INSIGHTS

A green turtle (*Chelonia mydas*) feeds on seagrass in the Caribbean Sea off the Mexican coast.

PERSPECTIVES

MARINE ECOLOGY

A call for seagrass protection

Seagrass conservation is crucial for climate mitigation, biodiversity protection, and food security

By **Leanne C. Cullen-Unsworth**[1] *and* **Richard Unsworth**[2]

Seagrasses are marine flowering plants that are found along temperate and tropical coastlines around the world. They provide habitat for fish, shellfish, and marine herbivores such as turtles (see the photo) and dugong and also serve important physical roles—for example, by filtering sediments and reducing wave and current energies near coasts (*1*). By filtering the water column of pathogens, seagrasses reduce contamination in seafood while also reducing coral disease (*2*). Given the global distribution of seagrass and its role in climate mitigation and food security, the protection of these ecosystems has implications for the planetary boundaries within which humanity can safely operate (*3*, *4*). Growing understanding of the roles of seagrass shows that their protection is crucial for staying within safe planetary boundaries and sustaining fisheries productivity and food security (see the figure).

Seagrass meadows are one of the most widespread coastal habitats on Earth. They are found throughout subarctic to tropical latitudes and exist in countries across the range of the human development index. However, like many of the world's natural habitats, seagrass meadows are in decline,

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with estimated global losses of ~7% annually since 1990 (*5*). Poor coastal water quality and coastal development are among the major drivers of the loss (*5*).

Seagrasses have received comparatively little consideration in conservation and scientific research (*6*), but this is beginning to change. Coordinated international calls for improved protection led by the World Seagrass Association and eventually signed by hundreds of scientists (*7*), together with advances in research, provide optimism for securing a future for seagrass.

Olsen *et al*. reported the genetic sequence of the most dominant seagrass species in the Northern Hemisphere, *Zostera marina* (*8*). This research showed how genetic adaptations of this species enabled seagrasses to become one of the world's most productive ecosystems. Key to this productivity was the ability to source the building blocks of photosynthesis in an aquatic saline environment. Thanks to this genome sequence, we can understand the reverse evolutionary trajectory that allowed angiosperms to live in the sea; as terrestrial plants adapted to life in the ocean, they developed genes that enabled them to take up nutrients and conduct O_2/CO_2 exchange in a saline environment through leaf epidermal cells (*8*).

The productivity of seagrasses and their ability to store carbon in their sediments means that they are increasingly considered to be a crucial component of the world's carbon stores (*5*, *6*). Seagrass is therefore a potentially crucial component of efforts to prevent rapid uncontrolled climate change. The Paris Climate Agreement has opened the door for integrating seagrass conservation programs into climate mitigation strategies. Evidence-based conservation decisions will require a more mechanistic understanding of the processes that drive the storage or release of this blue carbon.

Understanding how and why seagrass meadows store carbon in their sediments is based largely on correlative studies that attempt to use environmental or biological variables to predict carbon stock location and size across the broad range of seagrass bioregions (*9*). This research has, for example, shown how pollutants or disturbance can influence the microbial communities in seagrass sediments, weakening carbon storage capacity and providing a pathway to CO_2 release (*10*). Other recent research highlights the role of sediment oxidation by seagrass root rhizomes, altering abundances of sulfide-oxidizing bacteria (*11*).

Seagrasses may also be key to climate mitigation in other ways. Their role as productive net primary producers in the coastal zone (*12*) has led to suggestions that they provide a local pH buffering effect (*13*). This is due to their rapid uptake of CO_2, which pushes the carbonate chemistry toward a less acidic state (*13*). It remains to be shown whether seagrass-driven changes in the local carbonate chemistry can reduce the negative impacts of ocean acidification on other habitats and organisms, such as coral reefs (*13*).

Increasing recognition that seagrasses are an important part of the global and local carbon cycles is increasing the need for more accurate estimates of global seagrass cover. Around 300,000 km^2 of seagrass has been mapped across the globe, but estimates suggest that the actual coverage could be more than 10 times greater (*11*).

Seagrass meadows are also important ecologically because they support high biodiversity. The floral diversity in seagrass meadows is relatively low, with approximately 72 seagrass species recognized globally, but the three-dimensional structure of their shoots, roots, and rhizomes attracts a high abundance and diversity of other organisms. Small grazing invertebrates profit from the colonization of the large leaf surface area by microalgae and the abundance of plant detritus. Invertebrates benefit from the oxygenation of otherwise sulfide-rich sediments.

This abundance of diverse animal life creates a vast feeding resource for numerous important fishery species. Seagrass meadows form critical nursery habitats for juvenile fish for ~20% of the world's biggest fisheries, including for Atlantic cod and walleye pollock (*14*). An abundance of animal life in seagrass also creates fishing grounds that are highly accessible for fishers all around the world and require limited gear to fish. These fisheries are increasingly recognized as critical to the livelihoods of vulnerable people across the globe (*15*). The coastal location of seagrasses, however, also makes them vulnerable to land- and sea-derived threats, such

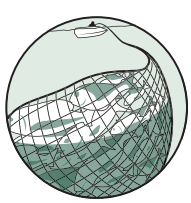
Threats to seagrass meadows

Seagrass meadows supply a vast suite of ecosystem services such as carbon sequestration, fisheries support, and coastal protection. They are part of an interconnected seascape; degradation of any habitat in this seascape has negative consequences for the other component habitats.

