Convention
on Wetlands
Ramsar

The contribution of blue carbon ecosystems to climate change mitigation

Purpose

The purpose of this Briefing Note is to expand knowledge on the extent and status of blue carbon ecosystems in Wetlands of International Importance (Ramsar Sites) and explore the contributions these ecosystems can make to climate change mitigation and adaptation through nature-based solutions. This Briefing Note also supports the application of the Convention on Wetlands' wise use guidelines to blue carbon ecosystems to protect their capacity to sequester and store carbon, as well as the many other benefits they provide, contributing towards the Convention's mission of promoting the wise use of wetlands.

Background

This Briefing Note was prepared by the Scientific and Technical Review Panel (STRP) of the Convention on Wetlands, in response to Resolution XIII.14, *Promoting conservation, restoration and sustainable management of coastal blue-carbon ecosystems*. This Briefing Note, which is based on a desktop study of blue carbon ecosystems in Ramsar Sites, describes the spatial extent, ecological characteristics and condition of coastal blue-carbon ecosystems across Ramsar Sites[1].

Blue carbon ecosystems, specifically mangrove forests, intertidal marshes and seagrass beds, are coastal wetlands that continuously take up atmospheric carbon dioxide, storing large amounts of this carbon in soils and sediments. The conservation and restoration of blue carbon ecosystems constitutes a nature-based approach to climate mitigation and adaptation, whilst also providing a range of other valuable ecosystem services.

Protection, management and restoration of blue carbon ecosystems can be strengthened through the designation of new Ramsar Sites, enhanced management of existing sites and minimization of threats that lead to coastal wetland degradation and loss. Such actions can be included in Nationally Determined Contributions (NDCs) towards meeting the objectives of the Paris Agreement of the UN Framework Convention on Climate Change (UNFCCC). Continued effort is needed to address uncertainty about the extent of blue carbon ecosystems, which currently limits the ability of Contracting Parties to manage them effectively for climate mitigation and adaptation and account for their carbon uptake and emissions.

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[1] Beers, L., S. Crooks, S. & Fennessy, S. (2020). Desktop Study of Blue Carbon Ecosystems in Ramsar Sites. Report by Silvestrum Climate Associates for the Scientific and Technical Review Panel of the Convention on Wetlands.

Relevant Ramsar documents

Resolution XI.14: *Climate change and wetlands: implications for the Ramsar Convention on Wetlands*

Resolution XII.13: *Wetlands and disaster risk reduction*

Resolution XIII.14: *Promoting conservation, restoration and sustainable management of coastal blue-carbon ecosystems*

Resolution XIII.15: *Cultural values and practices of indigenous peoples and local communities and their contribution to climate-change mitigation and adaptation in wetlands*

Resolution XIII.20: *Promoting the conservation and wise use of intertidal wetlands and ecologically-associated habitats*

Ramsar Handbook No. 12: *Coastal management*

Ramsar Technical Report No. 5: *A framework for assessing the vulnerability of wetlands to climate change*

Ramsar Briefing Note No. 10: *Wetland restoration for climate change resilience*

Ramsar Fact Sheet: *Realizing the full potential of marine and coastal wetlands: why their restoration matters*

Key messages

- **Blue carbon ecosystems take up and store significant amounts of carbon from the atmosphere. This makes their conservation and restoration an essential approach to mitigate climate change.** Blue carbon ecosystems are tidally influenced wetlands including mangrove forests, intertidal marshes and seagrass beds, where carbon is captured by living organisms and stored in biomass (the total mass of living organism in an area) and sediments. If undisturbed, the carbon stored in sediments is stable and can remain for thousands of years. Once disturbed or drained, substantial amounts of this carbon can be rapidly released. Because blue carbon ecosystems take up and store a high concentration of carbon per unit area, a strong case can be made for their inclusion in climate mitigation planning.

- **Blue carbon ecosystems are found on every continent except Antarctica and cover an estimated 49 million hectares** (The International Blue Carbon Initiative, 2020). **The total extent of blue carbon ecosystems located within Ramsar sites has not been fully mapped.** Global estimates of total carbon storage in blue carbon ecosystems range from 10,450 to 25,070 million tonnes of carbon in the first metre of soil. This includes 512 tonnes carbon per hectare in seagrass beds, and 917 and 1028 tonnes carbon per hectare in salt marshes and mangroves, respectively (Pendelton *et al.* 2012). Similarly, Ramsar sites with mangrove forests have the largest carbon stocks, storing between 212.1 and 725.1 tonnes per hectare (Beers *et al.* 2020). This is the equivalent of each hectare of mangrove forest storing the amount of carbon held in up to 1.1 million litres of petrol (United States Environmental Protection Agency, 2021).

- **The extent of mangrove forests in Ramsar Sites declined by an average of 4% between 1997 and 2016. This rate of loss (estimated at 0.2% annually) is one order of magnitude lower than the estimated global average annual loss of 2%.** Despite this, more than two thirds of mangrove forests within Ramsar Sites lost area, which means they lost not only the ability to sequester carbon but also suffered avoidable losses as the carbon stored in soils and biomass was released to the atmosphere. Another approximately 20% of Ramsar Sites, showed an increase in mangrove area and, thus, are sequestering more carbon, initially largely in tree biomass (Beers *et al.* 2020).

- **Accurate global mapping of blue carbon ecosystems remains a significant gap in our understanding of their overall geographic coverage, particularly for intertidal marshes and seagrass beds**. A survey among Contracting Parties identified this as the most common barrier that limits their protection, restoration and sustainable management. The absence of baseline inventory data for the overall extent of blue carbon ecosystems is also likely to cause their climate benefits to be underestimated.

- **There are policy action gaps that can be addressed, such as including blue carbon ecosystem protection and restoration in Nationally Determined Contributions under the Paris Climate Agreement.** Information on the extent of blue carbon ecosystems is a minimum requirement to be able to include blue carbon in Nationally Determined Contributions (NDCs). The Intergovernmental Panel on Climate Change (IPCC) Wetlands supplement can be used to account for blue carbon ecosystems in national greenhouse gas (GHG) inventories. So doing will align management actions with existing or developing international policy and national commitments to address climate change. Depending on a country's national definition of "forest," mangroves may also be included in its REDD+ programme.

- **While blue carbon ecosystems can be considered 'hot-spots' of carbon storage, they also offer many other benefits including contributing to ecosystem-based adaptation to climate change.** Beneficial contributions include flood and shoreline protection, water quality protection, support of livelihoods, biodiversity support and habitat for fish (e.g., nurseries), birds, invertebrates and mammals, as well as land-building capacity.

