An Assessment of the Impacts of the Sewage Treatment Plant Discharge on the Ecological Health of Burgess Creek

Interim Report

submitted to

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by

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1. Introduction

Burgess Creek extends from Noosa Heads, through Noosa National Park, past the residential area of Sunrise Beach and into the Pacific Ocean on Sunrise Beach. The EPA (Environmental Protection Agency) has given the Noosa Shire Council a notice to conduct an environmental evaluation of the downstream effects of the Noosa Coastal Wastewater Treatment Plant. The treatment plant discharges effluent into Burgess Creek, and there is also concern that seepage from the stockpiles of bio-solids near the treatment plant may permeate through the soil into the waters of Burgess Creek.

The primary aim of this project was to carry out surveys including biological assays and water column and sediment parameters during wet and dry (high and low flow) periods to determine the effects of the WWTP on the ecological health of Burgess Creek and the area surrounding its discharge into the Pacific Ocean at Sunrise Beach, and to compare this to the Marcus Creek which does not receive any sewage inputs.

2. Materials and Methods

2.1 Study Sites

Six sites were chosen along Burgess Creek and two along Marcus Creek (Fig. 1) as reference or control sites since Marcus Creek has no sewage inputs. The wet (high flow sampling) at all sites took place on the 5\textsuperscript{th} February, 2001. One site from each creek was situated beyond the surf zone directly out from the creek’s discharge point into the Pacific Ocean (MC3 & BC0). A site was located at the mouth of each creek in the dune area before the creek flows across the beach (MC1 & BC1). Within Burgess Creek a site was located within the national park after the confluence of Burgess Creek and Burgess Creek East (BC2), another also in the National Park mid way along Burgess Creek East (BCE), one at the wastewater treatment outfall (BCWWTP), and the final site upstream from the WWTP at A W Dan Park (BCU).
Figure 1 Map of sampling sites in Burgess Creek and Marcus Creek.
2.2 Water Column Parameters

Salinity (expressed on the Practical Salinity Scale), pH and dissolved oxygen were measured with a Horiba U-10 water quality meter (California, U.S.A.).

Secchi depth was used as a measure of water column turbidity, which involves lowering a 30 cm diameter secchi disk (black and white alternating quarters) through the water column until it is no longer possible to distinguish between the black and white sections.

2.2.1 Total Suspended Solids

Total suspended solids concentrations were determined using the methods of Clesceri et al. (1989). A known volume of water was filtered onto a pre-weighed and pre-dried (110 °C; 24 h) Whatman GF/C glass fibre filter. The filter was then oven dried at 60 °C for 24 h and total suspended solids calculated by comparing the initial and final weights (Clesceri et al., 1989).

2.2.2 Nutrients

Dissolved inorganic nutrients (NH$_4^+$, NO$_3^-$/NO$_2^-$, and PO$_4^{3-}$) were determined by filtering water samples through Sartorius Minisart 0.45 µm membrane filters and freezing them immediately. Samples were analysed within two weeks by the NATA accredited Queensland Health Analytical Services Laboratory in accordance with the methods of Clesceri et al., (1989) using a Skalar autoanalyser (Norcross, Georgia, U.S.A.).

2.2.3 Chlorophyll $a$

Chlorophyll $a$ concentrations were used as an indicator of phytoplankton biomass. At each site, chlorophyll $a$ concentration was determined by filtering a known volume of water through a Whatman GF/F filter which was immediately frozen. In the lab, the filter was ground in acetone to extract chlorophyll $a$, spectral extinction coefficients were determined on a spectrophotometer and chlorophyll $a$ concentrations calculated according to Parsons et al. (1989).
2.2.4 Phytoplankton Bioassays

Phytoplankton bioassays were used to determine the response of ambient phytoplankton to nutrient additions and changes in light intensity. Four litres of site water were filtered through a 63 µm mesh (to screen out the large zooplankton grazers) into one of 6 sealed transparent 4L plastic containers. Six treatments were established: a control (no nutrient addition), nitrate (200 µM, NO$_3^-$), ammonium (30 µM, NH$_4^+$), phosphate (20 µM, PO$_4^{3-}$), urea (5 µM, urea) and a +All treatment (all nutrients at concentrations mentioned). These concentrations were used as they are known to be saturating for phytoplankton in estuarine environments. The bioassay containers were placed in flow-through incubation tanks (2m diameter, 0.5 m deep) to maintain constant water temperature. To maintain constant irradiance, incubation tanks were covered with 50% neutral density shade screens. At identical daily circadian times, all bioassay bags were gently shaken and 20mL from each container was poured into pre-rinsed 30 ml glass test tubes and placed in darkness for 20 minutes to allow photosystems to dark adapt. Chlorophyll $a$ concentrations were determined from in vivo fluorescence (indicating phytoplankton biomass) on a Turner Design Fluorometer. An initial measure (time = 0) was taken on the control treatment and then for all treatments daily for 7 days.

