Biogeosciences Discussions, 1, S118–S124, 2004
www.biogeosciences.net/bgd/1/S118/

Biogeosciences Discussions

Interactive comment on "Carbon sources supporting benthic mineralization in mangrove and adjacent seagrass sediments (Gazi Bay, Kenya)" *by* S. Bouillon et al.

S. Bouillon et al.

Received and published: 6 September 2004

We are pleased with the very thoughtful and constructive comments offered by Referee#2, and will discuss the issues raised in detail below, with the original comments prior to each response.

REF: Section 4.1 While there is some correlation of seagrass sediment d13C with d13CPLFA (Figs 4, 6), this does not seem to hold for the mangrove sediments (Figure 4) and yet this aspect is not discussed (only depth dependant changes of carbon substrates to sedimentary bacteria).

REPLY: It is true that the between-site variations of PLFA d13C with bulk sedimentary d13C in the mangrove areas are not discussed in much detail in this paper, except for the much more pronounced depthwise variations in the PLFA isotope signatures when compared to bulk TOC d13C. These profiles clearly show a significant depthwise trend in PLFA d13C signatures (typically ~ 4 per mil) which is large when compared

to the overall range in mangrove sediment d13C values in this particular study (the overall range in average d13C-TOC for the mangrove sites is only 3 per mil). Thus, in the overall d13C-PLFA versus d13C-TOC plot (where each data point represents a single depth section of a single core), this results in a large scatter. In a previous study, however (Bouillon et al. 2004), we reported data from different mangrove sites in India and Sri Lanka where the overall range of d13C-TOC was much larger than reported here, and there, a clear correlation between d13C-TOC and d13C of most PLFA was found (note also that, as mentioned in our discussion;p320 line 7-11- the depthwise decrease in d13C-PLFA was less pronounced in the latter study).

REF: A simple mass balance calculation is used to estimate the likely proportion of mangrove organic matter at the seagrass sites. The mangrove end-member is used in this calculation. Is this appropriate given that it is earlier stated that mangrove sediment is 2 per mil enriched over plant source? Or is it assumed that a similar enrichment occurs for both seagrass and mangrove?

REPLY: This is a good point. We had indeed considered whether it would be relevant to take a small degree of fractionation into account for the (admittedly simplistic, see following remark) 2-end mixing calculations. The reasons why we decided not to do so are that (i) it is hard to put an exact value on this shift; different studies on various types of plant material come up with a range of values so even if we would put a number on it this would be uncertain, and (ii) although a shift in d13C on either or both of the end members would indeed result in different numbers for the relative contribution of mangrove C in the seagrass sediment and the relative importance of mangrove C as a substrate for mineralization, the important thing to note is that the covariation between both would remain the same. As an example, if we assume a 1 per mil shift towards more enriched values for both end members, the estimates for the % contribution of mangrove C to the seagrass sediment TOC pool would shift by ˜7 % on average towards a higher contribution of mangrove material, and an equally large shift for the estimated contribution of mangrove C to bacterial C assimilation. However, since the simple 2-

BGD

1, S118–S124, 2004

end mixing model makes a few other inherent assumptions which we cannot verify (see next point), our main point is not the absolute numbers. More importantly, the data show (i) that a significant part of seagrass sediment TOC is not local, and (ii) that the relative importance of this non-seagrass C to mineralization appears to be by and large proportional to its availability in the TOC pool. In line with this and the following comment, we have stressed these and other limitations of the simplified 2-end member approach in the revised version.

REF: I think that the limitations of using a simple, two source, mixing model were understated. Firstly the authors do not include phytoplankton inputs as the POC/chl-a ratios were high. While this is consistent with live phytoplankton being a small proportion of the suspended particulate load it does not mean that dead phytoplankton do not make a significant contribution to the suspended particulate load. The chlorophyll may degrade on phytoplankton death, increasing the C/chl ratio but the organic matter will persist for longer and the isotopic composition of the phytoplankton would not be significantly changed. Also, in section 4.3 the isotopically enriched d13Ci+a15:0 in the mangrove cores has been interpreted as possibly a microphytobenthos source to surface bacteria. Although there are no depth related data available why is this scenario not applicable to the seagrass cores, i.e. that microphytobenthos may represent a C source? Finally although it is difficult/impossible to quantify, could the seagrass epiphyte community not contribute to the sediment C through faunal grazing and defaecation? These discussions are pertinent to the solution of the bacterial -d13CPLFA 2-box model too.

