progress these emerging blue carbon ecosystems, research should be targeted to provide enhanced evidence of carbon storage and management and policy guidance should be developed to demonstrate how they may be included in GHG accounting.

3 Blue Carbon Ecosystems in the ROPME Sea Area

3.1 Overview

The total extent of the five blue carbon ecosystems in the RSA covered in this Report is shown in Figure 2. While a significant proportion of the coastline of the RSA support the blue carbon ecosystems described, their presence is not continuous along the whole coastline. These gaps are not necessarily indicative of the absence of blue carbon habitats in these areas but might represent data gaps. Further mapping and ground-truthing efforts would be required to increase confidence in the ecosystem distribution described by the map.

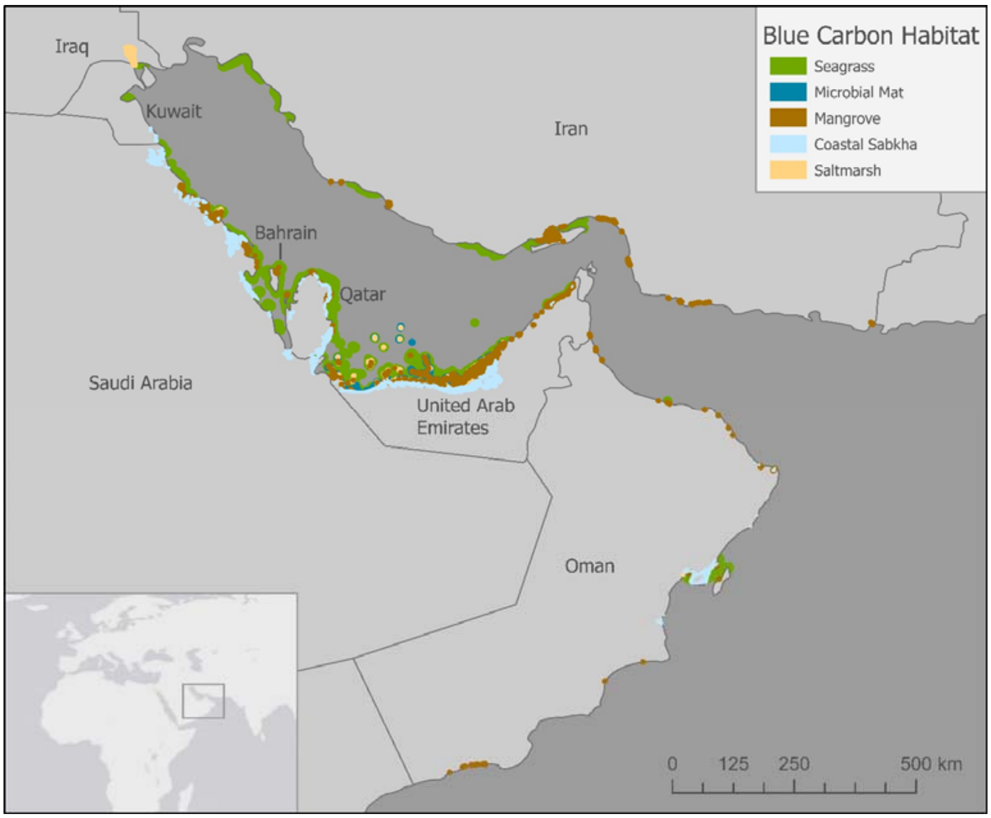

Figure 2: Distribution of blue carbon ecosystems of the ROPME Sea Area as summarised by the ROPME Technical Support Group for Blue Carbon in January 2020. The lack of information in some areas (i.e., saltmarsh or coastal sabkhas on the coast of Iran) may not indicate the absence of such ecosystem, rather the lack of spatial information for those ecosystems.

The extent of the five ecosystems is summarised in Table 1, with seagrass and sabkhas representing the most widespread ecosystem type. Current information suggests that the largest blue carbon ecosystem extents can be found in the UAE and Saudi Arabia, followed by Iran, Qatar and Oman, then Bahrain and Kuwait. The total of 15,009 km^2 is just slightly less than the total land area of Kuwait (17,818 km^2).

Table 1: Blue carbon ecosystem extents (km^2) within the ROPME Sea Area as summarised by the ROPME Technical Support Group for Blue Carbon in January 2020. *The lack of information in some areas (i.e., saltmarsh or coastal sabkhas on the RSA coast of Iran) maynot indicate the absence of an ecosystem, rather the lack of spatial information for those ecosystems.

Ecosystem	Bahrain	Iran	Iraq	Kuwait	Oman	Qatar	Saudi Arabia	UAE	Total
Mangrove	1	90	0	0	7	6	36	162	302
Seagrass	920	2,120	*	55	363	883	789	1,630	6,760
Saltmarsh	0	*	262	*	21	*	2	51	336
Coastal Sabkha	*	0	*	74	775	407	3,055	3,039	7,350
Algal Mat	*	*	*	*	69	*	*	193	262
Total	921	2,210	262	129	1,235	1,296	3,882	5,075	15,010

Figure 3-A shows the proportion each ecosystem type occupies as a fraction of the total blue carbon ecosystem area, illustrating the prevalence of sabkhas and seagrasses, which in combination account for 94% of the total coverage. Figure 3-B presents the relative distribution of the combined blue carbon ecosystem types across the eight ROPME countries. Saudi Arabia and the UAE combined account for nearly 60% of the blue carbon ecosystems across the RSA.

