Distribution and sources of organic carbon in a mangrove-seagrass ecosystem (Gazi Bay, Kenya)

Steven Bouillon[1], F. Dehairs[1], G. Abril[2], & A.V. Borges[3]
1 : Vrije Universiteit Brussel, dept. of Analytical and Environmental Chemistry, Brussels, Belgium. E-mail : steven.bouillon@vub.ac.be
2: Environnements et Paléoenvironnements Océaniques, Université Bordeaux 1, France
3: Unité d'Océanographie Chimique, Université de Liège, Belgium.

Introduction

► Given the importance of the tropics in the global riverine export of organic and inorganic carbon, the lack of data on the magnitude of carbon fluxes and transformations in river systems along the entire east African coastline represents one of the many gaps in our knowledge on carbon dynamics in the tropical coastal zone.

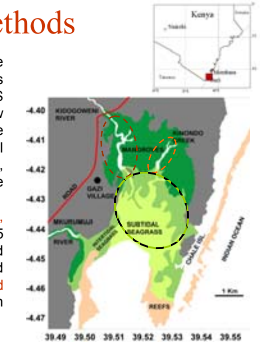
► The role of intertidal wetlands on carbon dynamics in estuaries is now widely recognized, since these highly productive ecosystems can induce major changes in the metabolic state of estuaries and the adjacent continental shelf (e.g. Cai et al. 1999 for salt marshes, Bouillon et al. 2003 for mangroves).

► Here, we report on the concentrations and stable isotope composition of different organic carbon pools in Gazi Bay (Kenya), a shallow tropical embayment with extensive mangrove forests bordering dense seagrass (*Thalassodendron ciliatum*) beds. A distinct spatial gradient in the relative contribution of seagrass- and mangrove-derived carbon was observed, and although a bidirectional exchange of material was clear, the data overall indicate that export of mangrove carbon is limited to an area close to the forest boundary and are unlikely to exert a major influence on nearshore waters.

Sampling area and Methods

► The carbon content and stable isotope composition of different organic carbon pools were studied in Gazi Bay (Kenya 4.4°S 39.5°E), in July 2003. Gazi Bay is a shallow tropical coastal ecosystem, with extensive mangrove forests intersected by 2 main tidal creeks (Kidogoweni and Kinondo, see Map), and a shallow bay largely covered by dense *Thalassodendron ciliatum* seagrass beds.

► Samples for suspended matter POC, PN, and $\delta^{13}C_{POC}$ were filtered on pre-combusted 25 mm Whatman GF/F filters, dried, and measured with standard techniques (EA and EA-IRMS). $\delta^{13}C$-DIC and $\delta^{18}O$ of dissolved oxygen were measured by headspace injection in an EA-IRMS setup.



Map: Location and detailed outline of the study area, with an indication of the three main sampling regions : (i) the salinity gradient of Kidogoweni creek, (ii) Kinondo creek, and (iii) the seagrass beds of Gazi Bay.

Acknowledgements

Financial support was granted by the FWO-Vlaanderen (contract G.0118.02) with which SB is a postdoctoral fellow, and by the FNRS (contracts 2.4596.01 and 1.5.066.03). J. Bosire and J. Kairo (KMFRI – Mombasa) have been invaluable in helping to organise the logistics.

Mangrove Management Group: Via http://www.vub.ac.be/ANCH

Unité d'Océanographie Chimique: http://www.ulg.ac.be/oceanbio/co2

References

Borges et al. (2003) CO_2 atmospheric flux from mangrove surrounding waters. Geophysical Research Letters 30 (11): 1558.

Boschker et al. (1999) The contribution of macrophyte-derived organic matter to microbial biomass in salt-marsh sediments : stable carbon isotope analysis of microbial biomarkers. Limnology & Oceanography 44: 309-319

Bouillon et al. (2003) Inorganic and organic carbon biogeochemistry in the Gautami Godavari estuary (Andhra Pradesh, India) during pre-monsoon : the local impact of extensive mangrove forests. Global Biogeochemical Cycles 17 (4): 1114.

Bouillon et al. (2004) Carbon sources sustaining benthic mineralization in mangrove and adjacent seagrass sediments (Gazi bay, Kenya). Biogeosciences 1: 71-78

Cai et al. (1999) Oxygen and carbon dioxide mass balance for the estuarine-intertidal marsh complex of five rivers in the southeastern U.S. Limnology and Oceanography 44: 639-649

Cai et al. (2003) The role of marsh-dominated heterotrophic continental margins in transport of CO2 between the atmosphere, the land-sea interface and the ocean. Geophysical Research Letters 30(16): 1849-doi:10.1029/2003GL017633

Ludwig et al. (1996) Predicting the oceanic input of organic carbon by continental erosion. Global Biogeochemical Cycles 10: 23-41.

Results & Discussion

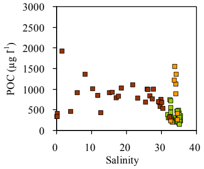


Figure 1: Distribution of POC in the mangrove creeks and seagrass bay.

