Thank you for taking the time to review our manuscript. We have carefully considered all of your comments and suggestions and revised the paper accordingly. We sincerely appreciate your thoughtful and constructive feedback, which has greatly helped us improve the clarity and overall quality of the manuscript. Below, we provide a detailed, point-by-point response to each of your comments, with your remarks shown in black and our replies in blue.

Referee: 2

Comments to the Author(s)

The manuscript presents two-season field measurements of CO_2 emissions from air-exposed sediments in 30 ponds across Mediterranean and temperate climate zones. Based on the significant relationship between hydroperiod lengths and CO_2 emissions in Mediterranean ponds in summer, the authors suggest that longer hydroperiods play a critical role in creating temporary conditions for higher CO_2 emissions. Using various statistical approaches, they further identified key drivers of sediment CO_2 emissions, including temperature and sediment contents of water and carbonate. The key findings from the well-designed study are novel and invite further study to elucidate the large temporal variability in CO_2 emissions from ponds, which have been understudied compared to other freshwater systems. Despite the novelty and significance of the key findings, the manuscript shows weakness in linking and interpreting these findings, as well as a lack of detail in several areas, as described below. I hope my comments will help the authors improve the logical flow and clarity of the manuscript.

Reply: Thank you for your thorough suggestions and comments. We have revised the manuscript based on your feedback; please see our responses to your questions below.

<u>General comments</u>

1. Hypotheses and data interpretation

Although hydroperiods and sediment water contents are suggested as the primary controls on sediment CO_2 emissions, descriptions across Introduction, Results, and Discussion appear not consistent, and in some cases contradictory.

First, hypotheses (2) and (3) need to provide more interrelated and mechanistic predictions. Higher sediment contents might be influenced more directly by more recent precipitation events (like 1-month or 1-week antecedent precipitation) than the yearly hydroperiod as considered here. Please provide a more detailed explanation of the relationship between hydroperiods and water contents. Any rationale for using hydroperiod rather than other drought indices would also be helpful.

Second, the findings shown in Fig. 4 indicate the significant relationship between hydroperiods and CO_2 emissions only for Mediterranean ponds in summer, and the significance appears controlled by a few sites with very long hydroperiods. However, this hydroperiod effect is emphasized too much across the R & D sections, with some of them having inconsistent connotations: for instance, refer to L 275-276 (“Mediterranean ponds exhibited higher air and sediment temperatures, shorter hydroperiods, typically drying in summer. They also showed lower sediment water content, and reduced macrophyte coverage, consistent with an earlier drying period.”). Please check the consistency of descriptions across R & D (sections 4.1 and 4.2 appear to address two separate stories regarding the hydroperiod effect) to provide a more coherent explanation for the relationship between hydroperiods and sediment water contents.

Reply: Thanks you for the comments. Here we provide a detailed response to all the comments in order:

- First, we selected hydroperiod length as a key explanatory variable because it provides a simple, readily measurable proxy for the cumulative effects of the preceding wet phase. Unlike single-point measurements, hydroperiod length integrates a suite of biotic and abiotic processes that occur during inundation (accumulation and transformation of organic carbon, macrophyte growth and senescence, and changes in nutrient loading), which can influence sediment properties and subsequent CO_2 dynamics during the dry phase. Therefore, using hydroperiod length allows us to capture these influences on carbon processing that occur before measurements, without requiring extensive, often unavailable, time-series data, such as precipitation data or water table levels. Short-term data as you suggest (e.g., 1-week to 1-month) are more directly reflected by site-specific sediment measurements, such as sediment water content. Although we found a moderate correlation between hydroperiod length and sediment water content (r =.47; Fig. B1), hydroperiod length captures broader conditions that are not completely explained by sediment water content (Fig. Sr2) and the combination of sediment water content and temperature (Fig. Sr3).