Over the 7 day period settlement of suspended solids within samples may occur and light availability increase above ambient levels. The response of the plankton community in the control bioassay container gives an indication of the ambient light conditions. Light stimulated phytoplankton bloom potential was calculated as the difference between initial (time = 0) and maximum in vivo fluorescence values in the control water sample over the 4 day incubation. Nutrient stimulated bloom potential was calculated as the difference between the maximum response in the nutrient treatments and the maximum response in the control (referred to as the stimulation factor). This stimulation factor can be used to determine the relative importance of the different nutrient additions compared with light.

2.3 Sediment Parameters

2.3.1 Sediment elements

Sediments were collected for metal content according to methods adopted for the sediment nutrients (above). Samples were oven dried and ground to a homogenous powder. Samples were microwave digested in a 1:5:4 mixture of HCl, HNO$_3$ and HF using a CEM MSP 1000 digester. Samples were then analysed by ICP MS scanning for the presence of metals and other elements (CSIRO Livestock Industries).
2.3.2 Sediment Nutrients

Three replicate samples were collected with 50 mL cut-off syringes, stored in ziplock plastic bags and stored on ice. Upon return to the laboratory, they were freeze dried and sent to the NATA accredited, Queensland Health Analytical Services to be analysed using acid digestion techniques. Subsamples were taken for analysis of organic content in a muffle furnace at 520 °C for 24 h to combust all organic material.

2.3.3 Sediment δ¹⁵N Isotopic Signature

Sediment %nitrogen and %carbon content, δ¹⁵N and δ¹³C were determined from three replicate samples collected with 50 mL cut-off syringes, stored in sterile ziplock bags and frozen. Samples, were oven dried to constant weight (24 h at 60 °C), ground and two sub-samples were oxidised in a Roboprep CN Biological Sample Converter (Europa Tracermass, Crewe, U.K.). The resultant N₂ was analysed by a continuous flow isotope ratio mass spectrometer (Europa Tracermass, Crewe, U.K.). Total %N of the sample was determined, and the ratio of ¹⁵N to ¹⁴N was expressed as the relative difference between the sample and a standard (N₂ in air) using the following equation (Peterson & Fry 1987):

\[ \delta^{15}N = \left( \frac{^{15}N/^{14}N\text{ (sample)}}{^{15}N/^{14}N\text{ (standard)}} - 1 \right) \times 1000 \text{‰} \]

2.3.4 Benthic Microalgae

Three replicate sub-samples of sediment to 2 cm depth were collected at each site using plastic syringes (5 mL, 1 cm diameter) with the ends removed. The syringe was stoppered with a rubber cork, placed in plastic bags and immediately frozen for determination of chlorophyll a as an indicator of benthic microalgal biomass. All benthic microalgal chlorophyll a samples was analysed using a modification of the spectrophotometric method of Parsons et al. (1989). Calculations were also adapted from Parsons et al. (1989). Chlorophyll a was extracted by grinding the sediment samples in 10 ml plastic centrifuge tubes with an air-powered drill. Sediment was ground for 30 seconds in dim light with 3 mL of 90% acetone. The acetone volume was then increased to 10 mL the tube capped, shaken gently, then placed in darkness at -4°C for at least 24 hours. Samples were then subsequently centrifuged for 15 minutes at 2,000 rpm and chlorophyll a concentration was determined after measurement of the spectrophotometric absorbance of the sample using a Beckman DU spectrophotometer.
2.4 Plant Parameters

2.4.1 Inhabitant Plant delta $\delta^{15}$N values

There are two naturally occurring forms of nitrogen (N), $^{14}$N and $^{15}$N with the former being the most common. The $\delta^{15}$N signature is calculated from the relative amount of $^{15}$N to $^{14}$N. Various sources of nitrogen have a specific and measurable $\delta^{15}$N signature. For example, sewage is enriched with $^{15}$N and therefore has a $\delta^{15}$N signature of approximately 10‰ (Heaton 1986). Plants uptake the nitrogen source and reflect this $\delta^{15}$N signature. Analysis of their tissue may indicate the nitrogen sources available to the plants. Aquatic plants were collected and dried at 60°C prior to grinding and analysis. Samples were analysed for $\delta^{15}$N using a Europa Scientific “Tracermass” continuous flow stable isotope ratio mass spectrometer with a Europa Scientific “Roboprep” preparation system. Total %N of the sample was determined, and the ratio of $^{15}$N to $^{14}$N was expressed as the relative difference between the sample and a standard (N$_2$ in air) using the following equation (Peterson & Fry, 1987): $\delta^{15}$N = ($^{15}$N/$^{14}$N (sample) / $^{15}$N/$^{14}$N (standard) – 1) x 1000 (‰).

