Reviewer 1 comments:

Review Williamson et al. – Carbon Storage in Coastal Reed Ecosystems

Williamson et al. quantified the carbon (C) storage in both above- and belowground biomass and sediments of common reed beds from different topographical zones along the Pojo Bay, Finland, in the northern Baltic Sea. The results indicate that reed beds, especially in intermittent zones, are important carbon sinks, with higher carbon contents stored in sediment and belowground biomass than aboveground. The manuscript addresses an interesting and relevant topic with significant potential. However, several major issues need to be resolved before it can be considered for publication.

GREEN: Thank you. We have replied to each comment/suggestion in green. Relevant lines existing in the current text are highlighted in red. We think that the constructive review has significantly improved the paper and thank you for providing detailed feedback.

General comments

The aim of the study is to investigate C storage in different parts of the reed bed ecosystem across different environmental gradients such as salinity and wave exposure.
RED: Line 12-13: The aim of this spatial study was to quantify how much C is stored in above- and belowground biomass, and sediments in different zones of reed beds along the Pojo Bay system of the northern Baltic Sea in coastal Finland.

GREEN: Thank you for bringing this to our attention. The goal of this paper is to quantify C stocks in different reed beds along coastal Finland, similar to what Buczko et al. 2021 did for the German coast. In this study, we did not intend to analyze the impacts of different environmental factors on C stocks, only quantify C stocks found in aboveground biomass (stems and leaves), belowground biomass (roots and rhizomes), and sediments from each of the different reed bed zones across our reed bed sites. Since published data on C stocks in reed beds in our area is lacking, we needed to quantify how much C is in the reed beds and where it is located before anything else. We have changed wording throughout the paper so that this is more clear.

We've changed the text in lines 15, 61, 65, 235, 237, 271-273, 286

We have added a sentence to line 307 (section 4.5 Remaining Uncertainties and Future Recommendations) that reads: “We collected data from sites that covered a range of different environmental gradients such as salinity and wave exposure as a baseline for future investigations that explore how different environmental factors influence C storage in reed beds. At these high-latitudes, coastal reed beds are strongly influenced by seasonal succession, implying that an insightful analysis of environmental drivers requires data collected across different seasons.”

- While the results may be described in too much detail, the environmental factors are subsequently mentioned several times but their influence on the carbon storage is not further evaluated. What influence do salinity and wave exposure have on carbon storage? How can the differences between the sites or topographical zones be explained? What is the resulting implication?

  GREEN: Please see our response above to the first General Comment.

These points should be more addressed in the discussion.

In addition, I recommend to

- add a schematic overview that highlights or summarizes the differences in carbon storage across the different topographical zones.

  GREEN: Thank you, adding a cross section is a great idea. We have created an overall reed bed zone cross section (please see below in our response to your other comment about a cross section). C storage across the different reed bed zones is shown in the corresponding sediment C storage, aboveground biomass C storage, and belowground biomass C storage figures.

- The authors recommend to treat reed beds as distinct ecosystems, and not as conventional salt marsh ecosystems, as they show a great potential for C storage (line 10). However, it is not entirely clear how reed beds differ from salt marshes in terms of carbon stocks. (e.g., line 250-254). It would be good if the differences are highlighted more clearly.
  RED: Lines 47-50 C stocks in reed beds could average around 17.4 kg C m-2 in comparison to estimated global average of C stocks in tidal salt marshes of approximatley 25 kg C m2. Pendleton et al. 2012, Buczko et al 2022, and Silan et al. 2024.

  GREEN: We highlight some of the differences between C storage potential in reed beds and tidal salt marsh ecosystems in other parts of the manuscript (for example, lines 47-50), but we can emphasize this point further around lines 50 and 231.
- The definition of “sediment C stock” is unclear (line 161 ff.). Can you please precisely define what the parameter “sediment C stock” refers to? Is it the total amount of C or the total amount of organic matter? In figure 3, you speak of “organic matter”. What precisely are the “carbon stocks” given in [g m^{-2}] in figure 4? To which depth interval does the parameter “carbon stock” refer to? You state that the sedimentary carbon stock was integrated over the entire core length (line 105). In general – at least for sediments – the carbon stock or inventory is given for a defined thickness of the surface sediment – e.g. the uppermost 10 cm.

  GREEN: Thank you for pointing this out. To clarify, our sediment C stocks refer to TOC (total organic carbon). We ran both TOC and LOI (loss of ignition) on our sediment samples and were

able to calculate a LOI conversion factor so we could calculate TOC for any sediment samples where TOC was not measured. We will discuss this further in the manuscript to clarify. We included figure 3 of the LOI data (Organic Matter %) in addition to the sediment C stock figure as an additional point of interest.

