



Commentary: Overstated Potential for Seagrass Meadows to Mitigate Coastal Ocean Acidification

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A Commentary on

Overstated Potential For Seagrass Meadows To Mitigate Coastal Ocean Acidification

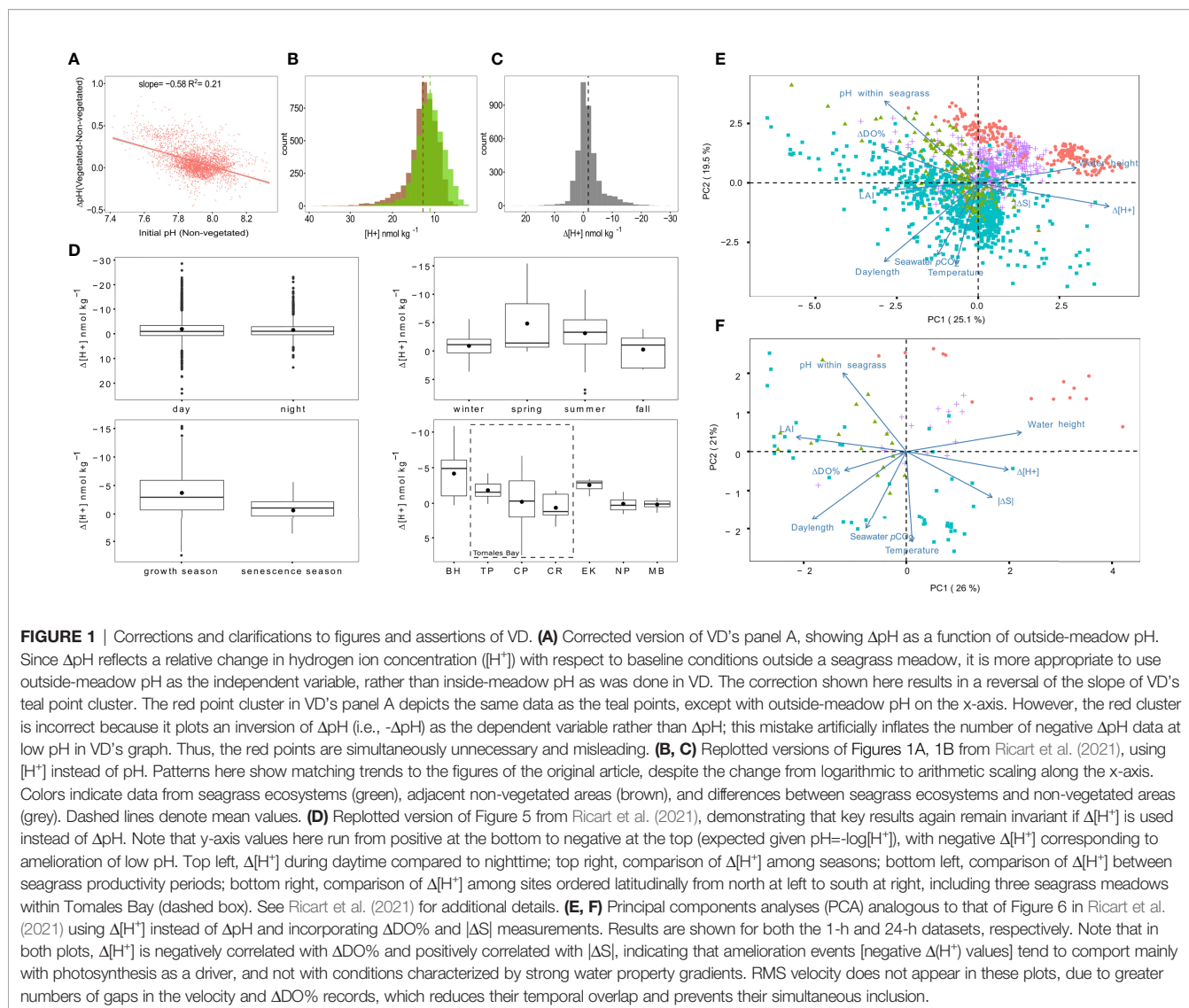
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Van Dam et al. (henceforth VD) published an Opinion (Van Dam et al., 2021a) and subsequent Corrigendum (Van Dam et al., 2021b) about our work regarding amelioration of low pH in seagrass ecosystems (Ricart et al., 2021). Below we discuss troubling details in the authors' approach, an unaddressed error, misrepresentations, and problematic inferences; each contravenes VD's argument of "overstated potential" for mitigation of low pH.

