Reply to the anonymous Referees #2

(**RC:** Referee Comment; **AR:** Author's Response)

We would like to thank both anonymous Referee #2 for the constructive feedback and thorough review of the manuscript. One main criticism of the reviewer is that the methods, both with regards to incubation and calculation of rates, should be explained in more detail. We agree and will address this issue further in the individual comments. We will also provide an improved description of the method, which should answer many of the reviewers' questions. Besides that, we followed all the suggestions given by the anonymous Referee #2.

Page 2 line 49

RC 2: In spite of their putative relevance as an ecosystem service, very little is known about N cycling and N transformation rates in the sediment. Substantial work has been done on sedimentary nitrogen in the North Sea (e.g. see reference lists of the two papers mentioned above) and I suggest softening this statement.

AR: We agree and will soften this statement in a revised version. We were referring to the fact that ammonification had not taken into consideration, and that we attempt a joint consideration of N-turnover processes, but this statement went a bit too far indeed.

Page 4 line 109

RC 2: cores. . . were incubated in a gas tight batch-incubation setup for 24 hours. The setup of this incubation is critical for the interpretation of the results and the authors need to include more detail: Were all batch incubations done on board or back in the lab? What was the time delay between coring and incubation? What was the length of the sediment cores and were all cores of equal length? What was the height of the water column above the cores, and what were the starting and end oxygen concentrations? Was the water column fully mixed in the core liners? Was stirring the same in all cores? What was the fauna in these cores and how was its activity accounted for? What were the light conditions during incubation? Were all cores incubated with the same water or with the water they came with?

AR: To answer your questions, we will expand the method section and create a new figure of the sediment core incubation for the supplementary material. Briefly, the incubations were done directly after sampling in the ship's laboratory at in-situ temperature. Core incubations were kept in the dark by wrapping cores and overlying water in aluminum foil. All sediment cores were incubated with site water. For faunal activity, we have quantitative assessments based on the observed abundance and biomass of macrofauna from parallel cores.
The water in the incubations was gently stirred, so that the water was mixed, but that surface sediment in the incubations was not resuspended. We will integrate this information in the revised version of the manuscript.

Page 4 line 114

RC 2: NH_4^+ and NO_3^- concentration of the added tracer solution was the same as the bottom water concentrations (Tab. 2). This is not clear. Does this mean that you added tracer while maintaining the original nutrient concentration, i.e. removed some water and then added a mix of water and tracer that had the same nutrient concentration as the original water? If that was the case, please specify how much tracer was added and if the different tracer additions (nutrient concentrations differed up to factor 20) could have influenced the incubation experiment. In Line 116 you mention that the label addition was calculated aiming for a maximum enrichment of 5.000 ‰ in substrates and products. How was this achieved if added tracer solution concentration was the same as the bottom water concentrations, and the incubations ran with the same volume of overlaying water?

AR: Yes, we replaced a small volume of site water with label solution, which was (in concentration and volume) adjusted so that no changes in total ammonium or nitrate concentration occurred. As background for the calculation, we used concentration data from previous cruises, assuming that these might be comparable. This assumption was confirmed by subsequent nutrient measurements in the home laboratory, so that we can indeed say that overall nutrient concentration remains unchanged during label addition. We will insert details regarding this in the revised manuscript version.
For the tracer injection, we used two stock solutions of 100 µmol l^{-1} with 50% 15N ($^{15}NH_4^+$ and $^{15}NO_3^-$) in MQ water. At each station, we diluted the stock solution to 2 to 5 µmol l^{-1} (NH_4^+ and NO_3^-) depending of the station in a 20 ml syringe and injected the appropriate volume into the overlying water (20 cm height above the sediment).

Page 5 line 118

RC 2: Upon sampling, incubation water was filtered with a syringe filter (material, manufacturer, 0.45 µm pore size) Insert material and manufacturer.

AR: We will add the material (cellulose acetate) and manufacturer (Sartorius) of the syringe filter.

Page 6 line 157

RC 2: The surface sediment samples of the cruises HE 383 (06/07.2012) and HE 447 (06.2015) for NOAH-D were analyzed for total carbon and total nitrogen contents with an elemental analyzer (Carlo Erba NA 1500) via gas chromatography calibrated against acetanilide. Please be more specific: How deep was the sediment layer termed “surface sediment”?

AR: “Surface sediment” refers to the first 1 cm. We will add this information in the new manuscript version.