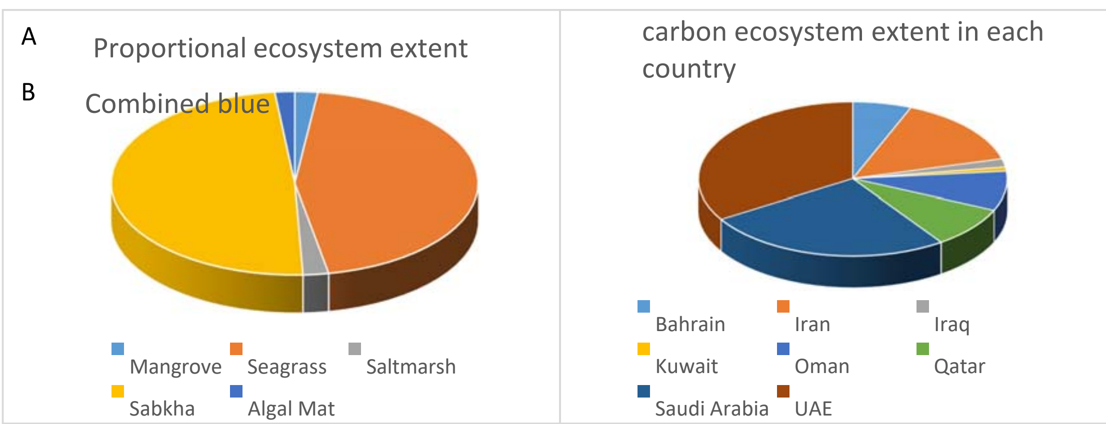

Figure 3: Proportion of total blue carbon habitat area covered by each type (A) and comparison between countries (B).

The carbon storage parameters for the different ecosystems are represented by sediment depth, organic carbon density within sediments and contained in vegetation biomass, percentage of organic carbon within the sediments and sediment accumulation rate per annum. Table 2 gives an overview of these parameters, indicates the number of samples on which the estimates were based, and gives their mean values as well as the range of values observed. Details pertaining to the individual habitat types are given in sections 3.2 to 3.6 below.

Table 2: Summary of sediment depth, organic carbon stocks and accumulation rates in blue carbon ecosystems in the RSA. In brackets after the mean is the standard error, na = not applicable, nd = no data (i.e. no value could be found in available literature) and n= number of data points extracted from literature.

Variable	Natural Mangrove	Planted Mangrove	Seagrass	Saltmarsh	Coastal Sabkha	Microbial Mat
Sediment Depth (cm)	(n = 22)	(n = 9)	(n = 30)	(n = 11)	(n = 5)	(n = 5)
Range	28-300	34-103	9-118	26-200	40-65	20-200
Mean	113.2	86.2	66.9	94.1	53.4	83.8
Soil Organic Carbon Density (up to 1 m depth) (Mg C/km^2)	(n = 31)	(n = 9)	(n = 30)	(n = 11)	(n = 5)	(n = 5)
Range	2,030-23,990	5,100-17,580	190-12,700	2,950-16,370	5,100-12,050	1,860-24,240
Mean	9,650 (± 320)	8,700 (± 910)	6,000 (± 130)	8,140 (± 230)	8,240 (± 370)	13,380 (± 240)
Biomass Carbon (Mg C/km)	(n = 28)	(n = 3)	(n = 18)	(n = 5)		
Range	730-14,750	70-920	3-113	190-720	na	na
Mean	5,130 (± 130)	540 (± 30)	40 (± 0)	360 (± 20)	na	na
Organic Carbon (%)	(n = 23)	(n = 9)	(n = 30)	(n = 11)	(n = 5)	(n = 13)
Range	0.5-13.0	0.4-1.6	0.2-1.1	0.4-2.4	0.9-2.6	1.0-12.1
Mean	2.43 (± 0.13)	0.92 (± 0.08)	0.64 (± 0.02)	0.97 (± 0.06)	1.47 (± 0.07)	4.69 (± 0.04)
Sediment Accumulation Rate (mm/yr)	(n = 6)	(n = 3)	(n = 12)	(n = 6)	(n = 2)	
Range	0.1-3.6	1.2-2.6	0.6-2.4	0.6-1.3	0.3-0.5	nd
Mean	1.77 (± 0.04)	1.81 (± 0.00)	1.33 (± 0.04)	0.99 (± 0.03)	0.40 (± 0.03)	nd
Carbon Accumulation Rate (g C/m^2/yr)	(n = 4)	(n = 3)	(n = 12)	(n = 6)		
Range	12-38	6.2-23	3.8-19	3.1-12	nd	nd
Mean	23 (± 0.4)	12.6 (± 0.0)	9.0 (± 0.2)	7.8 (± 0.3)	nd	nd

Total carbon stock estimates for the different ecosystems are shown in Table 3. Consistent with their large area, coastal sabkhas and seagrasses account for nearly 90% of the total carbon stock across all five ecosystems.

Table 3: Total carbon stocks in the five blue carbon ecosystems in the RSA. *Note*: ecosystem extents in some countries are missing, leading to a likely overall underestimation of the total stocks.