To start, VD's original comment was rejected previously by *Global Change Biology* due to 1425 spurious data points and two invalid graphs. Despite being informed of these mistakes, VD submitted the identical, unchanged critique to *Frontiers in Marine Science*. The erroneous publication and Corrigendum resulted.

Even following correction, we disagree with VD's two primary assertions:

1) VD claim that using ΔpH is "mathematically incorrect" because corresponding $\Delta[\text{H}^+]$ values depend on initial pH, a rather strident statement given the relationship is well known (Fassbender et al., 2021; note that in our study, initial pH is that outside seagrass; i.e., Δ =measurement inside minus that outside). VD then confusingly duplicate a single set of measurements in their Figure 1A, plotting it as two separate data clusters. One cluster (their red points) improperly inverts values to show " $-\Delta\text{pH}$ " instead of " ΔpH " on the y-axis. The other, teal cluster employs within-meadow pH rather than outside-meadow pH as the independent variable, a choice unsuited to assessing whether seagrass ecosystems elevate pH *relative to impinging waters*, and one that is misleading. The correct relationship (Figure 1A here) demonstrates that although ΔpH and pH indeed covary, the greatest low-pH amelioration (strongest $\Delta[\text{H}^+]$ depression) occurs when outside-meadow pH is low and



acidification stress is high. Most importantly, key patterns of Ricart et al. (2021) remain unchanged when $\Delta[\text{H}^+]$ is used instead of ΔpH (Figures 1B–D here). Therefore, our conclusions are robust to either ΔpH or $\Delta[\text{H}^+]$, and pH broadens audience accessibility.

2) VD claim that we overstate the capacity of seagrasses to ameliorate low pH. However, we believe this stance relies too heavily on categorical thinking.

- VD state we attribute “all positive ΔpH values strictly to seagrass photosynthetic activity.” We never say this, nor do we utilize “all or none” analyses. We explicitly discuss several alternative agents of pH change.
- VD fall into artificial “yes/no” interpretations through a narrow focus on a simple model: if aerobic metabolism drives pH change, then dissolved oxygen (DO%) must rise and fall in concert. Although reasonable as a starting point, this model applies strictly to biogeochemical dynamics at a

single time and place. In our study, inferences about pH amelioration derive from records differenced across space. Background patchiness in water properties creates spatiotemporal mismatches and noise in ΔpH vs. $\Delta\text{DO}\%$ relationships. The same is true of tidal flows that reverse at different times depending on where a recording instrument is located relative to shore. Subsets of ΔpH and $\Delta\text{DO}\%$ data will therefore deviate unavoidably from a simple photosynthesis model. What appears more relevant in VD's analysis is that the most common conditions at northern sites, where our study suggests amelioration of low pH was strongest, do align with photosynthesis as a driver (left teal bars in their figure 1c).

- The notion that photosynthesis is important only if ΔpH and $\Delta\text{DO}\%$ change in lockstep becomes especially problematic in broader interpretations of VD's Figure 1C. The authors assume if a measurement does not uphold their simple model, then it refutes it (binary outcome). This assumption