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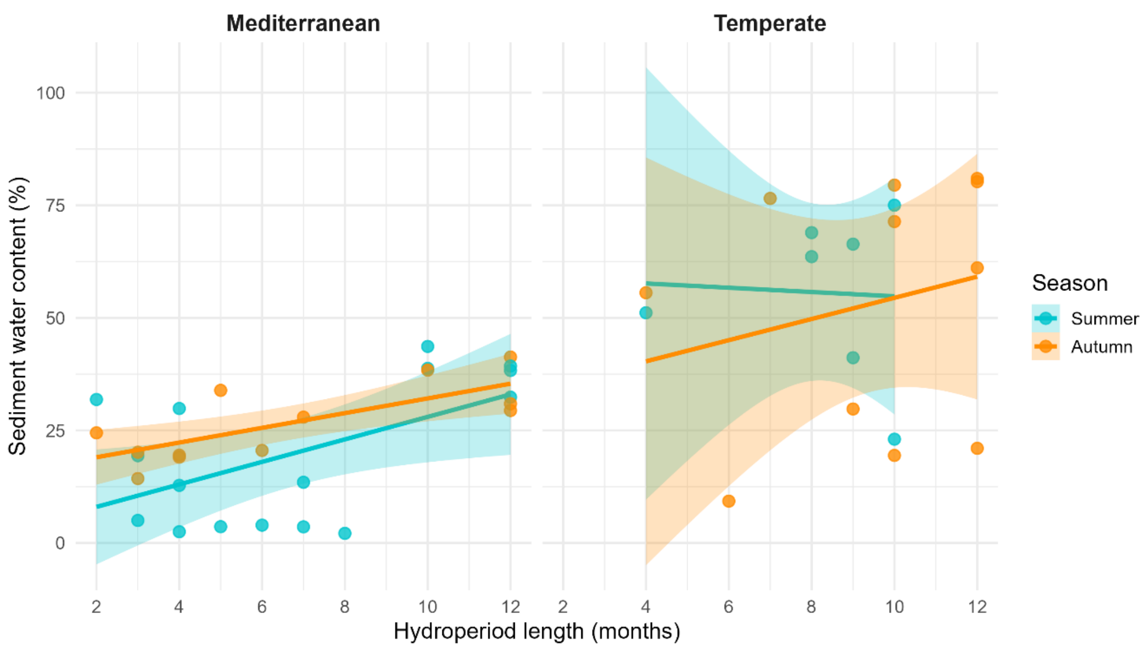

Fig Sr2. Relationship between hydroperiod length (months) and sediment water content (%) in ponds from Mediterranean and Temperate regions, separated by season (Blue= Summer and orange=Autumn). Each point represents the mean per pond and season, and the lines show the linear trend with its confidence interval (shaded area).

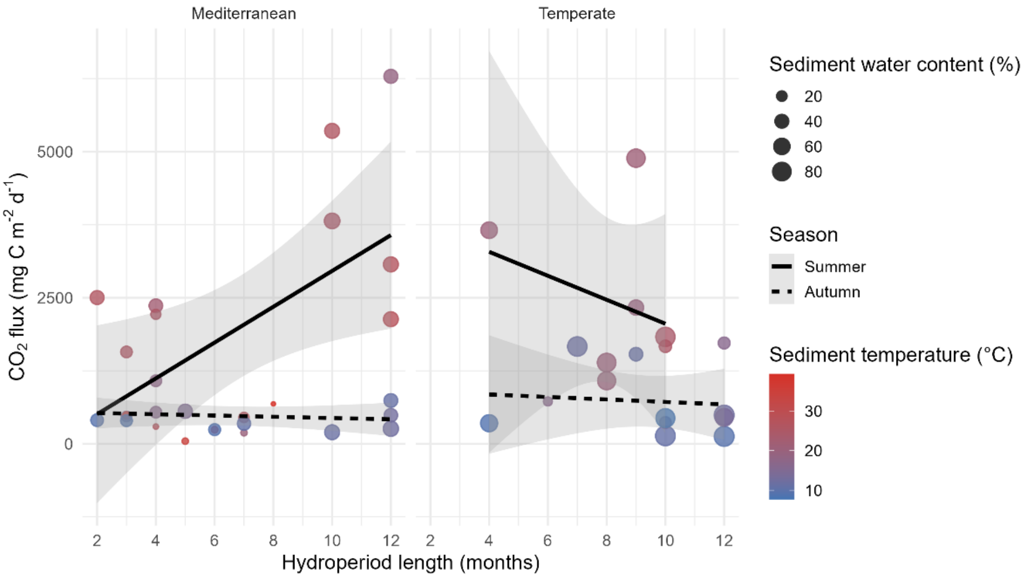

Fig. Sr3 Relationship between CO_2 fluxes and hydroperiod. To examine the drivers of emissions, dots represent the mean CO_2 flux per pond and season. Dot size corresponds to sediment water content, and colour indicates sediment temperature, ranging from blue (low) to red (high). Solid lines represent trends for summer, and dashed lines represent trends for autumn.

We have expanded the explanation in the Introduction (lines 94–96) and added a methodological justification in the Methods section (lines 145-148) to clarify this approach for readers.

