THE EFFECTS OF HYDROGRAPHY AND ANTHROPOGENIC PRESSURE ON BENTHIC NITROGEN CYCLING IN THE GULF OF FINLAND (BALTIC SEA)

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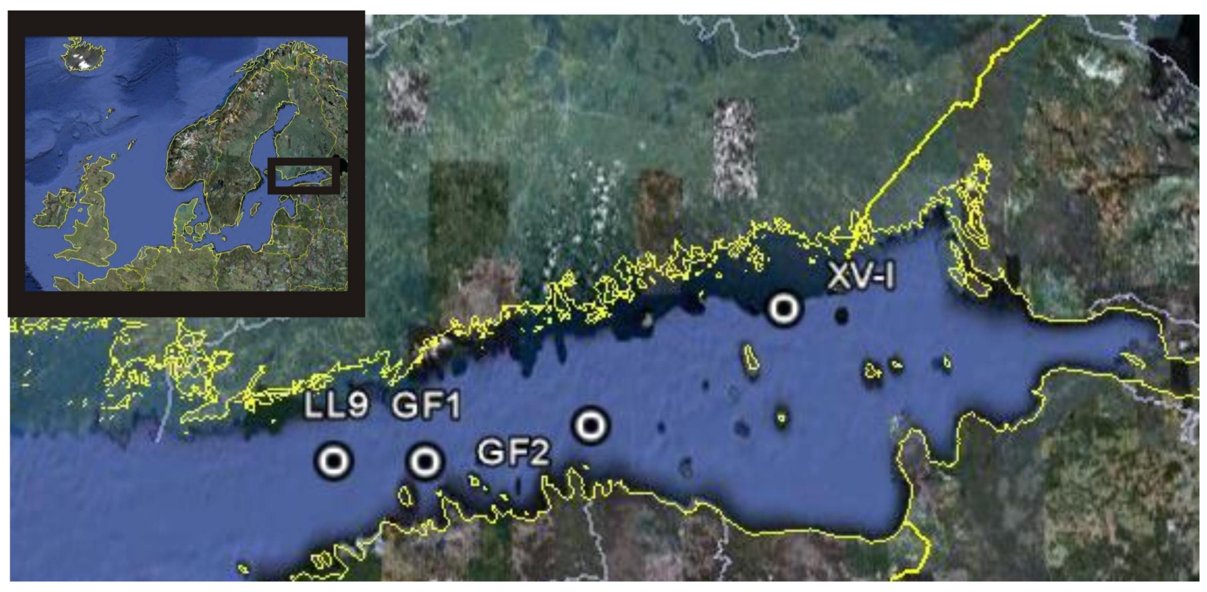
INTRODUCTION

Baltic Sea is one of the largest brackish water bodies in the world. The drainage basin is populated by approximately 80 million people, causing high anthropogenic nutrient loading to the sea. Gulf of Finland, one of the northern sub-basins, has the highest annual nitrogen load of the entire sea. The natural nitrogen removal capacity (denitrification) was approximately 45 kt N yr^{-1} in the 90s, which equals ~30 % of the external input (Tuominen *et al.* 1998). Since then, the bottom water oxygen has decreased considerably. To determine the nitrogen removal capacity in the current conditions, denitrification and anammox were measured in the sampling area in 2008. In addition, the dissimilatory nitrate reduction to ammonia (DNRA) was assessed to determine the alternative nitrate reduction pathways.



RESULTS

In GF1 and GF2 the 2008 measurements showed that the bottom water oxygen concentrations and the denitrification rates had decreased to less than a half from values in the mid 90s. In these two stations, DNRA was a more important nitrate reduction pathway than denitrification. Station LL9 overall had low nitrate reduction rates. Although GF1, GF2 and LL9 had very low oxygen concentrations, nitrate was available in the bottom water. XV-1, where the bottom water oxygen concentration was substantially higher than in the other stations, had a very high denitrification rate, and DNRA was a less important nitrate reduction pathway than denitrification (Figure 1).

