Constance Choquel on behalf of all authors

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Dear Referee,

Thank you for your constructive comment and your interest in our work. We agree with the majority of the suggestions that you bring to our study. Indeed, this study highlights the importance of the contributions of denitrifying benthic foraminifera regarding contrasted oxygen and nitrate conditions at two different sites in a fjord. We agree that the introductory part on the nitrogen cycle deserves to be better contextualized with more general bibliographical references. It is, however, premature to engage in the description of the effects of foram denitrification on primary production and nitrogen fixation. We prefer to remain cautious in the discussion and not speculate too much.

Question 1: In my opinion, the title should include the regional characteristics including Gullmar Fjord or the North Sea rather than a generalized focus on invasive species' contribution to nitrate uptake. Or the overall discussion of this MS should include more of; what does this mean? This invasive species is increasing in numbers in the region (maybe in other areas too?) which is capable of such contribution to N dynamics and we are expecting to see in the future. The observation of its increase in the region is valuable. Nevertheless, I am not sure this is exactly the message of this specific study.

Answer 1: We suggest a novel title as "Total nitrate uptake by benthic foraminifera in a sill fjord environment"

Question 2: Do authors think before the invasion of Nonionella sp. T1 benthic denitrification was overall less than their observations in this study or it has been overall the same values, but the other species are simply losing the competition now in the region? Is there any indication or previous study focusing on that? if this is the first time observation on this specific topic in this region, the authors should emphasize it even more.

Answer 2: Station GF17-3 (50 m) was sampled for the first time in this study. There is therefore no records on the benthic denitrification and the assemblages of foraminifera at this precise location of the Fjord.

Question 3: Please provide references for benthic foraminifera taxonomy in supplementary material, considering which publication (maybe even which figure) was used for identification of the species listed in Table S3 and S4.
Answer 3: Yes we will add them. We used Charrieau et al., (2018) and references therein.

Question 4: Abstract: Line 14: there is no flow/connection between the first 2-3 sentences. It would be better to focus on first the importance of invasive species in certain regions or the importance of oxygen, nitrate dynamics in such regions. I think authors should decide how to formulate the most important message of this MS. Line 18: micro-distribution: microhabitat instead? Line 19: worth to mention Gel methodology already here for least confusion of 2D geochemistry concept. The next sentence also needs a reshape giving a broader idea of these contrasting sites. Oxygenated overlying and bottom waters with high nitrate content in porewaters vs hypoxic bottom waters where porewater is nitrate scarce.

Answer 4: We will focus the abstract on the importance of the contribution of denitrifying forams in the Gullmar fjord according to the contrasting geochemical conditions in oxygen and nitrates. We will rewrite the sentence concerning the methodology of 2D gels.

Question 5: Introduction: First sentence: I am confused with nomenclature, unit choice, and conversion of values here. There are many studies focusing on different values for the term hypoxia so I highly recommend citing the publication that the authors followed. This is also valid for unit choice, I am familiar with dissolved oxygen concentration units of mL/L and umol/kg or umol/L. Generally, 2 ml/l is circa 90 umol/l. Most of the studies concerning benthic foraminifera in low oxygen environments focus on these units. I just wonder which study the authors decided to follow in this case.

Answer 5: We use only the unit µmol/L in the study. The hypoxia threshold used is 63 µmol/L cited by Breitburg 2018 corresponding to 2 mg/L and 1.4 ml/L.

Question 6: Line 33: contrasted dissolved O2 conditions: Over what time interval? a year? Different seasons? or different sampling sites? I know this information will be mentioned later but it would be nice to give the information here already.

Answer 6 : Yes. Two contrasting oxygen stations, one hypoxic in the deep basin (GF17-1) at the end of autumn 2017 and an oxic station towards the mouth of the fjord.

Question 7: Line 44: "total denitrification". Overall, denitrification together with anammox is also called N-loss. I recommend authors have a look at some other reviews on marine N cycle: Galloway et al., 2004, Gruber and Sarmiento, 1997; Gruber and Galloway, 2008. Maybe even Sigman et al 2009 (is in the direction of N isotope chemistry but is a nice review). These are reviews that would give a bit more insight and overview of the marine N cycle with perspective to open sea/ocean. There are many publications on coastal systems and while investigation on N2 loss and its impact on eutrophication I came across to Seitzinger 1988 I think should be included either to the introduction or the discussion to make the findings of this study more pronounced. It is worth mentioning the potential benefit of benthic denitrification to eutrophication already in the introduction giving examples from previous studies.

Answer 7: Some of these references can support the introductory part of the state of the art of the nitrogen cycle in marine sediments in order to contextualize more broadly the importance of identifying the sources and outputs of nitrogen from a system (Galloway, 2004). In most coastal environments such as the Baltic Sea the loss of nitrogen through denitrification exceeds the supply of nitrogen through nitrogen fixation. These sink regions of the ocean are the areas associated with the anoxic regions (Grubber and Sarmiento 1997). When benthic denitrification exceeds nitrogen fixation, eutrophication can be mitigated via nitrogen loss (Seitzinger 1988). The Gullmar Fjord would be a sink region.

