Section 4

Subchapter 4H

Marine plants

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Key points

- Marine plant species are spreading poleward due to climate heating, with mangroves encroaching into salt marshes.
- Restoration has established marine plants in small areas but not at a scale to match historical losses; preservation of existing marine plants provides many benefits.
- Rates of mangrove loss have slowed as policies to conserve and maintain existing mangroves are beginning to work. Some losses have been offset by low biodiversity reforestation projects.
- Sabkha plants, not covered in previous *World Ocean Assessments*, are overlooked but form important marine wetland ecosystems in arid and semi-arid regions.

1. Introduction

Vascular marine plants create biodiverse habitats providing goods and services that are essential for achieving the Sustainable Development Goals (sect. 4, subchaps. 5G–5I; see also table 1 below). There are 72 seagrass species, and their diversity is highest in the tropical Indo-Pacific. Some meadows have several seagrass species, but most are monospecific. *Thalassodendron pachyrhizum* is the deepest living marine plant and occurs down to 63 m depth (Martin and others, 2023). Mangrove diversity and extent peaks in tropical Asia with 69 species (and 13 hybrids) that belong to 18 families that include trees, shrubs, palms and ferns (Leal and Spalding, 2024). *Rhizophora mangle* is the most common mangrove tree species worldwide. Salt marshes occur from the tropics to the Arctic, with over 500 known species, including grasses, shrubs and herbs (Adam, 2016; Fitzgerald and Hughes, 2021). Sabkhas are often used for salt extraction (Alshenawy and others, 2021; Ghazanfar, 2024), and their flora, e.g. *Atriplex*, *Salicornia, Salsola* and *Suaeda* Species, tolerate high salinity, freshwater scarcity and extreme temperatures, with adaptations that include succulence, salt secretion and osmoregulation (Flowers and Colmer, 2008; Chenchouni, 2017).

2. Environmental change since the second *World Ocean Assessment*

Changes in overall status

Seagrasses

Twenty-two species are in decline due to the impacts of fishing, poor water quality, mariculture and coastal urban and industrial development (United Nations Environment Programme (UNEP), 2020). Ten are Vulnerable, and *Phyllospadix japonicus* and *Zostera geojeensis* are Endangered (International Union for Conservation of Nature (IUCN), 2024). Some seagrass meadows suffer from overconsumption by herbivores such as sea urchins (subchap. 4F) or turtles in places where their numbers have grown locally thanks to conservation measures (subchap. 5G). Seagrasses can recover when pressures on coastal systems are reduced; *Halodule wrightii* and *Zostera japonica* are increasing (United Nations Environment Programme, 2020), although invasive species are a growing threat (Beca-Carretero and others, 2024). "Blue carbon" and the role of marine plants in the carbon cycle are explained in subsection 5B, chapter 1. The only seagrass blue carbon project is in the United States of America, where 3,151 ha of *Zostera marina* has been restored since the publication of the second *World Ocean Assessment*.

Mangroves

Although rates of loss have slowed since the publication of the second *World Ocean Assessment*, some species, such as *Bruguiera hainesii,* remain Critically Endangered (Bunting and others, 2022; IUCN, 2024; Leal and Spalding, 2024). A global campaign,[1] launched in 2022 and supported by 50 Governments, is aimed at protecting 15 million ha of mangroves worldwide. Some recent losses have been offset by restoration projects (Leal and Spalding, 2024; see also subchap. 5H), which are mainly focused on the following mangrove species: *Rhizophora mangle, R. mucronata, R. apiculata, Bruguiera gymnorhiza, B. cylindrica, Ceriops tagal, Avicennia germinans, A. marina* and *Laguncularia racemosa* (Verra Registry;[2] Plan Vivo;[3] Climate Action Reserve;[4] Clean Development Mechanism[5]). The biodiversity of these plantations is lower than in natural mangrove forests (Lovelock and others, 2024).

