

# ***Interactive comment on “Warming enhances carbon dioxide and methane fluxes from Red Sea seagrass (*Halophila stipulacea*) sediments” by Celina Burkholz et al.***

**Celina Burkholz et al.**

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Authors' response

RC: Comments from referees/public, AR: Authors' response, AC: Authors' changes in manuscript

ANONYMOUS REFEREE #1

Interactive comment on “Warming enhances carbon dioxide and methane fluxes from Red Sea seagrass (*Halophila stipulacea*) sediments” by Celina Burkholz et al.

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Discussion paper



1) RC: This manuscript presents the results of a study in which experiments on impacts of warming and prolonged darkness on CO<sub>2</sub> and CH<sub>4</sub> fluxes are conducted in seagrass ecosystems of the Red Sea. Results show upward shifts in carbon dioxide and methane fluxes with warming and in the dark with a few exceptions under varied experimental conditions. Though it is known that a rise in temperature would increase metabolic rates the present set of results confirm thus driven elevated CO<sub>2</sub> and CH<sub>4</sub> fluxes for seagrass meadows in the Red sea. These results are of significance to understanding and quantifying the forcings and feedbacks of climate system. The Results and Discussion Sections were presented well but I found it difficult to follow some statements in Introduction section. Besides there is need to improve clarity to Material Methods Section by furnishing more details.

AR: We thank the reviewer for the constructive comments. We have made some changes to the manuscript to improve clarity.

Specific comments are given below.

2) RC: Page 2 Lines 8-10: “where autotrophic communities [net community production (NCP) > respiration (R)] act as a sink for carbon dioxide (CO<sub>2</sub>), while heterotrophic communities [net community production (NCP) < respiration (R)] act as a source of CO<sub>2</sub> (Duarte et al., 10 2011).” - Why not make it simple? Say ‘where net community production (NCP) > respiration (R)] the system becomes a sink for carbon dioxide (CO<sub>2</sub>).’?

AR: In fact, the statement was in error, besides complex. The sentence now reads as follows, which is a simpler, and most importantly, correct statement.

AC: Page 2, line 7-9: Ecosystem metabolism can also be a source of greenhouse gases, depending on the metabolic balance of the community, where autotrophic communities [net community production (NCP) > 0] act as a sink for carbon dioxide (CO<sub>2</sub>), while heterotrophic communities [net community production (NCP) < 0] act as a source of CO<sub>2</sub> (Duarte et al., 2011).

3) RC: Line 38-39: “warming at higher rates than those of the global ocean” - at what rates? Specific information will be helpful.

AR: We thank the reviewer for pointing out the missing information. We have added the rates as requested.

AC: Page 2, line 38-40: The Red Sea ranks as the warmest sea in the world, with summer seawater temperatures reaching 35 °C, and is warming at higher rates ( $0.17 \pm 0.07$  °C decade<sup>-1</sup>, Chaidez et al., 2017) than those of the global ocean ( $0.11$  °C decade<sup>-1</sup>, Rhein et al., 2013).

4) RC: Page 3 Line 30: “Once the cores were opened, the first 10 cm of the sediment and the plant biomass were collected and dried” - Is this biomass picked from the same sediment core or was it collected separately? In fact Line 24 says that sediments were collected to a depth of 10 cm. If yes, then what is ‘the first 10 cm’ in Line 30? This is confusing.

AR: We agree with the reviewer’s concern that this part can be confusing. We have edited the section accordingly. Regarding line 24, the cores were not taken at a depth of 10cm, the cores were pushed 10 cm into the sediment. We have added additional information for clarification. AC: Page 3, line 18-20: Two *H.stipulacea* meadows at a depth of 2-3 m, S1 (22°56.775’N, 38°52.677’E) and S2 (22°54.742’N, 38°53.848’E), were chosen to represent a range of organic matter content in the sediment, selected to evaluate greenhouse gas fluxes. Page 3, line 30-31: Once the cores were opened, the first 10 cm of the sediment and the plant biomass from the same cores were collected and dried.

5) RC: Page 4 Line 16 “triplicate cores from vegetated and adjacent bare (about 5 m from the edge of the seagrass patch)” - Can a sample just 5 m away from the edge of the seagrass patch be true representative of ‘bare’ sediment? Table 1 shows that sediment characteristics between vegetated and bare sediments of S2 are nearly the same but for marginal high organic matter content in the former. Only the other differ-

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ences expected under these circumstances could be nature and density of microbes on which 'respiration rate' essentially depends on!

AR: We have chosen a distance of 5 m to show the difference between the absence and presence of seagrass. A further location would have implied a variation of many other factors (depth, sediment type, etc) that could have affected the results. By having similar sediment conditions, we can imply that differences can be caused by the presence/absence of seagrass biomass.

6) RC: Line 22: "We then sampled 10 mL of air from each core using a syringe". Which replacement air was used to put into headspace each time 10 ml of air sample was drawn and how?

