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Global seagrass distribution and diversity: A bioregional model

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Abstract

Seagrasses, marine flowering plants, are widely distributed along temperate and tropical coastlines of the world. Seagrasses have key ecological roles in coastal ecosystems and can form extensive meadows supporting high biodiversity. The global species diversity of seagrasses is low (<60 species), but species can have ranges that extend for thousands of kilometers of coastline. Seagrass bioregions are defined here, based on species assemblages, species distributional ranges, and tropical and temperate influences. Six global bioregions are presented: four temperate and two tropical. The temperate bioregions include the Temperate North Atlantic, the Temperate North Pacific, the Mediterranean, and the Temperate Southern Oceans. The Temperate North Atlantic has low seagrass diversity, the major species being *Zostera marina*, typically occurring in estuaries and lagoons. The Temperate North Pacific has high seagrass diversity with *Zostera* spp. in estuaries and lagoons as well as *Phyllospadix* spp. in the surf zone. The Mediterranean region has clear water with vast meadows of moderate diversity of both temperate and tropical seagrasses, dominated by deep-growing *Posidonia oceanica*. The Temperate Southern Oceans bioregion includes the temperate southern coastlines of Australia, Africa and South America. Extensive meadows of low-to-high diversity temperate seagrasses are found in this bioregion, dominated by various species of *Posidonia* and *Zostera*. The tropical bioregions are the Tropical Atlantic and the Tropical Indo-Pacific, both supporting mega-herbivore grazers, including sea turtles and sirenia. The Tropical Atlantic bioregion has clear water with a high diversity of seagrasses on reefs and shallow banks, dominated by *Thalassia testudinum*. The vast Tropical Indo-Pacific has the highest seagrass diversity in the world, with as many as 14 species growing together on reef flats although seagrasses also occur in very deep waters. The global distribution of seagrass genera is remarkably consistent north and south of the equator; the northern and southern hemispheres share ten seagrass genera and only have one unique genus each. Some genera are much more speciose than others, with the genus *Halophila* having the most seagrass species. There are roughly the same number of temperate and tropical seagrass genera as well as species. The most widely distributed seagrass is *Ruppia maritima*, which occurs in tropical and temperate zones in a wide variety of habitats. Seagrass bioregions at the scale of ocean basins are identified based on species distributions which are supported by genetic patterns of diversity. Seagrass bioregions provide a useful framework for interpreting ecological, physiological and genetic results collected in specific locations or from particular species.

Keywords: Bioregional models; Diversity; Global distribution; Seagrass; Species; Temperate; Tropical

1. Introduction

The investigation of seagrass distribution globally is a complex and confounding task due to the wide range of species diversity patterns and areas where seagrasses are

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as yet undocumented as well as the fact that seagrass habitat is ever-changing. To facilitate a global assessment of seagrass distribution and diversity, we have developed bioregional models defined by the major oceans, climate, and seagrass species assemblages. Seagrass species distribution is, first, a baseline for understanding these complex habitats and their distinct bioregional characteristics. Additionally, knowledge of distribution allows comparisons of geography and evolution and provides a foundation for evaluating past and present human impacts to the global seagrass ecosystem.

Seagrasses form a critical marine ecosystem: their role in fisheries production, and in sediment accumulation and stabilization, is well documented (Green and Short, 2003; Larkum et al., 2006), but they contribute to the function of ocean ecosystems and have direct value to humanity (Duarte et al., in press). Seagrasses have relatively low biomass compared with terrestrial ecosystems, but have very high biomass compared to plankton-based oceanic communities. Highly productive seagrass ecosystems have a relatively complex physical structure, providing a combination of food and shelter that enables high biomass and productivity of commercially important fish species (Hemminga and Duarte, 2000; Beck et al., 2001). Seagrasses also provide an important nursery area for many species that support offshore fisheries and for adjacent habitats such as salt marshes, shellfish beds, coral reefs and mangrove forests. Worldwide, coastal peoples collect much of their protein from seagrass habitats (Green and Short, 2003). The association between commercially important species and seagrasses is not obligatory, as the same species are often found in other shallow marine habitats. However, the high animal biomass associated with seagrasses is greater than that of adjacent unvegetated areas (Hemminga and Duarte, 2000).

Seagrasses are the only submerged marine plants with an underground root and rhizome system. Seagrass below-ground biomass can equal that of above-ground biomass, and is often much higher (Duarte and Chiscano, 1999). The role of roots and rhizomes in binding sediments is highly important, as illustrated in a number of studies that have compared erosion on vegetated versus non-vegetated areas during storm events (Koch et al., 2006). The role of seagrass shoots in this process is also important, as this provides a stable surface layer above the benthos, baffling currents and thereby encouraging the settlement of sediments and inhibiting their resuspension (Short and Short, 1984; Ward et al., 1984). By enhancing processes of sedimentation, and through the relatively rapid uptake of nutrients both by seagrasses and their epiphytes, seagrass ecosystems remove nutrients and other contaminants from the water column. Once removed, these nutrients can be released only slowly through a process of decomposition and consumption, thereby reducing problems of eutrophication and binding organic pollutants (Hemminga and Duarte, 2000).

Seagrass habitat is critical for a number of threatened species, including sirenians (dugong and manatee), sea turtles and sea horses, all widely perceived to have high cultural, aesthetic or intrinsic values. Other seagrass functions include the maintenance of genetic variability, with potential biochemical utility, and a possible, though poorly understood, role in supporting resilience of the coastal environment. Beyond this, seagrasses clearly have a minor but important role to play in carbon sequestration, removing carbon dioxide from the atmosphere and binding it as organic matter. Their high areal productivity gives them a disproportionate influence on oceanwide primary productivity, typically producing considerably more organic carbon than the seagrass ecosystem requires (Duarte and Cebrian, 1996; Short and Neckles, 1999). Any removal of carbon, either through binding of organic material into the sediments or export into the deep waters off the continental shelf, represents effective removal of carbon dioxide from the ocean–atmosphere system which plays some role in the amelioration of climate change impacts.

For all species of seagrass, distribution is a product of combined plant sexual reproduction and clonal growth, influenced by dispersal and environmental limitations (Spalding et al., 2003). Many seagrass populations are highly clonal, largely relying on asexual reproduction for population maintenance (Rasheed, 1999; Waycott et al., 2006). Other seagrasses produce large numbers of sexual propagules (Kuo et al., 1991) or vary their reproductive strategies depending on environmental conditions (Phillips et al., 1983a; Robertson and Mann, 1984). The relatively limited phylogenetic diversity of seagrasses results in a limited range of life history strategies. All seagrass species are capable of asexual reproduction, producing modular units (ramets) through horizontal rhizome growth that may be physiologically independent but are genetically identical to the parent plant (genet). Seagrasses are also capable of sexual reproduction by producing fruits and seeds or viviparous seedlings (Kuo and Kirkman, 1987). Some species of seagrass have long-lived seeds which may form a “seed bank” (McMillan, 1983), but there is evidence that many populations lack seed banks (den Hartog, 1971; Inglis and Waycott, 2001). Seeds for most seagrass species are poorly adapted for dispersal and many are released below the sediment surface at the plant stem (den Hartog, 1970; Orth et al., 1994). A reproductive strategy involving clonal growth and production of long-lived, locally