Salt marshes

These habitats are declining worldwide (for estimates of the rate, see subchap. 5I), often due to land reclamation, conversion to agriculture, increased erosion, sea level rise, eutrophication (Niner and others, 2019; Roman and others, 2023; see also sect. 5, subchap. 5A) and invasive species (sect. 4, chap. 6). Salt marsh species are spreading poleward due to recent climate heating (Cavanaugh and others, 2019; Cohen and others, 2020) and planting and restoration work has been successful in some regions (Xiao and others, 2020; Liu and others, 2024).

3. Region-specific changes in biodiversity

Arctic Ocean

Zostera marina is the only seagrass reported in the Arctic. This region has approximately 17% of the global extent of salt marshes, with at least 113 species of vascular plants (12% of Arctic flora); information on recent changes in their status is lacking (Sergienko, 2013; Worthington and others, 2024)

[1] See https://climatechampions.unfccc.int/the-mangrove-breakthrough/?gad_source=1&gclid=CjwKCAjw74e1BhBnEiwAbqOAjBCngKwmr0oHNiBIXR-4Q4o5hZVtPnGcksOzlOs2zbILIDWI1IL8BoCgZoQAvD_BwE.
[2] See https://verra.org/registry/overview/.
[3] See https://www.planvivo.org/.
[4] See https://thereserve2.apx.com/myModule/rpt/myrpt.asp?r=111.
[5] See https://cdm.unfccc.int/Registry/index.html.

although the region is warming rapidly, which is expected to favour the northward spread of temperate marine plants but threaten those adapted to surviving seasonal freezing conditions.

North Atlantic Ocean, Baltic Sea, Black Sea, Mediterranean Sea and North Sea

Phragmites australis has invaded western North Atlantic salt marshes; it is expensive and difficult to remove, but can provide ecosystem benefits (Macy and others, 2021). Extensive areas of the previously degraded seagrasses *Zostera marina, Ruppia maritima* (Chesapeake Bay) and *Thalassia testudinum* (Tampa Bay) have recovered in the United States of America thanks to reductions in nutrient pollution. *Avicennia germinans* and *Rhizophora mangle* mangroves are expanding northward in the western North Atlantic (Cavanaugh and others, 2019; Vervaeke and others, 2024).

Blue carbon projects in the eastern North Atlantic are using *A. germinans, A. africana, Laguncularia racemosa* and *R. mangle*. Sabkhas can provide habitat for a wide diversity of vascular plant taxa (from 29 families) including endemics, e.g. *Echiochilon simonneaui* and *E. chazaliei* (Qninba and others, 2020), and critically endangered species, e.g. *Limonium mucronulatum*, which is found only in Cyprus (Senni and de Belair, 2020).

Endemic *Posidonia oceanica* meadows are receding in the Mediterranean due to human impacts, although some meadows of this and *Cymodocea nodosa* are expanding due to implemented legislation and restoration (de los Santos and others, 2019; see also table 2) and the use of best practices in transplantation (Pergent-Martini and others, 2024). *Halophila stipulacea* has spread in the region and *H. decipiens,* first reported in the Mediterranean in 2018, is expected to spread (Gerakaris and others, 2020) raising calls for improved biosecurity to prevent the arrival of non-native species (Galil and others, 2017).

South Atlantic Ocean and wider Caribbean

The main blue carbon species now being planted in this region are the mangroves *Laguncularia racemosa, Rhizophora mangle, Conocarpus erectus, Avicennia germinans* and *Rhizophora harisonii.* Several mangrove species are at elevated risk of extinction in the Caribbean (IUCN, 2024). Collection of and commercial trade in *Rhizophora mangle* is regulated in the Caribbean (see table 2). In Brazil, 80 to 90% of mangroves are in protected areas and the species are listed as of Least Concern (IUCN, 2024). The mangroves *Avicennia germinans, A. schaueriana, Rhizophora mangle* and *Laguncularia racemosa* are all expanding southward, causing the loss of salt

