

## Author response to Associate editor's comments

We thank you for your constructive comments. Below are the editor's comments and our responses to them. The original comments by the editor are in black font; they are followed by our responses in blue font. Line numbers in our responses are the line numbers of the revised manuscript. We have attached a marked-up manuscript that shows the changes we have made highlighted in yellow.

We have implemented almost all the suggestions made by the Editor and reviewer. The following suggestions were not implemented:

1) The reviewer was confused by the minus sign added at the beginning of the NCP equations (Comment #8 by the reviewer), and you also suggested that we use the absolute value at that point (Comment #5 by the editor). However, an absolute value would be inappropriate, because NCP can be negative when respiration exceeds GCP. We therefore think that it is reasonable to put a minus sign at the beginning of the equation, but for clarification we have rearranged the equation. We apologize that there were mistakes in other equations and have modified those equations. Because of those modifications, NCP rates and model output values changed by small amounts, but the discussion and conclusions were not changed.

2) The editor commented (Comment #7) that using different equations for the control and macroalgal metabolic parameters was a waste of space. However, we think that we should show both equations because macroalgal metabolic parameters have to be calculated by using control metabolic parameters to remove the effects of planktonic metabolism in the bags with macroalgae. To clarify this point, we have rearranged the equations.

3) The reviewer commented (Comment #25) that two of the references (Pessarrodona et al. 2018 and Pedersen et al. 2019) did not explicitly consider/measure POC export from macroalgal beds (rather POC production or release) and that we should perhaps consider removing them. However, we think that these referenced works are important because they show that macroalgal beds release large amounts of POC outside of the beds. We have removed the words "to depths below the mixed layer" and modified the sentence as follows: "The release and subsequent export of particulate macroalgal carbon (e.g., entire thalli and fragments) via physical processes would contribute to CO<sub>2</sub> sequestration" (L406)

[Comments before 2nd round review]

Dear Author,

Thank you for submitting a revised version of your manuscript submitted to Biogeosciences. I decided

to send it to referee #1 for another round of review. I will let you know the outcome as soon as possible.

Comment #1: I am not certain that the title adequately reflects the content of the manuscript. It is good that you added “can” to tone down the statement as only one bed was investigated and for only 2 days in the same season. Is “extended” justified? It is pretty strong especially considering the fact that no quantitative estimate of the particulate plus dissolved export is provided. Also, no estimate of the sink is provided. Perhaps “Macroalgal metabolism and lateral carbon flow can create significant carbon sinks”. Here the emphasis would be on carbon (particulate and dissolved) rather than on CO<sub>2</sub> which is only part of your story. Also “extended” would be toned down by using “significant”. Just a suggestion to stimulate a revision.

Response: We agree with your comment. We think that the title “Macroalgal metabolism and lateral carbon flows can create significant carbon sinks” is better because this title tones down the statement and includes DOC dynamics per your suggestion.

Change: We have changed the title to “Macroalgal metabolism and lateral carbon flows can create significant carbon sinks”.

Comment #2: I forgot to mention that Biogeosciences strongly promotes the full availability of the data sets reported in the papers that it publishes in order to facilitate future data comparison and compilation as well as meta-analysis. The availability of data by request to the authors is not satisfactory. You could upload the data sets in an existing database and providing the link(s) in the paper. Alternatively, the data sets can be published, for free, alongside the paper as supplementary information. The ascii (or text) format is preferred for data and any format can be handled for movies, animations etc...

Response: We agree with your comment.

Change: We have uploaded the dataset to the online database Zenodo. We have cited this database in the Data Availability section (L437).

[Comments after 2nd round review]

Comments to the Author:

Dear Author,

Thank you for submitting a revised version of your manuscript under consideration in Biogeosciences. It could be accepted for publication after minor revision (see below).

Comment #3: When submitting the revised version, please let me know which of the changes were not implemented, if any, and why. This would speed up final acceptance.

I look forward to hearing from you.

Best regards,  
Jean-Pierre Gattuso

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Response: We have implemented almost all the suggestions made by the Editor and reviewer. The suggestions that were not implemented were showed at the beginning of this letter.

Comment #4: - see comments provided in a pdf file by referee #1. Let me know if this file is not available to you.

- Section 2.4: I agree with referee #1. There are problems with the equations.

Response: Thank you for your suggestions.