In the last part of the discussion (4.4) it is possible to briefly provide more details on the eutrophication state of Gullmar Fjord. Primary production in Gullmar Fjord is dominated by diatoms bloom in spring and autumn (Lindahl and Hernroth, 1983). Since the 1990s Lindahl et al. (2003) observed the increase in primary production of the Gullmar Fjord, therefore a potential eutrophication of the Fjord. This increase in original productivity also shown in the adjacent Kattegat could be related to the nitrogen input loading from the land and atmosphere (Carstensen et al. (2003)). Lindahl et al. (2003), argued that primary production of the Gullmar fjord was due to climatic forces resulting from a strong positive North Atlantic Oscillation (NAO) index, which increased the availability of deepwater nutrients

(Kattegat nitrate-rich) and due to warmer ocean. The benthic denitrification of Gullmar Fjord makes it possible not to supply the system with nitrogen available for primary producers. Denitrifying foraminifera including *Nonionella* sp. T1 could thus help counterbalance this eutrophication by increasing the loss of N_2. Glock et al., (2013) also supported denitrifying forams in OMZ contributed to N-loss (until 46%). Then, foraminifera intracellular nitrates become unavailable to the system and can be bio-transported and permanently sequestered in sediments (Glock et al., 2013; Prokopenko et al., 2011).

Question 8: Line 48: nitrification cannot process under low oxygen conditions. How low? Please indicate the values here.

Answer 8: According to Mortimer et al., (2004) and Rysgaard et al., (1994) once the oxygen in the sediment is no longer detected (close to 0 µmol / L) the nitrification also becomes undetectable.

Question 9: Section 2 Methods Suggestion for site or expedition indicator throughout the text: Instead of 1st and 2nd cruise, authors could use years, e.g., 2017 and 2018.

Answer 9: Yes indeed it may be clearer using the dates of the missions

Question 10: Line 109: (see previous studies) please indicate references instead.

Answer 10: Nordberg and al., 2000; Filipsson and Nordberg, (2004)

Question 11: Line 127: is there a special reason for the choice of 100 um fraction? Whereas well accepted fractions are 63, 125, and 150 um?

Answer 11: In the previous studies in the Gullmar Fjord, Skagerrak and Kattegat, the size fraction > 100 µm has most commonly been used for foraminiferal analyses (see Charrieau et al., 2018 and references therein).

Question 12: Line 140 and figure 4: Is Figure 4 needed? Is this method described here the first time and different from Metzger et al., 2016?

Answer 12: This is the same method as Metzger et al., 2016 but since the steps in this method can be difficult to follow for non-specialists we find the diagram helps to easily visualize the method.

Question 13: Line 202: I find Table S1 rather important for this MS. What about involving it to the main MS but not only in supplementary information?

Answer 13: This table is better in SI and it is easy accessible on the webpage.

Question 14: 4. Discussion: Line 301: I think it should be GF17-1A and 1C in the parenthesis.

Answer 14: ok

Question 15: Line 309: (our results) data not shown and presented? If so, please mention or indicate where this information comes from. In the same line, it would be better to mention some of the previous studies showing differences too.

Answer 15: Ok

Question 16: I recommend changing the titles for the section 4.2 and 4.3 to ": : :T1/foraminifera habitat in relation with the nitrate micro-distribution: : :" since there might be other factors having an impact on the ecology of these species, it would be better to keep the focus on nitrate and oxygen in these sections of the discussion.

Answer 16: We will merge the two parts 4.2 and 4.3

4.3 The foraminifera ecology considering the nitrate micro-distribution

Inside, there will be a first paragraph about oxic station and a second paragraph about hypoxic station.

Question 17: Line 395: once again discussion on benthic N loss contribution to eutrophication: I think this needs a broader discussion and requires some references. Moreover, does N2 flux from sediment promote N2 fixation, and thus, e.g., cyanobacterial activity? Are there studies focusing on N2 fix vs N loss in Gullmar Fjord or similar settings? I think considering these would improve the discussion significantly.

Answer 17: it's difficult to answer this question without getting too speculative

The question here suggests that nitrogen supply via benthic denitrification of the forams could be captured by N_2-fixing cyanobacteria and participate in their development. Significant cyanobacteria blooms are already known in the Baltic Sea (Boesch 2003 Swedish agency report). In the Gullmar fjord there are few studies on cyanobacteria (Croot, 2003) the evolution of N_2-fixation by these cyanobacteria in Gullmar Fjord is not obvious and there is a lack of data. Benthic denitrification of the forams may participate in the N pool to be fixed by cyanobacteria but this hypothesis is too speculative, cyanobacteria in Gullmar Fjord do not appear to be a major threat to the system at this time.