Biogeochemical processes and sewage markers in Buffalo Creek, Darwin

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Photo: Jodie Smith

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Project Objectives

- To quantify the effect of sewage on biogeochemical processes in a hypereutrophic creek, Buffalo Creek
- To compare the results with a previous study showing limited effects of sewage on a creek (Myrmidon Creek) with smaller loads of nutrients

Summary of findings

This study examined a range of biogeochemical processes, water quality and sewage chemical markers in Buffalo Creek in December 2008. The results were compared with two other creeks, Myrmidon Creek (receiving sewage from Palmerston STP) and a reference creek (Fig. 1). Coprostanol (a sewage chemical marker), chlorophyll *a* and nutrient concentrations, primary productivity, sediment nutrient fluxes, pore water nutrients, water column and sediment respiration were all higher in Buffalo Creek than Myrmidon Creek or the reference creek. Dissolved oxygen concentrations and denitrification efficiency were lower and the phytoplankton community shifted towards diatoms. These differences were not only measured at upstream sites, but on the outgoing tide, were also measured in the downstream region of the creek. This suggests that sewage outfall is having substantial effects on the biogeochemical processes of the creek during the study, with the greatest effects being on the following processes: primary productivity in the water column, sediment nutrient fluxes, denitrification efficiency.

Methods and Results

A field trip was conducted to Buffalo Creek, Darwin by five scientists from Geoscience Australia, CSIRO, and Griffith University, with logistic support from staff at the Northern Territory Resources, Environment, the Arts and Sports (NRETAS) Department, from 1 to 8th December 2008. A number of sites were sampled down the length of the creek, from the most upstream site which was navigable by boat (BC0) through a downstream site near the mouth (BC4). All sampling was standardized on the outgoing tide to maximise the sewage effects and avoid the confounding effects of incoming oceanic water.

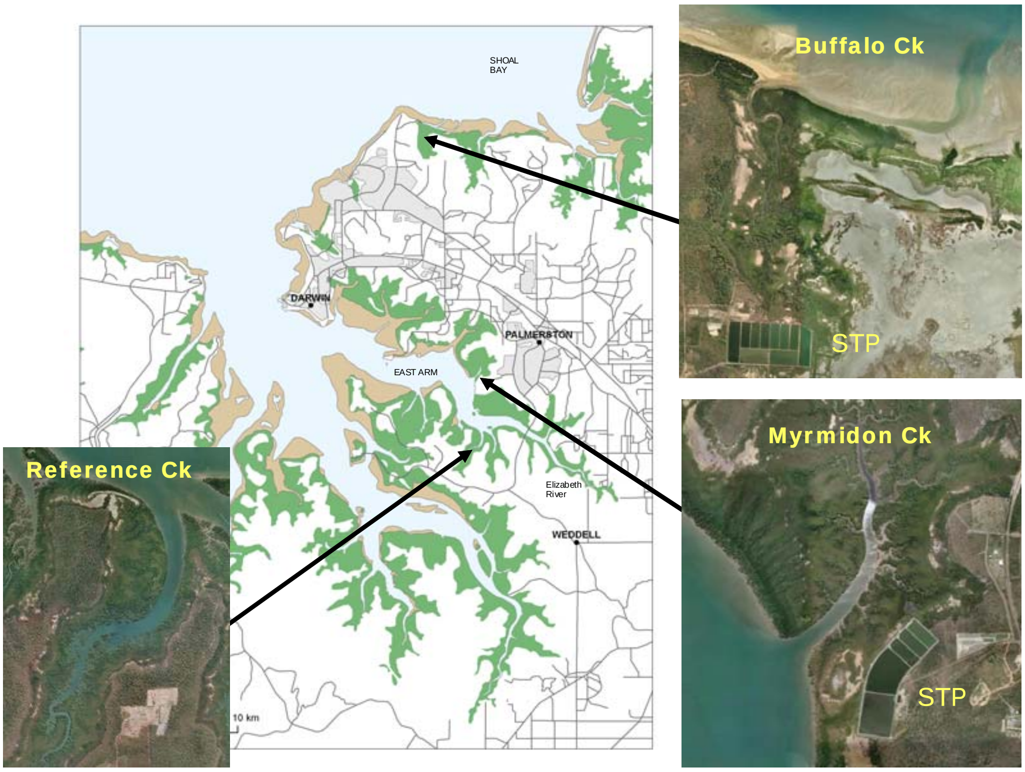

Figure 1: Location of Buffalo Creek, and location of the two other creeks (Myrmidon, reference) sampled in the study.