The sediment TOC data was used to calculate the C stock over the entire core length. While some papers look at the uppermost 10cm for sediment C stock data, there is less data published on C stocks from deeper soil depths and these depths can be interesting to look at. Because of this, we wanted to include our full core length data.

We have added sentences to line 129: A LOI conversion factor was calculated from samples where both LOI and TOC were measured. This conversion factor was then used to estimate sediment C stocks for samples where only LOI data was available.

- Furthermore, how is the carbon stock of above- and belowground biomass defined? How comparable are the carbon stocks of the different sample categories?

GREEN: Aboveground biomass is defined as stems and leaves and aboveground biomass is defined as roots and rhizomes. C was measured from subsamples of each of these collected within our 1x1m sampling plots and calculated to g sq m. C stocks.

These different sample categories are comparable to each other as they are showing a full vertical profile of the C stock within the 1x1m sampling plot (the sediment, the roots/rhizomes within it, and the stems/leaves above it). All C stocks shown are calculated in g m^-2.

We have added clarification to figure captions for the aboveground biomass and belowground biomass C stocks.

Line 209: Figure 6: Carbon stocks (g m^{-2}) in aboveground biomass (stems and leaves) across all reed bed zones and sites.

Line 219: Figure 7: Carbon stocks (g m^{-2}) in belowground biomass (roots and rhizomes) across all reed bed zones and sites.

- It would be very helpful to include an overview showing a simplified cross-section of a reed bed, including the three different topographical zones and the different sampling sites.

GREEN: We think this is a great idea and have worked up the following sketch in Biorender.

