Reviewer 1

Schepers et al. look to link tidal inundation from sea-level rise to decreasing soil strength in salt marshes, which can be related to the loss of belowground biomass from the increasing tidal inundation. The findings of this paper make sense based on what we know from previous work; however, the methods used here have issues/limitations that need to be addressed. There are also other variables that could impact soil strength in these marshes that are not discussed. Additionally, I believe the authors undervalue previous marsh work in the investigation of tidal inundation on soil strength.

We would like to thank the reviewer for the very insightful and critical comments on our manuscript. We have tried to include them in the manuscript.

Major Comments:

- Much of the paper's discussion and findings is based on the use of a shear vane device to interpret soil stability. This includes findings that belowground biomass increases soil strength. However, I think the authors need to acknowledge the issues related to using a shear vane as an indicator of soil stability, including that roots within the soils will directly impact the vane measurements. Hence it would make sense that there is a relationship between belowground biomass and soil/root strength if roots impact these measurements. Vane measurements can also be impacted by how fast the vane is rotated, which can vary across users.

  Thank you for this valuable comment. We have added a part in the discussion highlighting that a relation between shear vane shear strength and belowground biomass may be expected due to the methodology, but we also highlight that the penetrologger measurements also indicated an increasing soil penetration resistance with increasing biomass:

  Lines 316-321: "Our first main finding is the increase in marsh shear strength (Fig. 3b) and penetration resistance (see Appendix, Fig A2) with increasing belowground vegetation biomass. This can be partly explained by the methodological choice of using a shear vane for soil strength measurements, since roots can be expected to directly affect the shear vane measurements (Brooks et al., 2023). Additionally, since we found a similar relationship between the penetration resistance and belowground biomass, we believe that there is a causal relation."

  Additionally, as we were aware of the differences that can occur between different people taking the measurements, it was assured that they were taken by the same person each time while conducting the fieldwork.

- The paper also is missing context as to what the differences in soil strength really mean between sites. From a soil strength perspective, is the difference in strengths depicted in Figure 3 and Figure 5 really large enough to generate significant differences in the erodibility of the soil? And how do these differences compare to other studies? Comparing Figure 3 to the penetrologger data in Figure 4, the penetrologger differences are much larger than the vane differences so how does this fit into the narrative? The penetrologger data is not used in this paper as much as the vane data.

Thank you for this comment. We have split this answer into different points to respond to each question separately.

From a soil strength perspective, is the difference in strengths depicted in Figure 3 and Figure 5 really large enough to generate significant differences in the erodibility of the soil?

- *Since the shear strength ranges from >60 to less than 10 . $10^3 N/m^2$ and other salt marsh studies hardly ever report values above 60, we do believe that this shows a significant decrease in shear strength. Additionally, if you go to these field sites, the difference in soil stability are immediately felt. The sites with the highest shear strength values are very easy to walk on (our boots are not much sinking into the soil), while the lowest shear strength sites have very soft soils (if you take a wrong step you can sink about 50 cm into the sediment).*

How do these differences compare to other studies?

- *According to a recent paper by Brooks et al. 2023 the direct comparison of shear strength values between studies is difficult, since often different methods are used that can significantly influence the absolute values. Additionally, as you mentioned in a previous comment, the shear vane measurements are impacted by the person performing the measurements. Therefor we have chosen not to directly compare our values with other values, but focussing on the relative differences we see within our study. However we did check whether our shear vane values were in the same range as other publications, which is the case.*

- Comparing Figure 3 to the penetrologger data in Figure 4, the penetrologger differences are much larger than the vane differences so how does this fit into the narrative? The penetrologger data is not used in this paper as much as the vane data.

  - *The penentrologger measured the resistance of the soil to penetration, while the shear vane measured the shear resistance of the soil. These are two different measures of sediment strength and two different measurement methods, so differences between them are logical. However, the trends we see in the shear vane data, like the decrease in strength with depth, are also observed in the penetrologger data. Further, both the shear vane and penetrologger data show an increasing soil strength with increasing below-ground biomass. We have integrated the penetrologger data more in the discussion.*

  Line 295-297: "Our field study in a microtidal marsh (with mean tidal range of 0.06-0.63 m) with organic-rich soils (40-70 % organic matter) indicates that (1) an increase in tidal inundation of the marsh surface (i.e., for a hydroperiod increase from 50 to 95 %) is associated with a loss of soil strength (i.e. decrease in shear strength from around 60 to <10 x 10^3 N m^{-2} and soil penetration resistance from 450 to <100 10^3N m^{-2}) of the top soil horizon (0-0.10 m deep) (Fig. 2b);..."