REPLY: It is definitely true that the 2-end mixing model represents a significant simplification of reality, since there are obviously more than just these 2 sources present (including, as mentioned, phytoplankton, seagrass epiphytes, and microphytobenthos). And indeed, the high POC/chl a ratios suggestive of low live phytoplankton biomass does not necessarily imply that their role as a C substrate is negligible. Despite this fact, and since our data do not allow us to include any of these additional sources into

BGD

1, S118–S124, 2004

the calculations, we do feel that by taking the 2 most likely candidates (in terms of overall abundance and production) into consideration, such a simplified model is a worthy exercise, even though it should be kept in mind that it is merely an example calculation and that the absolute numbers resulting from it need to be used with appropriate caution. Our main outcome is then that in general, the estimated relative contribution of non-local C (in our approach, mangrove C) appears to correspond well to the relative contribution of the latter to the sedimentary TOC pool, with a slope between both not significantly different from 1. We feel that with some additional discussion provided in the revised version, this is made adequately clear to the reader so that these numbers can be interpreted and used for what they are. One must keep in mind that with only one tracer (d13C) at hand, a reliable estimate of the contribution or more than 2 sources is not possible. However, we can still reliable show that (i) external C-inputs (whatever their origin) are more often than not important in seagrass sediment TOC, and (ii) that in many cases such external inputs are a significant C source for mineralization.

REF: Is there any information on the role of bioturbation in these or these type of sediments? Would the depth dependant PLFA trends be expected to be maintained if the sediments were bioturbated?

REPLY: Bioturbation has been shown to be important in some mangrove and seagrass sediments but is known to be variable, depending on the type and abundance of bioturbating fauna present. If bioturbation is significant and would result in a very rapid mixing of the sediment layers in our mangrove sites, we would not expect to have some of the observed trends such as the distinct trends in PLFA abundances. In this context, it is worth mentioning that the preliminary results of 13C-labeling experiments (bicarbonate and acetate) performed at the seaward Sonneratia site during the same sampling period indicate that most of the label (applied at the surface) was only detectable in the first 2 cm of the sediments after a period of up to 14 days after the pulse labeling (own unpublished data). Also, a preliminary analysis of infauna (currently being processed) in the mangrove sediments sampled here suggests that the infauna is dominated by

BGD

1, S118–S124, 2004

meifauna-sized organisms, and strongly concentrated in the upper few centimetres.

REF: The PLFA and to some extent their isotopic signature relate only to bacterial biomass. Would it be expected that changes in biomass values would also be reflected in mineralisation rates, in so far as bacteria with the highest biomass may not do most of the remineralisation?

REPLY: This is an interesting question, but with the data at hand we can only speculate on this. There are several studies that have estimated or measured the depthwise trends of various degradation pathways or total CO2 production in mangrove sediments (e.g. Alongi et al. 2000a, b, 2004) but to our knowledge such data have never been combined with concurrent measurements of bacterial densities or estimates of bacterial C stocks. Moreover, the results of the abovementioned studies show that the depthwise patterns in mineralization rates (total or specific degradation processes) are variable within and between sites. As an example, the data in the Alongi et al papers report both conditions where sulfate reduction rates increase with depth, decrease with depth, show intermediate depth maxima, or intermediate depth minima, or (in Alongi et al. 2004, but without the raw data) situations where sulfate reduction appears to remain fairly constant down to a depth of 1 m. Thus, without combined studies measuring both types of data on the same cores/sites, it is impossible to link depthwise trends in bacterial abundance to trends in mineralization rates and hence, the relative productivity of bacteria per unit of biomass.

