First, we sincerely thank the editor and reviewers for their continued careful, constructive, and thoughtful evaluation of our manuscript. We greatly appreciate the time and effort devoted to this further round of review, as well as the reviewers' detailed comments, which have helped us refine the interpretation and presentation of the manuscript. We recognize that some aspects of our previous wording, particularly regarding the future implications of the proposed framework, required clearer alignment with the scope of the present dataset. In this revised version, we have carefully reconsidered all remaining comments and revised the manuscript accordingly to improve clarity, balance, and consistency with the available evidence. Our detailed point-by-point responses are provided below, together with the corresponding revisions indicated by page and line numbers in the revised manuscript.

– Response to the Editor Comments –

1. Comment: However, one important concern remains regarding the proposed "dual feedback" mechanism. While the manuscript suggests that declining oxygen concentrations associated with weakened deep-water formation may enhance subsurface nitrogen loss, the reviewer considers that this conclusion is not sufficiently supported by the data presented. Please either provide additional evidence supporting this hypothesis or substantially tone down the related statements, particularly in the Abstract and Section 3.5.

→ **Response:** We thank the editor for highlighting this important concern. We understand that the key issue is not the evidence for present-day N-reduction potential itself, but whether the manuscript sufficiently supported the proposed projection that future deoxygenation associated with weakened deep-water formation would enhance subsurface N loss.

We agree that the previous wording extended beyond what can be directly constrained by the present dataset. Although our results indicate a vertically persistent reservoir of N-reduction potential under present-day oxic conditions, our study does not include measurements of particulate organic matter, particle-associated oxygen microenvironments, oxygen depletion within sinking aggregates, or direct N-loss process rates. In addition, the EJS remained well oxygenated across our observations, which limits our ability to establish a robust relationship between dissolved oxygen concentration and N-reducing gene abundance.

(continued)

Following the editor's recommendation, we have substantially revised the Abstract and Section 3.5. Specifically, we removed statements implying that future deoxygenation would promote subsurface N loss and reframed this interpretation as a hypothesis requiring future observational and process-based validation. The revised text now focuses on conclusions directly supported by our data: the persistent low $NO_3^-:PO_4^{3-}$ signature, the limited explanatory power of external phosphorus inputs, the widespread potential for N reduction under present-day oxic conditions, and the observed vertical contrast in nutrient stoichiometry.

We believe these revisions improve the manuscript by more clearly separating data-supported conclusions from broader future implications, while preserving the main contribution of the study: providing a potential explanation for the anomalously low $NO_3^-:PO_4^{3-}$ ratios in the well-oxygenated EJS.

2. Comment: In addition, please address the minor technical corrections identified by Reviewer 2 (typographical, formatting, and proofreading issues) and provide a detailed response to all comments.

→ **Response:** We thank the editor for this reminder. We have carefully addressed all minor technical corrections identified by Reviewer 2, including typographical errors, number–unit spacing, formatting inconsistencies, and minor wording issues. In addition, we reviewed the manuscript as a whole to ensure consistency in terminology, notation, figure references, and reference formatting. A detailed point-by-point response to each reviewer comment is provided below, with the corresponding revisions indicated by page and line numbers in the revised manuscript. We have also submitted a marked-up version of the manuscript showing the changes made during this revision.

– Response to the Reviewer #2 Comments –

1. Comment: The paper has improved overall. However, I have significant concerns about the proposed "dual feedback" mechanism that should be addressed before publication. As stated in the title, the authors provide a potential explanation for the low NO_3:PO_4 ratio in the East Japan Sea and have overall improved the manuscript. However, I still have one major concern that should be addressed before the publication. Specifically, the authors do not adequately justify the proposed "dual feedback" mechanism for future conditions. The authors argue that a reduction in O_2 "driven by the weakening of deep-water formation, potentially favoring subsurface N loss". However, the authors did not justify this conclusion. To support this claim, the authors need to show a correlation between O_2 concentration and the abundance of N-reducing genes using their data samples. Alternatively, they should provide a correlation between O_2 concentration and the extent of O_2-depleted microenvironments. If the authors cannot provide this evidence, I propose to tone down or remove claims about the projection of this dual feedback (specifically from the abstract and Section 3.5).