marsh *Spartina alterniflora*, *S. densiflora* and *Acrostichum* plants (Cohen and others, 2020). The mangrove *Sonneratia apetala* has been introduced from the Indo-Pacific (Eysink and others, 2023). The seagrasses *Halodule wrightii* and *Halophila decipiens* have expanded south by approximately 250 km in the twenty-first century due to climate heating. The South Atlantic has vegetated hypersaline tidal flats (locally called “apicuns” or “salgados”) that are easily damaged by human activities (Albuquerque and others, 2014). The West African coast has one of the highest rates of recent mangrove plant loss worldwide, due to agriculture, urbanization and cutting wood to burn (Food and Agriculture Organization of the United Nations (FAO), 2023) as well as oil pollution and the spread of invasive nipa palm. The Calabar Protocol on Sustainable Mangrove Management to the Convention for Cooperation in the Protection, Management and Development of the Marine and Coastal Environment of the Atlantic Coast of the West, Central and Southern Africa Region (see table 2), adopted in 2019, establishes rules for the environmental protection and conservation of mangroves as well as their use.

Indian Ocean, Arabian Sea, Bay of Bengal, Red Sea, Gulf of Aden and Persian Gulf

Since 2018, the main species planted in blue carbon projects in this region are *Avicennia marina, Bruguiera gymnorhiza, Ceriops tagal, Rhizophora apiculata* and *R. mucronata.* Sundarbans is the largest mangrove forest in the world (10,200 km^2) and a world heritage site (see table 1). Here around 50% of the trees have been felled for timber and to create space for agriculture and shrimp farms. The forest is being rapidly altered due to sea level rise (Intergovernmental Panel on Climate Change (IPCC), 2022). Salt-tolerant species are increasing and spreading (e.g. *Avicennia marina* and *Phoenix paludosa)* with no plans in place to allow for the natural inland retreat of mangrove plants (Khan and others, 2020). The Indian Ocean mangroves *Bruguiera hainesii* and *Sonneratia griffithii* are critically endangered (Nuevo-Diego and others, 2021; IUCN, 2024).

Around the Persian Gulf and the Sea of Oman, conservation and restoration has contributed to the expansion of mangrove plants (Milani, 2018; Erfanifard and others, 2022). In the Islamic Republic of Iran they are expanding with sea level rise where landward margins remain unimpeded by coastal development (Hamzeh and Lahijani, 2022; Irani and others, 2024). Mangrove extent is now increasing in the Red Sea and the Gulf of Aden (Blanco-Sacristán and others, 2022) with *A. marina* plantations in Saudi Arabia, Egypt and the Sudan. Restoration of *A. marina, Bruguiera gymnorrhiza, Ceriops tagal* and *Rhizophora mucronata* mangroves is underway in Somalia, Mozambique, Madagascar, the United Republic of Tanzania and Kenya.

Middle Eastern coastal sabkhas host 12 marine plant families that form biodiversity hotspots and carbon sinks (Ghazanfar and others, 2019; Dar and others, 2022; Eid and others, 2023). Some are native to this region, such as *Arthrocnemum macrostachyum* and *Halopeplis perfoliata.* The few sabkha plants that have had their conservation status listed are categorized as of Least Concern (IUCN, 2024). Several types of sabkha plants are economically important (e.g. *Aeluropus lagopoides, Juncus rigidus*, *Phoenix dactylifera, Suaeda vermiculata*).

The first seagrass restoration initiative for this region was announced in 2024 to rescue and transplant eight Red Sea seagrass species. In the United Republic of Tanzania, best practices for the transplantation of *Syringodium isoetifolium* are being promoted (Wegoro and others, 2022). In Mozambique and South Africa, experimental transplantation of the regionally endangered *Zostera capensis* was recently achieved (Amone-Mabuto and others, 2022; Mokumo and Adams, 2023; Watson and others, 2023). In Kenya, there are attempts to restore the seagrasses *Thalassodendron ciliatum, Thalassia hemprichii, Enhalus acoroides,* and *Syringodium isoetifolium*. Under the framework of the Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region (see table 2), detailed guidelines on seagrass and mangrove ecosystem restoration were published in 2020. Trial transplantations of *Thalassodendron ciliatum* and *Thalassia hemprichii* confirm that protecting existing meadows is more effective than planting new ones.