The issue

Blue carbon refers to the carbon stored and sequestered in coastal wetlands and is defined under the Convention on Wetlands as: "[t]he carbon captured by living organisms in coastal (e.g. mangroves, salt [intertidal] marshes and seagrasses) and marine ecosystems and stored in biomass and sediments." [1] The majority of the captured carbon is stored in soils and sediments, resulting in long-term carbon accumulation (Windham-Myers *et al.* 2019, Chmura *et al.* 2003). As a result, coastal wetlands are an on-going and powerful carbon sink, with sediment carbon burial rates that are up to 55-times faster than tropical rainforests (McLeod *et al.* 2011). This carbon uptake helps counterbalance human GHG emissions, giving blue carbon ecosystems an important role in climate change mitigation. Blue carbon ecosystems also provide other important ecosystem benefits that contribute to human well-being, such as coastal protection from storms and floods, protection of water quality, biodiversity support, food to support sustainable livelihoods and as nursery grounds for many species of marine life[2].

When blue carbon ecosystems are lost or degraded, the impact on carbon is twofold. The first, is the lost potential for carbon sequestration (i.e., the annual carbon uptake) at the high rates per area that are commonly found in blue carbon ecosystems. The second, is the release to the atmosphere of ancient buried carbon that has been stored over the past centuries to millennia; this carbon increases warming (Pendelton *et al.* 2012). Such impacts can convert blue carbon ecosystems from net carbon sinks to net sources of GHGs. This briefing note provides a summary of what is known about blue carbon ecosystems with a focus on blue carbon ecosystems in Ramsar Sites (grouped by Ramsar Region) using available data and information to make estimates of their carbon sequestration and storage in a manner consistent with the IPCC Wetlands Supplement (2014).

Blue carbon ecosystems and the network of Ramsar Sites

Globally, all blue carbon ecosystems (not just those in Ramsar Sites) account for nearly 50% of carbon burial in marine sediments, despite taking up less than 2% of the ocean area (Duarte *et al.* 2013). This carbon is taken up from the atmosphere, stored in plant biomass before it moves to long-term storage in the sediments (Crooks *et al.* 2019). The conservation, restoration and wise use of wetlands to maintain ongoing carbon sequestration and storage functions and to halt and reverse emissions from degraded or destroyed sites are effective climate mitigation strategies (Ramsar Briefing Note No. 10, Crooks *et al.* 2019). Conversely, the loss and degradation of blue carbon ecosystems contribute significantly to global climate change. It is estimated that up to one billion tons of carbon dioxide are released each year from degraded blue carbon ecosystems, an amount that is equal to nearly 20% of the global emissions from deforestation (Pendelton *et al.* 2012). Current estimates are that about one third of the historical area once covered by blue carbon ecosystems has already been lost, and they continue to face ongoing threats. The high carbon content (carbon per unit area) in blue carbon ecosystems led the IPCC to develop guidelines for national inventories of their greenhouse gas emissions and removals. These guidelines form the basis for national assessment and reporting of blue carbon ecosystems in NDCs under the Paris Agreement of the UNFCCC. As of 2018, 58 countries have included blue carbon ecosystems as part of their NDC commitments to reduce net GHG emissions (Crooks *et al.* 2019). As a result, accurate carbon accounting for wetlands becomes vital to determine whether national targets and objectives are achieved.

The value of blue carbon ecosystems in accumulating and protecting disproportionately large carbon stocks extends to coastal wetlands whether or not they are included in Ramsar Sites. As such, all blue carbon ecosystems should be considered for conservation and restoration. In order to specifically characterize the extent and carbon sequestration and storage in Ramsar Sites, information from the Ramsar Sites Information Service (RSIS) database was used (note that some recent updates to the RSIS may not be included in this

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[1] The following caveat from Res. XIII.14 is worth noting: "However, not all Contracting Parties endorse this definition or recognize the Ramsar Convention as the competent forum to address mitigation reporting and accounting arrangements."

[2] See thebluecarboninitiative.org.

analysis). The result was a compilation of 780 Ramsar Sites that include at least one blue carbon ecosystem, with many of the sites containing multiple blue carbon ecosystems (Table 1, Figure 1).

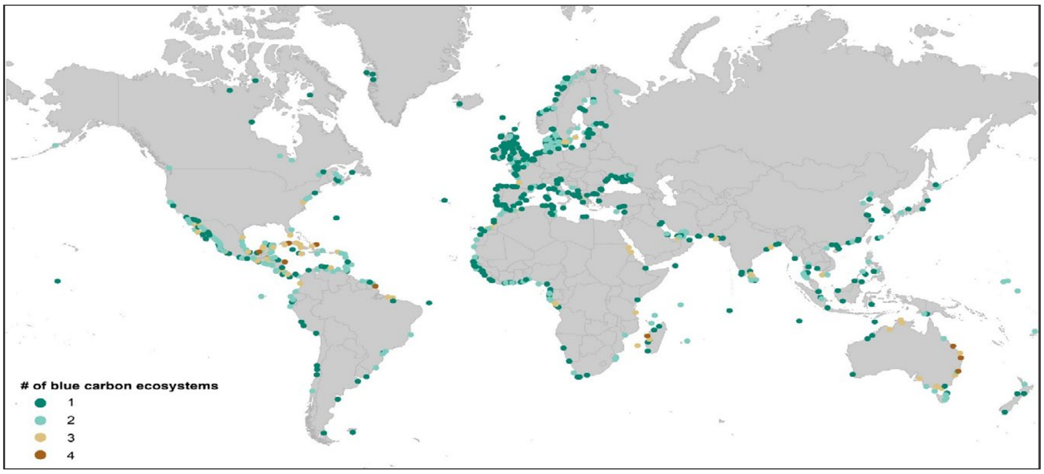

Figure 1
The distribution of Ramsar Sites containing blue carbon ecosystems (BCEs) indicating the number of BCEs within each site. Ecosystems include intertidal wetlands, intertidal forested wetlands, seagrass beds and shrub-dominated wetlands insert link (Beers *et al.* 2020).

Table 1. Occurrence (number and type) of blue carbon ecosystems in Ramsar Sites, by region. Note that some Ramsar Sites have multiple blue carbon ecosystems. Mangrove forests are a subset of intertidal forested wetlands (Beers *et al.* 2020).

Ramsar Region	Total # Ramsar Sites	Intertidal forested and shrub-dominated wetlands	Mangrove forests (subset of forested wetlands)	Intertidal marshes	Seagrass beds
Africa	116	78	61	61	41
Asia	93	70	62	38	29
Europe	337	53	20	286	103
Latin America & the Caribbean	87	83	72	52	36
North America	110	79	69	83	42
Oceania	37	31	17	27	20
Total	**780**	**394**	**301**	**547**	**271**

Mangrove forest extent

Historically, human activities have caused the loss of an estimated 30% of the original global mangrove area. Currently, mangrove forests occur in 121 countries located throughout the tropics and subtropics and 70 Contracting Parties support Ramsar Sites containing mangroves. To estimate mangrove area, carbon storage and the changes in each over time, the Global Mangrove Watch (GMW) dataset generated by Bunting *et al*. 2018 was used. Mangrove extent in the 1997, 2007 and 2016 datasets were compared to calculate changes in mangrove area on roughly a decadal basis (Table 2). Forty-five of the Ramsar Sites do not have GMW data associated with them[3] and thus are not included in the analysis.

