Annual Report 2014

Salty Lagoon Monitoring Program: Pre/Post Closure of the Artificial Channel

quality solutions sustainable future

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Salty Lagoon Monitoring Program: Pre/Post Closure of the Artificial Channel

Prepared for: Richmond Valley Council

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Executive Summary

GeoLINK and Aquatic Science and Management have been engaged by Richmond Valley Council (RVC) to implement the *Salty Lagoon Monitoring Program: Pre-Post Closure of Artificial Channel* (MPPC). Trial closure of the artificial channel forms part of RVC ongoing Salty Lagoon rehabilitation strategy. This report (*Annual Report 2014*) summarises the results of the MPPC monitoring undertaken between June 2013 and May 2014, which consists of the post-closure of the artificial channel monitoring period. Key findings include:

Water Quality (monitored at Salty Lagoon and Salty Creek)

- *Water Level*: The water level in Salty Lagoon was subject to very large fluctuations over the monitoring period, mostly as a result of drought conditions, but also in response to rainfall and water flow from Salty Creek.
- *Conductivity*: There were two key driving factors behind increases in the conductivity of the water recorded in Salty Lagoon during this reporting period. The first was evaporation, and the second was saltwater ingress from Salty Creek. This ingress can occur following heavy rainfall when saline water stored in Salty Creek flows into Salty Lagoon. This happens because Salty Creek rises faster than Salty Lagoon in response to rainfall.
- *Dissolved Oxygen*: During this reporting period the DO concentration measured at the Salty Lagoon PWQMS dropped below 1 mg/L on a large number of occasions. This resulted in 3 adaptive management site visits. In the current reporting period the DO concentration was 6 mg/L or less on approximately 83% of occasions and the DO concentration was 1mg/L or less on approximately 22% of occasions. The percentages of DO readings below 1 mg/L and 6 mg/L at Salty Lagoon in the year prior to the closure of the artificial channel were 15% and 73% respectively (GeoLINK 2012). In effect, the DO concentrations at the level of the sonde are at low levels more often than they were prior to closure of the artificial channel. There are a number of factors that may be contributing to this, including:
  - the higher water level since the closure of the artificial channel reducing both light penetration to the bottom of the water column and the impact of wind driven mixing at the bottom of the water column;
  - the ecosystem changes, including vegetation decomposition, occurring in Salty Lagoon in response to the closure of the artificial channel, which is likely to be resulting in increased oxygen consumption throughout the lagoon; and
  - a lower likelihood that saline water at the bottom of the water column, which tends to be associated with low DO concentrations in Salty Lagoon, will be flushed out in low flow events.
- *pH*: The pH measurements at the Salty Lagoon PWQMS have been very stable throughout this monitoring period. The periods of fluctuating pH, though small and over short time periods, have generally been associated with saline water ingress from Salty Creek and/or heavy rainfall. The processes that impact pH in Salty Lagoon are runoff from the catchment, effluent discharge from the Evans Head STP, and seawater ingress.
- *Temperature*: Over the reporting period temperature fluctuated according to both daily and seasonal patterns. There is a relationship between water level in Salty Lagoon and the magnitude of temperature variation.
- *Turbidity*: Turbidity measurements fluctuated widely throughout the monitoring period. During the current monitoring period the majority of higher turbidity measurements were associated with algal blooms and low water levels.
- *Nitrogen*: During the current reporting period the concentrations of TN were most strongly influenced by the drought conditions, which led to an increase in nitrogen concentrations due to evaporative distillation. The effects of this phenomenon were evident between September 2013 and March 2014. During the reporting period there was no obvious trend in the concentrations of DIN. A significant and long lasting algal bloom was associated with the elevated nitrogen concentrations observed during this reporting period. The availability of DIN would have contributed to, and been impacted by, the algal bloom.

- *Phosphorus*: As noted in the previous two annual reports, the concentrations of TP and orthophosphate were most often highest at S2, followed by S1 and S3. Site S2 is the site most influenced by discharged effluent from the Evans Head STP. Concentrations of phosphorus were lowest at S4 and S5, which are the two sites least influenced by discharged effluent from the Evans Head STP. The exception to this trend was the spike in the phosphorus concentration at S4 in November 2013, shortly before that site became dry. This result can be attributed to evaporative distillation of the nutrients at that site at that time. In contrast with the total nitrogen concentration, the concentration of total phosphorus did not continue to increase as water evaporated from the Salty Lagoon system. For the majority of the results, the greater proportion of the total phosphorus present was present as orthophosphate. This has important implications for the growth of algal material, which requires phosphorus to be present in the bioavailable form of orthophosphate. The phosphorus concentrations at the Salty Creek site remained low for the entire monitoring period.
- *Chlorophyll-a*: In contrast with previous results, chlorophyll-a concentrations remained high for the majority of the reporting period, indicating an algal bloom which fluctuated from small to large proportions from September 2013 until the end of the reporting period. The persistent algal bloom was caused by the increased nutrient concentrations (that occurred as a result of the drought conditions) and contributed to by the high water temperatures experienced over the same period. The high water temperatures were exacerbated by the low water levels that occurred as a result of the continued evaporation of water from the system. The algal concentrations reduced significantly following moderate rainfall in April 2013.
- *Blue Green Algae*: Blue green algae were not detected in any samples during the current reporting period.
- *Faecal Indicator Organisms*: With the exception of a few spikes in concentration the enterococcus and faecal coliform concentrations were low at all sites during the reporting period. The high concentrations measured in March and April 2014 occurred following rainfall events. The results do not suggest that discharge from the Evans Head STP or leaks from the Evans Head sewerage system are strongly influencing the concentrations of faecal indicator organisms.
- *STP Discharge Monitoring*: The daily discharge volumes from the Evans Head STP were within the licensing limits set by the EPA for the entire reporting period. The evidence suggests that the discharge from the Evans Head STP does not increase the water levels in Salty Lagoon. There have now been a number of occasions where water levels have decreased in Salty Lagoon at times of no rainfall and when Salty Lagoon is not flowing directly out to Salty Creek (i.e. STP discharge is not enough to maintain water levels). This indicates that evaporative and groundwater losses are larger than the input from the STP.

Macroinvertebrates

- A total of 19 macroinvertebrate taxa were recorded.
- The numbers of benthic macroinvertebrates captured at each site have varied over time; however, there are no clear patterns evident.
- There has been continued variation in the diversity, abundance and makeup of benthic macroinvertebrates collected during seasonal surveys.

Aquatic Vegetation / Weeds

- No introduced species of aquatic weeds have been recorded in the current monitoring period.
- Of the 26 aquatic plant types observed during the surveys, only two are considered to have the potential to become nuisance plants in Salty Lagoon: blue green algae (BGA) and Ferny Azolla.
- The risk of weed invasion into Salty Lagoon remains, particularly as the system continues the transition to a freshwater ecosystem.

Fish

- Across all surveys during the reporting period a total of four finfish species were captured. This is lower than the five species captured during the previous annual reporting period and the eight species captured during the first annual reporting period. The number of species captured at each of the sites has varied over time. There is no clear pattern to the observed variation
- A considerable degree of within site variation in fish abundance and diversity has been detected during the twelve fish surveys undertaken thus far for MPPC monitoring.

Waterfowl

- The diversity of species observed in waterbird surveys undertaken during the current reporting period has varied from season to season. With the exception of the autumn survey each season's results for the current reporting period include the highest species diversity for that season since the beginning of the MPPC, pointing to an increase in waterbird diversity since the closure of the artificial channel.

Frogs

- The results of frog monitoring were broadly consistent with the results of previous MMPC frog monitoring in terms of overall species diversity, species diversity in each habitat; species distribution at Transects 2 and 3 and the absence of acid frog species in the low lying areas adjacent to Salty Lagoon.
- As was recorded in the previous MPPC monitoring, at Transect 1 (north-west of Salty Lagoon), results differed slightly with Wallum Froglet recorded within Marsh. These differences are most likely to be attributed to localised differences in water quality and may have been influenced by the drought conditions that occurred for much of the monitoring period. It is predicted that in the future Wallum Froglet will retract westward along Transect 1 out of the Fringing Marsh and into the Swamp Forest and Sedge Swamp in response to the higher water levels and conversion towards a predominantly freshwater system.

1 Introduction

1.1 Background

GeoLINK and Aquatic Science and Management have been engaged by Richmond Valley Council (RVC) to implement the *Salty Lagoon Monitoring Program: Pre-Post Closure of Artificial Channel* (MPPC). This engagement is part of a detailed rehabilitation strategy for Salty Lagoon that has been implemented by RVC.

The rehabilitation strategy comprises three parts:

- Part 1: Issues evaluation and information gap analysis;
- Part 2: Rehabilitation and management options assessment; and
- Part 3: Implementation strategy.

A comprehensive description of the rehabilitation strategy is provided in the *Salty Lagoon Rehabilitation Plan* (Hydrosphere 2011).

Prior to this current engagement, RVC implemented the *Salty Lagoon Ecosystem Response Monitoring Program* (ERMP). In brief, the ERMP sought to monitor the ecological health of the system for a 2 year period, and to collect data across a range of disciplines to allow for further planning to be undertaken in accordance with the broader aims of the rehabilitation strategy. The study site for the ERMP was more extensive than that being monitored under the current engagement and included sampling sites along the entire length of the drainage channel from the Evans Head Sewage Treatment Plant (STP) to Salty Lagoon, and areas of adjoining bushland to the north of this facility. This work was completed in March 2010 (Hydrosphere 2010a) and included the following components:

- Water quality and hydrology.
- Diatoms
- Macroinvertebrates
- Fish
- Frogs and waterbirds.
- Flora and vegetation mapping.
- Weeds.

The current engagement is part of the final phase of work (Part 3), which documents the implementation strategy and deals specifically with the closure of the artificial channel and associated actions. As part of this strategy RVC is implementing the MPPC (Hydrosphere 2010b).

The objectives of the monitoring program are summarised as follows:

1. Confirm positive predicted changes in Salty Lagoon ecological and cultural values in response to the closure of the Artificial Channel.
2. Provide adaptive management response mechanisms before and after closure to inform future stages of the Rehabilitation Program.
3. Inform long term strategies with respect to the management of effluent from the Evans Head STP.

The MPPC was initiated in March 2011 and will end in June 2017. The full scope of works for this part of the strategy comprises:

- Ecosystem Health and Trend Assessment, including:
  - targeted terrestrial vertebrate survey and monitoring;
  - fish survey and monitoring;
  - macroinvertebrate survey and monitoring;
  - flora survey and monitoring assessments; and
  - water quality monitoring and review.
- Environmental Status and Risk Assessment including:
  - surface water quality and hydrology;
  - field observations and monitoring data review; and
  - photo record for nominated sites.
- Adaptive Management Response including:
  - water level and surface water quality; and
  - field observations.
- Existing Water Quality Logger Management (including calibration and maintenance);
- Professional advice on a range of issues including:
  - adequacy of monitoring and recommendations for change over the course of the program;
  - status of the ecosystem and emerging risks;
  - assessment of the outcomes of the artificial channel closure trial;
  - requirement for further monitoring beyond this engagement (anticipated to 2017); and
  - other matters as appropriate.
- Liaise closely and attend meetings with Council, Office of Environment and Heritage (OEH) and the Salty Lagoon Stakeholder Group throughout the course of the project.

This report (*Annual Report 2014*) summarises the results of the monitoring undertaken between June 2013 and May 2014 as part of the MPPC program.

2

Water Quality

2.1 Introduction

Adequate water quality is important to the maintenance of ecosystem processes in Salty Lagoon. Previous monitoring of Salty Lagoon has highlighted issues with water quality such as high nutrient concentrations and rapid changes in conductivity and dissolved oxygen. Poor water quality in the past has led to fish kills, indicating ecosystem collapse (Hydrosphere 2009). Water quality monitoring is central to the MPPC as a method of assessing the health of the ecosystem and informing adaptive management responses.