2.4.2 Deployed Macroalgae delta $\delta^{15}$N values

The extent of sewage derived nitrogen along the creeks and into the Pacific Ocean was assessed by the deployment of the macroalga *Catenella nipae* (sourced from a low nutrient area) in submerged chambers at half secchi depth to ensure uniform light availability. At each site, macroalgae are housed in transparent, perforated chambers and suspended in the water column using a combination of buoy, rope and weights. The algae are be incubated for 4 days to allow nutrient uptake by the algae. Algal samples are oven dried to constant weight (24 h at 60 °C), ground and two sub-samples are oxidised in a Roboprep CN Biological Sample Converter (Europa Tracermass, Crewe, U.K.). The resultant N$_2$ is analysed by a continuous flow isotope ratio mass spectrometer (Europa Tracermass, Crewe, U.K.). Total %N of the sample was determined, and the ratio of $^{15}$N to $^{14}$N was expressed as the relative difference between the sample and a standard (N$_2$ in air) using the following equation (Peterson & Fry, 1987): $\delta^{15}$N = ($^{15}$N/$^{14}$N (sample) / $^{15}$N/$^{14}$N (standard) – 1) x 1000 (‰).

2.4.3 Species Composition and Abundance of Aquatic Flora

The species composition and abundance of aquatic flora was determined at each site on a percentage cover basis. Sites with heterogeneous distributions were divided into regions based on vegetation type and composition and abundance described for each region. Percent cover of each species refers to the actual percent cover, and not the percentage that the species contributes to the overall cover. Overall cover for the entire site (all zones combined) is also represented.
3. Results & Discussion

3.1 Water Column Parameters

Secchi depth was constant (0.3 m – 0.5 m) at all sites within both creeks, but was significantly greater at both the ocean sites (3 m & 4 m). The salinity at all sites within the creeks was 0, and 35 at the two ocean sites. The water temperature increased from 26 °C to 29 °C from Burgess Creek East to the Wastewater Treatment Plant. The temperature decreased to 28 °C at the site at the mouth of the Burgess Creek (BC1), which was higher than the site at the mouth (MC1) of Marcus Creek (23.8 °C). The pH varied from 4.8 & 5.8 at the upstream sites (BCU and BCE, respectively) to 8.2 at the mouth of Burgess Creek (BC1). The site at the mouth of Marcus Creek had a pH of 5.0 (Table 1).

Table 1 Water quality parameters for Burgess Creek and Marcus Creek.

<table>
<thead>
<tr>
<th>Site</th>
<th>Secchi(m)</th>
<th>Salinity</th>
<th>Temp(°C)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCU</td>
<td>0.3</td>
<td>0</td>
<td>24</td>
<td>4.8</td>
</tr>
<tr>
<td>BCE</td>
<td>0.4</td>
<td>0</td>
<td>26</td>
<td>5.8</td>
</tr>
<tr>
<td>BCWWTP</td>
<td>0.3</td>
<td>0</td>
<td>29</td>
<td>7.3</td>
</tr>
<tr>
<td>BC2</td>
<td>0.5</td>
<td>0</td>
<td>29</td>
<td>6.6</td>
</tr>
<tr>
<td>BC1</td>
<td>0.5</td>
<td>0</td>
<td>28</td>
<td>8.2</td>
</tr>
<tr>
<td>BC0</td>
<td>3</td>
<td>35</td>
<td>26</td>
<td>7.8</td>
</tr>
<tr>
<td>MC1</td>
<td>0.4</td>
<td>0</td>
<td>23.8</td>
<td>5.0</td>
</tr>
<tr>
<td>MC3</td>
<td>4</td>
<td>35</td>
<td>25</td>
<td>8.2</td>
</tr>
</tbody>
</table>

3.1.1 Total Suspended Solids

Total suspended solids were highest (19 mg l\(^{-1}\)) at the upstream site (BCU), probably due to urban run-off during the recent rains. At all other sites within the creeks, TSS was relatively low (1.1 mg l\(^{-1}\) to 4.1 mg l\(^{-1}\)), and in at the ocean sites even lower (0.15 mg l\(^{-1}\) to 0.28 mg l\(^{-1}\)) (Fig. 2). Despite low turbidity, the high concentration of tannins in the water resulted in the relatively low secchi disk depths observed.

Figure 2 Total suspended solids concentrations for sites in Burgess Creek and Marcus Creek.
3.1.2 Dissolved Water Column Nutrients

Dissolved nutrients were relatively low at the two upstream sites (BCU & BCE). The highest concentration of NO$_3^-$ was at BCWWTP (79 µM). Sites BC2 and BC1 (Burgess Creek mouth site) had significantly higher concentrations of nutrients than the Marcus Creek mouth site (MC1). Nutrients at both the ocean sites (BC0 & MC3) were below detection limits (Fig. 3). High concentrations of NO$_3^-$ are typical of tertiary treated sewage effluent due to nitrification of NH$_4^+$ by bacterial treatment. The rapid decline in NO$_3^-$ between the WWTP and BC2 suggests in stream denitrification (conversion of NO$_3^-$ to N$_2$ gas), or biological uptake of NO$_3^-$ by stream flora. The increase in NO$_3^-$ downstream from BC2 to BC1 may be a result of inputs from septic systems still used by some houses in the area.