There was a distinct gradient in dissolved oxygen and pH down the creek with very low values in the upstream reaches (BC0). An example of data from one of the days is shown in Table 1.

Table 1: Example of physico-chemical and nutrient parameters down Buffalo Creek (BC0 was the most upstream site)

Site	Depth	Temperature °C	Cond. Ms/cm	DO mg/L	pH	Turbidity ntu	Ammonia mg/L	Oxides of N mg/L	Phosphate mg/L
BC0	Surface	31.17	37.2	0.99	7.17	12.9			
	Bottom	31.20	38.6	0.57	7.06	11.6			
BC1	Surface	34.51	42.3	1.09	7.17	8.7	0.827	0.231	0.346
	Bottom	31.76	47.5	0.62	7.15	9.4			
BC2	Surface	32.14	48.2	3.25	7.35	7.0			
	Bottom	31.83	57.7	2.53	7.48	11.0			
BC3	Surface	32.13	52.7	3.67	7.38	6.6	0.218	0.069	0.138
	Bottom	31.77	58.5	3.11	7.47	5.6			

Several classes of lipid markers were measured in order to assess primary organic matter sources. One of these, a sterol with the common name coprostanol, can be used to trace the influence of human derived faecal material in sediments and waterways. Comparison of coprostanol concentrations in the sediments of Buffalo creek, Myrmidon creek (receiving sewage from Palmerston sewage treatment plant) and a reference creek with no sewage inputs, potentially allows a gradient of sewage derived impact over time to be established (Fig. 2).

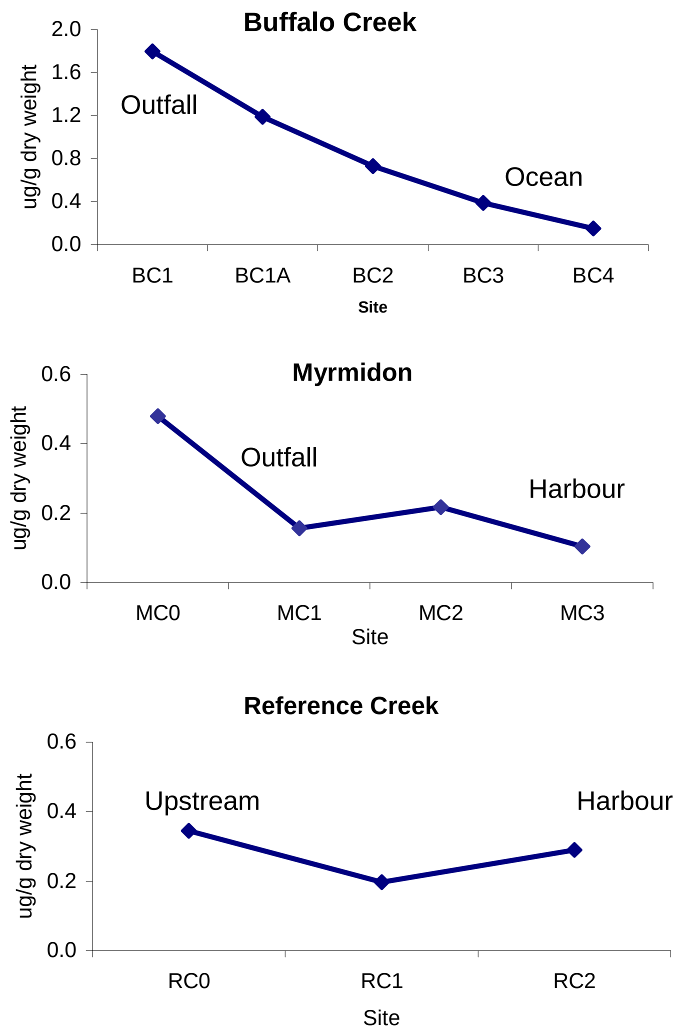

Figure 2: Average concentration (µg/g dry weight) of coprostanol in sediments from the three study creeks