Habitat	**Carbon stock in Tera-grams (10^{12} g)**	**Carbon accumulation in Giga-gramsper year (10^9 g/yr^1)**
Mangrove	5.6	60.8
Seagrass	40.8	2.6
Saltmarsh	2.9	6.9
Sabkha	60.6	No Data
Microbial mats	3.5	No Data
Total	**113.4**	**> 70.3**

Figure 4 depicts the soil organic carbon density in each blue carbon ecosystem, illustrating the high carbon stocks in the soils of microbial mats and mature mangroves, followed by planted mangroves, coastal sabkhas, saltmarshes and finally seagrasses.

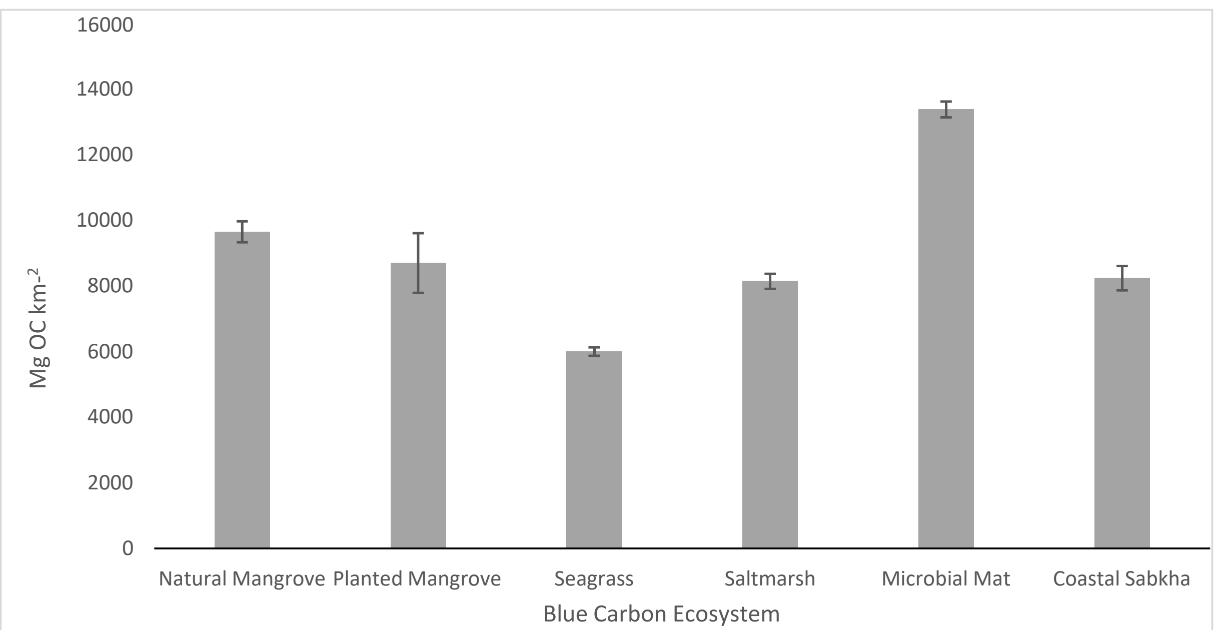

Figure 4: Soil Organic Carbon stocks (up to 1 m depth) in Mg C/km^2 for each blue carbon ecosystem. Error bars = standard error.

3.2 Mangroves

The global mangrove data used in this study were derived from Global Mangrove Watch (GMW) data, a global baseline map of mangrove extent and distribution (Bunting *et al.,* 2018). The extent calculated from the global mangrove data used in this Report is 172.8 km^2. A study by Almahasheer (2018), estimated mangrove extent in the I-RSA as roughly 165 km^2 based on solely Landsat optical satellite data and achieved an overall classification accuracy of 90.6%, whereas the GMW data was derived from a combination of Synthetic Aperture Radar (SAR) and Landsat optical data achieving an overall accuracy of 95.3%. Despite having higher classification accuracy, it is worth noting that this is a global- scale dataset, therefore classification accuracy is based on a global assessment and this level of accuracy may not be representative of mangroves in the RSA. The workshop edits of the polygon data resulted in a total mangrove extent as 302 km^2. This is greater than the mangrove extent calculated by the global and AGEDI datasets, however, the AGEDI dataset does not cover Iran which has large areas of mangrove. The global mangrove dataset has a spatial resolution of 30 m, therefore small patches of mangrove would be undetected, which may also generate further differences in mangrove extent between datasets.

Occurring along the coastlines of seven out of the eight Member States of the RSA, mangroves here are located at the one of the most environmentally extreme regions of their global distributions. Despite the challenging conditions, as the only natural evergreen forest in the Region (Friis and Burt 2020), mangroves are of significant importance to biodiversity. Mangroves are estimated to cover the smallest extent of all traditional blue carbon habitats in the RSA. Despite this, studies of mangroves inthe RSA have been increasing exponentially in recent decades (Friis and Burt, 2020) and as a result they are the most studied ecosystem included in this summary. Of all the Member States of the RSA Iran was found to be the most productive nation in terms of mangroves research, however, none of these studies were found to have quantified total ecosystem carbon stocks (Friis and Burt 2020).

Most natural mangrove stands in the RSA are monospecific, made up of *Avicennia marina*. However, *Rizophora mucronata* is also found distributed less commonly through the Region.