As of 2016, Ramsar Sites contain over 3.8 million hectares of mangrove forests (Table 2). Mangrove area declined by an average of 4% between 1997 and 2016 (Table 2). This follows trends that are seen globally; however, the rate of loss in Ramsar sites, estimated at 0.2% annually, is approximately 10-fold slower than the global average of 2% annual losses (The International Blue Carbon Initiative, 2020). While the reasons for this difference have not been documented in detail, blue carbon ecosystems within Ramsar Sites appear to be better protected than those outside.

Mangrove loss was seen in all Ramsar Regions with the exception of Europe, which showed a 14% increase over this time period (largely due to one site whose area increased by 55%). The greatest mangrove losses were seen in Latin America and the Caribbean, which has the

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[3] No reason for omission was provided in Bunting *et al.* (2018).

Mangrove Swamp, Pagbilao Quezon, Philippines
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largest overall mangrove extent, and the largest percent change was in North America, with a decline of 8%. In total, over 158,000 ha of mangrove were lost from the Ramsar Regions during this period.

Table 2. Total mangrove area (ha) in Ramsar Sites in 1997, 2007 and 2016 from the Global Mangrove Watch dataset and changes in area over time in each Ramsar Region. Negative values represent mangrove area loss and positive values represent mangrove area gain.

Ramsar Region	1997 area (ha)	2007 area (ha)	2016 area (ha)	1997 to 2007 change (ha)	2007 to 2016 change (ha)	1997 to 2016 change (ha)	% Change 1997 to 2016
Africa	693,010	686,445	661,711	-6,565	-24,734	-31,299	-5%
Asia	873,946	861,697	858,409	-12,249	-3,288	-15,537	-2%
Europe	37,418	39,938	42,702	2,520	2,764	5,284	14%
Latin America & the Caribbean	1,325,005	1,292,607	1,273,923	-32,398	-18,684	-51,082	-4%
North America	834,240	816,189	770,767	-18,051	-45,422	-63,473	-8%
Oceania	157,677	157,055	155,554	-622	-1,501	-2,123	-1%
Total	**3,921,296**	**3,853,931**	**3,763,066**	**-67,365**	**-90,865**	**-158,230**	**-4%**

Intertidal marsh wetland extent

Tidal marshes are the dominant blue carbon ecosystems in the temperate zone, although they also occur in some upper tidal locations in the tropics. Human use and conversion of tidal marshes has been going on for hundreds or thousands of years, making estimates of their original extent difficult (Lovelock *et al.* 2019). Unlike mangrove ecosystems, tidal marsh wetlands have not been systematically mapped globally or over time, making estimates of their extent and associated carbon uptake and storage difficult.

Because of the lack of data, changes in intertidal marsh area contained in Ramsar Sites could not be determined. Data were available for only 42% of sites (230 out of 546 sites). For sites that had been mapped, the Ord River Floodplain in Australia has the greatest mapped area (143,741 ha) whilst the average area is 2,494 ha.

Vue de la Baie du Mont-Saint-Michel photographiée depuis la côte d'Hirel, Ille-et-Vilaine (35).
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Table 3. Total intertidal marsh area where geospatial data were available (230 out of 546 Ramsar Sites) and the total estimated area of seagrass beds where data were available for each Ramsar Region. Due to limited data availability these numbers are likely underestimates of the totals for each region.

Ramsar Region	Mapped intertidal marsh area (ha)
Africa	713
Asia	37,104
Europe	287,773
Latin America & the Caribbean	6,152
North America	10,294
Oceania	251,470
Total	**593,506**

Source: Beers *et al.* 2020.

Seagrass bed extent

Seagrass beds have suffered huge losses of area globally, largely as a result of declining water quality (Forqurean *et al.* 2012). Although there is much uncertainty in estimates of the global area of seagrasses, estimates show that losses are increasing, from an estimated average of 0.9% per year before 1940 to 7% loss per year since 1990 (Waycott *et al.* 2009; UNEP, 2020). A major complication in gathering data on seagrass extent results from the difficulty of mapping these ecosystems. For instance, remote-sensing techniques used to map wetlands at a large scale are often not able to accurately penetrate water where seagrass beds occur. As a result, there is no comprehensive global dataset on their extent or changes in extent over time.

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To remedy this, the global distribution of seagrass beds has been estimated with models (Jayathilake & Costello, 2018). Using the World Atlas of Seagrasses (Green and Short, 2003), estimates of seagrass extent were compiled for sites in the Ramsar Regions where data were available (Table 4), although this is by no means comprehensive for the regions listed.

Table 4. Estimated area of seagrass beds across Ramsar regions where data are available.

Ramsar Region	Estimated Area (ha)
Africa	No data
North America[1]	2,431,500
Asia[2]	3,212,000
Europe[3]	894,000
Oceania[4]	9,641,800

Source: Green and Short, 2003; [1] Pacific coast of North America, Western North Atlantic Coast of USA, Mid-Atlantic coast of USA, Gulf of Mexico, East coast of Florida, Mexico; [2] Thailand, Peninsular Malaysia, Indonesia, India, Philippines, Viet Nam, Japan and Republic of Korea; [3] Scandinavia, Western Europe, Western Mediterranean and Euro-Asian Seas; [4] Western Australia, Eastern Australia and New Zealand.

Estimates of blue carbon ecosystems’ carbon stocks, removals and emissions

Mangrove forest carbon stocks

Mangroves are carbon-rich ecosystems with high carbon concentrations (carbon per unit area), making their conservation critical to enable continued sequestration and prevent the loss of stored carbon (avoidable emissions). Estimates of the carbon stocks held in mangrove biomass in the Ramsar Regions were made using modelled global values from Hutchinson *et al.* 2014. Much of the carbon stored in mangrove ecosystems is found in the soil. For

