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Interactive comment on "Prominent bacterial heterotrophy and sources of ^{13}C-depleted fatty acids to the interior Canada Basin" *by* S. R. Shah et al.

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bg-2013-149: "Prominent bacterial heterotrophy and sources of 13C-depleted fatty acids to the interior Canada Basin"

Author Comments

We thank both reviewers for their thoughtful comments and careful reviews. We provide a response to both reviews separately below. Comments are in the same order of the referee's comments.

Referee #1 –

1) We expand the last paragraph of the Introduction to include a discussion of fatty acid sources in marine particulate matter and their utility as source proxies. The last paragraph has been modified as shown below:

"To advance our understanding of organic carbon cycling in Canada Basin, we investigated the distribution and isotopic composition of fatty acids from suspended POC collected at two deep-basin stations in 2008, a summer with record-low sea ice coverage (Maslanik et al., 2011). Isotopic studies of bulk organic carbon pools have addressed the supply and fate of vertically- and laterally-delivered organic carbon to the interior Canada Basin (Griffith et al., 2012; Honjo et al., 2010; Hwang et al., 2008). The provenance and cycling of organic matter are better understood in the Mackenzie River and Beaufort shelf and slope because DOC and POC analyses have been complemented by isotopic studies of fatty acids and other biomarkers (Drenzek et al., 2007; Goñi et al., 2005; Tolosa et al., 2013). Fatty acids are integral components of bacterial and eukaryotic membranes. They can therefore derive both from microbial cells suspended at depth and from degraded organic carbon associated with sinking particles or re-suspended sediments when recovered from suspended POC. Although multiple sources are represented, isotopic analysis of fatty acids allows for more specific investigations of microbial processes which are difficult to resolve through bulk analyses. Here we present the results of our investigations and discuss the multiple organic carbon sources and bacterial metabolic strategies that could contribute to the observed profiles."

2) A location map is incorporated into the Sampling section of the Methods (Section 2.1) as Figure 1.

3) Undoubtedly seasonality must play a role in the distribution and isotopic composition of fatty acids in suspended POC, particularly at shallow depths. But as sampling in the deep Canada Basin has been restricted to the summer months, it is difficult to provide any detailed discussion of how seasonality affects the full profile. In the surface ocean, it is possible that the d13C difference we observed between ice-covered and open-

water stations is representative of the overall seasonal progression towards more open water during the summer, although we do not have a time series which could confirm this suspicion and therefore do not include it in the manuscript. We have, however, included a brief discussion of seasonality in Discussion section 4.3, suggesting that surface water processes, including seasonal influences, may not propagate to the deep basin.

4) We could not collect a sufficient quantity of fatty acid for compound-specific 14C, but the bulk radiocarbon analysis of suspended POC (Griffith et al., 2012) confirms the referee's suspicion that suspended POC has a longer residence time than sinking and advected (i.e., captured by moored sediment trap) POC. With a shorter residence time and/or greater importance of sinking POC, we would expect the fatty acid profile to show a greater resemblance to the 50 meter sample. Or we might see a greater similarity with sediment trap material, possible with a larger contribution from terrestrial long-chain fatty acids as we see at 3000 meters and below. Because these suggestions are speculative and limited information exists about recent particle flux in the Canada Basin, we are hesitant to include a discussion of residence time, however.

5) We definitely agree that C26-C32 fatty acids have been detected in many oceanic sediments, including the slopes surrounding the Canada Basin to the south and west. Because they have been found nearby (e.g. Drenzek et al., 2007; Belicka et al., 2004) as well as in Mackenzie River suspended sediments (Goni et al., 2005; Galy et al., unpublished), we think it is more likely that prolonged suspension in oxic water column conditions may cause their degradation than the possibility that they are not being produced in the terrestrial environment close to the study site.

6) Thank you for the correction from "can been seen" to "can be seen."

Referee #2 –

A number of organization and technical comments are made in the first paragraph, which have been addressed by modifying the manuscript as follows:

Page 6700 top part – This part is already in the Materials and Methods (Section 2.3) as suggested.