Carbon data were compiled from six published studies (Ray and Shahraki 2016, Schile *et al.,* 2017, Al- Nadabi and Sulaiman 2018, Cusack *et al.,* 2018, Chatting *et al.,* 2020) with a total of 44 study sites covering five Member States; Iran, Oman, Saudi Arabia, the UAE and Qatar. Of the five mangrove studies, two distinguished between natural and planted mangroves, which exhibit significant differences in several variables including soil organic carbon density. Sediment carbon stocks (to 1 m sediment depth) ranged from 3,670 - 23,990 Mg C/km^2 (Mean 12,140 Mg C/km^2) in natural mangroves.At nine sites in Saudi Arabia and the UAE, carbon stocks in planted mangroves at different stages of maturity ranged from 5,100 - 17,580 Mg C/km^2 (Mean 8,700 Mg C/km^2), which is significantly lower than the concentrations found in mature mangroves.

The soil depths sampled vary across studies and sites, and although all values reported are standardised to 1 m depth, the depth measured ranged from as low as 28 cm indicating that sedimentdepth at these sites could limit total ecosystem carbon stocks. Mangrove carbon stocks in the RSA are typically lower than global averages (Kauffman *et al.,* 2020) however, they are comparable to areas of the Red Sea (Almahasheer *et al.,* 2017).

Numerous studies have argued that mangroves in low-rainfall and hypersaline areas, exhibit a limited capacity to store carbon (Almahasheer *et al.,* 2017, Schile *et al.,* 2017, Chatting *et al.,* 2020, Sanders *et al.,* 2016). Strong associations have been found between rainfall, salinity, productivity and soil organic matter (Osland *et al.,* 2018). High salinities have been found to limit tree biomass and productivity of the mangrove forests and therefore limit locally derived carbon inputs (Saintilan *et al.,* 2013). In addition, as rainfall is low in arid regions there is also less opportunity for riverine inputs to be trapped in mangrove sediments.

Sediment texture is one of several factors that regulate organic matter preservation in soils and has been hypothesized to be a primary explanation for relatively small carbon stocks in sandy soils (Schile *et al.,* 2017). The single-most important factor required to preserve soil organic matter is anoxia, a condition that requires the microbial and plant oxygen consumption rate to exceed the oxygen resupply rate. Coarse-textured soils support rapid rates of water infiltration that allows porewater to rapidly drain and exchange with relatively oxygen-rich floodwaters or air during tidal cycles. Rapid porewater exchange inhibits development of the reducing, anoxic conditions, and favours more complete oxidation of organic carbon to CO_2.

Globally, mangroves have been described to contain a mean total ecosystem carbon stock of 85,300 Mg C/km^2 (Kauffman *et al.,* 2020). At site level this varied greatly, ranging from 7,900-220,800 Mg C/km^2. On Regional scale, total mangrove ecosystem carbon stocks in the RSA were found to be at the lowest end of this range. IPCC guidelines allow for the application of global default values for 'Tier 1' assessments, however, application of these values within the RSA would overestimate the total mangrove ecosystem carbon stocks, demonstrating the importance of the development of country - or Region-specific values as provided within this Report.

3.3 Seagrasses

Erftemeijer and Shuail (2012) estimated the total extent of seagrass habitats in the I-RSA to be approximately 7,000 km^2, but state this is likely an underestimate as large areas have not yet been surveyed. However, the workshop edited shapefile resulted in seagrass extent being calculated as 6,760 km^2. This extent is similar to the AGEDI dataset when taking into account that the AGEDI mapping effort did not cover the coast of Iran. The estimated extent of seagrass in the RSA using the global seagrass dataset was 11,345 km^2, this result was derived from various studies globally and compiled by UNEP-WCMC.

To accurately determine seagrass extent, it was first necessary to dissolve the polygons in the area to remove overlapping geometries and prevent overestimation. The greatest discrepancies between the global and AGEDI seagrass datasets were within the UAE, where the expert group considered the seagrass extent within the global shapefiles to be overestimated. Large portions of the data in the AGEDI shapefile were generated through a dedicated mapping project by the Environment Agency, Abu Dhabi. As a result, the accuracy and detail of habitat extent and distribution within the UAE is greater than that of the other Member States. Mangrove and seagrass spatial data for Member States outside of the UAE were compiled by AGEDI from the UNEP-WCMC data and other data sources.

Seagrass meadows are widely distributed and globally important ecosystems, valued for the role in providing nursery and feeding grounds for fishery species and megafauna such as dugongs and green turtles, and improving water quality through the sequestration of nutrients and carbon. A study by Price and Coles (1992) provides a semi-quantitative description of seagrasses at coastal sites along the western I-RSA described *Halodule uninervis, Halophila stipulacea* and *Halophila ovalis* as the three species present and a fourth species, *Syringodium isoetifolium*, was listed by Sheppard *et al.,* (1992). Compared to the Red Sea, where twelve seagrass species have been identified (El Shaffai 2011), this is a relatively small number, but as illustrated in the study by Al-Khayat (2007), more than 600 species from nine taxonomic groups are supported by these seagrass habitats, demonstrating the important biological role they play in supporting biodiversity.