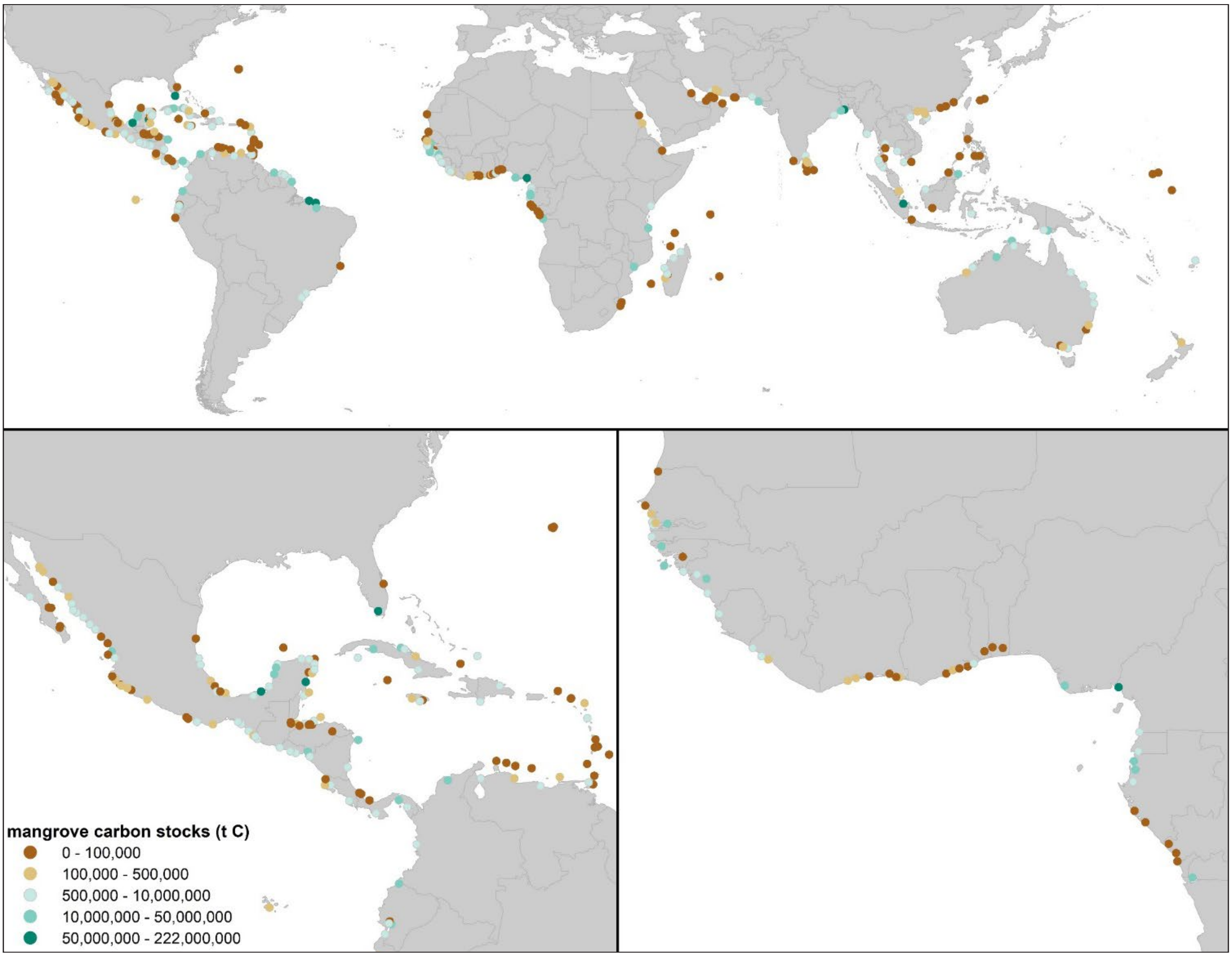


Figure 2
Total carbon stocks in mangrove ecosystems (trees plus soils) in Ramsar Sites (units in t C). Boxes in top map denote insets below (Beers *et al.* 2020).

this estimate, soil carbon stocks were derived from the Global Mangrove Watch. For sites that did not have soil or biomass data, the value from the closest Ramsar Site was used as a proxy. Calculations were made using only the top one metre of soil, which is likely to underestimate carbon stocks in many locations (Kauffman *et al.* 2020); however, there is no method currently available to model soil depth.

Ramsar Sites with mangrove forests hold an average of 432.6 tonnes of carbon per hectare (or t C ha^{-1}) combined in their soils and biomass, ranging from a low of 353.6 t C ha^{-1} in North America to a high of 522.8 t C ha^{-1} in Europe and similarly 514.81 in Latin America and the Caribbean (Table 5; Figure 2). The amount of carbon in the soil of Ramsar Sites ranged from 122 and 579 t C ha^{-1} (sites Estero el Chorro in Mexico and the Sembilang National Park in Indonesia, respectively). Sembilang National Park also had the highest total carbon stock (tree biomass plus soil; 725.13 t C ha^{-1}) and Basse Vallée de l'Ouémé, Lague de Porto-Novo, Lac Nokoué in Benin had the lowest (126.87 t C ha^{-1}), which is likely driven by differences in climate and hydrogeomorphic settings across Sites.

Carbon emissions and removals in mangrove forests with change in area

Estimates of total mangrove carbon losses (when carbon is released to the atmosphere; termed negative emissions) and removals (when carbon is taken up from the atmosphere) were made for Ramsar Sites over the 20-year period between 1997 and 2016 (Table 5; for details of this analysis, *see* Beers *et al.* 2020 [link to Ramsar website]). This analysis could only be done for mangroves as the other blue carbon ecosystems lack time series data. Two thirds of mangrove forests in Ramsar Sites have lost area over time and so have lost carbon. However, approximately 20% of Sites have had increases in mangrove habitat and are sequestering increasing amounts of carbon, largely in the tree biomass. Using the available data, the Ramsar mangrove forests in each Region hold between 19.2 and 620.7 million tonnes of carbon.

Table 5. Estimates of mean mangrove soil and biomass carbon (above- plus below- ground; t C per hectare) in Ramsar Sites by Ramsar Region. Also shown is the total amount of carbon potentially lost or gained by region from mangroves due to the loss of mangrove area over the period 1997-2016 (negative values indicate carbon lost; this is estimated for soil carbon to a depth of one meter), and of the total carbon stored in these sites (Beers *et al.* 2020) .

Ramsar Region	Mean Soil C (t C ha^{-1})	Mean Biomass C (above- + below-ground: t C ha^{-1})	Mean Total C stock (soil + biomass: t C ha^{-1})	Total C loss 1997 – 2016 (million metric tonnes, MT)	Total C held in all sites (million metric tonnes, MT)
Africa	291.71	107.80	399.51	-13.77	292.1
Asia	318.63	107.81	426.44	-4.97	289.7
Europe	410.52	109.02	522.84	1.92	19.2
Latin America & the Caribbean	401.25	115.78	514.81	-26.38	620.7
North America	264.90	88.63	353.53	-27.85	326.2
Oceania	303.19	75.02	378.22	-0.81	58.9
Average	**331.70**	**100.68**	**432.56**	**--**	**--**

Intertidal wetlands carbon stocks

Data is limited on the carbon sequestered and stored by intertidal wetlands. For example, there are no estimates for above- and below-ground biomass at the global level for intertidal wetlands. However, a recent study of a diverse selection of emergent wetlands, showed a narrow range (0.97 – 2.67 t C ha^{-1}) of biomass production values, which is likely to apply across global scales due to the diversity of species and wetland types used in these estimates (Byrd *et al.* 2019). The IPCC Wetlands Supplement provides Tier 2 (country-level) estimates to relate above-ground biomass to below-ground biomass.

