We thank the reviewer for the time taken to read and comment on the manuscript. Most of the suggestions and requests for additional clarification were implemented in the manuscript, including the addition of a new figure (which was also suggested by the other reviewer).

We did choose to keep the reference to unpublished works, from which data was used to support the modelling setup (Toussaint et al., *in review*, De Borger et al., *in review*). Both works are in the reviewing process (one requiring major revisions, mostly related to framing the novelty of the research, the other resubmitted after minor revisions). However, we understand the need for clarity in this manuscript itself, and opted to add additional information about the sampling procedure in the supplementary data, and to extend the explanation of the fitting procedure.

The changes were applied in track changes in the manuscript, and copied in this reply to individual answers. With these changes, we hope to have replied to this review in a satisfactory manner.

1. **Reviewer's comment:** How would the results change with bottom trawling gear with even greater penetration on the seabed? For instance, bottom trawl doors can penetrate tens of centimeters deep in the sediment, an order of magnitude greater than those you report in this study for the tickler chain (3.2 cm) and pulse wing (1.6 cm) gear types.

   Reply: Assuming that the eroded layer and the mixing depth scale with increasing total penetration depth of these other gears, the depletion effects should become even more pronounced. In a single trawling event more of the (reactive carbon rich) top sediment layer would be removed, there would be a higher mortality of organisms, and more of the nutrient build-up would be removed. For the trawling gears we investigated the depth distributions happened to be more or less known (please see our reply to comment #12 + the works of Depestele et al., 2016, 2019 on the eroded layer dynamics), which made it possible to realistically parametrize the modelling mechanics. To implement this remark (more concisely), as well as remark #23, we chose to restructure section 4.3 in the discussion entirely.

   Please note that we also added a reference to the differences in catch-efficiency between pulse gears and tickler-chain gears, so that we do not seem to suggest anymore that improvements to fishing gear do not matter.

   This section now reads:

   " *In our work the differences with respect to organic matter mineralization dynamics between gear types with differing penetration depths (e.g. 3.2 ± 1.2 cm vs. 1.6 ± 0.6 cm in mud) mostly remained suggestive, rather than statistically conclusive. The fishing gear type was only included as a significant predictor for the denitrification rates, with a small coefficient (-0.00038; Table 5). This is because the freshly deposited stocks of organic carbon are present near the sediment surface, and any gear that penetrates the sediment impacts this layer, especially for multiple trawling events per year (Figure 5, Table 5). This indicates that only a thin layer of surface sediment needs to be disturbed to generate significant biogeochemical changes (Dounas et al., 2005). Many biogeochemical processes are mediated by the dynamics of oxygen near the sediment-water interface, which itself is influenced by the composition, and permeability of the sediment. Permeable sediments allow for a deeper flow of oxidized bottom water into the sediment matrix, increasing the available oxygen for oxic mineralization processes (Huettel and Gust, 1992). Cohesive sediments on the other hand, mostly lack such advective transport (Huettel and Gust, 1992). Instead the exchange of solutes between sediment and the overlying water is diffusion dominated (molecular and biogenic), resulting in a less deep oxic zone at comparable organic matter loads, and an increased importance of other oxidants (e.g. MnO_2, FeOOH, SO_4^{2-}). A shift towards fining (an increased proportion of finer grain size classes) has been described in certain trawled areas, with expected consequences for sediment biogeochemistry, such as an increased rate of sulphate reduction (Trimmer et al., 2005). But the opposite occurs just as well (Depestele et al., 2019; Mengual et al., 2019; Tiano et al., 2019). In these cases resuspended fine-grained material is exported away from the trawling site, leaving a coarsened trawling track, with the results subtly different between gear types (Depestele et al., 2019; Tiano et al., 2019). This means that the effects of fishing gears on grain size sorting should be better characterized for various sediment types, to constrain the uncertainty around predictions of gear impacts on sediment functioning.*

   This does not imply that the penetration depth is irrelevant. Other studies have reported clear positive effects of reducing the penetrations depths of fishing gears, such as decreased sediment mobilization and homogenization, and reduced organic matter depletion (Depestele et al., 2019; Tiano et al., 2019). Conversely, assuming that the eroded layer and the mixing depth scale with more deeply penetrating gears than those tested here, the depletion effects should become more pronounced. In a single trawling event more of the (reactive carbon rich) top sediment layer would be removed, there would be a higher mortality of organisms, and more of the nutrient build-up would be removed.

Aside from the penetration depth, largest impacts occurred when increasing the trawling frequency from 0 to 1 trawling event per year, and the response of mineralization processes to increased trawling frequency was often non-linear, making them more difficult to predict. This would imply that management strategies aimed at maintaining the ecosystem functions provided by shelf sediments should be focused on spatial controls, bottom impact quotas, and effort control of trawling gears that per definition require contact with the bottom to catch commercially viable target species (McConnaughey et al., 2020). An effective strategy limits the impacted surface area, and allows carbon stocks and faunal communities in the sediment to recover from a disturbance, resulting in the recovery of vital biogeochemical functions such as denitrification and carbon burial. This includes technical adaptations to improve catch-efficiency. Whereas our study only focused on direct head-to-head comparisons between the two gear types, pulse trawls are associated with lower spatial footprints due to their relatively higher catch efficiencies compared to beam trawls (Poos et al., 2020; Rijnsdorp et al., 2020; ICES, 2020).

