United Nations
Educational, Scientific and
Cultural Organization

World
Heritage
Convention

UNESCO Marine World Heritage

Custodians of the globe's blue carbon assets

Sources of data, assumptions and calculations, references and other materials

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Appendix 1. Sources of data, assumptions and calculations

Estimates of areas occupied by different blue carbon ecosystems were provided, where available, by the local teams of the marine World Heritage sites. Where these data were not available, the authors derived these estimates from published and unpublished papers and reports. In some cases, presence of blue carbon ecosystems was confirmed but no information regarding habitat area was available; for these sites the authors acknowledge the presence of these habitats by assigning an area of 1 ha.

In the majority of the World Heritage sites there was no estimate for soil carbon stocks. In these cases, literature values were sought for soil organic carbon content and dry bulk density. If organic matter content was only available it was converted to organic carbon using local, ecosystem or global conversion factors. When dry bulk density data was lacking conversion factors from organic carbon/organic matter, or estimates based on grain size or sediment type were used. If no data was available for either parameter for the World Heritage site, carbon density from appropriate settings in the same country, latitude or ecosystem global average was used. The authors assumed a uniform distribution of carbon density with depth if soil data to 1 m was not available. For mangroves, the authors used published, 30-m resolution models by Giri et al. (2011), Sanderman et al. (2018), and Simard et al. (2019) to derive habitat area, soil carbon stocks, and aboveground biomass, respectively, for all sites except Lord Howe Island Group, East Rennell, Banc d'Arguin National Park, Brazilian Atlantic Islands: Fernando de Noronha and Atol das Rocas Reserve, and Archipiélago de Revillagigedo, which all had too small of mangrove habitat to be detected by remote sensing. See Table Appendix 1 for methods on how habitat area, soil carbon stocks, and aboveground biomass were estimated for these five mangrove sites.

In a number of marine World Heritage sites, the blue carbon ecosystems included in the property represent a fraction of the full extent of these ecosystems. In these cases, such as the Sundarbans mangroves, the authors included the broader extent of the ecosystem, given evidence that the declaration of the marine World Heritage site had spillover effects, leading to enhanced protection of the entire ecosystem, not just that included within the designated property. These are identified in the table summarizing the extent of blue carbon habitats at each marine World Heritage site (Table Appendix 2).

Specifically for seagrass, the assumptions around areal extent are the same as stated in the first and 3rd paragraph of this Appendix. Only five out of the 50 marine sites had site-specific estimates of soil organic carbon stocks (Ibiza Biodiversity and Culture, Great Barrier Reef, Shark Bay, Western Australia, Everglades National Park and Sian Ka'an). When site-specific data on soil carbon stocks was not available, we assumed that average stocks for the country, nearby countries or climate regions were representative for the marine sites (Table Appendix 1).

The CO_2 equivalent of the 5,02 billion tons of blue carbon embedded within the marine World Heritage sites was calculated by multiplying with 3,67. This is a standard conversion based on the atomic weight of one carbon atom ("blue carbon") versus one carbon atom and two oxygen atoms ("CO_2 or carbon dioxide").

Table Appendix 1. N/A indicates no seagrass or tidal marsh present at the UNESCO marine World Heritage site. Blank cells in the mangrove column with an asterisk (*) indicate that the authors used published, 30-m resolution models by Giri et al. (2011), Sanderman et al. (2018), and Simard et al. (2019) to derive habitat area, soil carbon stocks, and aboveground biomass, respectively.

		Data on seagrass soil C from	Data on tidal marsh soil C from	Data on mangrove area, aboveground biomass, and soil C from
1	Aldabra Atoll	Data from Tanzania in Belshe et al., 2018	N/A	*
2	Archipiélago de Revillagigedo	Average for Mexico	N/A	Soil carbon estimated using average soil C stocks for Mexico (Atwood et al., 2017) and aboveground biomass estimates came from Guerra-Santos et al., 2013.
3	Area de Conservación Guanacaste	Average for Mexico	N/A	*
4	Banc d'Arguin National Park	West coast of Africa	Wolff & Smit 1990	Habitat area was estimated from Fatoyinbo and Simard (2003), aboveground biomass estimates were based on data from Simard et al., 2019, and soil carbon stocks were calculated using the global average for mangroves (Atwood et al., 2017)
5	Belize Barrier Reef Reserve System	Average for Mexico	Average Gulf of Mexico Thorhaug et al., 2019	*
6	Brazilian Atlantic Islands: Fernando de Noronha and Atol das Rocas Reserves	Patos Lagos Brazil in Fourqurean et al., 2012	N/A	Soil carbon estimates came from managers and aboveground biomass estimates from da Motta Portillo et al., 2017 for *L. racemosa*
7	Cocos Island National Park	N/A	N/A	*
8	Coiba National Park & Special Zone of Marine Protection	Average for Mexico	N/A	*
9	East Rennell	Average for tropical Australia	N/A	Soil and aboveground carbon stocks were estimated using averages from Serrano et al., 2019
10	Everglades National Park	World Heritage site specific	Thorhaug et al., 2019	*
11	French Austral Lands and Seas	Data from Tanzania in Belshe et al., 2018	N/A	*
12	Galápagos Islands	Average for Mexico	Average Mexico Adame et al., 2013	*
13	Gough and Inaccessible Islands	N/A	N/A	*
14	Great Barrier Reef	World Heritage site specific	Serrano et al., 2019	*
15	Gulf of Porto: Calanche of Piana, Gulf of Girolata, Scandola Reserve	Average for P. oceanica in the Mediterranean Sea	N/A	*
16	Ha Long Bay	Specific to Viet Nam	Thanh et al., 2004	*
17	Heard and McDonald Islands	Average for Tasmania	N/A	*
18	High Coast/Kvarken Archipelago	N/A	N/A	*