There is also no global spatial dataset for intertidal wetland soil carbon stocks. To estimate soil Carbon per Ramsar Region, the IPCC Wetlands supplement Tier 1 (global) values were

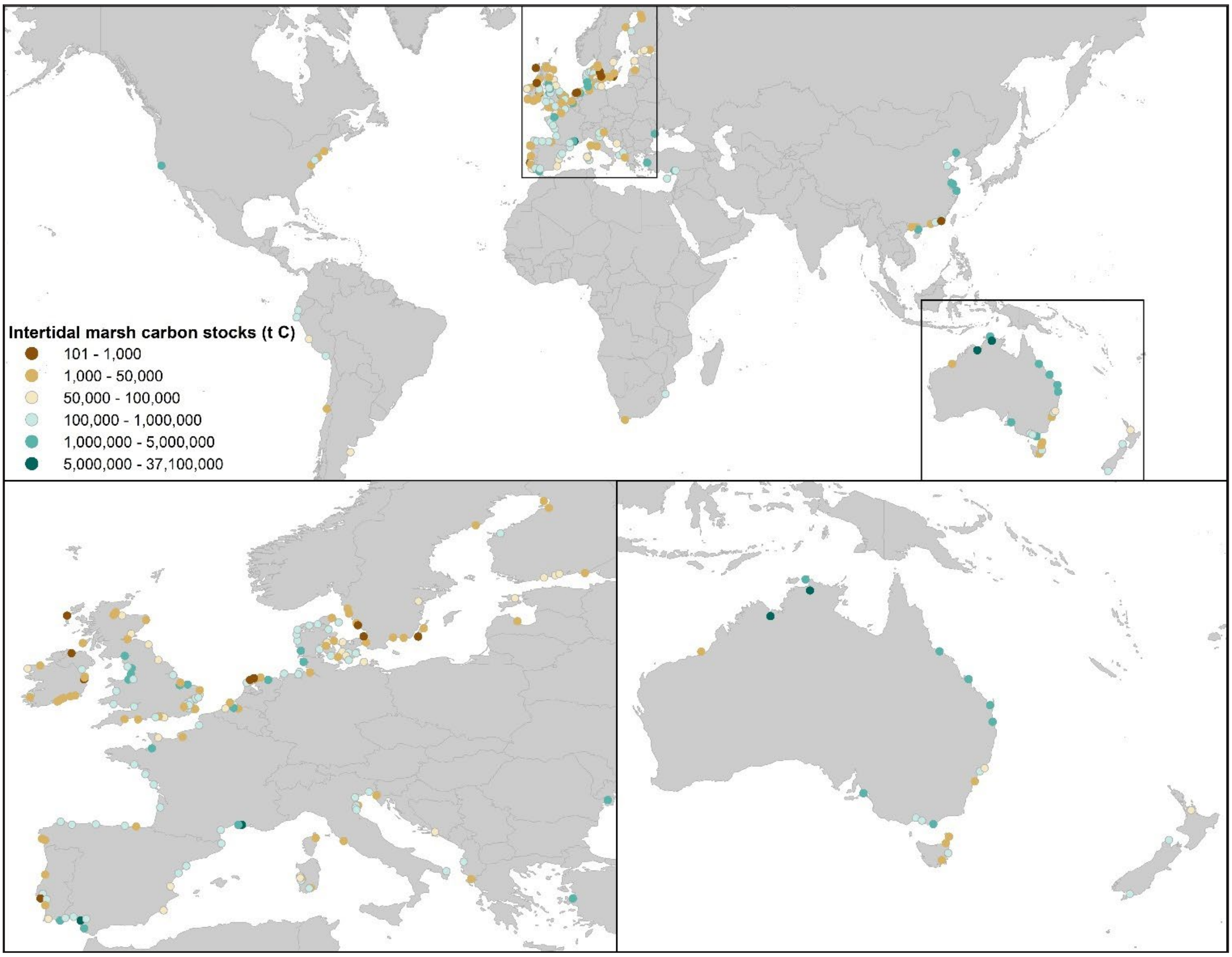


Figure 3
Total carbon stocks in intertidal marsh ecosystems in Ramsar Sites (units in t C). Boxes in top map denote insets below (Beers *et al.* 2020).

used (these can be used to 1 m depth based on soil type (e.g., mineral or organic soil; Table 6). Carbon storage (total) in intertidal wetlands in the Ramsar Regions ranged from 183,620 tonnes (Africa) to 74,159,600 tonnes (Europe). Oceania has a total of 251,470 ha of intertidal marsh that store nearly 65,000,000 tonnes of C (or ~65 teragrams; Table 3).

Table 6 Intertidal marsh carbon (above- plus below-ground biomass and soil; t C per hectare) in Ramsar Sites by Ramsar Region (Beers et al. 2020).

Ramsar Region	Number of Sites	Total area in region (ha)	Total C held in all sites (tonnes)
Africa	2	710	183,620
Asia	13	37,100	9,561,700
Europe	185	287,770	74,159,600
Latin America & the Caribbean	7	6,150	1,585,330
North America	6	10,290	2,652,720
Oceania	25	251,470	64,804,160
Total	**238**	**593,490**	**152,947,130**

Seagrass bed carbon stocks

Like intertidal wetlands, there is no global dataset for seagrass meadow biomass or underlying soil stocks, making estimates of carbon storage in these blue carbon ecosystems difficult. However, using existing literature, Fourqurean *et al.* 2012 assembled a dataset of total plant and soil carbon stocks at 946 distinct seagrass beds across the globe that can be applied to Ramsar Sites once seagrass areas are known. Where site-level above-ground biomass data is available, the IPCC Wetlands Supplement includes Tier 2 (region-level) conversions to below-ground biomass. The IPCC Wetlands supplement also presents Tier 1 (global) values for seagrass soil carbon stored to 1 m. When area estimates become available for additional Ramsar Sites containing seagrass beds, these IPCC conversions can be applied to estimate soil carbon stocks.

Soil carbon sequestration and GHG emission rates

Soil carbon sequestration represents the capacity of blue carbon ecosystems to take up carbon dioxide from the atmosphere and store in soils over the long-term, making it a vital process in reducing atmospheric carbon concentrations. Annual rates of carbon burial are typically higher in mangroves and intertidal marshes compared to seagrass beds (Table 7; Hiraishi *et al*. 2014). For Ramsar Sites where data are available on the extent of mangroves and/ or intertidal marshes, the IPCC's mean carbon burial rate for each ecosystem was used to estimate soil carbon sequestration rates.