  Line 319-321: "Additionally, since we found a similar relationship between the penetration resistance and belowground biomass, we believe that there is a causal relation."

- For the penetrologger profiles in Figure 4, which have the max strength near the surface, are there other factors other than roots that can also contribute to these differences along depth? For example, how does soil moisture change downcore? You only provide soil

moisture data for the topsoil. Where is the BD and OM data? Also, although you may no longer have live roots at deeper depths, you would expect to see dead roots along the profile that should also impact soil strength.

Thank you for this very accurate question. Water content, bulk density and organic matter were only analysed in the top 15 cm. However, data from a more recent study in the Blackwater marshes (Huyzentruyt et al., in review) show that the bulk density is fairly constant over a depth of 40 cm. There is however some variation of organic carbon with depth, but without a clear trend along the gradient of increasing hydroperiod (sometimes there is a slight increase with depth, other times a decrease). We may not exclude the presence of dead roots at depth, which could indeed influence the strength, but we do believe that this effect on the penetration resistance is lower than for living roots (giving the lack of turgor pressure for example). We have done some additional testing with the OM and BD data and added some additional discussion on these points (see our reply to comment below).

Line 189-196: "2.5 Statistical analysis

The effect of hydroperiod on shear strength and belowground biomass was analysed using linear mixed models (LMM), using field site as a random effect to account for within site clustering. A separate LMM analysis was performed to evaluate the influence of organic matter content, bulk density, water content, hydroperiod and belowground biomass on shear strength, again incorporating field site as a random effect. The differences in bulk density, water content, organic matter, shear strength and belowground biomass between sites were analysed using pairwise Wilcoxon rank sum test with Bonferroni correction. All analyses were executed in R (R core team, 2022), using the lme4 package (Bates et al., 2015) for the linear mixed models. The p-value threshold used is 0.05. "

- There are other variables not mentioned by the authors that could impact soil strength rather than just belowground biomass, including potential differences in bioturbation and differences in grain size distributions. There are also other factors other than tidal inundation that impact belowground biomass, including nutrient loadings, which can vary even along a marsh site.

  Thank you for this valuable comment. We have added a paragraph to the discussion integrating more potential influences on soil strength:

  Line 362-379: "We recognise that other factors, which are not considered in our study, may influence vertical variations in soil strength. For instance, higher water content has been shown to decrease the soil penetration resistance (Gillen et al., 2021; Stoorvogel et al., 2025). As soil water content may be higher in deeper soil layers, this may also contribute to lower soil strength deeper in the profile. Yet we expect this plays a minor role as field observations typically indicate water saturated soils over the whole soil profile. Additionally, variations in soil strength along the spatial marsh degradation gradient may be related to factors we did not account for. For instance, higher nutrient loading has been shown to decrease the soil organic matter content and belowground vegetation biomass and has been reported to be related to reduced soil strength (Turner et al., 2020). Bioturbation, especially burrowing by crabs, can increase the oxygenation of the sediment and facilitate the breakdown of belowground biomass (Wilson et al., 2012). Yet we have no data to test whether such factors varied along the spatial marsh degradation gradient and if they contributed to the observed spatial pattern of decreasing soil strength with

increasing marsh degradation. Lastly, sediment properties such as organic matter content, bulk density and clay content may play a role in the cohesion of sediment (Feagin et al., 2009; Gillen et al., 2021; Joensuu et al., 2018). Higher organic matter content may increase the sediment erosion resistance, which corresponds to our finding of higher organic matter content in the sites with higher shear and penetration resistance. Studies have shown that both higher bulk density and clay content decrease the erodibility of the marsh sediment (Brooks et al., 2022; Feagin et al., 2009b; Gillen et al., 2021; Lo et al., 2017; Stoorvogel et al., 2025). These studies are however located in minerogenic marsh systems, where bulk densities and clay contents are generally higher than in organogenic systems as ours. Therefor we believe that the influence of belowground biomass on shear and penetration resistance will dominate over the effect of bulk density and clay content."

- Data needs to be made publicly available either through supplemental materials or a data repository before this paper can be published.

