

SEAGRASS: A Potential Carbon Sink

**Rose Eveleth
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EXECUTIVE SUMMARY

Climate change is currently threatening every ecosystem on the planet. As we continue to burn fossil fuels and pump CO₂ into the atmosphere at an unprecedented rate, researchers, governments and citizens look for new ways to offset these inputs. Recently, tropical forests have entered into the UN's consideration as a sink for carbon. Now, "blue" carbon sinks – sinks found in oceanic ecosystems – are looking more and more promising as a big part of the many global carbon mitigation possibilities. These blue carbon sinks include mangroves, coral reefs, salt marshes and seagrasses – the last of which is quite possibly the most promising.

Seagrasses have the potential to sequester hundreds of tons of carbon in their underground root system. They take down and store carbon at a high rate compared to most other blue carbon sinks, and are some of the more highly productive ecosystems in the world.

Not only are seagrass communities important for carbon burial, but their high biodiversity and primary production supports hundreds of nurseries and fish stocks humans rely on for food. Add that to the important storm buffering and weather mitigating effects, and seagrasses make up a large part of the ocean's ecosystem services, supporting billions of dollars worth of industry, community and infrastructure.

As climate change and anthropogenic destruction threatens seagrasses, it is imperative for global leaders to reconsider the value of these sinks and invest substantial funds to saving this precious ecosystem. Seagrasses are disappearing faster than they are being regenerated, and with them the global climate system loses an extremely important carbon sink. Just as the UN has made room for green (rainforest preservation) it must too make room for the blue, to make their preservation economically viable for the hundreds of countries who manage them.

INTRODUCTION / BACKGROUND

Coastal Zones

The coastal zone is characterized by a number of different ecosystems, each dominated by different suites of primary producers. Coastal systems can be inhabited by phytoplankton, benthic microalgae, seaweeds, kelp, seagrasses, tidal marshes, mangroves and more (Thom 2001). In much of the literature, the terms coastal zones and wetlands are used interchangeably to mean areas where sea meets land. It is thus helpful to define these terms:

Coastal zone: coastal ocean and the portion of land adjacent to the coast that influences coastal waters

Wetlands: areas consistently inundated or saturated by surface or groundwater, with vegetation adapted to such conditions.

Costal habitats are some of the most productive regions in the world, despite their relatively small surface area. These systems are characterized by high primary production rates, nutrient concentrations and biodiversity (Thom 2001). Not only are they extremely important for the ocean's biogeochemical cycles, but they play a crucial role in the lives of millions of people. These highly productive regions, where land, sea and atmosphere meet, cover only 6% of the globe, but contain 12% of the world's carbon pool, account for between 14-30% of the ocean's primary production, support 90% of the world's fish catch and provide 43% of the world's total ecosystem services (Gattuso 1998, Erwin 2009). Three billion people live within 200km of a coastline, and 14 of the world's 17 largest cities are located along costs (Olsen 2006).

Seagrasses

One of the most important and productive types of coastal vegetation are seagrass meadows. Seagrasses are a relatively small group of flowering plants with about 50 species that represent 13 genera and just 5 families (Coles 2007). These 50 species make up less than 0.02% of the flowering plants on earth, but can be found all over the world, including under sea ice, next to coral reefs, and edging most continents (*Seagrasses: Prairies of the Sea* 2009).

Seagrass growth is characterized by repeated structural units that, in combination, form the body of the plant (Hemminga 2000). These units also make up the rhizomes (root-like stems) that extend below the sediments and create thick networks of detritus, leaves, old rhizomes and other organic matter called mattes, which can extend several meters

below the surface. It is in these mattes where the majority of carbon and nutrients are stored by seagrasses, and what makes them a potential carbon sink, as we'll discuss later.

Much like coastal zones, seagrasses represent a very small area, but have a very large impact. They cover only 0.15% of the ocean floor, yet contribute 1% of the net primary production and 12% of the net ecosystem production in the ocean (Duarte 1999). In fact, seagrass meadows have as much leaf area as rainforests, and are more productive than the most fertilized and productive agricultural systems: American corn fields (*Seagrasses: Prairies of the Sea* 2009). This high productivity, combined with their global distribution, makes them stand out from other coastal systems.

