

The authors have thoughtfully and thoroughly responded to comments on the previous draft and that effort is appreciated. This is a valuable contribution regarding early spring discharge at a tidewater glacier front, which convincingly combines a number of lines of evidence to support their conclusions of higher primary productivity under the ice in such fjords. The purpose and conclusions of the manuscript are now much clearer and, as such, the manuscript is overall greatly improved. I believe that the manuscript is now much improved and close to being ready for submission. However, I do have some specific suggestions below to once again, aid clarity, for the authors' consideration.

We want to thank the reviewer sincerely for the positive evaluation and very constructive and detailed last feedback which helped to improve the manuscript. We corrected the manuscript as outlined below or provide detailed explanations to more general questions of the reviewer. We also corrected some additional minor grammatical issues.

We also realized that Fig. 5, submitted with the last version was still missing the asterisks indicating significant linear regression and had values with too many digits behind the comma. We also realized that we plotted Nutrients against brine salinities, while a plot of Nutrients against bulk salinities are more meaningful (while showing the same trends). Thus, we now uploaded the corrected figure. This change has no implications on any conclusion drawn in the paper, but we believe it provides better illustration of the salinity versus nutrient relationship to the reader. In fig 1, we realized that we plotted CTD profiles starting from the water surface while it is much more meaningful to show data starting at the sea ice-water interface and we adjusted the plot accordingly.

L14: the meaning of the word "sufficient" is unclear. Do you mean the flux is sufficient or that the associated nutrient upwelling is sufficient? It would be good to be precise here.

We specified that the flux is sufficient in the following way: "We hypothesized that submarine discharge under sea ice is present in early spring and **that its flux is sufficient to increase phytoplankton primary productivity.**"

L18: change to "we still observed... and primary production at this time of year"

We changed the sentence accordingly.

L18-19: "subglacial meltwater" .. suggest changing / specifying "submarine discharge"?

We changed "subglacial meltwater" to "subglacial discharge" as suggested.

L20: the reason for the two-fold higher under-ice irradiance is not clear from the preceding sentences.

We added following detail: "...a two-fold higher under-ice irradiance **due to a thinner snow cover...**"

L22: "The nutrient supply increased primary production" .. how are you disentangling nutrient supply from the effects of stratification and irradiance?

We disentangled the effects of nutrients from stratification and irradiance based on the results of the reciprocal transplant experiment, where the addition of sterile filtered surface water from SG lead to higher primary production in both IE and SG systems, while filtered seawater from the IE had the opposite effect. We added following details: “Reciprocal transplant experiments showed that nutrient supply increased primary production by approximately 30 %.”

L22: increased primary production by 30% where? In the seawater? In the sea ice? Both?

In seawater. We added the information: “...increased phytoplankton primary production by approximately 30 %.”

L23: the meaning of the phrase “limiting the inhabitable place” is unclear

With a lower brine volume fraction the brine channels become smaller and fewer leading to place limitation. We added following specification: “inhabitable brine channel space”

L22-23: You switch here to talking about the sea ice communities I believe, and in then in the next sentences are back (?) to talking about the under ice marine communities.. it might be good to keep the discussion about the water together and then talk about the sea ice.

We talk about seawater in the beginning before adding one sentence about sea ice and finishing with a sentence about both sea ice and seawater combined. We tried now to clarify it by either using the term “sea ice” or “seawater”, or “phytoplankton” to make sure about what we are talking about in the different sentences.

L26-28: This last sentence (arguably an important one since it's the end of the abstract) is unclear. Suggest re-writing. Perhaps split into –making the part after “while sea ice” a new sentence. There are just too many qualifiers re: the sea ice to take in to come away with the overall take-home message as currently written. Also, for the first part of the sentence regarding the retreat of tidewater glaciers, I think the authors should instead emphasize the possibility of longer, more extensive melt seasons with climate change and thus the higher likelihood for more early season spring discharge and what that effect is on primary production. The study of this spring early-season discharge is really the novel aspect of this paper –so there's no need (in my opinion) to focus on the eventual retreat of tidewater glaciers –which is further into the future, and involves more complicated considerations of bed slopes.

We split the sentence as suggested. Regarding the first sentence, we prefer to keep the take home message. One main message of our paper is also that the submarine discharge is somewhat decoupled from snowmelt, which makes the argument of earlier and increased discharge with climate change a bit out of place in the context of our paper. Furthermore, it is not clear if the increased discharge can compensate the negative effects of a decreasing grounding line depth and a consequently decreasing plume dilution factor. Thus, we argue that tidewater glacier retreat to land is most important in the context of our study.

L38: change “upwelling” to “upwelled”

We changed the term accordingly.

L39 & L43: while I appreciate the authors adding in approximate distances, it seems strange that the region where primary productivity is low in front of the glaciers is in the same range as the region at some distance out where it is higher –particularly since the authors cite the same study.

