Response to Reviewer 2 comments on manuscript egusphere-2026-582 titled "Different paths, same destination: similar functional outcomes in nitrogen cycling within artificialized coastal habitat".

General Comments:

RC2-1: Pascal et al. have provided a well-written and concise manuscript about the biogeochemical and macrofaunal composition of sediments, both impacted and unimpacted by a 300 m-wide breakwater on the south shore of the St. Lawrence Estuary. In the introduction, the authors outlined the global relevance of the study by detailing the increasing prevalence of shoreline stabilization structures in response to sea-level rise and extreme climatic events. The authors indicated that there is a research gap in how these structures affect nitrogen cycling and potential coastal eutrophication. The methods and results sections are clearly presented and relevant to the objectives of the study. The authors found significant differences in sediment characteristics and macrofaunal composition, yet nitrogen fluxes were not significantly different between impacted and reference sites. The authors conclude by suggesting that functional plasticity within their study area allows for minimal differences in nitrogen cycling. Overall, I believe that this study provides an interesting and relevant contribution to Biogeosciences and is suitable for publication, with minor revisions.

AC-R2-1 : Dear Reviewer 2,
We thank you for your careful evaluation of our manuscript and supportive and constructive comments. We have carefully addressed all the concerns raised and responded to each comment below.
Please note that, as we have added new data to address both reviewers' comments, we have included Carole-Anne Guay in the author list. She collected the additional sediment samples and performed the solid-phase ascorbate-extractable iron analyses presented in the revised manuscript.

Specific Comments:

RC2-2: Section 2.1 Study area: Please provide some brief information on water temperature and salinity in your study area.

AC-R2-2 : Temperature and salinity during field campaigns are now given in section 2.3.

"*Sea water temperature and salinity during sampling were similar between years: 9 °C and 19.6 in 2021 and 10 °C and 18.7 and 2022.*"

RC2-3 : Line 125: My question is related to sample collection taking place over two years (June 2021 and 2022). This needs to be addressed and explained clearly. Was each site sampled twice (once each year) or were some sites sampled in 2021 and others sampled in 2022? Depending on how the sampling was conducted, please address the differences in ice cover between the two years (e.g., Galbraith et al. Physical Oceanographic Conditions in the Gulf of St. Lawrence during 2021 and 2022) and how that could affect the data.

AC-R2-3: We apologize for the confusion. See our response to RC1-4 below:
AC-R1-4: "All benthic flux incubations, including isotope pairing experiments, porewater extraction, and macrofauna sampling were conducted during a single campaign in June 2021, ensuring no interannual variability in our main dataset. The June 2022 campaign was specifically dedicated to strengthening this dataset by performing O2 microprofiles at SBW (which was not possible in 2021 due to logistical constraints) and to increasing the replication of baseline sediment characteristics. Cross-validation between the two field campaigns confirmed that spatial gradients remained consistent across years, based on sediment characteristics and O2 microprofiles at VS and US (Fig 1 and 2 below), further supporting the temporal stability of our observations."

Regarding interannual differences in ice cover, Galbraith et al. report that 2021 was characterized by anomalously low ice cover and volume in the Gulf of St. Lawrence, while 2022 was close to the long-term normal. However, these reports document regional-scale ice conditions and do not resolve local ice dynamics in coastal embayments such as Rivière-du-Loup Bay. Field observations before both campaigns confirmed the presence of sea ice in the bay at the study site in both years. Since all primary biogeochemical and ecological measurements were conducted in 2021, any interannual difference in sea ice conditions between 21 and 22 does not affect our main dataset. In addition, cross-validation was performed to support the representativeness of the micropifiles aquired at SBW in 2022 (See AC-R1-4 for further details).

RC2-4: Additionally, the authors specify that sampling was targeted for the beginning of the salt marsh growing season following winter ice cover. Please clarify why that is the case (e.g., due to short leaf length, which is mentioned on lines 171-172, or another reason?).

AC-R2-4: We have clarified the rationale for our sampling timing in the revised text. The beginning of the growing season was targeted for two reasons: (1) root oxygen release and rhizosphere processes are expected to be active during early plant growth, influencing nitrogen cycling; and (2) the short leaf canopy at this stage allows intact core incubation without cutting shoots. These sentences now read as follows: "*Sampling was performed in June 2021 and 2022, targeting the beginning of the salt marsh growing season following winter ice cover break-up. This period was chosen because salt marsh plants are entering their active growth phase, during which root oxygen release and associated rhizosphere processes are expected to influence sediment nitrogen cycling (Koop-Jakobsen & Giblin, 2010; Zheng et al., 2016). Additionally, the relatively short leaf canopy at this stage allows intact sediment cores with vegetation to be incubated without cutting shoots and associated artefacts. Sea water temperature and salinity during sampling were similar between years: 9 °C and 19.6 in 2021 and 10 °C and 18.7 and 2022.*"

RC2-5: Line 130: "with few if any core compaction", please be more specific. This reads as if you do not know if there was or not.

AC-R2-5: We apologize for the lack of precision. After verifications of our field records, we updated the sentence, which now reads as follows:

"*At each of the five sites, eight large sediment cores (10 cm diameter, ~ 15 cm of sediment and ~ 15 cm of air headspace) were manually collected at low tide using transparent acrylic liners (30 cm long), with compaction < 0.5 cm.*"

RC2-6: Line 142: "hydrogen peroxide on one sediment core", are you referring to the small sediment core collected at each location? Please specify.