Beyond simply their net primary production, seagrasses perform unique ecosystem services that make them an extremely important part of ocean nutrient cycling and the human-ocean interaction. Their physical structure provide breeding grounds and nurseries for crustaceans, finfish and shellfish, as well as food for green sea turtles, over 100 fish species, water birds and endangered marine mammals like the dugong (Coles 2007). They are the basis of a detrital food chain, filter nutrients and pollutants from the water, stabilize sediments and act as storm buffers. Economically, they support food webs and contribute to the local economy: in the Philippines alone, seagrasses provide around \$105,990 each year in annual revenue just from tourism (*Economic Values of Coral Reefs, Mangroves and Seagrasses: A Global Compilation* 2008).

Posidonia oceanica

Many of the studies on seagrasses cited in this report focus specifically on *Posidonia oceanica*, as it is currently the most promising species of seagrass for long term, large-scale carbon burial. As it grows, the plant accumulates large quantities of organic material in its below ground mat. All seagrass species create mattes, but *P. oceanica*'s are the largest, and longest lived (Duarte 2004). The species is widespread throughout most of the coastal Mediterranean, and contains one of the largest coastal reservoirs of CO₂ in the world (Iacono 2008).

Climate Change and Threats to Seagrasses

Climate change is widely recognized as a real threat to our natural and man-made systems (Laffoley 2009). Coastal zones and seagrasses are no exception. Seagrass meadows, while supporting a huge array of diversity, are often themselves not particularly diverse. Large areas of seagrass are often dominated by a single species (Ehlers 2008). They are also exceptionally vulnerable to changes in water clarity, light availability and temperature (Laffoley 2009). The combination of genetic homogeneity and vulnerability to changes in climatic and environmental factors makes seagrasses particularly vulnerable to global warming. In fact, some studies suggest that they are more vulnerable than many other ocean systems (Nellmann 2009).

Unfortunately, regardless of the projected impacts of climate change, human disturbances have already destroyed most of the world's seagrass beds. Eutrophication, land reclamation, changes in land use practices, increased development along coastlines, dredging, exploitation of coastal resources, boating, recreational activities and nutrient

runoffs have all heavily damaged coastal seagrasses (Coles 2007). Wherever there are boats seagrasses are in danger: the anchor from a single cruise ship can destroy an area of seagrasses the size of a football field (McKenzie 2008). In industrial areas of the North Atlantic, 65% of the native eelgrass has been lost (Laffoley 2009). The same study suggests that 2/3 of the world's seagrass meadows might have already been destroyed, and that this will most likely be accelerated by climate change. Coastal systems in general have the highest rates of loss of any system on the planet, four times the rate of rainforests (Nellemann 2009). Worldwide, the mortality of seagrasses is higher than the growth rate.

This report aims to bring new light to the value of seagrasses not just as a highly diverse and economically profitable ecosystem, but also as a valuable carbon sink that should certainly be considered into the UN's future carbon market decisions.