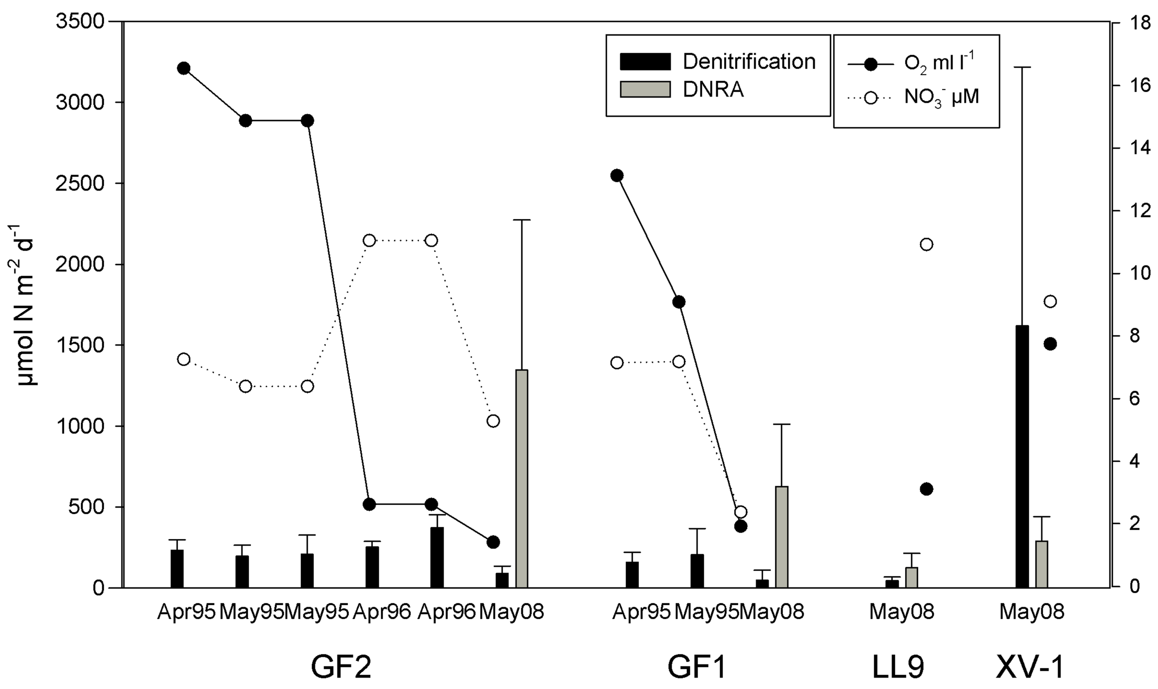


Figure 1. Benthic denitrification and DNRA rates (left axis), and bottom water nitrate and oxygen concentrations (right axis) in the Gulf of Finland. The 90s data from Tuominen *et al.* (1998). DNRA was not measured in the 90s.

DISCUSSION

The oxygen conditions in the Gulf of Finland are heavily influenced by salt water inflows from the Baltic Sea main basins. The saline water strengthens the halocline, which prevents mixing of the water column and causes bottom water anoxia. When the denitrification measurements were done in the mid 90s, there had been a long period without salt water inflows and the halocline had weakened. Consequently, the bottom water oxygen conditions were exceptionally good (Figure 2). An inflow occurred in 1995 and the oxygen concentration began to decrease, which probably also decreased the natural nitrogen removal capacity of the sediments.

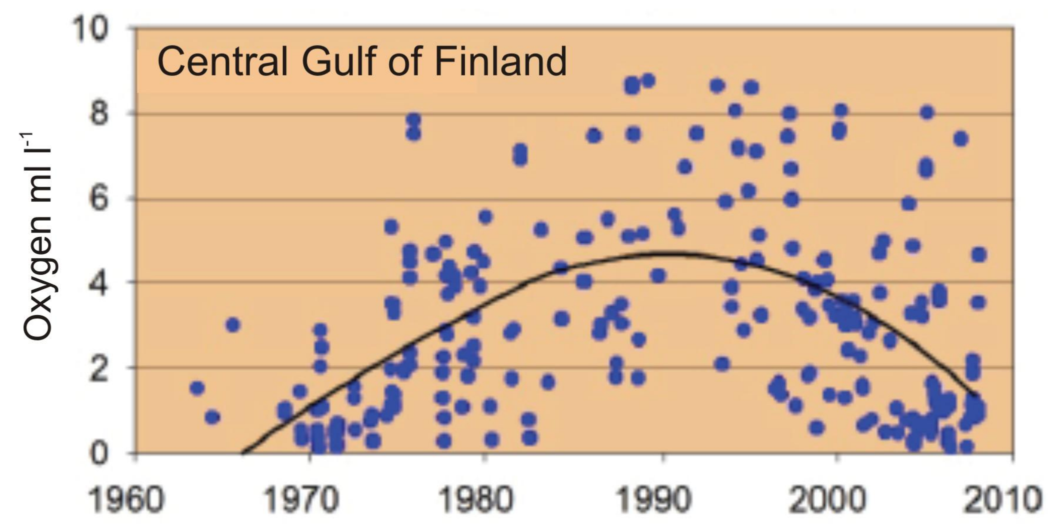


Figure 2. Long term bottom water oxygen concentration in the Central Gulf of Finland. Source: Finnish Environmental Institute

