Benthic Respiration and Nutrient Cycling in the Huon Estuary (Southern Tasmania)

By

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Declaration of originality

I declare that this thesis contains no material which has been accepted for the award of any other degree or diploma in any tertiary institution, and to the best of my knowledge contains no copy or paraphrase of material previously published or written by any other person except where due reference is made in the text of the thesis

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Abstract

Sediment biogeochemistry was studied in the Huon estuary, which is located in Southern Tasmania, Australia. The sources of organic matter and rates of decomposition were investigated as well as fluxes of nutrients, which are liberated during organic matter decomposition. The study aimed to develop a conceptual understanding of benthic respiration and nutrient cycling in the Huon estuary and the influence of organic carbon on these processes. This study also sought to evaluate the ecological significance of nutrient inputs from sediments compared with other nutrient sources to the estuary.

Sediments were studied over one year, including sampling in March, July and November in 2004 and then in April 2005. To represent the terrestrial and marine end members of the estuary, locations were situated in the upper and lower reaches respectively.

Employing a variety of organic – geochemical approaches, this study showed that sediments were dominated (i.e. >50%) by allochthonous, river-supplied terrestrial organic matter. Spatial differences were observed between the upper and lower locations with the upper estuary receiving most of its source of organic matter from terrestrial sources (approx. 75%). In contrast, the lower location had a greater variety of organic matter sources, with approximately 50% coming from terrestrial sources, approximately 20% from phytoplankton and about 15% from bacteria. No discernable differences were found between sampling stations within each location.

Organic matter source markers for some inputs, in particular markers for terrestrial organic matter, were higher in winter, most likely due to an increase in input from catchment runoff. Increased river flows were observed in July during this study, carrying higher concentrations of particulate organic matter from catchment runoff, which is likely to increase the terrestrial detritus load at the seafloor as indicated by the increase in terrestrial biomarkers during this period.

Oxygen and CO_2 fluxes indicated that aerobic respiration was one of the main pathway for carbon degradation in Huon estuary sediments, although anaerobic

respiration was also present. The low CO_2:O_2 and Alkalinity:O_2 flux ratios was evidence of aerobic respiration. Additionally modelled oxygen consumption profiles showed that the majority of oxygen was consumed near the surface, most likely due to aerobic heterotrophic bacteria. A small oxygen consumption peak was also observed at the anoxic/oxic interface most likely due to sulphide oxidation.

Spatial and temporal differences in respiration occurred with carbon contents and temperature considered the main drivers respectively for this variability. Differences also occurred between total versus diffusive oxygen uptake rates, and was likely due to the presence of benthic fauna. Respiration in Huon estuary sediments compared well with other deep coastal sediments whereby rates of TCO_2 and O_2 fluxes were very similar to Monterey Bay in California and the Southern Kattergat in the Baltic Sea

Benthic fluxes of nutrients were low in the Huon estuary. Average fluxes of ammonia, nitrate, phosphate and silicate were 1.3, 10.1, 1.6 and 32.5 $\mu mol\ m^{-2}\ h^{-1}$ respectively. An extrapolation of these measurements to the whole estuary revealed that the sediments were only a minor source of nutrients, providing approximately 96 tonnes of inorganic nitrogen, 32 tonnes of phosphate and 586 tonnes of silicate.

On all occasions, the DIN flux was dominated by nitrate, which was always released from the sediment to the overlying water. The effluxes of nitrate and influxes of nitrite and ammonium are most likely associated with intensive nitrification, stimulated by the presence of relatively deep oxygenated zones. Peaks of nitrate in the oxic zone observed from nitrate pore water profiles also provided additional evidence of nitrification. The net efflux of nitrate from the sediments, suggests that they act as net regenerators of nitrogen as opposed to nitrogen assimilators.

The benthic effluxes of nitrogen however were smaller then expected from carbon oxidation rates. The low N:P ratio of benthic fluxes (approx. 3:1) indicates that processes such as denitrification and anaerobic ammonium oxidation (ANAMMOX) may be important nitrogen elimination process. However another potential pathway for nitrogen released during organic matter remineralisation is for the decomposing bacteria to reassimilate some of the ammonium due to the low nitrogen content of the organic matter been decomposed.

Due to increasing levels of chlorophyll *a*, largely due to the growing aquaculture industry, a laboratory experiment was conducted to observe the response of Huon estuary sediments to increasing loads of labile organic carbon. The addition of *Spirulina*, produced a dramatic increase in the flux rates of all analytes. The change in fluxes for most analytes correlated well with increasing carbon loading however the rate change occurred in two distinct stages for some of the analytes, including oxygen and ammonium. Results showed rapid change in oxygen and ammonium flux rates and oxygen penetration with increasing carbon load size. However when the carbon load became >20.2 g C m^{-2} the change in flux rates and decrease in oxygen penetration slowed significantly for these analytes.

The point at which the rate change of fluxes slowed possibly indicates that the biogeochemical system was switching from one that was dominated by aerobic respiration to one dominated by anaerobic respiration. A number of trends in the data indicate this including increasing CO_2:O_2 ratio, increasing alkalinity fluxes out of the sediments, most likely due to sulphate reduction: an anaerobic metabolic process, and declining oxygen penetration depths. DIN fluxes also became dominated by ammonium rather then nitrate as sediments became more anaerobic. Nitrate effluxes, evidence of nitrification, rapidly became nitrate fluxes into the sediment, suggesting denitrifiers could no longer obtain nitrate *in situ* due to the reduction in nitrification, and thus the breakdown of coupled nitrification/denitrification. As the sediments became anaerobic, denitrification became dominated by direct denitrification whereby denitrifiers obtain their nitrate requirements from the water column, as evidenced by uptake of nitrate by the sediments. Dissimilatory nitrate reduction to ammonium (DNRA) may also have contributed to the large efflux of ammonium as sediments became more anaerobic.

This study has provided insights into how sediments function in relatively pristine coastal environments, in particular what the sediments are not doing at the moment (such as releasing large amounts of ammonium), but what they could be doing if labile organic carbon is increased. The findings have provided a good contrast to sediments that exist in environments exposed to increasing anthropogenic influence and provide a snapshot of how heavily polluted systems may once have functioned. This study has therefore added to the growing literature of how coastal sediments recycle carbon and nitrogen and their importance to local and global carbon and nitrogen cycles.

Finally this thesis has shown that it is difficult to interpret specific processes such as nitrification and denitrification from core incubations and the inferred stoichiometric relationships of the carbon, nitrogen and phosphate fluxes due to the complex nature of biogeochemical processes occurring in the sediments at any time. To build on the foundations laid by this study, the next step would be to carry out a set of carefully designed experiments in regards to both benthic respiration and nutrient cycling. In particular, an experiment that simultaneously measures bacterial nitrogen assimilation, ANAMMOX, denitrification and nitrification would be useful to gain a better understanding of the nitrogen cycle. These experiments should be carried out under both unimpacted and impacted sediments as while I have shown that organic carbon loading alters sediment metabolism which is consistent with the literature, at this stage it is still unknown as to exactly how benthic metabolism would be controlled if farming does greatly increase. Furthermore, how these individual processes (i.e. nitrification, ANAMMOX, denitrification and DNRA) collectively influence nutrient fluxes from the sediment under unimpacted and impacted conditions needs to be elucidated.

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