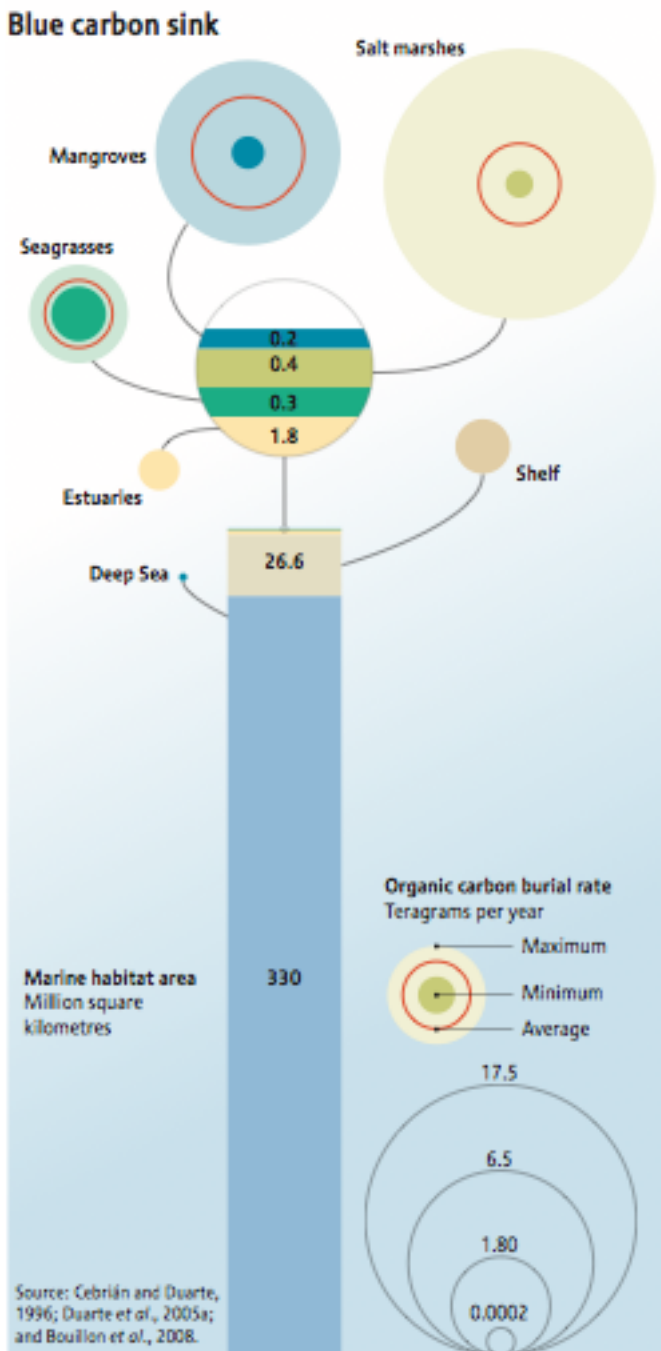
RESEARCH

BIOLOGY

Biomass and Production

Seagrasses have a relatively low biomass compared to places like tropical, or even temperate forests. On average, there is about 184gC/m² in seagrass meadows (Laffoley 2009). This is only 1.84 tons of Carbon per hectare, compared to 120 in tropical forests worldwide. Seagrasses thus represent less than 1% of the average standing biomass of tropical, temperate and boreal forests combined. Despite this, the rate of net primary

production of seagrass meadows is much higher than these same terrestrial systems at around 600 gC/m² each year.



Carbon Sequestration

We know that blue carbon sinks are some of the most important in the world. These habitats cover less than .5% of the ocean floor, but account for as much as 71% of the carbon storage in ocean sediments (Nellemann 2009). As a whole, blue carbon sinks – including mangroves, salt marshes, seagrasses, coral reefs and other habitats – store somewhere between 235 and 450 megatons of carbon every year (see Figure “Blue carbon sink”).

What makes seagrasses particularly special, in terms of the global carbon

cycle, is their strategy of depositing large amounts of carbon underground, where it is stored for thousands of years (Laffoley 2009). Specifically, seagrasses sequester about 83gC/m² each year, mostly in their below ground mat system. Unlike in mangroves

and salt marshes, which each have higher burial rates, the carbon buried in seagrasses stays in the sediments for thousands of years. While there is high variability between seagrass species in their capacity to store carbon, some species, particularly *Posidonia oceanica*, are extremely efficient at both burying and storing carbon for millennia.

The rate and success of carbon sequestration varies between and within seagrass species based on a whole suite of natural processes including herbivory, export of nutrients and decomposition (Gattuso 1998). As such, global storage estimates differ between species, sources and measuring methods. Despite these uncertainties, it is clear that seagrasses contribute a large portion of the ocean's ability to sequester carbon.

Measuring strategies

Recent developments in seismo-acoustic imaging have greatly increased our capability of measuring the depth and volume of seagrass mattes (Iacono 2008). Before this, it was difficult to measure the depth and volume of a seagrass matte without destroying some part of the meadow – literally digging until you reached the bottom. With these new methods, uninvasive measuring techniques can give precise estimates of matte volume, and a small amount of live sampling can help researchers calculate an extremely accurate estimate of carbon storage. Still, unlike tropical forests, seagrass carbon monitoring efforts have yet to settle on a consistent way to estimate seagrass carbon stocks and rate of sequestration (Chen 2009).

