Point-by-Point Response

Rain-fed streams dilute inorganic nutrients but subsidise organic matter-associated nutrients in coastal waters of the northeast Pacific Ocean

ANONYMOUS REFEREE #1

General comments

This paper presents valuable and unique riverine nutrient dataset with surprisingly low macronutrient concentrations. In general, we consider that riverine nutrient loadings fertilize coastal primary production and then ecosystems. However, the present study demonstrates a quite different picture. This paper contains useful data for both freshwater and marine researchers and can connect the separated research fields so far. The following points should be improved before this paper being considered for publishing in Biogeosciences.

Thank you very much for your considered and constructive feedback!

Major comments

1. A link between Introduction-results-discussion-conclusion is not established well. In particular, the key issues described in Discussion section are not appropriately raised in Introduction section. Some improvements for this can lead the reader smoothly from Introduction to Conclusion.

Thank you very much for this constructive comment. We have critically examined the links between the manuscript sections and identified a couple of topics discussed later in the manuscript that were not introduced at the outset. Notably, this was the case for the impact of the El Niño Southern Oscillation on the land–ocean connection and variability in nearshore mixing, which are now raised within the Introduction section, respectively.

2. Very low inorganic macronutrient concentrations in the present freshwater systems is unique and interesting. I would like to confirm whether freshwater nutrient concentrations in these watersheds have not been reported in past studies. If this is the first report, that should state clearly. If some previous studies exist, the authors should describe whether the present results are consistent with previous results.

Freshwater nutrient concentrations have not been previously reported for these watersheds. Only a subset (Aug. 2014 to Dec. 2016) of the dissolved organic carbon (DOC) concentrations have been previously published in Oliver et al. (2017) and St. Pierre and Oliver et al. (2020). A statement to this effect has been added to the methods.

Another important message of this study may be the importance of measurements of organic nutrients such as DON and DOP in addition to inorganic macronutrients, because organic nutrients are less frequently analyzed for river waters.

The sentence, “In contrast to the field’s prevailing focus on macronutrients (NO_{3^-}, PO_4^{3-}, $Si(OH)_4$), our results highlight the need to measure organic nutrient (DON, DOP) concentrations to fully understand the impact of freshwater exports on nearshore ecosystems." has been added to the conclusions.

Specific comments

3. L37. Silicon is usually treated as a macronutrient as shown by the authors for C:N:Si:P:Fe stoichiometery in the next paragraph.

The word "micronutrients" has been exchanged for "other nutrients".

4. L75. Readers need to know why this system should be targeted, but we cannot find any explanations in Introduction section.

The rationale for using the North Pacific Coastal Temperate Rainforest (NPCTR) more broadly as a study region is highlighted in the preceding paragraph, namely that there is a strong connection between land and sea across the region. To reinforce this idea, we now state in the introduction, "The Calvert and Hecate Island systems are broadly representative of the many small rainfall-dominated coastal watersheds that define the outer coast of the NPCTR in BC and Alaska (Oliver et al., 2017). Because of the large freshwater fluxes from the NPCTR to the coastal ocean, it is an ideal region in which to examine the connection between land and sea (Bidlack et al., in press)."

5. L215. Please show a reason for using the "Half".

Applying half the limit of detection is one of several possible conventions for dealing with analytical results below detection (Analytical Methods Committee, 2001). This approach is widely used, including by the National Pollutant Release Inventory of the Canadian federal government (link), and recognizes that values below this limit cannot be differentiated from any background noise, but is somewhat arbitrary (Croghan and Egeghy, 2003). While we acknowledge the biases of this method (Helsel, 2009), it is a reasonable approach for this dataset given the large number of parameters and systems that were modeled. We have added an explanation to this effect in the methods.

Analytical Methods Committee: What should be done with results below the detection limit? Mentioning the unmentionable. amc technical brief, Royal Society of Chemistry (Ed.), Vol. 5, 2001.

Croghan, C. and Egeghy, P.P.: Methods of dealing with values below the limit of detection using SAS. Presented at Southeastern SAS User Group, St. Petersburg Florida, September 22-24, 2003.

Helsel, D.R.: Summing Nondetects: Incorporating Low-Level Contaminants in Risk Assessment. Integrated Environmental Assessment and Management, 6, 361-366, 2009.

6. L261. Fig. 2a –> 2b

Reference to Fig. 2a-c has now been made at the end of this sentence.

7. L264. Highest temperatures are found in July from the X-axis label.

The text has been changed to reflect this.

8. L269. From Fig. 3a, highest Chl-a may be found in May 2015 for me.

Our mistake! Indeed the highest chlorophyll *a* concentration was recorded in May 2015 (3.917±0.3882 µg L^{-1}). The sentence has been adjusted to reflect this.

9. L270. Detailed explanations are required how the authors determine the peaks of primary production.

We recognize that this statement was ambiguous as the "peak" (i.e., highest mean monthly concentration of chlorophyll *a*) occurs in different months during each of the four study years: May in 2015 and 2017, June in 2016, and April in 2018. We have therefore edited the text to read, "… production peaked between April and June and again between July and August…". Peaks were identified as those time periods where concentrations of chlorophyll *a* were at their highest during the annual cycle.

