Biogeosciences Discuss.,
https://doi.org/10.5194/bg-2019-455-AC1, 2020

Biogeosciences Discussions

Interactive comment on "Reconstructing N_2-fixing cyanobacterial blooms in the Baltic Sea beyond observations using 6- and 7-methylheptadecanes in sediments as specific biomarkers" *by* Jérôme Kaiser et al.

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Received and published: 7 February 2020

Anonymous Referee #1 The paper by Kaiser et al. is well written. The authors take a systematic approach to applying 6 and 7-methylheptadecane (6+7Me-C17:0) as a biomarker for Nodularia cyanobacteria. They first analyzed 6+7Me-C17:0 in sediment traps from the Baltic and then in a series of sediment cores from nearby locations. In a core from 1860 – the present day the concentration of 6+7Me-C17:0 correlated well with the Baltic Sea SST at a decadal to multi-decadal timescale and with the AMO. There are some issues that I believe need to be addressed before this paper can be

accepted for publication. Unfortunately I do not agree that the authors have sufficiently shown that the sum of 6 and 7- Me-C17:0 is a "robust semi-quantitative biomarker for cyanobacteria" in the sediment trap samples or in the 1980 – 2015 section of the MSM51-2/20 core. Indeed, there are several mismatches in the sediment trap data and the MSM51-2/20 core data between 6+7Me-C17:0 and the presence of Nodularia.

Answer: We agree that there are several mismatches between the lipids in the trap and short core sediments and the presence of Nodularia. Indeed, there is a large amount of potential error sources as mentioned in the manuscript. But, based on the trap sediment data, and considering the age model error bars of the short sediment core, we still think that the sum of 6Me- and 7Me-C17:0 can be considered as potential semi-quantitative biomarkers for cyanobacteria; not for all cyanobacteria, but specifically for Nodularia. However, we have moderated the wording: we do not mention "robust" anymore in the text, and we have added "potentially" instead of "likely" and "very likely".

This raised concerns for me as the authors selected the sum of 6- and 7-Me-C17:0 as they were both detected in 4 strains of Nodularia by Bauersachs et al. (2017). I think it is important to note that Bauersachs et al. report a range of 10 hydrocarbons across 8 species of Baltic Sea cyanobacteria, from the genera Dolichospermum, Aphanizomenon and Nodularia. I feel that it would be more informative to present all the hydrocarbon data from the sediment traps samples, not just 6+7Me-C17:0. Information about the presence/absence of n-C17 and other monomethyl alkanes (MMAs) or dimethyl alkanes (DMAs) would be helpful (and really interesting). This full distribution could be compared (statistically) with a wider range of cell counts of e.g. Dolichospermum, Aphanizomenon and Nodularia species. This would provide a solid base for going forward with 6+7Me-C17:0 as a marker for Nodularia, if the data supports it. For example, I notice that Bauersachs et al. reported that Nodularia was the only genera that also produced DMAs. If those components were also found along with the 6+7Me-C17:0 it would make a much stronger argument for applying 6+7Me-C17:0 as a biomarker for the occurrence of Nodularia in the past Baltic Sea.

Answer: We have looked again carefully at the GC-MS data in case of possible error, but we came to the same results that the DMAs produced by Nodularia were not present in the samples, likely because of both a relatively low production and lipid degradation. Concerning MMAs, we didn't consider the MMAs (n-C16:0, n-C17:0) as these are not specific biomarkers, and can have many other sources than cyanobacteria in sediments. Furthermore, there is no correspondence when comparing n-C17:0 fluxes in trap sediments and the relative amounts of Aphanizomenon and Dolichospermum (as main producers following Bauersachs et al., 2017). As we are focusing on potential specific biomarkers for cyanobacteria in the present study, we prefer not to include n-C17:0 data to avoid confusion. The ubiquitous source of n-C17:0 alkane has been mentioned in the Introduction. The data are attached for Reviewer #1 (Table for R#1), but will not be published here. Finally, cell counts of Dolichospermum, Aphanizomenon, and Nodularia are unfortunately not available for the trap sediments so that a statistical comparison with the lipid distribution is not possible. The following sentence has now been added in the Results: "Bauersachs et al. (2017) found five monomethyl alkanes (6Me-C17:0, 7Me-C17:0, 8Me-C17:0, 7Me-C16:0 and 7Me-C15:0) and two dimethyl alkanes (6,12Me-C17:0 and 7,11Me-C17:0) in cultures of cyanobacteria strains belonging to the genera Dolichospermum, Aphanizomenon and Nodularia isolated from the Baltic Sea. However, no monomethyl alkanes other than 6Me-C17:0 and 7Me-C17:0 nor dimethyl alkanes were found in the sediments. This may be due to a relatively low production of these lipids and/or a poor preservation."

Furthermore, it is unfortunate that the separate abundances of 6- and 7- Me-C17:0 were not reported. In the Bauersachs et al. paper the 6 Me-C17:0 to 7- Me-C17:0 ratio was consistently around 0.25 in all 4 Nodularia species. For all the reader knows, the sum in this study could consist primarily of 6-methylheptadecane, which would not correspond to any of the profiles found by Bauersachs et al. Using GC-MS, it should be possible to estimate the proportion of 6 Me-C17:0 and 7- Me-C17:0 by integrating both components from their mass chromatograms. If the 6- and 7-methylheptadecanes come from a different source then a different ratio could be expected. As I said before,

I found the paper well written and interesting but, without a more robust connection between the biomarker and its cyanobacterial source, the extension of the study to the sediment cores carries a high risk. There is too much uncertainty arising from the fact the 6+7Me-C17:0 concentrations only show very low correlation with FCA and the Nodularia and Aphanizomenon biomass data.