		Data on seagrass soil C from	Data on tidal marsh soil C from	Data on mangrove area, aboveground biomass, and soil C from
19	Ibiza, Biodiversity and Culture	World Heritage site specific	Average for flora global Ouyong & Lee 2014	*
20	iSimangaliso Wetland Park	Average for Tanzania	Taylor et al., 2006	*
21	Islands & Protected Areas of the Gulf of California	Average from the north pacific region of Mexico	Soto-Jiménez et al., 2003	*
22	Kluane/Wrangell-St Elias/Glacier Bay/ Tatshenshini-Alsek	Extrapolated from the Pacific coast of Canada	N/A	*
23	Komodo National Park	Specific to Indonesia	Interpolated based on soils from Bali in restored mangrove.	*
24	Lagoons of New Caledonia	Average for Queensland	Mean Queensland Macreadie et al., 2017	*
25	Lord Howe Island Group	Average for temperate Australia region	N/A	Habitat area was estimated using Sheringham et al. (2016), soil carbon stock were estimated using the average for mangroves in Australia (Atwood et al. 2017), and aboveground biomass estimates came from similar species of mangroves in Shark Bay, Australia (Serrano et al. 2019)
26	Macquarie Island	N/A	N/A	*
27	Malpelo Fauna and Flora Sanctuary	N/A	N/A	*
28	Natural System of Wrangel Island Reserve	N/A	N/A	*
29	New Zealand Sub-Antarctic Islands	N/A	N/A	*
30	Ningaloo Coast	Median for tropical seagrass in Australia	From Giralia Bay - near by Lovelock CE, unpublished data	*
31	Ogasawara Islands	N/A	N/A	*
32	Papahānaumokuākea	Average for Mexico	N/A	*
33	Peninsula Valdès	Patos Lagos Brazil in Fourqurean et al., 2012	Bouza et al., 2017	*
34	Phoenix Islands Protected Area	N/A	N/A	*
35	Puerto-Princesa Subterranean River National Park	Specific to Philippines	N/A	*
36	Rock Islands Southern Lagoon	Specific to Philippines	N/A	*
37	Sanganeb Marine National Park and Dungonab Bay – Mukkawar Island Marine National Park	Average for Saudi Arabia	Median value from UAE. Schile et al., 2017	*
38	Shark Bay, Western Australia	World Heritage site specific	Serrano et al., 2019	*
39	Shiretoko	Average for E and SE Asian seagrass	N/A	*
40	Sian Ka'an	World Heritage site specific	Adame et al., 2013	*
41	Socotra Archipelago	Average for Saudi Arabia	Schile et al., 2017	*

		Data on seagrass soil C from	Data on tidal marsh soil C from	Data on mangrove area, aboveground biomass, and soil C from
42	St Kilda	N/A	N/A	*
43	Sundarbans National Park	Average for SE Asia	Kaviarasan et al., 2019	*
44	Surtsey Island	Average from Greenland	N/A	*
45	The Sundarbans	Specific to Myanmar	Kaviarasan et al., 2019	*
46	The Wadden Sea	Average for Zostera in Kattegatt-Skagerrak	Average Mueller et al., 2019; Sifleet et al., 2011	*
47	Tubbataha Reefs Natural Park	Specific to Philippines	N/A	*
48	Ujung Kulon National Park	Average for SE Asia	N/A	*
49	West Norwegian Fjords – Geirangerfjord and Nærøyfjord	Average for 3 Norwegian sites	Ward 2020	*
50	Whale Sanctuary of El Vizcaino	Average from the north pacific region of Mexico	Watson & Hinojosa Corona 2018	*

Appendix 2. Estimated extent and carbon stocks of blue carbon ecosystems in UNESCO marine World Heritage sites and adjoining waters.