The ranges specify a light inhibited area close to the glacier in contrast to an upwelling fertilized area further away. We tried to specify this in the following way: “Primary production is typically low in direct proximity to the glacier front (within hundreds of meters to kilometres from the glacier front...increase summer primary production at some distance (“more than hundreds of meters to kilometres away from the glacier front”

In L39 suggest refining the estimate for low primary productivity in close proximity to the glacier front according to the figure referenced in Halbach et al., 2019.

We added following details: “Primary production and biomass is typically low (e.g. $0.6 \pm 0.3 \text{ mg Chl a m}^{-3}$, Halbach et al., 2019) in direct proximity to the glacier front”

L41: add “type” after glacial bedrock

We added “type” as suggested.

L42: change “surface increase” to “surface canincrease”

We changed the statement accordingly.

L48: change to “anoverall lowdischarge flux”

We changed the sentence accordingly.

L49: change to “However, the limited amount”

We changed the sentence accordingly.

L50: change to “quantification of spring subglacial outflow” and “on bothsea ice..”

We changed the sentence accordingly.

L57: change to “Glacier terminus melt rates of basal ice at the glacier-marine ininterface..”

We changed the sentence accordingly.

L58: change to “seasonal subglacial outflow flux...”

We changed the sentence accordingly, but did not include the word seasonal, since it seems a bit misplaced.

L59: suggest change “terminus” to “basal” and “than in” to “compared to the” Also, was their evidence for winter upwelling in the Moon et al. (2018) study? Was the flux high enough to permit this? It’s unclear as written but if this was the case I would suggest explicitly stating so.

We changed the sentence accordingly. We also added a sentence putting the iceberg meltwater fluxes into context to other main sources. “The freshwater flux from these icebergs exceeds summer river runoff and reaches values of early summer (June-July) subglacial discharge (Moon et al., 2018), which may allow winter upwelling.”

L60: change depth to “depths”, change “deep terminus melt” to “basal ice melt”

We changed the sentence accordingly.

L63: I wonder why the authors are specifically mentioning cold-based glaciers here – especially as because later they emphasize that their results are extendable to warm or polythermal ice masses. Suggest deleting the specific mention of cold-based here and instead emphasize that this has been observed at several warm and polythermal ice masses in Svalbard.

We agree and removed the specific reference to cold-based glaciers.

L72: change “subglacial” to “submarine”?

We changed the sentence accordingly.

L75: change “to the summer situation” to “in the summer”.

We changed the sentence accordingly.

L80: change “nutrient ion enrichment” to “nutrient anion enrichment”?

We changed the sentence accordingly.

L82-84: Sentence beginning with “Especially” is very unclear and seems a tad redundant (at least as written).

We shortened the sentence and merged it with the sentence before to avoid redundancy and increase clarity: “We suggest that these nutrients can significantly increase primary production in front of tidewater glaciers compared to similar fjords without these glaciers especially after nutrients supplied via winter mixing are used up (Leu et al., 2015).”

L88-90: Would suggest deleting this sentence and focusing instead on impact of warmer and longer melt seasons –no need to extend to glacier retreat which is really beyond the scope of the study –see comments above for abstract.

As suggested above, we prefer to keep the description of tidewater glacier retreat. A main message of our paper is also that the submarine discharge is somewhat decoupled from snowmelt, which makes the argument of earlier and increased discharge with climate change less relevant than the shallowing grounding line depth. We do have a rather detailed discussion on the effect of the glacier grounding line depth effect on plume dilution, which benefits from an introduction of retreating and shallowing tidewater glacier. Furthermore, it is not clear if the increased discharge can compensate the negative effects of a decreasing grounding line depth and a consequently decreasing plume dilution factor. Thus, we argue that tidewater glacier retreat to land is most important in the context of our study.

L93: delete “ice algae start growing” and also

We changed the sentence accordingly.

L94: delete” within sea ice”

We changed the sentence accordingly.

L97: change “subglacial upwelling” to “subglacially induced upwelling”

We changed the sentence accordingly.

L101: extra space between “to” and “wind”

We removed the extra space.

L111-112: Re-write the last sentence: We suggest that even though subglacial upwelling is diminished in the spring, compared to the summer, in the absence of wind mixing, the enriched nutrient may enhance algal growth at this time of year.

We changed the sentence accordingly.

L114: The way this sentence is written begs the question –and what about the other glacier front.. why not describe that too?

We added the suggested details: “We used the natural conditions in a Svalbard fjord as a model system contrasting the biological response at two glacier fronts. Only one of the glacier fronts supplies submarine freshwater discharge during the winter/spring (early spring) transition period while a fast ice cover was present. In contrast, the other glacier front is mostly land-terminating.”

L146: I have to admit to still being confused as to why additional water was added to the sea ice cores for melting. Why not just directly melt the core?

