Ocean Science Discussions

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Comment on os-2021-59

Anonymous Referee #3

Referee comment on "Winter observations alter the seasonal perspectives of the nutrient transport pathways into the lower St. Lawrence Estuary" by Cynthia Evelyn Bluteau et al., Ocean Sci. Discuss., https://doi.org/10.5194/os-2021-59-RC3, 2021

This manuscript offers a valuable contribution to understanding the physical processes that supply nitrate to the St Lawrence Estuary and provides a new seasonal aspect to the problem using a data set collected during the challenging winter months. The main conclusion is that rivers supply a more important fraction of nitrate to the lower estuary than previously thought - vertical fluxes from deep nutrient rich water only exceed fluvial sources during the summer.

Overall the work presented is of good quality and for the most part well written. Ultimately I would like to see it published. However, there are a number of improvements and corrections that I believe should be made before it is accepted, to both elevate the quality of the manuscript and make it as accessible as possible to a wide readership - to the benefit of both the author and journal.

My major comments concern (1) better framing of the paper, (2) a more substantial discussion that draws upon a more complete budgeting exercise and (3) the method of calculation of vertical nitrate fluxes.

Also, given the conclusions drawn here, I think the title of the paper could be a bit bolder and more informative.

Major comments

(1) The introduction to this paper could do a much better job of framing the work that follows and in identifying its unique contribution to the understanding of nitrate supply to the St Laurence Estuary. The majority of the first paragraph for example is around access

to the Canadian Coast Guard vessel, information that belongs in the Methods section. I would advise that you consider re-structuring the introduction using the following generic guidance:

- Spell out what the importance (think global perspective) of the topic you are addressing is. i.e. why should we all care about nutrient budgets in estuaries
- Lay out (succinctly) what we already know
- Articulate what we don't know (or can't agree on), why this knowledge gap is important and what has prevented us from tackling it
- Tell the reader what this manuscript is offering to help address this gap

Much of the necessary material for this is there, but not laid out in a way that makes the necessary impact and clearly sets the scene for the work that follows. With some re-writing therefore the introduction could be significantly improved.

(2) In my opinion, the opportunity to present and discuss a (back of the envelope) nitrate budget for the lower St Laurence estuary has not been fully exploited. Lines 296-307 discuss a nitrate inventory, yet this is not compared to the total supply rates that are calculated here and summarised in Figure 8c. This is a shame. For example, between fall 2017 and winter 2018 there was a 280 mmol m^{-2} increase in depth integrated N within the lower estuary, which based on the 100 days between the surveys (and 6000 km^2 area) would have required a minimum supply rate of 195 mol s^{-1} (final paragraph of section 4.2). Based on the riverine (350 mol s^{-1}), tidal nutrient pump (6 mol s^{-1}) and shear within the LSLE (14 mol s^{-1}) that are calculated in this paper (total = 370 mol s^{-1}), and assuming that this is reflective of the period between the fall and winter surveys, approx. 175 mol s^{-1} of nitrate must have been lost from the LSLE during the same period. What processes (biological and physical) could account for this, e.g. estimated export out of the LSLE given typical velocities in the surface layer?

A similar calculation could be performed for the period between summer and fall 2017, albeit relying on summer fluxes reported in Cyr et al. 2015. Given that the total supply in the summer of 313 mol s^{-1} (river + tidal nutrient pump + shear in Figure 8c) is not hugely dissimilar to the winter (although the balance between sources has shifted) and that (by eye from Figure 5) it looks like the summer to fall increase in depth integrated N might be smaller, biological uptake may be playing a more important role (unsurprisingly). Reconciling that (roughly) with published uptake rates would nicely round off your story and improve the discussion section.

(a few more comments on lines 295-307 can be found below)

(3) Given the care that is taken to establish nitrate-salinity relationships and therefore accurate nitrate gradients, I am left a little unsatisfied that the vertical fluxes of nitrate have seemingly been taken at a fixed depth (e.g. 2.4 nmol m^{-2} s^{-1}at 80 m depth – line

356), as opposed to calculated on an isopycnal representative of the base of the surface layer. In a system that experiences considerable isopycnal heave this would be a much more robust approach.

Specific and more minor comments

Line 31 (and others throughout the whole manuscript). Use of the term 'upwelling' doesn't seem quite right here and is a bit mis-leading. My understanding is that oscillatory barotropic tidal currents heave isopycnals and nitrate isopleths up and down the face of the sill at the head of the channel. Turbulence generated over the sill (via e.g. internal wave generation /disspation, hydraulic jumps, Kelvin-Helmholtz instabilities, bottom friction...) then enables nitrate from the deep pool to be (irreversibly) mixed into the surface water. Cyr et al. (2015) uses the term tidal pump, which would be a good replacement for 'upwelling'.