  You are correct. We are working on compiling the data, so that by the time of publication a public repository will exist with the data.

Minor Comments:

- Sea-level rise should be hyphenated throughout.

  We have adjusted the text so that sea-level rise is always hyphenated

- Figure 1 can be improved by 1) making the symbol size larger (the symbols in 1b are too small); 2) making some of the text larger, including the labels of a, b, and c in the Figures; 3) adding in a symbol to indicate direction (e.g. a north arrow); 4) correcting the a,b,c labels in the figure caption to be consistent with the labeling in the figures. Also check with the journal requirements to see what type of labeling is required.

  Thank you for the suggestions. The changes have been made to figure 1 and adjusted in the text.

  Line 86-87: The mean tidal range decreases from 63 cm at Fishing Bay (bottom right of Fig. 1a ~~close to field site 1~~) to 6 cm at Lake Blackwater (top left of Fig. 1a ~~close to field site 4~~)

  Line 92-98: **Figure 1: ~~a~~A: Aerial images of the Blackwater marshes (black: water, light grey: marsh) with sampling locations (Copernicus – Sentinel data [2025]. Retrieved from Google Earth Engine, processed by ESA). The marsh loss (i.e. proportion of shallow open water ponds to total marsh area) is quantified for each site based on Schepers et al. (2017) ~~as 2% for site 1, 11 % for site 2; 33 % for site 3 and 58 % for site 4~~. The inset map shows the location of the Blackwater marshes in the Chesapeake Bay. The green box is the extent of panel ~~figure~~ ~~B~~ b. ~~B~~ b: pond locations (white) sampled at site 4. Values in the legend of (b) refer to the average pond diameter in each category. The yellow box is the extent of panel ~~figure C~~ c. ~~c~~C: marsh locations at the 58 % marsh loss site ~~site~~ 4 with (green) and without (yellow) vegetation.**

- Line 107 – yr-1 should be made a superscript and applied throughout the rest of the manuscript.

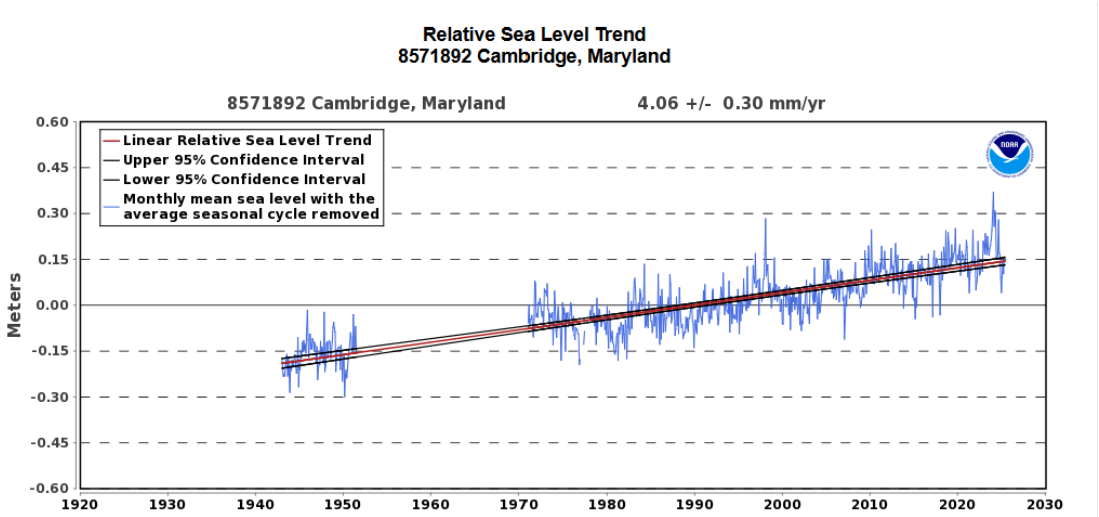
  Thank you for noticing, it has now been changed accordingly

- Also line 107 – Has the rate of SLR changed over time?

  Thank you for this question. No there is no evidence for a change in rate of SLR since the 1940s. The data (below) do not show an increase or decrease in the rate of SLR over this

period but a rather linear trend (source: NOAA tides and currents data). This was included in the text:

Line 113: "are less than the relatively constant long-term rate of relative sea-level rise of 4.06 mm yr^{-1} in Cambridge, MD, 1943-2025…"



- Section 2.3. – Later you bring up measurements down to 80 cm but you don't mention this anywhere in this section.