10. L271. What is the advantage to show mean nutrient concentrations in marine waters regardless of such large seasonal variations?

The rationale behind showing mean nutrient concentrations in marine waters was to contrast these with the freshwater systems. From these measurements, it is apparent that – on average – concentrations of NO_3^-, PO_4^{3-}, and $Si(OH)_4$ far exceed those in freshwaters, but freshwater concentrations of DOC far exceeded those in marine waters. Seasonal distinctions are discussed thereafter.

11. L319. PN –> particulate N (PN = TN - TDN)

The change has been made.

12. L387. St. Pierre and Oliver et al. –> St. Pierre et al.?

St. Pierre and Oliver shared first authorship of the 2020 publication in Limnology and Oceanography, hence why the reference is written as St. Pierre and Oliver et al. (2020) throughout the manuscript.

13. L390. The "assuming no loss" for dFe is generally not acceptable as shown in Fig. 6.

We completely agree with the reviewer that this is a major assumption. We are, however, lacking data on specific rates of dFe loss/reprocessing in nearshore waters of this region, so would be remiss to attempt an estimate otherwise. In acknowledgement of the limitations of this assumption, we have added a caveat in the sentence that follows this estimate: "However, given our observations (Fig. 6) and what is known about dFe loss from the water column in nearshore ecosystems, we acknowledge that the assumption of no loss is likely not realized and as such, these estimates represent a hypothetical upper bound on the possible stimulation of primary production by freshwater dFe exports."

14. L413. So, what are these related to the Kwakshua Channel system?

We have now added a statement in the discussion that applies these general findings about ENSO in the coastal northeast Pacific Ocean to our study region. Whereas Whitney and Welch (2002) observed the differences in nutrient availability across the wider northeast Pacific region, we do not find this to be the case at the scale of the Kwakshua Channel system, where seasonal nutrient depletion and replenishment was fairly consistent between years. Given that the Kwakshua Channel system is sheltered from direct offshore influences, we would still expect the patterns highlighted in the Whitney and Welch study to hold at larger spatial scales. This conclusion has been added to section 4.1.

15. L477. As well as heavily human-impacted watersheds, not impacted watersheds also probably have been studied. Such data can be picked up here and discussed with the present results.

We searched the literature quite thoroughly for examples of paired freshwater-marine nutrient surveys that were not within heavily human-impacted watersheds, but had difficulty coming up with examples where there was no significant human impact. There are some examples within the Arctic; however, Arctic watersheds are undergoing rapid environmental change (permafrost thaw, enhanced erosion, changing terrestrial productivity) that is significantly altering the exports of terrestrial materials and nutrients to nearshore environments such that comparing the Central Coast study sites to those in the Arctic is not without significant drawbacks. That being said, we have added an additional sentence to the paragraph further expanding on the reference to Cuevas et al., 2019.

Cuevas, L. A., Tapia, F. J., Iriarte, J. L., González, H. E., Silva, N., and Vargas, C. A.: Interplay between freshwater discharge and oceanic waters modulates phytoplankton size-structure in fjords and channel systems of the Chilean Patagonia, Progr. Oceanogr., 173, 103-113, https://doi.org/10.1016/j.pocean.2019.02.012, 2019.

16. L498. The terrestrial DON flux may elevate the contribution of riverine N on marine primary production of this system, but that is probably still quantitatively a small portion to support primary production.

Without site-specific regeneration rates, it is difficult to quantify (without a large degree of uncertainty) the impact that this DON flux has on marine primary production of the Kwakshua Channel system. The application of nitrogen regeneration potentials from other coastal areas to the Kwakshua Channels to the DON flux is the extent to which we feel comfortable quantitatively speculating on this potential subsidy, as described in more detail in response to point #19.

17. L502. Kortzinger et al. 2001?

The year “2001” has been added to the reference.

18. L508. The author should examine relative abundance of Si and N in subsurface waters, which is the primary source of nutrients for the Channel system surface waters. Si will be enriched than N in such source waters.

This is an excellent suggestion for future research within this system! Bottom water nutrient chemistry data have been collected from a small number of sites since the start of the sampling program, but has neither the spatial nor temporal resolution of the surface water dataset. As suggested by the other reviewer, we have expanded our discussion of the possible influence of bottom waters on surface nutrient biogeochemistry.

19. L631. Whether N input as DON have a significant impact on the spring bloom should be examined quantitatively with some assumptions. Lack of marine DON data may be an issue for this consideration.

Earlier in this section, we describe a quantitative assessment of the potential regeneration of DIN from DON using regeneration potentials from the Arctic region; however, these regeneration potentials are already speculative in that they are not based on local data, and we feel that extending these regeneration potentials to possible subsidy of the spring bloom would add too much uncertainty. We further describe the uncertainty of the initial estimate in the revised manuscript. As stated by the reviewer, the lack of detailed marine DON and NH_4^+ data do hinder our ability to place bounds on these regeneration estimates. Understanding nitrogen dynamics in nearshore waters is a top priority for research moving forwards in this area.