Melting ice cores in filtered seawater is a common and generally accepted approach in marine sea ice biology. If the ice core would melt directly, organisms living in the brine channels in Salinities commonly reaching 60PSU would be subject to very low bulk salinities (brine channel liquid + melted ice) mostly about 5 PSU. Consequently the organisms would experience osmotic shock and especially flagellates have been described to experience osmolysis, in addition to overall lower primary production

estimates due to osmotic stress. Hence, filtered seawater is added to reach salinities of the melted ice core of about 20 PSU (50% SW with 35 PSU + 50% sea ice of 5 PSU), which leads to less stress and survival of flagellates. We suggest that the reference that we already added gives detailed information about this approach and problem of direct melting of ice cores, which would be beyond the scope of this paper.

L247: Do you mean you transferred the phytoplankton communities into their respective environments? Sentence is a bit unclear.

We added following clarifications: “50 ml of the water containing the phytoplankton community communities of SG or IE were transferred into 50 ml sterile filtered (0.2 μ m) seawater of SG or IE in 100 ml polyethylene bottles. The bottles with IE communities were then incubated under the ice at the IE station and the SG communities under the ice at the SG station.”

L251-252: Last sentence is unclear. Is “adequate” the correct word here?
We replaced “adequate” with “respective”.

L321: Change therefor to therefore

We corrected the typo.

L325: extra space after 4 μ mol/L

We removed the extra space.

L345: It's unclear in this paragraph what site you are referring too? Is this for all the sites>

We added the specification that these calculations were done at the SG site.

L349-350: Is this estimate for inorganic nutrients valid in light of the non-conservative mixing discussed in the paragraph prior?

Inorganic nutrients behave conservatively in the seawater endmember (linear relationship with salinity), which allows us to use them for these mixing calculations. We added following sentence for clarification: “Inorganic nutrients behaved conservatively at the IE reference (Fig. 5a-c), which allows similar mixing calculation of the bottom water fraction.”

L437: Add phrase “there was no” after “In addition”

We added the phrase as suggested.

L444: change to “below the freezing point”

We changed the sentence accordingly.

L452: change to glacier meltwater contributions

We changed the sentence accordingly.

L462: change to have enriched silicate concentrations

We changed the sentence accordingly.

L464: Note emphasis here on warm or polythermal-based glaciers –see comment above regarding line in introduction on cold-based glaciers

We changed the statement in the introduction as suggested above.

L467: change “last” to late

We changed the sentence accordingly.

L468: change “melting” to melt season which as remained throughout the winter. (delete extra period)

We changed the sentence accordingly.

L473: change “substantially” to much

We changed the sentence accordingly.

L475: change “productions” to production.

We changed the sentence accordingly.

L505: move phrase “in Billerfjorden” to the end of the sentence

We changed the sentence accordingly.

L515: make second part of the sentence beginning with “explaining the higher summer ...” a newsentence or re-write to make it follow from the first part of the sentence. As written, it doesn’t.

We split the sentence in two: “In fact, the glacier terminus at SG was shallower (approx. 20 m) than any other studied tidewater glacier on Svalbard (70 m depth at Kronebreen, Halbach et al., 2019) or Greenland (> 100 m, Hopwood et al., 2020). Hence, the higher summer entrainment factors estimated in Kongsfjorden (3, Halbach et al., 2019) and Greenland (6 to 310, Hopwood et al., 2020) are not surprising.”

L519: is “it” referring to submarine upwelling? Suggest clarifying.

Yes it is. We added the information.

L547: With regards to stratification observed at the SG site, would the physical mechanism of upwelling disturb this stratification?

Considering the strength of the stratification due to salinity changes from around 35 to 5 within 1-2 m, and the low plume dilution factor of 1.6, we would not expect the upwelling to be strong enough for substantial physical disturbance.

L604: Typo in “studiy”

We corrected the typo.

L607: Change “studies” to study periods

We changed the sentence accordingly.

L682: Change “Last” to Lastly

We changed the term accordingly.

L698: Change “most of” to much and “different evidence” to different lines of evidence

We changed the sentence accordingly.

L704: systems more similar to NG or IE? NG seems appropriate to refer to here since this is actually an adjacent land-terminating site correct?

We agree and changed the sentence accordingly.

L705: change to “but would result in higher biomass..”

We changed the sentence accordingly.

L706: Sentence beginning with “The pelagic ..” is unclear and a fragment. Suggest re-writing.

We rewrote the sentence in the following way: “Considering the increased sedimentation rate at IE, we expect the pelagic/sympagic benthic coupling to become stronger”

L720: What is the depth of the effect of wind-induced vertical mixing?

The depth effect is highly dependent on the water column stratification (mostly salinity of the surface water) with strong seasonal and spatial variation. Thus, we cannot give any exact depth, but prefer to stay with this simplified statement of increased wind leading to increased mixing.