Traditionally the knowledge-base of reliable seagrass carbon stock data has been driven by research in the Mediterranean, North Atlantic and Eastern Indian Ocean (Fourqurean *et al.,* 2012), with limited numbers of studies in arid regions such as the RSA, where coastal ecosystems are recognised for being under stress from extreme environmental conditions (Campbell *et al.,* 2015).

Of all the literature reviewed for this Report, two studies assessed carbon storage in seagrass ecosystems in the RSA. This covered 30 sites across two Member States, Saudi Arabia (Cusack *et al.,* 2018) and the UAE (Campbell *et al.,* 2015).

Seagrass biomass was found to be significantly correlated to depth, sediment hydrocarbon and sediment grain size, but not to season, salinity, nutrient concentration, or heavy metals (Price and Coles 1992). Despite being small in stature, all of the species that dominate seagrass communities in the RSA have been found to contribute to sediment stabilisation and carbon storage (Lavery *et al.,* 2013, Campbell *et al.,* 2015).

The carbon stored in seagrass ecosystems is known to vary considerably, with global datasets reporting ranges over 5 orders of magnitude (Fourqurean *et al.,* 2012). This variability is driven by numerous biological and physical environmental factors that can influence rates of organic carbon deposition. These factors can include species' morphological and structural attributes that can influence above and below-ground biomass, the input of refractory organic matter as well as the degree of sediment stabilisation and particulate matter accumulation. Environmental factors that can influence both species distribution and carbon accumulation rates include depth, or tidal inundation and site exposure.

The carbon stored within the seagrasses of the RSA varied from 190 - 12,700 Mg C /km^2. In comparison to global estimates of carbon content of seagrass ecosystems (19,420 Mg C /km^2) these values are low. However, as there is extensive seagrass distribution in this Region seagrass ecosystems contribute a relatively large organic carbon store within the RSA (40.8 Tera-grams of Carbon), which is the second largest carbon pool estimated within this review.

3.4 Saltmarshes

The global saltmarsh dataset used in this Report was generated from a combination of remote sensing and field survey methods and collated into a single shapefile by the UNEP-WCMC (Mcowen *et al.,* 2017). The global saltmarsh dataset only has extent data for the UAE, other countries within the RSA with saltmarsh extent in Table 1 were calculated from polygons of saltmarsh habitat added into the shapefile during the workshop. The asterisks in Table 1 indicate countries in which the UNEP-WCMC saltmarsh dataset has identified areas of saltmarsh but have no information on spatial extent (Iran, Kuwait and Qatar). The locations of these saltmarshes are indicated by point data and contains information on the species present at each location. The global dataset indicated a total of 36 areas of saltmarsh in the RSA with saltmarsh habitat present in all countries except for Bahrain. The knowledge that saltmarshes are present, for example, in Iran (as there are point data and Ramsar sites) but no aerial extents available, highlights the need for improved mapping.

A saltmarsh, also known as a coastal salt marsh or a tidal marsh, is a coastal ecosystem in the upper coastal intertidal zone between land and open saltwater or brackish water that is regularly flooded by the tides. It is dominated by dense stands of salt-tolerant plants such as herbs, grasses, or low shrub,which are terrestrial in origin and are essential to the stability of the salt marsh in trapping and binding sediments (Adams 1990). Saltmarshes provide a wide range of ecosystem services: they act as valuable habitats for plants, birds and other animals and support coastal fisheries through export of energy andacting as refugia for juvenile fish. They also provide protection from storm surges, reduce nutrient loading and, importantly, store carbon (Chmura 2013). Salt marshes of the UAE are dominated by thelow succulent shrub *Arthrocnemum macrostachyum* and occur higher in elevation than mangroves or microbial mats but lower in elevation than sabkhas (Schile *et al.,* 2017). An earlier study carried out byAbdel-Razik and Ismail (1990) described twelve perennial species representing five different growth groups with a total cover between 10 and 50% for a saltmarsh in Qatar. The global extent of saltmarshes has been estimated as 55,000 km^2, with a range of carbon stocks in the order of 1.6-62.3 Mg/km^2 and a carbon flux of 0.24 (± 0.03) Mg $C/km^2/yr$. Compared to this estimate, the carbon flux given in Table 1 of 3.1-12 g $C/m^2/yr$ (equivalent to 3.1-12 Mg $C/km^2/yr$) is relatively high, though the limited available data on areal extent still make it overall a smaller contributor than other blue carbon ecosystems in the Region. Schile *et al.,* (2017) revealed that only about 5% of salt marsh carbon was inplant biomass, compared to almost 30% in mangroves.

3.5 Emerging blue carbon ecosystems

Further ecosystems such as microbial mats and coastal sabkhas are not yet widely regarded as "blue carbon" ecosystems but can contain (and possibly store for prolonged periods of time) significant amounts of carbon. The above information (Table 2) provides some numbers of carbon concentrations published, also in comparison to other blue carbon ecosystems such as mangroves, seagrass meadows and saltmarshes.