North Pacific Ocean

This region has around 250 to 300 salt marsh taxa, including species of *Suaeda*, *Triglochin*, and *Salicornia;* some, such as *T. maritima,* are vulnerable (IUCN, 2024). Over 200 salt marsh plant species grow along the western North Pacific (Wang and Chen, 2013) where invasive *Spartina alterniflora* has colonized and altered 63% of the coastal marshes of China (Zhang and others, 2023; Liu and others, 2024). The use of *S. alterniflora* for coastal protection has threatened indigenous marine plants, birds, fisheries and tourism (Xia and others, 2021; Zhu and others, 2024) so it is now being removed; 68,000 ha had been removed in China by 2025, according to the Special Action Plan for Spartina Removal and Coastal Marsh Restoration (2022-2025) by the State Forestry and Grassland Administration of China. There has also been large-scale replantating of native species such as the mangrove *Kandelia obovata*, salt marsh plants such as *Suaeda salsa, Scirpus mariqueter* and the seagrass *Zostera marina* (Feng and others, 2017; Yang and others, 2024). Invasive *S. alterniflora* is also spreading in Japan and the Republic of Korea, where large-scale eradication projects are ongoing (Maebara and others, 2020; Kim and others, 2023; Matsuda and others, 2023; Koyama and others, 2024).

Climate heating has caused the recent northward expansion of the mangroves *Conocarpus erectus* in Mexico (Ochoa-Gómez and others, 2021) and *Kandelia candel* in Taiwan Province of China. Iriomote Island in Japan has 11 species of mangrove plants and nearly 70% of the national mangrove area (Inoue and others, 2022). Here, species include *Kandelia obovata*, *Bruguiera gymnorrhiza*, and *Rhizophora stylosa*, which are conserved well in a natural world heritage site (United Nations Educational, Scientific and Cultural Organization (UNESCO), 2021; see also table 1). Some mangrove species are at an elevated threat of extinction along the North Pacific coasts of Central America (IUCN, 2024). China, home to 37 mangrove species, is reversing habitat loss with the Government's Special Action Plan for Spartina Removal and Coastal Marsh Restoration (2022–2025) which is aimed at the planting of over 8,800 ha of new forest and restoring 8,200 ha of mangroves (Ouyang and others, 2024). Restoration efforts also include rare and endangered species like *Lumnitzera littorea*, *Sonneratia hainanensis* and *S. ovata* (Zhang and others, 2024).

Zostera, Ruppia and *Phyllospadix* seagrasses are widely distributed in the North Pacific, where they are under pressure from some of the most densely populated areas in the world (Su and others, 2020; Xu and others, 2021). Species such as *Zostera caespitosa, Phyllospadix iwatensis* and *Halophila beccarii* are listed as vulnerable (Yoshida and others, 2019; Du and others, 2023; Zhou and others, 2023; IUCN, 2024). In the eastern North Pacific, eel grass decline has been exacerbated by marine heatwaves, sea star wasting disease, reduced water clarity and physical damage from human activities such as boating and coastal development (Christiaen and others, 2022; Nahirnick and others, 2020). Similarly, between 2015 and 2021, over 1,000 ha of *Zostera japonica* were lost in the Yellow River estuary in China due to *Spartina alterniflora* invasion and typhoons; restoration efforts are aimed at mitigating this damage (Zhou and others, 2023; Liu and Ma, 2024).