Shifting the fishing effort from peripheral areas to core fishing grounds would also reduce the area where the top sediment layer is removed on a regular basis, along with the associated reduction in mineralization of organic matter. This can be achieved through time-restricted bottom trawling, in which fishing grounds are closed off temporarily. Similarly, areas with high denitrification rates, crucial for eutrophication mitigation can be closed to trawling completely, as done in other regions of the world (Ferguson et al., 2020). Site-specific conditions such as rates of biogeochemical recovery and sedimentation rates need to be known to determine the resilience of ecosystems to trawling, and fine-tune management plans (Paradis et al., 2019)."

2. **Reviewer's comment:** Section 2.1.2 Model parametrization explains the different sediment cores collected to conduct the modelling approach. In this section, the authors redirect the reader to unpublished papers (De Borger et al., 2020; Toussaint et al., 2020) for additional information of the sampling procedure. Please refrain from referring to unpublished papers and provide all the necessary information of the sampling technique (e.g. subsampling boxcores, sediment analyses, frequency of analyses?). Similarly, please provide any necessary explanations of the steady state fitting procedure (lines 112-113) that is described in the manuscript that is in-preparation (De Borger et al. 2020). Finally, please correct the sources described in Table 2, and explain how the sinusoidal flux of C illustrated in Figure 3A was obtained.

Reply: With both manuscripts that are referred to still in review, we agree that additional information on the sampling procedure benefits the manuscript. Since in time these articles will be published as well, we therefor opted to add this rather lengthy detailing of the sampling and processing procedure in the supplementary information, and not in the main body of the text where we now refer to both manuscripts in review, as well as the supplementary information.

The text added to the supplement is shown at the bottom of this reply. More information on the steady-state fitting procedure was added to the main body of text as requested (by both reviewers) in lines 116-134: "*Model parameters included both measured concentrations in the bottom water, as well as process rate parameters that were derived following a 2-step steady state fitting procedure (Table 3). Using the measured DIC flux as the upper boundary carbon input flux, the O_2 flux and porewater profiles of O_2, NO_3^-, and NH_4^+ were first fitted manually by tweaking a limited set of model parameters. The degradation rate of refractory material (rSlow), and the biodiffusivity constant Db were constrained by fitting NH_4^+, and O_2 profiles. Mechanistically, decreasing the bioturbation rate reduces the build-up of NH_4^+ with depth, increases the oxygen penetration depth, and changes the shape of the NO_3^- profile (deepening the NO_3^- peak). Whereas the degradation rate of the refractory organic matter also impacts deep NH_4^+ concentrations, it has a larger effect on the shape of the NH_4^+ profile, with lower degradation rates causing a more gradual build-up with sediment depth. Subsequently, parameters affecting the NO_3^- and NH_4^+ profiles were tuned (the nitrification rate rnit, and denitrification constants ksNO3denit and kinO2denit). Higher nitrification rates increase the build-up of NH_4^+, and increase concentrations of NO_3^-, typically producing a nitrate concentration peak within the oxic zone. The shape of the oxygen profiles further constrained the oxidation rate of oxygen demanding units (ODU's), and inhibition constants for anoxic mineralization (kinO2anox, kinNO3anox).*
The manual fitting was followed by a constrained parameter fitting using an optimization algorithm. In this second step, the fitted parameters were allowed to vary in a range ± 10 % around the manually fitted parameter values. Also the DIC fluxes were refitted within a narrow range (0.98 -1.02 of measured value), to allow freedom to the fitting algorithm. A random-based minimization algorithm (Price, 1977) implemented in the R package FME (Soetaert and Petzoldt, 2010) was used. This algorithm pseudo-randomly sampled the parameter space, until the parameter set was found which returned the minimal model cost, the latter defined as the sum of variable costs (modeled - measured values), scaled using the mean - standard deviation relation determined for each nutrient."

The incoming carbon flux differs for each location. This is now clarified in section 2.1.2., lines 119 – 121. "*A sinusoidally varying carbon deposition flux with the model derived carbon flux (Cflux, Table 3) as the annual average, and imposing an amplitude of 1 was used as the upper boundary organic carbon flux (Figure 2 A). This resulted in differing organic carbon fluxes for each location.*" The second sentence was added, as well as the word "organic" in the first to aid with clarifying remark #23. Note also that Figure 3 and Figure 2 were switched to comply with remark #9.

3. **Reviewer's comment:** Mortality of benthic fauna affects the biogeochemical modelling approach by reducing bioturbation rates. Please comment and address other aspects of how this higher mortality can affect sediment biogeochemistry. For instance, with fewer benthic fauna, wouldn't that increase the burial of organic matter on the seafloor? Moreover, would the electrodes in pulse gear cause greater mortality of benthic species?