Coprostanol is mainly formed by bacteria in the gut of humans but small amounts have been recorded to naturally occur, particularly in anaerobic sediments. Background levels in Darwin harbour sediments appear to be up to 0.3 µg/g depending on sediment type. Thus we can see that the most impacted site in Myrmidon creek appears to be upstream of the outfall creek at a level around twice background. The most upstream site sampled in Buffalo creek however appears to be around 3-4 times more impacted than Myrmidon creek. This would appear to be consistent with other measurements of impact. The sewage derived influence appears to diminish rapidly with distance in Myrmidon creek, while in Buffalo creek, the influence extends much further.

Chlorophyll *a* concentrations in the water column were also higher in the upstream sites in Buffalo Creek and higher overall in Buffalo Creek than in Myrmidon Creek (Fig. 3). There were also significant differences in the pigment composition (an indicator of the algal groups) between the creek systems. Fucoxanthin, an indicator of diatoms and chrysophytes, was more dominant in Buffalo Creek while chlorophyll *b,* an indicator of green algae, and zeaxanthin, an indicator of cyanobacteria, was more dominant in Myrmidon Creek. Further work would be needed to establish if these differences hold over longer timeframes.

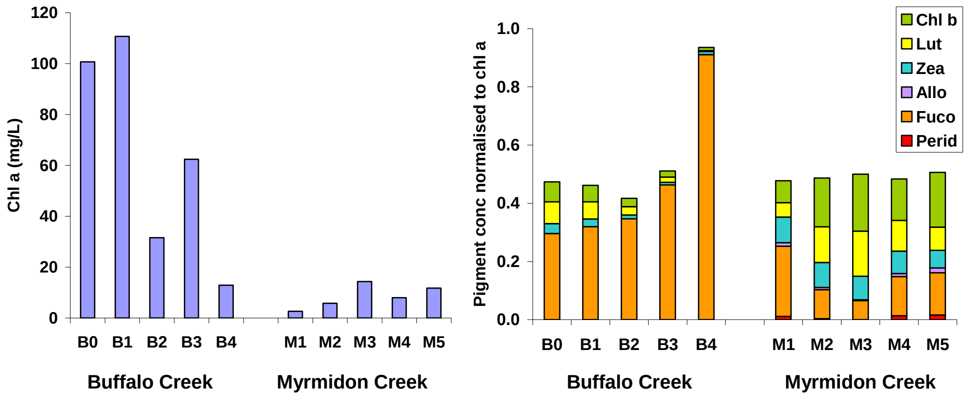

Figure 3: A comparison of chlorophyll a (µg/L) and algal pigment concentrations (normalised to chlorophyll a) at sites in Buffalo and Myrmidon Creeks.

Sediment chlorophyll *a* concentrations were also five times higher than those in Myrmidon Creek in March 2008. However maximum rates of primary productivity rates in the sediment were d comparable between Buffalo and Myrmidon creeks, probably due to the highly variable rates within sites.

Primary productivity rates in the water column were measured at three sites (BC1,2,3) and compared with the creeks studied in the sister project 5.4 (Fig. 4). Maximum primary productivity rates (P_{max}) were considerably higher in Buffalo Creek than either Myrmidon Creek (receiving sewage from Palmerston treatment plant) or a reference creek with no anthropogenic inputs.