Answer: We are now giving both the 6Me-C17:0 and the 7Me-C17:0 data in Tables 3, 4, 5, and 7 (the table captions have been modified consequently). In each dataset, the 6Me-C17:0 to 7Me-C17:0 is around 0.2 (0.22 $\pm$ 0.02 for the trap sediments; 0.19 $\pm$ 0.03 for the short core sediments; 0.27 $\pm$ 0.07 for the long core sediments). These values are close to the 0.25 values for Nodularia as published in Bauersachs et al. Therefore, Nodularia is very likely the main source of 6- and 7-methylheptadecanes in the Bothnian Sea Holocene sediments. We have now added the following sentence in the Results: "Furthermore, Bauersachs et al. (2017) found that the 6Me-C17:0 to 7Me-C17:0 ratio was consistently around 0.25 in all four Nodularia spumigena strains. Similar values were found in the Baltic Sea sediments with 0.22 $\pm$ 0.02 (mean and standard deviation) in the trap sediments, 0.19 $\pm$ 0.03 in core MSM51-2/20 sediments, and 0.27 $\pm$ 0.07 in core POS435/10 sediments."

Additional points to address: Abstract Line 10 – Change "time history" to "history"

Answer: Done.

Line 12 – Change "trap sediments" to "sediment traps"

Answer: We kept here "trap sediments" as we are here talking about the sediments from the sediment traps. Line 19 – Remove "rather"

Answer: Done.

Introduction Lines 32 – 34 (and at other points in the manuscript). It does not read well to have a list of items, separated by commas but with multiple cases of "and" as the conjunction. For example, I would write the sentence as: "If diazotrophic cyanobacteria

occur in large blooms they contribute to nitrogen-eutrophication, where the massive export and decay of cyanobacterial biomass results in O2 consumption, leading to the spread of bottom water hypoxia and anoxia (Zillen and Conley, 2010; Feistel et al., 2016)."

Answer: We are grateful to the reviewer. The sentence has been changed as suggested and we have also verified for similar cases and modified them whenever possible.

Line 61 – Change to "considered well suited"

Answer: Done.

Discussion Line 244 – 246 – Strange wording. I would change to "The 6+7Me-C17:0 content is not significantly positively correlated to the FCA index (r = 0.08; p = 0.71; n =22), nor to the biomass of Nodularia spumigena (r = 0.10; p = 0.62; n = 26), nor to the biomass of Aphanizomenon sp. (r = -0.36; p = 0.07; n = 26)."

Answer: Changed.

Line 255 – Should be "which may be"

Answer: Changed.

Line 277 – Figure number missing.

Answer: A number has been added (Fig. 5C).

Please also note the supplement to this comment:
https://www.biogeosciences-discuss.net/bg-2019-455/bg-2019-455-AC1-supplement.pdf

Interactive comment on Biogeosciences Discuss., https://doi.org/10.5194/bg-2019-455, 2019.

Sediment trap								Monitoring			Satellite	
Date	$C_{17:0}$ (µg/m²/day)	7Me-$C_{17:0}$ (µg/m²/day)	6Me-$C_{17:0}$ (µg/m²/day)	6+7Me-$C_{17:0}$ (µg/m²/day)	*Aphanizomenon* spp.*	*Dolichospermum*	*Nodularia* spp.	Date	*Aphanizomenon* spp. (mg/m³)	*Nodularia* spp. (mg/m³)	Date	FCA
17.05.2010	529.8	29.9	5.4	35.3	1			06.05.2010	3.1	--	02.06.2010	0.0
27.05.2010	28.4	7.0	1.6	8.7	1			17.05.2010	3.9	--	07.06.2010	0.0
21.06.2010	5.2	--	--	--	--			03.06.2010	16.3	--	12.06.2010	0.0
11.07.2010	0.0	--	--	--	--			01.07.2010	46.2	9.7	17.06.2010	0.0
16.07.2010	136.2	108.9	19.5	128.4	3	3	2	22.07.2010	42.1	95.3	22.06.2010	0.0
26.07.2010	2.9	2.9	0.6	3.4	3	3	2	19.08.2010	25.7	43.2	27.06.2010	0.0
05.08.2010	48.3	9.7	0.0	9.7	2	2	1	16.09.2010	6.6	--	02.07.2010	0.2
15.08.2010	84.3	164.9	33.3	198.2	2	2	2	04.10.2010	36.0	--	07.07.2010	5.3
04.09.2010	68.4	43.4	10.0	53.4	2	1	1	11.11.2010	4.6	--	12.07.2010	39.4
24.09.2010	9.2	--	--	--	1			16.11.2010	14.2	--	17.07.2010	21.5
04.10.2010	164.3	38.3	9.7	48.1	3	1	1	13.01.2011	--	--	22.07.2010	21.4
24.10.2010	0.9	--	--	--	2	1		07.02.2011	0.4	--	27.07.2010	15.8
25.11.2010	24.6	--	--	--	--			12.03.2011	0.1	--	01.08.2010	0.8
01.12.2010	27.2	--	--	--	--			26.03.2011	--	--	06.08.2010	0.2
07.12.2010	19.2	--	--	--	1			10.04.2011	--	--	11.08.2010	0.0
13.12.2010	57.6	--	--	--	1			14.05.2011	19.8	--	16.08.2010	0.6
25.12.2010	14.6	--	--	--	2						21.08.2010	0.0
09.01.2011	0.0	--	--	--	1						26.08.2010	1.1
											30.08.2010	0.0

* *1: present; 2: abundant; 3: highly abundant*

Fig. 1. Table for reviewer #1