Table 7. Rates of soil carbon burial in blue carbon ecosystems (from Hiraishi *et al.* 2014, Table 4.2; N sample size).

Ecosystem	Carbon burial rate (t C ha^{-1} yr^{-1})			N
	Mean	95% CI	Range	
Mangroves	1.62	1.3 - 2.0	0.10 – 2.2	69
Intertidal marshes	0.91	0.7 - 1.1	0.05 – 4.65	69
Seagrass beds	0.43	0.2 - 0.7	0.09 – 1.12	6

When blue carbon ecosystems are disturbed or converted to other land uses, they release stored carbon back to the atmosphere. In total, the three major GHGs, carbon dioxide (CO_2), methane (CH_4) and to a lesser extent nitrous oxide (N_2O, primarily from aquaculture), are

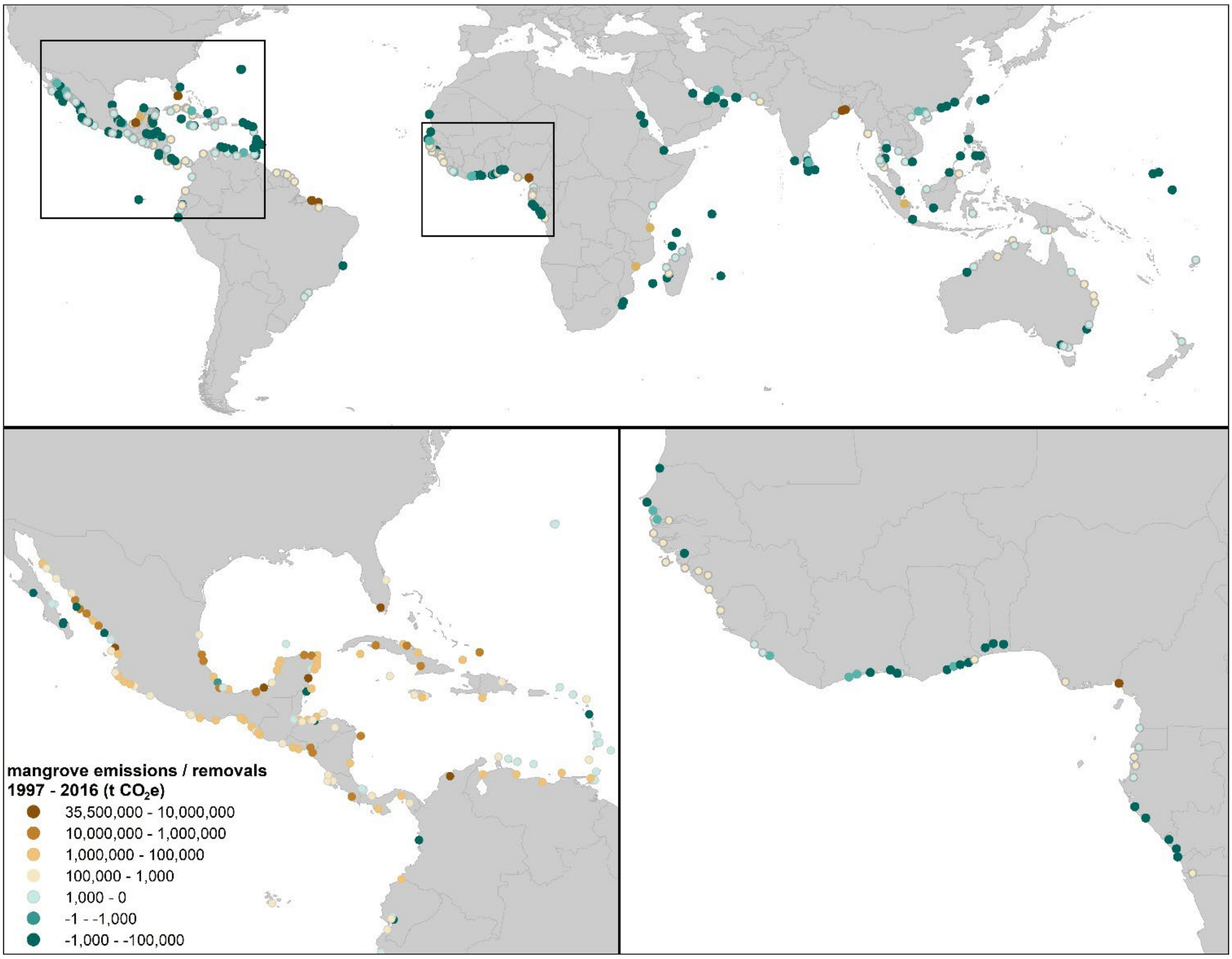


Figure 4
Emissions and removals from mangrove area change between 1997 and 2016 in Ramsar Sites (units in t CO_2e). Emissions are positive values and removals are negative values. Boxes in top map denote insets below (Beers *et al.* 2020).

released (Hu *et al.* 2012). In tidal wetland ecosystems, where the salinity is greater than 18 Practical Salinity Units (PSU), methane emissions are considered negligible. In estimating emissions from Ramsar Sites, all mangroves and salt marshes are assumed to have salinities greater than 18 PSU. Therefore, no methane emissions will occur. When salinities are less than 18 PSU, methane emissions can be quite variable; however, the IPCC Wetlands Supplement provides a default emissions value of 193.7 kg CH_4 ha^{-1} yr^{-1}, which is equal to 29.84 t CO_2e ha^{-1} yr^{-1} (i.e., carbon dioxide equivalents; Hiraishi *et al.* 2014) (Figure 4). As data on the extent of brackish and freshwater wetlands become more refined, the IPCC default value can be applied to improve these estimates.

Blue carbon and nationally determined contributions

The Paris Agreement (Decision I/CP.21) established NDCs to reduce GHG emissions as a means to address climate change. Under this Agreement, Parties are required to prepare and communicate NDCs, and establish measures required to achieve those carbon reduction goals as part of their proposed activities. Starting 2020, and every five years from that time, Parties will be requested to resubmit their NDCs with revised and more ambitious targets (Anisha *et al.* 2020).

Coastal blue carbon ecosystems may be included in NDCs as part of the planned climate mitigation and adaptation solutions. However, there are critical elements, such as mapping of wetland extent and determining carbon content of biomass, dead organic matter, and soils that are required to support effective contributions (Stocktake Report, 2017).

