Response to Associate Editor and Referees

Manuscript Title: **Macroalgal influence on particulate organic matter sources and early transformation in an Arctic fjord**

Authors: Ashok Shivaji Jagtap et al.

Dear Dr. Yuan Shen and referees,

We sincerely thank the Associate Editor and referees for their positive, constructive, and thorough evaluation of our manuscript. We greatly appreciate the recognition of our study's novelty, particularly the comprehensive multi-proxy approach integrating bulk elemental and stable isotopes, biopolymeric fractions, and molecular biomarkers (amino acids and monosaccharides) to elucidate how expanding Arctic macroalgal beds act as dynamic biogeochemical hotspots that laterally export and restructure pelagic particulate organic matter.

In accordance with the referees' and editor's suggestions, we have carefully revised the manuscript to improve clarity, strengthen interpretations, and address all specific comments in detail. We believe these revisions have substantially improved the quality and readability of the manuscript. Below is our detailed, point-by-point response to all comments raised during the interactive peer-review process, with line numbers referencing the revised manuscript.

Response to Referee 1 comments (RC1)

This manuscript investigates the influence of macroalgal beds in the Arctic Kongsfjorden on the sources and early transformation processes of surface particulate organic matter. By comparing surface water samples from four macroalgae-dominated sites and their adjacent waters (500 m and 1500 m), and employing a combination of elemental analysis, stable isotopes, macromolecular composition, and molecular biomarkers, the authors found that macroalgal beds are a significant source of labile carbon and nitrogen compounds in surface POM, with their molecular fingerprints (e.g., monosaccharide and amino acid composition) showing distinct signatures. POM derived from macroalgae can be exported to the fjord scale and undergoes selective transformation during lateral transport. Principal component analysis revealed a continuous biogeochemical gradient from the macroalgal beds to the adjacent waters. Among the sites, Brandal stands out as a distinct biogeochemical hotspot influenced by macroalgae. This study provides important multi-proxy evidence for understanding how expanding macroalgal communities, under rapid Arctic warming, influence the sources, transport, and transformation of coastal organic carbon through benthic-pelagic coupling processes. It holds clear academic value for deepening the understanding of the Arctic coastal carbon cycle and is worthy of publication after revision.

Response: We sincerely thank the referees for the positive and constructive evaluation of our manuscript. We greatly appreciate the referee's recognition of the novelty and multiproxy approach in elucidating the influence of Arctic macroalgal

beds on the sources, transport, and transformation of POM in Kongsfjorden. We appreciate the referee's acknowledgement of the importance of biochemical and molecular-level analysis, including elemental composition, stable isotopes, amino acids, sugars, and multivariate approaches, in identifying macroalgal-derived signatures and biogeochemical gradients from coastal beds to adjacent fjord waters. Following the referee's suggestions, we have carefully revised the manuscript to improve clarity, strengthen interpretations, and address all specific comments in detail. We believe these revisions have substantially improved the quality and readability of the manuscript.

Major Deficiencies and Revision Suggestions

1) The abstract and highlights sections are repetitive and could be further refined. (Lines 14-22, 24-45). It is suggested that the author revisits and integrates the content of these two sections. Consider refining the "Highlights" into the most concise and eye-catching core innovative findings, while the "Abstract" should maintain its independence, providing a complete yet succinct overview of the research background, methods, main results, and conclusions, avoiding simple repetition of the highlight statements.

Response: We thank the referee for this helpful comment. We have revised the abstract (Lines 34-40) to provide a complete overview of the research background, methods, main results, and conclusions. The highlights (Lines 14-19) have been revised to focus on core innovative findings in a concise manner, without repetition, and incorporated into the revised manuscript.

2) Lines 511-536: The explanation for the mechanism behind the finding that "Brandal is a biogeochemical hotspot influenced by macroalgae" is primarily attributed to "high biomass," "favorable growth conditions," and "possible promotion of detritus retention by hydrological conditions," which is somewhat general. It is suggested to add a subsection or paragraph to explore more specifically the potential local driving factors that make the Brandal site a hotspot. For example, can known information about the site's geographical location, water depth, hydrodynamic characteristics (e.g., whether it is in a circulation or upwelling area), degree of freshwater input, etc., or citations of relevant literature, be incorporated to support the speculation that "hydrological conditions promote retention," making the conclusion more robust.

Response: Thank you for the suggestions. We have revised Section 4.4 (Lines 540-558), expanding our discussion of local driving factors at Brandal in the revised manuscript.