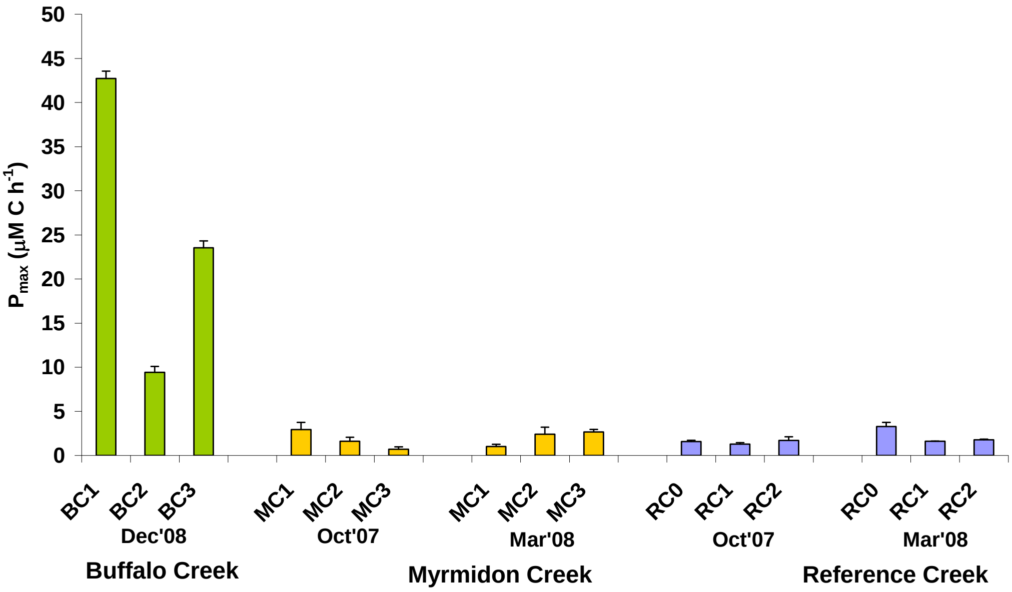

Figure 4: A comparison of maximum primary production (P_{max}, mean ± SE, µM C/h) at sites in Buffalo, Myrmidon and the reference Creek.

Experiments were conducted to determine the response of phytoplankton and benthic algae to the addition of nutrients. At BC1, an upstream site, there was no evidence of a response to the addition of either nitrogen or phosphorus singly or in combination (Figs. 5, 6). This suggests that the algal community has sufficient nutrients for growth, with the likely source being sewage nutrients. This contrasts with phytoplankton in Myrmidon and the reference creek where a response to nitrogen addition was seen. No clear response was seen by the benthic algal community. This suggests a significant impact of sewage on phytoplankton photosynthesis in Buffalo Creek, consistent with the high rates of primary productivity.

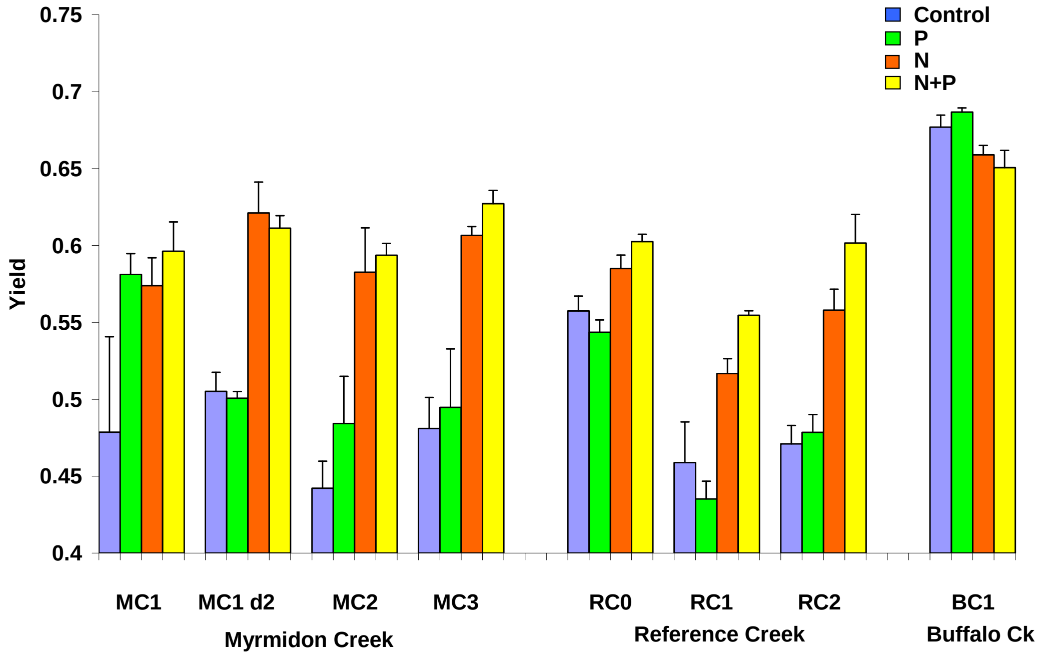

Figure 5: A comparison of nutrient responses (phosphorus, nitrogen, N+P) of phytoplankton at sites in Buffalo (BC), Myrmidon (MC) and the reference Creek (RC).

