CITY of PERTH

Point Fraser Monitoring and Evaluation Program

2012 Report

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Prepared for,

City of Perth

Mine Water and Environment Research Centre

Centre for Ecosystem Management

Report No. 2013-6

CENTRE *for* ECOSYSTEM MANAGEMENT

1 MINE WATER AND ENVIRONMENT RESEARCH CENTRE

Founded at Edith Cowan University in 2008, the Mine Water and Environment Research (MiWER) Centre was formed by Dr Clint McCullough and Associate Professor Mark Lund. The research group has a focus on pit lakes formed from mining, although research also covers all inland water bodies. Our research covers most aspects of rehabilitation, remediation and the ecology of inland waters.

MiWER is also a member of Edith Cowan University's research centre, the Centre for Ecosystem Management.

More information on MiWER and our projects can be found at www.miwer.org.

2 ACKNOWLEDGEMENTS

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2.1.1.1 FRONTISPIECE

Plate 1. Mark Lund collecting water samples at Site W2 (Point Fraser).

This report should be referenced as follows.

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4 EXECUTIVE SUMMARY

Point Fraser was developed in 2004 to convert former lawn area to a recreation space, with environmental values. In addition, a wetland was constructed to intercept and treat a stormwater drain from East Perth (catchment 18.3 ha) that had previously discharged untreated into the Swan River. In 2010, the City of Perth (COP) contracted the Mine Water and Environment Research Centre at Edith Cowan University to undertake a comprehensive monitoring program at the site. The aim was to determine how well the wetland and to a lesser extent other components of the development achieved the goals originally set for the site.

This report covers monthly monitoring of water quality in the wetland from January to December 2012. Results suggest that water quality is generally within the normal ranges that might be expected in stormwater wetland on the Swan Coastal Plain. Salinity was higher than might be expected in a freshwater lake, especially in the last ponds (W3 and W4) of the wetland. This is partially due to influx of saline Swan River water during high tides, and incoming slightly salty water from stormwater and Lake Vasto. The main loss of water from the wetland is evaporation which concentrates the salt up to undesirable levels. Salt levels are becoming problematic and might need active management to control (deliberate draining of the wetland).

Solar powered monitoring stations were established at both inlet and outlets to the wetland. These were designed to allow for quantification of nutrient loads in and out of the system so that the overall removal efficiency could be determined. This year reliable data on inflows and outflows was obtained for the majority of the year.

The team has identified in previous years issues associated with the inlet structure that means that much of the water (46% of the total water inputs) that enters the wetland later drains back into the drainage network, and as such it is effectively lost from the wetland. The reasons are two-fold, firstly the shallow slope of all the drains relative to the wetland mean that it is particularly susceptible to the relative heights of water in the incoming drains compared to the wetland (i.e. if the wetland is higher, water drains out and vice versa), and secondarily as there is probably a leak in the drainage network which is continuously reducing the height of the drain water allowing backflow to occur. This issue is significantly impacting on wetland function, as it means that the wetland treats only a proportion of the actual drain flow. Further the lack of water remaining in the wetland costs the COP in the additional expenses associated with using Lake Vasto waters to keep wetland wet. Resolution of this problem is beyond the scope of the monitoring project and needs to be undertaken urgently to ensure the wetland can perform its function.

Approximately 9.5 kg of N and 0.6 kg of P were estimated to enter Point Fraser with approximately 7 kg of N and 0.24 kg of P exported to Zone 3. This represents a removal efficiency of 27% for N and 62% for P. Although inputs of N have not substantially altered from 2011, removal efficiency has halved. The wetlands received approximately half the load of P compared to 2011, however removal efficiency dropped slightly. More water entered the wetland compared to 2011 and this probably reduced hydraulic residence times resulting in reduced removal efficiencies. Total N on a number of occasions (78% of samples) exceeded the target concentrations for discharge. Removal of P appeared successful in preventing exceedances of the target values for discharge. Uptake of P by the Supersorb Zeolite clays added to W1 and W2 appears to be a major pathway for its removal.

Wetland vegetation is growing well, there is evidence that the three major species (*Juncus kraussii, Baumea articulata* and *Eleocharis acuta*) are currently competing with each other for space and the extents of each will change over time. *Baumea articulata* has suffered a large dieback this year, possibly due to increasing salinity. *Typha domingensis* was recorded for the first time in W3; however it has now largely died out. A total of 17.77 kg of P were stored in the plant biomass (living) in October almost the same as recorded in 2011. Nitrogen decreased in October in living biomass to 20.2 kg in 2012 from 27.9 kg in 2011. These results indicate that the plant communities are now maturing and that unless areas increase little additional nutrient load will be taken up.

Biodiversity measured through bird and macroinvertebrate communities showed communities rich in cosmopolitan common taxa. Only 12 species of bird were recorded (only one sampling occasion) which is down from previous years. Macroinvertebrate communities in zone 1 were substantially different to those recorded in previous years and Zone 2. Zone 2 communities were similar to previous years. Increasing salinity in zone 1 may be responsible for the changes seen. Overall species richness was the lower than 2010 and 2011.

Social monitoring was undertaken to see how people use the site. Point Fraser does not appear to be a destination of choice but is used extensively as people pass through it primarily for exercise or park in the car parks to access the city.

Overall the wetland appears to performing its various functions successfully. However, as inflows increase as the catchment is restored, performance appears to be dropping. Increasing salinity in the wetland also appears to be reducing biodiversity.

5 INTRODUCTION

Point Fraser is named after the colonial botanist Sir Charles Fraser who explored the Swan River in 1827 when he accompanied Captain Stirling's expedition. The site was originally named 'Boodjargabbeelup' by Noongar peoples, when it was still a peninsula and prior to river reclamation in the 1930s. Point Fraser is located between Riverside Drive and the Swan River, next to the Causeway. The land was reclaimed using spoil from the dredging of the river used to deepen the water around Heirisson Island and causeway (see Figure 1a). Prior to 2004, the site was a lawn area containing a car park, a helipad and a shipping container used for bike hire. A stormwater drain (Point Fraser Main Drain) discharged into the river at this point. The catchment of the drain was 18.3 Ha of East Perth located mainly west of the WACA Cricket Ground (Figure 1b).

a)

b)

Figure 1. Aerial photographs of Point Fraser in a) 2000 and b) 2010 (showing catchment area for the wetland in red). Photographs taken from Google Earth, 2011.

After 2000, the City of Perth sort to improve the quality of stormwater discharge to the Swan River and improve aesthetic, recreational and environmental values of the area. This culminated in the Point Fraser redevelopment; the first stage was the creation of a constructed wetland which was completed in 2004. The second stage saw the redevelopment of the remaining area and was completed in 2007. The redevelopment included construction of new car parks, a bicycle hire facility, grassed areas, BBQ facilities, a children's playground, a mixture of native bush areas and parkland and the constructed wetland.

In 2012, the construction of a commercial development in the Point Fraser reserve commences. This will ultimately consist of shops and food outlets, a jetty and a foot bridge to Heirisson Island. An artist's impression is shown in Figure 2.

Figure 2. Artists impression of the new commercial development (centre) being constructed at Point Fraser (Source: WA Business News - http://www.wabusinessnews.com.au/article/Point-Fraser-development-gets-go-ahead)

The objectives of the Point Fraser redevelopment project were to:

1. "Improve the quality of urban stormwater discharging to the Swan River through the Point Fraser wetland, including stormwater management run-off from the surrounding area;
2. Establish a wetland habitat and breeding place for native fauna which will be attractive to avifauna, in particular Black Swans;
3. Promote passive recreation and community education, including use of the wetland to demonstrate stormwater management techniques;
4. Enhance the landscape and visual aesthetic; and
5. Provide a recreational and educational environment and experience for the public." (quoted from Syrinx Environmental Pl, 2005)

The effectiveness of the wetland in removing nutrients from stormwater is an important consideration in the entire re-development and will provide value information for similar projects in the City. The City of Perth commissioned the authors to undertake a 5 year monitoring program to evaluate how the redevelopment was meeting its original objectives. Specifically to monitor, evaluate and report on the following, as taken from the Point Fraser Monitoring and Evaluation Plan (PFMEP; COP, 2010):

1. The quality of urban stormwater discharging to the Swan River long term, as a result of the redevelopment of Point Fraser by determining the amount of pollutant removal via the constructed wetland;
2. The quality of wetland habitat and the quantity and quality of breeding places for native avifauna presence, behaviours and habitat use;
3. The ongoing ecological health of the constructed wetland via its conformance with relevant water quality guidelines and legislation requirements.
4. The quality, quantity and type of recreational and educational use of Point Fraser by determining the diversity of visitor presence, behaviour, use, expectations and satisfaction and awareness of reports/information specific to Point Fraser performance; and
5. The long term integrity and quality of the restoration of the foreshore edge, as a result of the redevelopment of Point Fraser by determining vegetation health and structural reliability.

This is the third annual report of the PFMEP and covers the period January to December 2012.

6 METHODS

6.1 STUDY SITE

The majority of the study was conducted in the constructed wetland in the Point Fraser reserve, however foreshore monitoring occurred in two areas (1 & 2) while avifauna and social monitoring were conducted across the entire reserve (Figure 3).

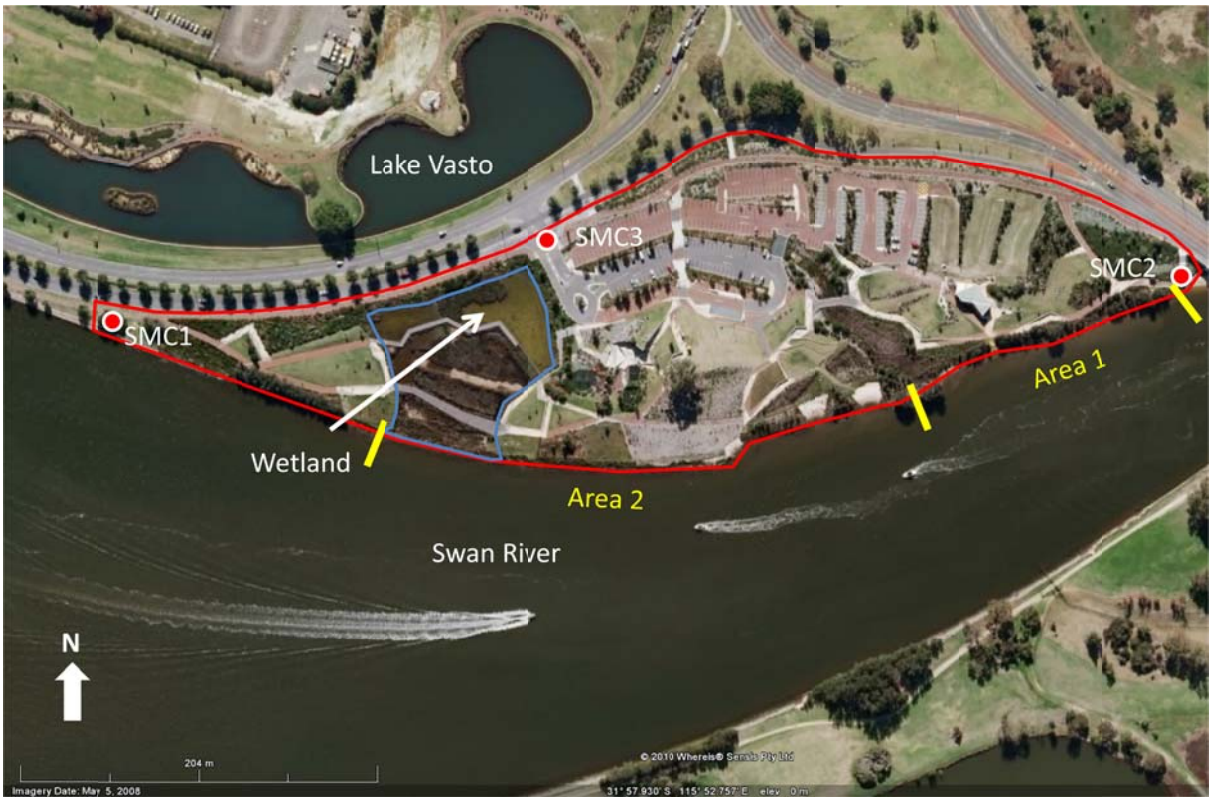

Figure 3. Aerial photograph of Point Fraser (bounded by the red line), showing the constructed wetland (bounded by the blue line), Lake Vasto, the social monitoring sites (red and white circles, SMC1-3) and the foreshore monitoring areas (yellow). Photograph adapted from Google Earth, 2010.

Water enters the wetland from the catchment via the East Perth drain; this arrives at the splitter box where low flows are directed via two pipes into a bubble-up grate (BUG) in W1 (Figure 4). High flows exceed the weir in the splitter box and part of the flow is directed via a pipe and another BUG into the Swan River. Bubble-up grates slow the flow rate reducing erosion and providing opportunities for particulates to settle. Water flows from W1 to W2 (Zone 1), and then when levels exceed those of the weir, water flows into W3 and then W4 (Zone 2) before exiting via a small pipe into the foreshore vegetation (Zone 3) and then into the Swan River. The boardwalk separating W1 and W2 from W3 contains a weir that is set higher than the control weir. The boardwalk weir is designed to overflow only in exceptionally high flow conditions. A similar weir lies under the boardwalk separating the discharge area from W4. This contains a valve to prevent ingress of water from the Swan River at times of exceptionally high tides, while also permitting exceptional high water levels in W4 to discharge. W1 to W4 are lined to prevent interaction with underlying acid sulphate soils (Syrinx Environmental Pl, 2009). W1 and W2 are covered with a thin layer (approx. 20 mm) of Supersorb activated zeolite clay, while W3 and W4 have layer of soil (100-200 mm deep) to grow plants in. The cleared strip between W3 and W4 is actually a small mound that effectively prevents water moving directly from the weir to the discharge point. Excessive build-up of salt in the mound, resulted in removal of the surface layer (Syrinx Environmental Pl, 2008), which is why it is currently devoid of plants. As stormwater flows infrequently into the wetland, the ponds W1 and W2 (which must remain under 250-300 mm of water and W3 and W4 which must be under 50-100 mm of water must be topped up with water taken from Lake Vasto (Syrinx Environmental Pl, 2009).

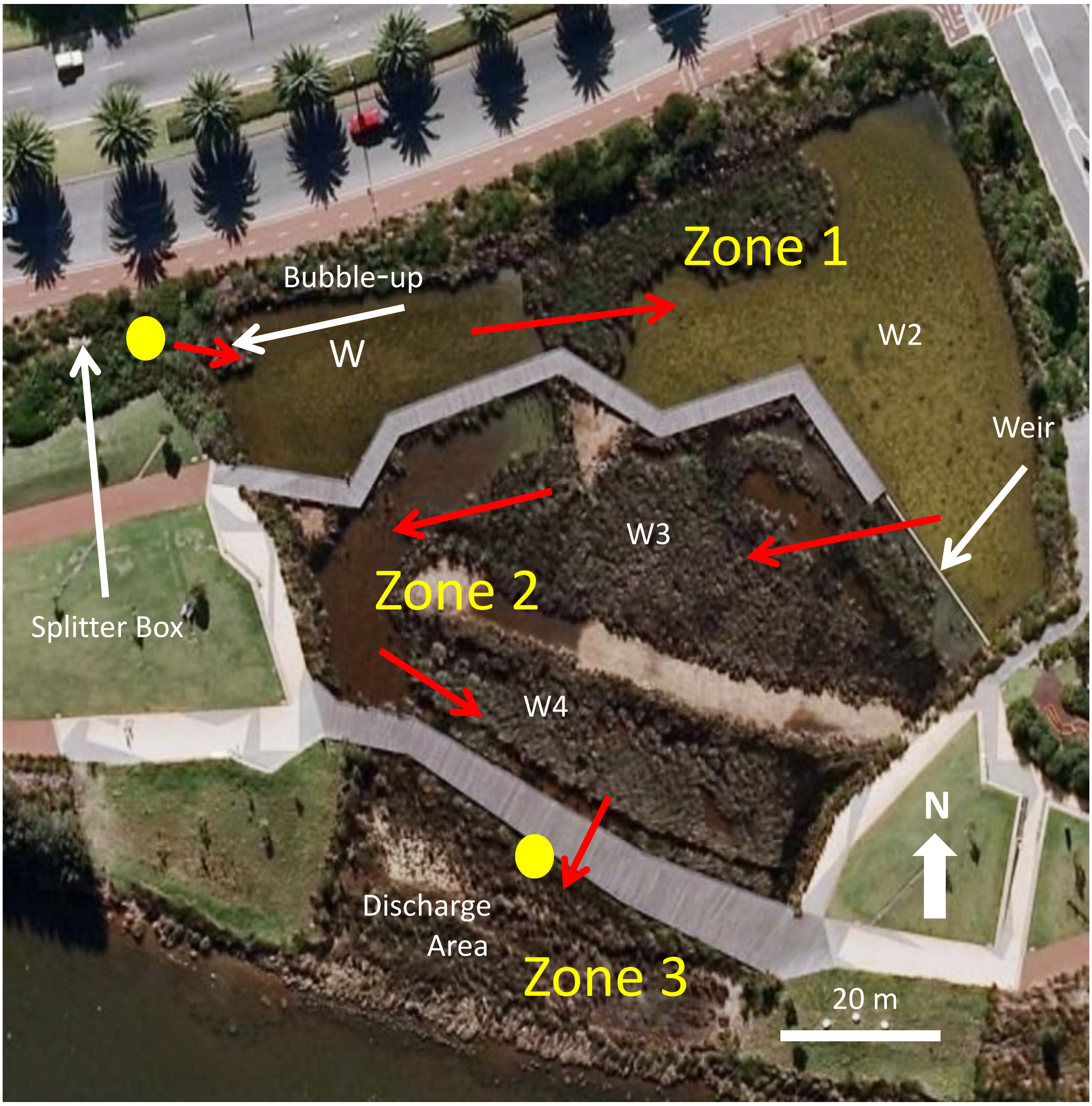

Figure 4. Aerial photograph showing the movement of water (red arrows) through the Point Fraser constructed wetland. Yellow circles mark the fixed inlet and outlet monitoring structures. Sampling sites are indicated as W1 to W4. Imagery adapted from Google Earth, 2010.

Photographs of all the sampling sites are shown in Figure 5.

a) W1

b) W2

c) W3

d) W4

e) Discharge area (Zone 3)

Figure 5. Photographs of the sampling sites in Point Fraser constructed wetland

6.2 SAMPLING

The sampling procedures used in this study are provided in condensed form below but are available in more detail in PFMEP (COP, 2010). The monitoring program commenced in April 2010, however this report covers the period January to December 2012.

6.2.1 WATER QUALITY (WSWQ)

Sampling for this study was conducted on the third week of every month. On each occasion, pH, oxidation reduction potential (ORP), conductivity, temperature and dissolved oxygen (% saturation and mg L^{-1}), turbidity and chlorophyll *a* were measured *in situ* in the water using a Hydrolab Datasonde (4a) multimeter at each site (and Ozone in April). At each site, a water sample was collected, an unfiltered aliquots (subsample) of this sample were bottled for determination of total nitrogen (total N[1]) and total phosphorus (total P). Another aliquot was filtered in the field (through 0.5 µm Pal Metrigard filter paper) before bottling prior to determination of nitrate/nitrite (NO_x), filterable reactive phosphorus (FRP) and ammonia (NH_3). At quarterly intervals (May, Aug, Nov), water was also collected for determination of Chlorophyll *a* and Phaeophytin, total hardness, metals (Al, Fe, Mn, As, Cd, Cr, Cu, Hg, Pb, Ni, Zn) and total suspended solids). Another aliquot was filtered in the field (through 0.5 µm Pal Metrigard filter paper) before bottling prior to determination of dissolved organic carbon (DOC).

Samples were sent to SGS Australia Ltd for analysis. SGS Australia offers NATA accredited analyses and detailed QA/QC processes (except where noted). All samples were collected, stored and preserved as recommended by the company.

6.2.2 SEDIMENT QUALITY (WSQ)

In May 2011, eight sediment cores were randomly taken each from W2 and W3. The cores were clear acrylic tubes (50 mm dia.). Cores were pressed into the sediment to a maximum depth of 100 mm or touching the liner (whichever came first), the top was sealed, core extracted and bottom sealed. Water was carefully decanted from each core and the sediment transferred to a glass jar. Four jars were analysed for total Kjeldahl N (TKN), Total P, total organic carbon (TOC), total metals (Al, Fe, Mn, As, Cd, Cr, Cu, Hg, Pb, Ni, Zn), wet and dry weight and loss on ignition (LOI) at 500 ^{o}C and 1000 ^{o}C. All analysis was undertaken at SGS Australia Ltd, except for the LOI which was not NATA accredited and therefore was undertaken at Edith Cowan University.

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[1] All nutrients are reported as per their respective elements i.e. Total N-N, Total P-P, FRP-P, NOx-N and NH_3-N

Sediment depth in W2 was measured at 8 random sites using a ruler as the distance from the surface to the liner. It was not possible to distinguish between the zeolite layer and accumulated sediment.

6.2.3 QUANTIFICATION OF LOADS IN AND OUT OF THE WETLAND (WSFM & AWWQ)

At the inlet to W1, an ISCO 6712 Autosampler was installed, this was triggered by an ISCO Bubble Flow Module when water depth in the BUG reached a set limit. In addition an Acoustic Doppler Velocity meter (Unidata) was used to measure flows in the pipes linking the splitter box and BUG. In 2010, this was located at the splitter box end of the pipe but was relocated to the BUG end on 2/7/11; this was to improve flow measurements which had been problematic in 2010. A solar panel is connected to the system to recharge the battery for the system. In addition, a tipping bucket rain gauge (Unidata) was installed. The rain gauge and acoustic Doppler are both connected to a data logger with telemetry (Unidata Neon). The autosampler pulls samples from the bubble-up pit; samples are taken every hour whilst flows are occurring.

At the outlet to W4 (pipe), an ISCO 6712 Autosampler was installed, this was triggered by a ISCO Bubble Flow Module. The bubble flow tube was attached to a hydrostatic depth sensor (Unidata) mounted in W4. When water depth exceeds the height of the discharge pipe, water starts to discharge from the wetland triggering sample collection. Samples are collected every 24 hours. This system is connected to a data logger with telemetry (Unidata Neon) and is supported by a solar panel recharging the battery.

Samples from the autosamplers were collected within 2-3 days of collection and sent to SGS for determination of total N and total P, turbidity and total suspended solids.

6.2.4 WETLAND VEGETATION (WV)

In October and May, the wetland vegetation was mapped. Photographs are taken at fixed points (Table 1; Figure 6) to record vegetation health.

