Author response to RC1

The authors presented a set of incubation experiments using vegetated and unvegetated sediment cores and explored production, respiration, and carbonate precipitation and dissolution rates for these two type of environments. Their general conclusions are as expected, i.e., seagrass vegetation enhances organic carbonate production along with net calcification, compared with bare sediments.

The manuscript is largely well written and easy to comprehend. The only major comment I have is with the way statistics is presented. It is unclear why the authors chose to report standard error instead of standard deviation for these replicate core incubations. Is the purpose to reduce the size of the error bar? I would report standard deviations instead to show variability.

Response: Thank you for your thoughtful feedback. We initially reported standard error (SE) instead of standard deviation (SD) to emphasize the precision of the mean metabolic estimates for each treatment, as SE reflects how well our sample mean represents the true population mean. However, we understand the importance of representing variability more explicitly. In response to your suggestion, we have revised the figures (Fig. 03 to Fig. 06) to display SD instead of SE, along with the corresponding text revisions.

There are also some confusions with how the two set of incubations are compared, please see detailed comments below.

The graphic abstract is inconsistent with abstract "… resulting in no significant difference in NEC between SG and BS". But in the graphic abstract, NEC = 10.9 and -2.3 in SG and BS sediments.

Response: Thank you for your comment. We acknowledge the concern regarding the apparent discrepancy between the values in the graphic abstract and the conclusion in the text. The values presented in the graphic abstract (NEC = 10.9 for SG and -2.3 for BS) accurately represent the mean NEC fluxes observed in our study. However, statistical analysis using an independent t-test ($t = 1.320$, $df = 10$, $p = 0.216$) indicates no significant difference between the two groups.

The numerical difference in mean NEC values is accompanied by high variability within each group (SG: SD = 15.66, BS: SD = 18.80). This suggests that while a numerical difference exists, the statistical test does not detect a significant effect, likely due to the substantial overlap in variability between the groups. We have provided the statistical results below for your reference.

Group Statistics

	Treatment	N	Mean	Std. Deviation	Std. Error Mean
NEC	1.00	6	10.8704	15.66210	6.39403
	2.00	6	-2.3097	18.79665	7.67370

1 – SG; 2 – BS

Independent Samples Test

		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
NEC	Equal variances assumed	1.320	10	.216	13.18009	9.98846	-9.07558	35.43576
	Equal variances not assumed	1.320	9.685	.217	13.18009	9.98846	-9.17419	35.53437

To clarify this in the abstract, we have revised the statement as follows:

"In contrast, SG exhibited net calcification with positive NEC values (10.9 ± 15.7 mmol $CaCO_3$ m^{-2} d^{-1}), driven by higher daytime carbonate production than nighttime dissolution, while BS showed net dissolution with negative NEC values (-2.3 ± 18.8 mmol $CaCO_3$ m^{-2} d^{-1}). Despite this, high variability in carbonate fluxes led to no significant difference between SG and BS ($p>0.05$)." (L25-L29)

Section 2.5, need to spell out assumptions for using short durations (a few hours) to estimate daily rates.

Response: Thank you for your suggestion. We have clarified our assumptions for using short incubation durations to estimate daily rates. Specifically, we used a 12-hour incubation period, consisting of a 6-hour dark incubation to maintain oxygen concentrations above 80% (Eyre et al., 2002) and a 6-hour light incubation to prevent oxygen supersaturation (Olivé et al., 2016). These assumptions have been incorporated in lines 167-169 of the manuscript.

"We implemented a 6-hour dark incubation period to ensure oxygen concentrations remained above 80% (Eyre et al., 2002) and a 6-hour light incubation period to prevent oxygen from reaching supersaturated levels (Olivé et al., 2016)."

L102, add citation for Coral Allen Atlas

Response: Thank you for your suggestion. We have added the citation for the Allen Coral Atlas (L105) and included it in the references as follows:

Allen Coral Atlas: Imagery, maps and monitoring of the world's tropical coral reefs. Zendodo. doi.org/10.5281/zenodo.3833242, 2020. (L472-473)

L141, change "checker" to "sonde"

Response: Thank you for your suggestion. We have changed "checker" with "sonde" (L145).

L163, change "difference" to "sum", adding respiration rate and NPP to get GPP.

Response: Thank you for your suggestion. We acknowledge that GPP is often calculated as the sum of NPP and R; however, in our study, we computed hourly GPP as the difference between NPP and R, following Equation 4. This approach maintains consistency with our metabolic flux calculations, where R is expressed as a negative value. Mathematically, subtracting a negative R is equivalent to adding its absolute value, yielding the same result as summing NPP and R. Given this formulation, we believe "difference" accurately reflects our approach. We have also revised our equation 4:

GPP = NPP (positive) – R (negative) (eq. 4) (L178)

This formulation is consistent with metabolic calculations used in studies such as Chen et al. (2019) and Eyre and Ferguson (2005).

