**Section 4**

**Subchapter 5G**

# Seagrass meadows

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## Key points

- Seagrass meadows are experiencing accelerated degradation due to urbanization, pollution and climate change, leading to a decline in their extent, biodiversity and ecological function.
- Seagrass meadows play a crucial role in carbon storage, habitat provision and water quality improvement, yet their functions are not widely recognized or fully utilized.
- There are insufficient systematic monitoring, protection and restoration technologies for seagrass meadow degradation, with insufficient scientific knowledge and policy support, highlighting the need for enhanced international collaboration and capacity-building.

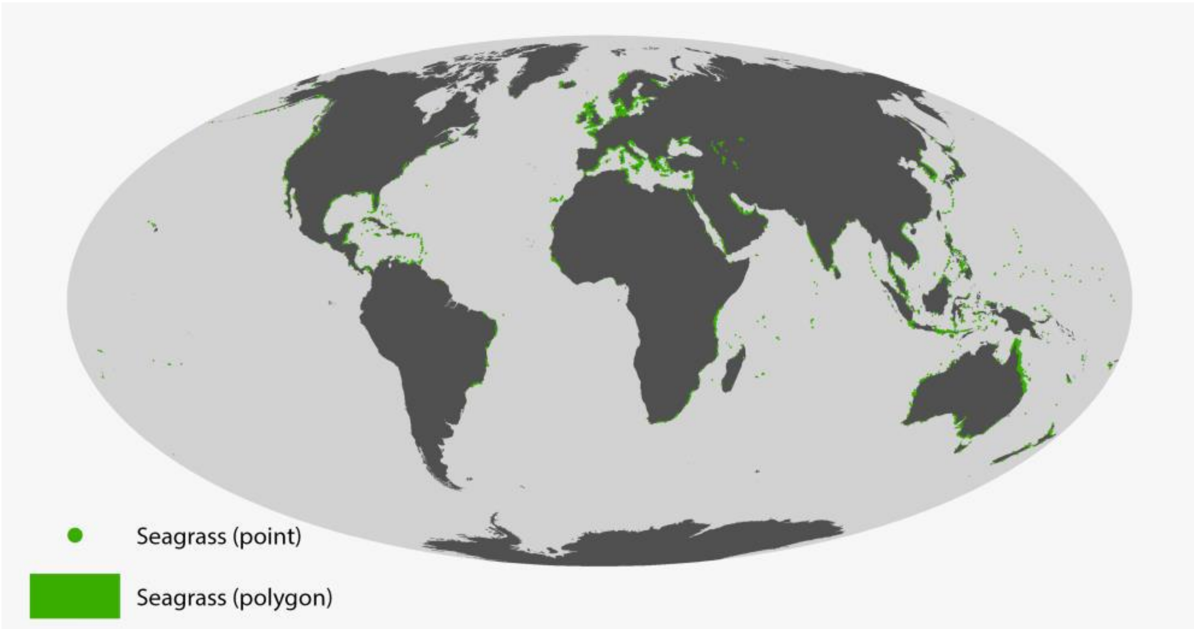
## 1. Introduction

Seagrass meadows are found across all climatic zones except Antarctica[1] (see figure I), providing essential services, such as carbon sequestration, climate regulation, nutrient cycling and habitat for various marine species. Despite their importance, these ecosystems are facing alarming rates of decline, with an estimated 29% of their global extent lost since records began in 1879 (Waycott and others, 2009). The primary causes of this decline include poor water quality, physical disturbances, coastal development and overfishing. These pressures have placed seagrass meadows among the most threatened ecosystems globally, alongside mangroves, coral reefs and tropical rainforests. Urgent and effective management strategies are needed to reverse this loss and preserve the critical role of seagrasses in maintaining coastal biodiversity and resilience. The present subchapter emphasizes ecosystem-level changes in seagrass meadows from 2018 to 2023, covering environmental change, contributing factors, socioeconomic impacts and the knowledge gaps in addressing these changes. It is focused on conditions, trends and responses, rather than taxonomy or species diversity.

[1] See https://data.unep-wcmc.org/datasets/7

Figure I

**Global distribution of seagrass**




*Source*: United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) and Short, 2021.

## 2. Environmental changes since the second *World Ocean Assessment*

### Changes in overall status

Estimates of the global seagrass area range between 160,387 km² and 266,562 km² (McKenzie and others, 2020), though measuring losses remains challenging. Dunic and others (2021) found that individual meadows lose 1–2% of their area annually, with larger meadows (>1,000 ha) declining more slowly. Europe, North America, Japan, China and South-East Asia face the greatest risks. Between 2000 and 2020, 60% of seagrass meadows in South-East Asia (68 sites across nine regions) declined by 10.9% annually, while 20% increased by 8.1% annually (Sudo and others, 2021).