A varied approach to water quality sampling involving permanent water quality monitors, discrete sampling of surface waters and additional sampling in response to specific environmental conditions forms the basis of water quality monitoring for the MPPC. The range of parameters covered by each of these approaches to water quality monitoring is described in Table 2.1.

Table 2.1 Approaches to Water Quality Monitoring and parameters measured for the MPPC

Approach	*Sampling Type*	*Parameters*
Permanent Water Quality Monitoring Stations (PWQMS)	Physico-chemical	Temperature, Conductivity, Dissolved Oxygen (DO), pH, Turbidity, Water Level
Monthly Discrete Sampling and Adaptive Management Response Sampling	Physico-chemical	Temperature, Conductivity, Dissolved Oxygen (DO), pH, Turbidity, Secchi Depth, Redox
	Chemical	Total Nitrogen, Ammonia, Nitrate, Nitrite, Total Kjeldahl Nitrogen, Total Phosphorus, Orthophosphate
	Biological	Chlorophyll-a, Blue Green Algae, Faecal Coliforms, Enterococci

2.2 Methods

2.2.1 Permanent Water Quality Monitoring Stations

There are two permanent water quality monitoring stations (PWQMS) in place for the duration of the MPPC, measuring water level, temperature, pH, conductivity, turbidity and dissolved oxygen (DO) concentration. Each PWQMS is fitted with an YSI Series 6 sonde and a CRS 800 data logger. Data from the PWQMS is sent to a Richmond Valley Council (RVC) server via a telemetry system. This data was accessed at least weekly, checked for errors and outlying data, and incorporated into a database for the current reporting period. The water level data was corrected prior to being included in this report using the surveyed levels of the measuring boards at each of the permanent water quality monitoring stations. Each YSI sonde is removed from the PWQMS, calibrated and serviced after a two month deployment.

The data from the PWQMS is used to inform the adaptive management strategy. Automatic alarms are received from the RVC server when DO concentration or water level changes at a specific rate. The triggers for the alarms were reviewed in April 2013 and adjusted during this reporting period. This is discussed further in Section 2.2.3.

2.2.2 Routine Discrete Sampling

Discrete water quality samples were taken from surface water (approx. 0.2 m depth) at four sites in Salty Lagoon (S1-S4) and a single site (S5) in Salty Creek on a monthly basis. An additional quality assurance (QA) replicate sample was collected from a randomly chosen site each month. The specific locations of all sites sampled are presented in Table 2.2 and displayed in Illustration 2.1. As a result of drought conditions there was no water to sample at S2 between January and March 2014 or at S4 between December 2013 and March 2014.

Table 2.2 Locations of Water Quality Sample Sites in Salty Lagoon and Salty Creek (WGS84)

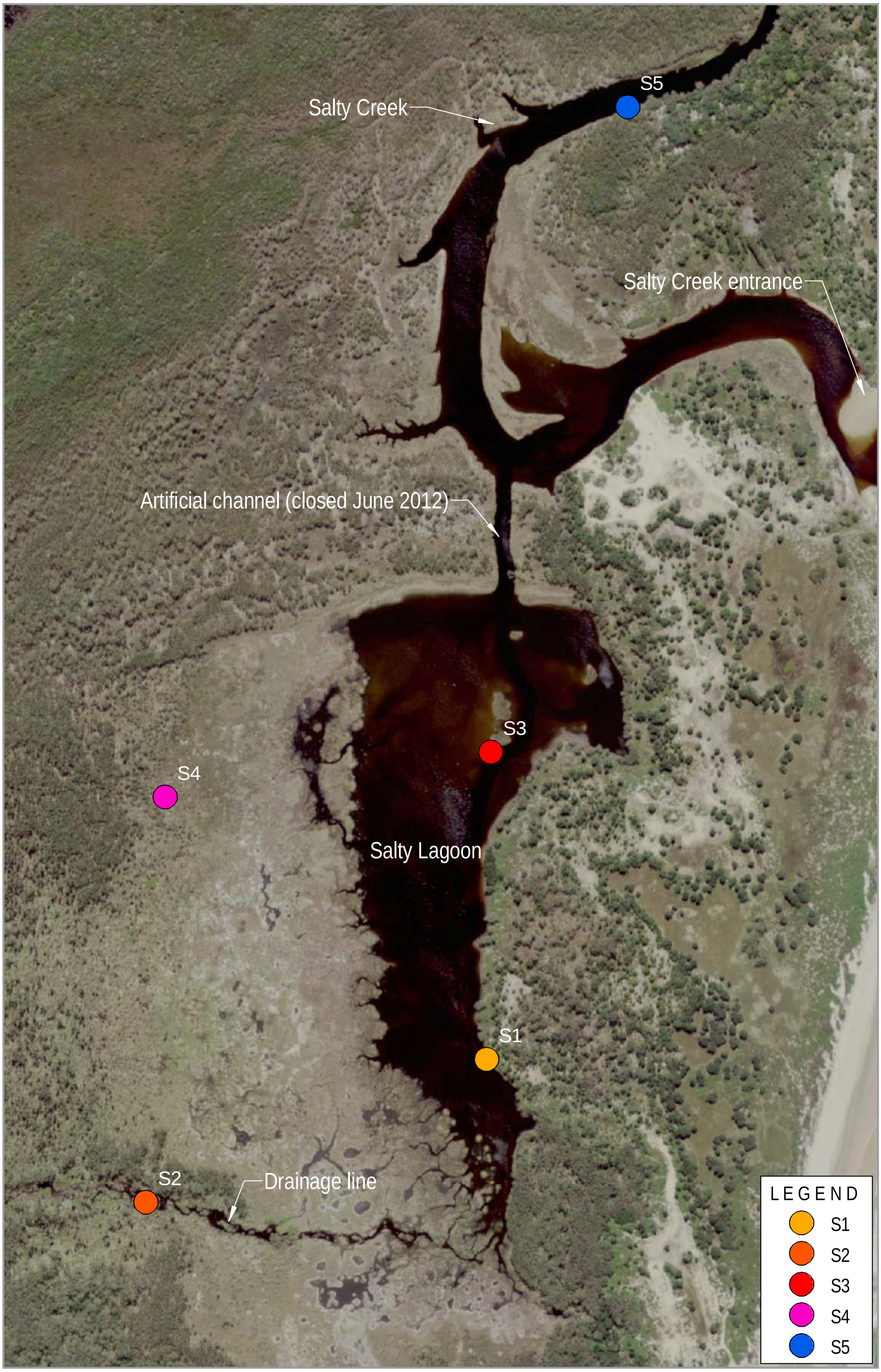
Site	S 1	S 2	S 3	S 4	S 5
Easting	0542064	0541799	0542037	0541738	0542187
Northing	6782801	6782669	6783013	6783033	6783665
Site Description	Salty Lagoon PWQMS	SE of Drainage Channel	NE area of lagoon	NW area of lagoon	Salty Creek PWQMS

Physico-chemical water quality parameters in discrete surface water samples were measured with an HORIBA U-52 hand held water quality meter. Depth profiling of physicochemical parameters was undertaken at 1m intervals at sites where depth was sufficient to allow it. Depth profiling is undertaken to improve the understanding of stratification of the water column at times when the water level is high. The results of depth profiling are reported in monthly ecosystem health reports and will not be repeated here.

Discrete samples were collected in jars for analysis of chemical and biological parameters at the Coffs Harbour Laboratory (CHL). Sterile jars were used for bacteriological analysis and brown glass jars were used for analysis of chlorophyll-a and blue green algal (BGA) content. Samples were placed upon ice in an Esky and delivered to CHL within 24 hours of collection.

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: RE Reviewed by: TJP Date: 28/10/2014
Source of base data: Richmond Valley Council



0 100

North

Location of Water Quality Sites

Illustration 2.1

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2.2.3 Adaptive Management WQ Sampling

The final water quality monitoring component of the MPPC is the 'adaptive management response'. The response process is documented in detail in the Environmental Incident Response Protocol (Hydrosphere Consulting 2009) that was developed previously for the Salty Lagoon Ecosystem Recovery Monitoring Program (refer to Hydrosphere Consulting 2010a). A review of the response process was prepared in April 2013 and adjustments have been implemented.

Essentially the adaptive management response component of the MPPC relates directly to the monitoring of potential significant environmental incidents that have periodically been known to occur at Salty Lagoon. It is informed by the two PWQMS, which record data at 15 minute intervals. Automatic alarms alert GeoLINK and RVC staff via email if certain water quality or water level parameters are detected. The triggers for an adaptive management response were revised as part of the review process. They are currently:

- Dissolved oxygen concentration < 1 mg/L – average over twelve hours.
- Conductivity > 3 mS/cm.
- Water temperature > 30 ˚C.

When an alarm is received the need for a site inspection is assessed based upon the perceived risk of an environmental incident using all the available information and understanding of the system gained from the monitoring to date.

2.2.4 Guiding Values

Guiding values for use in the preparation of the monthly report card were revised in September 2012 and were generated using water quality data collected between April 2011 and September 2012 as part of the MPPC project. Guiding values were developed separately for Salty Lagoon and Salty Creek. These guiding values were developed based on data collected from surface water at all sites and incorporated all parameters measured as part of the MPPC.

Guiding values were set at the 80th percentile value of the collected data set for the lagoon and the creek with the following exceptions:

- The guiding values for dissolved oxygen were set at the 20th percentile value.
- A guiding value range was developed for pH, conductivity and temperature in Salty Creek due to the varying influences of sea water and freshwater runoff. The outlying points for the guiding value ranges were set at the 10th and 90th percentile values.

Guiding values that have been developed based on the above methodology for all water quality parameters being sampled under the current monitoring program are presented in Table 2.3. The guiding values were developed to assist with the contextualisation of results, rather than as a measure of the health of the waterway. However, guiding values also provide a yardstick, around which the adaptive management of Salty Lagoon can be discussed.

Table 2.3 Guiding Values for all Water Quality Parameters

Measure		*Guiding Value*	
		Salty Lagoon	*Salty Creek*
Chemical	Total Nitrogen (mg/L)	1.6	1.64
	Ammonia (mg/L)	0.05	0.11
	Nitrate (mg/L)	0.01	0.01
	Nitrite (mg/L)	0.01	0.01
	Total Kjeldahl Nitrogen (mg/L)	1.6	1.64
	Total Phosphorus (mg/L)	0.14	0.04
	Orthophosphate (mg/L)	0.11	0.01

Measure		Guiding Value	
		Salty Lagoon	Salty Creek
Biological	Chlorophyll-a (µg/L)	5	3
	Faecal Coliforms (CFU/100mL)	135	150
	Enterococci (CFU/100mL)	170	40
	Blue Green Algae (cells/mL)	0	0
Physical	Dissolved Oxygen (mg/L)	4.09	5.52
	Turbidity (NTU)	13.0	11.0
	pH	6.9	4.3 – 6.8
	Conductivity (mS/cm)	8.0	0.3 – 21.5
	Temperature (˚C)	25.9	13.1 - 28.8

2.3 Results and Discussion

2.3.1 Permanent Water Quality Monitoring Stations

2.3.1.1 Data Quality and Consistency

There are a number of gaps in the data from the PWQMS. These are either:

- Regular short term gaps in the data set ranging from one 15 minute interval reading to over 3 hours.
- Gaps in the Salty Lagoon PWQMS dataset resulting from battery failure; or
- Gaps where erroneous data, occurring as a result of faulty water quality probes, have been highlighted within the dataset. The turbidity and dissolved oxygen probes have been particularly susceptible to such problems. A monthly review of the status of each sonde has been implemented in order to avoid these issues.

Over the monitoring period from 1 June 2013 to 31 May 2014 there were 2080 (5.9%) missed data points from the Salty Lagoon PWQMS and 778 (2.2%) from the Salty Creek PWQMS

As part of routine maintenance the logged results are compared in the field with data collected from a handheld water quality probe on a monthly basis. In general the results correlate very well.