→ **Response:** We thank the reviewer for this important and thoughtful comment. We agree that the original wording did not sufficiently distinguish between observations supported by the present dataset and broader implications regarding future environmental change.

As the reviewer correctly notes, our dataset does not include measurements of particulate organic matter abundance, particle-associated oxygen microenvironments, or direct oxygen depletion within sinking aggregates. We therefore cannot directly evaluate whether declining dissolved oxygen would increase oxygen-depleted microzones or enhance N-reduction activity. Although dissolved oxygen was measured throughout the water column, the relatively narrow oxygen range in this well-oxygenated system also limits our ability to establish a robust relationship between oxygen concentration and N-reducing gene abundance. Following the reviewer's recommendation, we substantially revised the Abstract and Section 3.5 to remove statements implying that future deoxygenation would promote subsurface N loss.

Instead, we now emphasize that such mechanisms remain hypothetical and require validation through future observational and process-based studies. The revised text focuses on what is directly supported by our data—a vertically persistent reservoir of N-reduction potential under present-day oxic conditions and the observed vertical contrast in NO_3^-:PO_4^{3-} stoichiometry—thereby better aligning the discussion with the scope of the available observations.

Original	A dual-scale feedback—short-term anthropogenic N deposition enriching surface waters (i.e., increasing NO_3^-:PO_4^{3-} ratio in the upper waters) and longer-term deoxygenation, driven by the weakening of deep-water formation, potentially favoring subsurface N loss (i.e., decreasing NO_3^-:PO_4^{3-} ratio in the deep waters)—may promote a vertically stratified NO_3^-:PO_4^{3-} regime in the future EJS. Our findings highlight the EJS as a sentinel system for how combined anthropogenic and climatic forces could reshape marine nutrient balances.
Revised	Our results further reveal a vertically structured stoichiometric regime in which anthropogenic N deposition is associated with elevated surface NO_3^-:PO_4^{3-} ratios, whereas long-term changes in ventilation and deep-water properties coincide with lower ratios at depth. Together, these findings highlight the importance of considering nutrient stoichiometry across distinct temporal and vertical scales and identify the EJS as a sentinel system for detecting biogeochemical responses to ongoing environmental change. More broadly, our study provides a mechanistic framework for interpreting persistent nutrient stoichiometric anomalies in oxygenated marginal seas. *(Page 1, line 18–23)*

(continued)

Original	Although these changes do not imply the development of basin-scale anoxia, the gradual decline in oxygen and reduced ventilation may influence the balance of the reactive N inventory over decadal timescales. In particular, declining oxygen concentrations and longer water-mass residence times may increase the relative importance of NO_3^- reduction pathways operating within localized low-oxygen microenvironments, such as particle-associated niches. Over decadal timescales, the cumulative effect of these processes could gradually reduce the deep-water N inventory, consistent with the observed decline in $NO_3^-:PO_4^{3-}$ ratios (e.g., $NO_3^-:PO_4^{3-}$1999 = 13.0 > $NO_3^-:PO_4^{3-}$2021 = 12.6; see Fig. S4).
Revised	Although these changes do not imply the development of basin-scale anoxia, they demonstrate that the EJS interior is undergoing a long-term transition in ventilation and oxygenation state. Such changes may influence the balance of biogeochemical processes that regulate the reactive N inventory over decadal timescales. However, the mechanisms linking declining oxygen concentrations to changes in N cycling cannot be resolved directly from the present dataset because neither particle-associated oxygen microenvironments nor their associated process rates were measured. Consequently, the observed decline in deep water $NO_3^-:PO_4^{3-}$ ratios between 1999 and 2021 (e.g., $NO_3^-:PO_4^{3-}$1999 = 13.0 > $NO_3^-:PO_4^{3-}$2021 = 12.6; see Fig. S4) should be viewed as an observational constraint rather than direct evidence for a specific N-loss mechanism. *(Page 14, line 349–355)*

Original	Taken together, these observations support a dual-scale framework in which short-term surface N enrichment driven by atmospheric deposition increases $NO_3^-:PO_4^{3-}$ ratios, while longer-term adjustments in the subsurface N inventory—linked to ventilation changes and microenvironment-mediated N loss—act in the opposite direction. These processes operate without requiring the onset of anoxia and instead reflect shifts in the balance of N cycling pathways across temporal and vertical scales. Given this dual sensitivity to atmospheric forcing and ventilation dynamics, the EJS may serve as a sentinel system for detecting biogeochemical responses to ongoing environmental change.