L175, state the duration of alkalinity difference measurements

Response: Thank you for your comment. The duration of alkalinity difference measurements is already stated in the revised manuscript (L187-190).

"Day and night incubations (lasting 12 hours) were conducted simultaneously with organic carbon metabolism to obtain daily NEC fluxes. The dark period (midnight to dawn) was used to measure

nighttime dissolution, while the light period (dawn to noon) was used for daytime calcification. Alkalinity was measured every 3 hours throughout the incubation period.

L205-207, suggest removing this sentence, otherwise worsening OA at night needs to be included.

Response: Thank you for your suggestion. We have removed the sentence.

L234-235, show the data.

Response: Thank you for your comment. In response, we have included the data as requested.

"Both R and GPP in SG and BS increased on the second day of incubation [SG (R: -3.1 vs -5.6 mmol O_2 m^{-2} h^{-1}; GPP: 23.3 vs 24.7 mmol O_2 m^{-2} h^{-1}); BS (R: -0.4 vs -0.81 mmol O_2 m^{-2} h^{-1}; GPP: 2.7 vs 3.1 mmol O_2 m^{-2} h^{-1})], while NEM in SG (218.04 vs 198.4 mmol O_2 m^{-2} d^{-1}) and BS (22.3 vs 17.8 mmol O_2 m^{-2} d^{-1}) showed a slight decrease. However, these changes were not statistically significant." (L241-245)

Fig. 5, use the same y-axis unit to avoid confusion

Response: Thank you for your feedback. We have revised Figure 5 to ensure consistency in the y-axis units, particularly the scale. However, we have retained the per-hour unit for GPP and R, and per-day for NEM. This distinction is necessary because our incubations only extend until noon, excluding afternoon fluxes, which makes per-hour rates more appropriate for GPP and R. (L246)