Change: We have modified some (but not all) of the equations. Please see details below.

Comment #5: - Referee #1 is confused with the minus sign added at the beginning of the NCP equations. I assume this sign is there to make NCP positive. This is not the way to do it and I recommend adding vertical bars to indicate that the absolute value is taken. Like: |xxxxx|

Response: Because  $\Delta$  DIC was calculated as the final minus initial concentrations,  $\Delta$  DIC became negative under autotrophic conditions. NCP under autotrophic conditions has generally been represented as a positive value in previous publications. However, NCP should not be considered to be an absolute value, because it can be negative when respiration exceeds GCP. We therefore think that it is reasonable to place a minus sign at the beginning of the equation. We apologize that there were mistakes in other equations. We have modified these equations. Because of those modifications, NCP rates and model output values changed by small amounts, but the discussion and conclusion were not changed.

Change: We have continued to place a minus sign at the beginning of the NCP equations, but for clarification, we have rearranged the equations. We have corrected the mistakes in the equations. In Eqs 5 and 10, we have added a minus sign at the beginning because CC is generally represented as a positive value in previous studies. In Eqs 5, 6, 10, and 11, we have modified the equations and added some explanation (L170). Based on these modifications, values of metabolic parameters and model output values were changed by small amounts (L25, 27, 252, 253, 257, 270, 275, 285, 300, 311, 380, 392, 399; Fig. 3, 7; Table 1, 2, 3).

Comment #6: - I suggest to use "l" and "d" for light and dark.

Response: We agree with your comment.

Change: We have modified the explanations and equations in accord with your suggestion. (L168)

Comment #7: - Using different equations for the control and macroalgal metabolic parameters is a waste of space. Why not use the same equation like  $NCP = |(\Delta DIC_{-1} - 1/2 \times \Delta TALK_{-1})| / T$ . And add below the set of equations " $\Delta DIC$ ,  $\Delta TALK$ , and  $\Delta DOC$  were calculated as the final minus initial concentrations in the control and macroalgal experiments."

Response: Because macroalgal metabolic parameters must be calculated by using control metabolic parameters, we think that we should show both equations for clarification.

Change: We have not made the change you suggested, but we have rearranged the equations to clarify them. We have modified the sentence in accord with your suggestion (L167).

Comment #8: - It is not a good idea to use multiple "/" signs such as " $x V / B / T$ ". It should rather be " $x V / (B \times T)$ ". Is that right?

Response: We agree with your comment.

Change: We have modified the equations in accord with your suggestion. (Eq. 7–11)

Comment #9: - 168-169 and 180-181: The source of the photoperiod and wind data should be provided: either a reference or the url of a web site.

Response: We agree with your comment.

Change: We have added the url. (L175, L188)

Comment #10: - 173:  $K \times S \times (...)$

Response: We agree with your comment.

Change: We have modified the equations in accord with your suggestion.

Comment #11: - 178:  $0.39 \times U$

Response: We agree with your comment.

Change: We have modified the equations in accord with your suggestion.

Comment #12: - 185: I assume you did not do the calculation of the carbonate chemistry with a calculator but with a software. Which one?

Response: We agree with your comment. We used the CO2SYS program.

Change: We have added an explanation as follows: "The values of  $fCO_{2water}$  were estimated with the CO2SYS program (Lewis and Wallace, 1998) and ..." (L191).

## Author response to RC1 by Albert Pessarrodona Silvestre

We thank you for your constructive comments. Below are the reviewer's comments and our responses to them. The original comments by the reviewer are in black font, followed by our responses in blue. Line numbers in our responses are the line numbers of the revised manuscript. We have attached a marked-up manuscript that shows the changes that we have made highlighted in yellow. We have changed the title in accord with the editor's suggestion.

Comment #1: The authors satisfactorily addressed most of my concerns. The new version of the manuscript features a different way of calculating  $EX_r$  taking into account more parameters (i.e. the four modelled parameters rather than just DIC). The new figures are insightful, the manuscript has significantly improved in quality and once published will make a valuable contribution to the field. I only have a few minor suggestions/edits to improve the overall readability and clarity of the text.

Response: Thank you for your comments and suggestions.

Change: We have modified the manuscript after taking into consideration your suggestions. Please see details below.