3.5.1 Microbial Mats

Microbial mats can make an important contribution to the nutrition of macrofaunal consumers, particularly in the absence of extensive macro-vegetation (Al-Zaidan *et al.,* 2006). In addition to their role in the food chain, their ability to accumulate and store carbon makes them a valuable habitat. Mean soil organic carbon in microbial mat ecosystems in the UAE has been estimated to be as high as 13,380 Mg C/km^2 (Schile *et al.,* 2017), with a range of 1,860-242,400 Mg C/km^2, which means that microbial mats here have similar organic carbon densities to that of natural mangroves and higher than any of the other blue carbon ecosystems. Unfortunately, no maps showing their extents are available for this Report. The statement "We demonstrate that microbial mats store carbon at rates comparable to vegetated intertidal ecosystems and argue that they meet the criteria of a blue carbon ecosystem." made by Schile *et al.,* (2017) illustrates the need to consider these systems in more detailwhen making future assessments.

3.5.2 Coastal Sabkhas

A coastal sabkha is a supratidal mudflat or sandflat in which minerals accumulate as the result of semiarid to arid climate; generally, they form a shallow basin containing several percent gypsum (a soft sulphate mineral) alongside a high carbon content (Briere 2000). Sabkha ecosystems have been described in detail by (Friedman and Krumbein 1985).

The coastal sabkha extent calculated from the workshop assessment (7,342 km^2) is significantly less than that of the AGEDI dataset (11,483 km^2). The AGEDI sabkha dataset was created in 2000 as part of a coastal sensitivity atlas within the I-RSA, as a result, the decrease in sabkha extent may be due to habitat loss due to coastal development or misclassification of sabkha habitat ecosystem in the original dataset (Brown and Böer 2004). The AGEDI sabkha dataset includes some areas that could beclassified as inland sabkha and the decrease in extent in the workshop edited data results from the exclusion of inland ecosystems.

The mean soil organic carbon density of coastal sabkhas has been reported as 8,240 Mg C/km^2 with arange of 5,100-12,050 Mg C/km^2 (Schile *et al.,* 2017). While this is significantly lower than that of mangroves or microbial mats, their aerial extent, even using the reduced figure derived from the workshop still means that a significant amount of organic carbon is potentially stored in coastal sabkha soils (60.6 Tera-grams of Carbon).

3.5.3 Sediments

Shelf sea sediments have been considered to contain significant carbon stocks (Diesing *et al.,* 2017) and are subject to a range of human impacts such as fishing (particularly trawling), construction and dredging; activities that can influence the fate of the carbon stores. Absolute carbon concentrations are usually not very high, however, the large areas covered result in very significant total amounts, providing a very valuable ecosystem service (Luisetti *et al.,* 2019). Data from sediments in Bahrain and Kuwait collected as part of pollutant sampling studies showed carbon concentrations of 0.03 – 1.48 %(Lyons *et al.,* 2015), which are lower per area than the other blue carbon habitats, however the total area covered by soft sediments and therefore resulting total carbon stocks are very large.

A very rough first estimate of carbon stored in surficial sediments can be derived (by making some assumptions specified in Appendix 2) and the average of 1.15 % organic carbon estimated by Behbahani *et al.,* (2015) is based on 76 bottom surface grab samples taken in the RSA. Integrating overthe top 10 cm, this would be equivalent to 1.52 kg/m^2 of carbon resulting in a total estimate of ca. 708 Tera-gram carbon over the 465,000 km^2 of the RSA. This carbon stock is about six-fold larger than the combined stock residing in the five other habitats.

Although sediments contain a large amount of carbon most of it is not directly manageable, and therefore does not meet the criteria for being considered as blue carbon. However, human activities can potentially impact sediment carbon stores in limited areas, and it is an area of active debate regarding how to account for sediment carbon in blue carbon inventories. Some consideration of sediment carbon could be considered in future blue carbon inventories, although they have not been included in this analysis.

4 Risks to Blue Carbon Ecosystems

Globally, blue carbon ecosystems are under threat from various human activities as well as climate change. What represents the greatest threat varies between ecosystems and regions, but there is some commonality. Significant areas of blue carbon ecosystems have already been degraded or lost, though currently no specific studies have quantified the losses of ecosystem extent within the RSA.

During the expert workshop, a review of local risks and threats to blue carbon habitats was conducted and is summarised below. Several of the threats identified are applicable to the entire Region, but are tabulated here as Member State specific:

Bahrain:

- Seagrass meadows are affected by dredging and previously trawl fishing, which is now banned(though questions remain as to whether the ban is it respected and maintained).
- Mangroves are threatened by land reclamation.

Iran:

- Saltmarshes have been affected by extensive damming, which has led to the drying out of many rivers and wetlands.

Iraq:

- As in Iran, saltmarshes have been affected by damming, which has led to a reduction in the water level in Tigris-Euphrates basin and tributaries and wetlands, particularly marshes.

Kuwait:

- Water quality issues and general pollution can threaten blue carbon ecosystems.

Oman:

- Development squeezes coastal blue carbon ecosystems and a lack of awareness exacerbatesthe problem.
- Trawl fishing still damages submerged blue carbon stocks in saltmarshes (despite a ban).
- Camel grazing (see Qatar).

Qatar:

- Camel grazing is a declining threat but has in the past been devastating for blue carbon ecosystems in Qatar and Oman.

Saudi Arabia:

- Urban development and land reclamation is considered a threat for mangroves in the kingdom.

UAE:

- Tourism can be detrimental. Seagrass is being removed for aesthetic reasons.
- Land reclamation and/or coastal modification mostly negatively impacts blue carbon habitatsbut can provide an opportunity for seagrass colonisation.

