

# Response to Reviewer 1 Comments

**Overall Response to Reviewer 1:** First we would like to thank the reviewer for taking the time to read the manuscript and give critical and constructive feedback. This study uses various types of data, and it was at times challenging to squeeze it all into a cohesive story. The reviewer gave a lot of useful suggestions to make our manuscript more concise and easier to read. This led to us removing certain superfluous aspects which were less important to the narrative. We also chose to place less emphasis on the ‘reference’ sites as the spatial variability of these sites make them less representative of the trawl treatment plots. All reference (now called untrawled adjacent) information can be found in the updated supplementary materials. Readers can focus on the before-after effects in the manuscript but may refer to the supplement if they are curious about potential temporal effects in the untrawled areas during the course of the experiments.

## Reviewer 1 comments

### General comments

This manuscript reports results from a comprehensive experimental investigation into the effects from two trawling gear types on *Lanice conchilega* habitats in the Vlakte van de Raan (Netherlands). Physical, biological and biogeochemical effects are well investigated and this work contributes significantly to the current evidence base, particularly regarding biochemical impacts from different gear types under varying environmental settings.

This paper matches well with the brief of the Biogeosciences journal, with other recent papers published in this journal on similar topics (e.g. Paradis, Pusceddu et al. (2019), De Borger, Tiano et al. (2021)). I would recommend the paper for publication after minor revisions.

### General concerns:

- Reviewer comment:** Reference sites: Reference site 2 seems to have significantly different grain size (Fig S1). Reference sites also have large variation in O<sub>2</sub> consumption and species densities (Fig 6), as well as higher mean mixing rates (Table 2) and generally higher species densities when compared to treatment sites (Fig 6). Are these sites definitely representative of treatment sites? Information should be provided in the methods on how it was assured that all treatment sites and reference sites were generally environmentally representative of each other.

**Response:** This is a valid issue that both reviewers have highlighted. The area had so much spatial variability that the ‘reference’ sites were not representative of all the treatment areas. The locations of the reference sites were, however, directly adjacent to the treatment sites. Data from these sites have thus been separated and named ‘Adjacent 1’ (AD1), and ‘Adjacent 2’ (AD2). We have also, now incorporated the third untrawled adjacent site (AD3) into text and Fig. 1 and have specified that the majority of its data came only at the T1 timestep (end of experimental period). When comparing between T0-T1 trawled treatments, we did not incorporate the “reference” sites in the analysis as we thought a before-after comparison would be more appropriate due to the large differences in spatial variation. Although inclusion of the reference/adjacent sites may help qualitative comparisons (observing potential temporal effects), to keep readers focused on the pure trawling effects, we have decided to move the reference/adjacent results from the main figures/Tables in the manuscript to the supplementary material. Upon further inspection, we also found a small error in the reporting and have seen that some of the reference T1 data was missing so this has been corrected. All reference/adjacent results can now be found in Supplementary Table S5. We have also removed the text referring to the BACI design of this study as perhaps it is not appropriate due to the before-after statistical comparison (i.e. lacking control).
- Reviewer comment:** Methods: It is not always clear how data analyses were undertaken e.g. Were the non-parametric tests undertaken in R and with what packages. How were the biological mixing models on bioturbation analysed, and with what software? Make sure sufficient detail is provided throughout the methods where necessary.

**Response:** We decided to exclude the results from the bio-mixing models as we are not confident that our results ( $D_B$ ) effectively describe the details of sediment transport in our study. As much of the data were consistent with non-local mixing models (often the case when tubeworms eat OM at the surface and inject it in depth) the  $D_B$  values only describe part of the sediment transport.

We have moved and modified our sentence stating that all statistics were conducted (and figures were created) using R, to the beginning of the statistics subsection in the methods. We also specify the R package used to carry out the mass budget analysis (“limSolve”; Soetaert et al., 2009) in the main text of the manuscript but we still feel like the detailed description of this methodology is best located in the supplementary material (our methods section is quite long already). Other software such as SpiArcBase (SPI), Qimera (bathymetry) and FMGeocoder Toolbox (backscatter) are specified in their respective sections in the methodology.