![Figure 3 Dissolved water column nutrient concentrations for sites in Burgess Creek and Marcus Creek.](image-url)
3.1.3 Chlorophyll a

The highest chlorophyll \( a \) concentration (phytoplankton biomass) was recorded at BCU (5.9 µg l\(^{-1}\)), and lowest at BCWWTP (0.27 µg l\(^{-1}\)) (Fig. 4). The remaining sites had relatively similar concentrations (0.4 µg l\(^{-1}\) to 0.9 µg l\(^{-1}\)).

![Figure 4 Chlorophyll a concentrations for sites in Burgess Creek and Marcus Creek.](image)

3.1.4 Phytoplankton Bioassays

Phytoplankton bioassays are an indication of potential phytoplankton response to increased nutrients and light. Initial fluorescence at all sites was very similar, ranging from 1.6 to 2.3. The upper Burgess Creek sites (BCU & BCE) produced relatively low phytoplankton bloom potential in response to added nutrients with 64 and 50, respectively after 7 days. The Wastewater Treatment Plant site (BCWWTP) had the highest response (365) in the plus all nutrients treatment, although \( \text{NH}_4^+ \), \( \text{PO}_4^{3-} \), and urea treatments produced similarly high responses. The next site downstream (BC2) peaked at 313, predominantly in the plus all nutrients treatment, and the Burgess Creek mouth site (BC1) peaked at 198. In contrast the Marcus Creek mouth site’s greatest response was 39. At both the creek mouth sites the control treatment responds equally to the nutrient treatments, and as such is interpreted as light limitation (Jones et al. 1998). Typically this is a consequence of settling of suspended particulates at turbid sites. Considering the low turbidity at the creek mouth sites, the light response was probably due to increased light during treatment, relative to the tree-shaded conditions at the sites. The oceanic sites had relatively small responses, but interestingly had a primary \( \text{NO}_3^- \) stimulated response at the ocean site out from Burgess Creek (BC0) and a primary urea stimulated response at the site offshore from Marcus Creek (MC3) (Fig. 5). The high responses within Burgess
Creek at the WWTP and the downstream sites indicate that although initial phytoplankton populations at these sites were no greater than the upstream sites, or sites within Marcus Creek, the phytoplankton communities at these sites were adapted to high nutrient concentrations and were capable of rapid blooms given elevated nutrients and light. In contrast, the other sites showed very small responses, indicating they are less likely to bloom.

Figure 5 Phytoplankton Bioassay responses for sites in Burgess Creek and Marcus Creek.
3.2 Sediment Parameters

3.2.1 Sediment elements

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC) specify guideline values (both low and high toxicity values) for a range of metals within sediments. The concentrations of all metals with specified ANZECC guideline values were below the low toxicity limit. The highest concentrations of these ANZECC specified metals were at site BC2, downstream of the BCWWTP site (Fig. 6). The lowest total concentrations were found at the upstream sites, BCU & BCE. There is no significant difference between the total concentration of metals between the sites at the creek mouths or the ocean sites (Fig. 6). The concentrations of all sediment elements measured are listed in Table 2.

Figure 6 Concentrations of metals with ANZECC toxicity guideline values for sites in Burgess Creek and Marcus Creek.
Table 2 Sediment element concentrations in Burgess Creek. Elements denoted with a * indicate those elements which have Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC) toxicity guideline values. No recorded values exceed the ANZECC guideline values. Values in parentheses are standard errors.