Page 6701, Line 11-15 – Discussion of results are removed from the Results section. A revised version of Results section 3.2 is included below (with revised figure numbering described in the response to the Figure comments):

"Analysis of fatty acids was performed on separate fractions of the same filters used for suspended POC measurements. As with POC, fatty acid concentrations decrease with depth. Below 1500 meters, the sill depth of the Canada Basin, fatty acid abundances at CB4 are <10 ng/L. Despite these low abundances, the concentration of fatty acids recovered from the blank filter was less than fatty acids from filtered seawater at all depths (Table 1). Although both POC and fatty acid concentrations are higher (per liter seawater) under ice cover than in open water (Fig. 2A), fatty acids account for a greater fraction of suspended particulate organic carbon at station CB4 compared to CB9 at 50 meters (Fig. 3A). POC-normalized fatty acids also reveal a subsurface enrichment of saturated, even-numbered fatty acids at 2500 meters depth (Fig. 3A). This peak results from disproportionately low suspended POC concentrations combined with fatty acid concentrations on par with the sample from 2000 meters (Table 1). At mesopelagic depths, between 150 and 1000 meters, a more modest enrichment in POC-normalized bacterial branched fatty acids was revealed at station CB4 (Fig. 3). These subsurface enrichments are superimposed on a general decreasing trend of POC-normalized fatty acids with depth. Similar POC-normalized values were observed in the shallow profile from CB9 (Fig. 3B). In the abyssal Canada Basin, however, very low POC-normalized concentrations were found which did not decrease with depth, suggesting a different composition or source of suspended POC in the deepest 1000 meters (Fig 3A)."

Page 6701, Line 18 – The reference to our 'blank value' is now modified to specify that it can be found in Table 1.

Page 6702, Line 3 – Discussion surrounding the reference to Honjo et al. (2010) it has

been removed and amplified in Discussion Section 4.4 where bacterial heterotrophy is discussed in more detail.

Page 6702 through Section 3.3 – Results sections have been re-written so that discussion of the results are no longer included. A revised version of Results Section 3.3 is included below (with revised figure numbering described in the response to the Figure comments):

"At 50 meters depth, the most abundant lipids at both stations were saturated C14 and C16 fatty acids (Fig. 2B). Monounsaturated (MUFAs) and polyunsaturated fatty acids (PUFAs), are only significant contributors to total fatty acids at station CB9 at 50 meters depth. Appreciable concentrations of PUFAs were not recovered from either station. Below 50 meters, C16 and C18 fatty acids make up the majority of total fatty acids, followed by iso- and anteiso-C15 at both stations. There is a general pattern of decreasing relative C14 abundance and increasing C18 abundance with depth, and a proportionally important contribution from C15 fatty acids in the shallowest 1000 meters (Fig. 2A). A similar pattern of relative abundances is observed at station CB9, although with two important exceptions: the C18-dominated sample at 150 meters where C18 also drives the larger concentration of total fatty acids found at CB9 compared to the same depth at CB4, and more abundant unsaturated fatty acids at 50 meters. At station CB4, Fig. 2B illustrates a distinction between the distribution of fatty acids found above 3000 meters, and those found at and below this depth. In the deepest 1000 meters, saturated C16 and C18 continue to be the most abundant fatty acids although C14 is relatively more abundant than above. We also observe greater proportions of MUFAs and branched fatty acids (BFAs), as well as long-chain C20-24 fatty acids, supporting a different source of suspended POC at these depths."

Page 6703 Line 11 – BFAs are now defined in the text

Page 6703 Line 24 – SFAs are now defined in the text

Section 4.1 – The reviewer's comment revealed this section to be unclear as we had

a different meaning in mind than came across. The discussion of blank correction has been revised and clarified, and volumes of seawater filtered have been added to Table 1 so that our blank calculations can be replicated by the reader. We also include uncorrected isotopic values in a supplementary table.

Section 4.5 – We believe this comment arises from a misunderstanding. We lump together chemoautotrophic and heterotrophic bacteria (acknowledging the isotopic difference expected between them) in order to calculate what the overall isotopic value is likely to be so that we can make an estimate of the dominant carbon metabolism. This discussion has also been clarified in the text

Table 1 – Volumes of filtered seawater have been added to Table 1.

A map of stations has been added as a new Figure 1.

Former Figure 1 (now Figure 2) has been modified to reverse the order of the panels and to include station labels on the vertical axes. Colors have also been changed for clarity.