Table 1. The Site codes, Site names and Site Coordinated of WV Monitoring Photopoints (GPS co-ordinates use UTM Zone 50 with datum GDA94)

Site Code	Site Name	Easting	Northing	Notes
WV1	Wetland #1 - Weir b/n Zone 1 and 2	393898	6462962	4 photos: NE, SE, E and S directions
WV2	Wetland #2 – Zone 2 middle	393869	6462969	3 photos: E, S and N directions
WV3	Wetland #3 – Zone 2 west side	393832	6462961	2 photos: E and S directions
WV4	Wetland #4 – Mound in Zone 2	393900	6462937	3 photos: NW, W and SW directions
WV5	Wetland #5 – Zone 1	393917	6462988	2 photos: SW and W directions

Figure 6. Location of vegetation monitoring photopoints (WV1-WV5)

Three quadrats (200 mm x 200 mm) were randomly taken from each major plant species (*Baumea articulata*, *Eleocharis acuta, Juncus kraussii*) where present in W1 and W2 (combined), W3, and W4. All the plant material (above and below ground) in the quadrat was removed. For each quadrat, the above ground material had each stem length measured, the percentage of leaves that mature, new or senescent determined and the number of flowers recorded. Dry weight of above and below ground material for each quadrat was measured, samples of dried material were sent to SGS Australia Ltd for analysis of TKN and Total P. Loss on ignition was then performed on composite biomass from each sample area (above and below ground) at 500 ^{o}C and then 1000 ^{o}C.

6.2.5 MACROINVERTEBRATES (MINVERT)

In May and October macroinvertebrate samples were collected from Zone 1 and Zone 2 using a 250 µm dip net over two 5 m transects per site. Samples were preserved in 70% ethanol and returned to the laboratory for sorting, identification (to Family) and counting.

6.2.6 SOCIAL MONITORING (SM)

In May and October visitor counts and visitor observations was undertaken. Social monitoring for each round was carried out between 7 am and 6:30 pm on a weekday and weekend day. Surveyors were based at each end of Point Fraser (see Figure 3) capturing walkers and cyclists moving through the park, a third person was based near the road entrance to capture people using the Point Fraser car-park for visiting the city. On the hour, for the first 15 minutes, the numbers of people and vehicles entering or leaving the park were recorded at the three sites on Observation Count data sheets. Between the hourly visitor counts, a surveyor walked from the east to west entrance ensuring all areas of the reserve were covered and recorded the behaviour of park users using the Observation Behaviour datasheet. An aerial photograph was used to mark the location of stationary park users. Copies of the datasheets were appended to the 2010 report.

6.2.7 AVIFAUNA

In early June and early November, a survey of all birds seen within the park or flying above it were recorded. Surveys were conducted in the early morning and were timed to avoid adverse weather conditions. During surveys, the entire area of parks and garden were surveyed by walking at a steady pace and recording all birds encountered by both call and sightings. Particular attention was paid to the wetland areas to ensure that cryptic species and water birds were recorded.

6.2.8 FORESHORE MONITORING

In May, the foreshore of Point Fraser was monitored at 3 sites in each of the two areas shown in Figure 3. Photographs were taken at each site and condition assessed. The locations of the foreshore monitoring sites are shown in Figure 7.

Figure 7. Locations of the foreshore monitoring sites (F1A-C and F2A-C) (taken from Google Earth 2010)

7 RESULTS AND DISCUSSION

7.1 HOW WELL DOES THE WETLAND WORK?

The Point Fraser constructed wetland is a highly engineered wetland designed to perform a range of tasks, primarily stormwater treatment but aesthetics and biodiversity values are also important constraints on the design. As the wetland is isolated from groundwater (by a liner) to prevent oxidation of underlying acid sulphate soils, this simplifies the hydrology of the ponds but has constrained the design in terms of wetland depth. Constructed wetlands attempt to maximize the retention time for water entering the systems as the longer the water is retained generally the more treatment is possible. Peak stormwater flows can scour the wetland, reduce treatment times and the overall wetland efficiency. To reduce the potential for this, the wetland has a splitter box that allows high flows to be split with a part of the flow directed into the Swan River.

Perth had below average rainfall in 2012 reaching only 608.2 mm rather than the 850 mm long-term average (Bureau of Meteorology, Perth Metro station). In Figure 8, daily rainfall measured at Point Fraser and by the Bureau of Meteorology (Perth Metro) is shown for comparison. These sites are all within a 5 km radius of each other, showing local variability in rainfall. Further, rainfall at Point Fraser was recorded each day from 12 am to 12 pm, while Bureau of Meteorology data are recorded at 9 am for each day and reflects the previous 24 h. This explains the Point Fraser data appearing out of sync by a day on some occasions. A total annual rainfall of 463.6 mm was recorded at Point Fraser, but close examination of the data suggests that the rainfall gauge was not recording correctly between 18/6/12 and 7/8/12 (accounting for 109.4 mm of the difference). In 2012, there was 47 mm less rainfall at Point Fraser compared to Mt Lawley rainfall data.

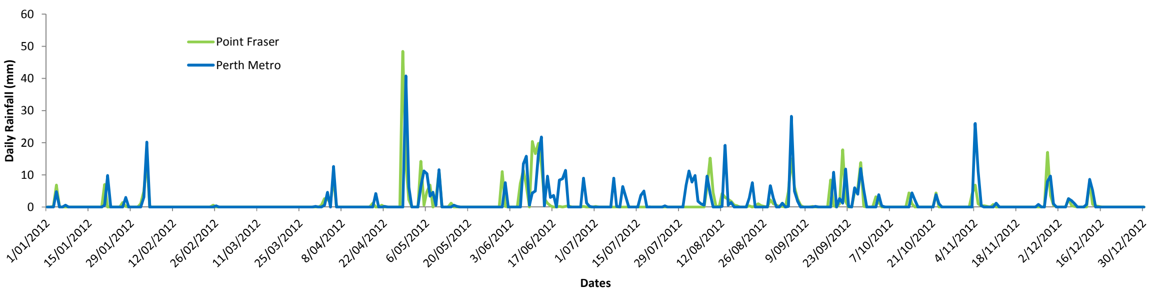


Figure 8. Daily rainfall measured at Point Fraser and Mt Lawley in 2011. Mt Lawley data (Perth Metro) from the Bureau of Meteorology and recorded 9 pm to 9 am, Point Fraser data recorded 12 am to 12 pm.

The largest single rainfall day was 48.4 mm on 29/4/12 compared to 56.8 mm last year (24/6/11). On only one other occasion at Point Fraser did the daily rainfall exceed 20 mm (10/6/12), however another 3 occasions >20 mm were noted for Perth Metro (3/2/12, 13/6/12 and 4/9/12). This difference appears to be due to the timing differences in measurements between the two sites.

There was more evidence of salt intrusion into W4 and pushing back to W2 from the Swan River during storm surges.

Recommendation 1.

Installation of a flap valve over the end of the outlet pipe is recommended to prevent saltwater intrusion into the wetland.

7.2 INFLOW AND OUTFLOW

The specific aims of measuring the inflow and outflow of the wetland were to:

1. Create a water budget for the wetland.

This will show how the water moves through the wetland (hydraulic residence times) as well as allowing quantification of nutrient loads.

2. Quantify nutrient loads in and out of the wetland

This will show how nutrient loads change during storm flows (the 'first flush' effect) and allows determination of wetland nutrient removal efficiency.

7.2.1 INFLOWS

This year, the Starflow worked throughout the year, although in December it produced a few spurious results (probably dirt on the sensor). The ISCO Bubble Flow meter (IBFM), worked reliably until October when issues with the ISCO prevented reliable data capture. It was therefore possible to determine the relationship between the IBFM water depths and those recorded by the Starflow. Therefore, a complete set of data was achieved for the year. In the event of discrepancies between Starflow depths and IBFM depths in terms of generating flows into the wetland, the Starflow was given primacy. On many occasions, negative flows were detected; these were removed from the calculations (reflecting possible drainage out of the wetland). Zero velocity was detected on occasions when depths suggested inflow should be occurring but this was taken as simply indicating that the BUG was full but not overflowing.

Recommendation 2.

The unique design of the inlet structure means that a depth sensor in the BUG, in addition to the Starflow is required to accurately estimate inflows. It is recommended that a Unidata depth sensor be purchased by COP and coupled to the Neon Telemetry System.

The catchment (assuming it was 18.3 ha) received a total of 111,000 m^3 (compared to 149,000 m^3 in 2011) of rainwater. Typically for hard surfaces, a runoff coefficient of 0.6 would be conservative suggesting that at least 66,800 m^3 of rainfall from the catchment should have reached the splitter box.

A total of 22,938 m^3 entered W1 through the BUG in 2012. This is substantially more than the 11,300 m^3 recorded for the much wetter 2011. Developments in the catchment have in previous years effectively reduced the size of the catchment. The catchment is slowly being reconnected and this probably explains the increased inputs despite reduced rainfall in 2012. This is also further compounded by a leak identified in the drainage network that is allowing water to backflow out of the Point Fraser wetland. No inflows were recorded between October and November, despite a total rainfall of 61.4 mm. In March, there were two large inflows that were not associated with any rainfall. Also in March and August through to September there were a number of moderate rainfall events that failed to generate any inflows.

Recommendation 3.

Backflow from W1 into the drainage network remains an important issue reducing the effectiveness of the wetland in treating stormwater.

The wetland is topped up by water pumped automatically from Lake Vasto (Ozone Reserve) when water levels drop to heights that might impact on the vegetation. COP records the inflows from the pumps and in March, and between May and September 2012 no water was pumped, with 2757 m^3 added throughout the rest of the year. This was an increase on 2011 (1567 m^2) and probably reflects the reduced rainfall in 2012.

In addition, the wetland received direct rainfall of 608.2 mm (using Perth Metro data) in 2012, which equates to 3,226 m^3 (area is 5,304.6 m^2).

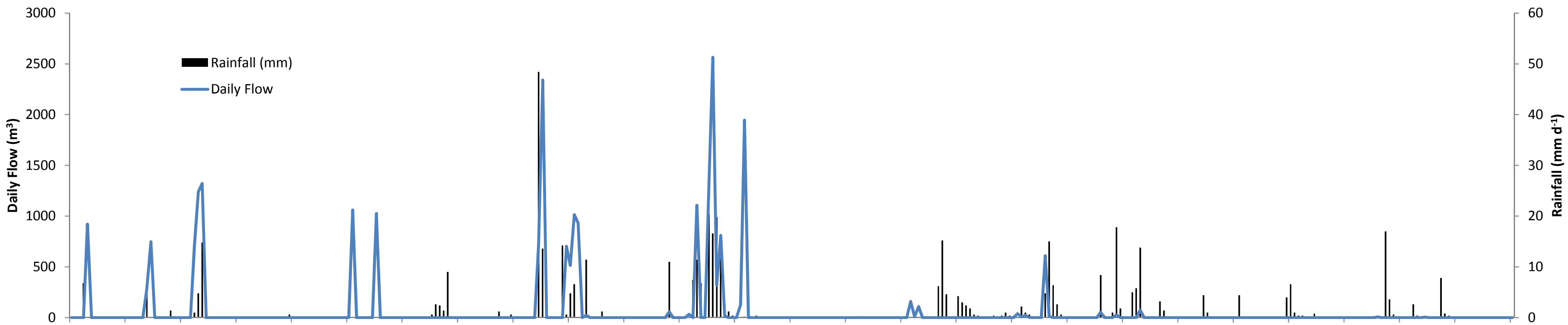
7.2.2 OUTFLOWS

ISCO Bubble Flow module collected depth data for the entire year. A partial blockage of the air hose appears to have caused some alterations to the height data (these have been adjusted for).The Unidata depth sensor was replaced in November 2013

A rating curve was developed using a Marsh McBirney Flow meter, by measuring velocity at a range of depths. The velocity data were used with cross sectional areas to create flow rates at particular depths, these data were plotted and a polynomial function fitted. As more data are collected this curve will be further refined. The constants from this equation were used to calculate flows for all water heights greater than the outlet (115 mm). Depths greater than 195 mm were considered to have reached the maximum discharge rate (i.e. the pipe was full).

The total daily discharge out of the wetland for 2013 is shown in Figure 9. Total outflow in 2012 was 5582.3 m^3. Calculating likely evaporation (ignoring transpiration, which can increase loss considerably depending on the species (Sanchez-Carrillo *et al.*, 2001)) using Bureau of Meteorology pan evaporations corrected with Black and Rosher (1980) values for the Peel Inlet (as cited in Congdon, 1985), then there was 1498.6 mm of evaporation which equates to a loss of 7,949 m^3 over 2012. Therefore the total outflow of 13,531 m^3 was substantially lower than the inflows (difference of 28,921 m^3). It is assumed that allowing for errors in the estimates that the difference can be accounted for by the backflow into the drainage network. This indicates that although substantially more water is entering the wetland compared to 2011, only a small fraction is moving through into W3 and W4, with the majority returning back to the drainage network. If this return, could be reduced then it is likely that the wetland would require less topping up.

a) 2012 Rainfall and inflows



b) 2012 Outflows

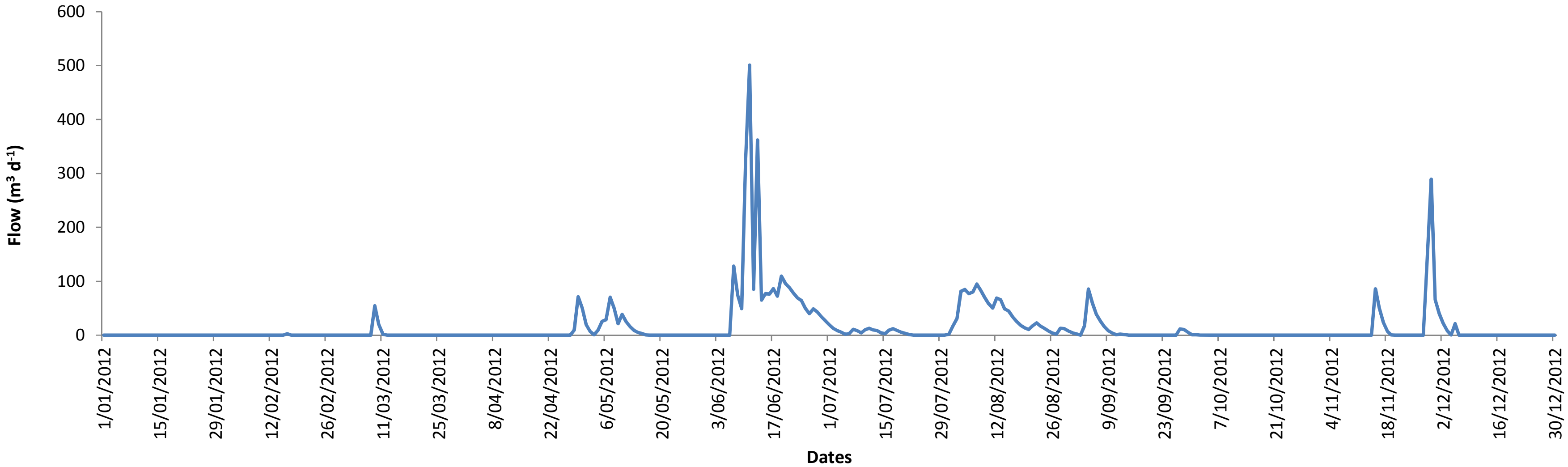
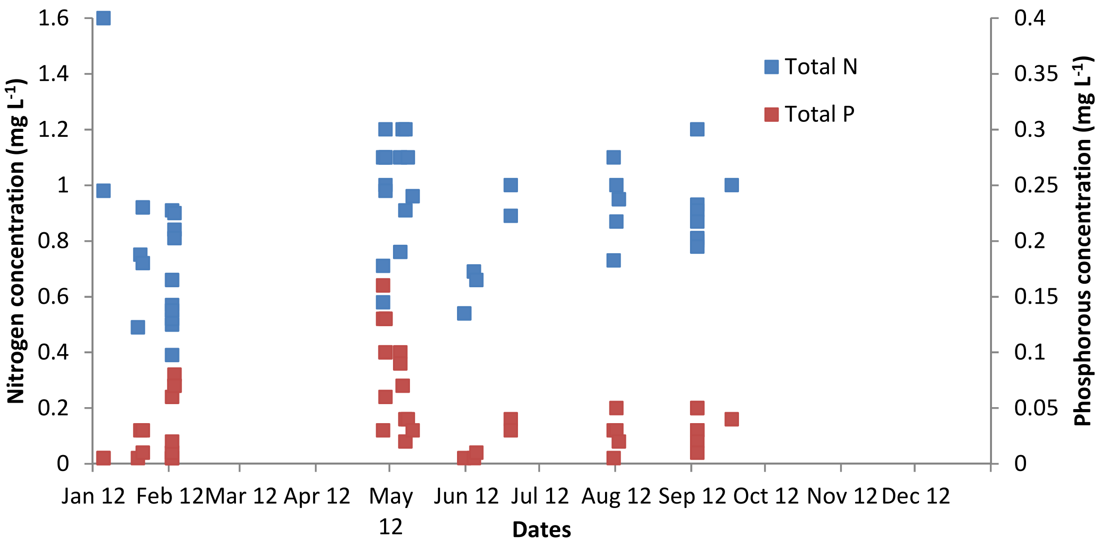


Figure 9. Daily totals for a) rainfall and inflows and b) outflows, for the Point Fraser wetland in 2012.

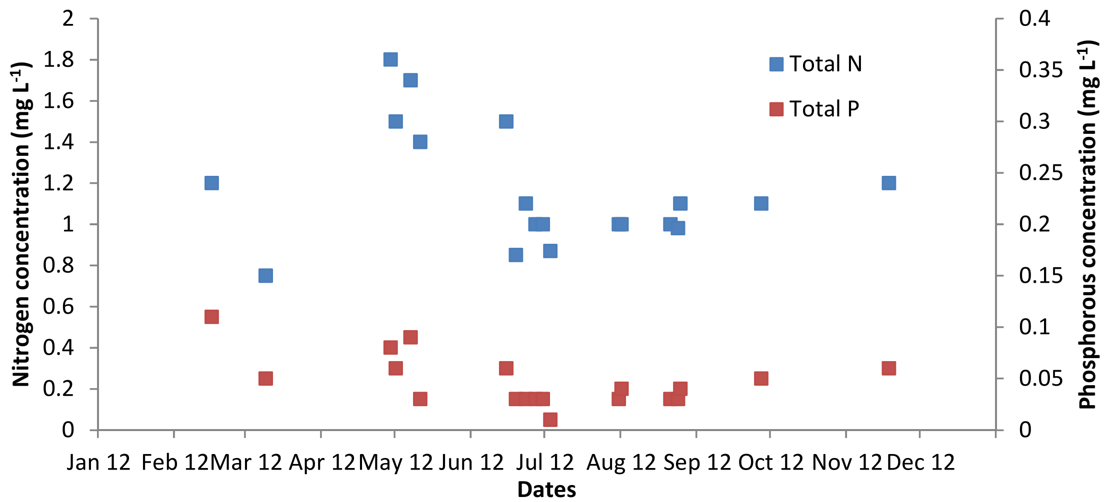
7.2.3 QUANTIFICATION OF NUTRIENT LOADS

Samples were collected during storm events for both the inlet and outlet. Inlet samples were taken at hourly intervals and the outlet at daily intervals reflecting the time that flow was present and the likely changes. Concentrations of total N were generally higher in the outlet than inlet (mean of 1.16±0.07 mg L^{-1} compared to 0.87±0.03 mg L^{-1}), total P showed a similar trend but with little average difference between inlet and outlet (0.04±0.01 mg L^{-1} vs 0.05±0.01 mg L^{-1}). The first flush is a theory which suggests that the first heavy rain following a period of dry weather will effectively wash the catchment and so the stormwater will initially contain high concentrations of mainly particulate material, which decreases as the storm event progresses. Although this makes intuitive sense, there is little evidence to support it (see Hall, 2006; Khwanboonbumpen, 2006). Analysing the storm events entering Point Fraser for total P, it can be seen in Figure 10 that particularly in the first half of the year that there was a slightly broader range of inflow concentrations compared towards the end of year. There was no consistent pattern as to when during the storm event that high or low concentrations occurred. Total N concentrations during storm events were much more variable than total P across the year for each event (and compared to 2011). There did appear to be a trend of highest total N concentrations at the start of each event. Total suspended solids concentrations were generally lower in the outlet compared to the inlet, except during February, when there were small outflows following rainfall. This outflow probably contained algae.

a) Inlet



b) Outlet



c) Total Suspended Solids (Inlet and Outlet)

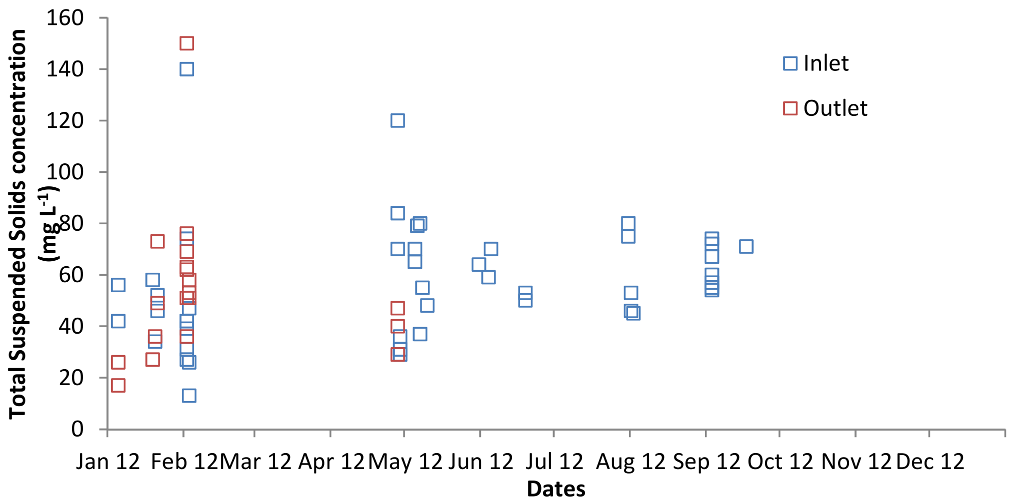


Figure 10. Concentrations of total P and total N recorded in the a) inlet, b) outlet, and c) total suspended solids for both inlet and outlet autosamplers over 2012.

Loads of N and P entering and leaving Point Fraser were estimated by multiplying flows by the concentrations from the storm event sampling. It was assumed that concentrations remained unchanged between sampling events. Backflow was estimated as the difference between inflow and outflow. As backflow quickly followed inflow, the loss of nutrients as a result of backflow is simply taken as the proportion of backflow of total inflow times the incoming nutrient load. Lake Vasto loads were estimated from monthly samples taken from Lake Vasto (where available) multiplied by the monthly quantity of water pumped. Rainfall loads were estimated using nutrient concentrations in rainfall taken from Khwanboonbumpen (2006) for Bannister Creek. Approximately 11 kg of N and 0.6 kg of P were estimated to enter Point Fraser (with >90% of the load coming in via the drain). A small quantity of the load was lost via backflow out of the wetland. Approximately 7 kg of N and 0.24 kg of P were estimated to be exported to Zone 3, with potentially some further removal prior to reaching the Swan River. This represents a removal efficiency of 37% for N and 60% for P. Removal efficiency is high for P and this is probably due to uptake by the Supersorb activated zeolite clay in W1 and W2. The wetland is not designed to specifically target N removal (no provision for subsurface flows or ponds with low ORP) other than through the use of Supersorb activated zeolite clay and plant uptake. While the Supersorb appears successful in reducing ammonia and NOx, total N in the form of particulate/organic N appears to increase through the system. Presumably this N is produced by plant biomass, the die-off of *Baumea articulata* may account for some of this material.