2.3.1.2 Key Points Arising from the Salty Lagoon Data Set

The results from the Salty Lagoon PWQMS are presented in Illustration 2.2 and are discussed below.

Water Level

The water level in Salty Lagoon was subject to very large fluctuations over the past twelve months, mostly as a result of drought conditions, but also in response to rainfall and water flow from Salty Creek. The chart in Illustration 2.2 indicates that:

- The water level in Salty Lagoon does not respond as quickly to rainfall in the catchment as the water level in Salty Creek. This means that a hydrological connection between the two water bodies usually results in an initial flow from Salty Creek into Salty Lagoon.
- Such hydrological connections are most likely to occur when the entrance to Salty Creek is closed but may also occur when the entrance is open and there is a combination of large swell conditions and very high tides.
- The effect of freshwater input from the Evans Head STP is not as great as the combined effects of groundwater drawdown and evaporation. In effect, freshwater input from Evans Head STP does not maintain water levels in Salty Lagoon (as evidenced by the reduction in water levels during the dry period from July 2013 to March 2014).

- The majority of drainage from Salty Lagoon into Salty Creek occurs when water levels in Salty Lagoon are above approximately 1.85 m AHD.

Conductivity

Conductivity is a measure of the saltiness of the water. There were two key driving factors behind increases in the conductivity of the water recorded in Salty Lagoon during this reporting period. The first was evaporation, and the second was saltwater ingress from Salty Creek. This ingress can occur following heavy rainfall when saline water stored in Salty Creek flows into Salty Lagoon. This happens because Salty Creek rises faster than Salty Lagoon in response to rainfall. It can also occur as a result of storm surge and high tides. Although it is not obvious from the logged data, the water column in Salty Lagoon is often stratified into a heavy salty layer at the bottom and a lighter freshwater layer at the surface. Small and short term variations in the conductivity measured at the Salty Lagoon PWQMS often result from changes in the intensity of wind and flow driven mixing of the water column. This is particularly apparent when water levels are low.

Dissolved Oxygen

The main dynamics of Dissolved Oxygen concentrations in Salty Lagoon post-channel closure are now well understood. The observed variations in DO concentrations include daily fluctuations in response to light availability (diurnal fluctuations), short term irregular variation in response to wind driven mixing and medium term fluctuations in response to rapid changes in the water quality, such as when saline water flows in from Salty Creek. The key factors that influence DO concentration in Salty Lagoon are:

- Diffusion - the surface of the water is exposed to the air and dissolves oxygen constantly through diffusion;
- Microalgal concentrations - microalgae produce oxygen during the day through photosynthesis and consume it at night through respiration.
- Light availability - this influences the photosynthetic activity of microalgae throughout the water column and attached to the benthos.
- Wind and flow driven mixing - mixing of the water column serves to bring well oxygenated water from the surface into lower parts of the water column. The stronger the wind or flow, the deeper the mixing. North and south winds have the greatest effect on Salty Lagoon due to the north-south orientation;
- Water level - the depth of the water determines the impact of wind driven mixing and the availability of light at the bottom of the water column.
- Turbidity - turbid waters reduce light availability throughout the water column.
- Salinity - the mechanism is not certain but there is often a sharp reduction in DO concentration associated with saline water ingress.

Although it is not apparent from the logged data, the water column in Salty Lagoon is often stratified with respect to DO concentration. At these times the water at the bottom of the water column can be hypoxic whilst the water at the surface is well oxygenated. This occurs most often when water levels are high and, therefore is likely to occur with increasing regularity as a result of the closure of the artificial channel. For this reason the adaptive management approach has been modified to reduce the number of unnecessary site inspections (refer to **Section 2.2.3**). The DO concentrations measured in surface waters between 1 June 2013 and 31 May 2014 are reported in **Section 2.3.2**.

During this reporting period the DO concentration measured at the Salty Lagoon PWQMS dropped below 1 mg/L on a large number of occasions. This resulted in 3 adaptive management site visits. In the current reporting period the DO concentration was 6 mg/L or less on approximately 83% of occasions and the DO concentration was 1mg/L or less on approximately 22% of occasions. The percentages of DO readings below 1 mg/L and 6 mg/L at Salty Lagoon in the year prior to the closure of the artificial channel were 15% and 73% respectively (GeoLINK 2012). In effect, the DO concentrations at the level of the sonde are at low levels more often than they were prior to closure of the artificial channel. There are a number of factors that may be contributing to this, including:

- The higher water level since the closure of the artificial channel reducing both light penetration to the bottom of the water column and the impact of wind driven mixing at the bottom of the water column.

- The ecosystem changes, including vegetation decomposition, occurring in Salty Lagoon in response to the closure of the artificial channel, which is likely to be resulting in increased oxygen consumption throughout the lagoon.
- A lower likelihood that saline water at the bottom of the water column, which tends to be associated with low DO concentrations in Salty Lagoon, will be flushed out in low flow events.

pH

The pH measurements at the Salty Lagoon PWQMS have been very stable throughout this monitoring period. The periods of fluctuating pH, though small and over short time periods, have generally been associated with saline water ingress from Salty Creek and/or heavy rainfall. The processes that impact pH in Salty Lagoon are runoff from the catchment, effluent discharge from the Evans Head STP, and seawater ingress.

Following periods of heavy rainfall, runoff from the catchment tends to be acidic, which lowers the pH at the Salty Lagoon PWQMS. During dry times, the main source of fresh water is the Evans Head STP, which releases treated water close to a neutral pH. Consequently, when effluent discharge is the dominant source of water, the pH at the Salty Lagoon PWQMS tends to be close to neutral. Saltwater ingress usually has the effect of raising the pH measured at the Salty Lagoon PWQMS. However, there appears to be a mechanism of pH buffering in Salty Lagoon resulting in a tendency towards neutral following any disturbance.

Temperature

Over the reporting period temperature fluctuated according to both daily and seasonal patterns. There is a relationship between water level in Salty Lagoon and the magnitude of temperature variation. In February and March 2014, when water levels were at their lowest, temperature fluctuations became extreme and temperatures > 35 °C were measured on several occasions. Water temperature impacts upon a number of other parameters. For example, at higher temperatures water has a lower oxygen carrying capacity and higher temperatures encourage microalgal growth and activity and contribute to algal blooms.

Turbidity

Turbidity is a measure of the capacity of water to transmit light. As light is scattered by particulate matter turbidity measurements give an indication of the sediment and other material suspended in the water column. Turbidity measurements fluctuated widely throughout the monitoring period. During the current monitoring period the majority of higher turbidity measurements were associated with algal blooms and low water levels. Low water levels increase the frequency of wind driven re-suspension of benthic material.

Plate 2.1 The Salty Lagoon PWQMS exposed by low water levels

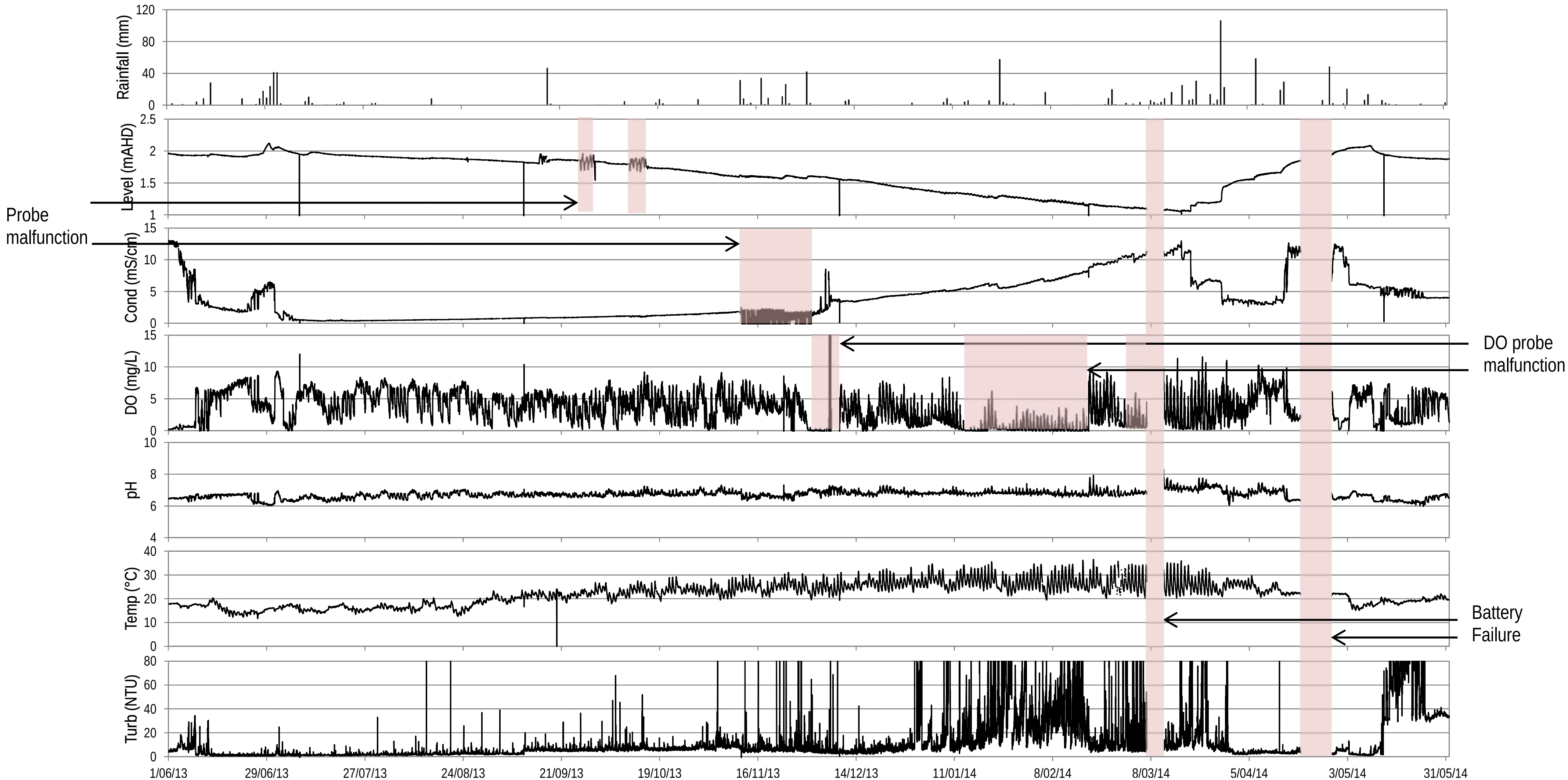


Illustration 2.2 Results from the Salty Lagoon PWQMS for the Period from 1 June 2013 until 31 May 2014

2.3.1.3 Key Points Arising from the Salty Creek Data Set

The Salty Creek PWQMS is important in the context of managing Salty Lagoon as it provides information about how water quality in Salty Creek can impact upon Salty Lagoon. The results from the Salty Creek PWQMS are presented in **Illustration 2.3.**

Water Level

The most important factor affecting the water level in Salty Creek is the status of its entrance. The entrance to Salty Creek only opened twice in the current reporting period, compared with 5 or 6 opening events in the previous 12 months and 17 opening events in the 12 months before that. The stability of the entrance to Salty Creek over the past 12 months is a result of the low rainfall experienced. The level of Salty Creek increased a number of times during the reporting period as a result of seawater ingress during large swell and storm surge conditions. There were two occasions during the reporting period where, following heavy rainfall, Salty Creek flowed into Salty Lagoon through existing natural channels.

Conductivity

The conductivity measurements from the Salty Creek PWQMS were high to very high for the majority of the reporting period. This demonstrates the dominance of seawater ingress over rainfall runoff during the current reporting period. After a very dry period between October 2013 and March 2014 the water in Salty Creek was more conductive than seawater due to evaporative loss. Consistent rainfall in March 2014 led to a reduction in the conductivity and also resulted in partial stratification of the water column. The factors that led to seawater ingress also created a closed entrance with a high entrance berm. This scenario, in combination with low rainfall between July and October 2013, resulted in a long period of very high conductivity measurements where saline water was 'trapped' in Salty Creek. Although the entrance opened towards the end of the reporting period, some saline influence remained.