Reply: With fewer bioturbating fauna, organic carbon will remain near the sediment surface for longer, exposed to oxygen. Organic matter will thus be degraded surficially through oxic mineralization processes. It is partly the burial of organic matter by bioturbators that exposes relatively fresh organic matter to sub- anoxic sediment conditions in deeper sediment horizons. After a certain arbitrary depth (e.g. 1 cm), you can then speak of burial.
Existing literature does not indicate an increased mortality of benthic fauna due to electrodes (van Marlen et al., 2009; Soetaert et al., 2015, 2016; Murray et al., 2016; ICES, 2020). The studies all show no, or very limited benthos mortality through electric exposure and only short term behavioural effects on macrobenthic species such as *Ensis sp.*, *Pagurus bernhardus*, *Asterias rubens*, *Spisula sp.*, *Nereis sp*. From our own direct observations in laboratory experiments (unpublished), we know that *Arenicola marina*, first of all survive electric pulses, and secondly recover their normal behaviour within 10 – 15 minutes after exposure.
As this is a good point that other readers of this manuscript may have, we have added the above references to the materials and methods section (line 144-) to justify why the depletion mechanics were the same for both gears. "*Electrical pulses were assumed to not affect benthos mortality in addition to the physical effects, since current available research shows very limited to no increased mortality by electrical pulses when compared to control situations (van Marlen et al., 2009; Soetaert et al., 2015, 2016; Murray et al., 2016; ICES, 2020).*"

4. **Reviewer's comment:** You mention how the low permeability of muddy sediments affect mineralization pathways (line 308). Could you elaborate here the effect on coarser and more permeable sediment?

Reply: We chose to implement this comment in lines 335-338, where a short discussion of the Coarse sediment was already present. These lines now read: "*Larger pore-spaces in these sediments allow for bottom water to penetrate more deeply into the sediment matrix, bringing oxygen and other reactants into deeper sediment layers. As a result, oxygen often fuels rapid mineralization in coarse grained sediments* (Huettel and Rusch, 2000; Ehrenhauss et al., 2004). *The increasing trawling frequency in coarse sediments thus had little effect on oxygen penetration, and nitrate concentrations only marginally increased (Figure 7: A-B), resulting in minor changes to mineralization pathways such as denitrification on average, although instantaneous effects could be prominent (Figure 7 C)*".

5. **Reviewer's comment:** Based on your results, how would bottom trawling affect the composition of OC (labile, semi-labile content of OC?). For instance, in line 210-211, do you mean that trawling increases the relative amount of labile OC?

Reply: That is indeed the correct interpretation of our result, valid for chronic bottom trawling. In our model, bottom trawling causes a depletion of the carbon build-up in the sediment. As organic carbon generally becomes less reactive with age (~ depth in the sediment), the total organic carbon pool becomes more reactive when less organic carbon gradually builds up to deeper layers. In the most extreme case (as an example), there is almost no organic carbon in the sediment due to continuous, chronic resuspension. If fresh organic carbon is then deposited on the sediment-water interface, the labile organic carbon will proportionally make up a considerable part of the total organic carbon pool.
Since also the other reviewer noted interest in changes to the reactive carbon pool, we added the figure (please see below) to the supplementary information, and refer to this figure on line 235: "*In FineL, MudL and MudH the ratio of labile organic carbon (FDET) to semi-labile organic carbon (SDET) increased between 25 and 34 % (Figure S3, supplement).*"
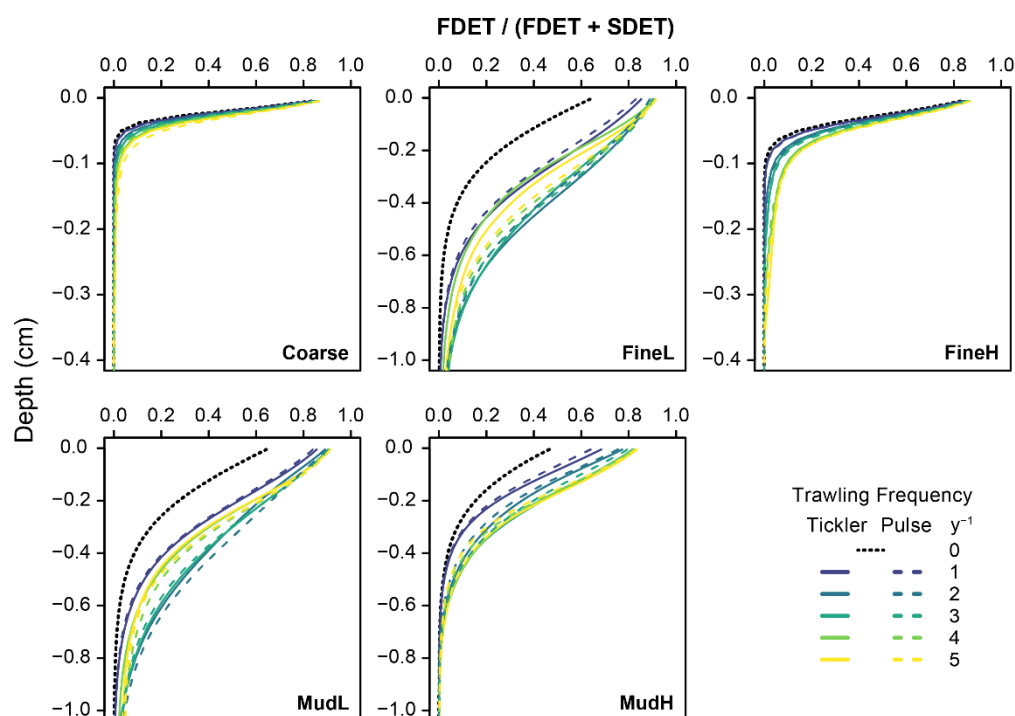
FDET / (FDET + SDET)

