An in situ examination of carbon fluxes in the estuarine environment at high temporal resolution and their relationship to aqueous and sedimentary nutrient composition

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Introduction
Estuarine systems are highly active biological communities, and are known to produce and consume key greenhouse enhancing gases including CO₂. The importance of these systems as producers or consumers of inorganic carbon, and their links to changes in the nitrogenous nutrient composition of the system is an area of current environmental investigation and concern. However, in situ studies of carbon processing with high temporal resolution are rare, especially of the Australian environment. This study investigated the balance between the production and consumption of inorganic carbon in situ while quantifying diurnal and seasonal changes in CO₂, CH₄ and N₂O fluxes. These changes were examined alongside the sedimentary and aqueous nutrient composition of the estuary in order to identify changes in the carbon processing occurring within the system.

Methods
• Hourly gas flux measurements during winter and summer 2006-2007
• Three sites in the near shore zone of Lake Illawarra, NSW, Australia (an estuarine lagoon)
• Flushed chamber system (Figure 1).
• Coincident measurements of key environmental parameters - pH, dissolved O₂, temperature, photosynthetically active radiation (PAR) and salinity.
• Concentrations of a variety of key carbon and nitrogen compounds in the water and sediment were also measured.

Results and Discussion
• The fluxes ranged from -4.0 to 42.4 mmol CO₂/m²/h, -1.7 to 3.1 mmol N₂O/m²/h and -0.007 to 1.6 mmol CH₄/m²/h.
• The sediments were rich in organic carbon and nitrogen.
• The estuarine system was found to act as a net CO₂ source to the atmosphere which varied seasonally and diurnally.

System Carbon balance – Net ecosystem production (NEP)
• Determined by examining the change in O₂, or the change in the inorganic carbon content (TIC) (Figure 2).

Calculating the change in total inorganic carbon
A simple equilibrium model based on established techniques was developed to determine the ΔTIC based on the CO₂ flux.

\[ \text{CO}_2 \text{Flux} = \alpha (P_{\text{CO}_2 \text{aq}} - P_{\text{CO}_2 \text{air}}) \]

\[ K_P \text{CO}_2 \text{aq} = [\text{H}_2\text{CO}_3^-] \]

\[ [\text{TIC}] = \left[1 - \frac{K_1}{[\text{H}^+]} + \frac{K_2}{[\text{H}^+]^2}\right] [\text{H}_2\text{CO}_3^-] \]

Comparing O₂ and TIC approaches
• NEP(O₂) tended to be negative (O₂ uptake i.e. TIC production) while NEP(C) varied diurnally with light and temperature (Figure 4).
• NEP rates were higher than those noted in other studies of deeper water environments [3,4].

Conclusion
Near shore sites play a unique role in the carbon processing within estuarine systems, quite different to that of deeper water areas. As such, they should be carefully accounted for when studying estuarine systems as a whole.

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References

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Further Information

Figure 1: Diagram of in situ system incorporating a Nicolet Avatar 380 Fourier Transform Infrared spectrometer (FT-IR) and a Multiple Atmospheric Layer Transmission (MALT) Winking approach [2] and the parameters measured: pH, dissolved O₂, temperature, photosynthetically active radiation (PAR) and salinity.

Figure 2: Calculating net ecosystem production using an O₂ based or a total inorganic carbon (TIC) based approach.

Figure 3: Schematic outlining the equilibrium model used to predict total inorganic carbon concentration based on water-to-air CO₂ flux, atmospheric CO₂ concentration, wind speed, salinity, temperature and pH.

Figure 4: a) Water temperature variation, b) Net ecosystem production (NEP(O₂)) and c) Net ecosystem production (NEP(C)) at an example site during summer 2007. Dashed lines are ± the standard error in the NEP. PAR and disturbance periods (e.g. wind induced wave activity) are also shown.

• Why? Anaerobic (non-O₂) based carbon processing played a larger role in these near shore environments than in the more studied deeper water sites
• Why? Nearshore sites = increased availability of C and N, PAR and temperature.