Dissolved Oxygen

Dissolved Oxygen (DO) concentrations measured at the Salty Creek PWQMS fluctuated widely throughout the year. The general patterns associated with the range of variation at the Salty Creek PWQMS were as follows:

- DO concentration tended to be higher during periods of freshwater dominance and when water levels were low.
- DO concentrations in Salty Creek fluctuated diurnally over the majority of the reporting period but such fluctuations were not particularly strong.
- The water column is often stratified with respect to DO concentration, although this is not apparent from the logged information.

The DO concentration measured at the Salty Creek PWQMS was 6 mg/L or less for approximately 80% of the reporting period and 1mg/L or less for approximately 24% of the reporting period. These figures are higher than those previously reported. This is likely to be associated with the extended period of entrance closure experience this year.

pH

The pH measurements from the Salty Creek PWQMS were relatively stable over the past year. There were two exceptions, being the two occasions that the entrance to Salty Creek opened and freshwater runoff was contributed from the catchment Runoff from the catchment is naturally acidic, resulting in a pH of < 5 in Salty Creek following rainfall. This contrasts strongly with the pH after seawater ingress which can have the effect of increasing the pH measurements to over pH 8.

Temperature and Turbidity

Temperature measurements in Salty Creek fluctuate on a daily and seasonal basis. Turbidity measurements from the Salty Creek PWQMS were generally low and stable, with the exception of the period between March and May 2014, when they increased dramatically in response to an algal bloom of moderate proportions.

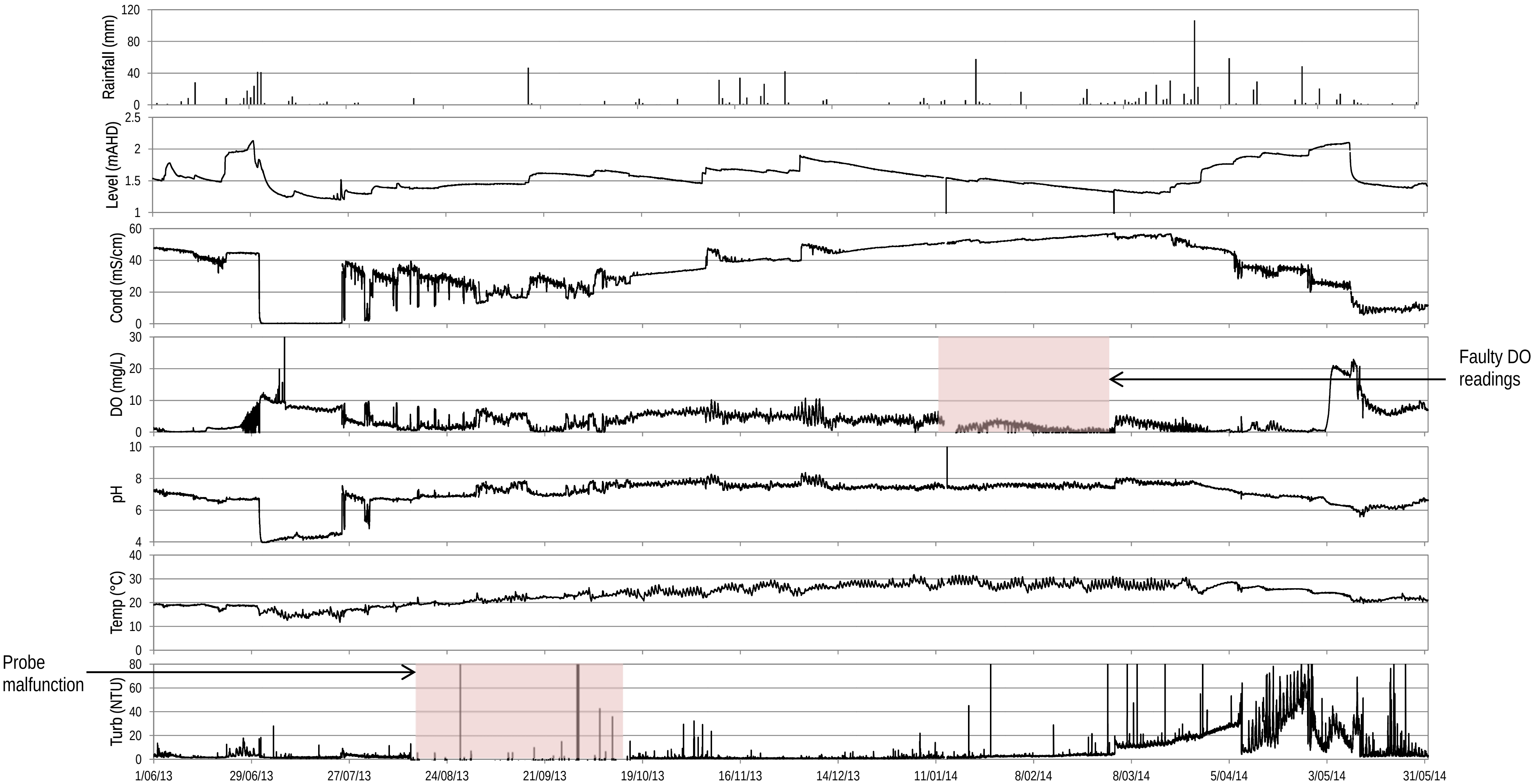


Illustration 2.3 Results from the Salty Creek PWQMS for the Period from 1 June 2013 until 31 May 2014.

2.3.2 Discrete Water Quality Samples

This section describes the results of discrete water quality samples collected during normal monthly water quality monitoring and extra water quality monitoring undertaken as part of the adaptive management protocols. A summary of median results for all samples from all sites is presented in Table 2.4. Results from individual sites are compared in Section 2.3.2.1 to Section 2.3.2.5.

Table 2.4 Median results of discrete samples from surface waters at all sites between 1 June 2013 and 31 May 2014

Indicator	*Site*				
	S1	*S2*	*S3*	*S4*	*S5*
Nitrite Nitrogen (mg/L)	0	0	0	0	0
Nitrate Nitrogen (mg/L)	0	0	0	0	0
Oxidized Nitrogen (mg/L)	0	0	0	0	0
Ammonia Nitrogen (mg/L)	0.045	0.01	0.0265	0.02	0.015
Total Kjeldahl Nitrogen (mg/L)	1.93	1.63	2.03	1.46	1.13
Total Nitrogen (mg/L)	1.935	1.63	2.03	1.46	1.13
Total Phosphorus (mg/L)	0.15	0.16	0.165	0.11	0
Orthophosphate (mg/L)	0.092	0.11	0.095	0.08	0
Chlorophyll-a (µg/L)	22.5	2	15.5	1	3
Enterococcus (CFU/100mL)	36	34	42.5	41.5	10.5
Faecal Coliforms (CFU/100mL)	69	90	65	27.5	5.5
Blue Green Algae (cells/L)	0	0	0	0	0
Temp (˚C)	22.27	19.88	22.86	17.19	23.79
pH	6.88	6.18	6.94	4.66	7.23
ORP (mV)	138	102.5	139.5	84	104.5
Cond (mS/cm)	3.29	0.901	3.5	1.42	26.25
Turbidity (NTU)	3.9	2.4	5.95	1.6	1.4
DO (mg/L)	5.5	2.54	6.36	2.83	6.18
DO (% sat)	63	30.2	70.8	29.9	75.9
TDS (ppt)	2.11	0.58	2.24	0.91	16.25
Salinity (ppt)	1.7	0.4	1.9	0.7	16.1

Note: red text: not compliant with MPPC guiding values (GeoLINK 2012)

2.3.2.1 *Nitrogen*

Nitrogen is an element that is essential to life. In waterways it plays an important role in supporting food webs. However, problems arise from excessive nitrogen concentrations in water. Nitrogen is frequently monitored as an indicator of water quality and its capacity to support a healthy aquatic ecosystem. Nitrogen is present in water in a number of forms. It can be dissolved or particulate and can be present in organic molecules that are unavailable for biological uptake or inorganic molecules that are bioavailable. For the MPPC nitrogen is measured as total nitrogen (TN), and the dissolved inorganic nitrogen (DIN) forms; ammonia, nitrate and nitrite.

Some of the factors that have been found to influence nitrogen concentrations in Salty Lagoon and Salty Creek include seawater ingress, tidal movements, historical pollution and rainfall runoff. Effluent discharge from the Evans Head STP does not appear to be a factor that strongly influences nitrogen concentrations in Salty Lagoon, as concentrations of TN at S2 are often the lowest.

During the current reporting period the concentrations of TN were most strongly influenced by the drought conditions, which led to an increase in nitrogen concentrations due to evaporative distillation. The effects of this phenomenon were evident between September 2013 and March 2014 (Illustration 2.4).

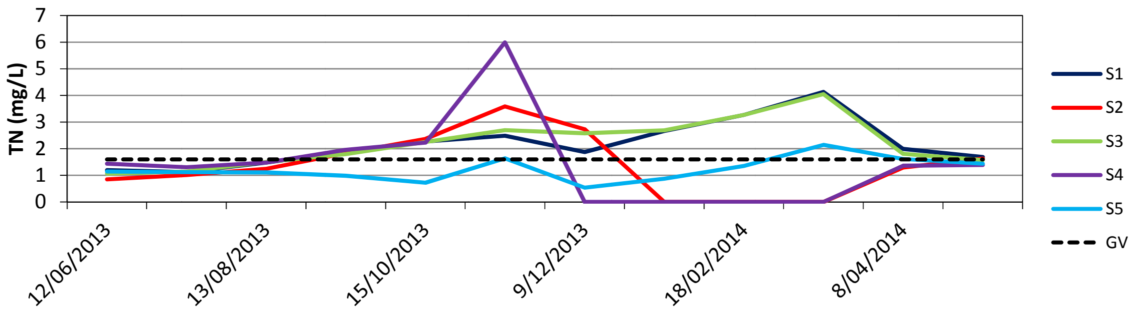


Illustration 2.4 Time series of TN concentrations from all sites for the monitoring period

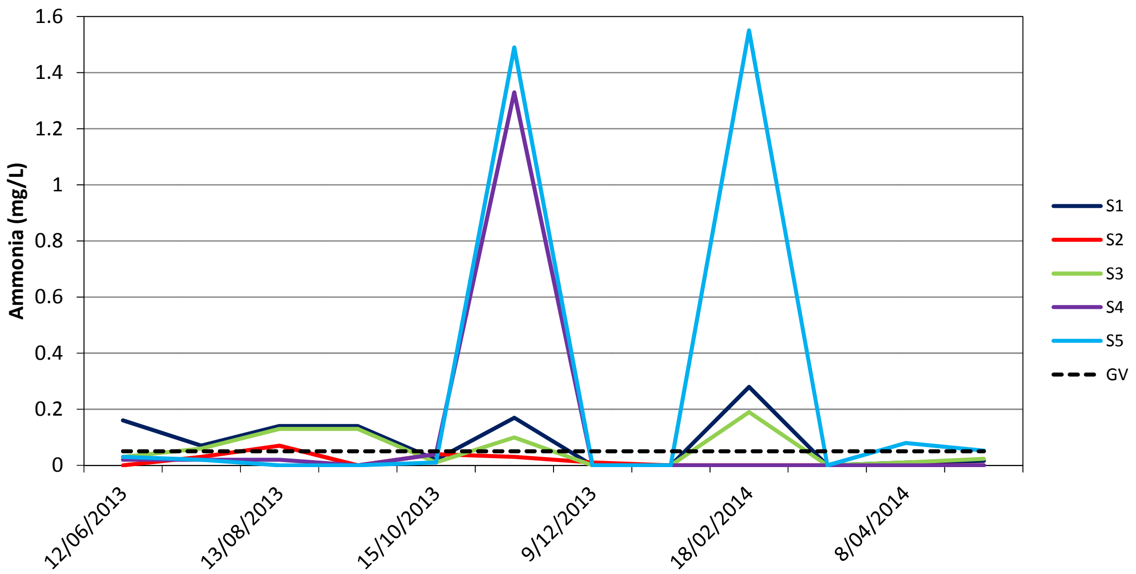


Illustration 2.5 Time series of ammonia concentrations from all sites for the monitoring period