Table 2. Water and nutrient budget for the Point Fraser wetland, including removal efficiency for nutrients. Numbers in brackets are total inputs without losses due to backflow. Removal efficiency determined from total input (excluding backflow) and total output.

	Water (m^3)	N (g)	P (g)	TSS (kg)
Inflow	22,938	18,916	889	1,228.3
Rainfall	3,226	865	68	0
Top-up from Vasto	2,757	831	190	0
Backflow	-15,390	-9,644	-537	-738.0
TOTAL INPUTS	13,531 (28,921)	10,968 (20,612)	610 (1,147)	490.3 (1,228.3)
Outflow	5,582	6958	241	311
Evaporation	7949	NA	NA	NA
TOTAL OUTPUTS	13,531	6958	241	311
Removal Efficiency		37%	60%	37%

Total N concentrations should be <1000 µg L^{-1} to meet the Mounts Bay Water Quality improvement targets (Swan River Trust, 2009a), however in the Point Fraser higher concentrations were seen in the outflow samples (15 out of 19 times) reaching a maximum value of 1800 µg L^{-1} on the 29/4/12. However, only 10 out of 49 values in the inlet exceeded the threshold for Total N reaching a maximum of 1600 µg L^{-1} on 5/1/12. Phosphorus concentrations in the wetland were generally below a target of <100 µg L^{-1} (Figure 12) recommended for the Mounts Bay Drain catchment by the Swan River Trust (Swan River Trust, 2009a), as part of the Swan-Canning Water Quality Improvement Plan (Swan River Trust, 2009b). However on 23/4/12 total P in the outlet reached the upper limit of 110 µg L^{-1}. In comparison, there were 4 out of 49 exceedances of the target in the inflow for Total P, with the peak value reaching 160 µg L^{-1}. In comparison to 2011, total P concentrations entering the wetland were generally lower. Removal efficiencies were also lower than in 2011. The estimates of losses of input nutrients in backflow have a potential to be higher than reality and this will reduce the apparent efficiency. Higher flows in 2012 could also see efficiencies drop due to reduced residency times and possible scour. The wetland also appeared to retain 37% of the particulates entering via the inflow. It is also likely that the nature of the particles changes to predominantly algal organic matter at the output. This change may also account for the high total N concentrations leaving the wetland.

7.2.4 CONCLUSIONS

1. Create a water budget for the wetland.

A water budget was created for 2012. Backflow out of wetland into the drainage network was estimated as 46% of the total inflows (including direct rainfall). A leak in the drainage network is believed responsible for the backflow. The slow reconnection of the wetland catchment following development activities has seen a significant increase in inflows despite reduced rainfall in 2012 (compared to 2011). This resulted in only slight increases in outflows from the wetland with most of the additional water draining back out via the drainage network.

2. Quantify nutrient loads in and out of the wetland

Approximately 11 kg of N and 0.6 kg of P were estimated to enter Point Fraser with approximately 7 kg of N and 0.24 kg of P exported to Zone 3. This represents a removal efficiency of 37% for N and 60% for P. Despite this efficiency, Total N on most occasions exceeded the target concentrations for discharge. Removal of P appeared successful in preventing exceedances of the target values for discharge.

7.3 WATER QUALITY IN THE WETLAND

The specific aims of measuring the water quality in the wetland were to:

1. Determine how physico-chemical variables and nutrient concentrations changed on a monthly timescale

This will show whether there are any management issues associated with water quality over the year. The data will allow the effectiveness of various processes responsible for nutrient uptake or release to be inferred.

2. Examine how key metals and other selected parameters change quarterly between all the ponds.

This will provide information on metal removal by the wetland but also highlight any metals of concern, which might require management actions.

7.3.1 MONTHLY DATA

Monthly data for common physico-chemical parameters are shown in Figure 11. Water temperatures at the time of measurement (9-12 am) were >25 ^{o}C in January, February, November and December.

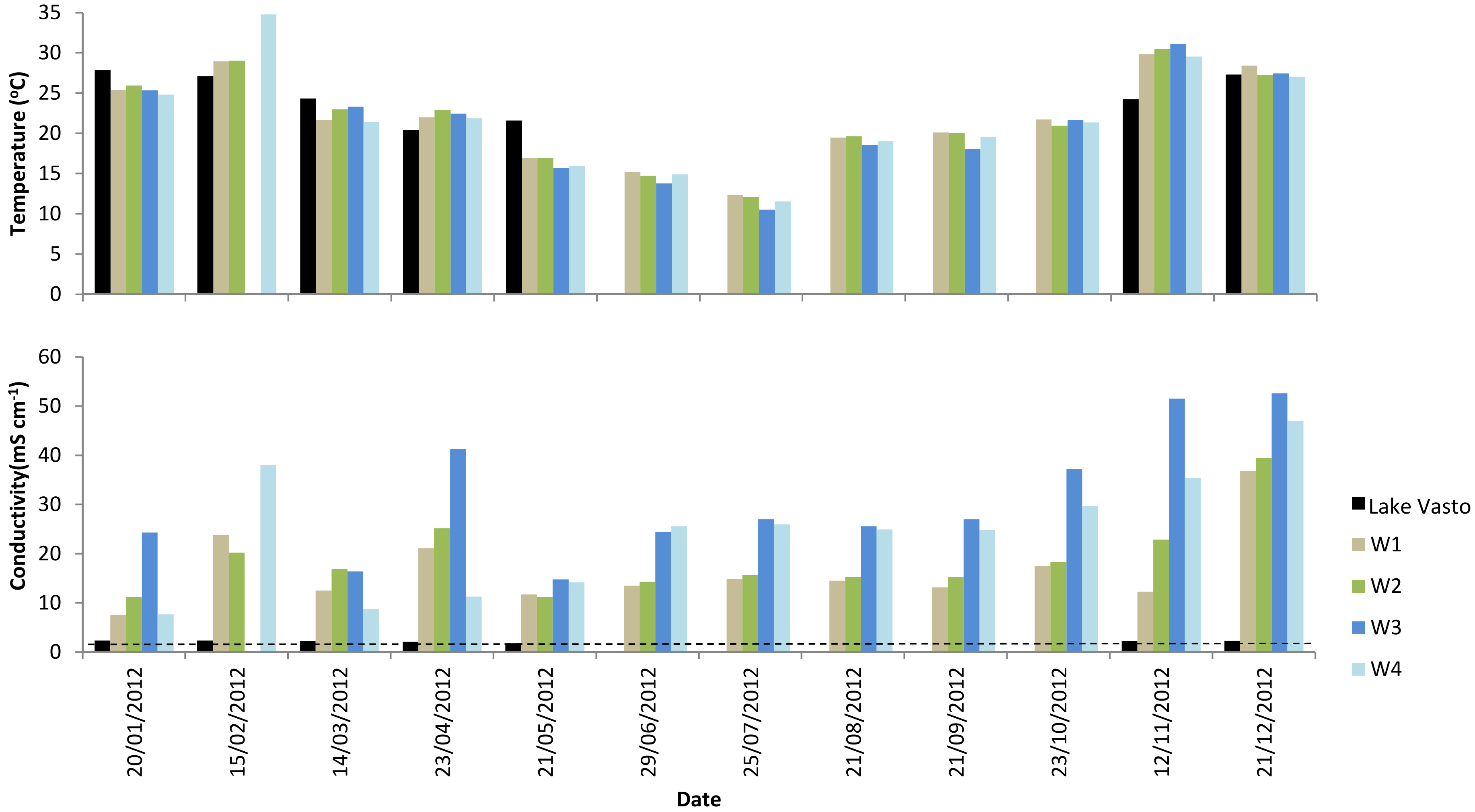
Lake Vasto is much less saline (2.19 ± 0.09 mS cm^{-1}) than the Point Fraser wetland during the months where it is used as top-up water. It therefore is useful in diluting the high salinities encountered in the wetland during the non-winter months (June to September). Water in the inflow ranged in conductivity from 2-3 mS cm^{-1} on average up until June where salinities rose to average >6 mS cm^{-1} dropping back in July to 3.9 mS cm^{-1}. Peak salinity in the inflow was >19 mS cm^{-1}, although this may reflect W1 water entering the BUG rather than outflow (as the ISCO will sample when the BUG is full). In 2011, W1 had much lower conductivities than the other ponds, however in 2012 the average conductivities were very similar in both W1 and W2 (16.6 ± 2.5 and 18.8 ± 2.2 mS cm^{-1} respectively). This suggests that saline water from the Swan is entering Zone 2 and this has pushed up into Zone 1, possibly aided by backflow out of W1 allowing reverse flow in the wetland. Conductivities were slightly higher in W3 and W4 however this was probably due to evapo-concentration. Salinities of >7 ppt (James & Hart, 1993) for the plants *Eleocharis acuta*, and >10 ppt for *Juncus kraussii* (Zedler *et al.*, 1990) and *Baumea articulata* (Chambers *et al.*, 1995) are known to impact on growth, this equates to an approximate conductivity of 12.5 and 18 mS cm^{-1} respectively. Conductivities in Point Fraser exceeded 12.5 mS cm^{-1} on 83% of occasions across all ponds.

Recommendation 4.

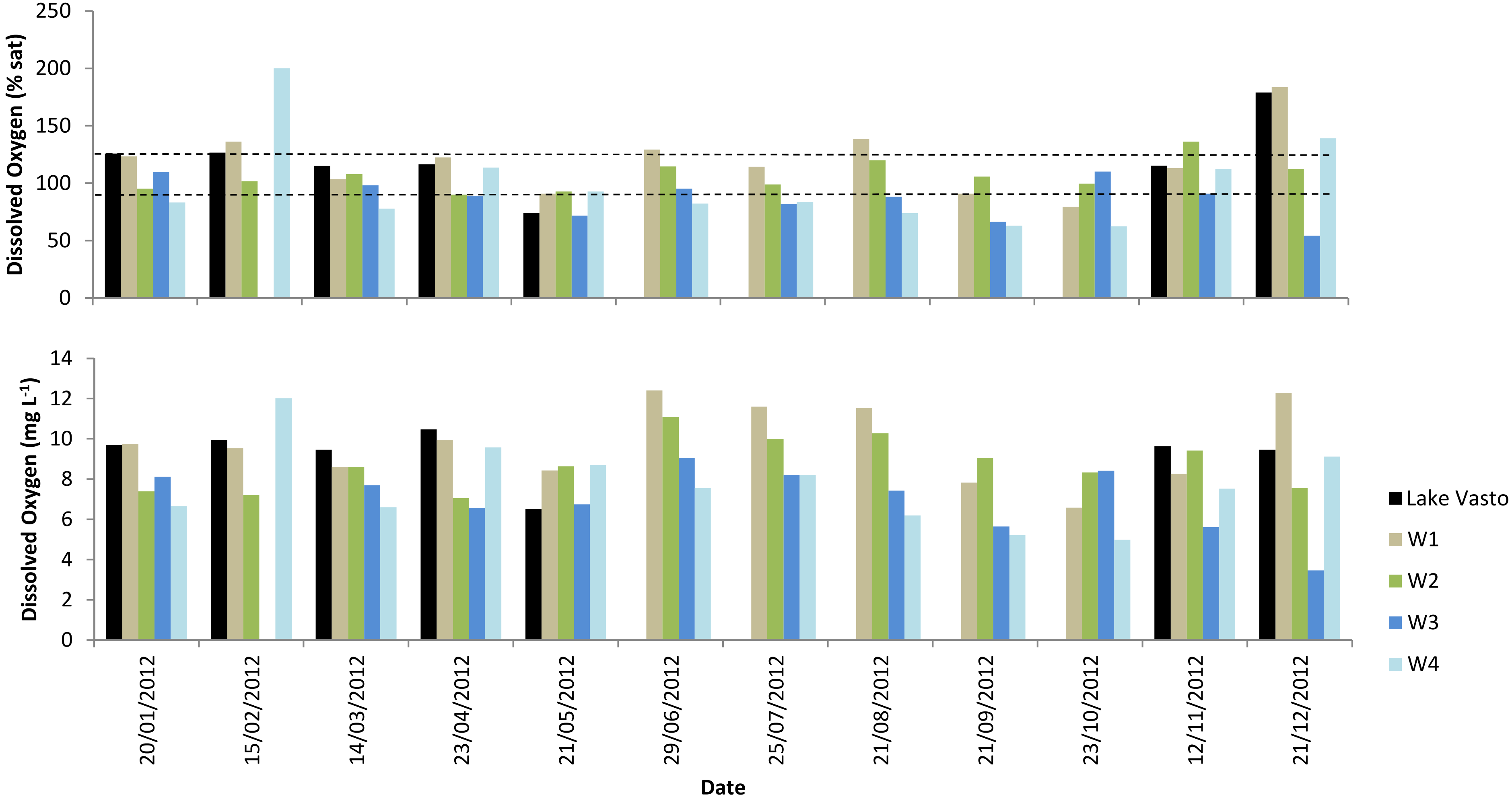
High salinities (>12.5 mS cm^{-1}) are becoming the norm in the wetland and are most likely stressing the vegetation. It is recommended that the cause of the high salinities be investigated. This includes measuring chloride in inflows, outflows and at depth in the wetland. This can be achieved by adding chloride as a parameter in the monitoring program.

Dissolved oxygen concentrations were recorded in excess of 100% saturation on a couple of occasions in W1 and Lake Vasto, indicating high algal growth in the water (high rates of photosynthesis can temporarily raise % saturation above 100%). Dissolved oxygen concentrations also on most occasions dropped below ANZECC & ARMCANZ (2000) recommended guidelines for protection of aquatic systems but not significantly. This may indicate increasing biological oxygen demand from the sediments due to build-up of organic material. At present, this is not a significant concern but if levels were to decline much more then it would need further investigation (Figure 11).

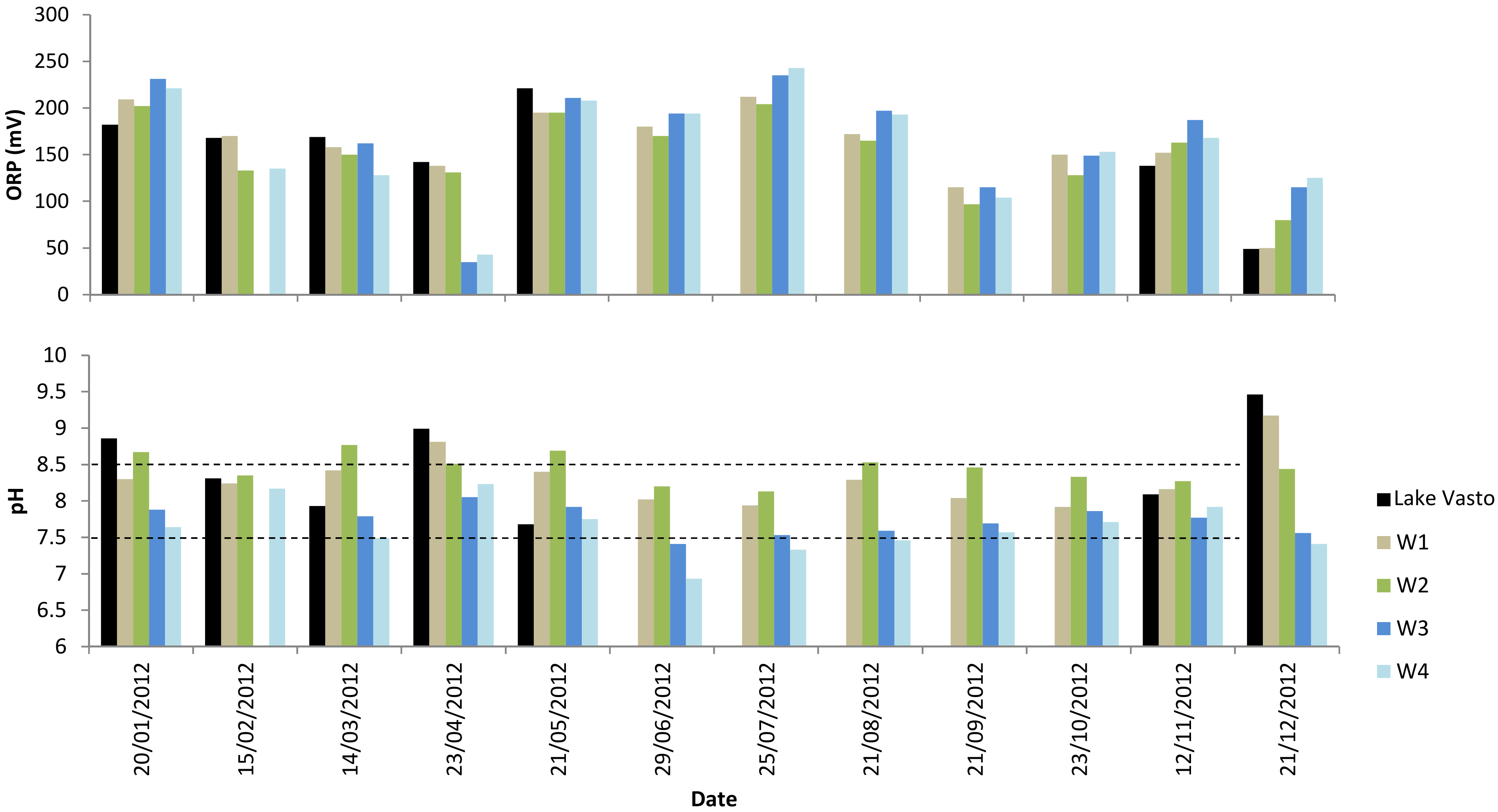
pH was always circumneutral to slightly alkaline, with only a couple of times when values occurred outside recommended guideline levels. pH was marginally higher in Zone 1 compared to Zone 2, suggesting that algae in the open water of Zone 1 may account for the higher values. Oxidation reduction potential values greater than 100 mV pose no issue for wetland processes. However, under 100 mV, the process of denitrification can occur which is the conversion of nitrates to nitrogen gas by bacteria. This is a desirable process for constructed wetlands as it results in the permanent loss of nitrogen from the system. Only in Zone 2 in December were ORP values <100 mV recorded. Turbidity was below ANZECC & ARMCANZ guideline levels, but was highest across the wetland in March. It appears that high turbidity is associated with low water levels as it was most common in W3. It is likely that the very shallow water depths allowed for sediment to be stirred up and measured as turbidity.



Temperature (ºC)
35
30
25
20
15
10
5
0
Conductivity(mS cm-1)
60
50
40
30
20
10
0
20/01/2012
15/02/2012
14/03/2012
23/04/2012
21/05/2012
29/06/2012
25/07/2012
21/08/2012
21/09/2012
23/10/2012
12/11/2012
21/12/2012
Date
Lake Vasto
W1
W2
W3
W4



Dissolved Oxygen (% sat)
250
200
150
100
50
0
Dissolved Oxygen (mg L-1)
14
12
10
8
6
4
2
0
20/01/2012
15/02/2012
14/03/2012
23/04/2012
21/05/2012
29/06/2012
25/07/2012
21/08/2012
21/09/2012
23/10/2012
12/11/2012
21/12/2012
Date
Lake Vasto
W1
W2
W3
W4



ORP (mV)
300
250
200
150
100
50
0
pH
10
9.5
9
8.5
8
7.5
7
6.5
6
20/01/2012
15/02/2012
14/03/2012
23/04/2012
21/05/2012
29/06/2012
25/07/2012
21/08/2012
21/09/2012
23/10/2012
12/11/2012
21/12/2012
Date
Lake Vasto
W1
W2
W3
W4