| Site | Al (%) | As* (mg kg⁻¹) | B (mg kg⁻¹) | Ca (mg kg⁻¹) | Cd* (mg kg⁻¹) | Cr* (mg kg⁻¹) | Cu* (mg kg⁻¹) | Fe (%) | Hg* (µg kg⁻¹) | K (mg kg⁻¹) | Mg (mg kg⁻¹) | Mn (mg kg⁻¹) | Mo (µg kg⁻¹) | Na (mg kg⁻¹) | Ni* (mg kg⁻¹) | P (mg kg⁻¹) | Pb* (mg kg⁻¹) | S (mg kg⁻¹) | Zn* (mg kg⁻¹) |
|------|--------|---------------|-------------|--------------|---------------|---------------|---------------|--------|---------------|------------|-------------|------------|-------------|------------|--------------|-------------|--------------|--------------|-------------|-------------|
| BCU  | 0 (0)  | 0.01 (0)      | 1.9 (0.36)  | 32.3 (3.6)   | 0.48 (0.05)   | 0.37 (0.05)   | 0.01 (0)      | 0      | 10.2 (0)      | 11.9 (3.9) | 0.49 (0.09)  | 5.4 (5.4)  | 29.7 (5.2)  | 0.1 (0.03)  | 2.85 (0.96)  | 0.55 (0.2)  | 11.1 (3.3)  | 1.6 (0.75)  |
| BCE  | 0 (0)  | 0.01 (0)      | 0.01 (0.27) | 20.4 (1.9)   | 0.06 (0.25)   | 0.25 (0.03)   | 0.01 (0)      | 0      | 10.2 (0)      | 8.4 (1.2)  | 2.7 (0.2)    | 0 (0)      | 39.5 (2.0)  | 0.05 (0)    | 2.1 (0.11)   | 0.4 (0.1)   | 1.3 (1.1)   | 1.3 (0.6)   |
| BC   | 0.03 (0)| 0.01 (0)      | 1.7 (0.6)   | 135 (58)     | 2.8 (1.2)     | 1.6 (0.2)     | 0.14 (0.06)   | 0      | 28.6 (8.7)    | 63.5 (18.1)| 12.5 (7.5)   | 44.8 (13.6)| 79.2 (59)   | 0.38 (0.07) | 119 (95)     | 2.9 (1.2)   | 361 (118)   | 5.6 (0.53) |
| WWTP | 0.02 (0.01)| 0.02 (0.01) | 0.01 (0.01)| 2.2 (1.6)    | 1.0 (0.76)    | 5.7 (3.8)     | 0.01 (0.01)   | 0      | 23.9 (13.7)  | 260 (203)  | 0.72 (0.3)   | 5.8 (5.8)  | 146 (87)    | 0.37 (0.23) | 6.9 (4.5)    | 8.4 (7)     | 1092 (874)  | 15.2 (8.5) |
| BC2  | 0.03 (0)| 0.12 (0.01)| 0.01 (0.01)| 2.2 (0.19)   | 0.05 (0.05)   | 0.28 (0.02)   | 0.08 (0.01)   | 0      | 36.7 (1.5)   | 567 (5.7)  | 4.3 (0.1)    | 22.4 (3.7) | 667 (29)    | 1.5 (0.17)  | 25.4 (1.1)   | 0.65 (3.8)  | 243 (3.8)   | 1.3 (0.25) |
| BC1  | 0.04 (0)| 0.18 (0.01)| 3.5 (0.8)   | 6949 (1368)  | 0.02 (0.02)   | 0.24 (0.01)   | 0.09 (0.01)   | 0      | 106 (5.4)    | 589 (27.3)| 5.3 (0.22)   | 30.4 (11.6)| 1772 (62)  | 4.2 (0.57)  | 29.7 (1.1)   | 0.44 (0.01) | 247 (10)    | 1.2 (0.16) |
| BC0  | 0.04 (0)| 0.06 (0)     | 3.6 (0.14)  | 411 (59)     | 0.09 (0.06)   | 0.38 (0.06)   | 0.09 (0)      | 0      | 13 (1.8)     | 156 (3.9)  | 4.9 (0.5)    | 48.3 (17.9)| 147 (5.1)  | 0.7 (0.04)  | 29.8 (2.9)   | 0.96 (0.18) | 36.7 (3.8)  | 2.5 (1.1)   |
| MC1  | 0.05 (0)| 0.17 (0.01)| 2.8 (0.45)  | 10939 (2784)| 0.09 (0.09)   | 0.38 (0.01)   | 0.11 (0)      | 0      | 44.5 (6.3)   | 617 (95)   | 7.6 (0.5)    | 19.4 (2.4) | 1365 (119)| 7.1 (1.8)   | 39 (2.6)     | 0.51 (0.02) | 209 (8.9)   | 2.5 (1.0)   |
| MC3  | 0.04 (0)| 0.18 (0.01)| 2.3 (0.45)  | 10939 (2784)| 0.09 (0.09)   | 0.38 (0.01)   | 0.11 (0)      | 0      | 44.5 (6.3)   | 617 (95)   | 7.6 (0.5)    | 19.4 (2.4) | 1365 (119)| 7.1 (1.8)   | 39 (2.6)     | 0.51 (0.02) | 209 (8.9)   | 2.5 (1.0)   |
3.2.2 Sediment Nutrients

The concentration of total nitrogen in the sediment increases downstream from 58 µM at BCU to peak at 400 µM at site BC2. The highest concentration of total phosphorus was 52 µM at BCWWTP. The concentrations of total nitrogen at the creek mouth sites and the ocean sites were all significantly lower than the other sites. However, the concentrations of total phosphorus at these sites were higher than all the other creek sites except the BCWWTP site.