Reed Zone Cross Section

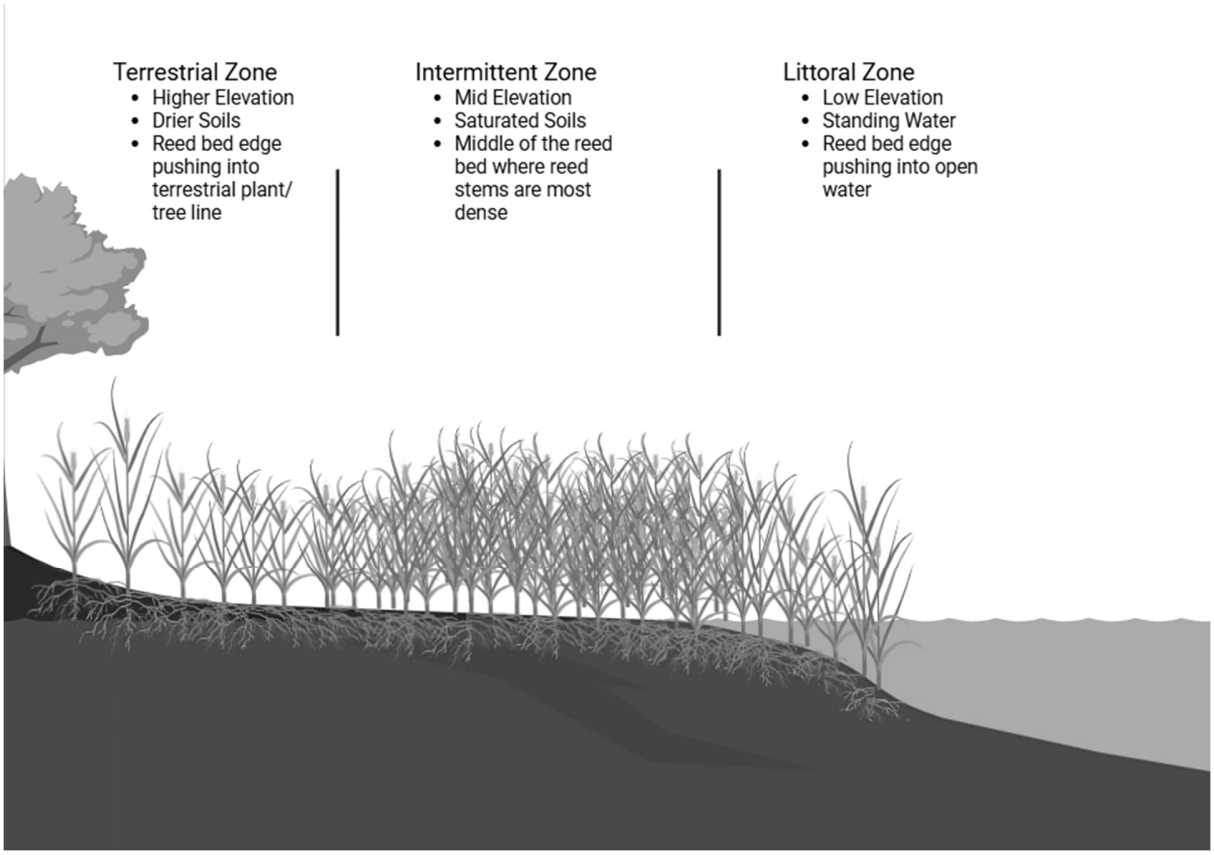


Figure X: Reed bed zone cross section. Created in BioRender. Williamson, M. (2025) https://BioRender.com/99fwu67

Specific comments

Lines 18-30: While the results are described in great detail in the abstract, the overarching implications of the study are missing at this point. The impact of differences in salinity and wave exposure is not explained (see general comment 1).

GREEN: Please see our response above to the first General Comment.

Lines 36-38: Carbon (C) and blue carbon (BC) are not introduced in the main text (except for the abstract). Moreover, besides vegetated coastal areas, fine-grained sediments have been shown to represent one of the most important long-term carbon sinks – including e.g. depocenters of mud and tidal flats (e.g., Müller et al., 2025, Biogeosciences, https://doi.org/10.5194/bg-22-2541-2025). These mud areas have received growing attention as important Blue Carbon coastal habitats. Please, therefore mention these as well.

GREEN: We have included mud and tidal flats and a citation for Müller et al. 2025 in line 38. Thank you for bringing this paper to our attention. Though mud flats and reed beds are different from one another and we did not conduct any sampling in mud flats, it is nice to have another citation to show the importance of coastal sediments in C storage.

Lines 65-67: What is the basis for hypothesizing that the highest rates of C storage would be found in reed bed sediments?

RED: Lines 248-250: Howard et al. 2014, Fiala 1976. Lines 274-276. Dong et al. 2012

GREEN: The basis for this hypothesis is discussed in lines 248-250 and lines 274-276. We have added discussion of these papers earlier in the manuscript so our hypothesis makes more sense.

Line 64: Published findings suggest that most C storage in other types of vegetated coastal systems occur in their sediment and belowground roots and rhizomes (Howard et al. 2014) and that this may hold true for reed beds as well (Dong et al. 2012).

Lines 86-89: This sentence is somewhat difficult to understand. This information about wave exposure (sheltered, semi-sheltered, long and exposed) could be integrated into the overview showing a simplified cross-section of a reed bed (see general comment 4).

GREEN: Please see above for the cross section we have drafted. We have also reworded the sentence around lines 86-89 to make it more succinct.