### Factors contributing to the changes observed

Seagrass decline is predominantly driven by poor water quality and coastal development (Dunic and others, 2021). Coastal development leads to both direct impacts, such as habitat loss due to port construction, and indirect impacts, such as reduced light availability from sediment plumes caused by dredging activities. Light deprivation caused by nutrient-induced algal growth and sedimentation compromises photosynthesis. Destructive fishing practices, including unsustainable bottom trawling in vulnerable habitats can also cause losses, with heavy equipment damaging seagrass habitats. Other methods, including seining and gleaning, also contribute to losses in some areas (Mwikamba and others, 2024). Climate change is an increasing threat, with rising temperatures and intensified storms (Wernberg and others, 2024) leading to significant seagrass loss. Marine heatwaves and storms have already caused extensive damage (Correia and Smee, 2022; Strydom and others, 2020). In addition, climate change may alter the distribution of herbivores and pathogens, further affecting seagrass health (Wernberg and others, 2024). Overgrazing by herbivores, such as sea urchins and sea turtles, has led to seagrass decline in multiple regions of the Atlantic, Indian and Pacific Oceans. Mitigating these pressures and restoring seagrass meadows is now a pressing conservation challenge. Restoration efforts, combined with efforts to address the root causes of decline, have demonstrated the potential for substantial seagrass recovery in several regions (Fernandes and others, 2022; Orth and others, 2020).

**Impacts of the changes on and interactions with other components of the marine system**

Seagrass ecosystems are shaped by interconnected factors, such as herbivory, climate change, habitat connectivity and interspecies interactions. Rising sea temperatures and ocean acidification due to climate change affect species distribution and seagrass productivity (James and others, 2023; Beca-Carretero and others, 2022). Herbivory by sea turtles and fish plays a critical role in regulating seagrass dynamics, with shifts in herbivory patterns observed in the Mediterranean (Santana-Garcon and others, 2023). Habitat connectivity supports organism movement and genetic exchange, strengthening ecosystem resilience (de Fouw, 2018). In addition, seagrass meadows play a crucial role in sediment storage and carbon export, sometimes over hundreds of kilometres (Huxham and others, 2018), highlighting their importance for coastal sustainability and ecosystem health.

**Social, economic and cultural aspects of the changes**

On the social front, seagrasses support livelihoods, especially in small-scale fisheries, ensuring food security for millions (Unsworth and others, 2019). On the economic front, seagrasses protect coastlines, enhance the productivity of fisheries, sequester carbon and stabilize sediment. On the cultural front, they are integral to Indigenous and local traditions, shaping fishing practices, rituals and community identities (Nordlund and others, 2016). The degradation of seagrass ecosystems disrupts biodiversity and socioeconomic benefits, with reduced fisheries productivity threatening economic stability and eroding cultural ties, thereby undermining community resilience.

Although public awareness of the importance of seagrasses has increased (Cullen-Unsworth and Unsworth, 2018), full recognition of their value among all stakeholders has yet to be achieved (United Nations Environment Programme (UNEP), 2020). Seagrass restoration efforts are becoming more common, however, often involving local communities. This increased focus on seagrasses has also led to their more frequent inclusion in management plans (Nordlund and others, 2016). Effective management requires a deeper understanding of seagrass dynamics and reliable baselines. Implementing policies that balance ecological, economic and cultural needs is essential to ensuring the long-term resilience of both ecosystems and the communities that depend on them (Unsworth and others, 2019).

In addition, such programmes as the Dugong and Seagrass Conservation Project[2] funded by the Global Environment Facility, the Convention on the Conservation of Migratory Species of Wild Animals, the Memorandum of Understanding on the Conservation and Management of Dugongs (*Dugong dugong*) and their Habitats throughout their Range[3] and the Seagrass Ecosystem Services Project[4] funded by the International Climate Initiative support conservation projects in countries by promoting coordinated,

[2] See www.dugongconservation.org.
[3] See www.cms.int/dugong/en/page/mou-text-0.
[4] See www.seagrasswatch.org/iki-seagrass-ecosystem.

international action to ensure the long-term survival of dugongs and the associated seagrass habitats they depend on.

### Implications for achieving the Sustainable Development Goal targets

Seagrasses contribute to several Sustainable Development Goals, including carbon sequestration and disaster resilience (Goal 13), protection of coastal communities (Goal 11) and food and economic security (Goal 10), while promoting sustainable use (Goal 12), marine conservation (Goal 14) and partnerships (Goal 17) (see General Assembly resolution 70/1). Their value was highlighted in the UNEP report entitled *Out of the Blue: the Value of Seagrasses to the Environment and to People* (UNEP, 2020). Seagrass conservation efforts, including the 2030 Seagrass Breakthrough project announced at the twenty-eighth session of the Conference of the Parties to the United Nations Framework Convention on Climate Change, align with global climate commitments and all 10 targets associated with Goal 14.