In contrast to the metal and sediment nutrient concentrations, the highest concentration of dissolved water column nutrients was recorded at the BCWWTP site (Fig. 3). This suggests that the nutrients and metals may be being sourced from the WWTP and being bound to sediments downstream in the creek. Alternatively there may be additional inputs of nutrients from stormwater run-off or septic systems in the vicinity.

![Figure 7 Sediment total nitrogen and total phosphorus concentrations for sites in Burgess Creek and Marcus Creek.](image)

3.2.3 Sediment $\delta^{15}$N Isotopic Signature

Most of the sites sampled were too low in nitrogen to be able to determine an accurate $\delta^{15}$N of the sediment, excepting sites BCWWTP and BC2, which had values of 4.1‰ and 2.4‰, respectively (Fig. 8). This rapid decline in $\delta^{15}$N is consistent with the decrease observed in the signature of the
deployed macroalgae (Fig. 11). The lower δ¹⁵N values at BC2 suggest that there is lower sewage derived nitrogen in the sediment, despite higher total sediment nitrogen, suggesting inputs from other sources, possibly from stormwater run-off or septic systems in the vicinity. However, in contrast the inhabitant plant δ¹⁵N remains high at sites BC2 and BC1, and these obtain their nutrients from the sediment and water column.

![Figure 8 Sediment δ¹⁵N concentrations for sites in Burgess Creek and Marcus Creek.](image)

### 3.2.4 Benthic Microalgae

The highest concentrations of benthic microalgae were at BCU (277 µg l⁻¹) and MC1 (391 µg l⁻¹), at the mouth of Marcus Creek. At all other sites, concentrations were below 20 mg l⁻¹ (Fig. 9). Typically, high concentrations of benthic microalgae are associated with relatively high nutrients, stable sediments and sufficient light (MacIntyre et al. 1996). However, despite being ubiquitous in most shallow water habitats, benthic microalgal distribution is typically very patchy and heterogeneous (MacIntyre & Cullen 1995). Additionally the depth profile of their distribution may be affected by a variety of parameters including sediment disturbance, and sediment grain size (Jones et al. unpubl. data). Benthic microalgae are typically observed as a green-brown tinge on the surface of sediments, and visual observations on-site suggested that the site at the mouth of Burgess Creek (BC1) higher concentration of benthic microalgae than the mouth of Marcus Creek (MC1). The highest concentration at each site was on the edge of the creek bank in the shallowest water, away from tree cover where light availability was highest. Despite low turbidity, the high concentration of tannins in the water result in relatively low light availability (secchi depth). It appears that in such a highly variable light environment, many more replicates need to be sampled. This will be included in the ‘dry’ sampling period.
3.3 Plant Parameters

3.3.1 Inhabitant Plant $\delta^{15}N$ isotopic signatures

Stable isotope ratios of nitrogen ($\delta^{15}N$) have been used widely in marine systems as tracers of discharged nitrogen from point and diffuse sources, including sewage effluent (Rau et al., 1981; Heaton, 1986; Wada et al., 1987; Van Dover et al., 1992; Macko & Ostrom, 1994; Cifuentes et al., 1996; McClelland & Valiela, 1998). Plant $\delta^{15}N$ signatures have been used to identify nitrogen sources available for plant uptake (Heaton, 1986). Elevated $\delta^{15}N$ signatures in aquatic flora have been attributed to assimilation of N from treated sewage effluent (Wada et al., 1987; Grice et al., 1996; Udy & Dennison, 1997; Abal et al., 1998). The presence of sewage derived nitrogen was determined by analysing the $\delta^{15}N$ signature of aquatic flora at all sites. Upstream of the BCWWTP site the $\delta^{15}N$ of inhabitant vegetation is approximately 5‰. The highest $\delta^{15}N$ of 23‰ was recorded at the BCWWTP site, which is one of the highest signatures recorded in the literature (Owens 1987). The next two sites (BC2 & BC1) downstream of the WWTP were not significantly reduced from the $\delta^{15}N$ of WWTP, indicating a strong influence of sewage nitrogen present at the sites. The $\delta^{15}N$ at the mouth of Marcus Creek (MC1) was significantly lower (2.5 ‰) than all the sites in Burgess Creek (Fig. 10), a value indicative of sites not influenced by sewage discharge (Costanzo et al. 2001). These results show that sewage derived nitrogen is present along the length of Burgess Creek from the WWTP downstream to the mouth (BC1).
Figure 10 $\delta^{15}\text{N}$ concentrations of inhabitant macrophytes for sites in Burgess Creek and Marcus Creek.