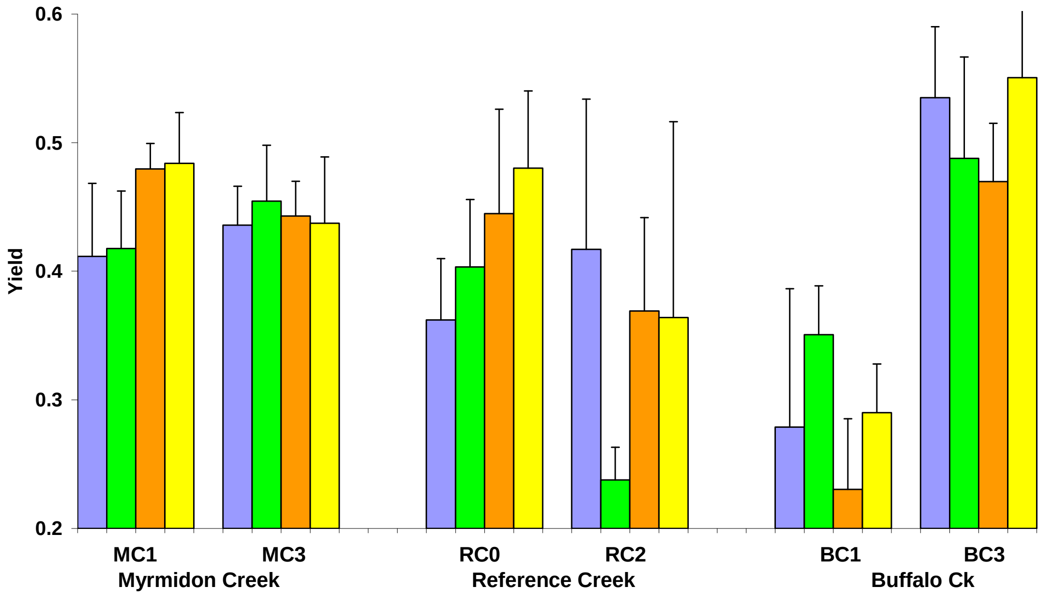

Figure 6: A comparison of nutrient responses (phosphorus, nitrogen, N+P) of benthic algae at sites in Buffalo (BC), Myrmidon (MC) and the reference Creek (RC).

Water column respiration was also much higher in Buffalo Creek than Myrmidon and the reference creek. In Buffalo Creek, the productivity and respiration also varied depending on water column conditions. Rates at BC1 were measured on three separate occasions and the productivity rates ranged from 68-157 µM h^{-1}. The respiration rates were much lower, ranging from -6 to -19 µM h^{-1}

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respectively. Despite this variability, these rates were consistently higher than in Myrmidon and the reference creek.

Sediment respiration rates (measured as benthic DIC fluxes) in Buffalo Creek were up to four times higher than those measured in Myrmidon and the reference Creek in October 2007 and March 2008 (Fig. 7). There was little difference in sediment respiration between the wet and dry seasons in Myrmidon and the reference creek and overall respiration rates were similar in Myrmidon and the reference creek. In Buffalo Creek, sediment respiration rates were high (>230 mmol m^{-2} d^{-1}) at both the upstream (BC1) and downstream (BC3) sites.

