Fields of Biological Production, Ecology/Environment

Achievement

Contribution to our understanding of marine ecosystems in a changing Earth, especially through pioneering research on Blue Carbon

Prof. Carlos M. Duarte (SPAIN)

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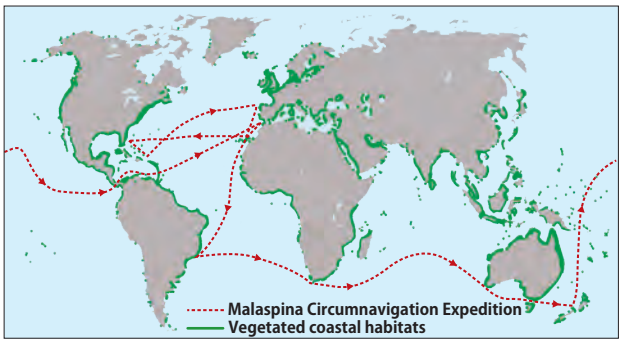
The overall structure and current state of marine ecosystems

The oceans cover approximately 70% of the Earth's surface, and they provide humanity with various benefits by mitigating the effects of climate change, supplying us with marine resources, and more. However, human activity is having a grave impact on marine environments due to increased carbon dioxide (CO_2) emissions, the destruction of biospheres, and other issues.

Duarte's thorough research into marine ecosystems has provided us with a clearer understanding of their overall structure and the extent of human influence on marine organisms and ecosystems. His work stands as a major achievement in the field of marine biology and has been published in more than 1,000 academic papers, and now provides vital guidelines for finding solutions to global environmental problems.

Between 2010 and 2011, Duarte led the Malaspina Circumnavigation Expedition, a study of marine environments across the globe (Fig. 1). A total of 800 researchers from around the world participated in this voyage, and have provided reports on a great variety of discoveries, from the current level of plastic pollution in marine environments to the mysterious structures of deep-sea ecosystems.



Source for vegetated coastal habitats: https://www.thebluecarboninitiative.org/
Source for expedition route: Duarte, C. M., *Limnology and Oceanography Bulletin* 2015, 24(1), 11-14.

Figure 1: Map showing route of the Duarte-led Malaspina Circumnavigation Voyage and extent of vegetated coastal habitats.

Blue Carbon – Carbon absorbed by marine organisms

Duarte's research into Blue Carbon is particularly important.

Carbon on Earth moves between the atmosphere, land, and oceans by changing into CO_2, organic matter, fossil fuels, and other forms (Fig. 2). Roughly 30% of the CO_2 emitted through human activity is absorbed by the oceans, and while most is dissolved into seawater, some is absorbed by plants and incorporated into marine ecosystems as organic carbon. Duarte has given this type of carbon the name "Blue Carbon."

Blue Carbon is created and moved primarily in two ways. The first is through the food chain: phytoplankton that have photosynthetically absorbed carbon are eaten by zooplankton, which are subsequently eaten by fish and finally deposited on the seafloor as bodily waste and dead organisms. The second way is when carbon is absorbed by coastal vegetation, and subsequently deposited on the seafloor when the plants die. Blue Carbon then remains sequestered on ocean floors without returning to the atmosphere for more than 1,000 years.

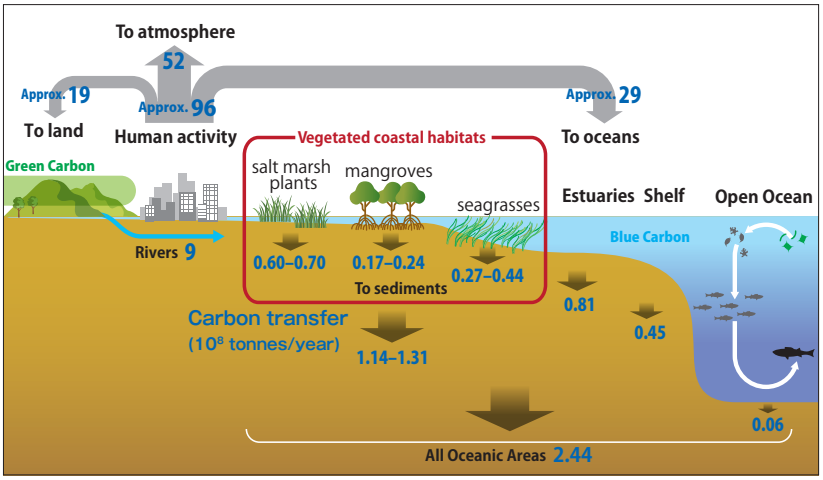


Figure 2: Carbon transfer pathways and annual transfer-amounts.

The burning of fossil fuels and other human activities result in the annual emission of approximately 9.6 billion tonnes of CO_2, of which roughly 2.9 billion tonnes are absorbed by the oceans. Some of the carbon transferred to the oceans is absorbed by ecosystems in the form of Blue Carbon and deposited on the ocean floor.