### 3.3.2 Deployed Macroalgae $\delta^{15}\text{N}$ isotopic signatures

The $\delta^{15}\text{N}$ of the deployed macroalgae (*Catenella nipae*) upstream of the WWTP (BCU & BCE) was less than 5‰. The peak value was 13‰ at the BCWWTP site. In contrast to the inhabitant vegetation, the $\delta^{15}\text{N}$ of the macroalgae at the downstream sites in Burgess Creek decreases quite rapidly, although remains elevated above the upstream sites, the ocean sites and the Marcus Creek sites. The elevated $\delta^{15}\text{N}$ of BC1 relative to BC2 may be due to septic run-off from unsewered houses in the region of the creek (Fig. 11), and is consistent with the increase in dissolved NO$_3^-$ also observed at BC1. The $\delta^{15}\text{N}$ of the macroalgae deployed at the two ocean sites was significantly lower the mouth of Burgess Creek (BC1), but not significantly different to the mouth of Marcus Creek (MC1). This suggests that the sewage derived nitrogen flowing out of Burgess Creek, despite being significant at the mouth of the creek, is being rapidly diluted and cannot be detected in the ocean.
Figure 11 δ¹⁵N concentrations of deployed macroalgae for sites in Burgess Creek and Marcus Creek.

The differences in δ¹⁵N between the inhabitant vegetation and the deployed macroalgae may be due differences in the source of nutrients for the plants. The inhabitant macrophytes typically get their nutrients from the sediments, whereas the macroalgae absorb nutrients from the water column. Also, the inhabitant plants have a longer integration time, compared with the 4 day incubation of the macroalgae. Given the wet sampling event, the elevated flow may have flushed the sewage derived nutrients from the system, resulting in a reduced δ¹⁵N signal in the macroalgae incubated during the period directly after the rains. The effects of flushing during high flow times on the occurrence of sewage nitrogen within the creek will be assessed by comparison with the ‘dry’ sampling trip results.
3.3.3 Species Composition and Abundance of Aquatic Flora

The composition and abundance of aquatic flora was mapped for each site. At some site where the coverage was heterogeneous, the site was divided into zones to give a more representative account. Percent cover of each species refers to the actual percent cover, and not the percentage that the species contributes to the overall cover. Overall cover for the entire site (all zones combined) is also represented (Fig. 18& 19). A species list listing the common name and providing a description of the plant is included (Table 3). Site BCU was homogeneous and classified as one region, and was dominated almost entirely by *Typha* sp. (Fig. 12, 18 & 19).

![Figure 12 Map of inhabitant macrophytes at site BCU in Burgess Creek.](image)

BCE was divided into three distinct zones: zone 1 being the upper waterfall zone with a rock substrate covered in filamentous algae (86%); zone 2, the pool with mixed rock and sediment with a total plant cover of 20%; and zone 3 covered in *Typha* (95%) (Fig. 13, 18 & 19).

BCWWTP was very homogeneous in cover, with 100% vegetation cover (excepting the region covered by rocks directly around the sewage outflow point), dominated by *Typha* (43%), and *Ludwigia* (35%) (Fig. 14, 18 & 19).
Figure 13 Map of inhabitant macrophytes at site BCE in Burgess Creek East.

Figure 14 Map of inhabitant macrophytes at site BCWWTP in Burgess Creek.
BC2 had a total cover of approximately 30% dominated by *Nymphaea* sp. (20%). The creek either side of the pool was dominated by *Typha* sp. (Fig. 15, 18 & 19).

![Figure 15 Map of inhabitant macrophytes at site BC2 in Burgess Creek.](image)

BC1 was shaded by a tree canopy, and the total cover of aquatic flora was only 5% most of which was *Schoenoplectus validus* (Fig. 16, 18 & 19).

MC1 had a total plant cover of 26%, but was split into 2 zones. Zone 1 had 10% cover, dominated by *Hemarthria* sp. Zone 2 had 30% cover and was dominated by *Nymphaea caerulea* subsp. Zanzibarensis (11%), *Schoenoplectus validus* (8%), and *Ludwigia peploides* subsp. Montevidensis (4%) (Fig. 17, 18 & 19).
Figure 16 Map of inhabitant macrophytes at site BC1 in Burgess Creek.

Figure 17 Map of inhabitant macrophytes at site MC1 in Marcus Creek.
Figure 18 Percentage cover for inhabitant vegetation at sites in Burgess Creek and Marcus Creek.
Figure 19 Combined percentage cover for inhabitant vegetation at sites in Burgess Creek and Marcus Creek.
Table 3 Species list including scientific name, common name and description for inhabitant vegetation from sites in Burgess Creek and Marcus Creek.