## 3. Region-specific changes

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

In the North-Western Atlantic, *Zostera marina* dominates in the north, while *Syringodium filiforme* is prevalent in the south, leading to research and restoration efforts shifting along a latitudinal gradient. While *S. filiforme* populations remain stable, *Z. marina* has experienced declines due to eutrophication, sedimentation and climate warming. In the North-Eastern Atlantic, including the Baltic, Black, Mediterranean and North Seas, research has focused on dominant species, such as *Z. marina* and *Posidonia oceanica*, with effort particularly concentrated in Western Europe and the Mediterranean. Between 1869 and 2016, Europe experienced a net loss of 35,000 ha of seagrass area, though recent trends show slower losses and some gains (de los Santos and others, 2019), such as *Z. marina* recolonizing the Mira Channel in Portugal (Guerrero-Meseguer and others, 2021). Restoration efforts, such as the recovery of 40,000 ha of seagrass in the Chesapeake Bay, United States of America, offer hope. In Europe, however, outdated or incomplete spatial data – mainly covering the Natura 2000 network – are hindering accurate tracking of seagrass changes, making it difficult to assess both losses and gains comprehensively (Huber and others, 2024; Poursanidis and others, 2023).

### South Atlantic Ocean and wider Caribbean

Understanding of seagrass meadows in the South Atlantic Ocean and the wider Caribbean remains limited. Although the region has historically experienced significant seagrass losses, recent trends indicate a balance, with losses matching gains. *Thalassia testudinum* forms extensive, dense and stable beds, but when disturbed it is replaced by faster-growing species, such as *S. filiforme* and *Halodule wrightii*, all classified as being of least concern. In 2022, a vast seagrass ecosystem, covering between 66,000 and 92,000 $km^2$, was discovered on the Bahamas Banks (Gallagher and others, 2022). Of the 18 seagrass species in the region, *Halodule bermudensis* and *Halodule ciliata* are critically endangered, with several others near threatened or vulnerable. Seagrass abundance has drastically declined across the Bermuda Platform due to overgrazing by sea turtles (Fourqurean and others, 2019). In addition, *Halophila ovalis* and *Halophila stipulacea* are invasive species expanding in the Caribbean (Winters and others, 2020). Global climate change is also causing shifts in the distribution of some species, such as *H. wrightii* and *Halophila decipiens*, as tropicalization alters habitat conditions.

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

East Africa, which has 14 recorded seagrass species, faces seagrass decline due primarily to the use of destructive fishing techniques, such as seine fishing, in sensitive areas. The collection of gastropods and crustaceans further disturbs seagrass meadows (Chitará-Nhandimo and others, 2022; Amone-Mabuto and others, 2023; Mwikamba and others, 2024). In Maputo Bay, Mozambique, seagrass cover decreased by 33.4% between 1991 and 2023 due to anthropogenic disturbances (Amone-Mabuto and others, 2024). In Kenya, *Thalassodendron ciliatum* has experienced significant decline due to the proliferation of sea urchins (Uku and others, 2021). In southern Mozambique, *Thalassodendron leptocaule* is considered near threatened, while *Zostera capensis* in South African estuaries is endangered (Duarte and others, 2012; Adams and van der Colff, 2018). In the Persian Gulf and Red Sea, research gaps hinder comprehensive understanding of seagrass ecosystems, though recent studies have recorded *Halophila decipiens* in Iraqi waters for the first time, expanding known biodiversity (Ibrahim, 2024). The invasion of *Halophila stipulacea* from the Red Sea to the Mediterranean highlights ecological shifts (Nguyen and others, 2018), while unique evolutionary processes in *Halophila ovalis* populations in the Red Sea underscore the region's distinct biodiversity. In addition, the discovery of *Halophila beccarii* in the Bangladeshi part of the Bay of Bengal emphasizes the importance of continued marine assessments (Haque and others, 2024).

**North Pacific Ocean**

In the North-Eastern Pacific, *Z. marina* is the dominant seagrass species, ranging from the Arctic to Mexico, where it coexists with *Ruppia maritima* and the invasive *Zostera japonica*. A recent genetic split of *Zostera pacifica* from *Z. marina* leaves the population status of this species uncertain. Localized seagrass declines in this region are attributed to coastal development and eutrophication. Similarly, since 2000, seagrass beds across South-East Asia and East Asia have experienced significant losses, with over 60% declining at an annual rate of 10.9%, due in large part to human activities and natural factors (Sudo and others, 2021). The widespread degradation of South-East Asian seagrass ecosystems is further exacerbated by significant knowledge gaps with respect to subtidal seagrass meadows, which limit effective conservation strategies and result in a persistent disconnect between scientific research, policy and management implementation (Fortes, 2018).