Revised	Taken together, these observations support a dual-scale framework in which short-term surface N enrichment driven by atmospheric deposition increases $NO_3^-:PO_4^{3-}$ ratios, whereas longer-term changes in subsurface ventilation and water mass properties coincide with declining $NO_3^-:PO_4^{3-}$ ratios at depth. While the mechanisms underlying these long-term changes remain incompletely resolved, the contrasting responses observed between surface and deep waters highlight the importance of considering nutrient stoichiometry across distinct temporal and vertical scales. These contrasting responses emerge without the onset of basin-scale anoxia and highlight the importance of considering nutrient stoichiometry across multiple temporal and vertical scales. Given this dual sensitivity to atmospheric forcing and ventilation dynamics, the EJS may serve as a sentinel system for detecting biogeochemical responses to ongoing environmental change. *(Page 15, line 356–363)*

2. Comment: Line 65: "physical circulation and remineralization" - Please explain how these processes contribute to the low $NO_3:PO_4$ ratio.

→ **Response:** We thank the reviewer for this helpful comment. We have revised the text to clarify how physical circulation and organic matter remineralization were proposed to contribute to the low $NO_3^-:PO_4^{3-}$ ratios in previous studies. Specifically, we now explain that the ventilation of low-$NO_3^-:PO_4^{3-}$ surface waters into the interior, together with Redfield-like remineralization of sinking organic matter, can yield a low deep-water $NO_3^-:PO_4^{3-}$ ratio of approximately 13 under steady-state conditions. This revision clarifies the mechanistic basis of the interpretation proposed by Kim and Kim (2013).

Original	Previous studies have attributed the low $NO_3^-:PO_4^{3-}$ ratios in the EJS to a combination of physical circulation and remineralization (Kim and Kim, 2013).
Revised	These include the combined effects of physical circulation and remineralization, whereby the ventilation of low $NO_3^-:PO_4^{3-}$ surface waters into the interior, together with Redfield-like remineralization of sinking organic matter, yields a low deep-water $NO_3^-{}_4^{3-}$ ratio of approximately 13 under steady-state conditions (Kim and Kim, 2013). *(Page 3, line 66–68)*

3. Comment: Line 65: “possible denitrification” – how was this concluded? observations?

→ **Response:** We thank the reviewer for this important clarification request. We have revised the text to specify that the previously proposed denitrification mechanism was not based on direct measurements of denitrification rates, but was inferred from box-model budgets of total nitrogen and phosphorus (TN and TP). Specifically, Yanagi (2002) suggested possible denitrification because the TN ratio in the Japan Sea (~11.3) was depleted relative to source-water values (~16.4–16.6). The revised text now clarifies that this was a budget-based inference rather than a direct observation of denitrification.

Original	and possible denitrification (Yanagi, 2002).
Revised	possible denitrification inferred from box-model total N and P (TN and TP) budgets showing that TN:TP ratios in the EJS were depleted relative to source-water values (Yanagi, 2002). *(Page 3, line 70–71)*

4. Comment: Line 85 (0m) - add a space between the ‘0’ and the ‘m’ (i.e., "0 m" not "0m").

→ **Response:** We thank the reviewer for pointing this out. We have corrected “0m” to “0 m” at the indicated location. We also reviewed the manuscript for similar number–unit spacing inconsistencies and corrected them where necessary. *(Page 4, line 91)*

5. Comment: Line 95 - Remove the unnecessary gap after "After quality control,”

→ **Response:** We thank the reviewer for pointing this out. We have corrected the spacing after “After quality control,” so that the sentence now reads properly. We also reviewed the manuscript for similar spacing inconsistencies and corrected them where necessary. *(Page 4, line 101)*

6. Comment: New Section 3.1 - great addition to the paper.

→ **Response:** We thank the reviewer for this positive comment. We are pleased that the newly added Section 3.1 strengthened the manuscript by providing a clearer observational basis for the depth-resolved NO_3^-, PO_4^{3-} and NO_3^-:PO_4^{3-} distributions. No further changes were made in response to this comment.