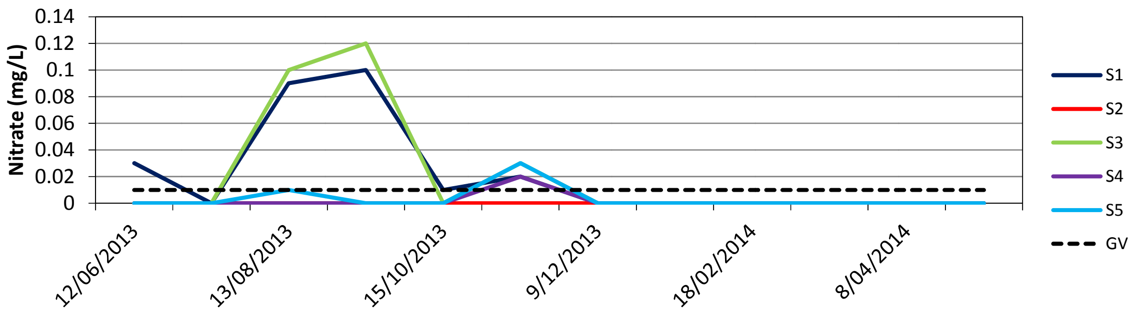


Illustration 2.6 Time series of nitrate concentrations from all sites for the monitoring period

During the reporting period there was no obvious trend in the concentrations of DIN. The concentrations of ammonia and nitrate spiked at different sites at different times (Illustration 2.5 and Illustration 2.6). The factors contributing to these spikes are factors that control the effectiveness of the pathways for nitrogen breakdown, such as temperature, dissolved oxygen availability, algal populations and light availability.

A significant and long lasting algal bloom was associated with the elevated nitrogen concentrations observed during this reporting period (Section 2.3.2.3). The availability of DIN would have contributed to, and been impacted by, the algal bloom.

2.3.2.2 Phosphorus

Phosphorus is also essential to life and, like nitrogen, plays a role in supporting aquatic food webs and can be detrimental to aquatic ecosystems at excessive concentrations. Phosphorus exists in a number of different forms in water, either as bioavailable phosphorus (orthophosphate) or organic molecules containing phosphorus unavailable for biological uptake.

As noted in the previous two annual reports, the concentrations of TP and orthophosphate were most often highest at S2, followed by S1 and S3. Site S2 is the site most influenced by discharged effluent from the Evans Head STP. Concentrations of phosphorus were lowest at S4 and S5, which are the two sites least influenced by discharged effluent from the Evans Head STP. The exception to this trend was the spike in the phosphorus concentration at S4 in November 2013, shortly before that site became dry. This result can be attributed to evaporative distillation of the nutrients at that site at that time.

In contrast with the total nitrogen concentration, the concentration of total phosphorus did not continue to increase as water evaporated from the Salty Lagoon system. The reason for this is not certain, but there appears to be some mechanism by which phosphorus is lost to the system or is stored in the sediments as the concentration in the water column increases. For the majority of the results, the greater proportion of the total phosphorus present was present as orthophosphate. This has important implications for the growth of algal material, which requires phosphorus to be present in the bioavailable form of orthophosphate.

The phosphorus concentrations at the Salty Creek site remained low for the entire monitoring period.

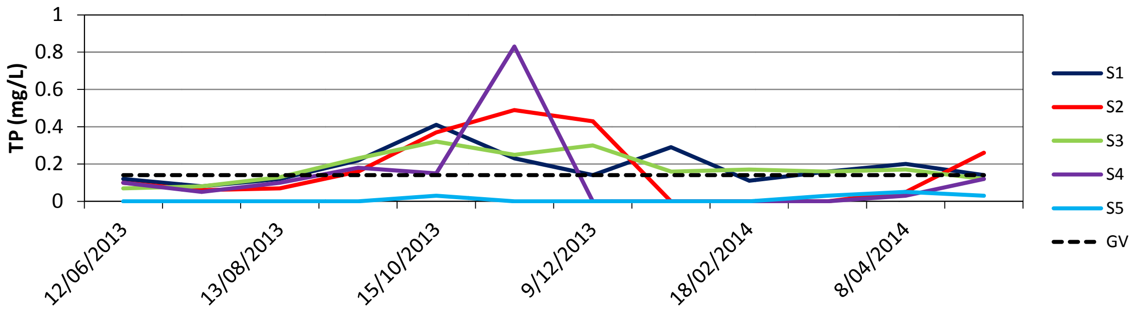


Illustration 2.7 Time series of TP concentrations from all sites for the monitoring period

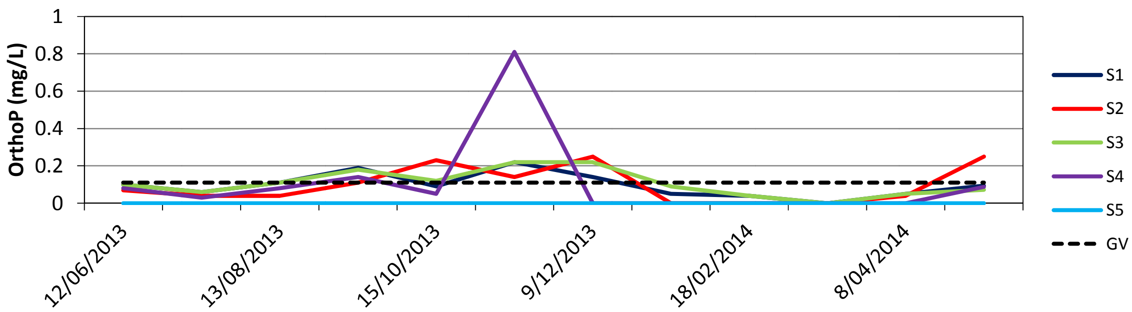


Illustration 2.8 Time series of Orthophosphate concentrations from all sites for the monitoring period

2.3.2.3 Chlorophyll-a

The concentration of chlorophyll-a is a measurement of microalgae in the water column. Microalgal abundance fluctuates naturally in response to temperature, nutrient concentrations and light availability, but algal blooms are usually considered to be an indication of poor ecosystem health.

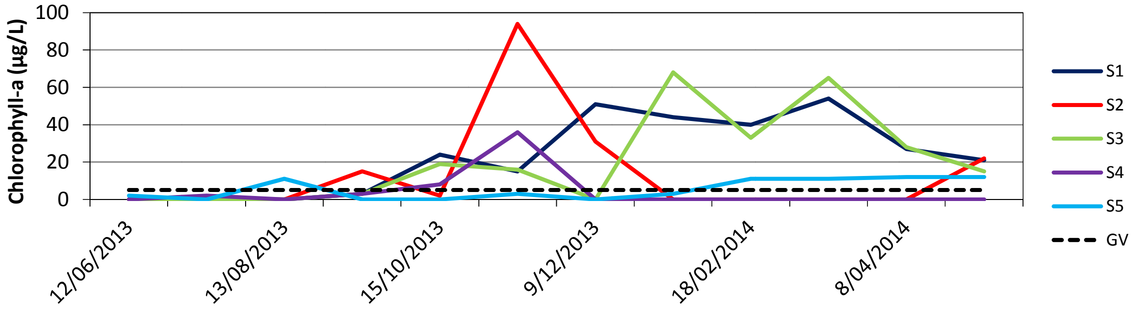


Illustration 2.9 Time series of Chlorophyll-a concentrations from all sites for the monitoring period

In contrast with previous results, chlorophyll-a concentrations remained high for the majority of the reporting period, indicating an algal bloom which fluctuated from small to large proportions from September 2013 until the end of the reporting period.

The persistent algal bloom was caused by the increased nutrient concentrations (that occurred as a result of the drought conditions) and contributed to by the high water temperatures experienced over the same period. The high water temperatures were exacerbated by the low water levels that occurred as a result of the continued evaporation of water from the system. The algal concentrations reduced significantly following moderate rainfall in April 2013. There were no blue-green algae present in any of the samples during this reporting period. The algae that were present in high concentrations were species of *Anabena* and *Euglena*. These species are non-toxic green algae.

2.3.2.4 Blue Green Algae

Blue green algae are naturally occurring photosynthetic bacteria. Under bloom conditions they can be toxic to humans and aquatic fauna and can cause other problems related to deoxygenation of the water column and reduced light penetration. Blue green algae were not detected in any samples during the current reporting period.

2.3.2.5 Faecal Indicator Organisms

Enterococcus and faecal coliforms are bacteria that can be measured as an indication of faecal pollution of waterways. Both enterococcus and faecal coliforms can be sourced from humans or animals and sometimes from rotting vegetation. Faecal indicator organisms are most commonly measured to assess the risks associated with recreational activity in and on waterways.

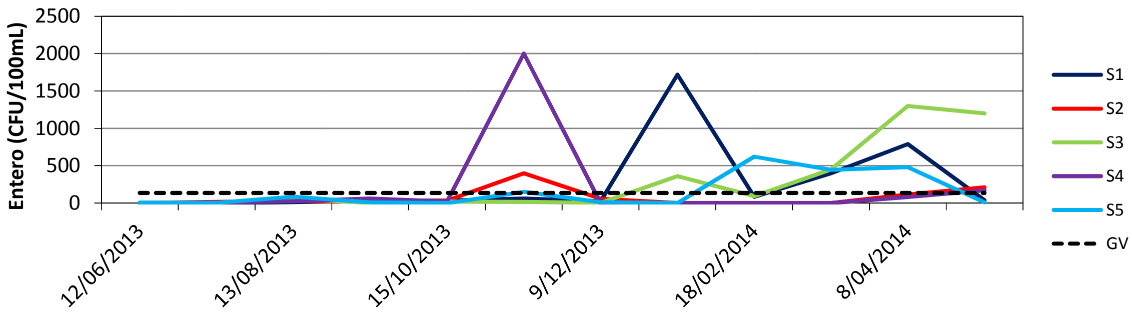


Illustration 2.10 Time series of enterococcus concentrations from all sites for the monitoring period

With the exception of a few spikes in concentration the enterococcus and faecal coliform concentrations were low at all sites during the reporting period. The high concentrations measured in March and April 2014 occurred following rainfall events.

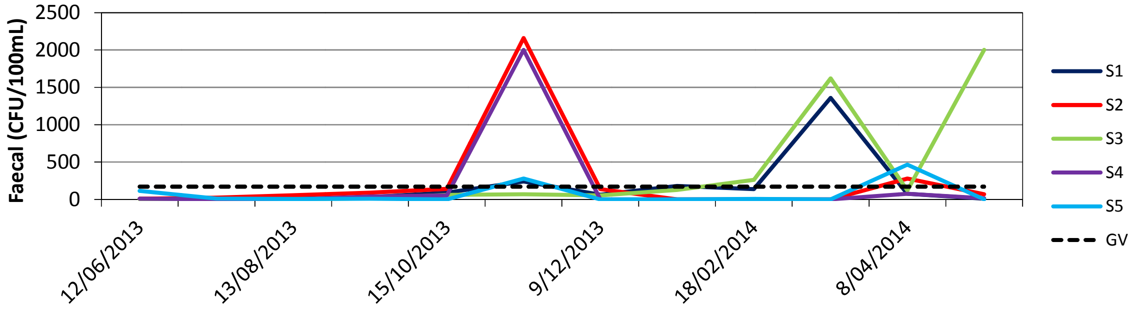


Illustration 2.11 Time series of faecal coliform concentrations from all sites for the monitoring period

The major contributors to the observed variation in the concentration of faecal indicator organisms are runoff from the catchment and the presence of waterfowl. The sources of faecal pollution in Salty Lagoon are most likely to be terrestrial fauna and avifauna utilising the lagoon and its immediate catchment. The results do not suggest that discharge from the Evans Head STP or leaks from the Evans Head sewerage system are strongly influencing the concentrations of faecal indicator organisms.