Figure S 1: Annually averaged modelled quality of the reactive organic carbon pool in the surface sediments (note different depths on y-axis between figures for visualization purposes). The carbon quality (x-axis) is represented as the proportion of fast degrading detritus (FDET, labile org. C) in the summed labile and semi-labile org. C pool (FDET + SDET). Black dotted line is the 0 trawl default, full and dotted coloured lines are tickler and pulse gear respectively, with increasing trawling frequencies as different colours.

6. **Reviewer's comment:** Could you elaborate on how your results differ from those modelled by Duplisea et al. (2001)?

   Reply: The main differences between the work of Duplisea et al., 2001 and our work stem from the different models that were used. We used diagenetic reactive transport model in which sediment depth is the spatial dimension, and the biogeochemical reactions that connect organic carbon and solutes are explicitly represented (please see materials and methods). Duplisea et al., used a food-web model in which different components (e.g. organic carbon pool, macrofauna, bacteria, meiofauna) exchange carbon with one-another. Additionally, this model contains no spatial dimension. So in fact, these are two completely different models, from which output is very different and difficult to compare.
   That being said, it is interesting that two findings (the stabilizing effect of macrofauna in terms of carbon, and an increased contribution of oxic/aerobic mineralization) are highlighted in both works, though also with different underlying mechanistic explanations.
   Besides this, there is not much to compare, as we reported on biogeochemical variables not included in the work of Duplisea et al., such as porewater profiles, relative changes of additional mineralization processes, the effects of different settings, the erosion-mixing effect,…

   We have added a short note on the comparison with the work of Duplisea et al. (2001) on lines 301- : "*The comparison with the work of Duplisea et al. (2001) is in fact remarkable, as Duplisea et al. (2001) used a food-web based model to investigate changes to carbon cycling, whereas a diagenetic model was used in this work. Both very different approaches, that both highlight a shift to more oxic mineralization, and the importance of benthic fauna as a stabilizing factor.*"

7. **Reviewer's comment:** Finally, this manuscript would benefit by addressing, based on your results, the effects of bottom trawling in different margins. Moreover, considering that bottom trawling now generally occurs at _500 m water depth (Watson and Morato, 2013, Fisheries Research), what would be the biogeochemical impacts of bottom trawling?

   Reply: For sure, we expect the effects in deeper waters (continental slope – deep sea) to be even greater, given the higher vulnerability of species (long-lived, slower growth), more cohesive seidments, as well as decreased deposition rates of organic matter. As an extreme example, recent studies on the effects of deep sea mining

show that effects of a mining trawl (10 – 20 cm of mixing) to sediment morphology (Gausepohl et al., 2020), as well as food-web structure remain visible after 26 (!) years (de Jonge et al., 2020), with also microbially regulated biogeochemical functions still impaired (Vonnahme et al., 2020).

We have rewritten lines 306-314 to accommodate this information concisely. *"Also, OM depletion as a result of long term fishing has been reported, even at water depths beyond 500 m (Martín et al., 2014; Pusceddu et al., 2014; Paradis et al., 2019), where comparisons between trawled and untrawled sites yielded a difference in OC between 20 and 60 % (Paradis et al., 2019), or 60 – 100 % of the daily input flux of organic carbon was removed from sediments by trawling (Pusceddu et al., 2014). In fact these deep-water sediments are particularly sensitive to trawling disturbances, a concerning fact given the steady expansion of fishing practices into deeper waters in recent decades (Morato et al., 2006; Puig et al., 2012; Watson and Morato, 2013). Deep-water species communities are slow-growing and thus recover slowly, organic matter deposition rates are low, and finer-grained sediments of the deep are easily resuspended following a trawl passage (Norse et al., 2012; Mengual et al., 2016). All three of these factors increase the impacts of trawling events on organic matter cycling in the model presented in this work."*

8. **Reviewer's comment:** Line 80-81. Is the incoming flux in all model scenario the same, irrespective of the OM content of the seafloor?