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Nymphaea caerulea</em> subsp. <em>Zanzibarensis</em></td>
<td>Cape Waterlily</td>
<td>A waterlily. Widespread</td>
</tr>
<tr>
<td><em>Schoenoplectus validus</em></td>
<td>Frog’s Mouth</td>
<td>A rush. Widespread in swampy areas, on damp soil and near freshwater</td>
</tr>
<tr>
<td><em>Philydrum lunuginosum</em></td>
<td>Frog’s Mouth</td>
<td>Rush-like aquatic plant. Found on margins of dams, streams, swamps and waterways</td>
</tr>
<tr>
<td><em>Ludwigia peploides</em> subsp. <em>Montevidensis</em></td>
<td>Water Primrose</td>
<td>A semi-aquatic shrub. Widespread in ponds or creeks on the east coast</td>
</tr>
<tr>
<td><em>Baumea juncea</em></td>
<td>Bare Twig Rush</td>
<td>A rush. Found in swampy areas freq. near brackish water</td>
</tr>
<tr>
<td>?</td>
<td>Clover weed</td>
<td>Aquatic herbaceous plant, leaves resembling clover. Unidentifiable – no flowering material</td>
</tr>
<tr>
<td><em>Eclipta prostrata</em></td>
<td>White Eclipta</td>
<td>A small herbaceous plant. Common on wet ground</td>
</tr>
<tr>
<td><em>Persicaria decipiens</em></td>
<td></td>
<td>A small herbaceous plant. Common in coastal areas beside creeks</td>
</tr>
<tr>
<td><em>Bacopa monnieri</em></td>
<td></td>
<td>A small herbaceous plant. Widespread on the edge of freshwater</td>
</tr>
<tr>
<td><em>Cyperus haspan</em></td>
<td></td>
<td>A sedge. Widespread</td>
</tr>
<tr>
<td>Unidentified Grass</td>
<td></td>
<td>A grass. Unidentifiable - flowering material not available</td>
</tr>
<tr>
<td><em>Triglochin procera</em></td>
<td></td>
<td>A rush-like aquatic plant. Moderately common in still to fast moving fresh water</td>
</tr>
<tr>
<td><em>Ischaemum</em></td>
<td></td>
<td>A wide bladed grass. Found in coastal areas on damp soil</td>
</tr>
<tr>
<td><em>Azolla pinnata</em></td>
<td></td>
<td>A small floating water fern</td>
</tr>
<tr>
<td>Filamentous algae in sediment</td>
<td></td>
<td>Filamentous green algae (Chlorophyta)</td>
</tr>
<tr>
<td><em>Paspalum urvillei</em></td>
<td></td>
<td>A tall grass (1.5 - 2m). Widespread</td>
</tr>
<tr>
<td><em>Rhizoclonium</em> spp</td>
<td></td>
<td>Filamentous green algae. Cosmopolitan, in alkaline or saline streams</td>
</tr>
<tr>
<td><em>Hyalotheca</em> spp</td>
<td></td>
<td>Filamentous green algae. Cosmopolitan, in semi-eutrophic streams or drains</td>
</tr>
<tr>
<td><em>Hemarthria sp.</em></td>
<td></td>
<td>A grass. Maybe <em>H. uncinata</em>, occurs on damp sandy soils</td>
</tr>
<tr>
<td><em>Nostoc</em> spp.</td>
<td></td>
<td>A cyanobacteria. Common and widespread</td>
</tr>
<tr>
<td>Filamentous algae on rocks</td>
<td></td>
<td>Filamentous green algae (Chlorophyta)</td>
</tr>
<tr>
<td><em>Cyperus polystachyos</em></td>
<td>Bunchy Sedge</td>
<td>A sedge. Widespread</td>
</tr>
<tr>
<td><em>Cyperus pilosus</em></td>
<td></td>
<td>A sedge. Widespread, found near creeks, swamps and damp places</td>
</tr>
<tr>
<td><em>Ludwigia octovalvis</em></td>
<td>Willow Primrose</td>
<td>A herbaceous semi-aquatic shrub</td>
</tr>
<tr>
<td><em>Typha</em> spp.</td>
<td>Bulrush</td>
<td>A tall (1.5-2m) bulrush. Forms dense clumps in streams and swamps</td>
</tr>
</tbody>
</table>
3.4 Summary

The discharge of treated sewage from the Burgess Creek Wastewater Treatment Plant appears to be compromising the ecological health of Burgess Creek. The parameters indicating degraded conditions included elevated dissolved water column nutrients, high phytoplankton bloom potential, and the strong sewage signature ($\delta^{15}N$) in the inhabitant flora. At all sites downstream of the WWTP, these parameters remained elevated above upstream values and those measured in Marcus Creek, a reference creek which receives no sewage inputs. Other parameters such as sediment nutrients and sediment elements (metals) were also more elevated at the WWTP than upstream, but peaked further downstream, and should be a focus of further investigations.

In summary, all sites downstream of the WWTP in Burgess Creek are impacted by the discharge of effluent, however ecological indicators suggest that rapid dilution within the ocean is limiting the extent of the impacts to mouth of the creek. In contrast, the biological parameters measured at the mouth of Marcus Creek, which receives no sewage inputs, are equivalent or lower than sites upstream of the WWTP in Burgess Creek, or the two ocean sites.
4. References


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