- Second, we have revised the manuscript to improve clarity and coherence in the description and interpretation of results related to hydroperiod (lines 414-417). We have included modifications along results and discussion to improve the new revised manuscript (e.g. line 457).

2. Realigning paragraphs

Although the manuscript was easy to follow on a sentence-by-sentence level, the use of very long or several scattered short paragraphs made it difficult to grasp the overall logical structure. In the Introduction, for example, the page-long initial paragraph is followed by five short paragraphs. A thorough revision of the manuscript is recommended to reorganize the long and short paragraphs in accordance with a coherent logical flow.

Reply: We appreciate the reviewer's observation regarding paragraph structure and logical flow. The Introduction and other sections have been thoroughly revised to improve readability and coherence.

3. Clarity of tables and figures

There are numerous missing or inaccurate details that could be improved through careful revision. Please refer to the specific comments below.

Reply: We have carefully revised the tables and figures in accordance with the suggestions and notifications received.

Specific comments

- Title: A slight change would enhance clarity: for example, Drivers of CO_2 emissions during the dry phase "in" Mediterranean and Temperate ponds or Drivers of CO_2 emissions "from" Mediterranean and Temperate ponds "during the dry phase".

  Reply: We have modified the title following the first suggestion, and it now reads: "Drivers of CO_2 emissions during the dry phase **in** Mediterranean and Temperate ponds."

- Line (L) 17: sources of carbon (or CO_2)?

  Reply: While "sources of carbon" is more general and correct, we agree that given the focus of our study it is more appropriate to specify "CO_2" here. The sentence has been revised accordingly (Line 17).

- L 17 "remain largely overlooked": This statement overlooks the decadal research on this topic.

  Reply: We agree that stating "remain largely overlooked" may be too categorical. The sentence has been revised to specify the ecosystem targeted in our study, now reading: "Emissions of CO_2 during their dry phases remain relatively understudied in some inland waters, such as pond" (Line 17).

- L 25: "the" interaction

  Reply: The error has been corrected (Line 26).

- L 35-38: Please provide some estimates of CO_2 and CH_4 emissions from ponds to describe their role more quantitatively.

  Reply: We have now added representative CO_2 emission values from the literature as a reference in lines 40-43. CH_4 emission values were not included, as the focus of the present study is on CO_2 emissions.

- L 85: Please define "hydroperiod length".

  Reply: In this study, hydroperiod refers to the duration of time each pond retained water prior to the dry phase, quantified as the number of months with water surface during the 12-month period preceding the last autumn sampling (conducted between late September and November). We have now included a definition of hydroperiod length in the manuscript for better clarification in lines 94-95.

  "Hydroperiod length (i.e., the duration of water presence prior the dry phase in a pond throughout the year)"

- L 96: Without the above-mentioned definition, it is difficult to understand "shorter hydroperiods leading to lower emissions due to reduced sediment water content".

  Reply: We have now explicitly defined hydroperiod length prior to this section (L96) in lines 94-95. We also rephrased the sentence to clarify this point in lines 107-108.

- L 99: Can you illustrate "conservation status" using an example?

  Reply: We thank the reviewer for the suggestion. An example illustrating "conservation status" has been added to the manuscript (lines 111-113), describing some characteristics of well-conserved ponds.

  "better conservation status (e.g., clear water with turbidity < 5 NTU, extensive native emergent vegetation, and ≥ 50 % hydrophytic plant cover, particularly vascular submerged species or charophytes covering > 75 % of the pond bottom), will exhibit greater CO_2 emissions due to increased vegetation senescence during the dry phase."

- L 117: Did 23 sites also include semi-permanent and permanent ponds? In the latter case, the described bare sediment would be contradictory to the definition of permanent ponds (L 110).

  Reply: Yes, they did. We would like to clarify that the classification of ponds as temporary, semi-permanent, or permanent is based on a three-year record. However, as explained in lines 124-128, during the sampling year (2022), extreme drought conditions caused even some semi-permanent and permanent ponds to dry almost completely. This resulted in large areas of exposed sediment, allowing us to measure CO_2 emissions under conditions that can occur in more permanent ponds during extreme dry years. We added a sentence in the manuscript to clarify this aspect (lines 127-128).

- L 130 "water presence": Do you mean rainy days or literal water presence in ponds?

  Reply: We refer to the literal presence of water in the ponds, not rainfall. We clarified this point in the manuscript (lines 145-146).

- L 154 (throughout the manuscript): not Chlorophyll a, but chlorophyll a

  Reply: Thank you for noting this. The error has been corrected throughout the revised manuscript.