To address the lack of wetland specific information, the IPCC prepared the 2013 Wetlands Supplement to its Guidelines for National Greenhouse Gas Inventories (IPCC, 2014). The Supplement covers inland wetlands on organic and mineral soils, coastal wetlands (mangroves, tidal marshes and seagrass beds) and wetlands constructed for wastewater treatment. It provides emission factors and guidance to use with particular land-use scenarios. For example, emission factors are provided for drained mangroves, which can become a significant source of carbon dioxide. The IPCC also developed an approach to account for new sources and sinks of blue carbon, for example, forest management in mangroves may include removal of wood (carbon loss) or replanting of mangroves on rewetted or saturated soils (carbon uptake) (summarized from Troxler *et al.* 2019).

If wetlands are to be included in the NDCs, the following considerations are important (from Beasley *et al.* 2019):

- **Determine the extent and geographic scope of blue carbon ecosystems.**
  - Identifying the extent of coastal wetlands is the first step in using the IPCC Wetlands Supplement, which only requires information on the area of blue carbon ecosystems combined with proxies to calculate the potential for carbon uptake and storage.
- **Establish specific mitigation targets and goals for blue coastal ecosystems.**
  - Targets for coastal ecosystems (e.g., management and restoration) can include GHG goals and methods similar to those used for forests to recognize blue carbon ecosystem protection, conservation or avoided emissions.
  - If mangroves are specified in the National Forest Definition, they may be a part of the country's REDD+ programme and can be included in the preparation of NDCs.
- **Adaptation.**
  - Blue carbon ecosystems may be included in the adaptation section of a country's NDC or in associated National Adaptation Plans (NAP) and/ or Adaptation Communications (AC). Given the high adaptation value provided by coastal wetlands, such as flood protection, and water and food security, blue carbon ecosystems are well suited for this approach.

Threat assessment in Ramsar blue carbon ecosystems

The effective conservation and restoration of coastal wetlands depends on an understanding of the anthropogenic disturbances, or threats that can lead to blue carbon ecosystem degradation and loss. Information on threats can aid in the assessment of the benefits of blue carbon ecosystems and plan for restoration. In order to characterize the threats to blue carbon ecosystems, information from the RSIS database submitted by Contracting Parties was used to tabulate the most common threats that are either within or near Ramsar Sites.

Threats to Ramsar Sites vary across ecosystems and Regions. In intertidal forested wetlands and mangroves, biological resource use tended to be the dominant threat, followed by pollution and natural system modifications (Figure 5). Notably, shrub-dominated wetlands in the Oceania Region were reported to be most threatened by climate change and severe weather, and seagrass beds have a greater prevalence of threats from pollution, resource use and natural system modification.

It should be noted that this tabulation of threats is relatively coarse. A more thorough assessment of threats and their magnitude may be warranted to more fully understand the risks that human activities pose to blue carbon ecosystems that would limit their inclusion as part of NDCs. One notable omission from the list of potential threats in the RSIS is sea level rise which stands to significantly impact most coastal ecosystems. This should be remedied by adding it to the list of possible threats that might impact blue carbon ecosystems moving forward.

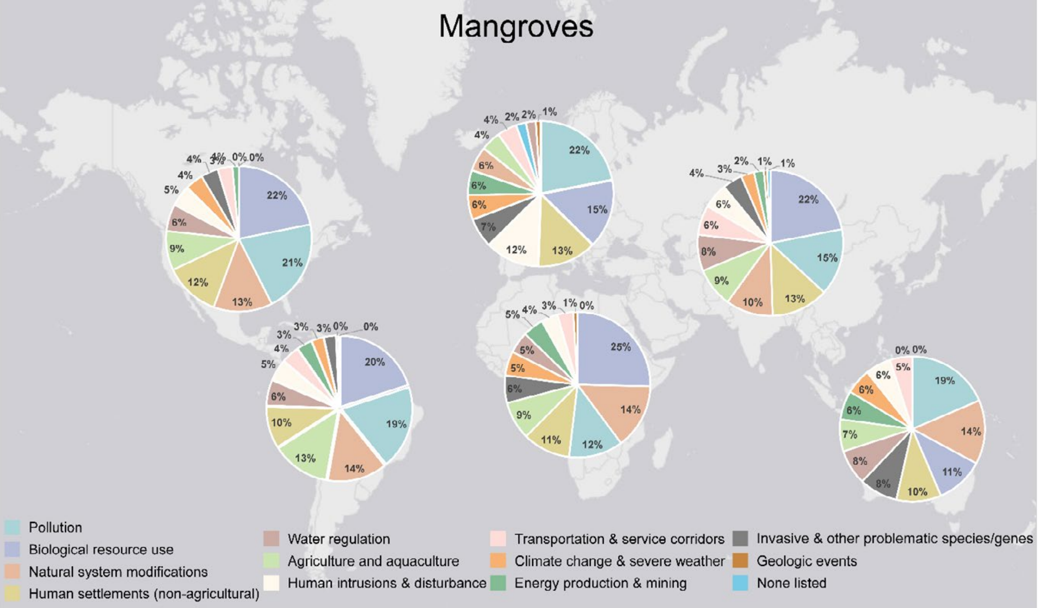


Figure 5
Percentage of Ramsar Sites that listed a given threat to mangrove ecosystems in the Ramsar Site Information Service across Ramsar Regions (Beers *et al.* 2020).