POLICY

Management strategies

Seagrasses have a longer history of management than many other coastal zones, and as such management strategies for seagrasses are numerous and diverse. Non-profits across the United States have addressed the seagrass degradation problem for decades, and government agencies have long recognized the importance of seagrass habitats (Fonseca 2000).

In the United States, local governments have spent many years and millions of dollars restoring their coastal seagrass communities. Seagrass bed restoration projects can be found in at least Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Pennsylvania, Maryland, Virginia, North Carolina, Tennessee, Florida, Louisiana, Texas, California, Oregon and Washington (Spalding 2009). There are a number of organizations working on large-scale seagrass restoration projects such as Seagrass Recovery, Restore-A-Scar, The Ocean Foundation and more. While their methodology may differ, each of these organizations has long worked on restoring damaged seagrass meadows.

Globally, scientists have understood the importance of seagrass ecosystems for years, and put together teams to monitor the growth and destruction of seagrasses across the globe (McKenzie 2000). These programs rely on both scientific and local knowledge, and train local residents to become not only stewards of these ecosystems, but also long term collectors of important data. Intergovernmental projects like the Land-Ocean Interactions in the Coastal Zone (LOICZ), and the Certification Program in the Governance of Coastal

Ecosystems (CEG) are all working to maintain and restore seagrass habitats through state and federal initiatives (Olsen 2009). This was all happening long before the carbon context.

Within the context of seagrasses as a carbon sink, management strategies are centered around widespread, slow growing species like *P. oceanica* (Laffoley 2009). But the keys to effective seagrass restoration are the same regardless of their potential as a carbon sink: genetic diversity, public awareness and maintaining ideal environmental conditions (Laffoley 2009, Erwin 2009). These are the same techniques that projects are currently employing, and that will help to preserve an important biogeochemical carbon cycle.

Now that carbon has entered the equation, seagrasses and other coastal systems are likely to find a fresh pool of money for restoration and conservation. Much like tropical forests, keeping seagrasses healthy is now worth something in the climate change context – although blue carbon is not yet part of the carbon market.

In a UN Context

Currently, the UN does not consider any blue carbon sinks in its climate change assessments (Nellemann 2009). Not only are the sinks available in blue carbon not being accounted for in the IPCC reports, but the sources of carbon that are released when these blue zones are destroyed are also not being factored into the global carbon emissions estimates (Laffoley 2009).

A recent study by the UNEP identifies five keys to integrate these blue carbon sinks – including seagrasses – into the bigger picture:

1. Create a fund for blue carbon, by which blue carbon sinks can be protected and restored. This would essentially be the basis for a market and mechanism to add blue carbon to the carbon market, and offer blue carbon credits for restoration projects.
2. Protect large swaths of seagrasses, salt marshes and mangrove forests through immediate and effective management.
3. Remove the threats that are currently facing blue carbon sinks such as irresponsible management practices.
4. Keep in mind the economic and social value of these systems, and create a policy that addresses not just environmental conservation.
5. Invest in strategies that allow benefits to all sectors involved in ocean trading, such as energy efficiency, sustainable energy production from ocean resources. (Nellemann 2009)

Many of these principles are already present in the UN's current work on coastal preservation. In 2009, the UN Ad Hoc Working Group of the Whole recommended a course of action for the General Assembly called the "Oceans and law of the sea." In it they proposed a global mechanism for reviewing the state of coastal systems, and outlined a tech transfer mechanism by which to improve marine technology (Davide 2009). Earlier that year, the Manado Ocean Declaration called attention to the increasing degradation of the marine environment.

All of these programs, initiatives and foundations will conserve coastal systems, seagrasses included. But these blue carbon sinks have still yet to be incorporated into the UN's carbon market as dictated by the Kyoto Protocol or the Copenhagen Accord. Local governments have been doing their part to preserve seagrasses long before the potential for carbon sequestration was discovered, and the UN would do well to incorporate those initiatives and programs into future legislation to bolster support for seagrass systems.