Comment #2: One of the key and most novel results of the paper is that a relevant fraction of the NCP of macroalgae is exported to the offshore site (via DOC), and that a portion of that is refractory (ln 25, 27). This significant result is "buried" towards the end of the results (e.g. ln 277) and discussion (e.g. ln 344) sections. Flipping the structure of the results and discussion (talking first about the most novel results and its implications for the CO<sub>2</sub> sequestration of macroalgae) could give it more of a punch. This is just a suggestion up to the authors discretion.

Response: Thank you for your suggestion. We agree with your comment.

Change: We have moved the sentences about the DOC budget to the beginning of the paragraph in the Results (L282). In addition, we have moved the section "Refractory DOC release by macroalgae" to the beginning of the Discussion (i.e., section 4.1) (L291).

Comment #3: Ln. 14. Evidence that macroalgae-derived carbon is locked away from the atmosphere for very long periods of time (decades-centuries) is still contentious, so I don't think the word "sequestration" is appropriate here. Perhaps carbon assimilation?

Response: We agree with your comment.

Change: We have modified this sentence as follows: "important pathways for CO<sub>2</sub> uptake by macroalgal beds" (L14).

Comment #4: Ln. 17. Add "the" before "productive"

Response: We agree with your comment.

Change: We have added “the” before “productive” (L16).

Comment #5: Ln. 18. Define here (a few words in a parenthesis would work) what a lateral carbon flow is, as a readers not familiar with that concept may not know what you are referring too.

Response: We agree with your comment.

Change: We have added the explanation as follows: “lateral carbon flows (i.e., carbon exchanges between the macroalgal bed and the offshore)” (L18).

Comment #6: Ln. 108. The field bag experiments were conducted during one day both in February and March right? This should be clear in the text.

Response: Yes, your are right. We agree with your comment.

Change: We have added the words “during one day in both February and March of 2019” in L102:

Comment #7: Ln. 113. Should be [of the] “study macroalgal bed” instead of “macroalgae”

Response: We agree with your comment.

Change: We have modified the sentence in accord with your suggestion. (L115)

Comment #8: Ln. 153. (1) I don’t understand the first negative sign, shouldn’t it just be  $\Delta\text{DIC} - 0.5 \cdot \Delta\text{Talk}$ ? (2) Also, for lns. 153-157 you have a variable expressed in  $\mu\text{mol C} \cdot \text{L}^{-1} \cdot \text{h}^{-1}$ , so the equation should account for volume of the bag right? (i.e. divided by TB not just T). (3) Finally, consider expressing your equations as  $12\Delta\text{Talk}$  or  $\frac{1}{2} \Delta\text{Talk}$  (same for other terms) as it is more clear what term of the equation is divided by what number

Response: (1) Because  $\Delta\text{DIC}$  was calculated as the final minus initial concentrations,  $\Delta\text{DIC}$  became negative under autotrophic conditions. NCP under autotrophic condition is generally represented as a positive value in previous studies. NCP is not an absolute value, because it can be negative when respiration exceeds GCP. We therefore think that it is reasonable to place a minus sign at the beginning of the equation. We apologize that there were mistakes in other equations. We have modified those equations. Because of these modifications, NCP rates and model output values changed by small amounts, but the discussion and conclusions were not changed. (2) In Eqs 2–6, we calculated the change in the concentrations due to phytoplankton in bags. The volume of the bag was not used in those equations. (3) Because we have changed the equations to fractional expressions for clarification purposes, we have expressed  $1/2$  as 0.5 for clarification.

Change: (1) We did not change the minus sign at the beginning of the NCP equations, but for clarification we have rearranged the equations. We have corrected the mistakes in the equations. In Eq 5 and 10, we have added a minus sign at the beginning because CC is generally represented as a

positive value in previous studies. In Eqs 5, 6, 10, and 11, we have modified the equations and added an explanation (L170). Because of this modification, metabolic parameters and model output values changed by small amounts (L25, 27, 252, 253, 257, 270, 275, 285, 300, 311, 380, 392, 399; Fig. 3, 7; Table 1, 2, 3). (2) We have made no change with respect to the volume. (3) We have changed the equations to fractional form to clarify them and expressed 1/2 as 0.5.

Comment #9: Ln. 121. Starting stating the aims of the paragraph will improve readability. Could try something like “To examine the degradation rates of macroalgal DOC, DOC samples were obtained ...”. Also make it clear that you are interested in measuring microbial-driven DOC degradation.