RSA-wide:

Across the Region, fragmentation of blue carbon ecosystems due to development threatens their integrity and viability, as do coastal regime changes (Almahasheer *et al.,* 2013). For example, the potential impacts on seagrasses from dredging and sand mining include the physical removal and/or burial of vegetation and the effects of increased turbidity and sedimentation (Erftemeijer and Shuail 2012, Erftemeijer and Robin Lewis 2006). Water diversions, for example through damming, affects thesystems in multiple ways, from impacts on salinity to reduction of carbon containing source materials reaching the coast to the complete drying out of wetland ecosystems. Another Regional issue is oil spills, which can be transboundary. Fortunately, they are decreasing due to improved standards and management controls within the oil industry, though they can continue to be a problem in ports and following releases from vessels (Ashok *et al.,* 2019).

Climate change affects all blue carbon ecosystems across the Region and can enhance the effects of the environmental impacts listed above. Climate change and the many ways in which it can affect carbon storage in blue carbon ecosystems has been considered in detail by Macreadie *et al.,* (2019), listing potential gains as well as losses. **Sea level rise** could result in a landward expansion of mangroves, saltmarshes and seagrasses, though often this is limited by inland areas being already developed, resulting in coastal squeeze with loss of the associated habitats. Increased sea level can also result in loss of seagrass meadows in deep waters. **Extreme storms**, including cyclones, can result in physical damage to the canopy of mangroves, reduced recruitment and potentially soil subsidence, though soil elevation gains due to increased sediment deposition are also possible. In the latter case,the effect could reduce the impact of sea level rise. Saltmarshes could equally be either lost due to subsidence and permanent flooding or experience an increase in elevation due to increased sedimentation. Seagrasses can suffer from direct erosion during storms or flood events associated with extreme rainfall, which may result in mortality, though some seagrass species are resistant to these major events. As for mangroves and saltmarshes, increased sedimentation can enhance sediment accretion and carbon sequestration. Air-borne dust storms can lead to increased turbidity and smothering of vegetation. **Higher temperatures** could lead to increased decomposition of soil organic carbon, and a poleward spread of mangroves at the expense of marshes. Seagrass meadows can respond negatively to temperature increases with thermal die-offs leading to loss of carbon stocks, though the increased productively or colonization of new poleward regions are also possible. **Increased CO_2** levels in the atmosphere generally benefit plant productivity across the ecosystems, with resulting increases in carbon stock. As the CO_2 dissolves in the water, causing **ocean acidification**,a loss of seagrass biodiversity can be experienced and cause a decrease in carbon stocks. Lastly, **alterations in precipitation**, particularly prolonged droughts, can cause die-back of the mangrove canopy as well as reduced productivity of saltmarshes. Areas that already experience variable or scarce rainfall might be strongly affected. Drying up of saltmarsh soils leads to increased carbon respiration, while the opposite effect, e.g., increased rainfalls, would be expected to result in increased productivity and carbon storage. If very strong precipitation falls over seagrass meadows, it has the potential to negatively affect them, particularly through interactions involving disease, though most seagrasses are tolerant of acute low salinity events. Reductions in rainfall generally reduce turbidity levels, which causes increases in light penetration and subsequently productivity.

In summary, climate change will affect all blue carbon ecosystems across the Region, with some potential positive effects on carbon storage, though on balance more processes resulting in reductions in carbon stores are anticipated. Climate change impacts are particularly severe due to extreme events, overlaying what is already an extreme environment in terms of temperature and low precipitation. Understanding the likely changes and their distributions in time and space will be important in understanding and, where possible, mitigating against the effects of climate change.

5 Potential for Mitigation and Adaptation of Climate Change and Wider Ecosystem Services

Reviewing the climate change mitigation potential arising from the carbon sequestration across the ecosystems covered in this Report (Table 3), represents one tool in the suite of efforts required to reduce GHG emissions. While their annual sequestration rates only represent a small fraction of Regional CO_2 emissions, the total amount of carbon they contain is significant as these carbon stores have developed over many centuries. Ensuring that these carbon stores are not released as a result of ecosystem degradation is essential to avoid additional GHG emissions.

Although the carbon storage capacity of blue carbon ecosystems in the RSA may be small compared to other regions or terrestrial ecosystems globally, within the arid Region of the RSA these are some of the largest organic carbon stocks.

In terms of adaptation to climate change, coastal blue carbon ecosystems play a vital role in coastal protection, mitigating against storm induced flooding and infrastructure damage from sea level rise. In sum, blue carbon ecosystems are a valuable part of NbS and merit protection.

In addition to their role in locking carbon away from release into the atmosphere, these systems provide a wide range of other important ecosystem services. To maximise benefits, it is important to protect and conserve existing blue carbon ecosystems, as restoration is costly and regaining the original carbon stock values is often a lengthy process. However, in cases where original systems have been damaged or removed, restoration projects should be considered as a step in the right direction.

6 Knowledge Gaps

Significant knowledge gaps remain in terms of a comprehensive inventory of blue carbon in the RSA. While some data are available for extents and carbon stocks across all habitats, the data coverage is inconsistent, and some Member States have significantly better coverage than others. In some countries, ecosystem extent maps are not readily and publicly accessible at all. Consistent methodology was not necessarily employed when collecting the available data, potentially adding sources of error, and reducing reasonable comparability between observations.