CONCLUSIONS

Commonalities with REDD

Rainforest degradation and deforestation has been getting much of the press recently in terms of carbon sinks. These rainforests do present an effective and important carbon source, and there are many commonalities between green and blue carbon sinks. Both tropical forests and blue carbon sinks such as seagrasses are highly biologically diverse, provide valuable and important ecosystem functions with high monetary values (including their carbon sink capacity) and are experiencing a sharp global decline (Nellemann 2009). We can and should learn from the Reduced Emissions from Deforestation and Degradation (REDD) model the ways in which blue carbon might be incorporated into the global carbon market.

The Future of Seagrasses

The carbon sequestered by blue carbon sinks constitute about half of the total emissions from the world's transportation systems (Nellemann 2009). If we were to conserve

these ecosystems – seagrasses included – we could offset between 3 and 7% of the current fossil fuel emissions in just 20 years. Seagrasses, however, currently look to be less effective as carbon sinks than salt marshes, mangroves or deep sea habitats (see “Blue carbon sinks” figure). Yet there are a number of reasons why money, time and effort should be put into seagrasses before some of these other systems:

1. Global distribution.

Because they are globally distributed, seagrasses offer the potential for blue carbon sinks at a much larger scale than mangroves, corals or salt marshes that might have a higher potential, but have smaller ranges (Laffoley 2009). Seagrasses could present a global component to the blue carbon sector.

2. Ecosystem services provided.

Regardless of their carbon sink potential, seagrasses are pivotal in the global ocean ecosystem services. They provide food security for millions of people, reduce the effects of coastal pollution, nutrient loading, erosion, extreme weather, sedimentation and more, and are worth billions of dollars in ecosystem services (Nellemann 2009). Seagrasses are also critical to the trophic structure of their surrounding ecosystems, many of which provide larger carbon sinks such as mangroves, salt marshes and coral reefs (Orth 2006).

3. Current projects.

Governments around the world are already working on preserving their seagrass ecosystems. Many organizations have verified and reliable methods of recovery and recolonization. Once the area has been recolonized, the return to a fully functioning

ecosystem happens much faster than in other, more complex systems like coral reefs (Orth 2006). The breadth and scope of current seagrass restoration projects is unparalleled in any of the other blue carbon sink systems.

4. Price and ease of restoration.

Compared to other blue carbon sinks, seagrass restoration projects are by far the least expensive.

Ecosystem	Average Cost / hectare	Source
Seagrasses	\$7,500	Spalding 2001
Rainforests	\$25,000	Neilan 2008
Salt Marshes	\$81,000	Spurgeon 1998
Mangroves	\$256,500	Spurgeon 1998
Coral Reefs	\$3,255,000	Spurgeon 1998

Table 1: Average cost per hectare for restoration projects by ecosystem.

In the UN context, there is certainly a buzz around blue carbon in general. It is still clear, however, that seagrasses cannot sequester the same volumes of carbon as other systems. Certainly more work is needed on not only the effectiveness of seagrasses at carbon burial, but the individual rates of each fifty species, their maximally efficient conditions, and ways in which we can capitalize on the native seagrasses of each region. Restoration methods must be improved and long term monitoring installed. Once we understand the mechanisms by which seagrasses sequester carbon, current and future seagrass projects could potentially be the most cost effective way to enhance the naturally occurring blue carbon sink.