Line 34. 'Entrainment of deep nutrient-rich water from estuarine circulation...' This is associated with shear-induced mixing that results from the estuarine circulation (and I presume also related to the propagation of internal waves?). In the re-working of the introduction, it would be good to provide a clearer mechanistic description of these processes.

Line 43. Vertical nitrate fluxes in the Mauritanian upwelling region are the highest ever reported then? If so, it would be good to make this more explicit in this sentence.

Line 45. Please make clear what process the 33 and 400 mol s^{-1} refers to.

Figure 1. Although the stations are marked with 'U..' and 'L..', The Upper- and Lower-St Laurence Estuary could be a little more clearly marked.

I understand the need for acronyms, but from a readability point of view, especially for those not so familiar with the area, you may like to consider cutting down on the use of HLC, LSLE and USLE, particularly early on in the manuscript. I do not suggest removing the acronyms all together, but a more blended approach might be helpful. Replacing LSLE and USLE with 'Lower- ' and 'Upper-estuary' would work fine in a lot of instances (also HLC with head of the channel) and make the manuscript much easier to read.

Line 75. 'The magnitude and impact of this nutrient transport process on primary production across the whole LSLE and Gulf system is debated'. Can you be a bit more explicit about what is in debate here – material more for the introduction. (ps. this is an instance where you might like to consider writing Lower St Laurence Estuary in full, rather

than the acronym).

Line 166. Is this the right way around? Do you instead mean that the nitrate supply at Quebec City is representative of what reaches the Lower estuary?

Liner 185. More specifically the 'mixing rate K' is the vertical eddy diffusivity.

Figure 4. Might be helpful to include vertical lines (at least in panel f) that mark 31.2 and 31.9 psu.

Line 264-265. 'Exaggerate'? This isn't especially well articulated. Please can you re-word. You mean upscale the vertical nitrate fluxes observed within the HLC based on an area of 200 km^2.

Line 273. Do you really mean Figure 4b?

Line 279. Figure 5. Small detail, but you might want to consider re-ordering the panels in Figure 5 so that they are referred to in order throughout the manuscript. It would be worth checking that this is also the case for other multi-panel figures.

Line 282. Figure 4a isn't the nitrate-salinity diagram. Do you mean Figure 4f?

Lines 296-307. As alluded to above, I think that this is material for the discussion section and is not yet used to full effect. Further to the suggestions above I'd emphasise the need to provide indicators of the magnitude of potential biological source and sink terms, e.g. what might remineralisation of organic matter over these months contribute?

Line 304 – it would be worth re-stating the area over which the averaging was performed. Also, state the seasons you are referring to with the statement 'between these two seasons' – it is rather inferred, but not crystal clear.

Query use of term 'load' in some contexts, e.g. line 306-307– is 195 mol s^{-1} not a supply rate?

Line 322. I presume (based on the following sentence) that the 350 mol s^{-1} is for February 2018 - but this needs making clearer.

Line 334. Looking at Figure 7e (yellow profile) I'd say that K exceeded 10^{-4} m^2 s^{-1} throughout the lower half of the water column, but not across 'most' of it. The upper 60 m is notably less than 10^{-4} m^2 s^{-1}.

Line 339-340. Can you be clearer as to which estimates of K might have been higher if collected at high tide – those in Cyr et al. 2015 or your own? From Fig 2 I thought that VMP profiles at L0 were collected at high water?

Line 344-346. The calculation here is of the vertical flux across a 200 km^2 area, assumed to be representative of the HLC - the assumption then is that this N supply is distributed across the whole LSLE – a much wider area downstream. The scentence needs re-wording to better articulate this (if this is indeed what is meant). This is the vertical flux associated with the processes operative at the head of the channel – i.e. tidal pumping.

Figure 8 – panel (c) should be placed below (a) and (b)

Please thoroughly check all the references. There are multiple examples of where the Journal name and/or article doi is missing.

Line 73. 'milder inflow'. You mean 'weaker'? 'Milder' is a slightly odd word to use here.

Line 75. Full stop after 'becomes saltier'.

Line 96. '...and nutrient concentrations...'

Line 106 (and others). Super and subscripts for NO_3^- etc

Line 241 – 'concentrations FROM the vmp...'

Line 269. First sentence needs re-wording.

Line 291. This sentence doesn’t end very clearly. Can you re-word slightly to make clearer that you mean that nitrate uptake in surface waters during the summer is higher than during winter and fall.