The dissolved inorganic nitrogen (DIN) concentrations in the open Gulf of Finland are variable (Figure 3) but show a trend where the DIN concentration increased from late 70s to the mid 80s, followed by a decrease in the mid 90s and then an increase again. The low DIN concentrations in the mid 90s occurred simultaneously with higher denitrification rates and weaker halocline. Hence, the increase in DIN concentration after the mid 90s may have been caused by the decrease in denitrification, since there was no an apparent increase in the nitrogen loading at that time.

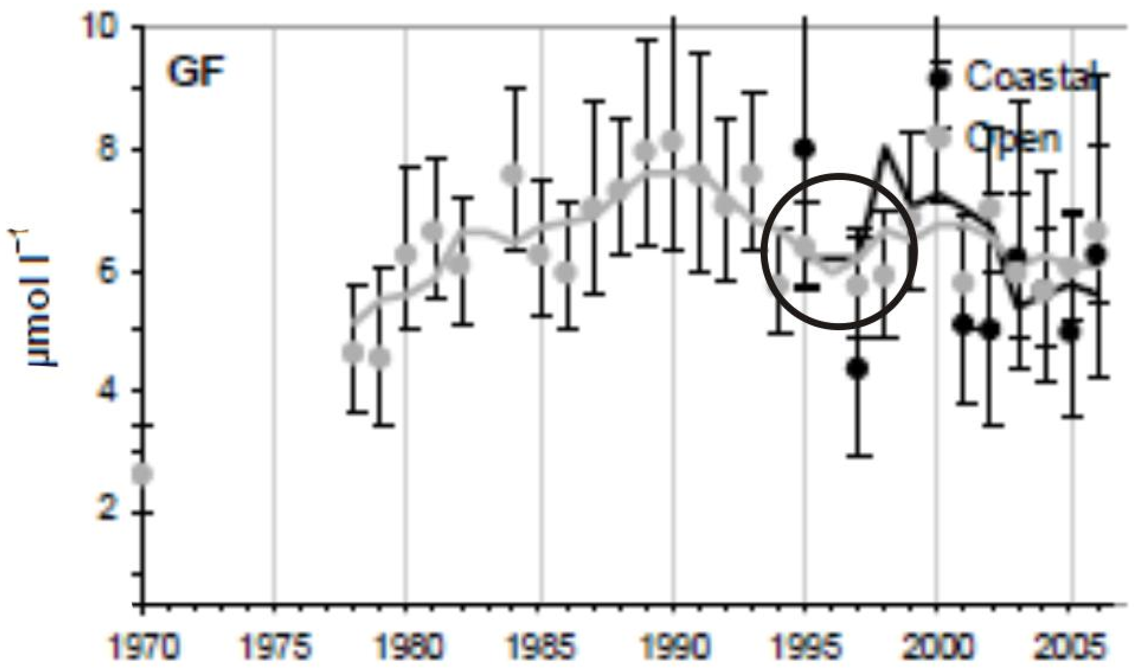


Figure 3. Long term DIN concentration in the Gulf of Finland. The period before and after the 90s denitrification measurements circled. Source: HELCOM

The 2008 measurements demonstrate that the bottom water oxygen concentration governs what the most important nitrate reduction pathway is. In low oxygen concentration DNRA is more important than denitrification, but when the bottom water oxygen concentration increases, the situation becomes the opposite and denitrification dominates nitrate reduction.

CONCLUSIONS

- The denitrification rates measured in the Gulf of Finland in the mid 90s represent maximum rates rather than average rates for the area. Hence the benthic nitrogen removal capacity in longer time scales may be significantly less than what has been estimated.

- The changes in DIN concentration cannot be explained by nitrogen loading, however fluctuations in the nitrogen removal capacity may be the explanatory factor, suggesting that the availability of nitrogen is dependent on the strength of the halocline and oxygen conditions, rather than the nitrogen loading from the drainage basin.

- Although denitrification operates also during hypoxia (O_2< 2 ml l^{-1}) nitrogen is more likely to be retained in the system by DNRA. In very low oxygen conditions nitrogen enters the vicious cycle of eutrophication, where nitrogen is not removed, but instead retained in the system.

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