Works Cited

- Chen, Chen-Tung Arthur. "Reconciling Opposing Views on Carbon Cycling in the Coastal Ocean: Continental Shelves as Sinks and Near-shore Ecosystems as Sources of Atmospheric CO₂." *Deep Sea Research II* 56 (2009): 578-90. Print.
- Coles, R. G., McKenzie, L. J., Rasheed, M. A., Mellors, J. E., Taylor, H., Dew, K. McKenna, S., Sankey, T. L., Carter A. B. and Grech A. (2007). *Status and Trends of Seagrass Habitats in the Great Barrier Reef World Heritage Area*. Report to the Marine and Tropical Sciences Research Facility. Reef and Rainforest Research Centre Limited, Cairns (122 pp.).
- Conservation International. 2008. *Economic Values of Coral Reefs, Mangroves, and Seagrasses: A Global Compilation*. Center for Applied Biodiversity Science, Conservation International, Arlington, VA, USA.
- Davide, Hilario G. *Report on the Work of the Ad Hoc Working Group of the Whole to Recommend a Course of Action to the General Assembly on the Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socio-economic Aspects*. Rep. UN General Assembly, 2009. Print.
- Duarte, C. M. "Major Role of Marine Vegetation on the Oceanic Carbon Cycle." *Biogeosciences Discussions* 1 (2004): 659-79. Print.
- Duarte, Carlos M. "Seagrass Biomass and Production: a Reassessment." *Aquatic Botany* 65 (1999): 159-74. Print.
- Ehlers, Anneli. "Importance of Genetic Diversity in Eelgrass *Zostera Marina* for Its Resilience to Global Warming." *Marine Ecology Progress Series* 355 (2008): 1-7. Print.
- Erwin, Kevin L. "Wetlands and Global Climate Change: the Role of Wetland Restoration in a Changing World." *Wetlands Ecology and Management* 17 (2009): 71-84. Print.
- Fonseca, Mark S. "Integrating Biology and Economics in Seagrass Restoration: How Much Is Enough and Why?" *Ecological Engineering* 15 (2000): 227-37. Print.
- Gattuso, J. P. "Carbon and Carbonate Metabolism in Coastal Aquatic Ecosystems." *Annual Review of Ecology, Evolution and Systematics* 29 (1998): 405-34. Print.
- Hemminga, Marten. *Seagrass Ecology*. Cambridge University Press. New York, New York. 2000.
- Iacono, Claudio Lo, and Miguel Angel Mateo. "Very High-resolution Seismo-acoustic Imaging of Seagrass Meadows (Mediterranean Sea): Implications for Carbon Sink Estimates." *Geophysical Research Letters* 35 (2008): 1-5. Print.

Laffoley, Dan. *The Management of Natural Coastal Carbon Sinks*. Gland, Switzerland: International Union for Conservation of Nature and Natural Resources, 2009. Print.

McKenzie, L. J., and W. J. Lee Long. "Seagrass-Watch: Community Based Monitoring of Seagrass Resources." *Biol. Mar. Medit* 7.2 (2000): 393-96. Print.

Neilan, Wendy, Carla Catterall, John Kanowski, and Stephen McKenna. *A New Role for Weeds in Rainforest Restoration*. Vol. 4. Rainforest CRC. *CRC Research*. Web. <www.rainforest-crc.jcu.edu.au>.

Nellemann, C., Corcoran, E., Duarte, C. M., Valdés, L., De Young, C., Fonseca, L., Grimsditch, G. (Eds). 2009. **Blue Carbon**. A Rapid Response Assessment. United Nations Environment Programme, GRID-Arendal, www.grida.no

Olsen, Stephen Bloye, and Stell Maris Vallejo. "A Certification Programme in the Governance of Coastal Ecosystems." *LOICZ Inprint* 2 (2009): 15-18. Print.

Orth, Robert J., Timothy L.J. B. Carruthers, and William C. Dennison. "A Global Crisis for Seagrass Ecosystems." *BioScience* 56.12 (2006): 987-96. Print.

Seagrasses: Prairies of the Sea. National Center for Ecological Analysis and Synthesis, 2009. Print.

Spalding, J., Mark. The Ocean Foundation. *Absolute Global Cooling Through Seagrass Bed Restoration*. *The Oceans Foundation*. 7 Oct. 2001. Web. 3 Mar. 2009. <<http://www.oceanfdn.org/index.php?ht=a/GetDocumentAction/i/1869>>.

Spurgeon, James. "The Socio-Economic Costs and Benefits of Coastal Habitat Rehabilitation and Creation." *Marine Pollution Bulletin* 37 (1998): 373-82. Print.

Thom, Ronald M. "Carbon Sinks in Nearshore Marine Vegetated Ecosystems." *Pacific Northwest Laboratory, Marine Science Laboratory* (2001). Print.

IMAGES

"Blue Carbon Sinks." UNEP/GRID-Arendal Maps and Graphics Library. 2009. UNEP/GRID-Arendal. 2 Mar 2010 <<http://maps.grida.no/go/graphic/blue-carbon-sinks>>.