AR: There was no replacement air used to add to the headspace. We followed the same methodology described in Garcias-Bonet et al. (2017) and Sea et al. (2018): First, the water inside the cores was replaced by fresh seawater leaving a headspace, and the cores were closed again with stoppers containing gas tight valves. The cores were left for one hour to allow for equilibration between the seawater and the headspace air. We then sampled 10 mL of air from each core using a syringe and injected the air sample in a cavity ring-down spectrometer through a small sample isotopic module extension (SSIM A0314, Picarro). One sample from each core was taken at the start (T0), after 12 hours of light (T1) and after 12 hours of dark (T2).

7) RC: Line 30-31: "In March 2018, we collected eight vegetated and eight bare sediment cores from site S2 to evaluate the response of greenhouse gas fluxes to warming." - This sentence says eight cores each from vegetated and bare sediments. But how the number became NINE each in

AR: We thank the reviewer for pointing out the error. We have edited the sentence as follows:

AC: Page 4, line 32-33: In March 2018, we collected eighteen vegetated and eighteen

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bare sediment cores from site S2 to evaluate the response of greenhouse gas fluxes to warming.

8) RC: Lines 32-33 (“Nine vegetated and nine bare sediment cores were placed in each two aquaria”)? Also what is ‘were placed in each two aquaria’? Did they mean ‘were placed separately in two aquaria’? Since they collected 8 cores each from vegetative and bare sediment zones I would expect them to place 4 cores from each zone (total 8 cores) in each aquarium! Their write-up is confusing!!! Or more clarity is needed in presentation.

AR: We share the reviewer’s concern that this phrasing might have been confusing. We have changed the sentences as follows:

AC: Page 4, line 34-36: Nine vegetated and nine bare sediment cores each were placed in two aquaria with flow-through seawater set at in situ temperature (25 °C) and a 12 h L (up to 200  $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$ ): 12 h D cycle.

9) RC: Page 6: Lines 24-25: “Carbon, nitrogen, and phosphorus concentrations in seagrass leaves were low, but C, N and P leaf concentrations were 4- to 25 40-fold” - Did the authors mean ‘vegetative sediments or sediments for seagrass leaves’?

AR: We agree with the reviewer that this is not clear, we have added the missing information that we were referring to both sediments, vegetated and bare. AC: Page 6, line 26-27: Carbon, nitrogen (N), and phosphorus (P) concentrations in seagrass leaves were low, but they were 4- to 40-fold higher than vegetated and bare sediment concentrations (Table 1). 10) RC: Page 8: Line 8: “ranging from a minimum average of  $-11.55 \pm 5.32 \text{ ‰}$  to a maximum average of  $-17.89 \pm 1.81 \text{ ‰}$   $\delta^{13}\text{C}$ ” – are minimum and maximum interchanged? Please note that these values are bear negative sign.

AR: We thank the reviewer for pointing out this mistake. The sentence was corrected accordingly.

AC: Page 8, line 9-12: The isotopic signature of the  $\delta^{13}\text{C}\text{-CO}_2$  became heavier with

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warming in the bare sediment, increasing from  $-22.36 \pm -4.97$  ‰  $\delta^{13}\text{C}$  at 25 °C to  $-9.01 \pm 0.98$  ‰  $\delta^{13}\text{C}$  at 37 °C ( $R^2 = 0.91$ ,  $p < 0.001$ ), while the other treatments showed similar values over time, ranging from a minimum average of  $-17.89 \pm 1.81$  ‰ to a maximum average of  $-11.55 \pm 5.32$  ‰  $\delta^{13}\text{C}$  (Fig. 6A-D).

11) RC: Lines 20-21: “CO<sub>2</sub> fluxes were also 10-fold higher in vegetated compared to adjacent, but bare sediments, indicating elevated microbial remineralization rates in vegetated sediments.” Rewrite as words are repetitive and a bit confusing too. Given this statement minimal microbial description of these sediments will be very helpful.

AR: We thank the reviewer for the comment, we changed the sentence for clarification. Since we are unable to relate specific metabolic processes to specific microbial taxa, we have removed the term “microbial”, and just refer to remineralization, as we cannot exclude contributions from other components of the benthic community.

AC: Page 9, line 15-17: Both CO<sub>2</sub> and CH<sub>4</sub> fluxes were higher in vegetated compared to adjacent bare sediments, indicating elevated remineralization rates in vegetated sediments as well as a higher susceptibility of seagrass sediment to increasing temperatures.

12) RC: Lines 34-35: “Mean CH<sub>4</sub> fluxes at in situ temperature (25 °C) in vegetated sediments were lower than the mean value of  $85.09 \pm 27.80$   $\mu\text{mol CH}_4 \text{ m}^{-2} \text{ d}^{-1}$ ” - Caution needs to be exercised when expressing flux values to the second decimal. This is unnecessary given the uncertainties associated with flux estimates in general and large mean deviation in this particular case. \*\*\*

AR: We thank the reviewer for pointing this out, we have changed the sentence as follows:

AC: Page 9, line 28-29: Mean CH<sub>4</sub> fluxes at in situ temperature (25 °C) in vegetated sediments were lower than the mean value of  $85.1 \pm 27.8$   $\mu\text{mol CH}_4 \text{ m}^{-2} \text{ d}^{-1}$  reported for other seagrass meadows in the Red Sea (Garcias-Bonet and Duarte, 2017).

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