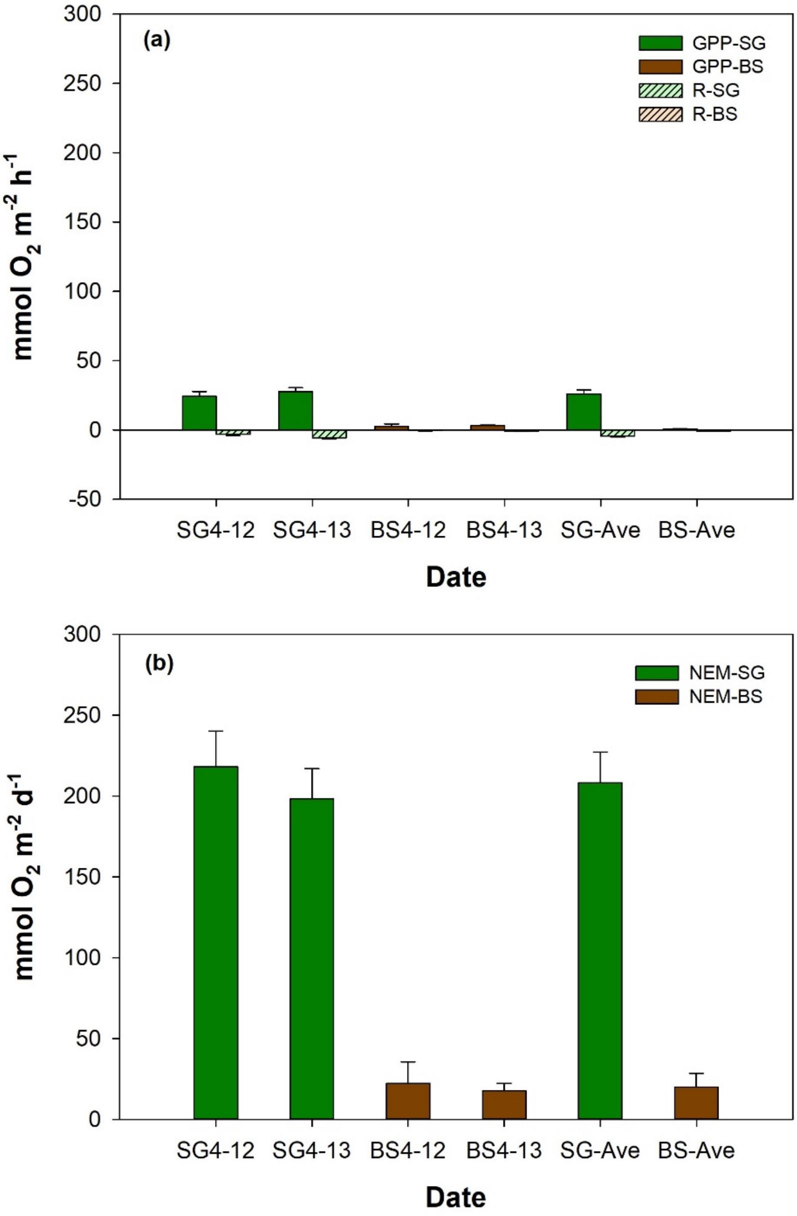

Figure 1: Mean (± SD, standard deviation) values of (a) metabolic rates such as respiration (R), gross primary productivity (GPP), and (b) net ecosystem metabolism (NEM,) of restored seagrass (SG, green bars) and bare sediment (BS, brown bars) in Penghu during the two-day (April 12-13, 2024) incubation (n=9).

L287, reword to "when GPP is lower".

Response: Thank you for your suggestion. We have revised the sentence to reflect better the findings of Duarte et al. (2010). The revised sentence now reads:

"According to Duarte et al. (2010), seagrass meadows generally act as autotrophic (NEM > 0) CO_2 sinks when GPP exceeds 186 mmol O_2 m^{-2} d^{-1}, and shift to heterotrophy (NEM < 0) when GPP falls below this threshold." (L295-297)

Table 1, why not use the same unit to facilitate comparisons?

Response: Thank you for your comment. We chose to use per-hour units to facilitate more accurate comparisons, as our incubation periods differ: respiration was measured from 12:00 midnight to 6:00 AM, and NPP from 6:00 AM to 12:00 noon. Using per-hour units ensures consistency within these time frames and avoids assumptions about afternoon fluxes.

Fig. 7, need error bars

Response: We thank the reviewer for their suggestion. We have added error bars to Figure 7, as well as Figure 8 and 9. Please see the revised figures below.

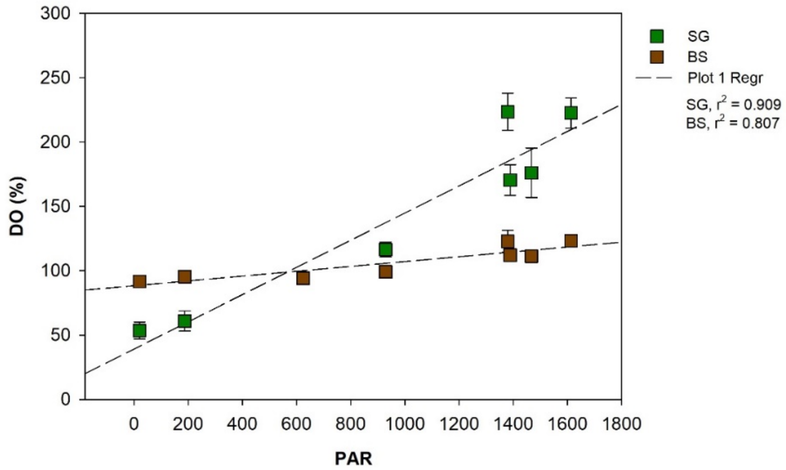

Figure 7: Regression plot between photosynthetically active radiation (PAR, µmol m-2 s-1) vs dissolved oxygen (DO, %) in restored seagrass (SG, green square) and bare sediment (BS, brown square). Error bars represent standard deviation (SD).

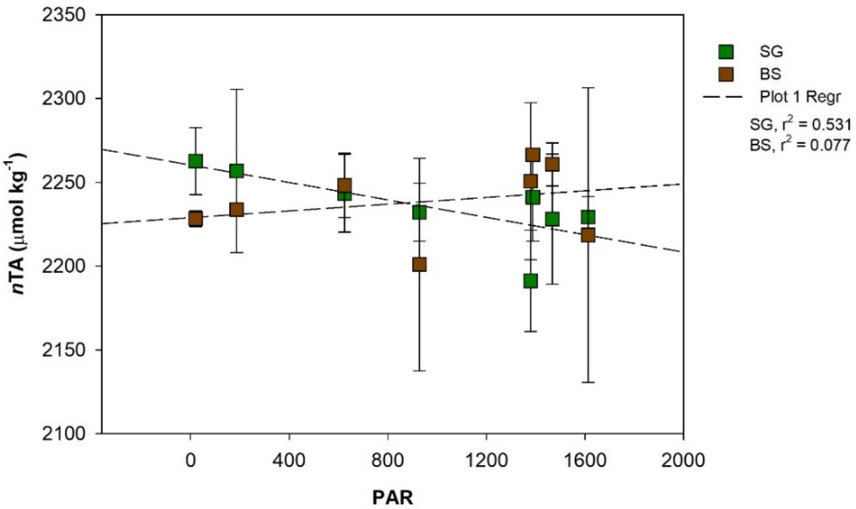

Figure 8: Regression plot between photosynthetically active radiation (PAR, µmol m-2 s-1) vs normalized total alkalinity (nTA, µmol kg-1) in restored seagrass (SG, green square) and bare sediment (BS, brown square). Error bars represent standard deviation (SD).