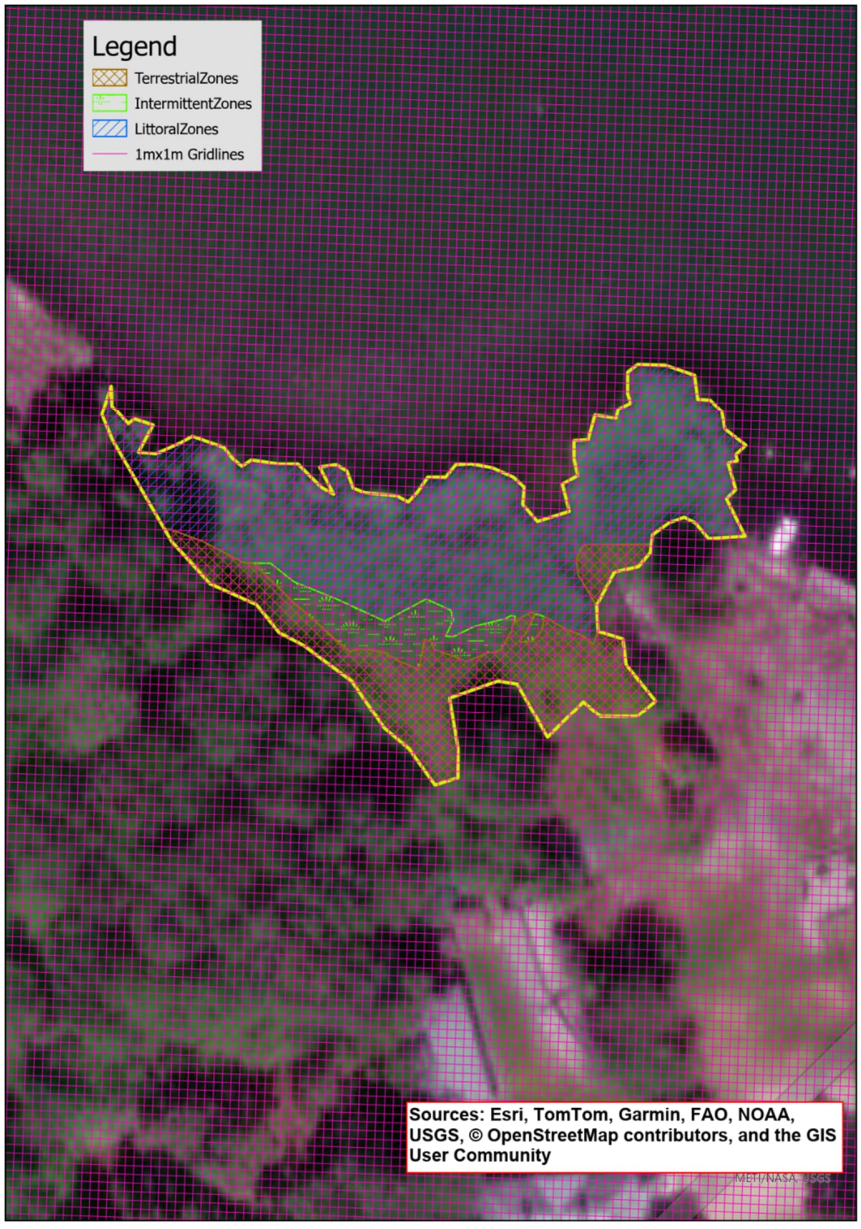
Line 86: Within each reed bed, the littoral zones are along the open water's edge, the intermittent zones are in the middle, and the terrestrial zones are along the edge that pushes into the terrestrial tree line (see Fig X Reed Bed Zone Cross Section).

Lines 90-95: Could this information on sampling be presented visually in the supplementary material? The description does not make it clear how the sampling grid was structured.

GREEN: Yes. We have included an example of a map with the 1x1m grid over top of a reed bed. We have included this in the supplementary material as Fig 1

Additional Supplementary Materials

Supplementary Figure 1: Example map of 1x1m grid for random sampling starting point selection



Line 111: What does “when possible” mean in this context?

RED: lines 113-114: soil cores that contained large amounts of clay required soaking in water for 24h back in the laboratory and then additional sieving.

GREEN: We explain in lines 113-114 that some soil cores had large amounts of clay in them and required further soaking in water for 24 hours back in the laboratory before additional sieving. We have removed “when possible” in line 111 to reduce confusion as the process is discussed in further detail over the next 2 lines.

Line 120 ff.: Please, state which certified sediment standard reference material was used to assess the quality of the carbon analyses in the sediment samples.

RED: Lines 115-119: samples were run… birch leaf lab standards, USGS88, and USGS91. Lines 127-128: C analysis for sediment samples analzyed at Jyväskylä in the same manner as mentioned above for biomass.

GREEN: We mention which standards were used above in lines 115-119 and then clarified that the same process was used for sediment samples in lines 127-128. We have reworded the sentence around 127-128 to clarify.

Lines 127-128: C analysis (total organic carbon, TOC) was also run on 127 of the total 305 sediment samples and analyzed at the University of Jyväskylä using the same standards, equipment, and methods as mentioned above for biomass.

Line 145: The salinity measurement is not included in chapter 2 (Material and Methods).

GREEN: We have added a sentence about the method for measuring salinity at each site at the end of line 96.

Line 96: Surface water level salinity was measured at each site with an YSI Pro Solo DO/CT meter

Lines 145-190: The results are described in great detail. It would be better to describe the general trends, differences and/or similarities.

GREEN: Thank you for this suggestion. We have attempted to reduce some of the detail listed here and point readers towards the corresponding tables, figures, and supplementary materials for further information.

Line 169 ff.: All three paragraphs of this subchapter start with “We detected statistically significant differences…”. This does not read very elegant. Can you rephrase and vary a bit?

GREEN: Yes. We have adjusted the wording to be more varied throughout the rest of the text.

Line 210 ff.: You refer to “Carbon stocks (g m^{-2}) in belowground biomass” here. Which defined sediment or belowground interval do you refer to here?