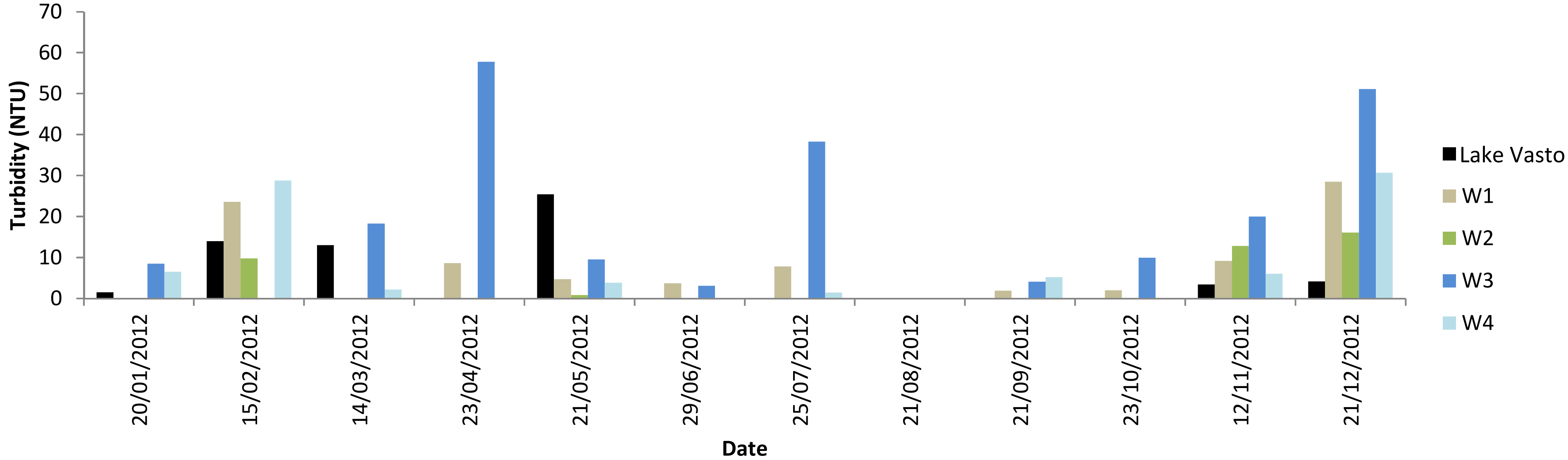
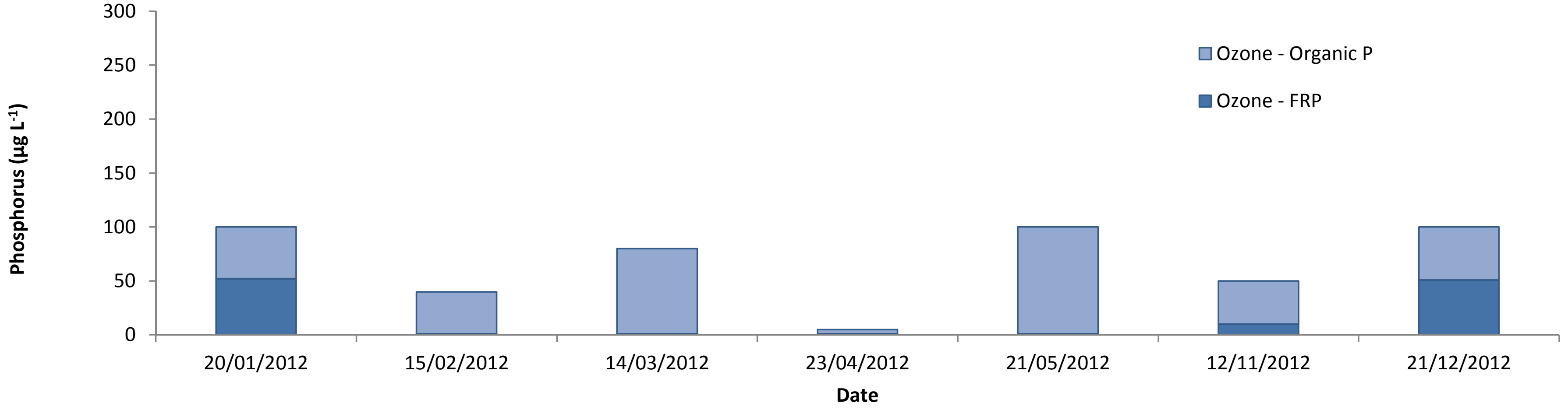
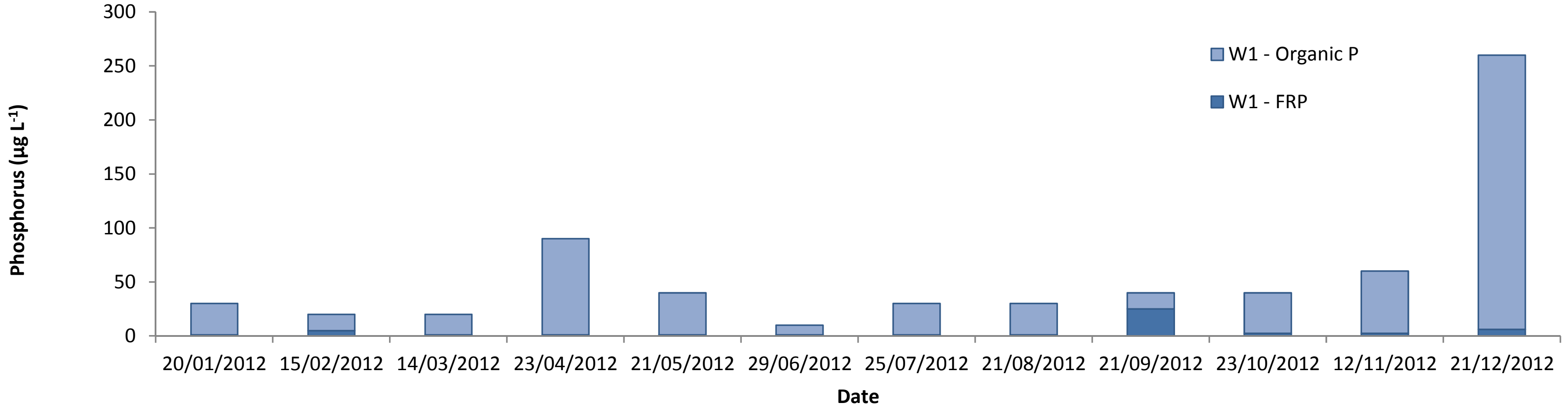
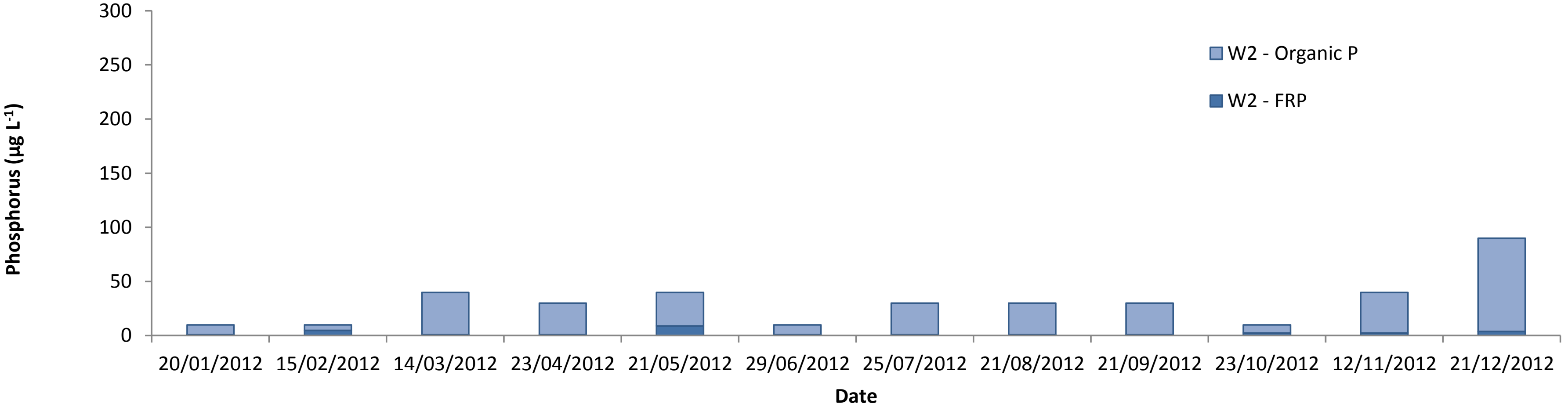


Figure 11. Physico-chemical parameters measured monthly at Point Fraser sites (W1-W4 and Lake Vasto. Dotted lines show relevant ANZECC & ARMCANZ (2000) guideline levels (see Table 3 for details).

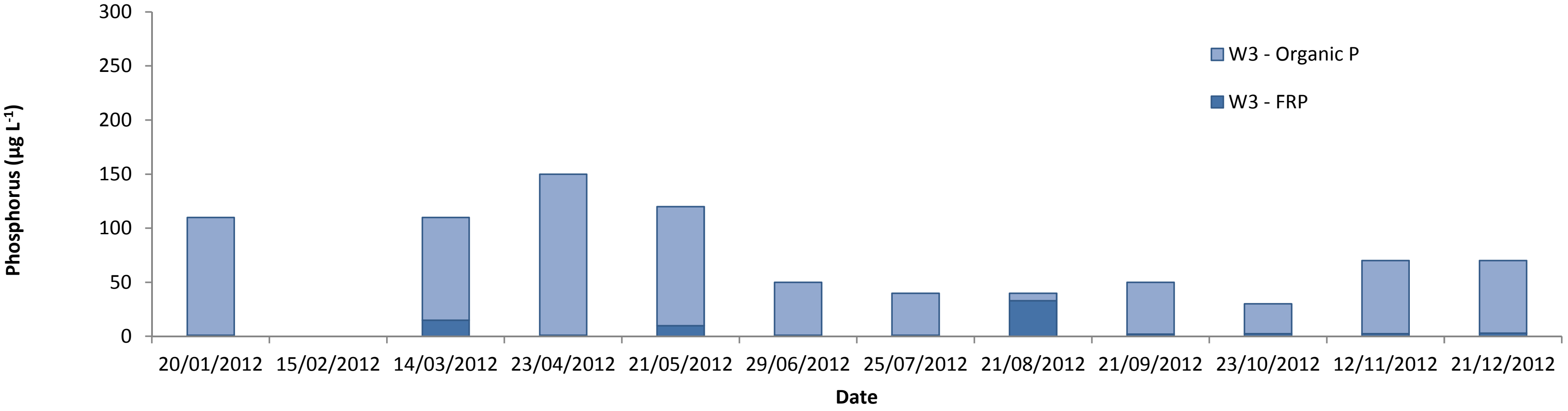
Phosphorus concentrations were lowest in W2, due to settling of particulates and binding onto the Supersorb clay added to W2. Concentrations picked up in W3 and declined again in W4. These increases are more likely due to the impact of evapo-concentration and water volumes rather than any releases of P from the sediments. Algal blooms also account for occasional spikes of total P across the wetland. Concentrations at these times often exceeded the targets of <100 µg L^{-1} (Figure 12) recommended for the Mounts Bay Drain catchment by the Swan River Trust (Swan River Trust, 2009a), as part of the Swan-Canning Water Quality Improvement Plan (Swan River Trust, 2009b). This appears to contradict the findings of the nutrient budget which showed that P was greatly reduced from inlet to outlet. However, at times of outflow, concentrations in W4 were all below the target level. Lake Vasto had the highest total P concentrations exceeding >100 µg L^{-1} on four occasions and high FRP up to 50 µg L^{-1} on three occasions. The high FRP is in contrast to very low levels in 2011. As the principle function of Lake Vasto is to precipitate iron prior to the water being used for irrigation, iron binds P, hence this should keep FRP concentrations low but explains the high particulate P. Topping up the wetland with Lake Vasto water, adds about 25% of the P that enters W1.


Phosphorus (µg L-1)
300
250
200
150
100
50
0
Ozone - Organic P
Ozone - FRP
20/01/2012
15/02/2012
14/03/2012
23/04/2012
21/05/2012
12/11/2012
21/12/2012
Date


Phosphorus (µg L-1)
300
250
200
150
100
50
0
W1 - Organic P
W1 - FRP
20/01/2012
15/02/2012
14/03/2012
23/04/2012
21/05/2012
29/06/2012
25/07/2012
21/08/2012
21/09/2012
23/10/2012
12/11/2012
21/12/2012
Date



W2 - Organic P
W2 - FRP
Phosphorus (µg L-1)
300
250
200
150
100
50
0
20/01/2012
15/02/2012
14/03/2012
23/04/2012
21/05/2012
29/06/2012
25/07/2012
21/08/2012
21/09/2012
23/10/2012
12/11/2012
21/12/2012
Date



W3 - Organic P
W3 - FRP
Phosphorus (µg L-1)
300
250
200
150
100
50
0
20/01/2012
15/02/2012
14/03/2012
23/04/2012
21/05/2012
29/06/2012
25/07/2012
21/08/2012
21/09/2012
23/10/2012
12/11/2012
21/12/2012
Date

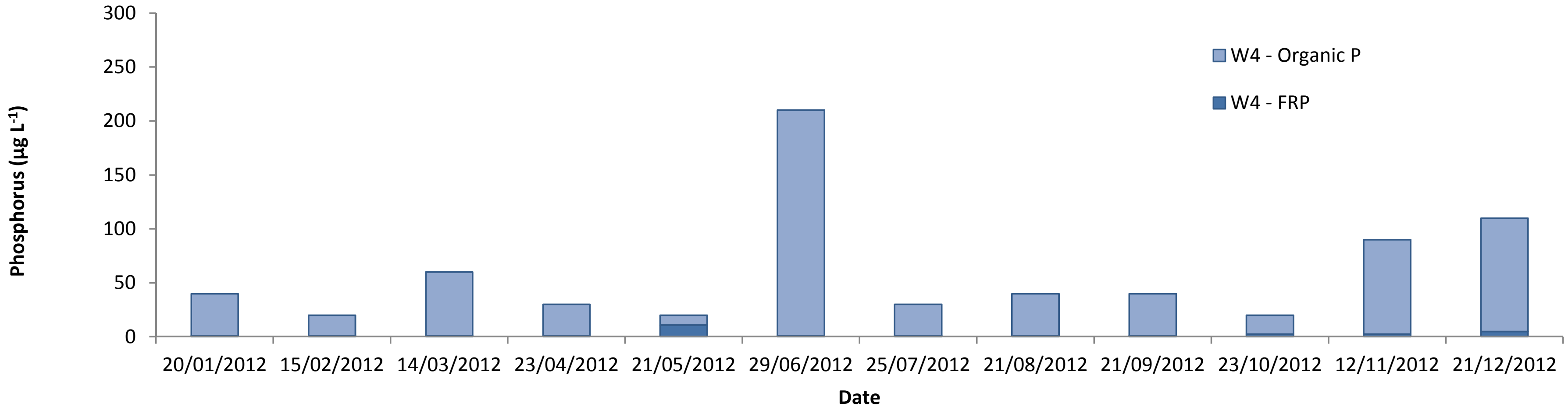
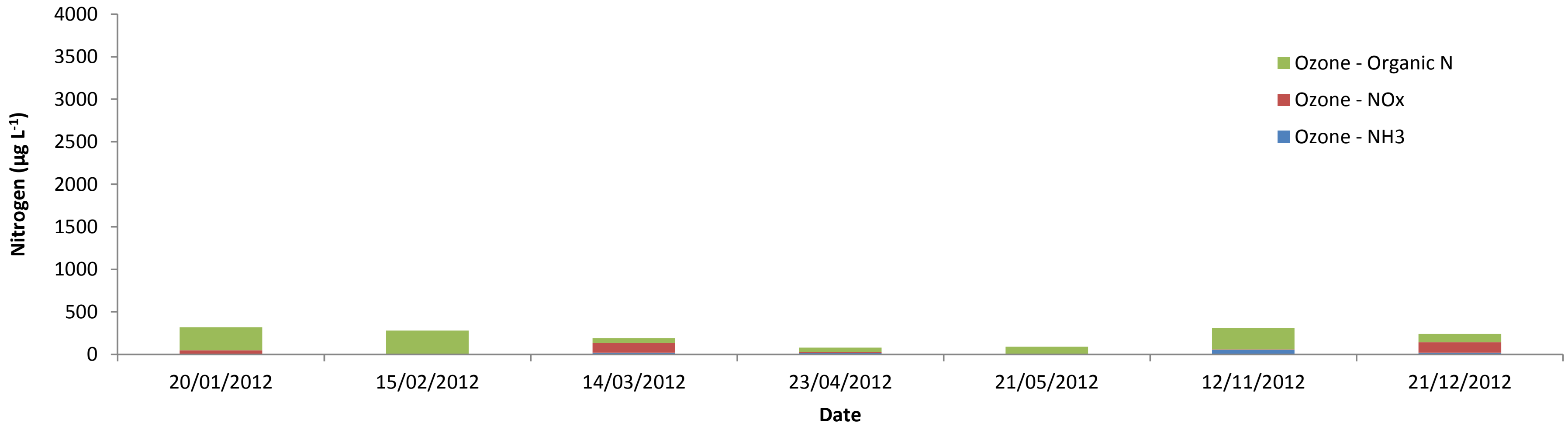


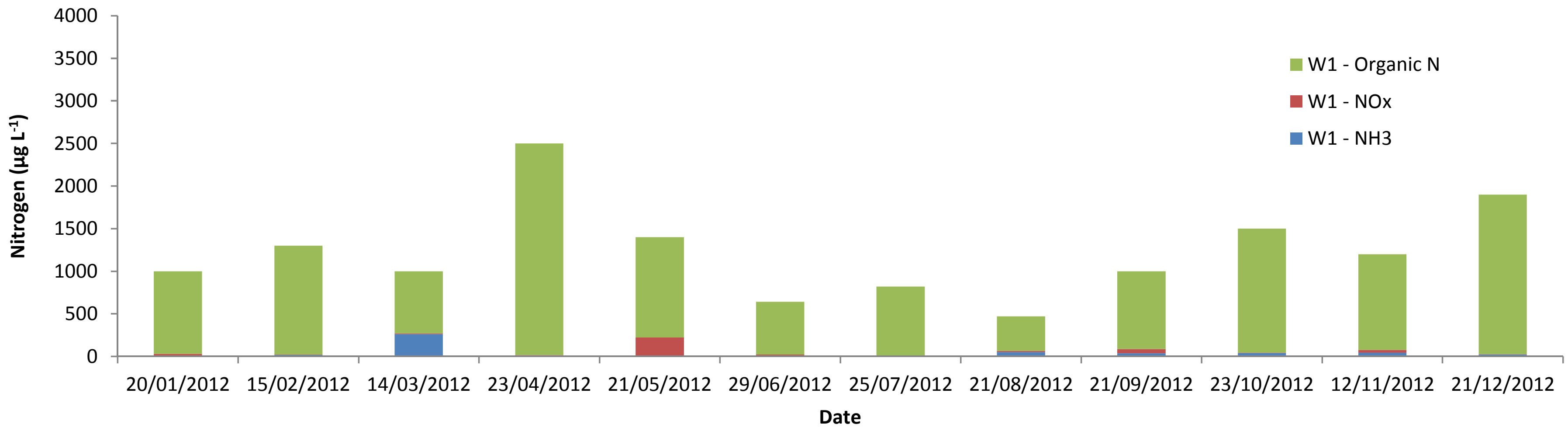
Figure 12. Phosphorus (Total P = Organic P + FRP) concentrations recorded at all sites in the wetland. Majority of FRP concentrations were below detection at 2 µg L^{-1}.

Lake Vasto contained relatively low total N (<400 µg L^{-1}) concentrations with NOx and NH_3 being low (<120 µg L^{-1}). In all ponds, organic N (organic or particulate) accounted for the majority of the N present. Concentrations of total N generally increased across the wetland, declining only in W4. This appears to be due to algal growth in the summer months and probably evapo-concentrations effects in W3 and W4. Unlike in 2011, more total N moved through the system and was discharged.

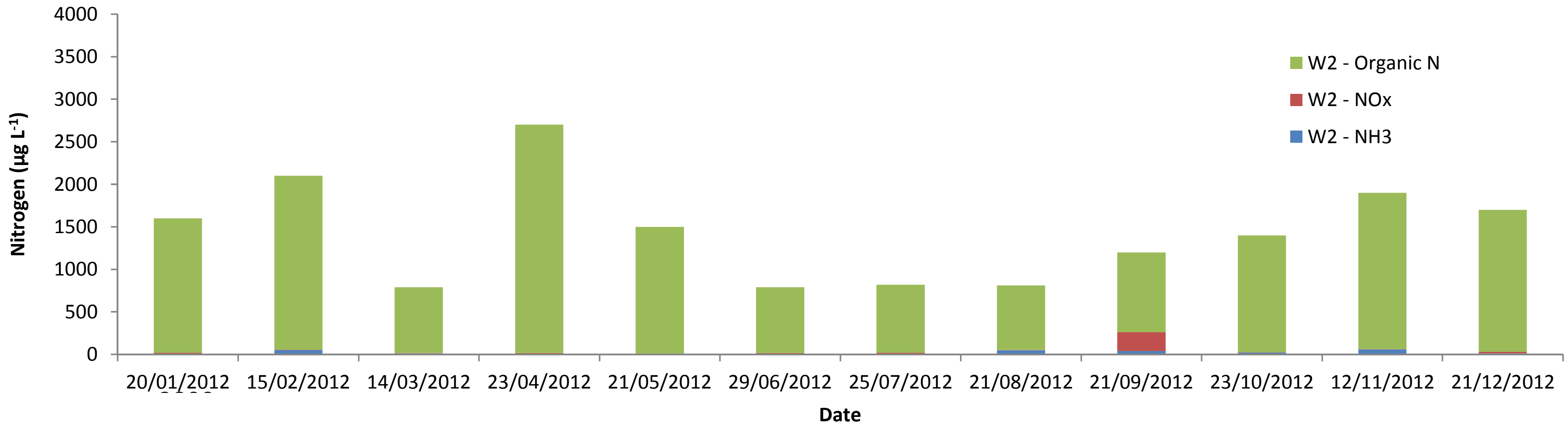
The ANZECC/ARMCANZ (2000) guidelines for aquatic ecosystems in the south west of Australia for wetlands or lakes/reservoirs are presented in Table 3. These trigger values are designed for natural wetlands and are only indicative of possible issues. Constructed wetlands would be expected to exceed many of these trigger values as their role is treat water of poor quality, however it would be expected that as water passes through the wetland, the frequency of exceedance would decrease as the water is treated. Overall, there is little difference in the number of exceedances across the wetland, indicating the wetland may not be having much influence on water quality. Salinities were higher than the guidelines, as the incoming water (at least from Lake Vasto) is already saltier than the guidelines. Dissolved oxygen was both higher and lower than the recommended value at different times. Concentrations of dissolved oxygen do not presently represent a cause for concern.

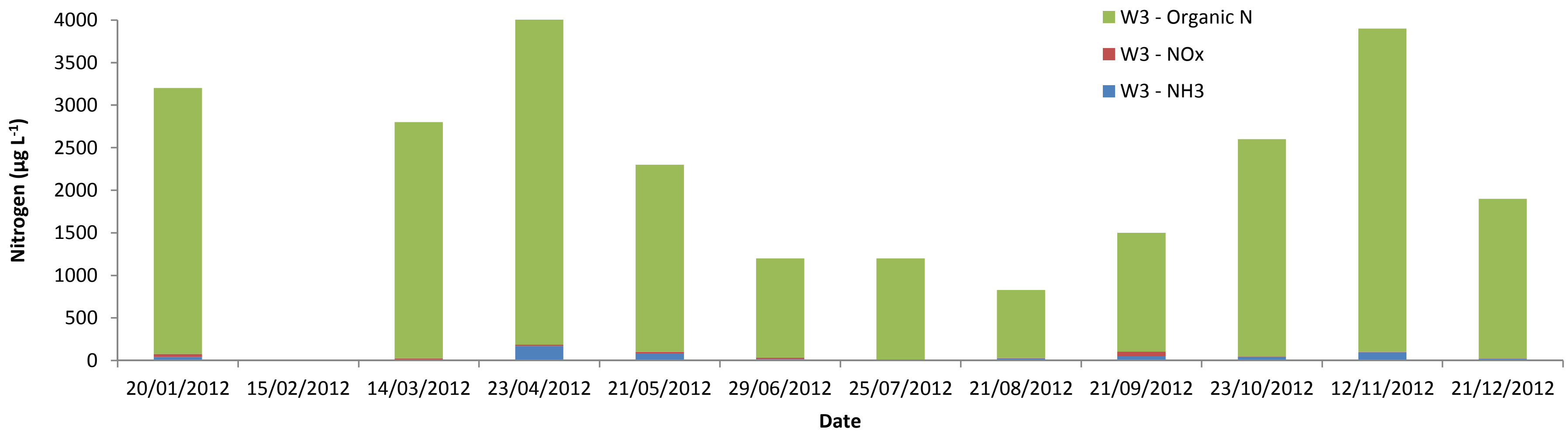


4000
3500
3000
2500
2000
1500
1000
500
0
Nitrogen (µg L-1)
Ozone - Organic N
Ozone - NOx
Ozone - NH3
20/01/2012
15/02/2012
14/03/2012
23/04/2012
21/05/2012
12/11/2012
21/12/2012
Date



4000
3500
3000
2500
2000
1500
1000
500
0
Nitrogen (µg L-1)
W1 - Organic N
W1 - NOx
W1 - NH3
20/01/2012
15/02/2012
14/03/2012
23/04/2012
21/05/2012
29/06/2012
25/07/2012
21/08/2012
21/09/2012
23/10/2012
12/11/2012
21/12/2012
Date


Nitrogen (µg L-1)
4000
3500
3000
2500
2000
1500
1000
500
0
W2 - Organic N
W2 - NOx
W2 - NH3
20/01/2012
15/02/2012
14/03/2012
23/04/2012
21/05/2012
29/06/2012
25/07/2012
21/08/2012
21/09/2012
23/10/2012
12/11/2012
21/12/2012
Date


Nitrogen (µg L-1)
4000
3500
3000
2500
2000
1500
1000
500
0
W3 - Organic N
W3 - NOx
W3 - NH3
20/01/2012
15/02/2012
14/03/2012
23/04/2012
21/05/2012
29/06/2012
25/07/2012
21/08/2012
21/09/2012
23/10/2012
12/11/2012
21/12/2012
Date

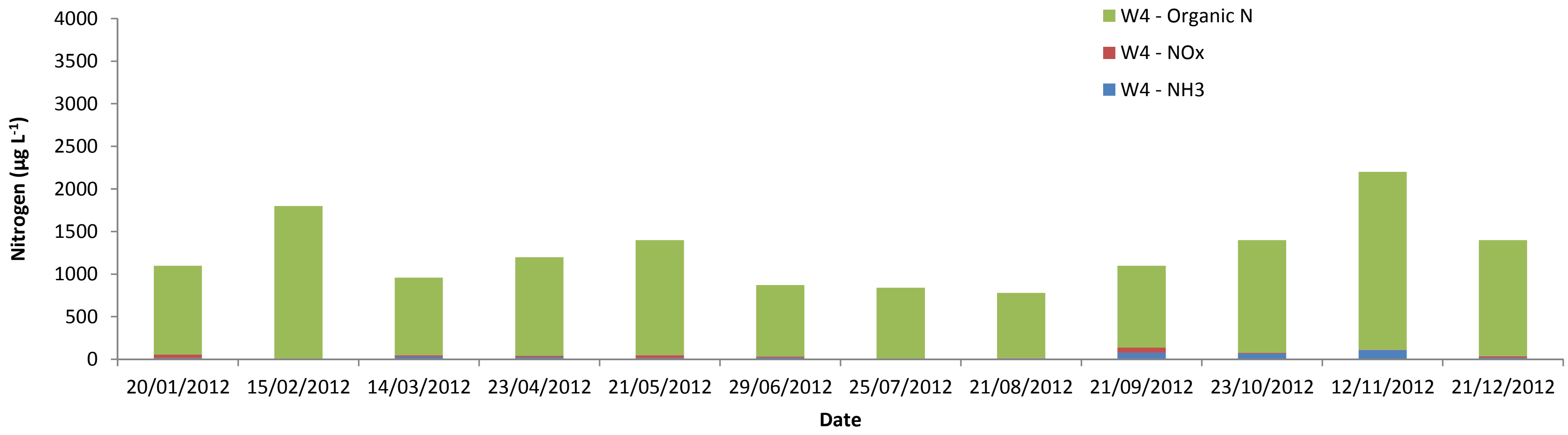


Figure 13. Nitrogen (Total N = Organic N + NH_3 + NOx) concentrations recorded at all sites in the wetland. Note on the 22/12/10 analytical error prevented Organic N being determined.