  Thank you for noticing, we have added a more detailed description in section 2.3.

  Line 164-166:"The measurement was taken at all marsh sites (five plots in the 2 %, 11 % and 33 % marsh loss site and 17 in the 58 % marsh loss site) an pond sites in the upper 80 cm of sediment."

- Section 2.4. heading should be changed to include soil C

  Thank you for the suggestion, we have changed the title of Section 2.4 to:

  Line 168: "Belowground biomass sampling and sediment analysis"

- Why only collect soils to 15cm depth when you measure soil strength to 30cm?

  Thank you for this question, as this is indeed not clear from the text. The shear vane soil strength was measured at the top of the profile (0-10 cm) to investigate the relationship between soil shear strength and the amount of belowground biomass. The 30 cm measurement was assumed to be below the rooting depth of Schoenoplectus americanus, as to try and see the effect of belowground biomass on the soil shear strength. This assumption has also been verified in a field campaign for a different study in this area, where we noticed living roots were hardly present anymore at deeper depths.

- How much time was soil ashed at 550 to determine organic content?

  We have added more specifications on the LOI protocol in the methods as follows:

  Line 177: "One half was dried, ground and homogenized with a 0.5-mm grinder (Retsch ZM2000) and heated to 550°C and ashed for four hours to determine the organic content of the soil samples (loss on ignition)."

- Organic content is barely mentioned in the manuscript

  Thank you for the valuable comment. We have extended the analysis on organic matter by looking at differences between sites and including it in the linear mixed model for shear strength. In correspondence with comments from you and reviewer 2, we have added a paragraph describing other potential influencing factors, among which organic matter. (see comment 2).

- Table 1 – is the font in the last line of the caption different from the rest of the caption? It looks smaller to me.

  Thank you for noticing, we have corrected the font size so that it matches.

- Table 2 – font size of this table looks different from the other tables.

  Thank you for noticing, we have corrected the font size so that it matches.

- Figure 3 – the gray and yellow coefficients are hard to read and all coefficients can be made larger.

  Thank you for the suggestion. In accordance with the comments of reviewer 2, we have changed the content of fig 3 (fig 3A became fig 3b and 3b was omitted). Additionally, we increased the size and darkened the color of the coefficient in the previous figure 3a according to your comment.

- Line 223 – unclear what difference the authors are referring to.

  Thank you for the valuable suggestion. We have changed the phrase as follows:

  Line 264: "At soil depths below 30 cm this ~~difference~~ variability between sites was not systematically present anymore (Fig. 4)."

- Figure 5 – Why are you comparing pond soils and bare patches to just the 30cm marsh depth rather than the 15cm marsh depth?

  Thank you for this question. Since pond bottoms and bare patches don't contain living vegetation, we can also assume that there are hardly any living belowground biomass left. Therefor it seems more logical for the figure to compare these values with the 30 cm depth values, as they were taken to represent densities below the rooting depth of Schoenoplectus americanus. In the text however, we do also compare the results to the top 15 cm marsh results shown in figure 3.

- Line 260 – Do studies that examine soil strength with tidal inundation along a marsh elevation gradient not count?

  Thank you for the question. We have emphasised the difference between our and other studies a bit more:

  Line 306-310: "Our study is to our knowledge the first providing direct empirical evidence of the relationships between increasing tidal inundation (induced by sea level rise), decreasing soil strength, and increasing marsh to pond conversion. Our study is observational and conducted in a specific system (a micro-tidal marsh with organic-rich soils), which intrinsically limits drawing generalized conclusions and causal relationships. While we do acknowledge such limitations, this does not take away that the relationships that we observe are there. Moreover, our findings are in line with other studies, ~~confirmed~~

~~by similar studies, Although no previous studies a field gradient of increasing marsh to pond conversion exist, there are recent studies that demonstrate relationships between marsh soil strength and tidal hydroperiod,~~ based on a comparison of soil strength between marsh locations along a gradient from low to high marsh. For instance, Jafari et al. (2024) and Stoorvogel et al. (2024; 2025) found a decrease in marsh soil strength with increasing tidal hydroperiod along a field gradient from low to high marsh locations."

- Line 261 – seems like a word or two is missing here.

  Thank you for noticing. Based on the previous comment and a comment of reviewer 2 this sentence is now changed and the issue of the missing words is resolved.