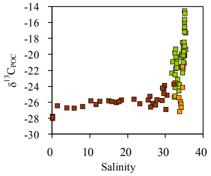


Figure 2: Stable carbon isotope composition of POC as a function of salinity.

►The distribution of particulate organic carbon along the salinity gradient of the tidal creeks indicated significant local inputs of organic carbon, with a $\delta^{13}C$ signature (~ -27 ‰) consistent with that of the dominant vegetation, i.e. mangroves (Figure 1 and 2)

► Low water column Chl a values and high POC/Chl a ratios (Figure 3) are indicative of the predominance of macrophyte material or highly degraded organic matter in the water column.

► At the boundary of the mangrove-seagrass interface, however, coinciding with a salinity of ~30, the carbon isotope composition of POC changes drastically, from about -27 ‰ to values as high as -14 ‰, indicative of a geographically sharp change in the relative contribution of mangrove and seagrass-derived organic carbon (Figure 2). [Note : seagrasses in the area have a spatially variable $\delta^{13}C$ signature, ranging between ~-19 and -11 ‰]

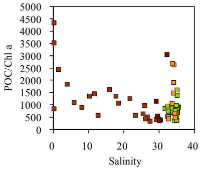


Figure 3: POC/Chl a ratios in the mangrove creeks and seagrass bed water column

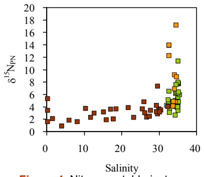


Figure 4: Nitrogen stable isotope composition of particulate N as a function of salinity.

► $\delta^{15}N$ signatures of particulate N (Figure 4) show a distinct increase in the seagrass beds and in particular, in the eastern mangrove creek (Kinondo). Nutrient data will need to identify the mechanisms for these contrasting signatures.

Colours of data points refer to the 3 main sampling areas, as indicated on the top map
■ : Kidogoweni, mangrove creek ■ : Kinondo, mangrove creek
■ :Seagrass beds

► The sedimentary record, however, does indicate that mangrove carbon is exported from the system boundaries and trapped in the seagrass beds adjacent to the mangrove forest – $\delta^{13}C$ values of sediment organic C are significantly more depleted than those of local seagrass material. This exported mangrove C has also been shown to contribute significantly to benthic mineralization (Figure 5, 6). On the other hand, seagrass material is similarly imported into the mangrove areas, but the contribution of seagrass material in mangrove sediments appears to be limited, overall.

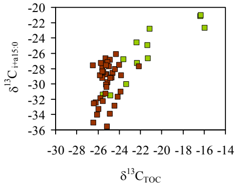


Figure 5: Stable isotope composition of bacterial membrane lipids (the phosopholipid-derived fatty acids i+a15:0) versus $\delta^{13}C$ of bulk sedimentary organic carbon for a range of mangrove and seagrass sediments. Data from Bouillon et al. (2004).

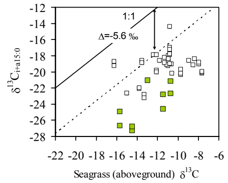


Figure 6: Stable isotope composition of the bacterial markers i+a15:0 versus $\delta^{13}C$ of seagrass tissues. Data in green are from the study site (taken from Bouillon et al. 2004), open squares are a compilation of literature data.The dotted line represents the expected $\delta^{13}C$ signature for i+a15:0 when seagrass C is the dominant C substrate, allowing for a 5.6 ‰ fractionation effect (Boschker et al. 1999)

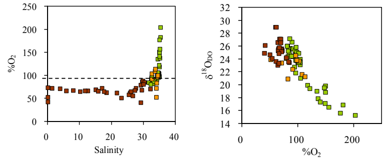


Figure 7 (A, B): Oxygen saturation levels versus salinity in the mangrove creeks and seagrass bed water column, and stable oxygen isotope composition of dissolved oxygen versus $\%O_2$.

►The high spatial variability in the sources of the aquatic organic carbon pools is also mirrored in the distribution of pCO_2 (data not shown), $\%O_2$, and the $\delta^{18}O$ signature of dissolved O_2 (Figure 7),which indicate a distinct gradient from a highly heterotrophic system (mangrove creeks: marked undersaturation of O_2 coinciding with elevated $\delta^{18}O_{DO}$ due to microbial oxygen consumption which leaves the residual O_2 pool enriched in ^{18}O) to a net autotrophic region (seagrass beds: high O_2 oversaturation, low $\delta^{18}O_{DO}$ due to the input of photosynthetic 'light' O_2). Similarly, the $\delta^{13}C_{DIC}$ profile (Figure 8) shows internal production of isotopically light DIC in the mangrove creeks, consistent with inputs from mineralization. Overall, the data indicate that export of mangrove-derived organic carbon is limited to a geographically limited area close to the forest boundary, and unlikely to reach the coastal shelf area, i.e. unlike the South Atlantic Bight saltmarsh-dominated system (Cai et al. 2003).

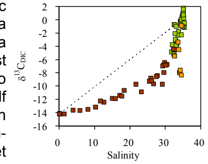


Figure 8: Distribution of $\delta^{13}C$-DIC along the salinity gradient. The dotted line represents the conservative mixing scenario