2.4 STP Discharge Monitoring

As part of licensing conditions, the Evans Head STP is required to monitor discharge quality on a fortnightly basis. A suite of effluent quality parameters are sampled including faecal coliform, TN and TP concentrations. The data collected from the Evans Head STP is used to contextualise results collected during the MPPC and inform any pollution incidents that may occur during the project. Monitoring results from the Evans Head STP are presented in Illustration 2.12, Illustration 2.13, Illustration 2.14 and Illustration 2.15. With the exception of one faecal coliform measurement, which exceeded the maximum limit, all results for the entire monitoring period were within the licensing limits set for the Evans Head STP by the EPA.

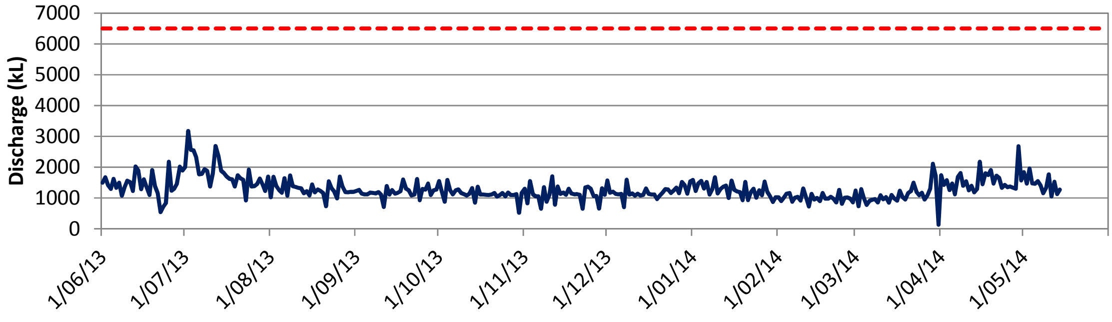


Illustration 2.12 Time series of daily discharge volumes from the Evans Head STP (maximum allowed discharge volume in red)

The daily discharge volumes from the Evans Head STP were within the licensing limits set by the EPA for the entire reporting period. The evidence suggests that the discharge from the Evans Head STP does not increase the water levels in Salty Lagoon. There have now been a number of occasions where water levels have decreased in Salty Lagoon at times of no rainfall and when Salty Lagoon is not flowing directly out to Salty Creek (i.e. STP discharge is not enough to maintain water levels). This indicates that evaporative and groundwater losses are larger than the input from the STP. In addition, the channel from the STP dried out between January and March 2014, indicating that no water from the STP reached Salty Lagoon over that period.

In general, faecal coliform concentrations in discharged effluent are very low. In fact the measured concentrations of faecal coliforms in the discharged effluent are generally lower than the median concentrations of faecal coliforms at all water quality sites sampled as part of the MPPC project. Because faecal coliforms do not persist in the environment for a long period of time it is highly unlikely that discharged effluent is contributing significant numbers of faecal coliforms to the measurements in Salty Lagoon.

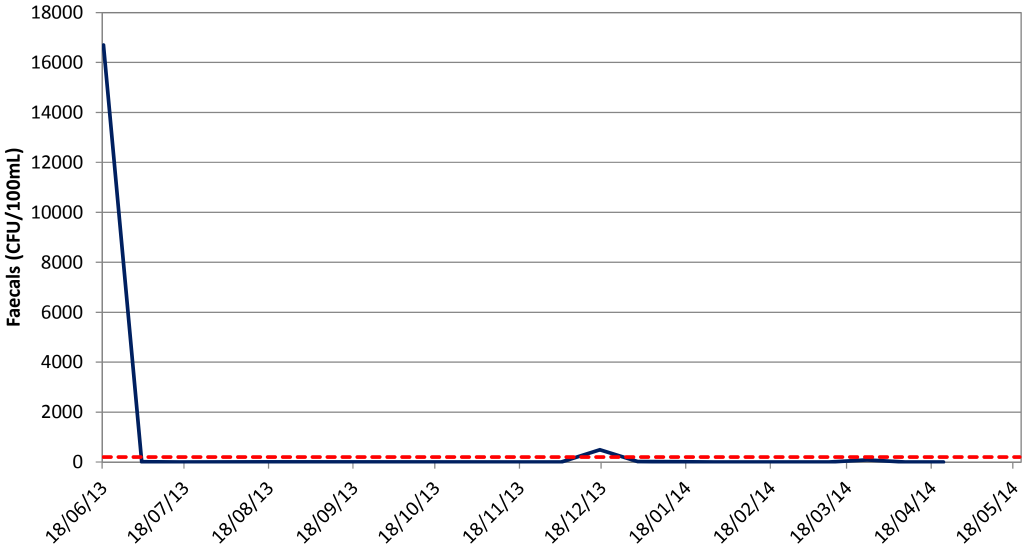


Illustration 2.13 Time series of faecal coliform concentrations from the Evans Head STP discharge (90th percentile limit in red)

The concentrations of TN in discharged effluent are generally 2 to 4 times higher than those measured at any site within Salty Lagoon. Thus, it appears that the majority of the nitrogen in discharged effluent is processed by the ecosystems occurring along the drainage channel upstream of Salty Lagoon (as described in the ERMP project, Hydrosphere 2010a). Supporting this theory is the fact that the nitrogen concentrations in Salty Lagoon continued to increase (as a result of evaporation) over the period between January and March 2014 when the channel from the STP was dry and not transporting water.

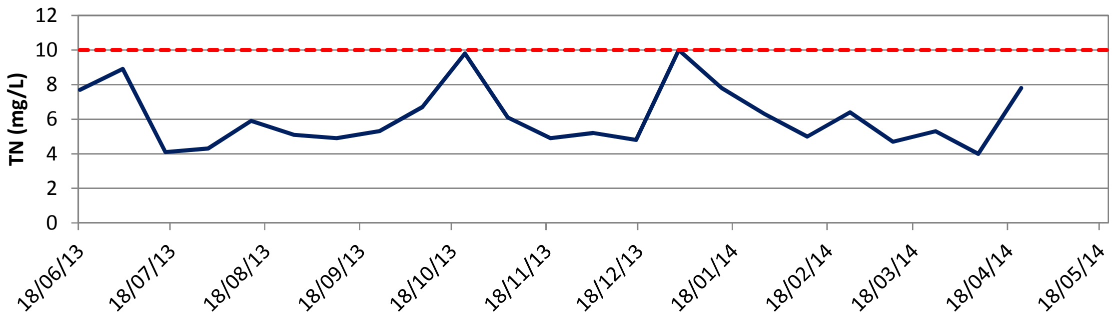


Illustration 2.14 Time series of TN concentration from the Evans Head STP discharge (90th percentile limit in red)

In contrast to TN concentrations, the concentrations of TP in discharged effluent are generally comparable to those measured at S2, where the drainage channel opens out into Salty Lagoon. Hydrosphere (2010a) found an increasing trend of TP concentration along the drainage channel from the STP to Salty Lagoon and linked it to the release of phosphorus stored in sediments after years of effluent discharge rather than a lack of ecosystem processing of phosphorus released from the STP along the drainage channel. It is likely that this is still the case and that it will continue for some time into the future.

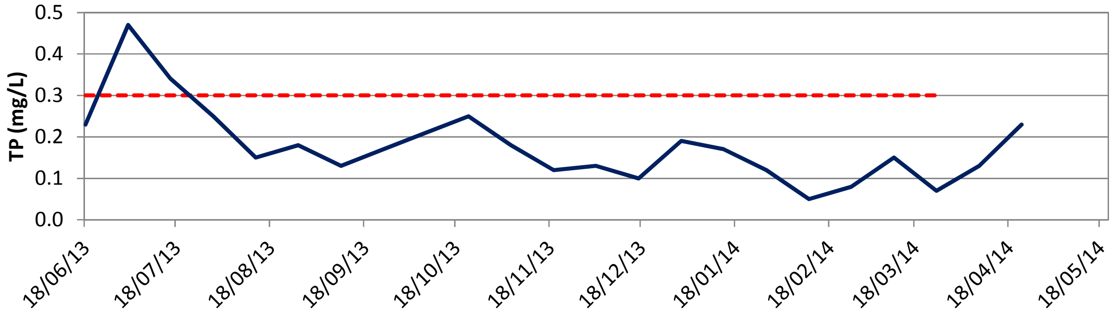


Illustration 2.15 Time series of TP concentration from the Evans Head STP discharge (90th percentile limit in red)

3

Macroinvertebrates

3.1 Introduction

Benthic macroinvertebrates are part of all aquatic systems, and fulfil various roles in the ecosystem and food chain. Benthic macroinvertebrate communities are known to respond, over relatively short timeframes, to changes in the physical, chemical and biological makeup of ecosystems. Different species of benthic macroinvertebrate communities are more or less tolerant to particular environmental conditions such as nutrient availability, water quality, depth, flow and various classes of pollution. For this reason they are widely utilised as an indicator of ecosystem health status and change (Boulton & Brock 1999).

In Salty Lagoon, benthic macroinvertebrate communities have previously been monitored to assess the effects of improvements to the operation and discharge from the Evans Head STP (Hydrosphere 2010a). The closure of the artificial channel between Salty Lagoon and Salty Creek was predicted to improve the diversity and robustness of communities and lead to related changes in the distribution and abundance of benthic macroinvertebrates (Hydrosphere 2010b). As a part of the MPPC project, benthic macroinvertebrate communities are being monitored to confirm predicted changes, inform assessments of ecosystem health and adaptive management and to contribute to the overall picture of medium to long term ecosystem change in Salty Lagoon following the closure of the artificial channel.

3.2 Methods

3.2.1 Site Location

Macroinvertebrates were collected from four sites within the study area (BM1 - BM4). The sites are distributed at points around the study area that broadly reflect the different physical, chemical and biological processes that occur in Salty Lagoon. The specific locations of all sites sampled are presented in **Table 3.1** and mapped in **Illustration 3.1**.

The four sites differ in respect to the benthic material present and the key physical, chemical and biological processes that drive them. For this reason the monitoring is designed to assess changes within sites over time as opposed to changes between sites. A description of the key factors present at each site is presented in **Table 3.1**.