- Reviewer comment:** Results: Some of the results seem superfluous. e.g SMP POC and TN; and backscatter testing between all pairwise combinations and factors. Throughout the manuscript, results should only be reported where they contribute to the narrative of the paper and are mentioned within the discussion. I realise it is tempting to report all results which were produced within the investigation but, results should be removed where they are superfluous to the narrative, discussions or conclusions.  
**Response:** We have removed the water column results for SPM, POC and TN and have also removed the backscatter results describing potential differences between sample sites. The between site comparisons were meant to give some indication of the spatial variability of the experimental area, however, we see that this may not be communicated well and is probably confusing for readers. We have, thus moved the backscatter figure (originally Fig. 3) to the supplementary material (Fig. S6).

### Specific comments

- Reviewer comment:** L16: To add context it should be noted within the abstract that this is looking at “acute impacts by experimental disturbance from representative fishing gears”; or other similar phrasing conveying the same message.  
**Response:** The text has been edited to show that the two types of bottom trawls are specifically used to exploit North Sea sole.  
“This study explores the physical, biological and biogeochemical effects of ~~electric pulse and tickler chain rigged beam trawls~~ bottom trawl fishing on a coastal ecosystem dominated by the tube building polychaete, *Lanice conchilega*. Two specific gears types, both used to exploit North Sea sole (*Solea solea*), were compared: electric pulse trawls and tickler chain rigged beam trawls.”
- Reviewer comment:** L23: Taxon densities and species richness of what?  
**Response:** We have edited the text to state “macrobenthos densities and species richness”.
- Reviewer comment:** L35-36: It seems contradictory to say *L. conchilega* habitats are under “considerable threat” from bottom trawling, and then state that they have “biological resilience to bottom trawl impacts”.  
**Response:** Our original text here was not so clear. We want to state that biogenic reefs are well known to be vulnerable to trawl disturbance (Fariñas-Franco et al., 2018; Grabowski et al., 2014; Kaiser et al., 2002), however, *L. conchilega* habitats have been linked with resilience to bottom trawling (Rabaut et al., 2008). We added a few key words to these sentences which will hopefully help convey this point:  
“Bottom trawling activities are a common occurrence in North Sea *L. conchilega* dominated habitats (Rabaut, 2009) and can present a considerable threat to most biogenic reef ecosystems (Kaiser et al., 2002; Fariñas-Franco et al., 2018). Biological resilience to bottom trawl impacts have, however, been linked to both *L. conchilega* reefs (Rabaut et al., 2008) and the dynamic sandy habitats they are often found in...”
- Reviewer comment:** L40: Alter to state “Bottom fishing affects carbon cycling on the seafloor” or “in seabed sediments”.  
**Response:** We have modified the text to state “benthic carbon cycling”.
- Reviewer comment:** L42-43: again add “reduced mineralization of organic carbon in seabed sediments”.  
**Response:** We have added, “in seabed sediments” to the end of the sentence.
- Reviewer comment:** L91: State the minimum distance experimental areas were separated by.  
**Response:** The treatment plots were separated by a minimum of 100 m to try to avoid indirect impacts from nearby trawling. This information has now been added to this section.

