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Interactive comment on "Technical note: Estimating light-use efficiency of benthic habitats using underwater O_2 eddy covariance" *by* Karl M. Attard and Ronnie N. Glud

Karl M. Attard and Ronnie N. Glud

karl.attard@biology.sdu.dk

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Reviewer 1

This is a well-written, interesting technical note but the data analysis needs further explanations. In this study, the authors use the underwater eddy covariance technique to measure oxygen flux in shallow coastal environments where light reaches the seafloor. From these fluxes, they compute hourly and daily light-use efficiency of the phototrophic benthic community. One of the key findings is that the hourly light-use efficiency may approach the maximum theoretical limit and that it decreases rapidly towards the middle of the day. These are nice results that are also supported by

previous work by Berg and colleagues and should be of interest for the readers of Biogeosciences.

Light use efficiency is a useful parameter for characterizing and comparing shallow benthic habitats and for assessing environmental change. In a time when coastal water quality is deteriorating globally, a technique allow evaluation of the activity of the phototrophic benthic community is very helpful. I propose expanding the discussion of the calculations of GPP and R and their limitations.

Gross primary production (GPP, here total oxygen produced through photosynthesis) was calculated as the sum of the daytime measured net oxygen production and the oxygen consumed through respiration (R) at night. As pointed out by the authors, daytime respiration typically exceeds nighttime respiration, but daytime respiration could not be measured directly in this study. Thus, four different daytime respiration rates were calculated, two static rates and two dynamic rates (linear or sigmoid increases) to determine the respiration behavior that would fit best with the measured data. The accuracy of the determination of R and GPP defines the quality of the light use efficiency estimates that are at the center of this study. In a tidal regime, the eddy covariance instrument may not interrogate the same area of the seafloor during day and night, and thereby produce nighttime R data that are not representative, even after some corrections, of the area producing the daytime flux data. The actual differences in R may be small, however, R then represents a best guess, not a known flux. Another point that could be addressed in more detail are the other controlling factors of benthic photosynthesis besides light intensity, e.g. the spectral composition of the light, roles of grazers, nutrient availability, temperature and current strength.

Author response: Thank you for taking the time to review our paper. We appreciate the comments and we agree with these two points- as such we are happy to implement these suggestions. The dataset from Greenland is from a tidal embayment with muddy sediments. The embayment has semidiurnal tides i.e. two high and two low tides every day, so we do interrogate different parts of the seafloor throughout the day. In the mussel reef from the Baltic Sea, the flow direction is less variable since it is determined by large-scale atmospheric patterns. The convention when deriving daily rates as well as P-I relationships using eddy covariance is to assume no significant horizontal flux divergence since the measurements integrate over the small-scale patchiness (Rheuban & Berg 2013). However, we appreciate that this may add variability to our data and in the revised paper we will include an analysis on direction-dependence. We will also expand our discussion on controlling factors of benthic photosynthesis by (1) including an analysis on flow-flux relationships for our datasets, and (2) referencing other studies on other controlling factors.

Cited literature: Rheuban J.E. and Berg P. 2013. The effects of spatial and temporal variability at the sediment surface on aquatic eddy correlation flux measurements. Limnol. Oceanogr.: Methods 11: 351–359, doi:10.4319/lom.2013.11.351

In figure 1, the data could be interpreted differently, i.e. further increase of the light saturation curves with increasing light. These are four consecutive days of measurements, and the curves of the third and fourth days increase until 300 PAR at least if not farther.

Author response: The main purpose of this figure is to illustrate that there is no significant flux hysteresis in this dataset. In our revision we will expand our description of day-to-day variations in the light-saturation curves and the P-I fitting parameters, as suggested. We will mention how the parameters change in relation to light availability. In addition to the reviewer suggestions we will also add that day 2 has the lowest Ik and highest alpha, indicating a potential low light acclimation.

In figure 2, second panel, N1+N2 should be changed to be (N1+N2) average.

Author response: Thank you for catching this, we will correct it in our revision.

Although R is about 20% higher in plot 2 of figure 2, GPP is almost identical, and an explanation for this unexpected behavior would be helpful. Similarly, as R increases

over time in fig. 2, c and c, one could expect that the curvature of the light-saturation curves would increase but it does the opposite.

Author response: Figure 2b: Thank you for catching this; we did a mistake in the calculation and offset the daytime fluxes by 3.01 instead of 3.11. We will correct this in the revision and recalculate the P-I relationship.

Fig 2c+d: The curvature does indeed increase compared to panels a+b: the light-saturation parameter Ik decreases, and the alpha increases, by âĄŞ20%. This indicates that the curve becomes less linear-like following the correction, which is what we would expect when we correctly account for hysteresis.

All four GPP plots in fig. 2 are nearly identical suggesting that magnitude and dynamics of R have little influence on GPP. This is counterintuitive as in many coastal environments R reaches similar magnitude as GPP (as also seen in figure 2) and also follows dynamics that may be similar to those of the GPP (as in fig. 2 d). This needs more detailed explanation.

Author response: It is true that in this dataset, there is a relatively low impact of light hysteresis on the O2 fluxes. Other eddy covariance studies have documented much larger effects (e.g. Rheuban et al. 2014 Fig. 6). Despite having collected very many datasets in different settings, flux hysteresis is not prevalent in our data, and this is one of the best examples we could find. We will clarify this point in the revised document. Having said that, the exercise in Fig. 2 indicates that hysteresis does have a clear effect on the P-I relationships. The fitting parameters Ik and alpha hold real-world significance- they represent the photosynthetic performance of the benthic community, so any biases should be accounted for as much as possible.

Cited literature: Rheuban J.E., Berg P., McGlathery K.J. 2014. Multiple timescale processes drive ecosystem metabolism in eelgrass (Zostera marina) meadows. Marine Ecology Progress Series 507: 1–13. doi: 10.3354/meps10843

Please also note the supplement to this comment:
https://www.biogeosciences-discuss.net/bg-2020-140/bg-2020-140-AC1-supplement.pdf

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