- L 167: Please provide key details on the chamber design, including the used material, size, ventilation, etc.

  Reply: We used static, opaque chambers with a surface area of 0.075 m^2 and a total volume of 8 L (diameter 345 mm, height 160 mm). The chambers were made of polypropylene (PP) plastic, and no additional materials such as tubes or pumps were used during the measurements. We have added the requested details on the chamber design, including material, size, and ventilation in the manuscript (lines 185-192).

- L 174-177: It would provide useful information for assessing the accuracy of sensor data if you compare sensor and additional GC measurements.

  Reply: We thank the reviewer for the suggestion. CO_2 samples measured by GC are available for comparison with the sensors; however, as our study focuses on fluxes, the absolute concentration is less critical than the relative changes over time. The manufacturer-stated precision (± 30 ppm) ensures that relative changes in CO_2 concentrations are reliable for flux calculations, we followed the methodology of

Bastviken et al. (2015), who demonstrated that mini loggers provide cost-efficient and accurate CO_2 flux estimates in terrestrial and aquatic environments (see https://doi.org/10.5194/bg-12-3849-2015 for accuracy and reliability details). We have explicitly referred to this study in the manuscript to clarify and support the validity of the methodological approach followed (lines 212-213).

- L 195: Please provide a relevant reference for this carbonation estimation.

  Reply: We have included the reference in the revised manuscript (line 223).

- L 224: How did you test the normal distribution of your datasets?

  Reply: We tested the normality of our datasets using the Shapiro–Wilk test. However, some data did not meet the assumption of normality. Accordingly, we reanalyzed the data using a non-parametric approach (Mann–Whitney test). Despite this adjustment, our results remained unchanged, showing the same significant differences, now confirmed with the appropriate statistical approach. This information has been added in lines 252-257.

- L 265: Are these negative values from partially water-flooded sediments where phytoplankton take up CO_2? Please elaborate on the site characteristics and discuss the meaning of these values (if outside measurement error ranges).

  Reply: We observed negative CO_2 fluxes only in a few cases, representing approximately 4% of the total fluxes reported (10 out of 249). Typically, there was only one negative measurement per pond, except for one pond (SP044), which showed two. The mean ± SD of these negative fluxes was -257.6 ± 191.3 mg C m^{-2} d^{-1} (N = 10; min = -611.2, max = -1.4; median = −244.7), with no significant difference between seasons (Summer: N = 5, -275.5 ± 259.1 mg C m^{-2} d^{-1}; Autumn: N = 5, -239.7 ± 120.2 mg C m^{-2} d^{-1}; $t = -0.28$, $df = 8$, $p = 0.787$). These sites did not show any consistent relationship with the main drivers of CO_2 emissions, such as sediment temperature or water content. The magnitude of these negative fluxes is consistent with values reported in other studies using closed chambers. For instance, Keller et al. (2019) reported -324 mg C m^{-2} d^{-1}, while Ma et al. (2013) observed -290 and -436 mg C m^{-2} d^{-1} in under-canopy and inter-plant spaces, respectively. Similarly, Koschorreck et al. (2022) found fluxes ranging from -1,440 to 13,620 mg C m^{-2} d^{-1}, with negative values representing 6% of all measurements. Since all measurements in our study were conducted using opaque chambers, and we measured fluxes in bare sediments, it is unlikely that these negative values are due to CO_2 uptake by residual phytoplankton, plants, or cryptobiotic crusts. Therefore, these negative fluxes most likely reflect physico-chemical processes in the sediments, probably linked to inorganic reactions (Ma et al., 2013; Marcé et al., 2019). This explanation has been incorporated into the Discussion section of the revised manuscript (lines 468-474).

- L 284-286: Please clarify whether you are talking about the proportion of each component based on unit mass of sediment or DOC.

  Reply: We appreciate the reviewer's observation. The comparison refers to the relative proportion of each PARAFAC component within the total fluorescent DOC signal, rather than to values normalized by sediment mass. We have clarified this in the revised manuscript (lines 309-310).

- L 288-293: These sentences are good examples of unnecessary separation mentioned before.

  Reply: The unnecessary separation between sentences has been removed in the revised version.

- L 300: Given the significance of the hydroperiod effect, it would be helpful to elaborate more as to how "the effect of hydroperiod was season-specific and climate-dependent" as displayed in Fig 4.

  Reply: We have clarified the description of the hydroperiod effect in lines 331-337 to better explain how it was season-specific and climate-dependent. Additionally, the corresponding p-values have been added to Table 1 to provide more detailed information.