7. Comment: Line 200: Please separate "1000" from "m" (i.e., "1000 m" not "1000m").

→ **Response:** We thank the reviewer for pointing this out. We have corrected “1000m” to “1000 m” at the indicated location. We also checked the manuscript for similar number–unit spacing issues and corrected them where necessary. *(Page 10, line 228–231)*

8. Comment: I suggest moving the Section ‘External phosphorous input cannot explain the low NO_3:PO_4 ratios” to its earlier position (i.e., after Section 3.1)

→ **Response:** We thank the reviewer for this helpful suggestion. We agree that evaluating external phosphorus inputs immediately after presenting the depth-resolved nutrient distributions provides a clearer logical progression. Accordingly, we have moved the section “External phosphorus input cannot explain the low NO_3^-:PO_4^{3-} ratios” to immediately follow Section 3.1. This revised structure first establishes the observed low NO_3^-:PO_4^{3-} signature, then evaluates whether enhanced phosphorus inputs can explain this pattern, before turning to microbial evidence for N-reduction potential. *(Page 7–8, line 153–195*)

– Response to the Reviewer #3 Comments –

1. Comment: This revised manuscript provides an innovative and compelling biogeochemical rationale for the persistent low NO_3^-:PO_4^{3-} ratio in the oxygenated water column of the East/Japan Sea (EJS). The authors have successfully integrated constructive feedback from the previous review, significantly strengthening the logical foundation of the study. In particular, the newly added depth-resolved nutrient distributions and the quantitative exclusion of external sources such as riverine and sedimentary inputs provide strong support for the main conclusions of the manuscript. Consequently, the revised manuscript is considered to be of sufficient merit for publication, pending a few minor technical revisions.

→ **Response:** We thank the reviewer for this positive evaluation of the revised manuscript. We are pleased that the reviewer finds the additional depth-resolved nutrient analyses and the quantitative assessment of alternative nutrient sources to have strengthened the overall interpretation and support the main conclusions of the study. We appreciate the reviewer's assessment that the manuscript is suitable for publication pending minor technical revisions.

2. Comment: Revision (p. 2, line 36): The reference "Tyrell, 1999" appears to be a typographical error and should be corrected to "Tyrrell, 1999".

→ **Response:** We thank the reviewer for pointing out this typographical error. We have corrected the reference from "Tyrell (1999)" to "Tyrrell (1999)" in the revised manuscript. *(Page 2, line 37*)

3. Comment: Revision (Figure 2, p. 6): The sentence "The dashed gray line indicating the canonical Redfield ratio (16:1)" lacks a main verb.

→ **Response:** We thank the reviewer for identifying this grammatical error. The figure legend has been revised to include the missing main verb and now reads: "A dashed gray line indicates the canonical Redfield ratio (16:1)." *(Page 2, Figure 2 caption*)

4. Comment: Revision (Figure 2, p. 6): The expression “below 0.05 < μmol L^{-1}” is redundant in its notation.

→ **Response:** We thank the reviewer for identifying this redundancy. The notation has been corrected by removing the redundant symbol, and the text now reads: “excluding samples with PO_4^{3-} concentrations below 0.05 μmol L^{-1}.” *(Page 2, Figure 2 caption*)

5. Comment: In addition, I recommend a thorough final proofreading of the manuscript to ensure consistency in spelling and proper alignment of all references.

→ **Response:** We thank the reviewer for this helpful recommendation. We have carefully proofread the entire manuscript to improve consistency in spelling, grammar, terminology, and reference formatting. In addition, we have verified the alignment and accuracy of all in-text citations and reference entries throughout the manuscript. *(throughout the manuscript*)

6. Comment: Finally, while this study provides important insights into nutrient stoichiometry and microbial responses in the EJS, it is limited by the specific sampling period. To better understand the long-term impacts of environmental variability and climate change on nutrient distributions, future research should be considered to require long-term observational datasets, together with high-resolution numerical modeling and autonomous observing platforms, in order to quantitatively resolve the relative contributions of physical transport and biological processes.

→ **Response:** We thank the reviewer for this thoughtful perspective. We agree that the present study is constrained by the temporal scope of the available observations and that a more comprehensive understanding of long-term variability will require sustained observational programs, high-resolution numerical modeling, and emerging autonomous observing technologies. We appreciate this valuable suggestion and consider it an important direction for future research. No changes were made to the manuscript in response to this comment.