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Interactive comment on "Total nitrate uptake by an invasive benthic foraminifer in marine sediments" *by* Constance Choquel et al.

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Dear Editor and referees, Thank you for your interest in our work and your comments to improve the paper "Denitrification by benthic foraminifera and their contribution to N-loss from a fjord environment". Please find the revised manuscript attached. The main corrections performed to the manuscript are highlighted in yellow.

Briefly, we have changed the title of the manuscript, the new title highlights the denitrification of foraminifera and their impact on the nitrogen cycle. The abstract has been adapted accordingly.

In the first paragraph of the introduction, a contextualization of the importance of the ni-

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trogen cycle in semi-enclosed environments subject to hypoxia has been added. Then, a paragraph in discussion 4.3 has been added to inform readers about the eutrophication state of Gullmar Fjord. Discussion sections formerly 4.2 and 4.3 have been merged under the name “ 4.2 Foraminifera ecology considering nitrate micro-distribution”.

To take into account the remarks of the short comment and the referees, we have changed the term "invasive" Nonionella sp. T1 by non-indigenous species (NIS). The term “invasive” is introduced because it is cited in the existing literature. The potential invasiveness of Nonionella sp. T1 in the Gullmar fjord is mentioned later in the discussion sub-section 4.1.

Figure 4 of the material and method about the 2D gel method has been removed as potential interested readers can consult the original paper that details the procedure.

A conversion and a unit error have been found for the denitrification rates (nmol cm-3 d-1). The final contribution results remain unchanged as the conversion error was done for both denitrification rates for foraminifera and cores (see changes Fig. 5, Table 1, Annex Equation S2, and associated text). For more details on minor changes please refer to the replies to referees.

Best regards.

Interactive comment on Biogeosciences Discuss., https://doi.org/10.5194/bg-2020-287, 2020.

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Discussion paper

Denitrification by benthic foraminifera and their contribution to N-loss from a fjord environment

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Abstract.

Oxygen and nitrate availabilities impact the marine nitrogen cycle at a range of spatial and temporal scales. Here, we demonstrate the impact of denitrifying foraminifera on the nitrogen cycle at two oxygen and nitrate contrasting stations in a fjord environment (Gullmar Fjord, Sweden). The foraminifera contribution to benthic denitrification was estimated by coupling living foraminifera microhabitat, denitrification rate measurement and sedimentary nitrate 2D distribution, combining diffusive equilibrium in thin films (DET) colorimetry and hyperspectral imagery. Oxygenated bottom waters with high nitrate content in sediment porewaters were dominated by the non-indigenous species (NIS) *Nonionella* sp. T1 which could denitrify up to 50-100 % of nitrate porewater. Contrastingly, hypoxic bottom waters where sediment porewaters were nitrate low, denitrifying foraminifera were scarce and did not contribute to nitrogen removal (~ 5 %). Our study showed that benthic foraminifera can be a major contributor of nitrogen mitigation in oxic coastal ecosystems and should be included in ecological and diagenetic models aiming at understanding biogeochemical cycles coupled to nitrogen.

1 Introduction

Hypoxic water occurs frequently in bottom-waters of shallow coastal seas, due to remineralization of organic matter and water stratification. In this study we used the hypoxia threshold of 63 µmol L^{-1} (e.g. Diaz et al., 2008; Breitburg et al., 2018). Hypoxia may have large ecological effects (Levin et al., 2009; Rabalais et al., 2010; Zhang et al., 2010), such as an increase of fauna mortality (Diaz et al., 2001). However, certain microorganisms, e.g. bacteria and foraminifera, can perform denitrification by respiring nitrate (Risgaard-Petersen et al., 2006) and thereby survive in depleted oxygen environments. The effects of decreasing dissolved oxygen availability at spatial and temporal scales will impact biogeochemical cycles such as the nitrogen cycle (Childs et al., 2002; Kemp et al., 2005; Conley et al., 2007; Diaz et al., 2008; Neubacher et al., 2013; Breitburg et al., 2018). The nitrogen cycle in marine sediments is a perpetual balance between nitrogen inputs (e.g. terrestrial

Fig. 1. Choquel et al revised manuscript

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Denitrification by benthic foraminifera and their contribution to N-loss from a sill fjord

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Supplementary material

Fig. 2. Choquel et al revised supplementary

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