- L 301: Was the summer trend also significant for the temperate sites?

  Reply: The summer trend was not significant for the Temperate sites. To clarify this point, we have added the corresponding p-values in the revised manuscript in Table 1 (lines 340). When both climatic regions are considered together, the overall trend is significant; however, when analyzed separately, the significant effect is only observed for the Mediterranean ponds.

- L 320-330: In a sense, this part seems secondary but covers the bulk of section 3.2. More space could be saved for more relevant drivers.

  Reply: This section (lines 351-355) has been considerably reduced in the revised manuscript in accordance with your comment, to focus more on the most relevant drivers.

- L 354 "all ponds emitted CO_2 during the dry phase": This statement is contradictory to the result descriptions (Fig. 2).

  Reply: Only a few measurements (10 out of 249) showed negative CO_2 fluxes, but these were minor and isolated occurrences, with overall flux patterns indicating CO_2 emission across ponds. To more accurate statement, we modify the manuscript in line 383.

- L 357: "shaped" or "was shaped by"?

  Reply: We thank the reviewer for this comment. We have retained the active form "shaped" in the manuscript, as it accurately reflects the causal relationship described (line 386).

- L 445: It would help readers to compare the magnitudes of plant uptake vs. CO_2 emissions if you provide some literature values estimating plant C uptake.

  Reply: We thank the reviewer for this suggestion. While we agree that it would be valuable to provide literature values for plant C uptake to compare with CO_2

emissions, such values strongly depend on the macrophyte species and the characteristics of the specific waterbody. Due to this high variability, it was not possible to provide reliable estimates of species-specific CO_2 uptake for our study system. However, to give readers a quantitative perspective, we have now included literature-reported ranges of carbon burial in small ponds depending on vegetation cover (Taylor et al., 2019), as well as a comparison of CO_2 fluxes measured in bare and vegetated areas of wetlands under both light and dark conditions to assess the potential of aquatic vegetation to offset CO_2 emissions (Sharma et al., under revision), and information on net ecosystem exchange (NEE) from Madaschi et al. (2025). These additions are included in lines 485-492.

L 417: Fig 5 shows the generally highest levels of CO_2 emissions across the highest temperature ranges.

Reply: We agree with the reviewer. The corresponding correction has been included in the manuscript in line 451.

- L 460 "ponds with more permanent hydroperiod": This is quite confusing, given your descriptions of your sites. Did you mean simply "longer hydroperiod"?

  Reply: We have modified the sentence, now reading "longer hydroperiods" (line 510).

- Fig 1 caption: Countries "are"

  Reply: The figure caption has been corrected in the revised manuscript (line 120).

- Fig 2: Please complete the vertical axis title with the second parenthesis.

  Reply: The error has been corrected in the revised version of the manuscript.

- Table 2: If this displays the same data as Fig 2, please think about removing or revising it to avoid double presentation.

  Reply: Table 2 has been moved to the Supplementary Material (Table S1) for readers interested in specific details on CO_2 fluxes.

- Fig 4: Please indicate the significance levels for the depicted regressions. It would be easier to find out the significance if only significant regressions were shown as regression lines.

  Reply: The significance levels of the regressions are now included in Table 1 to indicate which relationships are statistically significant, complementing Fig. 4.

- Tables 3, 4, 5: Please explain in the caption the abbreviations including SE, df, CL, AIC, BIC, and CI.

  Reply: Explanations of all abbreviations (SE, df, CL, AIC, BIC, and CI) have been added to the captions of all tables.

- Figure 5: What is ORQ? Are all the depicted trends statistically significant?

Reply: ORQ (Ordered Quantile normalization) is a data transformation applied to meet the assumptions of normality, This has been added to the Figure 5 caption. The partial trends shown in Figure 5 were evaluated using 95% confidence intervals of model-predicted values (via the R package visreg). While the confidence intervals for the three sediment temperature levels (9.4 °C, 18.2 °C, and 27.7 °C), cross zero, significance is assessed at the model level. In this GLMM, the interaction between sediment water content and sediment temperature is statistically significant based on the fixed-effects confidence intervals.

- Table 5: What about showing the employed models in a separate column?

Reply: We have clarified the model used in the table caption for better readability. Since all estimates come from the same model, adding a separate column in Table 3 was deemed necessary for clarity or aesthetics (line 378).

- Table "6" (page 18): Please also correct the unnecessary values below the decimal point.

Reply: Thank you for noting these issues. The table number has been corrected, and the unnecessary decimal values have been removed in the revised version of the manuscript.