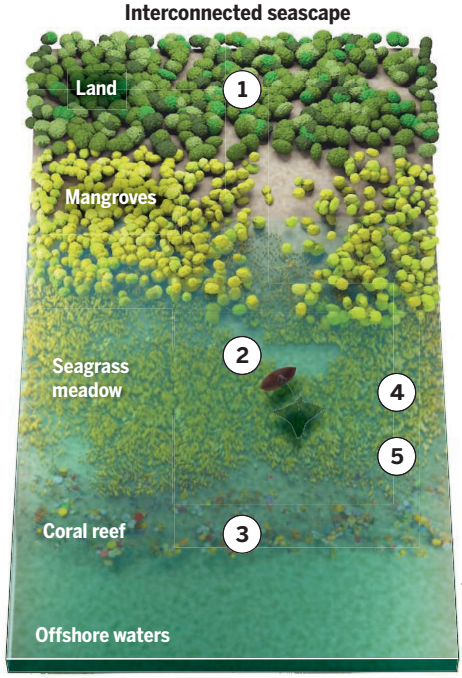
Major threats

1 Habitat destruction, coastal development, and aquaculture lead to increasing inputs of nutrients and other pollutants into the sea, threatening coastal habitats.

2 Overfishing threatens biodiversity, ecosystem resilience, and the food security of local people. Anchors and moorings result in direct physical damage to seagrass meadows.

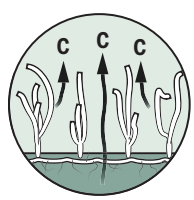


Interconnected seascape

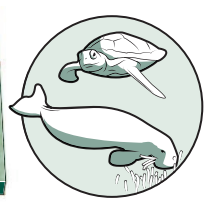


Consequences

3 Local buffering of ocean acidification by healthy seagrass meadows may help to reduce the negative impacts of changing pH on nearby **calcifying organisms such as corals.**



4 Seagrass meadows store large amounts of carbon in both the plants and the sediments below. If their integrity is disturbed, this **carbon is released.**



5 Seagrass meadows are important habitats for **marine herbivores** such as turtles and dugong. Loss of these habitats threatens **the survival of these species.**

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as fertilizer runoff and the impacts of anchor use by boats, as well as to overexploitation of their productive fisheries.

The widespread threats to seagrasses places their long-term viability in doubt. But although scientists are documenting extensive degradation of seagrass meadows and their associated fauna (*5*), the evolving understanding of seagrass ecology also increases our capacity to conserve seagrass ecosystems. The Paris Climate Agreement, the Convention on Biological Diversity, the Millennium Ecosystem Assessment, and other major international agreements such as the Convention on Migratory Species have helped to drive knowledge acquisition and the desire to protect seagrass meadows. With the right science and the political and financial will, seagrass meadows can thrive and contribute to ensuring our planet stays within its sustainable boundaries. But maintaining momentum in seagrass science, building on recent advances, and increasing public awareness is crucial for the long-term viability of seagrass systems. ■

"With the right science and the political and financial will, seagrass meadows can thrive and contribute to ensuring our planet stays within its sustainable boundaries."

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A view of the martian south polar ice cap was captured by the European Space Agency's Mars Express spacecraft.

PHOTO: ESA/DLR/FU BERLIN/BILL DUNFORD

PLANETARY SCIENCE

Liquid water on Mars

A water body exists below the martian south polar ice cap

By **Anja Diez**

Without water, no form of life as we know it could exist. There is therefore great interest in detecting liquid water on other planets of our Solar System. Landforms such as dry river valleys and lakes show that liquid water must have been present on Mars in the past (*1*). Nowadays, small amounts of gaseous water exist in the martian atmosphere, and some water ice is found on the planet's surface. Water droplets were seen condensing onto the Phoenix lander (*2*), and there may be reoccurring water activity on slopes during the martian summer (*3*). However, stable bodies of liquid water have not been found on Mars. On page 490 of this issue, Orosei *et al.* (*4*) report an analysis of radar data from the Mars Express mission that shows the existence of stable liquid water below 1.5 km of ice, close to the martian south pole.

Ice caps similar to those on Earth exist at the martian north and south poles, known as the North and South Polar Layered Deposits (NPLD and SPLD, respectively). More than 30 years ago, Clifford hypothesized that liquid water might be present below the martian polar ice caps (*5*). Despite mean annual air temperatures of around −60°C, lakes exist below Earth's Antarctic ice sheet (*6*). Glacier ice insulates the bed from the cold surface. Thus, temperatures at the base of the Antarctic ice sheet, which may be as thick as 4.8 km, can reach the pressure melting point of water; the melting point is reduced owing to the pressure of the ice layer above. Water at the ice base reduces basal friction, leading to increased flow speeds. Finding liquid water below the martian ice caps might solve ongoing debates about whether the NPLD ice flow is due to deformation of the ice, deformation of the bed, or gliding over the bed or whether it is not flowing at all (*7*).

Water below the Antarctic ice sheet has been detected and analyzed by using radar waves that are transmitted actively above the surface. As the electromagnetic radar waves pass downward through the ice, they are reflected back at the interfaces between different materials, such as contacts between ice and bedrock, sediment, or liquid water (see the figure). Along a flight track, measurements are continuously carried out to form an image of the subsurface. Such a radargram shows reflectors from the surface and the base and often multiple weaker reflections from within the ice body. The radar wave reflection is stronger from

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