GREEN: We have added “(roots and rhizomes)” in the caption for Figure 7 to clarify (please see our response in your General Comments section). Roots and rhizomes were sieved from the soil cores and are a separate category of C stock measurement than the sediment C stocks.

Line 239 (GREEN: should be line 230, I believe): You state here that it is imperative “to develop more accurate coastal BC budgets to combat climate change”. As mentioned above, please at least also briefly mention the role of fine-grained sediments in the coastal realm in this context as they represent the key and really most important long-term C sinks.

GREEN: Yes. Please see our response above for more detailed information about our inclusion of Müller et al. 2025 in line 38. We will avoid discussing mud flat ecosystems in too much depth as this research was conducted in reed beds only but we have included the citation to further show the importance of coastal sediments in C storage.

Lines 234-240: The title of this subchapter is “Dry bulk density and LOI”. However, the impact of the environmental factors on the DBD and LOI is not discussed.

GREEN: Please see our response above to the first General Comment.

Lines 237 and 246: You mention anthropogenic activities here. Which activities are specifically meant here, and to what extent do they influence DBD and LOI?

GREEN: We did not intend to emphasize anthropogenic activities here and we have reworded the section to avoid confusion. We have included some further discussion on the relationship between DBD and OM and talked about how our DBD and LOI results show similar relationships to each other as those found by Cleophas et al. 2024 (higher DBD aligning with lower OM). Our DBDs were highest in terrestrial and littoral zones than intermittent zones which are more buffered. Sediment C stocks and LOI results were highest in intermittent zones.

Line 238: Cleophas et al. 2024 found that higher DBD was associated with lower OM and we see these trends clearly in our own DBD and LOI data.

Lines 238 and 243: The reference USDA-NRCS 2019 is not a scientific publication, but rather a guide for educators. Publications describing the influence of DBD on infiltration and organic matter and nutrient contents should be cited here.

GREEN: We have removed the USDA-NRCS 2019 reference at lines 238 and 243-244. We have included citations for Warrence et al. 2003 and Cleophas et al. 2024 in these lines, respectively.

Lines 242-243: To what extent can the differences in sediment carbon stocks between different zones and sites be attributed to differences in DBD? This is not explained here.

GREEN: Please see our responses above on the relationship between DBD and OM and our conversion factors between LOI and TOC. We have included a sentence about the trends shown in our LOI, DBD, and sediment C stock figures for further clarification.

Line 245: The C stocks shown in figure 4 correspond with the same LOI and DBD trends found in Clephas et al. 2024 and discussed in the previous section.

Lines 245-246: Here, various environmental factors are mentioned but not discussed further (see general comment 1). How does, for example, different salinity influence sedimentary carbon stocks?

GREEN: Please see our response above to the first General Comment. We have adjusted wording throughout the paper accordingly.

Lines 250-254: The calculated sediment carbon stocks are ~8 kg C m^{-2}, which is lower than the estimated global average of 25 kg C m^{-2}. Does this mean that less carbon is stored in reed bed sediments compared to sediments in tidal salt marshes (see general comment 2)?

GREEN: The purpose of these sentences is to compare our results to those from Buczko et al. 2022. Both papers found C stocks in reed bed sediments that are lower than approximate averages known for tidal salt marshes.

Lines 271-273: Again, several environmental factors are mentioned here (anthropogenic activities, wave exposure, changes in soil characteristics), but not discussed with regard to their impact on aboveground biomass carbon stocks. Also, which soil conditions are being referred to here, and what causes these changes?

GREEN: Please see our response above to the first General Comment. We have adjusted wording throughout the paper accordingly.

Lines 275-281: This section is a bit misleading and the phrasing should be improved. First, it is stated that removing aboveground biomass reduces the nutrients in a system (line 275). Then, it is argued that removing aboveground biomass can lead to the release of nutrients (line 278). The relationship between removing reed and the release of nutrients should be explained in more detail. Further, how should carbon storage in reed beds be considered in the development of management practices? This is not clearly described here.

GREEN: We have reworded this section to avoid confusion.