Table 3 ANZECC/ARMCANZ (2000) guideline for aquatic ecosystems in the south west of Australia for wetlands or lakes/reservoirs

Parameter	Acceptable range	Number of Exceedances (# samples)			
		W1	W2	W3	W4
Dissolved oxygen	90-120% saturation	7 (12)	1 (12)	7 (11)	9 (12)
pH	7.0-8.5	2 (12)	7 (12)	0 (11)	1 (12)
Conductivity	0.3-1.5 mS cm^{-1}	12 (12)	12 (12)	11 (11)	12 (12)
Turbidity	10-100 NTU	0 (12)	0 (12)	0 (11)	0 (12)
Total P	<60 µg L^{-1}	3 (12)	1 (12)	6 (11)	4 (12)
FRP	<30 µg L^{-1}	0 (12)	0 (12)	1 (11)	0 (12)
Total N	<1500 µg L^{-1}	3 (12)	6 (12)	6 (11)	2 (12)
NOx	<100 µg L^{-1}	1 (12)	1 (12)	0 (11)	0 (12)
Ammonia	<40 µg L^{-1}	3 (12)	3 (12)	7 (11)	3 (12)

7.3.2 QUARTERLY DATA

A broader range of parameters and metals were sampled from each pond at quarterly intervals (Table 4). Water hardness was 'extremely high' throughout the year, except in Lake Vasto where it was hard (Table 5). Total suspended solids (TSS) measures all the particulates retained on a filter, it can often be approximated (for a specific site) by turbidity. The correlation between turbidity and TSS was r=0.32, suggesting that turbidity was a poor substitute for measuring TSS. TSS tends to be higher in W3 and W4, presumably as Zone 1 is designed to settle particulates while Zone 2 is shallow and potentially more mixed by winds re-suspending sediment. This may also help explain the increased organic N concentrations in this zone. Chlorophyll *a* concentrations were low. Biological oxygen demand remained below detection on all occasions (<5 mg L^{-1}) except in W4 in February where it reached 10 mg L^{-1}.

All the metals measured had concentrations (due to water hardness in some cases) that were below the ANZECC/ARMCANZ (2000) trigger values for the 95% protection of aquatic systems with the exception of Cu, Zn and Ni. Nickel reached extremely high levels of 560 µg L^{-1} in November in W3. It is possible this was the result of contamination of the sample. Zinc exceeded trigger values in W4 and Ozone in May reaching 80 and 60 µg L^{-1} respectively. Zinc has been exceeded trigger values in previous years, although its appearance is variable and typically intermittent.

Table 4. Quarterly concentrations of metals and selected other parameters recorded in May, August, October 2010. ANZECC/ARMCANZ (2000) trigger values for protection of 95% of species in aquatic ecosystems provided. (H= must be adjusted for hardness as in Table 5, C = does not necessarily protect against chronic effects, B= possible biomagnification needs to be considered). Values in blue have detection limits above the trigger value, while red values exceed the trigger value.

	ANZECC (2000)	15/02/2012					21/05/2012				
Analysis (mg L^{-1})	Trigger Values	W1	W2	W3	W4	Ozone	W1	W2	W3	W4	Ozone
Total Suspended Solids		110	62		130	11	60	54	72	76	22
Total Hardness ($CaCO_3$)		2300	1800		3700	170	1200	1100	1600	1500	140
Ca											
Mg											
Al (µg L^{-1})	55	<20	<20		<20	<20	<20	<20	<20	<20	<20
As (µg L^{-1})	13 As(V)	<20	<20		<20	<20	<20	<20	<20	<20	<20
Cd (µg L^{-1})	0.2^{H}	<1	<1		<1	<1	<1	<1	<1	<1	<1
Cr (µg L^{-1})	1 Cr^{C} (VI)	<5	<5		<5	<5	<5	<5	<5	<5	<5
Cu (µg L^{-1})	1.4^{H}	17	15		21	9	6	5	7	7	<5
Ni (µg L^{-1})	11^{H}	5	<5		<5	<5	8	7	8	6	<5
Pb (µg L^{-1})	3.4^{H}	<5	<5		<5	<5	<5	<5	<5	<5	<5
Zn (µg L^{-1})	8^{CH}	10	20		20	10	30	20	50	80	60
Mn (µg L^{-1})	1900^{C}	22	36		130	310	5	14	66	27	71
Fe (µg L^{-1})		<20	30		20	30	20	40	570	430	<20
Hg (µg L^{-1})	0.6(Inorganic)^{B}	<0.05	<0.05		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
DOC		14	24		29	1.4	14	20	37	28	1
Chlorophyll *a* (µg L^{-1})		1.1	2.1		4.5	4	1.1	1.3	4.5	2.3	1.9
Phaeophytin (µg L^{-1})		<0.5	<0.5		<0.5	<0.5	0.5	<0.5	<0.5	<0.5	<0.5
TKN (µg L^{-1})		1.3	2.1		1.8	0.3	1.2	1.5	2.3	1.3	0.1
BOD		<5	<5		10	<5	<5	<5	<5	<5	<5
Turbidity (NTU)		0.4	0.4		0.9	2.1	2.3	2.5	4.2	0.2	23.0

Analysis (mg L^{-1})	ANZECC (2000) Trigger Values	21/08/2012 W1	W2	W3	W4	12/11/2012 W1	W2	W3	W4	Ozone
Total Suspended Solids		53	46	90	100	43	81	38	36	7
Total Hardness (CaCO3)		1400	1500	2600	2500	1200	2300	5500	3900	160
Ca		110	110	210	210	0.2	87	160	370	300
Mg		270	280	510	490	0.1	230	480	1100	760
Al (µg L^{-1})	55	<20	<20	<20	<20	20	<20	<20	<20	<20
As (µg L^{-1})	13 As(V)	<20	<20	<20	<20	<20	<20	<20	<20	<20
Cd (µg L^{-1})	0.2[H]	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cr (µg L^{-1})	1 Cr[C] (VI)	<5	<5	<5	<5	<5	<5	<5	<5	<5
Cu (µg L^{-1})	1.4[H]	6	5	7	7	17	20	<5	<5	8
Ni (µg L^{-1})	11[H]	9	10	10	10	8	9	560	<5	<5
Pb (µg L^{-1})	3.4[H]	<5	<5	<5	<5	<5	6	<5	<5	<5
Zn (µg L^{-1})	8[CH]	20	<10	40	30	30	20	<10	<10	10
Mn (µg L^{-1})	1900[C]	21	7	24	26	74	63	130	<5	750
Fe (µg L^{-1})		30	<20	130	160	50	40	<20	<20	130
Hg (µg L^{-1})	0.6(Inorganic)[B]	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
DOC		8.1	9.7	15	12	11	23	53	27	2.2
Chlorophyll *a* (µg L^{-1})		5	1.4	1.6	4.4	5.1	5.1	3.5	8.3	<0.5
Phaeophytin (µg L^{-1})		<0.5	0.5	<0.5	<0.5	<0.5	<0.5	0.5	<0.5	<0.5
TKN (µg L^{-1})		0.5	0.8	0.8	0.8	1.2	1.9	3.9	2.2	0.3
BOD		<5	<5	<5	<5	<5	<5	<5	<5	<5
Turbidity (NTU)		0.7	0.7	1.4	0.5	3.6	3.1	16.0	4.8	4.7

Table 5 Approximate factors to apply to soft water trigger values for selected metals in freshwaters of varying water hardness (taken from (ANZECC/ARMCANZ, 2000) (TV = Trigger value).

Hardness category (mg/L as $CaCO_3$)	Cd	Cu	Pb	Ni	Zn
Soft (0–59)	TV	TV	TV	TV	TV
Moderate (60–119)	X 2.7	X 2.5	X 4.0	X 2.5	X 2.5
Hard (120–179)	X 4.2	X 3.9	X 7.6	X 3.9	X 3.9
Very hard (180–240)	X 5.7	X 5.2	X 11.8	X 5.2	X 5.2

Copper concentrations were higher than in 2011, with exceedances in February and November, in W1 and W2 at 15-20 µg L^{-1}. Lake Vasto in November exceeded the trigger value with a concentration of 8 µg L^{-1} (due to the lower hardness), while in February W4 had a concentration of 21 µg L^{-1}. Only for As did the detection limit exceed the trigger value, preventing detection of any exceedances.

7.3.3 CONCLUSIONS

1. Determine how physico-chemical variables and nutrient concentrations changed on a monthly timescale
2. Examine how key metals and other selected parameters change quarterly between all the ponds

There were clear exceedances of ANZECC/ARMCANZ (2000) guidelines for metals concentration for both Cu, Zn and on one occasion for Ni (although this is most likely due to sample contamination). It is likely that the wetland would have discharged some of these concentrations into the Swan River. The wetland appeared to achieve its principal objective of discharging water meeting the requirements of the Swan-Canning Water Quality Improvement Plan (Swan River Trust, 2009a, b) for P but not for N. Close examination of physico-chemical parameters found a number of exceedances of ANZECC/ARMCANZ (2000) guidelines however with the exception of salinity, these exceedances were unlikely to be of significant consequence. Salinities within the wetland have increased steadily since 2010 and exceeded that of seawater on two occasions.

7.4 SEDIMENT

The specific aims of measuring the sediment quality in the wetland were to:

1. Determine how key metal and nutrients were accumulating in the sediment.

This will show whether there are any management issues associated with sediment quality. The data will allow the effectiveness of various processes responsible for nutrient uptake or release to be inferred.

2. To evaluate how the sediment is developing over time.

Comparison to previous years will allow the development of sediment to be measured.

Sediments were sampled in May 2012 for a range of metals and nutrients as shown in Table 6. The average depth of sediment to the liner in W2 was 111 ± 7.8 mm, an increase of 12 mm over 2011 and the rate of increase is almost identical to that between 2010 and 2011.The sediment in W3 remained unchanged at 140 ±13.7 mm compared to 146 ± 15.0 mm for 2011 and 2012 respectively. The sediment sample for W2 produced nutrient and metal concentrations (except for TOC) almost 10 fold lower than recorded in 2011. This suggests that there was an error in the analysis, however the QA/QC data was rechecked by SGS Ltd and no error found. No metal concentrations exceeded any ANZECC & ARMCANZ (2000) guidelines for sediment.

Table 6. Sediment concentrations of selected metals and nutrients in W2 and W3 in a) May 2012 and b) 2011. (where some of the four replicate samples were below detection levels, the number of samples used in the mean is indicated by n=)

a) 2012

Variable (mg kg^{-1})	ANZECC & ARMCANZ (2000) Interim Guidelines (Low-High)	W2	W3
TKN		725.0 ± 135.1	295.0 ± 106.0
TP		75.3 ± 14.4	57.3 ± 8.1
TOC		5.0 ± 0.4	1.0 (n=1)
Al		2705.0 ± 998.5	1320.0 ± 278.2
As	20-70	<1	1.5 (n=2)
Cd	1.5-10	<0.1	<0.1
Cr	80-370	0.8 ± 0.15 (n=3)	4 ± 1
Cu	65-270	1.5 ± 0.3	4 ± 1
Fe		895 ± 206	2325 ± 394
Ni	21-52	1.0 (n=2)	1 ± 0
Pb	50-220	2.0 ± 0.6	10.0 ± 2.9
Zn	200-410	8.3 ± 1.4	29.0 ± 8.4
Mn		37.3 ± 9.5	14.0 ± 2.9
Hg	0.15-1	<0.05	<0.05

b) 2011

Variable (mg kg^{-1})	ANZECC & ARMCANZ (2000) Interim Guidelines (Low-High)	W2	W3
TKN		6975 ± 448	1495 ± 588
TP		775 ± 81	60 ± 15
TOC		1.0 ± 0.8	2.8 ± 2.0
Al		80000 ± 12356	1345 ± 190
As	20-70	14.3 ± 0.9	<2
Cd	1.5-10	<0.4	<0.4
Cr	80-370	11.0 ± 4.8	<5
Cu	65-270	12.0 ± 1.7	<5
Fe		13250 ± 2056	2700 ± 534
Ni	21-52	11.0 ± 3.6	<4
Pb	50-220	32.0 ± 7.1	9.0 ± 0.5
Zn	200-410	82.5 ± 16.1	25.0 ± 6.2
Mn		422.5 ± 67.5	10.3 ± 1.3
Hg	0.15-1	<0.05	<0.05

Figure 14. Photograph of a sediment cores taken at W2 (left) and W3 (right).

7.5 VEGETATION

The specific aims of sampling the vegetation were to:

1. Map the coverage of the aquatic plant species in the wetland.

This will show how the plant communities in the wetland are developing. It will also allow the area of each species to be determined and this information will be used in the nutrient load calculations.

2. Measure development of biomass of major plant species within the wetland (Zones 1 and 2).

This will show whether the plants are becoming larger and/or denser. It also provides a basis to determine nutrient loads in the vegetation.

3. Measure the concentration of nutrients (N & P) in live, dead and below ground parts of each species in each site.

This will allow the total load of nutrients stored in plant material to be determined. It will also indicate which species are best for nutrient uptake.

The specific aims of the foreshore monitoring were to:

4. Establish some regular sites where the condition of the foreshore can be monitored. Key items of interest are erosion, weed invasion and the effectiveness of armouring that may have been put in place.

This will allow issues on the foreshore that require management action to be identified and acted upon before substantial damage is done to the site.

7.5.1.1 CHANGES IN VEGETATION DISTRIBUTION FROM 2010 TO 2012

Five main plant communities were determined and mapped during the initial monitoring (Year 1; May 2010). These communities were remapped twice in 2011 and twice in 2012 with particular focus on detecting any change in the extent and condition of these main vegetation types (), as well as any recruitment and colonisation by new plants. In general, the spatial distribution of plant communities has remained reasonably stable between 2011 and 2012. Specifically, the following minor changes between 2011 and 2012 were noted:

1) *Baumea articulata* – the original single patch of *Baumea articulata* sedgeland which expanded (to triple its area) from 2010 to 2011 has now contracted to close to its original size during 2012. The remaining patch now contains many dead and dying plants, suggesting this species and community type may be disappearing from the wetlands. Approximately 60-80% of plants appear to be dead in this patch of *B. articulata* and most of the other plants appear to be under stress (possibly from drought and/or increased water salinity). A second smaller patch of *B. articulata* which developed to the north-east of the main patch in 2011 has now disappeared. The contraction of *B. articulata* in the wetland appears to have started during spring 2011 (see 2011 monitoring report) and continued over the summer of 2011-12, again suggesting the decline has been caused by drought and/or salinity. Little recovery or expansion of *B. articulata* occurred during winter 2012, in contrast to the winter of 2011 when a major expansion occurred.

2) *Eleocharis acuta* – This community is dominated by *Eleocharis acuta* (Common Spikerush, Cyperaceae) but is mixed with small amounts of *Juncus kraussii*. During 2012, there has been further contraction of this sedgeland community at its margins (Figure 15), mainly at the expense of expanding *J. kraussii*-dominated vegetation. The relative cover of *J. kraussii* has again increased in some patches of this community. This suggests that *J. kraussii* may be slowly taking over this community.

3) *Ficinia nodosa* – this community is dominated by Knotted Club Rush (previously *Isolepis nodosa*) and tends to occur on surrounding slopes on non-inundated areas. Its distribution has been more or less stable over the past year.

4) *Juncus kraussii* – this is the most widespread vegetation type of the wetland and dominants each wetland zone. It consists of dense stands of *Juncus kraussii* (Sea Rush, Juncaceae) of between 70 to 100% cover. It is expanding at its margins, particularly where it abuts *E. acuta* community (type 2 above; Figure 15). However this community is also contracting slightly where it abuts open water, particularly in zone 2. Consequently its total coverage (in m^2) is more-or-less the same as 2010 and 2011 (see Table 7 & Table 8) as the contractions are about equal in extent to its expansion elsewhere. The density of *J. kraussii* plants and its dominance over other species is gradually increasing (now generally 80-100% cover).

5) Samphire and other halophytes – This community is dominated by *Tecticornia indica* and other *Tecticornia* spp. (commonly known as samphires and until recently in the genus *Halosarcia*). Such species are not on the original planting list and so are likely to have colonised raised mounds of the wetland and other areas which dry in summer. These raised areas appear to accumulate salts during the drying phase and also support other halophytes such as *Frankenia pauciflora* (which has been increasing in cover). This community appears to have been stable during 2012 (Figure 15 & Table 8).

In addition to these plant communities, other habitats were found:

- Mixed shrubs on embankments – this community consists of a range of shrub species with medium to high cover. Dominant species include *Scaevola crassifolia, Kunzea ericifolia, Myoporum caprarioides, Ficinia nodosa* and *Atriplex cinerea*. Most of these species were planted around the edge of the wetland.
- Open Water – no plant species were found in these areas (although filamentous algae were common). The area of open water has again increased in Zone 2 over the last year, mainly due to contraction of *J. kraussii* vegetation (Figure 15 & Table 8).
- A small patch of *Typha domingensis* has colonised open water of Zone 2 between May and October 2012 (Figure 15). However by late October 2012, this small patch of plants was mostly dead and a positive identification of the species was not possible. It will be interesting to track the progress of this potentially invasive species.

Tree & Shrub Species

Melaleuca cuticularis – two patches of young trees were observed on slightly raised mounds, both within Zone 2. These are most likely plants surviving from original planting in 2004. The trees are mostly found on the margin of *Juncus* community where it abuts samphire/halophytes. One mound had 7 trees in 2010; all but one of these had survived as of October 2012 and had grown slightly (Figure 18). The other mound had 10 trees in 2010, and all these were still living, healthy and growing at October 2012.

Melaleuca lateritia – this compact shrub was found interspersed throughout the *Juncus* community of Zone 2. Some 20 plants were observed in 2010 and some 28 plants were counted in 2011. Monitoring in 2012 showed 31 individual plants. The increased numbers are likely to be due to improved detectability (due to shrubs emerging above generally dense cover of *Juncus* in this area) rather than recruitment of new individuals.

7.5.1.2 CHANGE IN AREA CALCULATED USING GIS

B. articulata was only found in Zone 2 and *J. kraussii* was the only species recorded in Zone 1 (Table 8). Zone 1 was predominantly open water as the design intended. *Juncus kraussii* was planted in Zone 1 in an area of deeper sediments and does not appear to have spread out from this area, although it has contracted slightly in Zone 2 in areas of deeper water. *Baumea articulata* is a species that prefers deeper and reliable inundation, the highly variable nature of the water levels in Zone 2 do not appear to have helped this species. Possibly the high salinity in 2011 and/or drought conditions over 2011/2 summer has impacted this species, which suffered a severe decline of this species starting in spring 2011 and ending in autumn 2012. The deep water conditions of Zone 1 might suit this species and it can potentially recruit into this area. *Ficinia nodosa* is only found along the eastern edge of Zone 2 and northern edge of Zone 3. *Eleocharis acuta* occurred in patches and strips around the edge of *J. kraussii*. At this stage it is difficult to determine whether this is the species finding their specific niches or competition between the two species. High salinities and this species lower tolerance to them than *J. kraussii* may also explain the apparent movement of *J. kraussii* into the *E. acuta* beds during 2012. Samphires appear to have colonized Zone 2 and 3 from areas outside the wetland, being common species along the Swan River. The high salt levels in the sediments resulting from the drying of the zones appear to favour these species; the samphires do not survive prolonged inundation.

A photographic record of each vegetation community was taken at fixed locations (Figure 16 to Figure 22).

Table 7. Area (m²) of each cover type and its percentage of total study area and of wetland area (as of May 2010, May 2011 and October 2012).

Type	2010 Area (m^2)	2011 Area (m^2)	2012 Area (m^2)	% total 2010	% total 2012	% wetland 2010	% wetland 2012
Baumea articulata	16.9	64.3	24.2	0.2	0.3	0.2	0.3
Eleocharis acuta	405.6	352.4	287.3	4.7	3.3	5.7	4.5
Ficinia nodosa	154.3	154.3	154.3	1.8	1.8	2.2	2.2
Juncus kraussii	3234.3	3229.3	3179.0	37.7	37.0	45.6	44.9
Samphire / halophytes	355.1	383.0	387.7	4.1	4.5	5.0	5.5
Open Water	2305.0	2287.9	2438.9	26.9	28.4	32.5	34.4
Boardwalk, Weir etc	615.9	615.9	615.9	7.2	7.2	8.7	8.7
Total Wetland	7087.2	7087.1	7087.2	82.6	82.6	100	100
Mixed shrubs (slopes)	1285.6	1285.6	1285.6	15.0	15.0		
Raised Ground (~bare)	209.9	209.9	209.9	2.4	2.4		
Grand Total	8582.7	8582.6	8582.7	100	100		

Table 8 Area (m²) of each plant community by wetland zone as of November 2012 (area changes in m² from May 2010 are indicated in parenthesis).