10. **Reviewer comment:** L92-93/Fig 1: It would be clearer if these three sampling stations (western, middle and eastern) were shown within the figure. E.g. with lined boxes.  
**Response:** We attempted to create the map using lined boxes as suggested, however, this crowded the image and made it difficult to view the sample locations. The significance of the northwest, central and southeast stations (changed from: western, middle and eastern) was simply to gather three replicates representative of each trawled plot.
11. **Reviewer comment:** L94: What was the size of the reference areas? How close were they to treatment areas?  
**Response:** The reference areas were within 200-250 m to the nearest trawling locations as seen in figure 1. For this, we simply specified a point on the map which was near the trawled areas but far enough away to have a low chance of disturbance. The actual sampled locations varied within 80 m of the specified sampling coordinates. The text has been edited to describe these points.
12. **Reviewer comment:** L94: It would be good to give some descriptive information on how the different treatment and reference areas were determined to have similar/same environmental and biological settings.  
**Response:** The orientation and location of treatment plots and reference/adjacent areas were determined based on their position in a particular bathymetric depression. This depression was chosen based on previous data showing high macrobenthic biomass coupled with low trawling effort (as described in the first paragraph of the methods). We have added information regarding the position of the treatment plots and reference/adjacent areas to show that they were positioned to represent the different sections within this bathymetric depression.
13. **Reviewer comment:** L102: It would be clearer to move Table 1 to the supplementary material as it is overly detailed - simply put a descriptive sentence here (L102). E.g. that samples were collected between x-x hours before trawling and x-x hours after.  
**Response:** This issue was also pointed out by Reviewer 2. The table specifying exact sampling details has been moved to the supplementary materials. We have also shortened the text and referred to the table specifying sampling dates (Table S1).
14. **Reviewer comment:** L156-59: Here, and in other places within the methods (e.g. L141-146), you do not need to repeat the dates of sample collection if they are already reported in Table 1. If you want to add a brief descriptor in terms of time before/after trawling then try to be more general as suggested above (with reference to Table 1 for more detail).  
**Response:** The text has been shortened and modified to refer to Table S1 in the supplement which contains more detailed sampling information.
15. **Reviewer comment:** L161: I think it would be clearer if this simply said “Two out of the three box cores were subsampled for sediment parameters from each treatment and reference station”.  
**Response:** We have edited the text, as suggested, by the reviewer (it sounds nicer).
16. **Reviewer comment:** L163: Did all of the sediment pass through 1mm? If not, was this fraction considered?  
**Response:** Various shells and shell fragments did not pass through the 1mm sieve, however, these larger particles were not considered for grain size analysis. As seen in supplementary Fig. S1 most sediment particles measured were well under 500 micrometres.
17. **Reviewer comment:** L179: Should be simplified to state “Pore water was collected from the same box cores as used for sediment parameter sampling”.  
**Response:** As suggested, the text has been modified to show that the porewater cores were collected in the same box cores as the sediment parameter samples.
18. **Reviewer comment:** L293-295: The details of the results from all the different bio-mixing models do not seem to be reported. They should be present in a Supplementary table with the AIC scores for each model and the selected optimal model highlighted.  
**Response:** As detailed in the response to comment 1, we have removed information regarding the bio-mixing models. These were a late addition to the study and although, we were excited to include them, they probably do not fit the narrative so well.

19. **Reviewer comment:** L230: LMMs were used to investigate what about the stated responses variables? Significant differences between T0 and T1 for each treatment separately? This needs to be explained better.  
**Response:** We have modified the text to clarify that we are making statistical comparisons from before fishing (T0) and after fishing (T1) for individual parameters and fishing treatments. See text as follows:  
 “Linear mixed effects models (LMM) were used to investigate significant differences before and after fishing (T0 – T1) for: SPI pmeasurements, penetration depth, sediment parameters, porewater nutrient concentrations, biogeochemical fluxes, mass budget model results and ecological characteristics (individual macrobenthos densities, biomass, species richness) using the lmer-function in the R package: “lme4” (Bates et al., 2015). For each a given treatment variable and treatment (example: oxygen flux and tickler treatment), a “full-model-a” was created to include specified using the “timestep” (T0 or T1) as a fixed effect variable, “temperature” as a co-variate, and “station” as a random effect variable to minimize spatial autocorrelation between sample locations. A “reduced-model-b” was created to consider only the random effect variable (station). The full Model-a and reduced models model-b were tested against each other using a partial F test. This approach was taken to assess the effect of fishing disturbance (timestep = before-after statistical comparison) in respect to temperature while minimizing spatial autocorrelation between stations.”
20. **Reviewer comment:** L250-253: There is no use/discussion of SPM POC and TN in the discussion. Remove from results as the information seems to be superfluous.  
**Response:** These results have now been removed. There was some discussion about these topics in previous versions of the manuscript, however, since that has been removed, it is also appropriate to remove these parameters from the results (and methods).
21. **Reviewer comment:** L269-270: Backscatter results seem overly explorative as much of the reported differences (or lack of differences) are not mentioned in the discussion. E.g. Why are you testing for differences between sites separate from the consideration of trawling impact?  
**Response:** The inclusion of the backscatter data in the different plots (as well as between T0-T1 fishing) was meant to convey the large amount of spatial variation. We understand, however, that this is not so clear and decided to move the backscatter figure to the supplementary material.
22. **Reviewer comment:** L265: It is not clear where these statistical tests have been reported. The legends of Table S1 and Table S2 should be expanded so it is clear how statistical significance was determined.  
**Response:** Some text has been added outside of the table legends to describe the statistical results in these tables. We felt that this information would be better communicated outside of the table legends.
23. **Reviewer comment:** L268-269: Again Fig 3 does not report the statistical tests. Where are these reported?  
**Response:** We originally reported that there no significant p-values with the Benjamini-Hochberg correction (Dunn test) between experimental plots. We then reported uncorrected p-values showing significant differences between certain plots. As corrected p-values show no significant differences we think we should leave the figure unchanged but have decided to move it to the supplementary material as it describes a minor part our study. Hopefully this helps streamline the reading of the manuscript. We have also removed the sentences regarding uncorrected and corrected statistical differences between experimental plots to have readers focus more on the trawling effects.
24. **Reviewer comment:** L270: Again, where are these p-values and pairwise differences reported? They are not shown in Fig. 3  
**Response:** As described in the response to comment 23, we have removed the sentences regarding uncorrected p-values.
25. **Reviewer comment:** L284-287: It is not clear what this adds to the story of the paper. Remove to aid clarity.  
**Response:** This text has been removed to streamline the reading.
26. **Reviewer comment:** L287: In the methods “Robust regression analysis” is only discussed in relation to Section 2.7.4 (Impact of Lanice conchilega). It is not clear why/how it is used here.  
**Response:** This sentence is not so important to the narrative (and may also be superfluous knowing the relationship between chl-a and silt) so it has been removed.
27. **Reviewer comment:** L288-290: Add “between T0 and T1” to the end of this sentence to aid clarity.  
**Response:** The text has been edited to make it clear that it is referring to T0 – T1 fishing treatments.