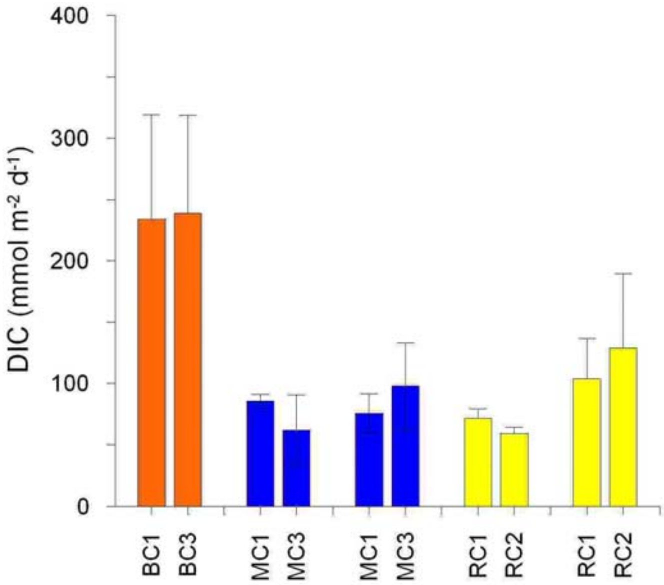

Figure 7: A comparison of sediment respiration rates (DIC mean ± SD, mmol m^{-2} d^{-1}) at sites in Buffalo, Myrmidon and the reference Creek.

Benthic nutrient fluxes, i.e. the release of nutrients from the sediments to the overlying water column, were several orders of magnitude higher in Buffalo Creek compared to Myrmidon and the reference creek (Fig. 8). The ammonia (NH_4-N) and phosphate (PO_4-P) fluxes in Myrmidon Creek and the reference creek were low (<1 mmol m^{-2} d^{-1} and < 0.3 mmol m^{-2} d^{-1}, respectively). Nutrient fluxes at the outfall site in Myrmidon Creek (MC1) were no higher than in the reference creek despite additional nutrient inputs from sewage effluent at this site. In Buffalo Creek, ammonia fluxes were 99 times and 24 times higher at the upstream (BC1) and downstream (BC3) sites compared to the average fluxes in Myrmidon and the reference creek. Phosphate fluxes were 103 times and 6 times higher at the upstream and downstream sites respectively compared to the average fluxes in Myrmidon and the reference creek.