Zone	*Baumea articulata*	*Eleocharis acuta*	*Ficinia nodosa*	*Juncus kraussii*	Open Water	Samphire/ Halophytes	TOTAL
1	0	0	0	625.1	1363.1	0	1988.2
2	24.2	244.6	65.1	1815.2	1075.8	145.8	3370.7
	(+7.3)	(-107.2)		(-46.3)	(+133.9)	(+7.8)	
3	0	42.7	89.3	738.7	0.0	237.3	1108.0
		(-11.1)		(-9.0)		(+20.1)	
TOTAL	24.2	287.3	154.4	3179.0	2438.9	383.1	6466.9

Figure 15. Map of vegetation types and other cover as of October 2012. Changes from 2011 and general direction of expanding vegetation/cover types are indicated by arrows.

May 2010

October 2010

October 2011

October 2012

Figure 16. Photographs taken at photopoint WV1 looking south-east

May 2010

October 2011

October 2012

Figure 17. Photograph taken at photopoint WV2 looking south. Vegetation here is dense *Juncus kraussii* and its extent and condition is generally stable

May 2010

October 2010

May 2011

October 2011

October 2012

Figure 18. Photographs taken at photopoint WV2 looking west towards patch of *Melaleuca* trees. These trees are growing slowly but are surviving.

Figure 19. Photograph taken at photopoint WV3 looking east (note expansion and subsequent death of *Baumea articulata* over the years). Photos have been taken in slightly different directions (top is due east, whilst others are ESE to focus more on the declining *Baumea*).

Figure 20. Photographs taken at photopoint WV4 looking west along drainage culvert. Note samphires and other halophtyes on the banks of the culvert.

Figure 21. Photograph taken at photopoint WV4 looking north towards city. NB: Direction and elevation of photograph has varied slightly each year.

May 2010

May 2011

October 2012

Figure 22. Photographs taken at photopoint WV5 looking south-west

7.5.2 VEGETATION BIOMASS AND GROWTH

Baumea articulata declined in 2012, however there is some evidence that there is new growth in 2012, with no flowers[2] produced, shorter leaf length in May 2012 compared to same time 2011 but with a substantial increase in the number of leaves per m^2 (Figure 23). *Typha domingensis* became established in W3 in 2012, it was still in a growth phase, with no flowers but similar leaf lengths and leaf counts per m^2 as *B. articulata*. Both *J. kraussii* and *E. acuta* had flowers in similar percentages in both seasons, although for *E. acuta* the percentage of leaves with flowers was approximately half that seen in 2011. This could be due to new growth as leaf length was also shorter than in 2011. *Juncus kraussii* in terms of percentage of leaves with flowers, leaf length and number of leaves per m^2 was very similar to 2011.

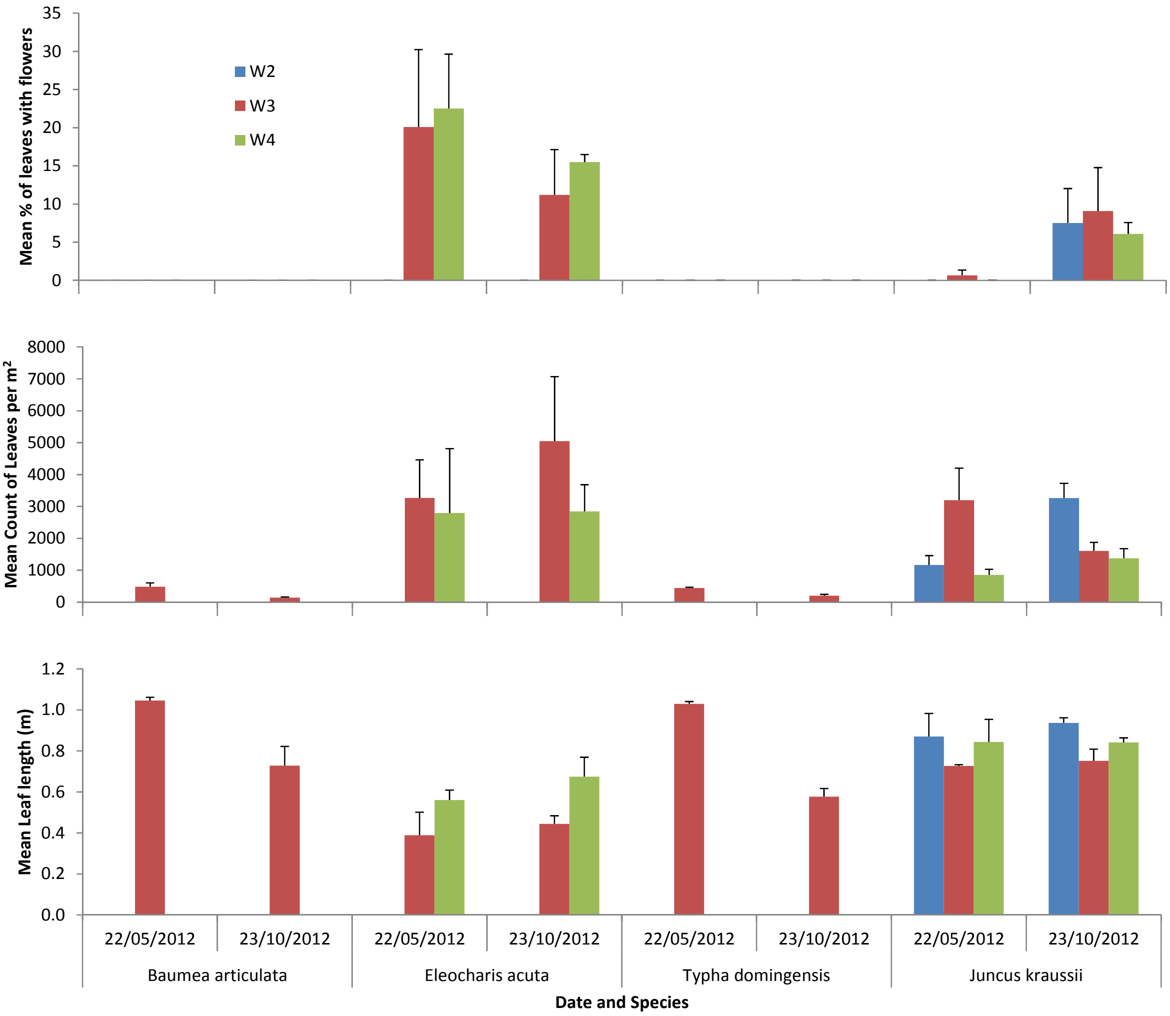
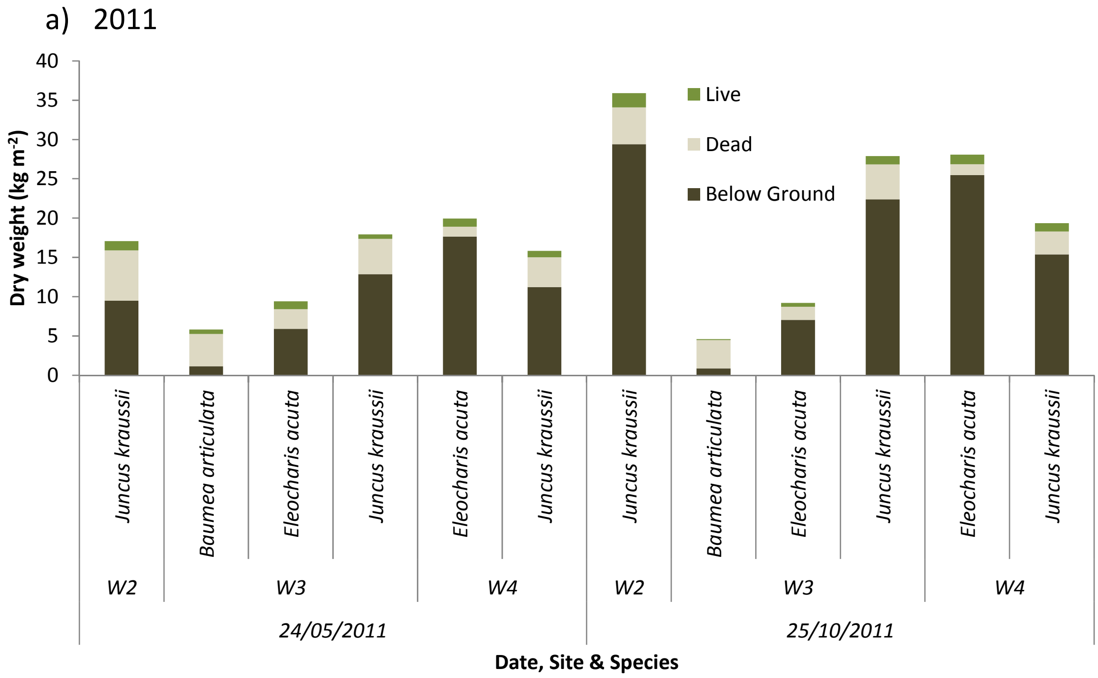


Figure 23. Mean (±SE) for percentage of leaves with flowers, count of leaves per m^2 and leaf length for each species on each sampling occasion for each wetland site.

[2] For these species, the flower is actually an inflorescence – a cluster of multiple flowers.

The amount of dead leaves appears to have generally declined in 2012 compared to 2011 and this has been accompanied by slight increases in live biomass for all species (Figure 24). Below ground biomass can been seen to be relatively variable probably reflecting the inherent problems involved in its collection. This variability is most pronounced for *J. kraussii*, whose root mats are the hardest to isolate from the sediment.



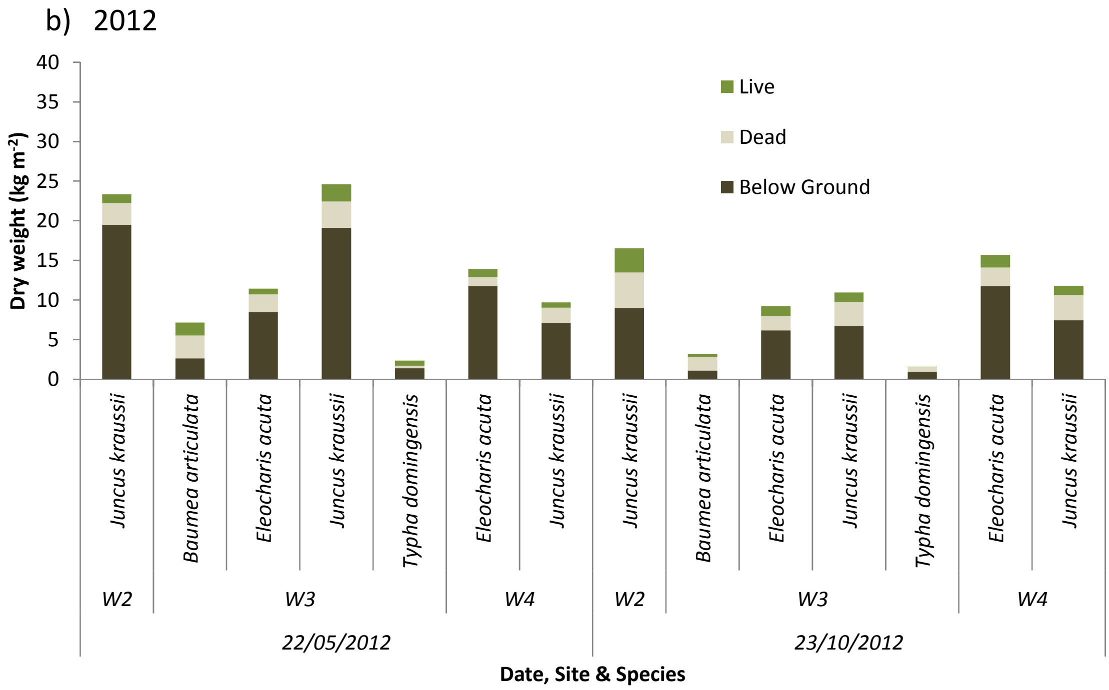
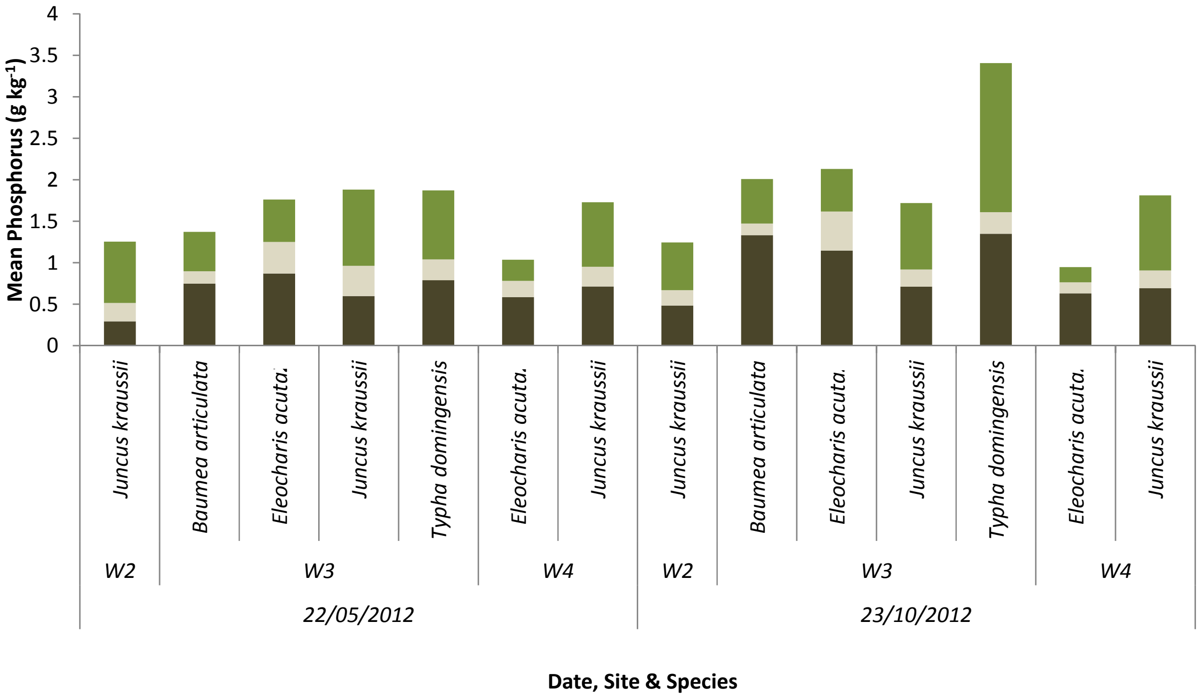


Figure 24 Mean dry weight (g) of live, dead and below material from collected species, from sites on two occasions in a) 2011 and b) 2012.

7.5.3 VEGETATION NUTRIENT LOADS

Baumea articulata, E. acuta and *J. kraussii* have similar concentrations of P and N in live above ground material compared to 2010 (Figure 25). P concentrations tend to be similar in plants from year to year as few species accumulate P. N concentrations are more variable but higher concentrations tend to be associated with active growth as N is not stored but is reflected in proteins and enzymes. The drier conditions of 2012 appear to reduced differences in nutrient concentrations between parts of the plants and species compared to 2011.



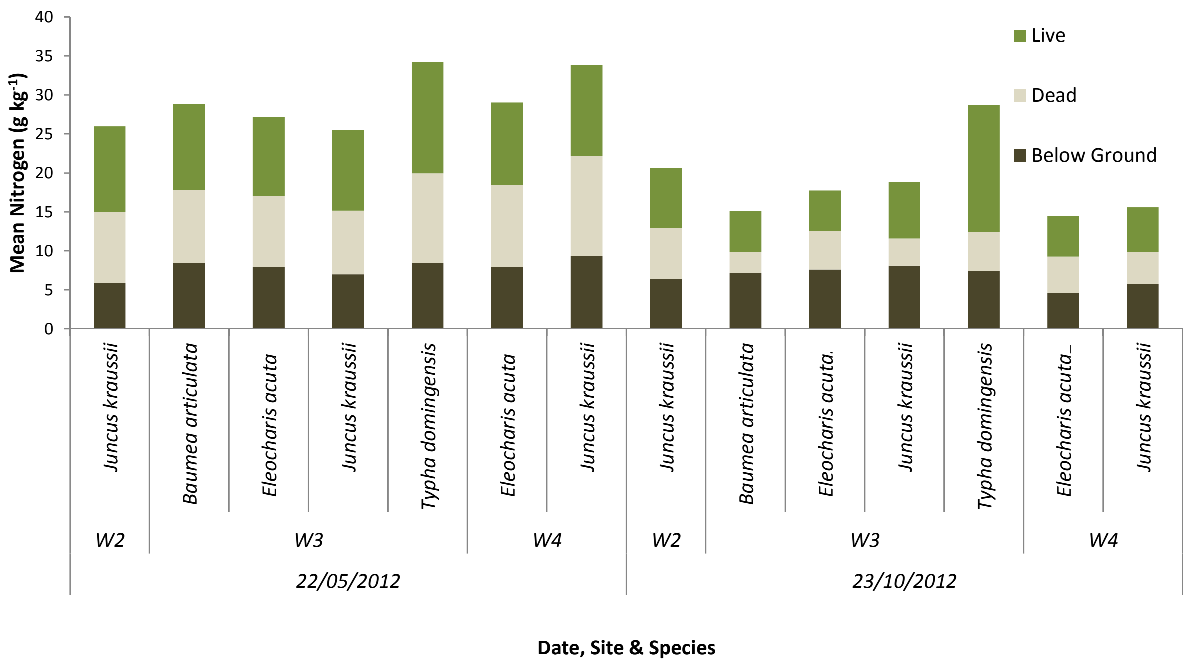


Figure 25. Mean quantities of phosphorus and nitrogen stored per kg of dry weight of live, dead and below ground parts of sampled species, over the seasons and between sites.

The loads of P bound in live *J. kraussii* in Zone 1 changed little from May 2011 to October 2012, but decreased for total N, suggesting poorer growing conditions (Table 9). Dead material for this species declined from 2011 for P and N. In Zone 2, there were minor increases and some decreases in nutrients in live material over the same period across the species. Dead material showed a similar pattern to zone 1. These results show relatively low changes in plant biomass and nutrient loads which suggest that perhaps the vegetation stands are now mature and that nutrient uptake will slow.

Table 9. Total loads of N and P in living (above and below ground) and dead biomass per area of stands at each site. Note that the 2010 figures have been recalculated for *Eleocharis acuta* and *Juncus kraussii* for Zone 2.

			Area (m^2)			P Live (kg)			N Live (kg)			P Dead (kg)			N Dead (kg)		
Date	**Zone**	**Species**	**2010**	**2011**	**2012**	**2010**	**2011**	**2012**	**2010**	**2011**	**2012**	**2010**	**2011**	**2012**	**2010**	**2011**	**2012**
May	1	*Juncus kraussii*	625.1	625.1	625.1	3.02	2.54	3.11	36.42	54.97	62.30	1.12	1.08	0.38	17.62	38.89	15.69
	2	*Baumea articulata*	16.9	64.3	24.2	0.04	0.07	0.17	0.37	1.03	2.57	0.00	0.06	0.03	0.00	1.63	1.70
		Eleocharis acuta	351.8	309.7	244.6	1.35	1.21	1.94	10.01	22.14	24.75	0.20	0.27	0.18	6.51	6.60	4.79
		Juncus kraussii	1861.4	1865.4	1815.2	5.74	12.45	19.21	58.56	180.03	208.79	1.06	1.91	1.37	43.61	101.19	46.58
		Typha domingensis	-	-	10	-	-	0.02	-	-	0.20	-	-	0.00	-	-	0.03
October	1	*Juncus kraussii*	625.1	625.1	625.1	1.66	4.67	3.73	34.33	83.22	49.52	0.49	0.50	0.47	27.00	15.65	17.90
	2	*Baumea articulata*	16.9	64.3	24.2	0.08	0.02	0.03	1.05	0.07	0.17	0.01	0.01	0.00	0.28	0.98	0.08
		Eleocharis acuta	351.8	309.7	244.6	1.18	1.69	2.71	17.33	23.29	18.36	0.13	0.14	0.21	4.87	3.90	3.48
		Juncus kraussii	1861.4	1865.4	1815.2	8.13	11.13	11.29	122.25	140.49	98.49	1.95	2.03	1.24	54.73	54.56	20.63
		Typha domingensis	-	-	10	-	-	0.01	-	-	0.08	-	-	0.00	-	-	0.03

Table 10. Total loads of N and P in living (above and below ground) and dead biomass per area of stands at each site standardized for a fixed stand size of 100 m^2.

			P Live (kg)			N Live (kg)			P Dead (kg)			N Dead (kg)		
Date	**Zone**	**Species**	**2010**	**2011**	**2012**	**2010**	**2011**	**2012**	**2010**	**2011**	**2012**	**2010**	**2011**	**2012**
May	1	*Juncus kraussii*	0.48	0.41	0.50	5.83	8.79	9.97	0.18	0.17	0.06	17.62	2.82	2.51
	2	*Baumea articulata*	0.26	0.11	0.27	2.18	1.59	3.99	0	0.1	0.04	0	0	2.64
		Eleocharis acuta	0.38	0.39	0.63	2.85	7.15	7.99	0.06	0.09	0.06	6.51	1.85	1.55
		Juncus kraussii	0.31	0.67	1.03	3.15	9.65	11.19	0.06	0.1	0.07	43.61	2.34	2.50
		Typha domingensis	-	-	0.16	-	-	2.05	-	-	0.01	-	-	0.32
October	1	*Juncus kraussii*	0.27	0.75	0.60	5.49	13.31	7.92	0.08	0.08	0.08	27	4.32	2.86
	2	*Baumea articulata*	0.45	0.12	0.17	6.19	0.42	0.99	0.04	0.04	0.02	0.28	1.67	0.50
		Eleocharis acuta	0.33	0.48	0.77	4.93	6.62	5.22	0.04	0.04	0.06	4.87	1.38	0.99
		Juncus kraussii	0.44	0.6	0.61	6.57	7.55	5.29	0.1	0.11	0.07	54.73	2.94	1.11
		Typha domingensis	-	-	0.13	-	-	0.78	-	-	0.02	-	-	0.27

When the effects of area are removed and simply efficiency of storage is assessed as in Table 10, it shows that *B. articulata* and *Typha domingensis* store the least N and P, with the other species being very similar for P and N in live material. In dead material there was little change between 2010 and 2012 in P but there was a decline in *J. kraussii* N loads.