   Reply: The incoming carbon flux differs for each location. This is now clarified in section 2.1.2., lines 119 – 121. "A sinusoidally varying carbon deposition flux with the model derived carbon flux (*Cflux*, Table 3) as the annual average, and imposing an amplitude of 1 was used as the upper boundary organic carbon flux (Figure 2 A). This resulted in differing organic carbon fluxes for each location." The second sentence was added, as well as the word "organic" in the first to aid with clarifying remark #23.

9. **Reviewer's comment:** Note that you refer to Figure 3 before referring to Figure 2. Please amend this.

   Reply: Thank you for noticing this. This has now been rectified, by switching the positions (and numbering) of figures 2 and 3.

10. **Reviewer's comment:** Line 135, 137. Provide the definition of mud.

    Reply: The definition of mud has been added between brackets on line 137, which now reads: *"It was calculated based on the total gear penetration depth (TPD, i.e. the sum of the eroded layer depth and the penetration depth, in cm), and the mud content (% mud¸ particles < 63 µm) of the sediment, as described in Eq. 3Error! Reference source not found. derived from Sciberras et al. (2018)."*

11. **Reviewer's comment:** Please refer to the tables in order of appearance. Currently in the text, you refer to the tables in the following order of appearance: Table 1, 2, 4, 5, 3. Please Change the order of the tables so that they are referred to sequentially

    Reply: This has now been rectified, by changing the order of the tables, and moving tables 5 and 7 to supplementary information.

12. **Reviewer's comment:** Line 157. Pitcher et al. (2020) do not talk about the penetration depths of different trawling gear. Where do you get these values?

    Reply: A manuscript by Pitcher et al., co-authored by an author of this article (Rijnsdorp, A.) is currently in review. In this manuscript, trawling impacts on seabed habitat status of different regions is assessed. As part of this work, current knowledge on average penetration depths of trawling gears were aggregated, and this information was shared with us to prepare our own work. So, we have changed the reference to (pers. comm.).

13. **Reviewer's comment:** Line 160; 217. Please correct the missing reference source here.

    Reply: Thank you for noticing this, these referencing errors have been corrected.

14. **Reviewer's comment:** Line 181-183. Specify that the higher remineralization rates here are due to the higher organic matter content of these sites (MudH, FineH).

Reply: A reference to the higher organic matter deposition fluxes between the low – high nutrient sites has been added to this section: *"The two muddy stations had either very high or very low total mineralization rates (MudH: 82 mmol C m^{-2} d^{-1}, MudL: 8.5 mmol C m^{-2} d^{-1}), and similar for the two fine sandy stations (FineH: 30 mmol C m^{-2} d^{-1}, FineL: 8.1 mmol C m^{-2} d^{-1}), related to the difference in organic matter deposition between nearshore – offshore locations (Table 3)."*

15. **Reviewer's comment:** Line 195-196. This sentence refers to both Figure 4 and Figure 5.

    Reply: The additional reference has been added.

16. **Reviewer's comment:** Lines 231-240. Refer to Table 7 in the text.

    Reply: References to the corresponding figure and table have been added,

17. **Reviewer's comment:** Line 238-239. "Trawling frequencies of $1 - 2$ y^{-1} caused increases in the denitrification for the Coarse sediment, and FineH and MudL". Considering the error, denitrification in these sediment types did not increase in these trawling frequencies, only for the MudH sediment, as you mention later on.

    Reply: This is indeed correct. We have rectified line 238-239 as follows: *"Trawling frequencies of $1 - 2$ y^{-1} did not consistently alter denitrification for the Coarse sediment, and FineH and MudL."*

18. **Reviewer's comment:** Lines 241-245. Where is the data that illustrates this?

    Reply: This information is derived from the denitrification rates now shown in the supplement, but are not represented separately in a table.

19. **Reviewer's comment:** Lines 334-335. Just earlier, you mention increases in denitrification, but here you mention that your results are comparable to those of Ferguson et al. (2020) who observed decreases in denitrification. Please clarify that your results, with the exception of MudH, also present decreases in denitrification.

    Reply: This has been clarified by adding this distinction to lines 334-335: *"Though the key role of redox microniches is not directly investigated here, we acquired decreases in denitrification rates in a similar range in all sediments besides MudH, especially when trawling frequencies increased."*

20. **Reviewer's comment:** Line 361. Change "resuspended silt" to "resuspended fine-grained sediment", since both silt and clay can be resuspended and preferentially advected away from bottom trawling grounds (Martin et al., 2014, PLoS ONE). You focus on how this kind of effect varies with different bottom trawling gear types, but could you elaborate on how this would affect sediment biogeochemistry?

    Reply: We have changed the wording to "fine-grained material". The granulometry plays an important role in the regulation of sediment biogeochemistry. The grainsize distribution, permeability (the capacity to transmit fluid, dependent on the grain size), and porosity (the water content in a given volume of bulk sediment), influence the redox zonation patterns in which microbially mediated mineralization processes occur (Probandt et al., 2017), by providing binding sites for organic matter (Mayer, 1994) and by regulating the exchange of oxygen, organic matter and other reactants between the sediment and the overlying water (Huettel et al., 2014). Large, connected pore-spaces in coarse grained, permeable sediments allow for advective flows, resulting in high organic matter turnover rates fuelled by a high oxygen supply (Huettel and Rusch, 2000; Ehrenhauss et al., 2004). In contrast, cohesive sediments are characterised by smaller and less connected interstitial spaces, so that diffusive processes, molecular diffusion or transport stimulated by benthic fauna, dominate solute and particle transport (Huettel et al., 2014). A shift in grainsize to either finer sediments through settling of advected fine-grained sediments (fining), or coarsening (larger median grainsize) will thus change the biogeochemical regime in an area.