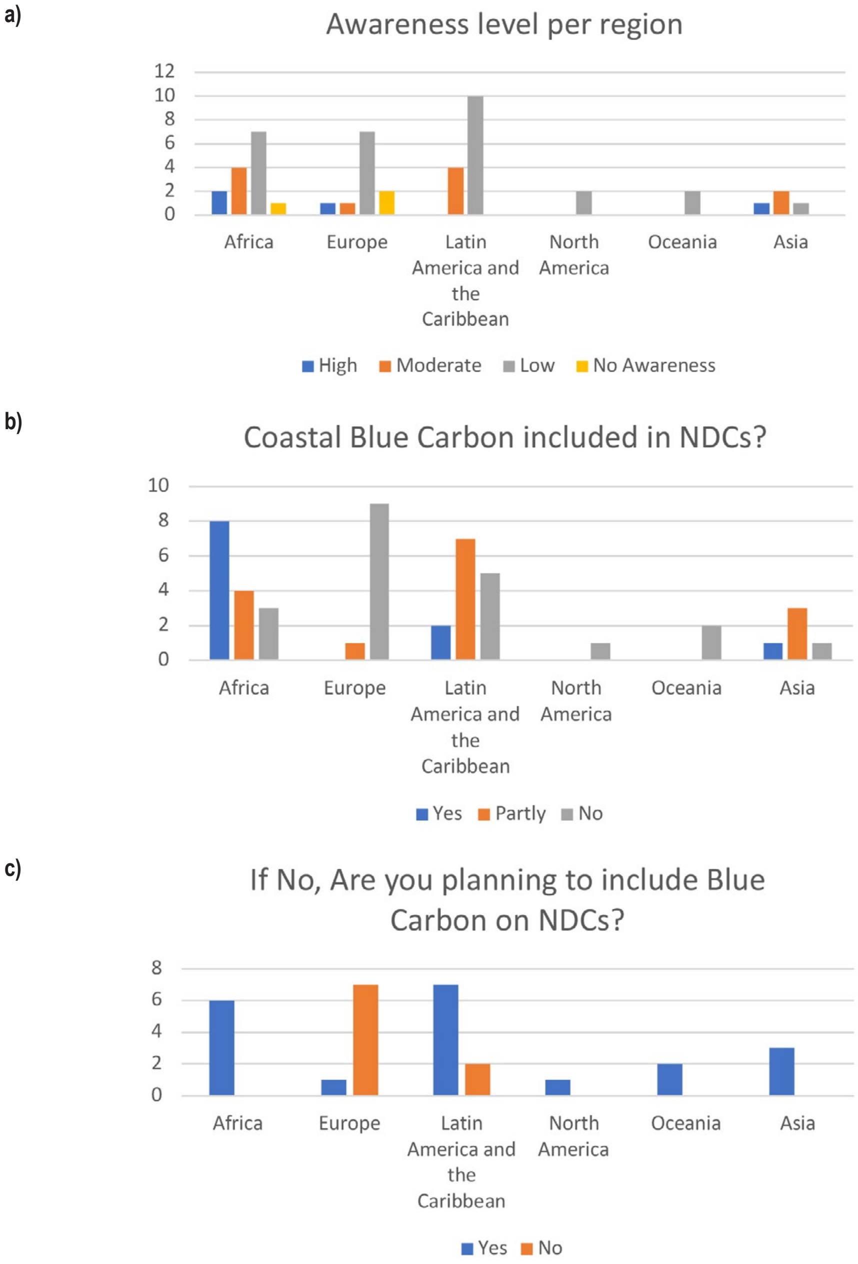
Survey of the needs of Contracting Parties with respect to blue carbon ecosystems

Coastal wetland protection, management and restoration can make a concrete and significant contribution to climate change mitigation and should therefore be considered a strategy for inclusion in NDCs. Building the capacity to include blue carbon in NDCs requires country specific information on the extent and types of coastal wetlands and a progression to assess and quantify their extent and carbon status. To evaluate this capacity in Ramsar Contracting Parties a survey was conducted to determine the requirements and needs in managing coastal wetlands. Fifty-five Contracting Parties participated.

In considering blue carbon ecosystems, the Contracting Parties who replied to the survey reported that work is needed to increase the awareness of blue carbon ecosystems on the part of governments, from community through to national levels. Within each Ramsar Region, an average of 70% of countries reported low to no government awareness of what blue carbon ecosystems are, or what benefits they provide (Figure 6a). Only four countries reported that the awareness of blue carbon ecosystems is high, and the Africa Region showed the highest awareness overall, with 22 (40%) countries reporting moderate to high awareness. This lack of understanding of the benefits of blue carbon and the important co-benefits that blue carbon ecosystems bring is a significant barrier to their inclusion in NDCs.

The proportion of Contracting Parties in the Ramsar Regions that have included, or are planning to include, coastal wetlands in their NDCs is highly variable; across all Ramsar Regions, an average of 50% of countries reported that coastal wetlands were not currently

Figure 6
Responses of Contracting Parties who responded to Ramsar Secretariat's 'Survey on Managing Blue Carbon Ecosystems' grouped by Ramsar Region on questions a) What is the level of awareness, including in government, provincial and community levels of what coastal blue carbon ecosystems are, and their importance; b) Does your country include coastal blue carbon ecosystems in your Nationally Determined Contributions to implement the Paris Agreement? and c) If no, are you considering including coastal blue carbon ecosystems in future pledges under your Nationally Determined Contributions?



included in their NDCs. Of these, more than half indicated that they plan to include blue carbon ecosystems in their NDC in the future (Figure 6b, c).

Globally, accurate mapping of blue carbon ecosystems is a significant gap in our understanding of their extent and geographic scope, particularly for tidal marshes and seagrass beds. Contracting Parties clearly identified this gap, with nearly 80% of respondents indicating that coastal wetlands were only partially mapped or had not been mapped at all. Only eight countries (or an average of 14% across Ramsar Regions) indicated that all blue carbon ecosystems were fully mapped. The need for comprehensive mapping was the most common barrier identified (expressed by over 50%), limiting the ability of Contracting Parties to protect, restore and sustainable manage blue carbon ecosystems. The second most common concern (expressed by 25% of countries) centred on the need to build the capacity to assess carbon stocks and changes in those stocks within coastal blue carbon ecosystems, including acquiring/ finding data to fill existing data gaps.

Inclusion of coastal wetland protection and management in NDCs and NAPs can contribute to enhancing their conservation status while deriving other ecosystem service benefits. In doing so Contracting Parties can leverage climate obligations with the multiple co-benefits wetlands provide. The IPCC 2013 Wetlands Supplement and the methodological guidance it provides on estimating emissions and removals has significantly advanced the carbon accounting needed to determine the climate contributions of blue carbon ecosystems.

Conclusions

Ramsar Sites protect only a small percentage of the total extent of blue carbon ecosystems in the Ramsar Regions; however, they sequester and store substantial amounts of carbon, contributing to climate change mitigation and supporting other valued ecosystem services. The Ramsar designation provides an important international level of protection for these wetland types, as evidenced in the slower than average loss of mangrove forests in Ramsar Sites and provides Contracting Parties with further opportunities to protect blue carbon ecosystems, through either enhanced management, expansion of existing Sites and/ or designating new Sites. Evidence for this is seen in the slower than average loss of mangrove forests in Ramsar Sites. Sites under special protection or management also constitute an important element in broader, national or ecosystem-scale plans for the wise use of all wetlands.

The significant gaps in knowledge of the full geographical coverage and extent of coastal wetlands in the global Ramsar network is a barrier for Contracting Parties to effectively manage their blue carbon ecosystems. This means that blue carbon is not yet being fully employed as an important means to mitigate climate change and its impacts. This data gap is not restricted to Ramsar Sites but rather is an important global knowledge gap that needs to be addressed to achieve multiple benefits for the climate, nature and people. Coastal wetland protection, management and restoration can be defined as part of NDCs, either through the establishment of new Ramsar sites, improving management of existing sites, and reducing threats that lead to wetland degradation and loss. Some blue carbon ecosystems may also be captured by other national, regional or international protected area designations for example, many near coastal ecosystems and islands are protected in formal marine park networks and also as part of inscribed World Heritage properties, such as in Australia and other countries in the Oceania Region. Ultimately, the mission of the Convention of Wetlands, to promote the wise use of all wetlands, applies to efforts to protect the stored and sequestered carbon in all coastal wetlands, as well as the other benefits these wetlands provide. To this end, Contracting Parties with coastlines should consider including coastal wetlands as part of their climate strategies.

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