7.5.4 FORESHORE MONITORING

The clear deterioration in foreshore condition at Monitoring Area 1 measured during 2011 has continued in 2012. Further erosion of the river bed has occurred and root systems of planted *Casuarina* trees upslope are now starting to be exposed, jeopardising the health of these trees (see photographs below). A greater proportion of foreshore is classified as having significant to severe erosion (Table 11). Planted and naturally colonised areas of *Juncus* and other fringing wetland plants have all but disappeared along this section of foreshore and this appears to have made the sediment in this area more prone to erosion by wind- and boat-driven waves. Irrigation pipes, presumably buried in the sediment to facilitate revegetation of foreshore has now been exposed due to erosion, which demonstrates that a strip of sediment several metres wide and up to 0.3 m deep has been lost to erosion in Monitoring Area 1.

The headland area between Monitoring Areas 1 & 2 has been particularly affected by increased erosion. During 2010 and 2011 large roots of the large *Casuarina* trees had been exposed through erosion of sediment despite various attempts to protect this stand of trees by rock re-enforcement and shells/pebbles, and during 2011 one large tree has fallen into the river and died. More roots have been exposed through erosion over the 2012 although the remaining large trees at this headland so far appear to be healthy in terms of crown condition.

Recommendation 6.

It is recommended that the foreshore around Area 1 (including the headland between Areas 1 & 2) receive immediate remedial treatment in the form of sandbagging and planting of fringing sedges/rushes to reduce erosion and help prevent further loss of trees.

Monitoring Area 2 remains relatively stable with dense *Juncus* and sedge cover protecting the foreshore from erosion (Table 11). Access to Foreshore Monitoring sites 2A and 2B was restricted in 2012 due to redevelopment in the area (i.e. fenced off) and therefore it was not possible to fully complete foreshore assessment and monitoring photographs during 2012 (although a nearby photo was taken for site 2A).

Table 11. Condition Summary Table at each Study Site as of October 2012. Data for 2010 and 2011 is included in parentheses (**in red for 2010** **and blue for 2011**) where different from 2012. Note F2A and F2B could not be monitored in 2012 (fenced off).

Site	Erosion	Slumping	Sedimentation	Vege-tation	Regen-eration	Weeds	Log/Brush	Rock Work	Beach Areas	Fauna Use	Comments / Notes
F1A	0% Minimal (**30%, 25%**); 25% Localised (**60%, 55%**); 50%Significant (**10%, 15%**); 25% Severe (**0%, 5%**)	20% Minimal (40%); 30% Localised (50%); 40% Significant (10%); 10% Severe (0%)	80% Minimal; 20% Localised	3 (2)	4 (**3**)	3	N/A	Mostly consists of shell; Increased erosion of shells and underlying mud	Stable; but some erosion at high water mark	Nil	Needs infill planting to stop erosion; erosion is mostly confined to areas with little plant (rush) cover. Rush/sedege cover is severely reduced from 2010 (cause for concern)
F1B	0 Minimal (**20%**); 20% Localised (**30%, 40%**); 30%Significant (**50%**); 50% Severe (**10%, 30%**)	20% Minimal (**40%, 30%**); 30% Localised (**50%**); 30% Significant (**10%**); 20% Severe (**0%, 10%**)	80% Minimal (**70%**); 20% Localised (**30%**)	3	4 (3)	3	N/A	Rock armoury around headland no longer effective. Wave action and high tides have eroded soil around trees exposing roots	Mostly stable; some erosion around edges near headlands	Nil	Erosion of headland either side of beach is significant exposing roots of trees; one tree has fallen into river; these areas need rock (or sandbag) armoury and infill planting.
F1C	20% Minimal (**85%, 40%**); 25% Localised (**10%, 20%**); 25% Significant (**5%, 20%**); 30% Severe (**0%, 20%**)	20% Minimal (**90%, 50%**); 40% Localised (**10%, 20%**); 40% Significant (**0%, 30%**)	80 Minimal (90%); 20% Localised (10%)	3 (**1**)	4 (**3**)	4	Limited effective-ness	N/A	Loss of rushes and sedges at edge. Major increase in erosion in this area	Nil	Stability from dense rush/sedge cover has been lost since 2010. Increased erosion including roots of Casuarina trees
F2A	100% Minimal	100% Minimal	70% Minimal (**60%**); 30% Localised (**40%**)	2	3	2 (**3**)	Stable	Small amount of sedimentation	N/A	Trampling of veg'n by waterbirds	Increase in amount of rubbish washed up from river (high tide). More couch grass invasion.
F2B	60% Minimal; 10% Localised (**20%**); 20% Significant; 10% Severe (**0%**)	70% Minimal; 10% Localised; 20% Significant	90% Minimal (**70%**); 10% Localised (**30%**)	2 (**1**)	4	3	Stable	Intact with minimal sedimentation	N/A	Trampling of veg,n by waterbirds	Some human trampling (to access river)
F2C	75% Minimal (**95%, 85%**); 5% Localised; 25% Significant (**0%, 5%**); 5% Severe (**0%**)	90% Minimal; 10% Localised	80% Minimal (**70%**); 20% Localised (**30%**)	2	3 (2)	2 (**3**)	Stable	Minor sedimentation; rock work not effective against high tides and storm surges – erosion of mud around tree roots	Erosion mostly on margins; Reasonably stable	Nil	Stable embayment, but increased erosion of headland and flanks; increase in weed cover

Note 1: Erosion/Slumping/Sedimentation Classes: 0-5 % Minimal - Little evidence of erosion/slumping/sedimentation; 5-20 % Localized - Localized areas of erosion/slumping/ sedimentation; 20-50 % Significant - Active erosion/slumping/sedimentation is obvious along many parts of this section; >50% Severe - Significant erosion/slumping/sedimentation is more or less continuous along this section.

Note 2: Vegetation Condition: 1=Healthy- There is no observable damage or injury to the vegetation; 2=Some Sick - Some species show signs of insect/human damage above normal levels or a general decline in health such as defoliation or presence of dying branches; 3=Many sick or dying- Many plants show sign of severe decline in health with a number of dead and dying plants present; 4=Majority dead- Few of the native plants present are healthy

Note 3: Vegetation Regeneration: 1=Abundant- Seedlings occur in high numbers and are observable from any section of the area; 2=Frequent- Seedlings are common. Regeneration may occur in small stands of sporadically over large areas of the section; 3=Occasional: Seedlings are infrequent, occurring no more than once or twice with the area; 4=Rare: Seedlings occur very infrequently and may be observed only once or twice within the surveyed section.

Note 4: Weeds: 1=Abundant- Weeds are predominating. They can be seen from any section of the surveyed area; 2=Frequent- Weeds are common. They are patchy or occur in low numbers over a large percentage of the site; 3=Occasional- Weeds occur sporadically, more than once or twice within the area; 4=Rare- Weeds occur infrequently within the area. They may be observed only once or twice.

7.6 FORESHORE PHOTOGRAPHS

Photographs taken at Foreshore Monitoring Site 1A in an easterly direction. Note: loss of sedge/rush vegetation and increased erosion at the river edge.

May 2010

May 2011

October 2010

October 2011

October 2012

Photographs taken at Foreshore Monitoring Site 1A showing severe erosion in October 2012

Photographs taken at Foreshore Monitoring Site 1B in westerly direction. Note: *Casuarina* tree on headland has fallen into the river.

May 2010

May 2011

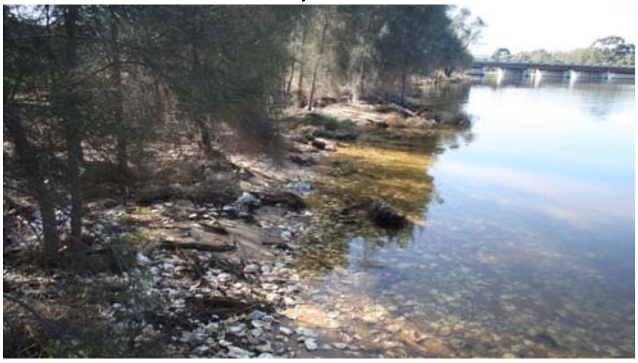
October 2011

October 2012

Photographs taken at Foreshore Monitoring Site 1B in an Easterly direction

May 2010

May 2011



October 2012

Photographs taken at Foreshore Monitoring Site 2A in a Southerly direction. Note access to this site was restricted in 2012 due to redevelopment program

May 2010

May 2011

October 2012

Photographs taken at Foreshore Monitoring Site 2C in Southerly direction

May 2010

October 2010

October 2011

October 2012

Photographs taken at Foreshore Monitoring Site 2C in a Westerly direction.

May 2010

May 2011

October 2011

October 2012

Photographs taken at Foreshore Monitoring Site 2C in an Easterly direction.

May 2010

May 2011

October 2011

October 2012

Photographs taken of *Casuarina* Trees at Headland between Foreshore Monitoring Sites 2C and 1A

May 2010

October 2011

October 2012

7.6.1 CONCLUSIONS

1. Map the coverage of the aquatic plant species in the wetland.

Aquatic plant coverage was successfully mapped with *Juncus kraussii* remaining as the dominant plant species, followed by *Eleocharis acuta.* The small patch of *Baumea articulata* has continued to contract during 2012. A small patch of *Typha domingensis* colonised open water in Zone 2 during 2012 but by the end of October, it was almost dead. There is little evidence of weed invasion, although the wetland appears to have been colonised by species from the foreshore (possibly including *J. kraussii*). Overall, the extent of the various plant species and vegetation types has remained relatively stable from over 2012.

2. Measure development of biomass of major plant species within the wetland (Zones 1 and 2).

Biomass of all major plant species in the wetland were measured in both May and October (dead, above ground and below ground). Biomass appears to be stabilising and has changed little from 2011.

3. Measure the concentration of nutrients (N & P) in live, dead and below ground parts of each species in each site.

Loads of nutrients in aquatic plants changed slightly between 2011 and 2012 indicating that the wetland vegetation might be approaching maturity which might limit its ability to uptake nutrients from incoming water.

4. Establish some regular sites where the condition of the foreshore can be monitored. Key items of interest are erosion, weed invasion and the effectiveness of armouring that may have been put in place.

Sites have been established and erosion in some areas was significant.

7.7 AVIFAUNA

The specific aims of sampling the avifauna were to:

1. Determine the range of birds utilizing the park

Biodiversity is an important goal of the redevelopment of the Point Fraser reserve and avifauna are a good indicator of changes in biodiversity.

Since 2010 a total of 27 species of bird have been recorded at Point Fraser, with 12 species in 2012 (Table 12). This is consistent with past years and with the ongoing dry summers being experienced in Perth. Due to these conditions, numbers of both bush birds and water birds were very low, as seen in Table 12. Although it was expected that the permanent water at the site would act as a drought refuge for waterbirds, it is likely that birds sought more permanent and larger wetlands elsewhere on the Swan Coastal Plain. Pacific Black Ducks are always encountered and are likely to be resident throughout most of the year. Other species of waterbird tend to be uncommon and brief visitors to the site. This is likely to reflect the low availability of food, roosting and nesting habitats for many duck species.

Based on the surveys so far, the Point Fraser wetlands support only a moderate diversity of water birds and a low diversity of other bird groups. No new species were added in 2012, suggesting that most species commonly using the wetlands have now been recorded.

One encouraging trend noted in 2012, was the low number of introduced Rainbow Lorikeets. This may be a reflection of on-going control actions by the Department of Environment and Conservation. This is to be seen as a positive outcome given the competitive interactions between this and local native species of nectarivore.

Native honeyeater species continue to be well represented at the site, with 4 species recorded in 2012 and in good numbers. All species are utilising the flowering native species for feeding and are a positive indication of the success of local plantings in the area.

On-going surveys are planned to further characterize the utilization of the wetlands by birds. It is too early to draw any firm conclusions on habitat preferences or habitat quality for birds.

Table 12. Avifauna recorded in the Point Fraser Reserve in June 2012

Common Name	Species	No.	Notes
Anatidae (ducks and swans)			
Pacific Black Duck	*Anas superciliosa*	7	Loafing in pond
Columbidae (pigeons and doves)			
Spotted Dove	*Streptopeila chinensis*	1	Perched in tree
Laridae (terns and gulls)			
Silver Gull	*Chroicocephalus novaehollandiae*	1	In flight over site
Psittacidae (lorikeets and parrots)			
Rainbow Lorikeet	*Trichoglossus haeatodus*	9	Introduced
Pardalotidae (pardalotes)			
Striated Pardalote	*Pardalotus striatus*	2	In *Eucalyptus rudis*
Meliphagidae (honeyeaters)			
Singing Honeyeater	*Lichenostomus virescens*	9	In flowering shrubs
Western Wattlebird	*Anthochaera lunulata*		
Red Wattlebird	*Anthochaera carunculata*	11	In flowering shrubs
Brown Honeyeater	*Lichmera indistincta*	7	
White-cheeked Honeyeater	*Phylidonyris niger*	5	In flowering shrubs
Rhipiduridae (flycatchers)			
Willie Wagtail	*Rhipidura leucophrys*	3	Using lawns
Corvidae			
Australian Raven	*Corvus coronoides*	1	In low shrubs
Monarchidae			
Magpie-lark	*Grallina cyanoleuca*	1	Heard Calling
Number of Species		12	

7.7.1 CONCLUSIONS

1. Determine the range of birds utilizing the park

Achieved, with 12 species recorded.

7.8 MACROINVERTEBRATES

The specific aims of the macroinvertebrate monitoring program were to:

1. Determine what species were using different zones of the wetland

This will show the ability of the wetland to support biodiversity and provides a baseline for any development of biodiversity.

A total of 21 taxa were collected in the wetland in 2012 (Table 13) a reduction from 35 in 2011, and 26 in 2010 (Figure 26a). Taxa were generally salt tolerant and Foraminifera and Polychaeta are primarily marine groups. The taxa collected were generally cosmopolitan and tolerant. The most abundant taxa were the Ostracoda; the high numbers were partially due to the use of 250 µm net which ensures these taxa are collected. October or spring is generally considered the time of highest species richness and abundance on the Swan Coastal Plain (Davis *et al.*, 1993). This was reflected in the Point Fraser wetlands particularly in species richness which increased by 7-10 taxa, but not for abundance. In contrast to previous years, Zone 1 had fewer taxa richness than zone 2. Increasing salinity in Zone 1 is probably responsible for the change in taxa richness and abundance, with the loss of sensitive species.

The Primer 6 (Primer-E Ltd) software package was used to produce ordinations of the data (MDS), a technique for translating the similarities in communities in terms of richness and abundance into a physical distance and then plotting that distance to visually demonstrate those relationships. In Figure 26b, it can be seen that the community in zone 2 was originally quite different to the other zones and times, however by 2011 it was very similar to zone 1 and 2012 zone 2 samples. Interestingly zone 1 in 2012 has moved away from the previous community and is now quite different to previous years and the other zone. Presumably the combination of open water and higher salinities is responsible.

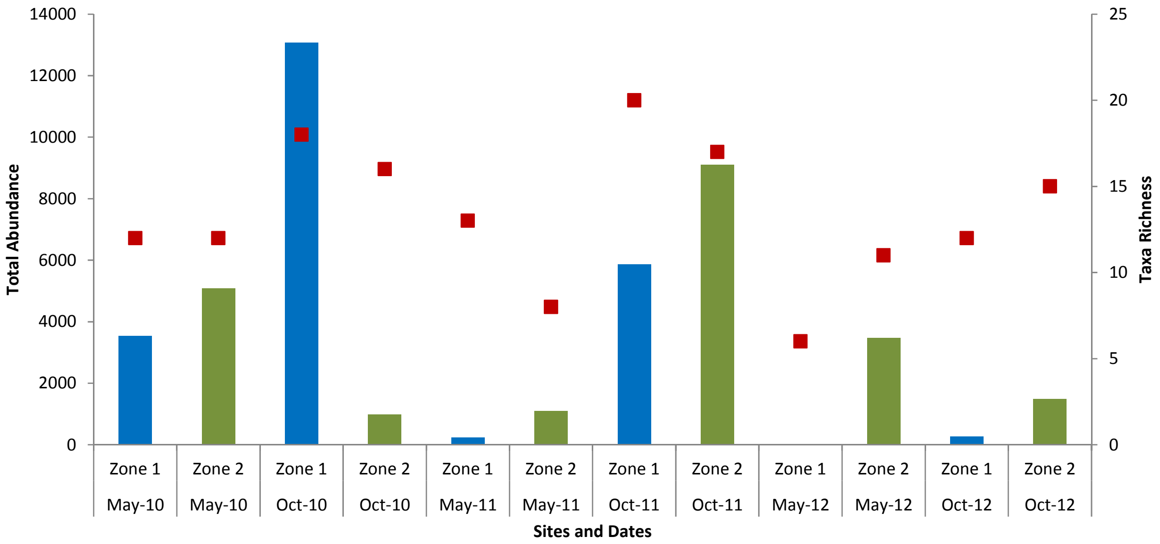
The introduced fish *Gambusia holbrooki* was observed in W1 and W2 in the summer months. They are known predators of a many surface dwelling macroinvertebrates and amphibians (Pyke, 2008). On occasion, *G. holbrooki* were also seen in W3 and W4. Removal and control of *G. holbrooki* populations is difficult and ultimately unlikely to be effective. Amphibians were not sampled during this study.

Table 13. Total abundance (from two 5 m transects) at Zone 1 and 2 of macroinvertebrates (>250 µm) in May and October 2010 to 2012. Taxa in **bold** indicate new taxa for 2012; J=Juveniles (too small to identify), L= larvae, P = Pupa.

							2010				2011				2012			
							May		October		May		October		May		October	
Phyla	**Class**	**Order**	**sub Order**	**Family**	**sub Family**	**Life-stage**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Aracnida		Acariformes		Orabatidae					48		9		8	30		9		
Arthropoda	Insecta	Diptera		Ceratopogonidae	Dasyheleinae	L		46	20	15								3
						L							2					
				Chironomidae		J		120		15								
						P											2	
					Chironominae	L	200	1336	103	465	2	3	139	91	6	59	137	12
					Tanypodinae	L			22	71		1	21	9			1	
						P								1				
					Orthocladiinae	L	15	24					9					
				Tipulidae		L					2						1	1
		Coleoptera		Dytiscidae		L	15	23	4	3	2		1					
				Hydrophilidae		L	5	1	4	2	1		2	2				1
				Hydraenidae		L					1							
		Hemiptera		Corixidae			5	35	29	10			1				1	
				Veliidae							1		1	1				
		Odonata	Epiprocta			J	5			1								
				Telephlebiidae					3	1								
			Zygoptera			J	5	42	1	1						1		
				Libellulidae				1										
				Chorismagrionidae			2											
				Coenagrionidae					3	10					2			1
				Lestidae									2					
		Trichoptera		Hydroptilidae	L			4										
				Leptoceridae		L	26			2			1	1			1	1
						P			1									
	Crustacea	Amphipoda	Paramelitidae									85						
				Ceinidae													11	
			Cladocera	Chydoridae					52									
	Copepoda	Calanoida					20		1016	6						1	72	42
		Cyclopoida					25	40	100	15	1		11	19				1
		Harpacticoida											2					
	Isopoda			Sphaeromatidae			5		88	56	19	132	12	49	5	22	4	258

							2010				2011				2012			
							May		**October**		**May**		**October**		**May**		**October**	
Phyla	**Class**	**Order**	**sub Order**	**Family**	**sub Family**	**Life-stage**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
	Ostracoda						2960	3400	11568	294	189	926	5505	8374	3	3184	34	936
	Decapoda			Palaemonidae								12		2				
Foramnifera										9	4	5	8	304		176		171
Mollusca	Gastropoda			Physidae									2					
				Pomatiopsidae			25				1	20	52	7	2	5	1	1
				Ancylidae										1				
				Sphaeriidae												1		3
Annelida	Polychaeta								4	7				7		2		29
	Oligochaeta													53				
	Hirundinea						230	20	4		5	10	9	149	1	20	3	29
Nematoda														1				
					Species Richness		14	13	19	18	13	8	20	18	6	11	12	15
					Abundance		3541	5090	13074	983	237	1109	5873	9101	19	3480	268	1489

a)



b)

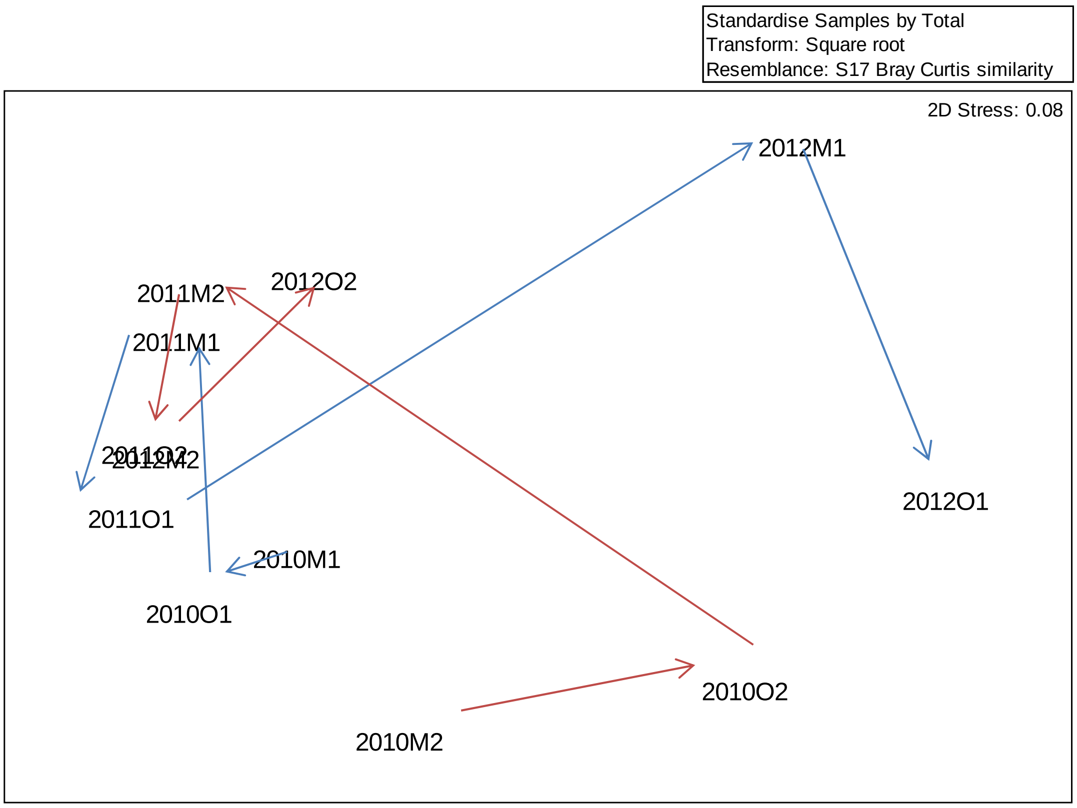


Figure 26. Macroinvertebrate a) Abundance and taxa richness, and b) Multi-dimensional scaling plot showing similarity of sites to each other in terms of community structure, data collected from zones (2010M2 – year, month (May or October) and zone) at Point Fraser in May and October 2010 to 2012 (arrows indicate direction of movement in that zone over time).