3) Specific citation suggestions:

1) Lines 89-91: In the introduction, when discussing the complexity of organic matter sources in the Arctic coastal zone, after ".....(Singh et al., 2024b) and sediments (Roy et al., 2025) in Kongsfjorden", add: "Similarly, studies on the Qinghai-Tibetan Plateau saline lakes have shown that the molecular composition of dissolved organic matter is also strongly influenced by watershed inputs and internal biological processes (Jiang et al., 2022), and that terrestrially derived organic matter can be transformed driven by aquatic microbial communities (Yang et al., 2020)."

Response: We thank the referee for this suggestion. We have incorporated the relevant citations (Line 93-97) into the introduction in the revised manuscript.

2) Line 457: After "observed decline in POC from MDS to Adj-W", insert: "This aligns with the classical understanding of preferential degradation of labile components in marine environments. In lake sediment systems, inputs of algal and terrestrial organic matter have been shown to stimulate significantly different microbial degradation processes (priming effects) (Yang et al., 2023), with methanogenesis potentially dominating the carbon flow under anoxic conditions (Yang et al., 2025), implying the key control of organic matter molecular composition on its transformation pathways."

Response: We thank the referee for the suggestion. We have incorporated the relevant citations in the revised manuscript.

3) Line 517: After "matter within this macroalgal-dominated habitat", insert: "Habitat heterogeneity is considered a primary factor driving microbial community assembly and functional differentiation in extreme environments (Huang et al., 2026). In Qinghai Lake, the assembly mechanisms of prokaryotic and microeukaryotic communities have been shown to be significantly different and regulated by different environmental factors (Han et al., 2023). Similarly, research in the Aral Sea region indicates that minor differences in salinity and mineralogy can lead to distinctly different responses in microbial and endophytic communities (Jiang et al., 2021). Therefore, the Brandal hotspot may result from the combined action of its unique substrate (macroalgal bed), local hydrodynamics (forming a 'retention zone'), and the resulting unique microbial community, reflecting the high specificity of biogeochemical processes at the microhabitat scale."

Response: We thank the referee for this insightful suggestion. We have integrated the relevant citations in the revised manuscript.

Response to Referee 2 comments (RC2)

Overall, this is a strong and timely study that applies a comprehensive multi-proxy approach to explore macroalgal influences on particulate organic matter dynamics in an Arctic fjord. The dataset is robust and the analyses are generally well interpreted, providing valuable insight into benthic–pelagic coupling in a rapidly changing Arctic coastal system. A number of revisions would further strengthen the manuscript, particularly improvements to figure clarity and accessibility, minor typographical and formatting corrections, and additional detail in the statistical methods to improve transparency and reproducibility. The manuscript would also benefit from some streamlining of lengthy results sections and clearer structuring of the discussion, including a brief synthesis of key findings and a slightly stronger emphasis on broader implications. Addressing these points would enhance readability and ensure the study's contributions are fully accessible to a wide readership.

Reply: We sincerely thank the reviewer for the positive and thoughtful evaluation of our manuscript. We greatly appreciate the reviewers' recognition of the novelty and comprehensive multi-proxy approach of this study, as well as its contribution to understanding particulate organic matter dynamics in Arctic coastal systems undergoing rapid environmental change. We also appreciate the reviewers' constructive suggestions for improving the manuscript. In response, we have carefully revised the figures to improve clarity, readability, and accessibility, and corrected the identified typographical errors throughout the manuscript. Additional details on statistical analysis have been included to enhance transparency and reproducibility. We have also streamlined the Results section to improve flow and readability, and reorganized the Discussion section to provide a clearer thematic structure, stronger synthesis of the main findings, and broader contextual implications for Arctic coastal carbon cycling under climate warming. We believe these revisions have substantially strengthened the manuscript and improved its accessibility to a wider readership.

General typos and suggestions for clarification

Line 26 This study investigates
Reply: Thank you for pointing out the grammatical error; we have corrected it (Line 26) in the revised manuscript.

Lines 67 – 70 not needed, can remove
Reply: Thank you for the suggestion. As suggested, the statement has been removed in the revised manuscript.

Lines 71 – 73, how are the macroalgal beds lost? Provide an example of the process / reasons for these losses.
Reply: Thank you for the comment. To clarify, the focus of lines 70–74 is specifically on **macroalgal blade erosion and fragmentation** rather than the loss of the entire macroalgal bed. This distinction is important because blade erosion represents a continuous, daily contribution of organic material to the Particulate Organic Carbon (POC) pool, even while the macroalgal bed remains intact. For clarity, the process of

macroalgal blade erosion is provided, which is mainly driven by mechanical stress, physical abrasion against rocky substrates, seasonal increases in tissue brittleness, and biological weakening by epiphytes. All of these facilitate the gradual fragmentation of the blade into the particulate organic matter pool.