AC-R2-6: This paragraph has been corrected. See our answer to RC1-33. The new paragraph reads as follows:

"2.4 Characterization of the sediment

Sediment characteristics were analyzed using samples from the top layer (0 - 0.5 cm) of the five small sediment cores collected at each location. One core was dedicated to measuring sediment grain size (D50), porosity (ϕ), and organic carbon (Corg) and total nitrogen (TN) contents, as well as Corg natural isotope composition (δ^13

C_{org}). From this core, D50 was assessed by laser diffraction (Malvern Instruments©, 2 µm detection limit) after OM digestion with hydrogen peroxide and porosity was determined by measuring water loss after freeze-drying, corrected for sea salt content, using a dry sediment density of 2.65 g cm-3. Prior the Corg and $\delta^{13}C_{org}$ analyses, inorganic carbon was removed by fuming of sediments in a closed container in the presence of an open beaker of concentrated HCl. Elemental characteristics of the OM, (i.e., Corg, TN) of the sediment were determined using an elemental analyzer (Carlo Erba© NC2500). The $\delta^{13}C_{org}$ was then measured using a Micromass Isoprime 100 isotope ratio mass spectrometer coupled to an Elementar Vario MicroCube elemental analyzer. Carbon isotope ratios are reported using the delta notation, relative to the Vienna Pee Dee Belemnite standard. The remaining sediment from this first core, along with the other four cores, was used to determine the OM content via loss on ignition (LOI, n=5), as the weight loss after combustion at 550 ˚C during 4 h. Due to storage failure, LOI was not assessed at US."

RC2-7: Line 146: Same question as line 142.

AC-R2-7: See our answer to RC2-6.

RC2-8: Figure 2c. Please define the square data points above the 0cm depth line.

AC-R2-8: The squares represent the nutrient concentrations in the overlying water. This is now mentioned in the figure caption.

"*Figure 2: Porewater solute concentrations. (a) Diffusive O_2 uptake (DOU) by the sediment and (b) O_2 penetration depth (OPD). (c) overlying (square) and porewater (circle) NO_2^- , NO_3^-, NH_4^+ and PO_4^{3-} concentrations at each site (n = 1 with 5 pseudo replicates for DOU and OPD). Different letters indicate significant ($p < 0.05$, Tuckey contrast) differences among the different levels of Site (a and b)*"

RC2-9: Line 313: "densities tended to be higher at the sites LBWS and LBWN than at VS and US (Fig. 3)." This is a misleading statement since LBWN is statistically similar to VS and US according to Fig 3.

AC-R2-9: We agree and we have corrected the sentence which should now read as follows:

"*Total densities tended to be higher at the sites LBWS than at LBWN, VS and US (Fig. 3).*"

RC2-10: Discussion: I would like to see more discussion regarding why the authors think that nitrogen cycling was similar between sites, despite differences in sediment characteristics and macrofaunal assemblages. The authors could compare results to other studies and provide hypotheses on why they are not seeing impacts from the structure. This seems to be a significant missing piece given the emphasis on nitrogen throughout the rest of the manuscript, including the title.

AC-R2-10: We agree with the reviewer, and Reviewer 1 raised a similar concern (RC1-2). We have thoroughly revised Sections 4.1 and 4.3 to address this point. Briefly, we argue that similar denitrification rates across sites despite contrasting sediment characteristics and macrofaunal assemblages result from distinct but functionally equivalent biogeochemical pathways: at VS, rhizosphere oxygenation by S. alterniflora roots sustains sub surface coupled nitrification-denitrification, while at LBWS, high densities of subsurface bioturbators enhance sediment irrigation and oxygen supply, achieving comparable nitrogen removal through a bioturbation-driven pathway. We also now compare our denitrification rates with published values for temperate intertidal mudflats and salt marshes to contextualize our findings. We refer the reviewer to our detailed response in AC-R1-2 for a full account of the revisions made to the Discussion.

Technical Corrections:

RC2-11: 92: “south shore” instead of “South shore”.

AC-R2-11: This has been corrected

RC2-12: Figure 1a: Capital L for both Latitude and Longitude. Decimal Degrees on both axes (latitude currently says decimals degree). Capital G for Gulf of St. Lawrence.

AC-R2-12: This has been corrected, See our answer to reviewer 1 (AC-R1-29) for the new Fig. 1.

RC2-13: Lines 131-132: diameter, 1 cm long) “were” collected at each site for analysis “of” surficial sediment characteristics, and stored at -20C until “analysis”.

AC-R2-13: This has been corrected

RC2-14: Line 152: within an hour “of” sampling...

AC-R2-14: This has been corrected

RC2-15: Line 154: using ice “packs”...

AC-R2-15: This has been corrected

RC2-16: Line 185: A pre-incubation period of 3 “h”...

AC-R2-16: This has been corrected.

RC2-17: Line 240: gently bubbled with He “for” 5 min...

AC-R2-17: This has been corrected.

RC2-18: Line 267: measured on “a” separate single sediment core...

AC-R2-18: This has been corrected.

RC2-19: Line 323: “and” Gastropods).

AC-R2-19: This has been corrected.