REF: Technical corrections In material and methods, sediments from seagrass beds were collected at 7 locations and yet in Figures 2B and 3 there are more than 7 seagrass data points. Figure 1 does not clearly show the seagrass sites, a lighter background for the mangrove areas would help. Presumably the seagrass sites are not discrete meadows but are sampling sites within continuous meadows?

REPLY: A lighter background for the seagrass beds has been applied. The reason why there are more than 7 data points for the seagrass sites is that in most of the seagrass

BGD

1, S118–S124, 2004

stations, 2 duplicate cores were taken (see Materials and Methods, p315, line 24-25), and the data were presented in full.

REF: In Figure 2 the identifiers A and B are not visible and the 2y axis on 2B needs the scale adjusting. The legend to Figures 3 and 4 have been swapped. Figure 4A should be cited in the text at the end of the 1st paragraph of the results. In the results section, bulk seagrass sediment values have not been reported.

REPLY: These technical corrections have been dealt with in a revised version.

REF: It is stated that bacterial PLFAs were selected for isotope analysis, on what basis was this selection undertaken?

REPLY: In general, the selection of PLFAs to be included for interpretation of d13C will depend on their chromatographic separation (which needs to be good for consistent d13C measurements), their specificity to bacteria or certain bacterial groups, and for this type of study their common occurrence in different sites may also play a role. In this ms, we focus on i+a15:0 in view of the fact that it is always present in sufficient amounts for adequate analysis, and the availability of fractionation data in the literature – obtained from experiments with natural substrates. Moreover, in view of the latter, data on i+a15:0 have been most reported on in the literature and allows for an intercomparison with data from other studies (as presented in Figure 6).

REF:Can the significance (p values) of the depth trend in bulk d13C at the mangrove sites be added to the results and section 4.1.

REPLY: Yes. A paired t-test on the d13C-TOC data results in the following p values: for 0-1 cm versus 4-10 cm: p=0.05, for 1-2 cm versus 4-10 cm p=0.01. These are now mentioned in the revised version.

REF: Section 4.2 Can the p value for the significance of the depth-wise increase in relative abundance of sulfate reducer PLFA and the difference between seagrass and mangrove sites and correlation between cy 19:0 be given.

BGD

1, S118–S124, 2004

Interactive Comment

REPLY: Yes. For the depthwise increase in %(10Me16:0+i17:0), a paired t-test results in the following p-values : p=0.02 for 0-1 cm versus 4-10 cm sections, and $p<0.001$ for 0-1 cm versus 2-4 cm sections.

REF: Section 4.3 Second paragraph can the phrase "correlates fairly well" be given some statistical value.

REPLY: R^2=0.78, $p<0.001$. These are now mentioned in the revised version.

REF: In Figure 6, the A is not visible on the graph. Page 322 line 17 "an" should be "and" REPLY: These technical corrections have been dealt with in a revised version.

References cited:

Bouillon S, Moens T, Koedam N, Dahdouh-Guebas F, Baeyens W, & Dehairs F (2004) Variability in the origin of carbon substrates for bacterial communities in mangrove sediments. FEMS Microbiology Ecology 49: 171-179

Alongi DM, Tirendi F, & Clough BF (2000a) Below-ground decomposition of organic matter in forests of the mangroves Rhizophora stylosa and Avicennia marina along the arid coast of Western Australia. Aquatic Botany 68 : 97-122

Alongi DM, Tirendi F, Trott LA, & Xuan TT (2000b) Benthic decomposition rates and pathways in plantations of the mangrove Rhizophora apiculata in the Mekong delta, Vietnam. Marine Ecology Progress Series 194 : 87-101

Alongi DM, Sasekumar A, Chong VC, Pfitzner J, Trott LA, Tirendi F, Dixon P, & Brunskill GJ (2004) Sediment accumulation and organic material flux in a managed mangrove ecosystem: estimates of land-ocean-atmosphere exchange in peninsular Malaysia. Marine Geology 208: 383-402

Interactive comment on Biogeosciences Discussions, 1, 311, 2004.