Figure 1 – Consider adding place names and enlarge latitude/longitude text.
Reply: Thank you for the suggestion. As suggested, the place names were added in Figure 1, and the font size of the latitude and longitude text was increased for better visibility.

Section 2.7 Statistical analysis – what packages did you use in R for your statistical analysis? Did you test for equal variance and normality assumptions before proceeding to ANOVA?

Reply: We have updated Section 2.7 statistical analysis in the revised manuscript (Line 197 - 202).

Tabel 1 – if you're abbreviating, include the abbreviation in brackets in your table cation (e.g. sal for salinity).
Reply: Thank you for pointing out that we have updated the abbreviation in the revised manuscript (Table 1).

Figure 2 – this is very hard to read, consider enlarging and making all text bigger
Reply: Thank you for the constructive feedback regarding Figure 2. As suggested, we have revised the figure to ensure readability.

Table 2 – fix table caption
Reply: Thank you for the suggestion. We have revised the caption for Table 2 to be more comprehensive in the revised manuscript.

Figure 3 – avoid using red (colour blind implications)
Reply: Thank you for the valuable suggestions. We have revised Figure 3 to avoid the use of red, ensuring that the plot is accessible to readers with colour vision deficiencies.

Sections 3.3.2, 3.3.3 and 3.3.4 – consider summarising all the data ranges in tables to avoid big text sections. You could potentially include these in the Appendices since you already include graphs.
Reply: We thank the reviewer for this helpful suggestion to improve the manuscript flow. As suggested, we have summarized this biochemical characterization and the percentages in Supplementary Table (S2) and streamlined the corresponding text (283-286, 292-294, 310-313) to improve the clarity of the Results section.

Line 351 – PCA analysis should be PCA
Reply: Thank you for pointing out this redundancy. We have corrected the text (Line 351) in the revised manuscript to "PCA" instead of "PCA analysis."

Section 4 Discussion – consider adding a short paragraph at the beginning that summarises all your key findings and then expand on the detail in the subsequent sections.

Reply: Thank you for this excellent suggestion. We have added a short paragraph (Line 368-378) in the revised manuscript.

The emphasis on Brandal as a biogeochemical hotspot is well supported by the data; however, a brief discussion on how representative this site may be of Arctic macroalgal beds more broadly, or which site characteristics may limit generalisation, would help place the findings in a wider Arctic context.

Reply: We thank the reviewer for this insightful suggestion. We have added a brief discussion (Line 552-558) in the revised manuscript addressing the representativeness of the brandal within Arctic macroalgal systems and the limitations associated with extrapolating these findings across the Arctic.

Figure 6 – add labels for 55 and 1500, add arrows with the label decreasing for the compounds/concentrations

Reply: Thank you for these specific suggestions to improve the clarity of our conceptual model in Figure 6. We have revised the figure as suggested to include the labels for 500m and 1500m sampling stations in bold text in the revised manuscript. Furthermore, we have added directional arrows to clearly illustrate the decreasing and increasing concentrations of key biochemical compounds as they are transported away from macroalgal beds.

Line 551 – missing full stop

Reply: Thank you for pointing out this redundancy. We have corrected the grammatical error in the revised manuscript.

Section 4.5 Implications – lines 538 – 548 is a summary of your results, consider moving this, along with Figure 6, to the start of your discussion. Expand on the implications sections so it focusses on the 'so what does this mean for future research and climate/ecosystem implications'. The novelty of the study would benefit from being made more explicit, particularly in relation to previous POM studies in Kongsfjorden. A short clarification of what is fundamentally new here (e.g. molecular resolution, spatial design, or integration of proxies) would help situate the contribution more clearly within the existing literature.

Reply: We thank the reviewer for this strategic advice on the structure and impact of the discussion. We have reorganized the Discussion section by moving the summary-oriented content from Section 4.5, along with Figure 6, to the beginning of the Discussion to provide a clearer conceptual overview of the main findings. We have also substantially revised and expanded the implications section (Line 561-565) to focus more explicitly on the broader significance of our findings for future Arctic research and climate-driven ecosystem change. We have clarified the novelty and key advances of this study in relation to previous POM studies conducted in Kongsfjorden.