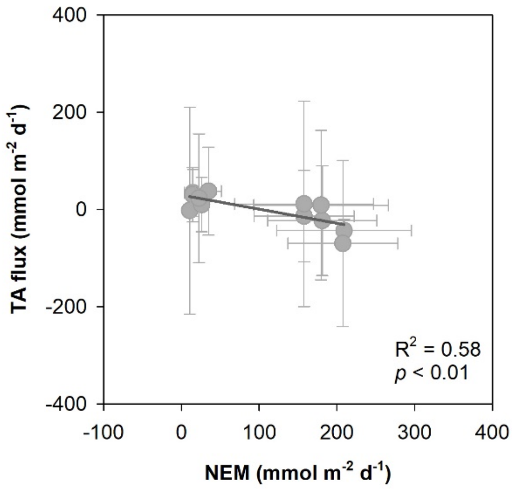

Figure 9. Linear regression showing the relationship between total alkalinity (TA; mmole m^{-2} d^{-1}) flux and net ecosystem metabolism (NEM; mmol m^{-2} d^{-1}) in restored seagrass meadows. Error bars represent standard deviation (SD).

L356, remove "shoot density" or change to high shoot density and root biomass.

Response: Thank you for your suggestion. We have revised the text accordingly by changing it to 'high shoot density and root biomass' as recommended.

"High shoot density and root biomass in restored seagrass meadows enhance organic matter supply and decomposition in sediment, further driving nighttime dissolution (Holmer et al., 2013)." (L367-L369)

L383, but earlier in the text (L216), Ω between the two sets are not significantly different, which contradict with L213 however.

Response: Thank you for your helpful comment. We understand the concern regarding the apparent contradiction between the statements in L383 and L216, and we appreciate the opportunity to clarify this.

In L216, we reported that there was no significant difference in ΩAr between SG and BS (p = 0.511) based on our Mann–Whitney test. This statistical result indicates no significant distinction in aragonite saturation state between the two environments.

In the Discussion (L383), we initially stated that SG environments exhibit significantly higher aragonite saturation than BS, with notable peaks in SG. To better align with the statistical results, we have revised the discussion to focus on the average ΩAr values rather than the maximum values. These changes are reflected in Lines 396-397.

"Our data reveal a higher mean Ω_{Ar} in SG (3.14 ± 1) compared to BS (2.72 ± 0.4)."

L391-392, with NEC much different, why alkalinity fluxes are similar? Or is it because the variations are larger than the difference of the means?

Response: Thank you for your comment. Despite the apparent differences in NEC between SG (10.9 ± 15.66) and BS (-2.3 ± 18.80), the similarity in alkalinity fluxes is primarily attributed to the high variability within each group. While the mean NEC values for SG and BS differ, with SG showing a positive value and BS showing a negative value, the considerable overlap in their standard deviations and wide confidence intervals (SG: -5.57 to 27.31, BS: -22.04 to 17.42) suggest that the variability within each group outweighs the difference in their averages. The differences in NEC, therefore, may not be statistically significant, despite the numerical distinction in the means.

L396-397, note the cited study use a seawater that may or may not be the same as the seawater in your case, so it is useful to do some calculation.

Response: Thank you for your suggestion. We appreciate the note regarding the seawater conditions used in the cited study by Frankignouelle (1994). We acknowledge the importance of considering potential differences in environmental factors, such as seawater chemistry, that could affect carbonate dynamics. To address this, we have calculated the size of CO_2 source or sink (Φ) values using the equation described by Humphreys et al. (2018), based on the specific seawater parameters observed in our study. Our calculations yielded a Φ value of 0.61 for the SG system and 0.65 for the BS system.

In the revised manuscript, we state:

"In terms of carbonate dynamics, we applied Φ, as described by Humphreys et al. (2018), to calculate the size of CO_2 source or sink for each system. In the SG system, which is net calcifying, Φ indicates a CO_2 source, with 0.61 moles of CO_2 released into the seawater for each mole of $CaCO_3$ precipitated. In contrast, the BS system, which is net dissolving, Φ represents a CO_2 sink, with 0.65 moles of CO_2 absorbed for each mole of $CaCO_3$ dissolved. These values are comparable to previous findings, which reported a CO_2 flux-to-$CaCO_3$ precipitation ratio of 0.63 (Frankignoulle et al., 1994; Smith, 2013; Mazarrasa et al., 2015)." (L408-414)