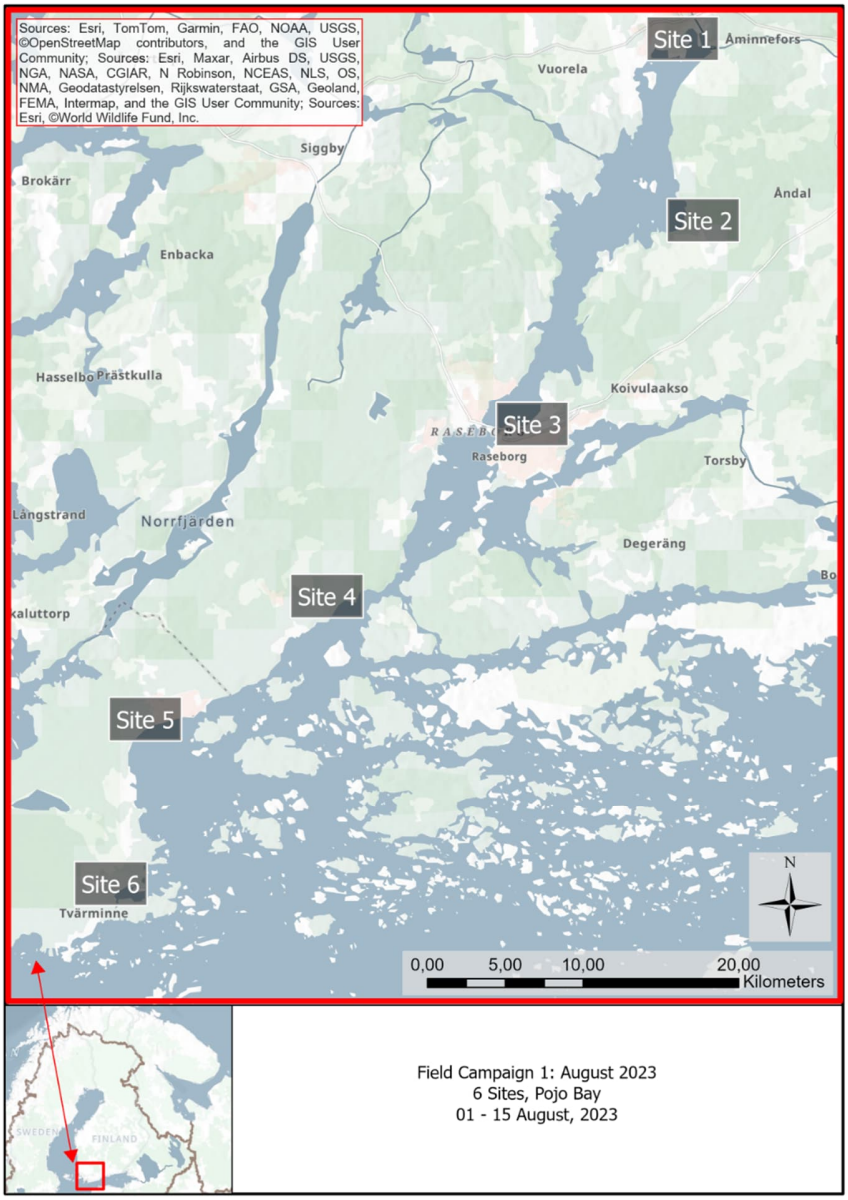
Lines 274-281+: There has been an increased interest in reed bed management practices focused on removing aboveground biomass (e.g., Finnish-Swedish Interreg BalticReed project co-funded by the European Union). Some of these projects argue that removing aboveground biomass can serve as a way to reducing nutrient inputs to major water bodies, however previous research indicates

aboveground biomass contains relatively low C content (Dong et al. 2012) and our findings support this. The density of aboveground biomass in reed beds can substantially impact erosion and water quality (Horppila et al. 2013) and management practices focused on removing aboveground biomass, such as mowing, can disturb reed bed sediments, releasing nutrients stored in reed beds into the surrounding environment (Güsewell 2003) or even greenhouse gas fluxes (Rietl et al. 2017). In light of this, C storage in reed beds must be taken into account when developing management practices in coastal reed bed ecosystems so the C storage potential of their sediments is not compromised during harvesting processes.

Figure 1: The figure in the bottom left-hand corner (Study Area) is too small to be seen properly. Additionally, the contrast between the two shades of grey is insufficient. One suggestion is to color the water areas blue. Furthermore, the individual stations at the different sites cannot be seen because they overlap.

GREEN: We have adjusted the map to better show the location of the reed bed sites.

Updated Fig 1:



Figures 2 and 3: The figures are slightly pixelated, and the symbols are faint. Additionally, the axis labels ('Soil Depth' and 'Dry Bulk Density/Organic Matter') are rather large, and the depth labels ('0-100 cm') are rather squashed.

GREEN: We have revised the figures to increase the opaqueness of the symbols, make the axis labels smaller, and increase the spacing between the depth labels.