28. **Reviewer comment:** L299-303: There is a lot in the results, to keep the focus of the reader I would remove this more descriptive information if it is not used later in this paper. Its presence in the supplementary is sufficient.  
**Response:** The descriptive information that does not refer to statistical significance, has been removed. A sentence has been added to refer readers to Table 1 and Table S5 for more information on nutrient fluxes.
29. **Reviewer comment:** L311: Restructure sentence so it starts “For all fishing treatments....”. Just so it is clear you are no longer talking about just Tickler.  
**Response:** We have modified the sentence to begin with the suggested phrase.
30. **Reviewer comment:** L343: It is not clear why Fig 3 is specifically referenced here.  
**Response:** The figure describing backscatter differences was also meant to convey spatial variability. This is, however, not so intuitive so the reference has been removed.
31. **Reviewer comment:** L347-349: Remove this sentence. There is no need to introduce the discussion by saying you are going to “discuss”.  
**Response:** This sentence has been removed.
32. **Reviewer comment:** L360-369: Is it not also possible that increased current speeds would transport trawl-induced resuspended sediment away from potential sampling equipment more quickly, therefore reducing likely SPM effect? Or is it considered that the sampling equipment were too close to the trawl disturbance for this to be an influencing factor?  
**Response:** As described in section 2.3 (Water Column measurements [methods]) the RV positioned itself within 80 m of the trawled area during trawling while making sure to be positioned against the current and the trawl disturbance to (hopefully) capture the effect of the sediment cloud. It is difficult to say whether this was close enough to capture the trawling disturbance as we could not visibly observe the extent of the sediment plume caused by the trawling. Using the same method, we were able to clearly record the effect of trawl-induced sediment resuspension in the Frisian Front with an instrument located further away (100 m) with lower current speeds (Tiano et al., 2019). The sediments in the current study, however, are sandier than those in the Frisian Front and so it may be that the resuspended sediments settled much faster before they could be detected. It may also be possible, as mentioned by the reviewer, that the increased current speeds could have hindered the detection of trawl effects, though we speculate that this may be more of a dilution effect from increased dispersion of particles.
- We have added some text speculating on dilution based on current-induced dispersion of resuspended particles in high energy habitats.
33. **Reviewer comment:** L376: Remove statement about variation between northern and southern plots. It does not add anything to the messaging of the paper.  
**Response:** This statement has been removed.
34. **Reviewer comment:** L389: Some mention should be made into the significant difference in anoxic sediment in the reference sites between T0 and T1, and how this may influence results of treatment sites.  
**Response:** We have modified the text here to include the anoxic surface area results although after separating the reference/adjacent sites, this was only statistically significant for one of the sites. We have, thus specified this and ensured that the text is more speculative rather than indicative.  
“Furthermore, higher percentages in the anoxic surface area from the SPI images taken in adjacent sites (significant for AD1) may suggest increased mineralization in undisturbed areas during the course of the experiments (Table S5 in the Supplement). Mass budget estimates for mineralization were also higher on average at T1 for AD1 and AD2, though this was not statistically significant. If the benthic metabolism in untrawled areas did increase during the experimental period, the trawling effects detected in this study (lower metabolism after trawling) may be considered to be conservative estimates”
35. **Reviewer comment:** L394: Remove discussion of reference sites – again it is not clear how this contributes to the discussion and messaging of the paper in general.  
**Response:** This text has been removed.
36. **Reviewer comment:** L396: I think it is important to reiterate here that it was not statistically significant.  
**Response:** The text regarding sediment mixing has been removed as detailed in the response to comment 2.