UNESCO marine World Heritage site	Country	Tidal marsh area (ha)	Tidal marsh total C stock (Mg C)	Seagrass area (ha)	Seagrass total C stock (Mg C)	Mangroves area (ha)	Mangroves total C stock (Mg C)	**Total blue carbon ecosystem area (ha)**	**Total blue carbon ecosystem C stock (Mg C)**
Aldabra Atoll	Seychelles	0	0	7 540	255 606	1 700	785 400	**9 240**	**1 041 006**
Archipiélago de Revillagigedo	Mexico	0	0	1	129	1	384	**2**	**513**
Area de Conservación Guanacaste	Costa Rica	0	0	1	129	417	166 383	**418**	**166 512**
Banc d'Arguin National Park	Mauritania	31 000	2 585 400	781 000	109 502 448	40	11 920	**812 040**	**112 099 768**
Belize Barrier Reef Reserve System	Belize	1	177	1	129	1 882	690 694	**1 884**	**691 000**
Brazilian Atlantic Islands: Fernando de Noronha and Atol das Rocas Reserves	Brazil	0	0	5	1 696	1	192	**6**	**1 888**
Cocos Island National Park	Costa Rica	0	0	0	0	0	0	**0**	**0**
Coiba National Park and its Special Zone of Marine Protection	Panama	0	0	1	129	1 758	850 872	**1 759**	**851 001**
East Rennell	Solomon Islands	0	0	1	48	1	423	**2**	**471**

UNESCO marine World Heritage site	Country	Tidal marsh area (ha)	Tidal marsh total C stock (Mg C)	Seagrass area (ha)	Seagrass total C stock (Mg C)	Mangroves area (ha)	Mangroves total C stock (Mg C)	**Total blue carbon ecosystem area (ha)**	**Total blue carbon ecosystem C stock (Mg C)**
Everglades National Park	United States of America	900	155 700	1 800 000	295 200 000	192 200	104 941 200	**1 993 100**	**400 296 900**
French Austral Lands and Seas	France	0	0	1	34	0	0	**1**	**34**
Galápagos Islands	Ecuador	1	168	1	129	3 690	1 752 750	**3 692**	**1 753 047**
Gough and Inaccessible Islands	United Kingdom of Great Britain and Northern Ireland	0	0	0	0	0	0	**0**	**0**
Great Barrier Reef	Australia	186 700	28 565 100	4 570 000	403 928 590	207 000	69 552 000	**4 963 700**	**502 045 690**
Gulf of Porto: Calanche of Piana, Gulf of Girolata, Scandola Reserve	France	0	0	1 006	377 250	0	0	**1 006**	**377 250**
Ha Long Bay	Viet Nam	0	0	30	4 784	100	24 700	**130**	**29 484**
Heard and McDonald Islands	Australia	0	0	1	114	0	0	**1**	**114**
High Coast/Kvarken Archipelago	Finland / Sweden	0	0	0	0	0	0	**0**	**0**
Ibiza, Biodiversity and Culture	Spain	1	117	55 795	41 427 788	0	0	**55 796**	**41 427 905**
iSimangaliso Wetland Park	South Africa	1 367	232 390	432	14 645	658	238 196	**2 457**	**485 231**
Islands and Protected Areas of the Gulf of California	Mexico	32 275	4 776 700	1	193	16 463	4 132 213	**48 739**	**8 909 106**
Kluane/Wrangell-St Elias/Glacier Bay/ Tatshenshini-Alsek	Canada / United States of America	0	0	1	40	0	0	**1**	**40**
Komodo National Park	Indonesia	154	18 451	3 185	799 435	1 030	425 390	**4 369**	**1 243 276**
Lagoons of New Caledonia: Reef Diversity and Associated Ecosystems	France	1	186	40 000	2 716 360	3 156	1 142 472	**43 157**	**3 859 018**
Lord Howe Island Group	Australia	0	0	1	113	1	292	**2**	**405**
Macquarie Island	Australia	0	0	0	0	0	0	**0**	**0**
Malpelo Fauna and Flora Sanctuary	Colombia	0	0	0	0	0	0	**0**	**0**
Natural System of Wrangel Island Reserve	Russian Federation	0	0	0	0	0	0	**0**	**0**
New Zealand Sub-Antarctic Islands	New Zealand	0	0	0	0	0	0	**0**	**0**
Ningaloo Coast	Australia	40	3 640	26 200	1 257 600	18	6 624	**26 258**	**1 267 864**
Ogasawara Islands	Japan	0	0	0	0	0	0	**0**	**0**
Papahānaumokuākea	United States of America	0	0	1	129	0	0	**1**	**129**
Peninsula Valdès	Argentina	356	106 800	1	339	0	0	**357**	**107 139**
Phoenix Islands Protected Area	Kiribati	0	0	0	0	0	0	**0**	**0**