Sources:
Amount of carbon transferred to the atmosphere, land, and oceans: Friedlingstein et al., *ESSD* 2022, 14(11), 4811-4900
Amount of carbon transferred through rivers: IPCC Report (2013)
Blue Carbon sediment data: UNEP report on Blue Carbon (2009)

Vegetated coastal habitats are the largest store of Blue Carbon

Duarte calculated the amount of Blue Carbon deposited on the ocean floor as sediment in different regions, from coastal areas to the open ocean (Fig. 2), in order to clarify how much can be found in each. This led to the discovery that although the open ocean makes up more than 90% of total ocean area, it holds only a negligible amount of Blue Carbon. In contrast, Duarte found that while vegetated coastal habitats (Fig. 1) populated by salt marsh plants, mangroves, and seagrasses (Fig. 3) account for only 0.5% of total ocean area, they account for the equivalent of 50% of the total annual carbon burial in marine sediments. It was also confirmed that Blue Carbon deposited in vegetated coastal habitats is transferred to and deposited in neighboring marine regions by water currents. In other words, vegetated coastal habitats absorb, store, and sequester carbon in the marine environment, and serve as the largest reservoir of Blue Carbon.

The role played by vegetated coastal habitats was still unknown when Duarte released his research, and it shocked the world. A 2009 United Nations Environment Programme (UNEP) report listed Blue Carbon as a new option for addressing global warming alongside Green Carbon, or carbon absorbed by terrestrial plants, and it pointed out the particular importance of vegetated coastal habitats as carbon sinks. Vegetated coastal habitats are now recognized as the "most important biospheres" in the fight to mitigate global warming.

Conserving and restoring marine ecosystems for the future

Vegetated coastal habitats serve not only as stores for Blue Carbon, but also have rich biodiversity, help nurture invertebrate larvae and juvenile fish that grow to become marine resources, and protect coastal land from strong winds and high waves.

However, as these habitats lie on the boundary between sea and land, they are easily affected by human activity, and land reclamation and other projects have resulted in the continuous destruction of these ecosystems. By 2009, the area covered by vegetated coastal habitats had decreased to between one-half and two-thirds of the area that existed in the 1940s, and that area continues to shrink (Fig. 4).

That being said, Duarte argues that "It's not too late," and he is putting in an active effort towards conserving and restoring vegetated coastal habitats. In collaboration with UN agencies and other organizations, a total of 50 marine sites have been registered on the UNESCO World Heritage List. Recently, Duarte has also been working to promote the incorporation of vegetated coastal habitats into economic systems as "natural capital."

Duarte's own experiences have led him to the belief that the world stands at a crossroads today, and that the key to a sustainable future lies in harnessing the functionality of existing marine ecosystems. Prof. Carlos M. Duarte's research into Blue Carbon and other work are a beacon of hope for the future, and an opportunity to expand the conservation and restoration of marine ecosystems.

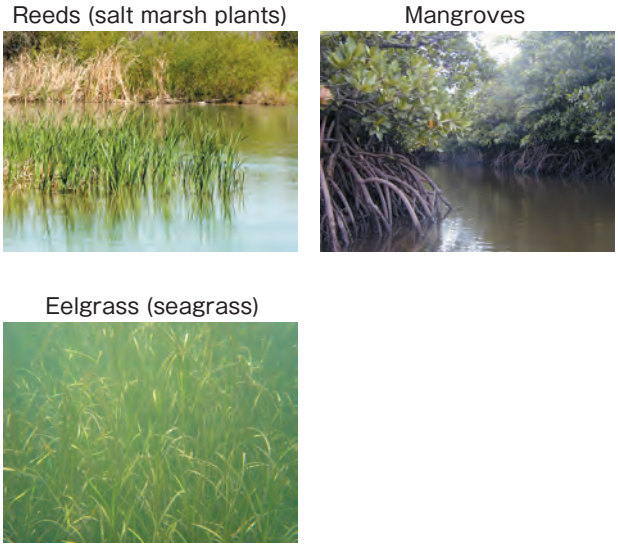
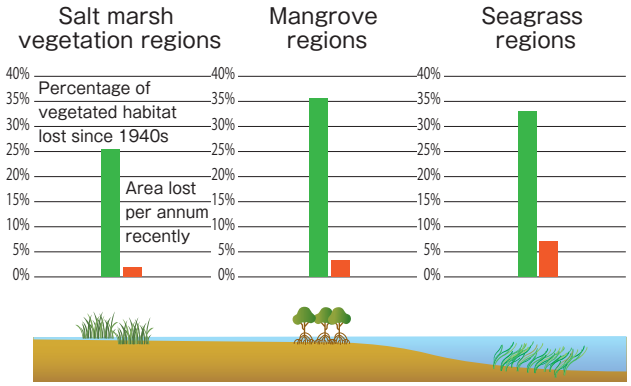


Figure 3: Typical plants that absorb Blue Carbon in vegetated coastal areas.

Source: Mangrove and eelgrass photographs provided by Japanese Fisheries Research and Education Agency



Source: Nellemann, C., et al. (2009). Blue Carbon: The Role of Healthy Oceans in Binding Carbon

Figure 4: Percentage of salt marsh, mangrove, and seagrass habitat areas lost.

Percentage of vegetated habitat lost since (the) 1940s (green bars). Each of these regions has decreased to between one-half and two-thirds of the area that existed in the 1940s. Recent years (2009) have seen habitats continue to shrink (percentage shown with orange bars).