Fig 2 Updates

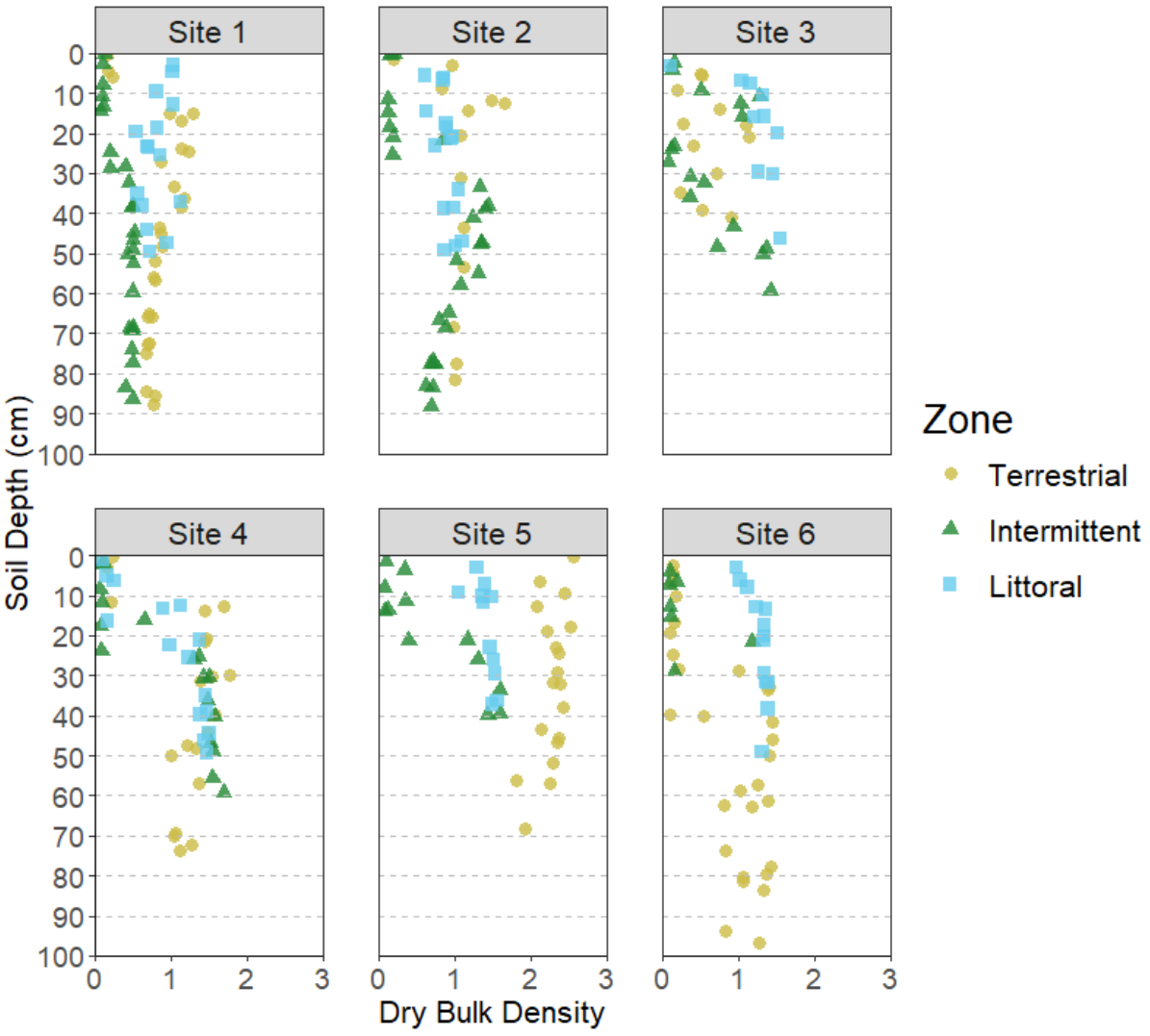
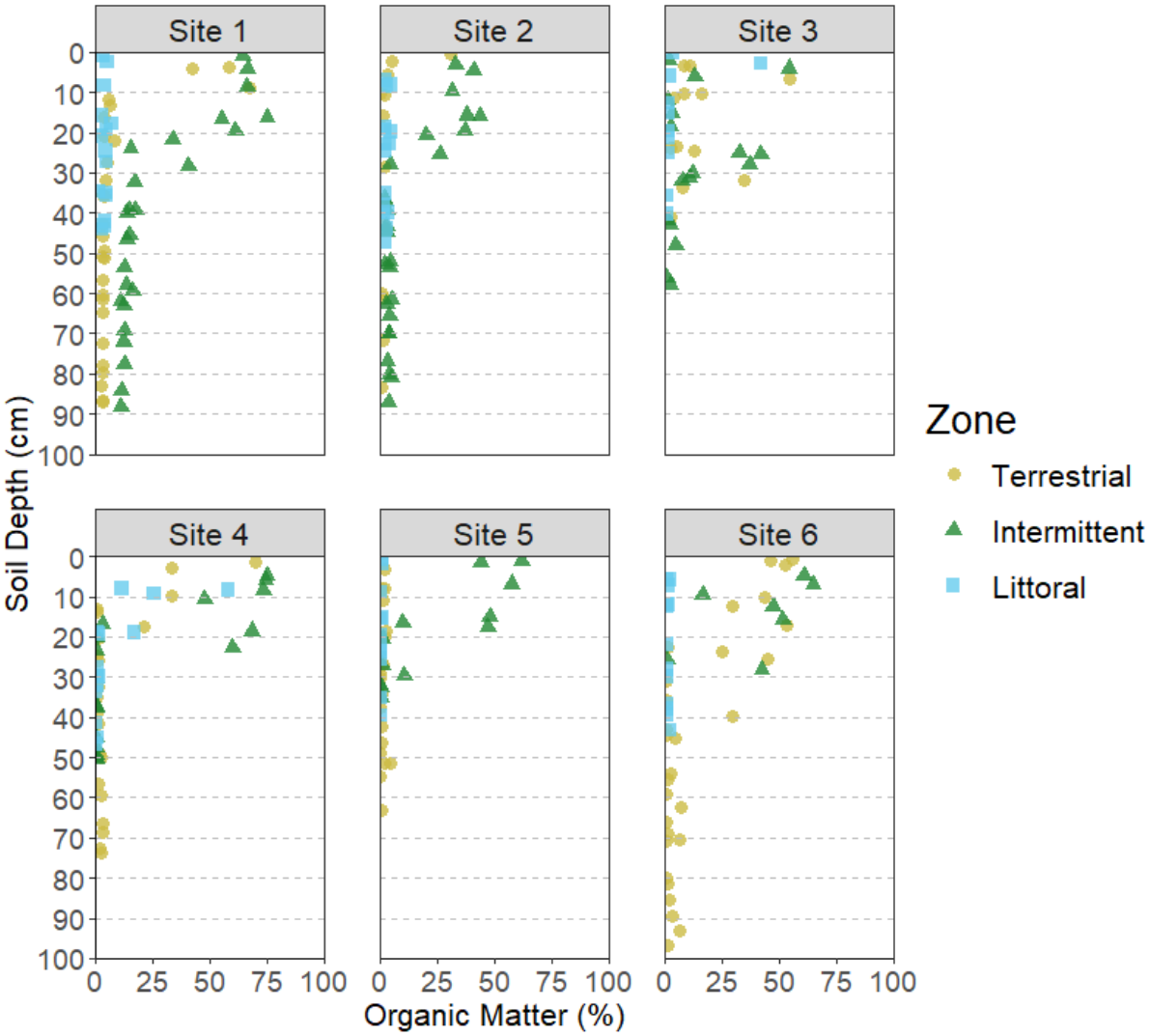


Fig 3 Updates



Figures 4 to 7: The figures 4 to 7 show the carbon stocks for the four sample categories. Since the labeling of the y-axis is not the same, it is difficult to compare the values with each other. Moreover, there is something missing in the caption of figure 4: Carbon stocks (g m^{-2}) in sediment“s of“ all reed bed …..?

GREEN: All C stocks are shown in g m^-2 but there is also a figure showing stem count results. We have placed the stem count figure elsewhere so it does not break up the flow of the C stock figures.

Technical corrections

Line 93: “Square” instead of “quadrat”?

GREEN: We were not aware that there was some debate about the term “quadrat”. This is a term also seen in the publications of other coastal ecologists (example: Hillmann et al. 2020).

Table 1 and 2: The table captions should be placed above the table. In addition, the first lines of the tables should not contain “Table 1” or “Table 2.”

GREEN: The table captions have been adjusted within the document accordingly

The word “understandable” is used very frequently in the discussion and could be replaced, for example, by „reasonable”, “explained by” or “consistent with”.

GREEN: Wording has been adjusted throughout the paper to provide more variety.