The original 3-part figures for stations CB4 (Fig. 2) and CB9 (Fig. 3) have been reorganized and redrawn to better follow with the discussion in the manuscript. Normalized fatty acid concentrations from both stations are now panels A and B on the new Figure 3 (which includes the modification suggested for the horizontal axis), and d13C from both stations are panels A and B on the new Figure 4. We leave the vertical axes as they are, however, to emphasize the profile at station CB9 is not a full-depth profile.

The original Fig. 4 has been separated into two individual figures; the depth and area for the calculations are described in the manuscript discussion, but now also in the figure caption. The f_bacteria value has also been added in the figure caption.

Interactive comment on Biogeosciences Discuss., 10, 6695, 2013.

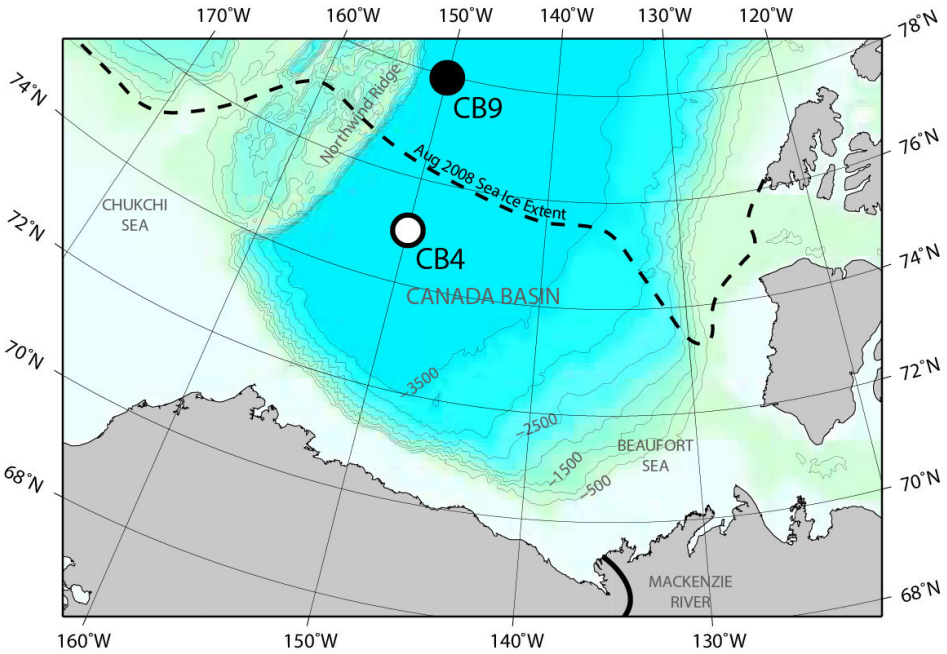

Fig. 1. Sampling locations in the Canada Basin mapped with approximate sea-ice extent in August 2008 (http://nsidc.org/data/).

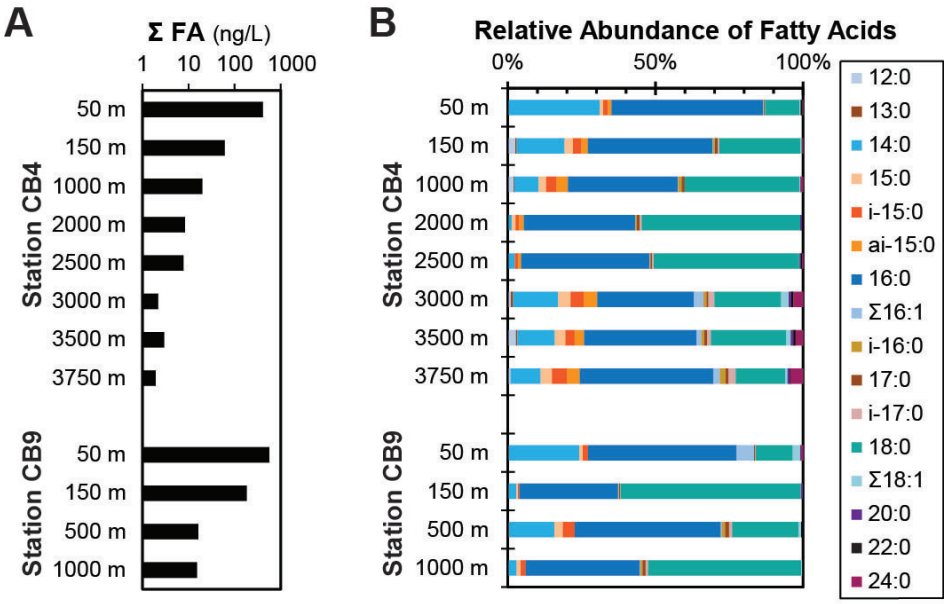

Fig. 2. (a) Summed concentration of total fatty acids. (b) Relative abundances of individual fatty acids with blue shades representing even-numbered fatty acids and orange shades representing odd-numbered and