7.8.1 CONCLUSIONS

1. Determine what species were using different zones of the wetland

Achieved, with 21 taxa collected which is lower than recorded in 2011. Taxa richness and abundance have declined from previous years and this is probably due to increasing salinity in Zone 1.

7.9 SOCIAL MONITORING

The specific aims of the social monitoring program were to:

1. Determine visitor usage of Point Fraser

This will show how people are utilising the reserve, including the mode of transport in and out

2. Observe usage of Point Fraser by the public

This will show what people are doing once at the reserve

3. Interview park users for why they used the park

This will provide a better understanding of why the park is being used by the public.

In order to achieve the aims, three assessment tools were applied in a biannual (May and October) sampling program: (1) visitor counts; (2) visitor surveys; and (3) visitor behaviour observations. Survey collection, visitor counts and observation of behaviour occurred for two days each monitoring event as outlined in Table 14. No visitor surveys were conducted in Round 4, 5 or 6 as per agreement with City of Perth due to issues of survey saturation identified during Round 3.

Table 14. Dates of year 1, 2 and 3 assessment events

			Dates of Data Collection		Types of Data Collection	
		Round	**Weekday**	**Weekend**	**Visitor Observations & Behaviour Counts**	**Visitor Surveys**
YEAR 1 – 2010	May	1	Wed 19 May 2010	Sat 29 May 2010	Yes	Yes
	October	2	Wed 27 Oct 2010	Sat 30 Oct 2010	Yes	Yes
YEAR 2 – 2011	May	3	Wed 25 May 2011	Sat 28 May 2011	Yes	Yes
	October	4	Wed 26 Oct 2011	Sat 5 Nov 2011	Yes	No
YEAR 3 – 2012	May	5	Wed 23 May 2012	Sat 26 May 2012	Yes	No
	October	6	Wed 24 Oct 2012	Sat 27 Oct 2012	Yes	No

7.9.1 VISITOR COUNTS

Observation counts results for 2012 are presented for the weekday monitoring event and the weekend monitoring event for each survey round, May in Table 15, and October in Table 16. Table 17 displays the monitoring results from the path along the outside of Point Fraser parkland. The data was recorded for a 15 minute period and extrapolated out to an hour periods.

The main entry points for both pedestrians and cyclists were the West (SMC1) and East (SMC2) Entrances (roughly equal use) while the car park entrance (SMC3) was predominately used as an access point for a commuter car park by city workers during the week. On the weekend, car park use was significantly lower as few people seemed to access Point Fraser by car for recreational purposes.

The main traffic patterns at SMC 1 and SMC2 entrances are exercise in the early morning and commuting during peak periods, with a combination of both running / walking and cycling. There is evidence of cyclists commuting during peak periods and to a lesser extent people on foot, particularly in May. The weather was recorded as hot in October, so this could explain the lower numbers of commuters at this time of the year. In the middle of the day on a weekday, it is common in both May and October to use Point Fraser as a place to eat lunch or to exercise, though generally on foot.

Overall SMC1 has significantly more visitors on foot than cyclists, either during the week or weekend and either May or October. SMC2 has more comparable numbers of visitors on foot and cycling and this is consistent over the different days and months, the data was collected. It is evident that SMC3's main use is as a commuter car park, with a clear correlation between vehicles going into the car park and pedestrians going out. There is less use by cyclists or other people on foot at SMC3.

SMC1 outside the park records the volume of people who travel either on foot or cycling on the path around Point Fraser. There are consistently high numbers of both pedestrians and cyclists that do not go into the park. It appears that people exercising on foot use the park but commuters, especially cyclist, bypass the park. It has been noted that the entrance for the car park is not ideal as the cycle path crosses the entrance.

Table 15. Extrapolated visitor counts data – Round 5, May 2012 survey round (All sites).

WEEKDAY - MAY 2012																								
Site	**SMC1**				**SMC2**				**SMC3**								**Total (SMC1 & SMC2)**			
Type	**Walking**		**Cycling**		**Walking**		**Cycling**		**Walking†**		**Cycling†**		**Vehicle†**		**Walking‡**		**Walking**		**Cycling**	
Time*	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**
7	12	0	0	4	16	8	32	32	0	8	0	0	84	0	0	68	28	8	32	36
8	32	8	4	12	20	20	120	112	0	12	8	4	72	4	0	48	52	28	124	124
9	8	8	0	0	24	12	8	12	0	4	0	0	60	4	0	12	32	20	8	12
10	0	0	0	0	16	12	8	24	0	4	0	0	4	16	0	0	16	12	8	24
11	8	20	4	4	12	0	44	20	8	0	0	0	16	8	4	4	20	20	48	24
12	16	16	0	0	16	0	0	20	8	4	0	0	16	24	16	12	32	16	0	20
13	48	24	0	0	44	4	12	0	0	8	12	12	4	12	4	4	92	28	12	0
14	8	4	0	0	8	16	4	12	8	0	4	0	12	20	28	8	16	20	4	12
15	16	12	0	0	16	20	4	4	0	0	0	0	12	20	12	4	32	32	4	4
16	12	12	0	0	32	32	40	12	0	4	0	0	16	44	32	4	44	44	40	12
17	68	48	0	0	48	48	104	104	16	4	4	4	8	144	108	4	116	96	104	104
18	8	48	0	0	92	20	8	20	4	0	0	0	0	60	20	8	100	68	8	20
Total	**236**	**200**	**8**	**20**	**344**	**192**	**384**	**372**	**44**	**48**	**28**	**20**	**304**	**356**	**224**	**176**	**580**	**392**	**392**	**392**
Total	**94%**		**6%**		**41%**		**59%**		**8%**		**4%**		**55%**		**33%**		**55%**		**45%**	

* hourly data was extrapolated from hourly 15 minute counts commencing on the hour

† main road entrance

‡ pedestrian entrance

Table 15 (cont.)

WEEKEND - MAY 2012																				
Site	**SMC1**				**SMC2**				**SMC3**								**Total (SMC1 & SMC2)**			
Type	**Walking**		**Cycling**		**Walking**		**Cycling**		**Walking†**		**Cycling†**		**Vehicle†**		**Walking‡**		**Walking**		**Cycling**	
Time*	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**
7	0	0	0	0	0	0	16	20	0	0	0	0	0	0	0	0	0	0	16	20
8	4	12	0	0	16	0	28	48	4	12	0	8	4	4	0	0	20	12	28	48
9	20	32	8	12	20	4	36	28	0	0	4	0	4	4	0	0	40	36	44	40
10	24	8	0	12	28	16	8	36	0	8	0	0	28	0	0	20	52	24	8	48
11	12	16	4	4	16	36	32	40	0	0	4	8	4	0	0	0	28	52	36	44
12	16	8	4	24	20	0	24	32	0	0	0	12	20	12	0	0	36	8	28	56
13	16	16	4	4	24	8	20	24	0	0	0	0	12	16	4	8	40	24	24	28
14	16	12	8	8	8	24	20	44	4	0	0	68	12	20	0	12	24	36	28	52
15	60	48	20	12	16	20	24	32	0	8	20	0	8	8	4	0	76	68	44	44
16	28	20	0	0	32	16	80	40	0	28	0	20	36	48	0	16	60	36	80	40
17	16	24	0	4	76	16	24	12	0	12	4	0	12	28	0	24	92	40	24	16
18	0	12	0	0	8	8	0	0	0	0	0	0	8	0	0	0	8	20	0	0
Total	**212**	**208**	**48**	**80**	**264**	**148**	**312**	**356**	**8**	**68**	**32**	**116**	**148**	**140**	**8**	**80**	**476**	**356**	**360**	**436**
Total	**77%**		**23%**		**38%**		**62%**		**13%**		**25%**		**48%**		**14%**		**55%**		**45%**	

* hourly data was extrapolated from hourly 15 minute counts commencing on the hour

† main road entrance

‡ pedestrian entrance

Table 16. Extrapolated visitor counts data – Round 6, October 2012 survey round (All sites)

WEEKDAY - OCTOBER 2012																				
Site	**SMC1**				**SMC2**				**SMC3**								**Total (SMC1 & SMC2)**			
Type	**Walking**		**Cycling**		**Walking**		**Cycling**		**Walking†**		**Cycling†**		**Vehicle†**		**Walking‡**		**Walking**		**Cycling**	
Time*	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**
7	16	16	4	4	20	28	0	24	0	20	0	0	48	0	0	32	36	44	4	28
8	4	8	0	0	12	8	8	0	0	20	0	8	96	0	4	72	16	16	8	0
9	0	0	12	0	0	0	4	4	4	16	0	20	56	12	0	52	0	0	16	4
10	16	20	0	0	20	16	0	0	4	0	0	0	28	12	0	8	36	36	0	0
11	20	16	8	0	16	16	0	4	8	0	0	4	8	0	0	16	36	32	8	4
12	20	8	0	0	8	8	8	12	8	4	4	4	20	12	16	8	28	16	8	12
13	24	12	0	0	12	12	12	0	0	8	0	0	16	16	8	0	36	24	12	0
14	4	0	0	0	8	8	4	0	0	0	0	4	8	16	0	8	12	8	4	0
15	0	4	4	0	4	0	4	0	0	0	0	4	4	36	20	0	4	4	8	0
16	36	0	0	0	8	20	8	0	4	0	4	0	4	36	40	12	44	20	8	0
17	20	4	0	0	8	8	4	0	4	28	4	16	8	96	60	0	28	12	4	0
18	72	56	4	0	36	48	0	4	4	16	0	4	16	80	64	28	108	104	4	4
Total	**232**	**144**	**32**	**4**	**152**	**172**	**52**	**48**	**36**	**112**	**12**	**64**	**312**	**316**	**212**	**236**	**384**	**316**	**84**	**52**
Total	**91%**		**9%**		**76%**		**24%**		**11%**		**6%**		**48%**		**35%**		**84%**		**16%**	

* hourly data was extrapolated from hourly 15 minute counts commencing on the hour

† main road entrance

‡ pedestrian entrance

Table 16 (cont)

WEEKEND - OCTOBER 2012																				
Site	**SMC1**				**SMC2**				**SMC3**								**Total (SMC1 & SMC2)**			
Type	**Walking**		**Cycling**		**Walking**		**Cycling**		**Walking†**		**Cycling†**		**Vehicle†**		**Walking‡**		**Walking**		**Cycling**	
Time*	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**
7	32	12	16	0	24	20	4	12	0	0	0	4	8	0	0	12	56	32	20	12
8	12	8	0	0	28	8	16	8	0	32	12	4	40	20	0	0	40	16	16	8
9	44	16	0	0	24	8	8	0	0	8	0	0	28	4	4	4	68	24	8	0
10	12	0	0	0	44	16	28	20	0	36	4	24	20	16	0	0	56	16	28	20
11	28	8	8	0	16	32	16	8	0	8	4	16	4	20	0	0	44	40	24	8
12	12	4	20	4	48	48	8	16	0	0	0	12	8	12	20	4	60	52	28	20
13	4	8	8	0	32	40	0	12	0	8	0	0	28	24	0	0	36	48	8	12
14	4	0	0	0	0	40	4	4	0	0	0	40	20	4	0	4	4	40	4	4
15	20	0	0	8	8	68	12	0	0	0	0	0	24	16	8	20	28	68	12	8
16	12	4	4	0	40	24	4	4	0	0	0	0	8	12	0	8	52	28	8	4
17	60	16	28	16	8	0	0	0	12	28	0	8	8	4	0	0	68	16	28	16
18	12	16	4	4	12	8	16	0	0	8	0	8	4	12	0	0	24	24	20	4
Total	**252**	**92**	**88**	**32**	**284**	**312**	**116**	**84**	**12**	**128**	**20**	**116**	**200**	**144**	**32**	**52**	**536**	**404**	**204**	**116**
Total	**74%**		**26%**		**75%**		**25%**		**20%**		**19%**		**49%**		**12%**		**75%**		**25%**	

* hourly data was extrapolated from hourly 15 minute counts commencing on the hour

† main road entrance

‡ pedestrian entrance

Table 17. Extrapolated visitor counts data – Round 5, May and Round 6, October 2012 survey rounds (SMC1 – Path along the outside of parkland)

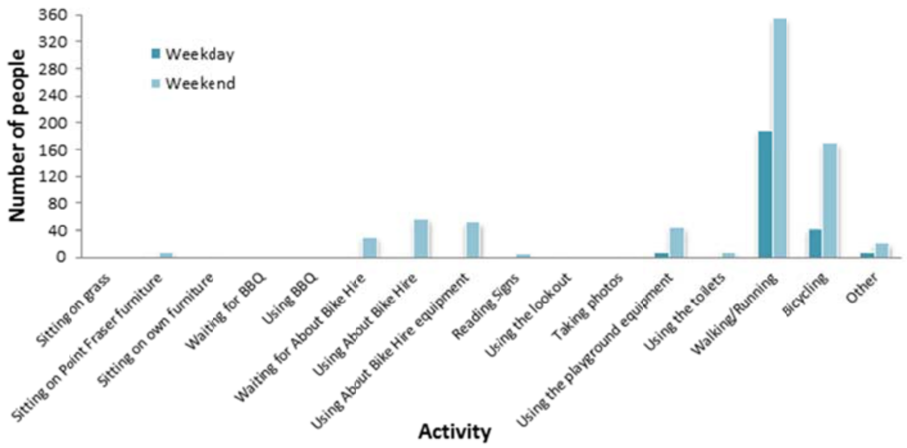
MAY 2012 (SMC1 Outside Park)								
	WEEKDAY				WEEKEND			
Type	Walking/Running		Cycling		Walking/Running		Cycling	
Time*	To city	From city	To city	From city	To city	From city	To city	From city
7	28	32	208	20	0	0	92	0
8	8	4	160	24	0	48	44	12
9	8	8	12	20	24	64	52	48
10	32	20	28	28	28	24	64	40
11	4	4	24	32	20	36	88	64
12	4	16	12	28	28	16	48	44
13	20	12	4	8	12	24	28	24
14	12	4	8	12	20	4	116	40
15	20	20	16	40	8	8	24	104
16	40	8	24	28	32	32	44	40
17	44	44	40	224	48	32	8	60
18	60	64	64	80	24	8	12	8
Total	**280**	**236**	**600**	**544**	**244**	**296**	**620**	**484**
OCTOBER 2012								
7	64	12	180	56	68	12	200	60
8	36	12	168	52	108	52	600	100
9	20	16	60	32	76	60	92	88
10	8	40	28	20	84	32	52	108
11	28	16	20	24	12	12	72	44
12	28	24	4	8	4	4	48	36
13	32	20	64	12	8	0	8	60
14	4	16	16	28	24	24	84	36
15	20	24	12	36	4	0	12	8
16	24	12	28	80	12	12	17	20
17	44	16	56	220	20	20	8	32
18	100	88	52	176	28	8	72	64
Total	**408**	**296**	**688**	**744**	**448**	**236**	**1265**	**656**

* hourly data was extrapolated from hourly 15 minute counts commencing on the hour

7.9.2 VISITOR OBSERVATIONS – BEHAVIOUR

Between the hourly visitor counts, a surveyor walked from the east to west entrance ensuring all areas of the reserve were covered and recorded the behaviour of park users using the Observation Behaviour datasheet. They also had an aerial photograph to record the spatial arrangement of stationary visitors. Nevertheless, very few people were stationary and as such this tool rendered insufficient data for useful analysis. Visitor behaviour observations highlights that the vast majority of visitors use the parkland as an area to pass through during their regular exercise activity such as walking, running or cycling (Figure 27). The activities undertaken are similar across May and October and between weekday and weekend, with the exception of walkers / runners in May. In May there was almost double the amount of walkers / runners than in October. Recreational facilities, such as About a Bike Hire was more commonly used on the weekends.

a) Round 5 – May 2012



b) Round 6 – October 2012

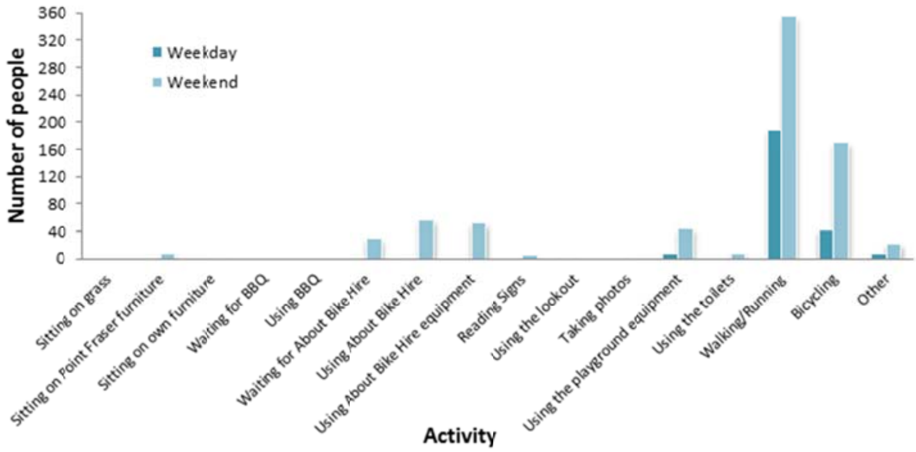


Figure 27. Number of people observed to engage in specific activities during hourly single-pass behaviour observations.

7.9.3 CONCLUSIONS

1. Determine visitor usage of Point Fraser
2. Observe usage of Point Fraser by the public
3. Interview park users for why they used the park

Point Fraser is well visited by the public, however most are passing through as part of an exercise regime (walking, jogging or cycling). The car park is heavily used by city workers during the week.

8 CONCLUSIONS

1. The quality of urban stormwater discharging to the Swan River long term, as a result of the redevelopment of Point Fraser by determining the amount of pollutant removal via the constructed wetland;

In 2011, quantitative estimates of removal efficiency for nutrients were achieved with excellent removal of P and good removal of N. However, with increased inflows in 2012, efficiencies dropped, particularly for N. Backflow out of the wetland has still not been resolved, it reduces the accuracy of water budget estimation and removal efficiencies. No evidence of a first flush was recorded although higher concentrations of nutrients were recorded earlier in the year in the stormwater. Although wetland retention of metals and P kept concentrations below guideline levels for the most part, N concentrations did exceed guidelines and appear to increase across the wetland (ANZECC/ARMCANZ, 2000; Swan River Trust, 2009a, b).

2. The quality of wetland habitat and the quantity and quality of breeding places for native avifauna presence, behaviours and habitat use;

Wetland vegetation is developing strongly with three main species *Juncus kraussii*, *Eleocharis acuta* and *Baumea articulata* competing with each other for space especially in Zone 2. *Baumea articulata* and *Typha domingensis* (which colonised in early 2012) although initially expanding in area, suffered a major dieback, possibly due to the high salinities. Weed penetration into the wetlands is very low. The vegetation has survived well with minor issues associated with low water levels on occasion and peaks in water salinity. Increasing water salinity remains a major concern and concentrations are now often likely to limiting plant growth and recruitment. The wetland has attracted a broad range of avifauna, including a number of exotics. It does not appear that the wetland is currently being used heavily for breeding.

3. The on-going ecological health of the constructed wetland via its conformance with relevant water quality guidelines and legislation requirements.

The wetland is developing a typical macroinvertebrate community, although the salinity levels in Zone 2 are encouraging more marine species than typical wetland species. The community is mainly composed of cosmopolitan and tolerant fauna. A more sensitive taxa was recorded which suggests that the wetland biodiversity will continue to improve. The introduction of *Gambusia holbrooki* (Mosquitofish) probably from the drainage network is unfortunate as they have a negative impact on surface dwelling macroinvertebrates. They are virtually impossible to eliminate without use of rotenone or by drying the wetland.

4. The quality, quantity and type of recreational and educational use of Point Fraser by determining the diversity of visitor presence, behaviour, use, expectations and satisfaction and awareness of reports/information specific to Point Fraser performance; and

Point Fraser is heavily used by the public, however the main reasons for visiting are for parking (during the week) and passing through (mainly for exercise as part of the pathway around this part of the Swan River).

5. The long term integrity and quality of the restoration of the foreshore edge, as a result of the redevelopment of Point Fraser by determining vegetation health and structural reliability.

The foreshore was damaged in a number of areas by high tides and strong winds resulting in the loss of some *Melaleuca's*, on-going management of this area is required to prevent erosion becoming more difficult to control.

9 SUMMARY OF RECOMMENDATIONS

Recommendation 1.

Installation of a flap valve over the end of the outlet pipe is recommended to prevent saltwater intrusion into the wetland.

Priority: HIGH
Responsibility: COP

Comments: In 2011 and in 2012, entry of Swan River Water at a high tide was observed entering W4 through the outlet structure. High salinities are problematic in the wetland and this is a significant source that could be easily controlled using a one way valve on the end of the pipe.

Recommendation 2.

Backflow from W1 into the drainage network remains the most important issue reducing the effectiveness of the wetland in treating stormwater.

Priority: HIGH
Responsibility: COP

Comments: Leaks in the drain line upstream of the wetland appear responsible for the W1 backflowing into the drainage network. Flows into the wetland are well below estimates for the design catchment which indicate that the wetland is operating well below its design capacity which may also be responsible for the high removal efficiencies seen.

Recommendation 3.

The unique design of the inlet structure means that a depth sensor in the BUG as well as the Starflow are required to accurately estimate inflows. It is recommended that a Unidata depth sensor be purchased by COP and coupled to the Neon Telemetry System.

Priority: HIGH
Responsibility: ECU/COP

Comments: Measuring the inlet is challenging given the problems with incoming flow and backflow. ECU have resolved the issues associated with the monitoring equipment in 2010, however it has been determined that purchase by COP of an additional depth sensor for the BUG is necessary to produce quality data.

Recommendation 4.

The Unidata sensor at the outlet has failed again and needs to be replaced. Currently standard sensors are being used, it is recommended that the due to the high salinity of the water that titanium sensors (salt resistant) be used at both inlet and outlet.

Priority: HIGH
Responsibility: ECU/COP

Comments: At the present, the monitoring system is reliant on ECU provided Bubble Flow Samplers. Purchase of these sensors would add useful data as well as potentially eliminating the need for the Bubble Flow Samplers

Recommendation 5.

High salinities (>12.5 mS cm^{-1}) are becoming more frequent in the wetland and are most likely stressing the vegetation. It is recommended that the cause of the high salinities be investigated. This includes measuring chloride in inflows, outflows and at depth in the wetland. This can be achieved by adding chloride as a parameter in the monitoring program.

Priority: HIGH
Responsibility: ECU/COP

Comments: Adding measurement of chloride to the inflows, outflows and monthly monitoring data will allow the salt budget to be estimated. It is important to understand the salt balance between inflows and outflows to ensure that salinity does not continue to rise in the wetland leading to the death of vegetation.

Recommendation 6.

It is recommended that the foreshore around Area 1 (including the headland between Areas 1 & 2) receive immediate remedial treatment in the form of sandbagging and planting of fringing sedges/rushes to reduce erosion and help prevent further loss of trees.

Priority: HIGH
Responsibility: COP

Comments: None

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