Page 7 line 184

RC 2: Three O_2 profiles were measured in one sediment core of each station. Please specify the conditions: When exactly where those profiles measured, i.e. how long after retrieval of the core? What were the conditions during the measurements e.g. was there a water layer above the sediment?

AR: The O_2 profiles were measured directly after core retrieval, The time between sampling and O2 profile measurements was always about 10 to 15 minutes. Overlying water column was always adjusted to 20 cm height, and temperature in the temperature-controlled lab was the same as the temperature in the bottom water. We will add this information in the revised manuscript.

Page 7 line 195

RC 2: The lowest oxygen flux was determined at the permeable sediment station NOAH-A with -10.0 mmol m^{-2} d^{-1} (Fig. 2), the highest oxygen flux was measured at the impermeable sediment station NOAH-C with -53 mmol m^{-2} d^{-1}. The semi-permeable sediment station NOAH-D had an oxygen flux of -18.5 to -30.6 mmol m^{-2} d^{-1}. As pointed out by the authors in the discussion section, the fluxes in the permeable sediment vary with the flow above the sediment. For which flow setting were the fluxes reported here? The same question applies to the statement in Line 203: The lowest ammonification rates were measured in the semi-impermeable sediment at station NOAH-D.

AR: All oxygen fluxes were measured in the sediment core incubations, and gentle stirring was applied, where care was taken not to resuspend the surface sediment.
We are aware of the fact that the rates can, in such an experimental setup, never be identical to the true in situ rates. However, this methodological problem arises for all sediment incubations, and we wanted to demonstrate the relevance and magnitude of ammonification for German Bight sediments – which fits well with rate measurements from previous studies.
However, we will specify the methodological details in a revision.

Page 10 line 283

RC 2: In total, though, we estimate that benthic N fluxes support between 13 % (at a water depth of 38 m) and 61 % at 10 m depth (Tab. 3) of primary production As this is based on one time summer sampling only, I suggest softening this statement.

AR: We will include a statement regarding seasonal variability.

Page 10 Line 307:

RC 2: Nitrification rates are relatively independent of permeability, in contrast to ammonification. This needs further explanation. In the discussion, you mention the potential importance of the flushing of the permeable sediment, which could transport organic matter and oxygen into the sediment. This would have direct implications for both, ammonification as well as nitrification. Why was nitrification relatively independent of permeability?

AR: We found that the sediment permeability and organic matter reactivity affect the ammonification directly, whereas oxygen concentration and ammonification affect the nitrification.

Highest ammonification was measured in impermeable sediments with lowest oxygen penetration depth in sediments, whereas lowest ammonification rates were measured in semi-permeable and permeable sediments with higher oxygen penetration depth. Nitrification is controlled by oxygen availability as well as substrate (ammonium) availability, and we assume that this co-dependence disguises the correlation with permeability (because high oxygen penetration might lead to decreased substrate availability). Overall, permeability of course hast an effect on nitrification, but it is not clearly correlated. We will discuss the complex interplay of sediment characteristics, faunal activity, and resulting N-turnover in a revision.

Page 11 line 311

RC 2: Nitrification rates are lowest at Station NOAH-A. Here, oxygen penetration depth is highest, and the sediment has low organic matter content (Tab. 2), which obviously limits nitrification rates. This statement contradicts the statement on line 307, where you say that "nitrification rates are relatively independent of permeability".

AR: Nitrification rates are affected by oxygen concentration depth in the sediment and by ammonification. At NOAH-A, we measured the highest oxygen concentration depth, which support nitrification, and the lowest organic matter content, which limits the ammonification rate. Here, organic matter turnover indirectly controls nitrification rates (page 11, line 312). Stating that nitrification as such is independent of permeability is indeed not correct – it is poorly correlated in our sample set, but that is of course not the same. We will modify and improve this section in the revised manuscript.

Page 20 table 2

RC 2: Random frictionless packing in sand produces a porosity of 0.39, and although lower numbers can sometimes be measured, a porosity of 0.29 seems unrealistic. Was the core fully water-saturated? Please check whether these numbers were reported as weight or volume ratios. Practical salinity is based on ratios and should be expressed by dimensionless number only.

AR: Regarding porosity at station NOAH-E, the initially stated value of 0.29 is indeed too low. This value was calculated from a sediment sample intended for particle analysis, which was not fully water saturated at the time of measurement. The correct porosity is 0.41 (v/v) and was measured on a fully saturated sample. We will update the manuscript accordingly, and we will change salinity to dimensionless numbers where appropriate.