Response: We agree with your comment.

Change: We have added the sentence “To quantify the degradation rates of macroalgal DOC due to microbial activity and to estimate the refractory fraction of that DOC, ...” in L124.

Comment #10: Ln. 203. replace “from the results” for “from changes in DIC, TALK, and DOC measured in the field bag experiments”

Response: We agree with your comment.

Change: We have modified the sentence in accord with your suggestion. (L209)

Comment #11: Ln. 214. Cite here some factors (examples) that may be driving  $EX_r$ , so the reader gets a better idea of what that term  $EX_r$  represents. Could wind-driven water exchange be one of them?

Response: We agree with your comment.

Change: We have added examples as follows “e.g., wind-driven water exchange and coastal currents”. (L221)

Comment #12: Ln. 241. Consider changing the sentence to state that, on average, DOC was higher in the macroalgal bed during both sampling times, but differences between the bed and offshore site were only significant in March.

Response: We agree with your comment.

Change: We have added the sentence “On average, the DOC concentrations were higher in the macroalgal bed than at the offshore site, but the difference between them was significant only in March” in L247.

Comment #13: Ln 249. State that NCC was positive during both months (~11-21 mmol C m<sup>-2</sup> d<sup>-1</sup>) and that “the average carbon fluxes due to NCC were one to two orders of magnitude lower than those derived from NCP”

Response: We agree with your comment.

Change: We have modified the sentence as follows: “The net community calcification (NCC) of macroalgae was positive during both months (11–21 mmol-C m<sup>-2</sup> d<sup>-1</sup>), but the average carbon fluxes due to NCC were one to two orders of magnitude lower than those associated with NCP.” (L253)

Comment #14: Ln. 257. State somewhere in the paragraph that there was less decrease in March.

Response: We agree with your comment.

Change: We have modified the sentence as follows: “The degradation rate (*k*) for 150-day incubations was higher in February (0.0044 d<sup>-1</sup>) than in March (0.0021 d<sup>-1</sup>).” (L266)

Comment #15: Ln. 258. Link this sentence with the first one in ln 259 by inserting “suggesting that” at the end of ln 258.

Response: We agree with your comment.

Change: We have modified the sentence as follows: “In contrast, the stability of DOC concentrations collected from control bags during the experiments (*p* > 0.05) suggested that ...”. (L264)

Comment #16: Ln. 265. Something along the lines of “the RMSEs for the best-fitting models considering water exchange (mean: February, 0.55; March, 0.86) were lower than those assuming water exchange was zero (mean: February, 3.85; March, 3.13; Table 2)” might make the sentence a bit more clear.

Response: We agree with your comment.

Change: We have modified the sentence in accord with your suggestion. (L270)

Comment #17: Ln 267. Replace “changed little” for “saw little to no improvement”

Response: We agree with your comment.

Change: We have modified the sentence as follows: “those of DOC and TALK showed little or no improvement”. (L274)

Comment #18: Ln 268. Are 39 and 43 the percentage relative to EX (i.e. what percentage of EX is due to EX<sub>r</sub>), or just its total value? As far as I gather from ln 268, it refers to its total value and that means that EX<sub>r</sub> was the main driver of EX right? If so, make it clear in the text.

Response: Yes, they are relative to its total value.

Change: We have modified the sentences as follows: “The EX<sub>r</sub> rates were the main components of the hourly water exchange rates (the sums of EX<sub>tide</sub> and EX<sub>r</sub>), which were estimated to be 39–52 % and 42–68 % in February and March, respectively (Fig. 3 and Table 3).” (L275)

Comment #19: Ln. 322. Perhaps it would be more interesting for comparison’s sake to convert Randall

et al. 2019 estimates to carbon values assuming a photosynthetic quotient of 1?

Response: We agree with your comment.

Change: We have modified the sentence in accord with your suggestion. (L382)

Comment #20: Ln. 332. I don't understand how the relative growth rates (% d<sup>-1</sup>) values were obtained if the field bag experiments were conducted only during one day. Please clarify.

Response: Thank you for your comment. As we mentioned in the Materials and methods section, we estimated the daily metabolic parameters such as NCP by using the lengths of the photoperiods and the results of both transparent and dark bags. To clarify this point, we have modified the sentence.