37. **Reviewer comment:** L406-407: This is already mentioned in Section 4.2; no need to repeat here.  
**Response:** The text has been removed to reduce redundancy.
38. **Reviewer comment:** L408: Change to “Despite the lower impact of Chl a”  
**Response:** This has been changed to “Despite the lower trawl penetration into the sediment” to provide clarity. There was only a relatively lower impact on Chl a compared to Tiano et al., (2019), however, the absolute levels of Chl a removed in the current study were much higher.
39. **Reviewer comment:** L471-472: Rephrase, to remove “environmental benefit”. Fishing cannot really be said to have environmental benefit. Perhaps change to say “there is potential for reduced environmental impact from pulse trawls due to its higher catch efficiency.....”  
**Response:** We changed the wording of this sentence to remove the phrase “environmental benefit” and emphasize the potential for a reduced environmental footprint stemming from increased catch efficiencies rather than any decrease in direct impacts.
40. **Reviewer comment:** L745: Alter to state “Example sediment profile imagery...”  
**Response:** The text has been edited.
41. **Reviewer comment:** Tables: Table 2 and Table 3 should be combined. This would aid clarity and there is no need for them to be separated.  
**Response:** These tables have now been merged. The newly formed table in the manuscript is now Table 1 (the table with sampling information was moved to the supplement).

#### Technical corrections

42. **Reviewer comment:** L134: I assume this is meant to state T1 rather than T2.  
**Response:** This sentence is probably not necessary and has been removed.

#### Literature Cited

- Fariñas-Franco, J. M., Allcock, A. L., & Roberts, D. (2018). Protection alone may not promote natural recovery of biogenic habitats of high biodiversity damaged by mobile fishing gears. *Marine Environmental Research*, 135(September 2017), 18–28. <https://doi.org/10.1016/j.marenvres.2018.01.009>
- Grabowski, J. H., Bachman, M., Demarest, C., Eayrs, S., Harris, B. P., Malkoski, V., Packer, D., & Stevenson, D. (2014). Assessing the Vulnerability of Marine Benthos to Fishing Gear Impacts. *Reviews in Fisheries Science & Aquaculture*, 22(2), 142–155. <https://doi.org/10.1080/10641262.2013.846292>
- Kaiser, M. J., Collie, J. S., Hall, S. J., Jennings, S., & Poiner, I. R. (2002). Modification of marine habitats by trawling activities: prognosis and solutions. *Fish and Fisheries*, 3, 114–136.
- Rabaut, M., Braeckman, U., Hendrickx, F., Vincx, M., & Degraer, S. (2008). Experimental beam-trawling in Lanice conchilega reefs: Impact on the associated fauna. *Fisheries Research*, 90(1–3), 209–216. <https://doi.org/10.1016/j.fishres.2007.10.009>
- Tiano, J. C., Witbaard, R., Bergman, M. J. N., Rijswijk, P. Van, Tramper, A., Oevelen, D. Van, & Soetaert, K. (2019). Acute impacts of bottom trawl gears on benthic metabolism and nutrient cycling. *ICES Journal of Marine Science*. <https://doi.org/10.1093/icesjms/fsz027>