Table 3.1 Description of benthic macroinvertebrate sites and their locations (WGS84)

Site	*Description*	*Easting*	*Northing*
BM1	This site is located near to the Salty Lagoon PWQMS. The benthic material is mostly silt and mud with some coarse organic matter. The surrounding vegetation consists mostly of Saltwater Couch (*Paspalum vaginatum*), although the nearby extent of this is reducing and Common Reed (*Phragmites australis*) is increasing. The average water levels at this site have increased since the closure of the artificial channel. During the drought conditions coinciding with the summer 2014 sampling event the water at this site became brackish.	0542065	6782781

Site	*Description*	*Easting*	*Northing*
BM2	This site is located near the outlet of the drainage channel from the STP into Salty Lagoon. The benthos at this site is dominated by coarse organic material bound by a low percentage of mud. Fallen branches from overhanging vegetation are common. The vegetation at this site is dominated by Cumbungi (*Typha orientalis*), Common Reed (*Phragmites australis*), Jointed Twig-rush (*Baumea articulata*), and Broad-leaved Paperbark (*Melaleuca quinquenervia*). Twigs, leaves, matted algae and fungal hyphae dominate sieved samples from this site. This site was mostly freshwater during the reporting period, though prior to drying out in January 2014 it became brackish. The site was dry during the summer 2014 sampling event. The quality of the freshwater changes at this site in response to dry times; when effluent discharge dominates, and wet times; when lower pH catchment runoff dominates.	0541981	6782659
BM3	This site is located in open water towards the northern end of Salty Lagoon. The benthic material consists of sand and silt, and organic matter is uncommon at this site. This site is affected the most by saltwater flow from Salty Creek. During the drought conditions coinciding with the summer 2014 sampling event, the water at this site became brackish. The nearest vegetation consists of Saltwater Couch, which is reducing in its nearby extent.	0542073	6783082
BM4	This site is located in the rushlands in the north-western part of Salty Lagoon. The benthic material is primarily coarse organic material bound by a low percentage of mud. Leaves, fungal hyphae and matted algae dominate sieved samples. The surrounding vegetation is in a state of rapid flux, with nearby saltmarsh vegetation receding rapidly and being replaced slowly by freshwater tolerant vegetation dominated by Saltwater Couch. The water quality in this part of the lagoon is dominated by freshwater runoff from the catchment and generally has a low pH. This site was dry during the summer 2014 sampling event.	0541738	6783005

3.2.2 Sample Collection

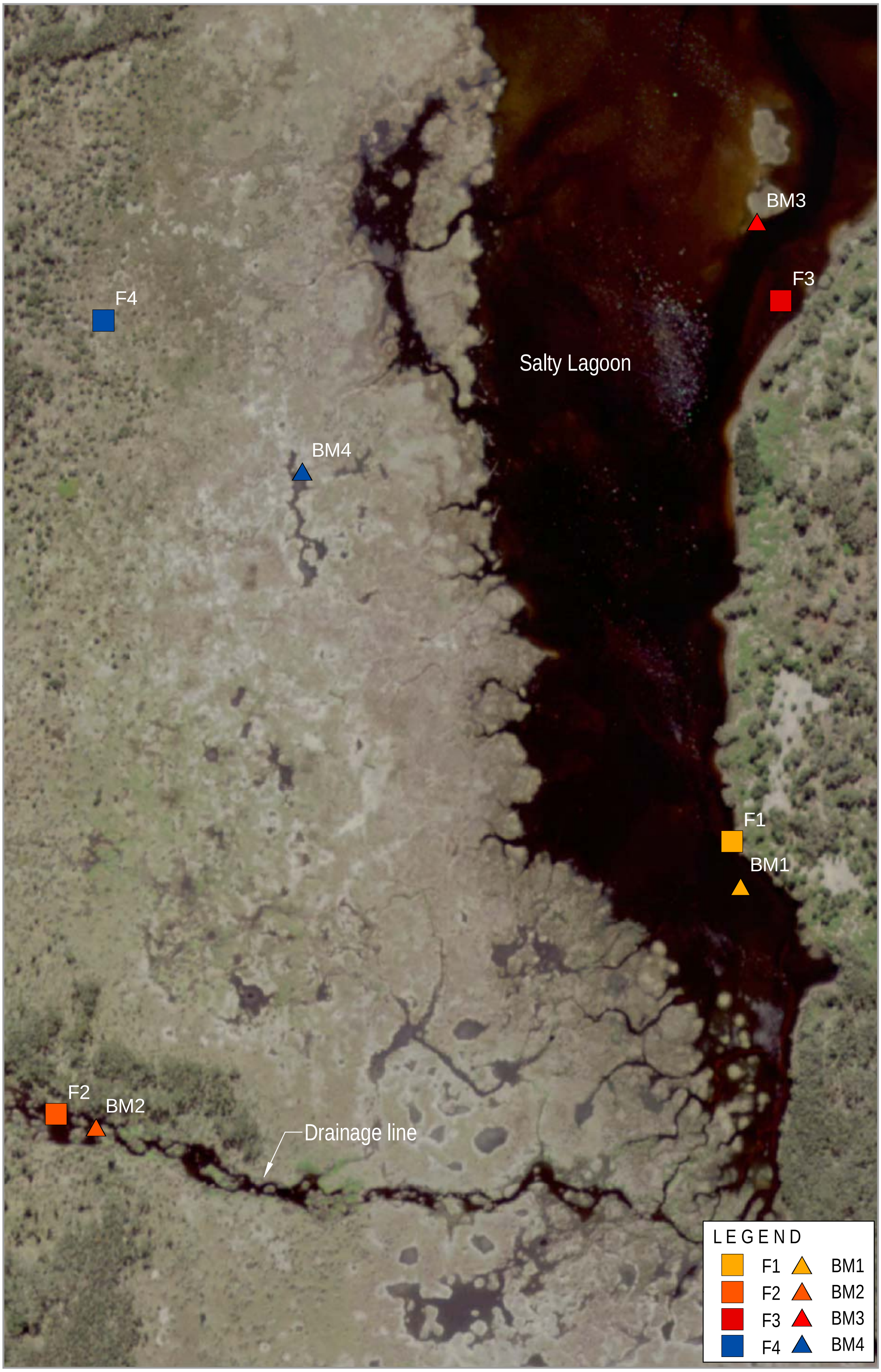
Benthic macroinvertebrates were sampled once per season. The dates of benthic macroinvertebrate collection were 9 July 2013, 15 October 2013, 13 January 2014 and 8 April 2014. At each of four sites, 3 benthic cores were collected at intervals of between 1 m and 2 m. The cores were taken using a 10 cm diameter round corer inserted to a depth of 10 cm. Cores were field rinsed over a 1 mm sieve using water from the immediate environment, prior to being transferred into a labelled sample bag with minimal water. Once all samples had been collected they were fixed with 70% ethanol solution and transported to the laboratory.

3.2.3 Sample Processing

At the laboratory, samples were re-rinsed over a 1 mm sieve and transferred into jars in a 70% ethanol solution. Samples were sorted over a binocular microscope and all fauna removed, identified to family level (subfamily level for non-biting midges (family: *Chironomidae*) and subclass for springtails (Collembola)), counted and stored. Pupating individuals were not included in counts, nor were invertebrates known to be terrestrial or restricted to the water surface. Sorted sediment was retained and 20% of the sorted sample checked for missed animals. If animals were found a further 20% was re-sorted until such time as no animals were found.

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: RE Reviewed by: TJP Date: 28/10/2014
Source of base data: Richmond Valley Council



Location of Benthic Macroinvertebrate and Fish Sites

GeoLINK environmental management and design

Annual Report 2014 - Salty Lagoon Monitoring Program:
Pre-Post Closure of Artificial Channel

Illustration 3.1

1731-1132

3.3 Results and Discussion

3.3.1 Conditions at the time of sampling

The conditions at the time of sampling were highly variable between seasons at each of the four sites. Water quality is among the most important environmental factors driving variability in benthic macroinvertebrate communities. A summary of water quality results collected from all sites on the survey days is presented in Table 3.2. The water levels varied widely between surveys with a difference of 0.59 m between the highest and lowest levels. Two sites were completely dry during the summer 2014 sampling event. Water temperature, conductivity and nutrient concentrations also varied greatly within sites and between sampling times.

Table 3.2 Water quality at all sites at the time of benthic macroinvertebrate sample collection

Site	*Survey*	*Date*	*Water Level (mAHD)*	*Temp (˚C)*	*pH*	*Cond (mS/cm)*	*TN (mg/L)*	*TP (mg/L)*
BM1	Winter 2013	9/07/2013	1.92	14.66	6.39	0.455	1.13	0.08
	Spring 2013	15/10/2013	1.75	21.83	6.95	1.22	2.27	0.41
	Summer 2014	13/01/2014	1.33	27.44	7.12	5.56	2.66	0.29
	Autumn 2014	8/04/2014	1.63	20.94	6.84	2.97	1.99	0.2
BM2	Winter 2013	9/07/2013	1.92	12.09	6.08	0.203	1.01	0.06
	Spring 2013	15/10/2013	1.75	20.32	6.4	1.17	2.37	0.37
	Summer 2014	13/01/2014	1.33*	-	-	-	-	-
	Autumn 2014	8/04/2014	1.63	20.18	5.19	1.09	1.29	0.05
BM3	Winter 2013	9/07/2013	1.92	14.87	6.42	0.537	1.14	0.08
	Spring 2013	15/10/2013	1.75	22.88	7.13	1.23	2.25	0.32
	Summer 2014	13/01/2014	1.33	30.37	8.45	5.62	2.69	0.16
	Autumn 2014	8/04/2014	1.63	21.16	7.17	3.4	1.81	0.17
BM4	Winter 2013	9/07/2013	1.92	11.95	4.66	0.416	1.3	0.05
	Spring 2013	15/10/2013	1.75	17.51	4.55	1.42	2.23	0.15
	Summer 2014	13/01/2014	1.33*	-	-	-	-	0.06
	Autumn 2014	8/04/2014	1.63	19.45	4.45	6.03	1.36	0.03

Note: Highest value of each parameter measured at each site reported in red and the lowest in blue.
Water levels reported are the average measurement from the Salty Lagoon PWQMS over the survey day.
Site BM4 is not located at the same position as water quality S4. However, it is part of the same functional area of Salty Lagoon and results are considered adequately representative.
* Site BM2 and BM4 dry during this sample

The main water quality factor providing background environmental variation during the benthic macroinvertebrate sampling events was the response of the system to drought conditions between September 2013 and March 2014. The drought conditions led to very low water levels at the time of the summer 2014 sampling event (dry at BM2 and BM4), higher than normal conductivities, nutrient concentrations and water temperatures at all sites and higher pH values at all sites.

3.3.2 Diversity

A total of 19 macroinvertebrate taxa have been identified from samples collected to date. Of the 19 taxa identified, five have only been observed in one of the thirteen seasonal surveys undertaken. Only fourteen of the 19 taxa were collected during the first five surveys of the MPPC. The list of all taxa collected and their presence throughout the various surveys is presented in Table 3.3. Only one of the 19 taxa collected to date has been observed in each of the thirteen surveys. An additional taxa has been collected in 12 of the 13 surveys and two others in 11 of the 13 surveys.

The most common taxa captured during the current reporting period were the *Chironominae*, *Hydrobiidae* and *Corixidae*. In the previous reporting period the most common taxa collected were the *Chironominae*, *Mytilidae* and *Spionidae* (Table 3.4). In the first annual reporting period the most common taxa were the *Chironominae*, *Spionidae*, *Hydrobiidae* and *Capitellidae*.

Table 3.3 Total number of Benthic Macroinvertebrate Taxa and Individuals captured during each survey

Survey	*Number Taxa*	*Number of Individuals*
Autumn 2011	6	43
Winter 2011	10	143
Spring 2011	7	14
Summer 2012	6	66
Autumn 2012	8	137
Winter 2012	9	43
Spring 2012	10	105
Summer 2013	7	159
Autumn 2013	8	303
Winter 2013	6	79
Spring 2013	11	136
Summer 2014	10	270
Autumn 2014	8	418

With respect to the whole system, the clearest changes over time have been the increase in the number of *Chironominae*, *Corixidae* and *Hydrobiidae* and a reduction in the number of spionid and capitellid polychaetes. The *Capitellidae* are found mostly at S3 and the reduction in observed abundance is likely to reflect the greater depths and more stable lower salinity since the closure of the artificial channel. A number of taxa have now been observed in numbers at all four sites, including the *Chironominae*, *Hydrobiidae* and *Sphaeromatidae* (see Table 3.4). These taxa appear to be adapting well to changing conditions.