leads them to conclude that “...pH increases were most often caused by factors other than seagrass photosynthetic CO₂ uptake.” However, an elementary thought experiment indicates the impropriety of this assertion. We focus on categories of their Figure 1C where spatial differences in salinity suggest distinct water masses bathed stations inside vs. outside meadows (i.e., $|\Delta S| > 0.1$; green and purple bars). Under such conditions, a water mass flowing inside a meadow could have started, prior to interacting with the seagrass ecosystem, with lower $[H^+]$ than the nearby but separate water mass flowing outside the meadow. This background gradient in pH between inside and outside stations would then inflate the perceived role of seagrass by engendering a more negative $\Delta[H^+]$. Importantly, however, the opposite is also possible: an inside meadow water mass could have started, prior to interacting with a meadow, with sufficiently high $[H^+]$ that photosynthesis could decrease $[H^+]$ and still not induce a negative $\Delta[H^+]$ between inside and outside stations. In VD’s calculations, this latter scenario would count incorrectly as refuting a photosynthesis effect, even though such an effect was active. Together these contrasting situations (and analogous ones for $\Delta DO\%$) indicate that conditions where strong water property gradients exist are agnostic for revealing whether seagrass photosynthesis decreased $[H^+]$. Employing such cases (i.e., anytime $|\Delta S| > 0.1$) as evidence against a photosynthesis effect is therefore inappropriate. Indeed, a mirroring of VD’s logic enables just as easily the claim that 1085 records were *potentially consistent* with a photosynthesis model. This number equals 70% of the low-pH amelioration measurements in the analysis. Spatiotemporal mismatches noted above, or additional non-photosynthetic processes, including ones active in sediments and pore waters, could contribute to the remaining fraction and warrant study (e.g., left red bars in VD’s Figure 1C). However, they too are components of “seagrass ecosystems,” the term we use preferentially in our paper over just “seagrasses.”

- VD selectively ignore evidence that conflicts with their arguments. In our study, ΔpH co-varies with leaf area index and daylength (factors associated with photosynthesis; Figure 6, Ricart et al., 2021) but is negatively correlated with water height and RMS velocity (factors that dilute and disperse signatures of photosynthesis). These trends do not align with VD’s argument that water mass differences biased patterns of ΔpH . Furthermore, if the principal components

analysis is elaborated to include $\Delta[H^+]$ instead of ΔpH , along with $\Delta DO\%$ and $|\Delta S|$, vectors of $\Delta[H^+]$ and $\Delta DO\%$ orient in opposite directions, as expected, while $|\Delta S|$ aligns with $\Delta[H^+]$. The latter suggests water mass differences were not a primary driver of the observed patterns (Figures 1E, F here); indeed, if strong water property gradients were inflating amelioration events, the $|\Delta S|$ vector would be reversed.

More issues: Our study documents that >65% of hourly records showed elevated pH within meadows. VD incorrectly report 62%, confusing matters by ignoring 1425 valid ΔpH measurements (a remarkable inversion of their original error, where they inserted an identical number of false oxygen values). They also describe their 62% as “marginally” above what “chance alone would dictate”. However, the null model underlying this statistical assertion appears inappropriate. Data for pH and DO are not black or white balls being drawn from a jar; they are continuous variables, and the null expectation of their distributions is more complicated. This distinction is one reason our study relies on analyses of actual values rather than lumped categorical tallies.

We similarly find unconvincing VD’s statement, “... the claim that OA amelioration persists overnight and ‘up to 21 days’ should be revisited”, where they assert that water masses will be completely replaced during low tides. Complete exchange of water masses does not occur in our meadows, where only shallower portions become emergent during extreme low tides (pH/DO/salinity/temperature sensors located mid-depth, submerged >97% of the time). Moreover, seawater that does exit is often returned on the next high tide and can be processed further chemically; indeed, flow reversals habitually lengthen residence times in estuaries (Fischer et al., 1979).

Additional work is indisputably necessary to dissect mechanisms of pH modification in macrophyte habitats. Regardless of those mechanisms, in our study, low pH was routinely ameliorated in seagrass ecosystems, where photosynthetic activity seemed to play an important role.

AUTHOR CONTRIBUTIONS

AR and BG analyzed the data. AR led the writing of the manuscript. BG, TH, ES, KK, YT, MW, PS, AN, SM, and KE contributed critically to the drafts and gave final approval for publication.

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