    This has been implemented in the rewritten section 4.3., please see our reply to remark #1.

21. **Reviewer's comment:** Line 367-368. Modify "deep and shallow penetrating gear types", since 3 cm of penetration is not considered to be deep.

Reply: This sentence has now been relocated to the beginning of section 4.3, and now reads: "*In our work the differences with respect to organic matter mineralization dynamics between gear types with differing penetration depths (e.g. 3.2 ± 1.2 cm vs. 1.6 ± 0.6 cm in mud) mostly remained suggestive, rather than statistically conclusive. The fishing gear type was only included as a significant predictor for the denitrification rates, with a small coefficient (-0.00038; Table 5).*"

22. **Reviewer's comment:** Table 2: Please provide definition of the acronyms (MGS, SD.9, SD.1, VFines). Could you also give the proportion of sand (2 mm – 63 _m) content (%)? Provide also the grain size ranges to define the proportion of silt and fine-grained sediment. If finegrained sediment is consistent with the grain size range of clays (< 4 _m), please consider giving it this terminology.

    Reply: This comment was implemented by extending the table caption with the definitions, and by updating the table itself with the % sand, and the size classes sand and mud represent. Please see the new table below, but note our reply to comment #2, for choosing to keep the references to the manuscripts in review.:

Table 1: Characteristics of the selected sites. Low and High nutrient classification is based on relative differences in nutrient build-up for the same sediment type (see figure S1 in supplement). MGS, SD.1, and SD.9 are median grainsize, and the boundaries of the 10ᵗʰ and 90ᵗʰ percentile of the grainsize respectively (in μm). Percentage of sand (63 – 1000 μm), and mud (< 63 μm), are weight percentages of a dried sediment sample sieved over a 1 mm sieve.

Sediment type	Nutrients	Name	Lat (Deg. N)	Lon (Deg. E)	Depth (m)	MGS (μm)	SD.1 (μm)	SD.9 (μm)	Sand (%)	Mud (%)	Source*
Coarse sand	Low	Coarse	51.43483	2.809822	22	433 ± 43	286 ± 31	660 ± 67	99 ± 1	0 ± 0	a
Fine sand	Low	FineL	55.17374	3.161264	26	216 ± 2	143 ± 0	328 ± 7	99 ± 7	0 ± 0	b
	High	FineH	51.1853	2.7013	9	220 ± 8	91 ± 61	394 ± 67	81 ± 5	9 ± 5	a
Mud	Low	MudL	58.20097	0.525871	148	24 ± 1	4 ± 0	67 ± 3	10 ± 7	88 ± 1	b
	High	MudH	51.2714	2.905033	11	19 ± 1	3 ± 0	208 ± 28	25 ± 4	74 ± 5	a

*a: Toussaint et al., *in review***; b: De Borger et al.,** *in review***.**

23. **Reviewer's comment:** Figure 3: A. Consider using "Day of year" in the axis title. If this carbon flux consists of only DIC, why is it applicable to both organic and inorganic fluxes? In lines 119-120 you refer to this figure as the carbon flux. Please provide more information. B. Where did the data from this figure come from? C. According to Eq. 3, biota depletion depends on both penetration depth and sediment grain size, but only penetration depth (which varies with different gear) is shown in this figure. Please include the effect of sediment grain size in this figure, since it is a very important parameter, rather than giving it in Table 3.

    Reply: We have amended this figure by (1) changing the main title and x-axis title of panel A, (2) changing the positions of panel B and C, in accordance with the text. The penetration depth per sediment type originates from Pitcher (pers. comm), please see our reply to remark #12. In terms of showing all decreases of bioturbation, we feel that this example panel (Figure 2 B), in combination with Table 4 (note the numbering has changed) and Eq. 3 should suffice.

24. **Reviewer's comment:** Consider converting Tables 5 and 7 as figures, since the changes in terms of frequency, gear type, and sediment type would be more visual.