**South Pacific Ocean**

Seagrass meadows are found in 17 of the 22 Pacific island countries and territories, with the highest species richness in Papua New Guinea, which hosts 13 species. It should be noted, however, that seagrasses remain understudied compared with coral reefs and mangroves. Recent studies from the period 2018–2023 highlight increasing threats to these ecosystems, in particular from coastal development, pollution and climate change. For instance, seagrass cover in parts of Fiji and Solomon Islands has declined due to land-based pollution and destructive fishing practices. There are also emerging threats from habitat loss, with projections suggesting a 5–20% loss in seagrass habitat by 2035 (Waycott and others, 2009). Over 5% of seagrass extent has been lost in Australia since the 1930s, with substantial losses of temperate *Posidonia* species (Statton and others, 2018). *Posidonia australis* in parts of New South Wales is now listed as a threatened ecological community under Australian legislation. Tropical and subtropical seagrass meadows have also been lost, with substantial losses following extreme storm events with very heavy rain, causing run-off and high turbidity. Multiple restoration efforts are now under way around Australia, with the success of efforts steadily improving (Sinclair and others, 2021).

## 4. Key remaining knowledge and capacity gaps and new gaps

### Key changes in knowledge and understanding gaps

A key knowledge gap recognized by seagrass scientists and managers today is how to raise societal awareness about the global significance of seagrasses, which remain relatively unknown (Unsworth and others, 2019). This is a pressing challenge, as increasing awareness can lead to broader support for seagrass conservation, citizen science, informed decision-making on marine biodiversity, improved funding for research and management, and ultimately a healthier planet (UNEP, 2020). Engaging the public through education and collaboration with communication experts is crucial for achieving this. While advances have been made in seagrass mapping and monitoring, in particular with remote sensing technology (Traganos and others, 2022), significant gaps remain with respect to understanding the distribution of seagrasses in the tropical Atlantic, Pacific, Indian and Southern Oceans, especially in deep or turbid waters. Knowledge of seagrass ecosystem services has improved in some regions, but remains incomplete in many others (Creed and others, 2023). In addition, economic assessments are limited and often undervalue seagrass systems. Better models linking ecological and economic factors are needed for a more integrated approach. Identifying local drivers and stressors continues to be a challenge in relation to targeted management efforts, and there is still limited understanding of how seagrasses will adapt to climate change, particularly under the combined pressures of human activities and environmental shifts.

### Key changes in capacity gaps

In addition to knowledge gaps, significant capacity gaps exist in the management of seagrass ecosystems, especially as regards habitat mapping, centralized data repositories, restoration and management frameworks.

(a) **Habitat mapping and monitoring.** Accurate and up-to-date information on seagrass distribution is essential for effective conservation. The current global seagrass map is outdated, and reports of habitat loss (Dunic and others, 2021; Sudo and others, 2021; Adi and others, 2024) highlight the need for improvement. New tools, such as drones, artificial intelligence and cloud-based platforms, are enhancing seagrass mapping capacity, especially on the regional and local scales (Malerba and others, 2023).

(b) **Centralized data repositories.** As seagrass research expands, the volume of data grows significantly (Strydom and others, 2023). However, cross-platform incompatibility continues to hinder efficient data exchange. Establishing a centralized repository with a standardized framework would streamline integration and improve access to seagrass data across various platforms.

(c) **Restoration.** Seagrass restoration is a key nature-based solution for climate change mitigation, but projects often fail due to challenges in relation to site selection, seed germination and maintenance (Unsworth and others, 2023). Scaling up restoration efforts requires practical, simple methods and a better understanding of the interactions among the diverse components of seagrass ecosystems to improve success rates (Orth and Heck, 2023).

(d) **Management framework.** Effective management of seagrass ecosystems requires strong legal, policy and planning frameworks. These vary widely across countries, from well-developed systems, such as those of Canada (Murphy and others, 2021), to ineffective or non-existent policies, as seen in Belize and India (Acharyya and others, 2023; Grimm and others, 2023). Robust frameworks are necessary in order to allocate resources (including funding, personnel and law enforcement) to seagrass conservation.

**Remaining gaps**

While significant progress has been made in understanding seagrass biology and ecology (Orth and Heck, 2023), several knowledge gaps remain. These relate to such areas as developing cost-effective technologies for habitat mapping and monitoring with improved spatial-temporal accuracy, as well as innovations in seagrass restoration techniques, from site selection to habitat maintenance. The impacts of climate change on seagrasses, particularly in temperate and tropical regions, and the role of seagrasses in carbon sequestration and emissions are still not fully understood.. Furthermore, there is a lack of coordination and transparency in global seagrass observations, which limits collective understanding of seagrass ecosystems and the drivers of change. Making seagrass data more accessible, standardized and easily shareable across platforms would greatly enhance efforts to better understand and conserve seagrass habitats worldwide.

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