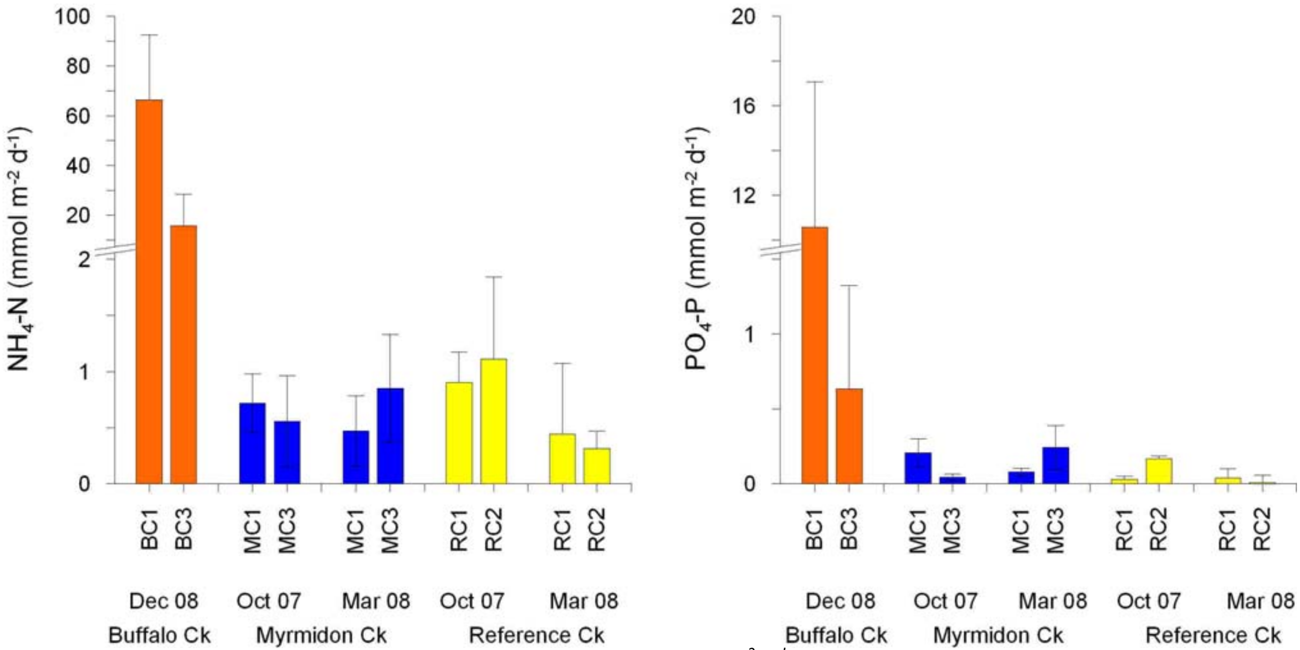

Figure 8. A comparison of sediment nutrient fluxes (mean ± SD, mmol m^{-2} d^{-1}) at sites in Buffalo, Myrmidon and the reference Creek.

Sediment nutrient pools were calculated as the sum of dissolved porewater nutrients in the upper 10 cm of the sediment profile. The sediment nutrient pools at the upstream site (BC1) in Buffalo Creek were significantly higher than in Myrmidon and the reference Creek (Fig. 9). This indicates the sediments in Buffalo Creek contain a large source of dissolved nutrients. This is significant because it indicates the sediments will continue to release nutrients to the overlying water column for a long period even if sewage discharge was ceased. As shown in Figure 8, the sediment nutrient pools are contributing a large flux of nutrients to the overlying water column in Buffalo Creek and these nutrients are readily available for uptake by phytoplankton and benthic algae.

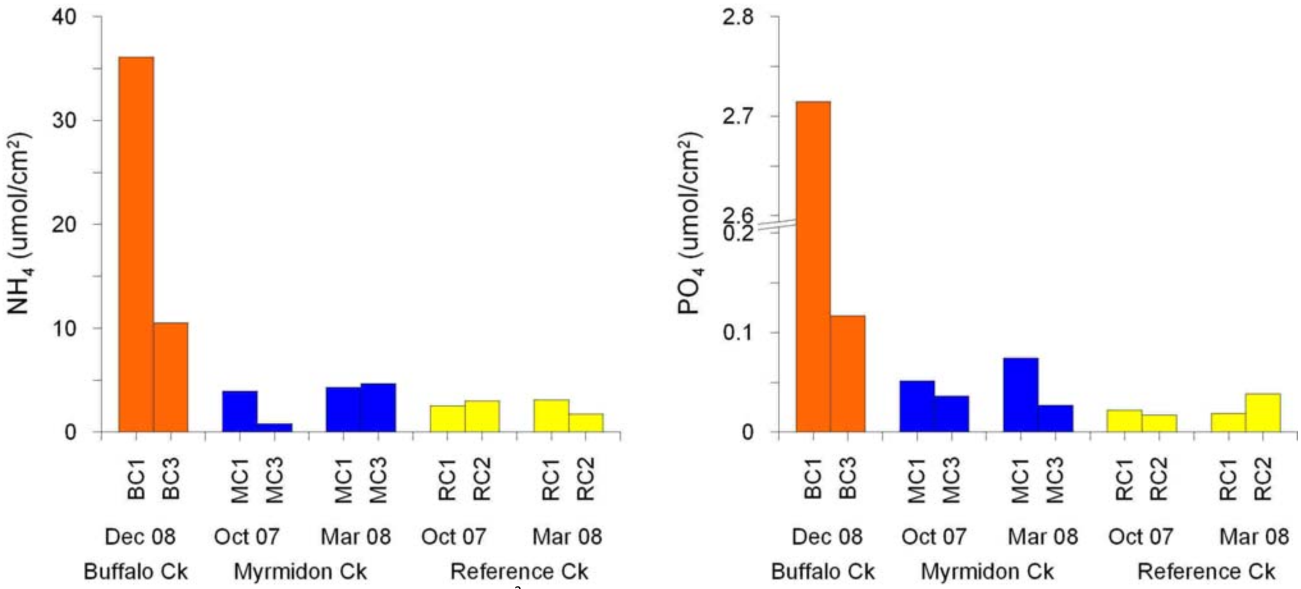

Figure 9: A comparison of nutrient pools (µmol cm^{-2}) in the upper 10 cm of the sediments at sites in Buffalo, Myrmidon and the reference Creek.