UNESCO marine World Heritage site	Country	Tidal marsh area (ha)	Tidal marsh total C stock (Mg C)	Seagrass area (ha)	Seagrass total C stock (Mg C)	Mangroves area (ha)	Mangroves total C stock (Mg C)	**Total blue carbon ecosystem area (ha)**	**Total blue carbon ecosystem C stock (Mg C)**
Puerto-Princesa Subterranean River National Park	Philippines	0	0	9	2 134	60	33 360	**69**	**35 494**
Rock Islands Southern Lagoon	Palau	0	0	660	165 660	180	130 860	**840**	**296 520**
Sanganeb Marine National Park and Dungonab Bay – Mukkawar Island Marine National Park	Sudan	350	24 850	1 180	40 120	9	2 799	**1 539**	**67 769**
Shark Bay, Western Australia	Australia	3 825	520 200	342 200	43 801 600	1 300	418 600	**347 325**	**44 740 400**
Shiretoko	Japan	0	0	1	72	0	0	**1**	**72**
Sian Ka'an	Mexico	112 640	19 937 192	14 792	2 397 325	58 837	26 829 672	**186 269**	**49 164 188**
Socotra Archipelago	Yemen	68	6 596	1	34	294	81 438	**363**	**88 068**
St Kilda	United Kingdom of Great Britain and Northern Ireland	0	0	0	0	0	0	**0**	**0**
Sundarbans National Park	India	1	55	1	251	426 000	60 066 000	**426 002**	**60 066 306**
Surtsey	Iceland	0	0	1	41	0	0	**1**	**41**
The Sundarbans	Bangladesh	1	55	70	6 775	601 700	108 306 000	**601 771**	**108 312 830**
Tubbataha Reefs Natural Park	Philippines	0	0	1	251	0	0	**1**	**251**
Ujung Kulon National Park	Indonesia	0	0	1	251	1 912	1 305 896	**1 913**	**1 306 147**
Wadden Sea	Germany / Netherlands / Denmark	40 000	6 736 000	23 114	4 495 673	0	0	**63 114**	**11 231 673**
West Norwegian Fjords – Geirangerfjord and Nærøyfjord	Norway	1	32	418	23 140	0	0	**419**	**23 172**
Whale Sanctuary of El Vizcaino	Mexico	2 000	364 000	66 195	12 770 141	16 401	4 067 448	**84 596**	**17 201 589**
TOTAL		**411 682**	**64 033 808**	**7 733 850**	**919 191 325**	**1 536 809**	**385 964 178**	**9 682 340**	**1 369 189 310**

Appendix 3. Estimated extent and carbon stocks of mangrove habitats in non-marine natural World Heritage sites.

non-marine natural World Heritage site	Country	Mangrove area (ha)	Mangrove total carbon stock (Mg)
Alejandro de Humboldt National Park	Cuba	603	258 193
Desembarco del Granma National Park	Cuba	853	358 405
Discovery Coast Atlantic Forest Reserves	Brazil	291	116 927
Fraser Island	Australia	2 839	751 199
Kakadu National Park	Australia	10 262	3 386 255
Lorentz National Park	Indonesia	189 129	116 429 704
Paraty and Ilha Grande - Culture and Biodiversity	Brazil	246	110 700
Río Plátano Biosphere Reserve	Honduras	10 420	5 094 963
Tropical Rainforest Heritage of Sumatra	Indonesia	204	121 272
Wet Tropics of Queensland	Australia	15 459	6 092 083

Appendix 4. Mean and range (in brackets) of area and carbon density (top 1 m) of blue carbon ecosystems of UNESCO marine World Heritage sites.

Where the ecosystems extend beyond the boundaries of the property, the entire extent and stock inside and outside the boundaries were considered. In the case of mangrove biomass, both aboveground stock (abg) and soil (soil) carbon density are shown. Carbon density is expressed as megagrams of carbon per hectare. Carbon stock is expressed in teragrams.

	Tidal marshes	Seagrasses	Mangroves	Blue Carbon Ecosystems
Area (ha)	29,400 (40 – 186,700)	368,300 (10 – 4,570,000)	56,900 (1 – 601,700)	322,700 (10 – 4,963,700)
Carbon Density (Mg C ha-1)	140 (32 – 300)	159 (34 – 743)	44 (abg); 334 (soil) (abg: 1 – 142; soil: 120 –671)	493 (34-978)