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Organic carbon preservation in tropical seagrass-bed sediments: importance of sorptive vs. non-sorptive mechanisms

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Large benthic primary producers such as seagrasses and seaweeds often exhibit extremely high CO_2-fixing ability and are expected to have a potential to mitigate the deteriorative influence of ocean acidification on local communities. In particular, the seagrass community has also a capacity of accumulating and sequestering organic carbon (OC) in the sediment underlying it, which implies that it functions as a self-complete, long-term CO_2 sink in the biogeochemical carbon cycle. This feature has been recognized as one of the major ecosystem services of the coastal marine ecosystem. In this study, we investigated the distribution, the physical state, and the potential origins of OC stored in the sediments from tropical, subtropical, and temperate seagrass communities.

The concentration of OC per salt-corrected dry weight of sediment normally ranged between 500 and 1300 μmol C g^{-1} in both temperate and subtropical seagrass beds, although extremely high values up to 4000 μmol C g^{-1} have been found in some tropical seagrass sediments that were affected by OC inputs from adjacent mangrove forest. The carbon isotopic composition (δ^{13}C) of OC varied broadly from -28 ‰ to -12 ‰ (vs. VPDB), although the majority of seagrass bed sediments exhibited -20 $\pm$ 3 ‰. The variability in δ^{13}C could be interpreted by varying contribution of multiple OC sources to the sediment, including seagrasses (c. -10 ‰), sinking particles derived from phytoplankton (c. -22 ‰), and allochthonous OC including terrestrial plant and mangrove detritus (c. -28 ‰).

The specific surface area (SSA) of sediment grains ranged between 1 - 20 m^2 g^{-1} for seagrass bed sediments. In the case of temperate seagrass sediments, the concentration of OC was closely correlated to SSA (r = 0.9405), with the average OC/SSA ratio being 0.72 mg C m^{-2}. This trend, as well as the OC/SSA ratio, is consistent with the well-known sorptive preservation model of sediment OC originally proposed for shelf sediments (OC/SSA = 0.6 - 0.9 mg C m^{-2}; Keil et al. 1994, Mayer 1994). In contrast, no clear relationship between OC and SSA was detected for subtropical and tropical seagrass sediments. The OC/SSA ratio was generally higher for subtropical (up to 4.2) and tropical (up to 8.5) samples than temperate ones. Two clearly different trends of the δ^{13}C of OC vs. the OC/SSA ratio could be distinguished for tropical and subtropical samples. In one trend, the δ^{13}C converged to between -28 ‰ and -26 ‰ with increasing OC/SSA ratio. This trend was typically observed in mangrove-affected tropical seagrass beds and therefore could be ascribed to accumulation of mangrove-derived OC particles within seagrass sediments. The other trend, in which the δ^{13}C gradually increased up to -12 ‰ with increasing OC/SSA, was found mainly in subtropical seagrass beds. This trend indicates an accumulation of OC particles of relatively high δ^{13}C, putatively derived from the underground parts of seagrasses.

Overall, the above results demonstrated that the seagrass community actually has a large capacity to accumulate and store organic carbon of both autochthonous and allochthonous origins. However, the physical state of OC stored in the sediment seemed contrasting between temperate and tropical/subtropical seagrass communities. In the former, OC seemed to be stabilized by adsorption onto mineral particles as suggested by the consistent OC/SSA ratio. In the latter, accumulation of refractory detrital OC particles apparently played the major role in the OC storage in the sediment. The source of refractory OC particles could have been autochthonous (e.g. seagrass roots) or allochthonous (e.g. mangrove debris) depending on the environment. We are now investigating what causes such a difference in the accumulation state of OC depending on climatic and/or biological factors.

Keywords: carbon cycle, organic matter, coastal ocean, seagrass beds, sediment, specific surface area