Change: We have modified the sentence as follows: "The metabolic parameters were converted to daily areal rates (mmol-C m<sup>-2</sup> d<sup>-1</sup>) by using the mean macroalgal biomass, the mean water depth, the lengths of the photoperiods, and the results of both daytime and night-time experiments." (L171)

Comment #21: Ln. 351-353. Collate in just one sentence.

Response: We agree with your comment.

Change: We have modified the sentence as follows: "Our results showed that Sargassum algae sometimes release a similar percentage of production as DOC (February, 35 %; March; 6 %), and the percentages were very different between the two months, despite the similarity of the DOC release rates (Fig. 7)." (L299)

Comment #22: Ln. 372. Should be "30-day"

Response: We agree with your comment.

Change: We have modified this text in accord with your suggestion. (L320)

Comment #23: Ln. 375. Start sentence with "Recalcitrant macroalgae compounds such as phlorotannins vary ..."

Response: We agree with your comment.

Change: We have modified the text in accord with your suggestion. (L323)

Comment #24: Ln. 382. Add "microbial" before "degradation" to make clear that you only measured microbial-driven degradation of DOC under controlled conditions. Add a sentence somewhere in the paragraph stating that other factors (e.g. photochemical degradation) not measured in the study could also be important in driving DOC degradation. Also, change "should be overestimated" for "are potentially overestimates".

Response: We agree with your comment.

Change: We have modified the sentences in accord with your suggestion (L330, L331). We have added

the new reference and the sentence “The rates of DOC degradation processes, which were not measured in this study (e.g., photochemical degradation), might also be important in driving macroalgal DOC degradation (Wada et al., 2015).” (L337)

Comment #25: Ln. 396 Pessarrodona et al. 2018 and Pedersen et al. 2019 did not explicitly consider/measure POC export from macroalgal beds (rather POC production or release), so perhaps consider removing them.

Response: We think that these referenced works are important to show that macroalgal beds release large amount of POC to the outside of the beds. We have modified the sentence to clarify it.

Change: We have removed the words “to depths below the mixed layer” and modified the sentence as follows: “The release and subsequent export of particulate macroalgal carbon (e.g., entire thalli and fragments) via physical processes would contribute to CO<sub>2</sub> sequestration” (L406)

Comment #26: Ln 400. Main pathway of macroalgal DOC sequestration is thought to be export below the mixed layer (rather than “deep sea”)

Response: We agree with your comment.

Change: We have modified the sentences in accord with your suggestion. (L411, L415)

Comment #27: Ln. 402. Perhaps saying that “the maximum residence time of dissolved mater in the study’s oceanographic basin is approximately between 100-200 (depending on the season)” would make a stronger case for the potential export of your macroalgal RDOC outside the Seto Inland Sea.

Response: We agree with your comment.

Change: We have modified the sentence as “The maximum residence time of dissolved matter in the study’s oceanographic basin is between 95–218 days depending on the season (Balotro et al., 2002), indicating that macroalgal RDOC can be exported to the outside of the Seto Inland Sea and to depths below the mixed layer via vertical mixing.” (L413)

Comment #28: Ln. 421. Delete “to the surrounding water”

Response: We agree with your comment.

Change: We have modified the sentences in accord with your suggestion. (L433)

Comment #29: Figure 2. This is a great Figure!

Response: Thank you for your first-round review comment.

Change: No change.

Comment #30: Figure 3. Perhaps labelling February and March on top of the left and right columns

respectively could help with readability.

Response: We agree with your comment.

Change: We have modified the figure in accord with your suggestion. (Fig. 3)

Comment #31: Figure 4. The relationships have an R<sup>2</sup> of 1, but the plots show some deviance of the predicted relationship (i.e. data points away from the regression line) in March for instance. The R<sup>2</sup> seems a bit high for empirical data?

Response:  $R^2 = 0.996$  in February and  $0.995$  in March.

Change: We have increased the number of decimal places. (Fig. 4)

Comment #32: Figure 7. The sentence “The carbon flows due solely [...]” should go after the first sentence in the caption to inform the reader what the parentheses mean.

Response: We agree with your comment.

Change: We have modified the figure legend in accord with your suggestion. (Fig. 7)

Comment #33: Table S2. Add “measured” in front of “in the surface”

Response: We agree with your comment.

Change: We have modified the table caption in accord with your suggestion. (Table S2 in the Supplement)