South Pacific Ocean

Improved water quality has resulted in recent regrowth of the seagrasses *Posidonia australis* and *Posidonia sinuosa* (Fernandes and others, 2022). *Avicennia marina*, the only mangrove species in New Zealand, is expanding south throughout the South Pacific, encroaching upon salt marshes (Whitt and others, 2020). In Australia, subtropical and temperate coastal salt marsh plants are threatened (IUCN, 2024), but taxa are being conserved and recovered, such as *Sarcocornia quinqueflora*, *Suaeda australis* and *Sporobolus virginicus* (Beaumont and Dittman, 2022; Rankin and others, 2023). *Posidonia australis* restoration has worked in small areas (Sinclair and others, 2021), but not yet at a scale to match historical losses. *Zostera chilensis* is considered endangered in the South-East Pacific.

Note: there are no marine plants in the Southern Ocean.

4. Key remaining knowledge and capacity gaps

Much of what is known about changes in marine plants worldwide comes from remote sensing. A lack of in situ monitoring, due to a lack of marine botanists and funding, means that there are knowledge gaps regarding the status of marine plants in most regions, with sabkhas especially overlooked. Molecular techniques have been developed for marine plant identification, but the infrastructure and human resources to do this work is lacking in many regions. The resilience of most marine plants to changing climate and ocean conditions has not been assessed.

Increased protection of marine plants requires international attention, support and cooperation. Marine plants provide biodiversity and ecosystem function support and coastal protection and contribute to livelihoods and improved water quality (Macreadie and others, 2019). In some areas, mangroves have been so damaged that these services have been lost and the habitats have become a source, rather than a sink, of greenhouse gasses (Bruederle and Hodler, 2019; Ochoa-Gómez and Keke, 2022). Criticisms of carbon markets largely centre around the integrity and additional benefit of carbon credits and certification schemes (Guizar-Coutiño and others, 2022; West and others, 2020; Comte and others, 2023). Assessments of carbon stored by marine plants present difficulties in submersed ecosystems (Macreadie and others, 2022; Niner and Randalls, 2021). Many blue carbon projects depend on philanthropy, rather than carbon credit finance; the viability of carbon finance for marine plant conservation is a current knowledge gap.

Table 1

Global legal and policy instruments applicable to marine plants

Category	Instrument
Marine biological diversity	United Nations Convention on the Law of the Sea (1982)
	Convention on Biological Diversity (1992)

	Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction (2023)
Wetlands	Convention on Wetlands of International Importance especially as Waterfowl Habitat (1971) (Ramsar Convention)
Natural heritage	Convention for the Protection of the World Cultural and Natural Heritage (1972)
Trade in endangered species	Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (1973)
Climate	United Nations Framework Convention on Climate Change (1992)
Shipping	International Convention on the Control of Harmful Anti-fouling Systems on Ships (2001)
	International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004
Life below water	Sustainable Development Goal 14 (2015) (non-binding)

Source: Prepared by the writing team.

Table 2

Regional legal instruments applicable to marine plants

Region	Instrument
Europe	Convention on the Conservation of European Wildlife and Natural Habitats (1979) (Bern Convention)
European Union	Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora
	European Union Marine Strategy Framework Directive (2008)
	Nature Restoration Law of the European Union (2024)
Baltic Sea	Convention on the Protection of the Marine Environment of the Baltic Sea Area (1974) (Helsinki Convention)
North-East Atlantic Ocean	Convention for the Protection of the Marine Environment of the North-East Atlantic (1992) (OSPAR Convention)
Mediterranean Sea	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (1976) (Barcelona Convention)

South-East Atlantic Ocean	Convention for Cooperation in the Protection, Management and Development of the Marine and Coastal Environment of the Atlantic Coast of the West, Central and Southern Africa Region (1981) (Abidjan Convention)
Western Indian Ocean	Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region (1985) (Nairobi Convention)
Red Sea and Gulf of Aden	Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment (1982) (Jeddah Convention)
Caspian Sea	Framework Convention for the Protection of the Marine Environment of the Caspian Sea (2003) (Tehran Convention)
South Pacific Ocean	Convention on Conservation of Nature in the South Pacific (1976) (Apia Convention)
Caribbean Sea	Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (1983) (Cartagena Convention)

Source: Prepared by the writing team.

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