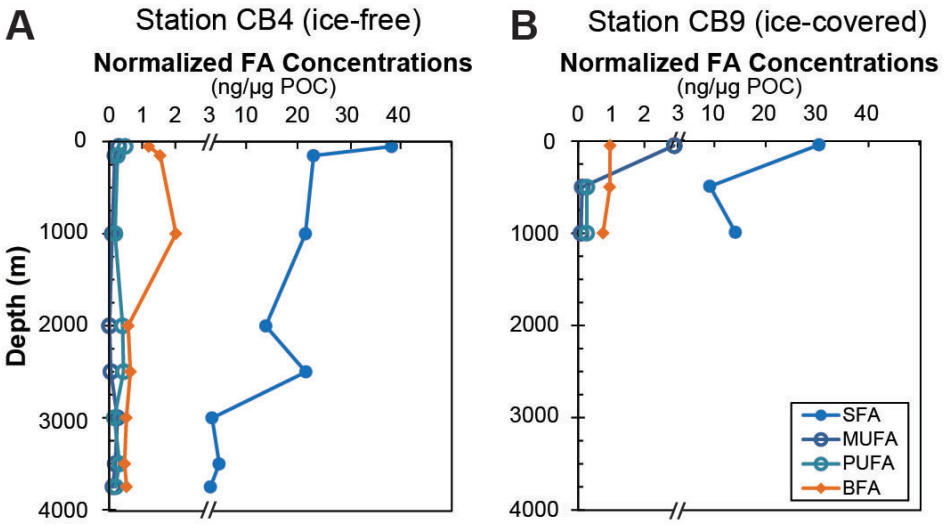

Fig. 3. POC-normalized concentrations of fatty acids grouped into saturated (SFA), branched (BFA), monounsaturated (MUFA) and polyunsaturated (PUFA) and plotted with depth at (a) Station CB4 and (b) Station C

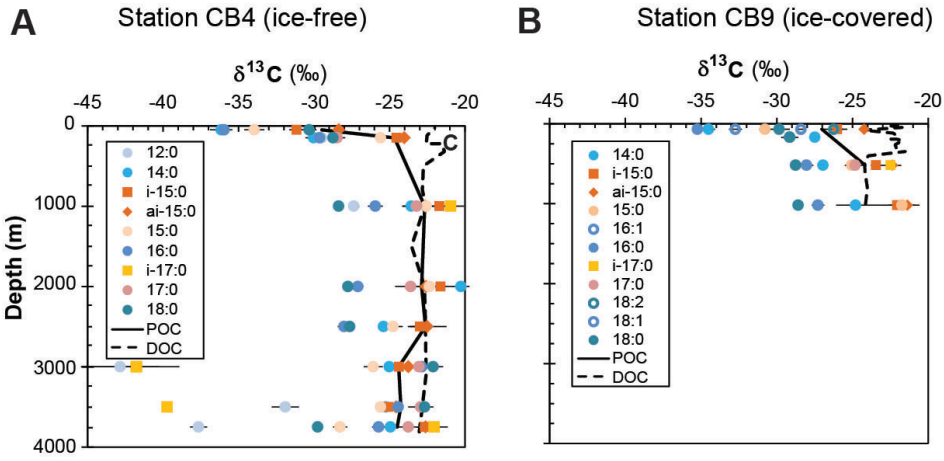

Fig. 4. δ13C values of individual fatty acids with depth where SFAs are in blue shades, BFAs are in orange shades and open circles represent MUFAs and PUFAs for (a) Station CB4 and (b) Station CB9.