    Reply: Tables 5 and 7 have been moved to the supplementary material (now resp. Table S1 and S2). In place of Table 5 is now a slightly adapted version of Figure S2, previously in the supplement, showing averaged nutrient profiles per trawling intensity for each location. There is now also a figure to replace Table 7 (please see below), that shows the same information graphically. To make space for these figures, we chose to remove Figure 4, the range in porewater concentrations throughout the year, to the supplement.
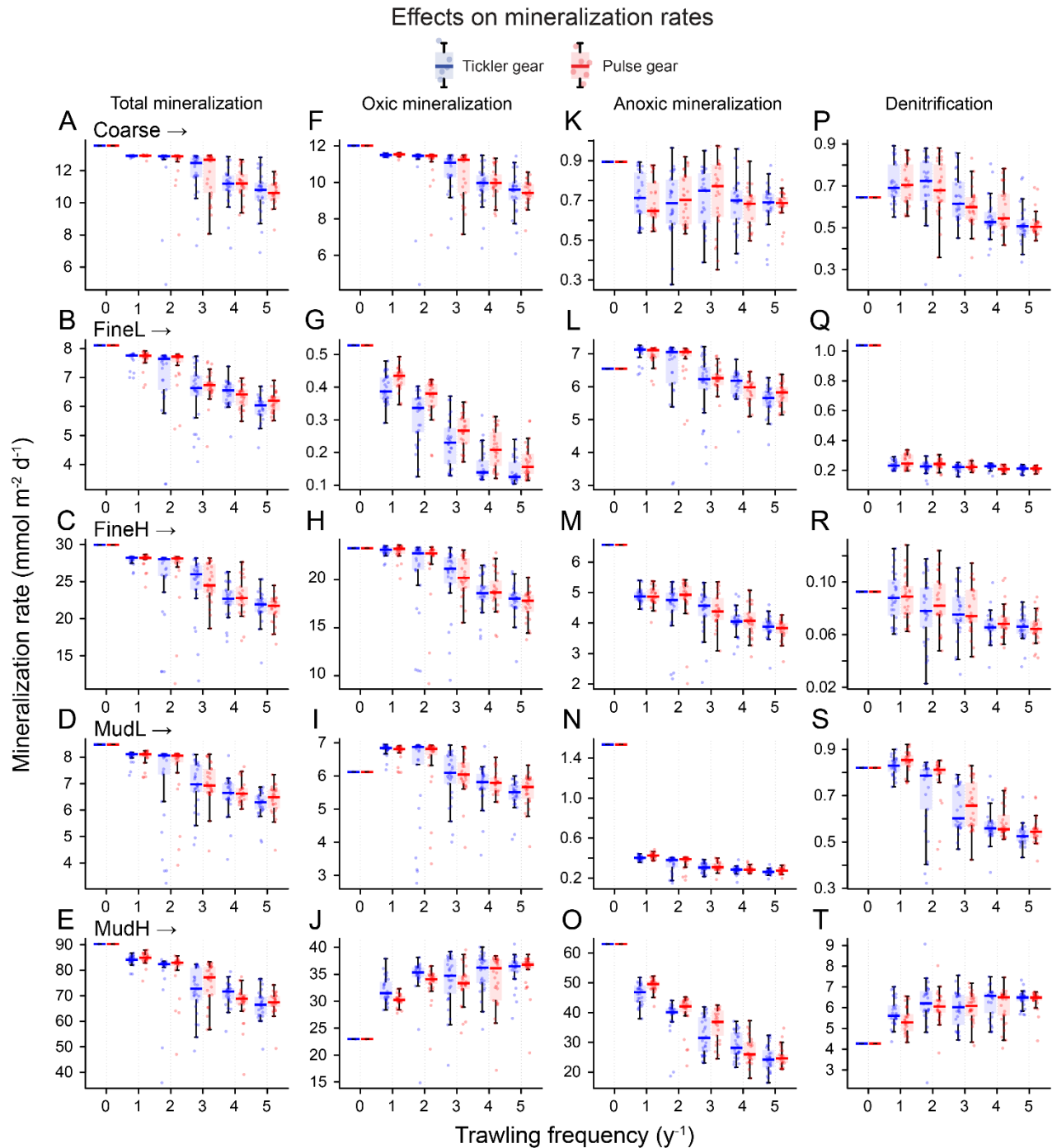
Figure 1: Rates of total mineralization (A - E), and the three main mineralization processes (F - J: oxic; K - O: anoxic; P - T: denitrification) (y-axis, mmol m^{-2} d^{-1}) for each gear type (blue boxes: tickler gear; red boxes: pulse gear), and for increasing trawling frequency (x-axis, y^{-1})

25. **Reviewer's comment:** Figure S1: The fitted red lines for FineL-oxygen, MudH-nitrate are not adjusted to the concentration profiles measured.

   Reply: For FineL there was no oxygen profile to fit the model to, as we did not want to risk damaging the oxygen sensor on visibly present shell fragments in this sediment on the second day into a 15 day research cruise. The MudH NO$_3^-$ profiles could not be fitted without simultaneously compromising deep NH$_4^+$ concentrations, with the latter more representative of nutrient build-up with increasing depth. Additionally, we believe it is likely that the NO$_3^-$ concentrations represent a part of the considerable NH$_4^+$ content that has been oxidized during experimental procedures.

Added text to supplement:

S.1. Data collection for parametrization

S.1.1. General sampling design
In September 2017, locations Coarse, FineH, and MudH were sampled in the Belgian Part of the North Sea (Toussaint et al., *in review*), whereas FineL and MudL were sampled in the Central-Northern North Sea in May-June of 2018 (De Borger et al., *in review*). A stainless steel NIOZ boxcorer was used to sample the sediments used to describe the different locations in this modelling study (30 cm ID, 50 cm height). At each location, triplicate intact boxcores were collected.