Uncertainties remain in habitat extents and carbon stocks, but particularly accumulation rates are rarely available for most areas and ecosystems, and completely missing for sabkhas and microbial mats. This information is important to determine whether these ecosystems can be classified in international policy as actionable blue carbon habitats. Understanding changes in habitat extent is also essential for the development of successful blue carbon projects. The emerging blue carbon ecosystems reviewed, still require extensive observational programmes to ascertain their climate mitigation potential.

Lastly and looking forward, it will be important to establish what impact management actions can have and to what extent the current threats experienced by the reviewed blue carbon ecosystems already result in avoidable GHG emissions.

7 Conclusions

From the information reviewed above, it is apparent that the RSA is home to a large range of blue carbon ecosystems that perform very important, diverse, and valuable functions for the Region. Information regarding ecosystem locations, extents and condition, and specific analytical results in terms of carbon stocks and accumulation rates is patchy. Further efforts to increase this knowledge base would likely strengthen the case for their protection. While studies focussing on carbon storagein coastal ecosystems have been well published in Saudi Arabia and the UAE, data availability from other Member States is lacking. It is also noteworthy, that to date, no accumulation rates have been reported for sabkhas and microbial mats. This makes it difficult to fully access the climate mitigation potential of these systems. Equally, seabed sediments, which cover a large area and are estimated tocontain very significant carbon stocks, have not been evaluated in detail for their role in the Regional carbon cycle.

In terms of the carbon contents identified in the RSA ecosystems, it is apparent that this arid Region has significantly lower values than those used as global default values by the IPCC. It is therefore important to adopt Regionally relevant values such as those specified in this Report or refined by future research efforts.

Although the annual accumulation rates of blue carbon habitats across the RSA are small compared to current total emissions by ROPME Member States, the importance of these habitats can also be considered in terms of (i) greater proportion of emissions they would account for once total emissions have been significantly reduced, (ii) the total carbon stored, and (iii) the important wider ecosystem services delivered by these ecosystems.

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Appendix 1. Participants of the Workshop of the TSG on Blue Carbon in the RSA, Muscat, Oman, January 2020

Name	Organization
Dr. Thamer Salim Ali Al-Dawood	Arabian Gulf University, Kingdom of Bahrain
Dr. Mohammad Reza Shokri	Shahid Beheshti University, Islamic Republic of Iran
Dr. Talib Abbas Khalaf	Marine Science Centre, Al Basrah, Republic of Iraq
Dr. Alanoud Al-Ragum	Kuwait Institute for Scientific Research (KISR), State of Kuwait
Dr. Simon Wilson	Five Oceans Environmental Services L.L.C, Sultanate of Oman
Ms. Cecilia Martin	King Abdullah University of Science and Technology, Kingdom of Saudi Arabia
Ms. Marina Antonopoulou	Emirates Nature – WWF, United Arab Emirates
Mr. Daniel Mateos-Molina	Emirates Nature – WWF, United Arab Emirates
Eng. Hilal Sultan Ali Al-Shukaili	Ministry of Environment & Climate Affairs (MECA), Sultanate of Oman
Mr. Badar Yousef Al-Bulushi	MECA, Sultanate of Oman
Mr. Ahmed Mohammed Al-Habsi	MECA, Sultanate of Oman
Dr. Hilal Al Shaqsi	MECA, Sultanate of Oman
Mr. Ibrahim Said Al Anboori	MECA, Sultanate of Oman
Eng. Aida Al Jabri	MECA, Sultanate of Oman
Ms. Sana Ali Al Jardani	MECA, Sultanate of Oman
Ms. Muna Hashil Al Tarshi	MECA, Sultanate of Oman
Ms. Aziza Said Humaid Al Adhasbi	MECA, Sultanate of Oman
Ms. Abdulrahman Al Abri	MECA, Sultanate of Oman
Dr. Will Le Quesne	Cefas, United Kingdom
Dr. Ella Howes	Cefas, United Kingdom
Ms. Lisa Benson	Cefas, United Kingdom
Dr. Hassan Mohammadi	ROPME
Dr. Wahid Mohamed Moufaddal	ROPME

Appendix 2. Sediment carbon estimation

A very rough first estimate of carbon stored in surficial sediments can be derived assuming a porosity of 50 % (equivalent to ca. 20% mud using an equation from Jenkins (2005), and a grain density of 2,650 kg/m^3 (Diesing *et al.,* 2017), resulting in a bulk density of 1,325 kg/m^3.

Average carbon values measured by Behbahani *et al.,* (2015) from 76 surface grab samples taken in the RSA contained 1.15 % organic carbon.

Integrating over the top 10 cm (0.1 m *0.0115*1325 kg/m^3 = 1.52 kg/m^2), this would be equivalent to 1.52 kg/m^2 of carbon resulting in a total estimate of 706.8 Teragram carbon over the 465,000 km^2 of the RSA.

REGIONAL ORGANIZATION FOR THE PROTECTION OF
THE MARINE ENVIRONMENT (ROPME)

Granada, Jamal Abdul Nasser Street, Area:3,
P.O.BOX: 26388, SAFAT –13124, STATE OF KUWAIT
Tel: (965) 22093939 / 24861442
Fax: (965) 24864212 / 24861668
Email: ropme@ropme.org
www. ropme.org