Denitrification, a process whereby inorganic nitrogen is converted into dinitrogen gas, was measured in the sediments as an indication of the efficiency of nitrogen removal from the system. It provides a useful indicator of ecosystem health. In Myrmidon and the reference creek, denitrification efficiency was very high (80-90%) indicating most of the inorganic nitrogen is released from the sediments back into the atmosphere. However, in Buffalo Creek, denitrification efficiency was very low (3% at BC1) and the majority of inorganic nitrogen is released back into the water column (as ammonia and nitrate) where it is bioavailable. This suggests the ecosystem health has been severely impacted in Buffalo Creek and the natural mechanism for maintaining low nitrogen concentrations is now inhibited, allowing nitrogen to build up in the system and be continually recycled between the sediments, water column and algae.

The sediments in Buffalo Creek contain high concentrations of phosphorus. In the upper 10 cm of sediments, phosphorus concentrations range from 1052 to 1558 and 746 to 1008 mg/kg at the upstream (BC1) and downstream (BC3) sites respectively. In the reference creek, phosphorus concentrations are low and range from 384 to 589 mg/kg. In Myrmidon Creek, phosphorus concentrations are higher than in the reference creek but lower than in Buffalo Creek. At the outfall site (MC1) phosphorus concentrations range from 803-903 mg/kg.

The degree to which the sediments have retained additional phosphorus from sewage inputs was assessed by determining the different phosphorus fractions in the sediments. Initial results indicate that the additional phosphorus at the outfall site in Myrmidon Creek (MC1) and Buffalo Creek (BC1) is retained in the adsorbed and oxide-associated fraction (Fig. 10). This fraction is a bioavailable source for phytoplankton and microbenthic algae growth. Importantly, there is potentially a risk of phosphorus release into the overlying water column under anoxic conditions which are known to occur in Buffalo Creek. These results indicate that the intertidal sediments are not effective at removing phosphorus from the system by retaining it in the non-bioavailable fractions.

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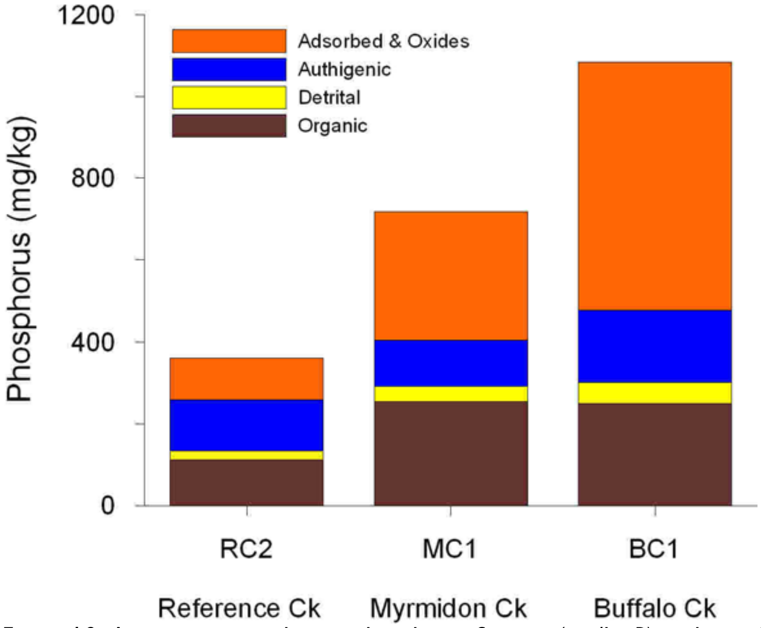

Figure 10: A comparison sediment phosphorus fraction (mg/kg P) in the surface sediments at sites in Buffalo, Myrmidon and the reference Creek.

Experiments were conducted to measure nitrogen fixation in Buffalo Creek. The results indicate that nitrogen fixation is not an important process in this tidal creek system.