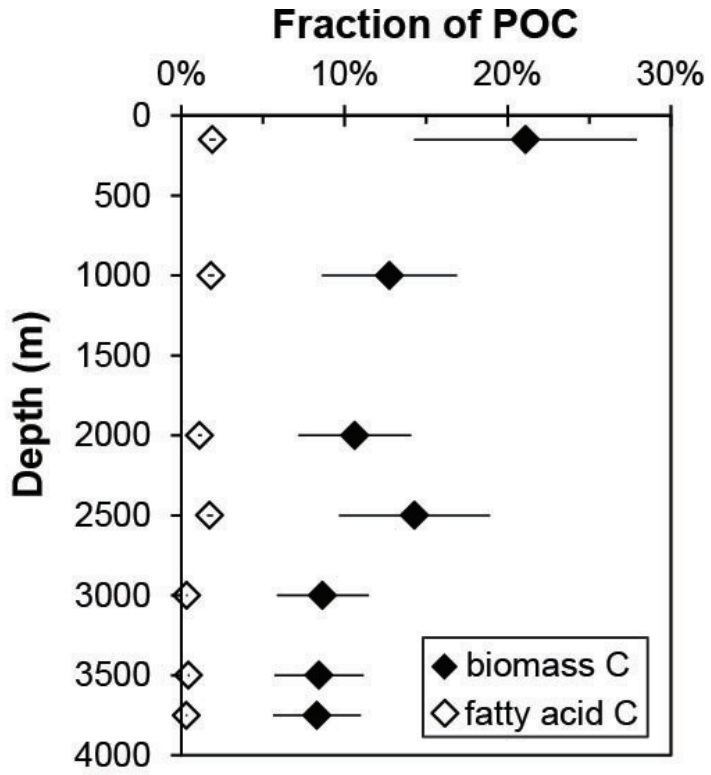

Fig. 5. Proportions of total POC that can be attributed to organic carbon from prokaryotic biomass and organic carbon from fatty acids (FA). Prokaryotic organic carbon calculated from abundances reported by U

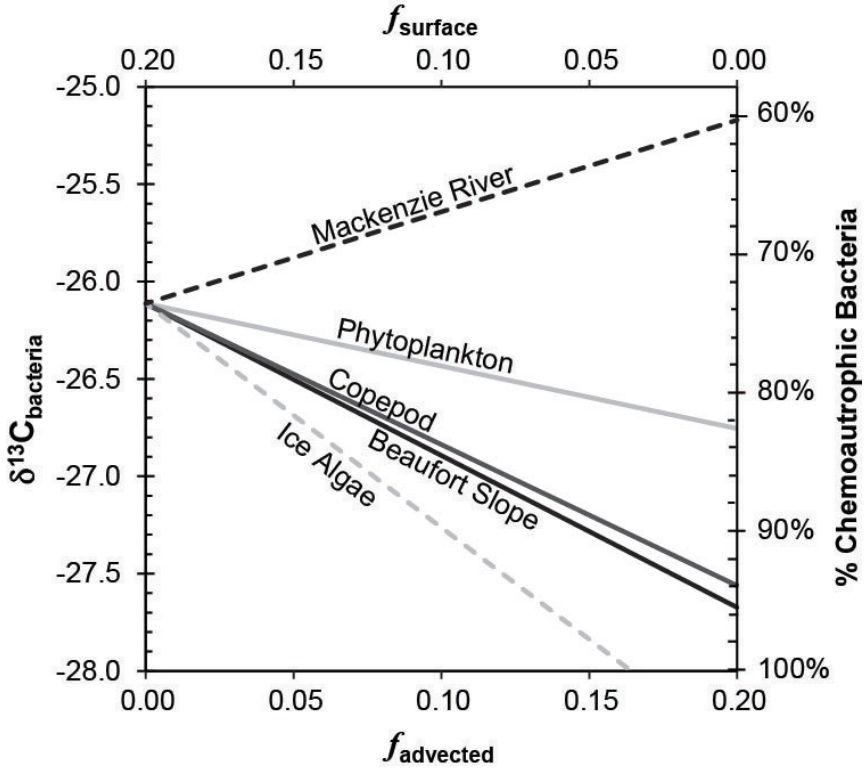

Fig. 6. Results of isotopic mass balance model for δ13Cbacteria as a function of fadvected between 1000 and 2500 meters depth . Each line represents a solution for isotopically distinct sources of advected or