From the September 2017 samples, a set of subcores was taken from each boxcore sample for: incubation purposes (Ø 19 Plexiglass sampling cores for coarse grained sediment to allow for a stirring mechanism for advective flows; Ø 10 cm for cohesive sediment, 10-15 cm deep + 10 cm of overlying water), to determine porewater nutrient profiles (Ø 10 cm Plexiglass sampling core), and to determine sediment characteristics (cut off syringe, upper 3 cm). Incubations were performed in the dark (to prevent photosynthetic activity), and in climate controlled laboratory conditions with disk (coarse) of teflon (cohesive) stirrers agitating the overlying water, and exchange rates of oxygen, dissolved inorganic carbon (DIC), and dissolved inorganic nitrogen (DIN) were measured.

In the May-June samples, ship-board incubations (dark) were performed using the entire boxcore sample, measuring the same parameters as previously mentioned. For this, the boxcore "bucket" containing the sediment was sealed with a Plexiglass lid containing a Teflon stirrer, and placed in a buffering vat on deck to maintain steady temperature. After this shipboard incubation, subcores were collected to measure porewater nutrient profiles (Ø 10 cm Plexiglass sampling core), oxygen microprofiles (Ø 5 cm Plexiglass sampling core), and sediment characteristics (cut off syringe, upper 2 cm).

S.1.2. Flux calculations
During incubations, the oxygen concentration in the overlying water was monitored using optode sensors (FirestingO2, Pyroscience, 2-point calibration), set at 1 Hz. At the same time, DIC and DIN concentrations were sampled from the overlying water with syringes at discreet time intervals. 5 – 10 mL were collected for DIN, and filtered through a 0.45 µm syringe filter, and stored at -20 °C until further processing. 6 - 10 mL of water were collected in headspace vials for DIC, and subsequently poisoned with 1 µL of saturated HgCl2 per mL sample for preservation and kept refrigerated at 4 °C until further processing. During incubations, O_2 concentrations did not decrease below 50 % of the initial oxygen concentration. As such, incubations in the 2017 samples lasted between 2 – 8 hours, and 24 – 36 hours in 2018.

Upon thawing, nutrient concentrations were determined by a SEAL QuAAtro segmented flow analyser (Jodo et al., 1992). DIC analysis was performed using a segmented flow analyser (San++ SKALAR) following (Stoll et al., 2001). Fluxes (in mmol m^{-2} d^{-1}) were calculated by fitting a linear regression through the concentration time series, and multiplying the regression coefficient by the height of the overlying water to convert from volumetric to surficial rates. For oxygen fluxes the same method was applied to a consistently decreasing section of the oxygen concentration data.

S.1.3. Porewater nutrient profiles
Porewater nutrients (DIN) were collected in 1-2 cm interval depth slices down to 12 cm deep, using rhizon samplers (0.15 µm pore size, Rhizosphere Research Products). The rhizons were inserted into the sediment core through pre-drilled holes in the core wall, and a maximum of 4 mL of porewater was extracted from each interval using a 5 mL syringe connected to the rhizon sampler (Seeberg-Elverfeldt et al., 2005; Dickens et al., 2007; Shotbolt, 2010). Further processing of the nutrient samples was done the same as for the nutrient flux samples.

S.1.4. Oxygen microprofiles
Oxygen-depth profiles in the sediment were measured using Clark-type O_2 micro-electrodes (50 µm tip diameter, Unisense) (Revsbech, 1989). Readings were taken at 100 µm intervals, starting 2000 µm (2 mm) above the sediment-water interface (water aerated to 100% O_2 saturation before the experiment) down to the depth in the sediment at which all oxygen was depleted. A two-point calibration was conducted prior to measurements using 100 and 0 % oxygen saturated seawater to represent water column and anoxic O_2 concentrations, respectively. In each sediment core, up to three replicate profiles were taken from different areas of the sediment (except in Coarse, where the risk of damage to the sensor due to coarseness of the sediment was determined too great).

S.1.5. Sediment characteristics
Sediment grain size was determined by laser diffraction on freeze-dried and sieved (< 1 mm) sediment samples in a Malvern Mastersizer 2000 (McCave et al., 1986). Grain size fractions were determined as volume percentages according to the Wentworth scale (Wentworth, 1922): clay/silt (< 63 µm), very fine sand (vfines: 63 – 125 µm),

fine sand (fines: 125 – 250 μm), medium sand (250 – 500 μm), and coarse sand (500 μm – 1 mm). In this manuscript, the percentage of sand was calculated by summing grainsize classes between 63 and 1000 μm. The median grain size (MGS) was calculated on the fraction < 1 mm. Water content was determined as the volume of water removed by freeze drying wet sediment samples. The sediment density was determined by measuring the water displacement of a given weight of dried sediment. Sediment porosity was determined from water content and solid phase density measurements, accounting for the salt content of the pore water.

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