Table 3.4 Annual totals of benthic macroinvertebrate taxa by site

Taxa	*Common Name*	*BM1*			*BM2*			*BM3*			*BM4*		
		2012	*2013*	*2014*	*2012*	*2013*	*2014*	*2012*	*2013*	*2014*	*2012*	*2013*	*2014*
Chironominae	Midge	19	7	318	98	137	43	23	23	197	2	3	12
Tanypodinae	Midge	0	0	0	0	0	0	0	0	0	2	1	3
Ceratopogonidae	Biting midge	10	1	0	0	2	2	0	1	1	3	0	0
Sialidae	Toebiters	0	0	0	0	0	0	0	0	0	1	0	0
Libellulidae	Dragonfly	0	0	0	5	4	0	0	0	0	2	0	1
Hemiphlebidae	Damselfly	1	0	0	0	0	0	0	0	0	0	0	0
Crambidae	Caterpillar	0	0	0	0	1	0	0	0	0	0	0	0
Hygrobiidae	Screech Beetle	0	0	0	0	0	0	0	0	0	1	0	0

Taxa	Common Name	BM1			BM2			BM3			BM4		
		2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
Hydrophiidae	Water Beetle	0	0	1	0	0	5	0	0	0	0	1	1
Dytiscidae	Diving Beetle	0	0	0	0	0	1	0	0	0	0	1	0
Corixidae	Water Boatmen	0	0	20	0	0	0	0	0	40	0	0	4
Collembola	Springtail	2	7	2	1	0	4	1	1	0	0	3	3
Capitellidae	Polychaete	5	2	4	0	0	0	42	14	17	0	0	0
Spionidae	Polychaete	92	8	11	1	0	0	11	91	26	2	0	0
Mytilidae	Mussel	1	85	4	1	0	0	3	172	56	0	0	0
Hydrobiidae	Snail	3	4	31	3	20	0	0	6	66	54	1	5
Planorbidae	Snail	0	0	0	0	1	0	0	0	0	0	0	4
Sphaeromatidae	Isopod	0	4	5	3	1	0	1	5	16	9	3	0
Hymenosomatidae	Crab	0	0	0	0	0	0	1	0	0	0	0	0
Total animals		133	118	396	112	166	55	82	313	419	76	13	33
Total taxa		9	9	10	8	8	6	8	9	9	10	8	9

The diversity of taxa in macroinvertebrate samples varied within sites over time. However, there are no obvious patterns in the variation of species diversity with respect to either seasonal changes or environmental conditions at the time of sampling. At BM1 and BM3 the diversity of captured animals appears to have increased slightly since the beginning of the MPPC though the results are not conclusive (Illustration 3.2). At BM2 and BM4 there are no apparent trends overall. The lower numbers of animals captured at these sites (see Section 3.3.3) may contribute to difficulties in determining any changes that are occurring.

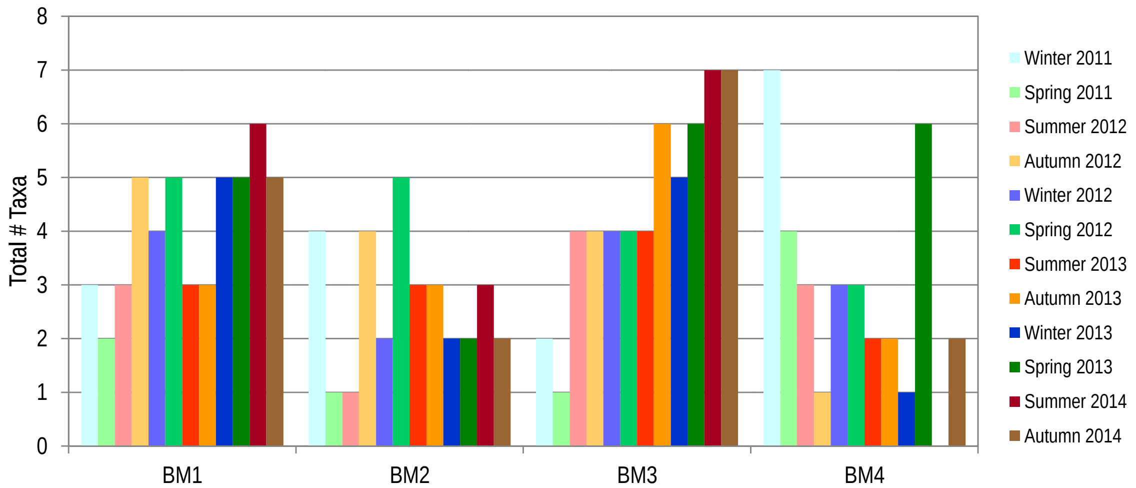


Illustration 3.2 Total number of taxa captured at each of the four sites in surveys since winter 2011

3.3.3 Abundance

The numbers of benthic macroinvertebrates captured at each site have varied over time (Illustration 3.3). However, there are no clear patterns evident in the data set. The largest total numbers of individuals were chironomids captured at BM1 and BM3 in summer and autumn 2014, mussels captured at BM3 in autumn 2013, and spionids captured at BM1 in winter 2011 and BM3 in spring 2012. Low abundances have persisted at BM4 since the beginning of the MPPC.

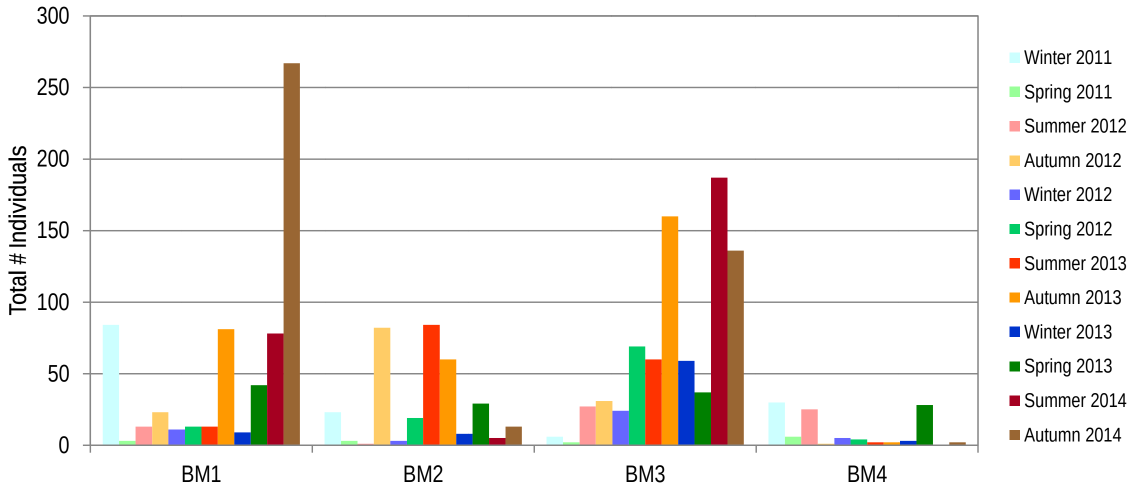


Illustration 3.3 Total number of animals captured at all sites in surveys since winter 2011

At BM1 there does not appear to be a trend with respect to abundance. However, except for large numbers of *Spionidae* observed in the winter 2011, *Mytilidae* observed in the autumn 2013 sample and *Chironominae* in spring 2013, summer 2014 and autumn 2014 surveys, the numbers have been relatively stable since the beginning of the MPPC. As Salty Lagoon continues its conversion to a predominantly freshwater system, there may be a change in the species makeup, with a reduction in the numbers of taxa that prefer brackish water, such as *Spionidae*, to taxa more aligned with freshwater such as *Chironominae* and *Hydrobiidae*.

At BM2 there does not appear to be a trend with respect to abundance. The majority of the variation in the total number of individuals is explained by the number of *Chironominae* and *Hydrobiidae* captured. The variation cannot be attributed to seasonal factors at this stage of the project, nor is it adequately explained by the collected environmental factors.

At BM3 there is no apparent pattern to the variation of abundance (Illustration 3.3). As with the other sites the variation is mostly explained by short term spikes in the numbers of individual taxa. There has been an increase in the numbers of freshwater taxa such as *Hydrobiidae* and *Chironominae* since the closure of the artificial channel but this has not been accompanied by an obvious decrease in the numbers of brackish water taxa such as *Spionidae* and *Capitellidae*.

At BM4 there appears to be a general trend towards decreasing abundance (Illustration 3.3), though abundances have generally been low since the beginning of the MPPC.

3.3.4 Conclusions

There has been continued variation in the diversity, abundance and makeup of benthic macroinvertebrates collected during seasonal surveys. Benthic macroinvertebrate surveys are providing insight into the changes occurring in Salty Lagoon as a result of the closure of the artificial channel.

At each site there have been variations in the numbers of macroinvertebrate taxa captured between seasons, indicating temporal fluctuations in diversity around Salty Lagoon. However, as with the previous reporting periods there are no clear patterns of association with seasonal or measured environmental changes that can be concluded with certainty.

There has also been considerable variation in the numbers of individual macroinvertebrate captured at each site over time, indicating that macroinvertebrate abundance has fluctuated throughout Salty Lagoon during the reporting period. The direction of change has varied over time and between sites. Again there is no clear evidence that the variation is strongly linked to either seasonal changes or short term water quality changes. Continued monitoring should allow for stronger conclusions to be made.

The specific makeup of benthic macroinvertebrate communities continues to change over time. It appears that taxa usually associated with freshwater are increasing in abundance in the open water area of Salty Lagoon and taxa associated with brackish water are decreasing in abundance at one site in Salty Lagoon. The trend is reflective of a shift from an intermittently open and closed waterbody to a freshwater wetland. The reduction in the numbers of capitellid and spionid polychaetes collected and increased numbers of hydrobiid snails and chironomids are good indicators of this. Again, continued monitoring will improve the clarity from which reliable conclusions can be drawn.

The observed variation in abundance and diversity of taxa may reflect a response to a combination of a large number of factors. Some of these factors include:

- Stochastic factors associated with the sampling procedures.
- Long term changes in the environment due to improved sewage treatment at the Evans Head STP.
- Long term changes to the environment due to reduced variation in salinity.
- Short term changes to the environment resulting from seasonal changes and the weather, such as the drought conditions prevalent between September 2013 and March 2014.

In attempting to understand the observed variation in diversity and abundance it should be noted that the above factors complicate data interpretation and are likely to be working in combination rather than as individual impacts. However, it is likely that future results will show a lower degree of variability as the environment in and around Salty Lagoon stabilises.

Plate 3.1 Core sampling for benthic macroinvertebrates at BM4 during the drought

4

Aquatic Vegetation / Weeds

4.1 Introduction

Aquatic weed invasion is considered a significant risk during the period following the closure of the artificial channel as Salty Lagoon makes the transition to a permanently fresh water system. In order to assess the response of aquatic vegetation to the changes and to provide a mechanism for adaptive management of aquatic weeds a regular survey is undertaken as part of the MPPC program. Incidental observations of aquatic weeds noted during the monthly site inspections are also recorded.

4.2 Methods

Aquatic weeds were monitored on a seasonal basis across all seasons except winter. The dates of the aquatic weed surveys undertaken during this reporting period are 15 October 2013, 13 January 2014 and 8 April 2014.

The aquatic weed surveys involved following a meandering transect selected to cover most of the open water areas of Salty Lagoon. Each species of aquatic plant, weedy or otherwise, encountered during the survey was recorded. The position of any aquatic weed encountered was recorded with a hand held GPS unit and the aerial extent of the weed population estimated and recorded. Plants that could not be identified in the field were sampled and transported back to the laboratory for identification.

The pathway of the meandering transect was recorded using the tracking feature of a handheld GPS set to track points at intervals of 20 seconds. The approximate transect pathways used during weed surveys and the location and species of all aquatic weeds encountered is displayed in Illustration 4.1.

4.3 Results

There have been no invasive aquatic plants or introduced aquatic plants identified in the aquatic weeds surveys. A total of 26 types of plant have been observed during the surveys since the beginning of the MPPC. Of these, 19 were observed during the current reporting period (refer to Table 4.1). Two types of plant sometimes regards as nuisance plants have been encountered. These were blue green algae (BGA, various species) and Ferny Azolla (*Azolla pinnata*). Both have been observed at a reduced frequency since the closure of the artificial channel.

During the aquatic weed surveys a list of all aquatic plant species encountered was collected and a basic estimate of their abundance made. The list of aquatic plant species encountered is shown in Table 4.1.

Table 4.1 List of all aquatic plant species detected during aquatic weed surveys and an assessment of their abundance.

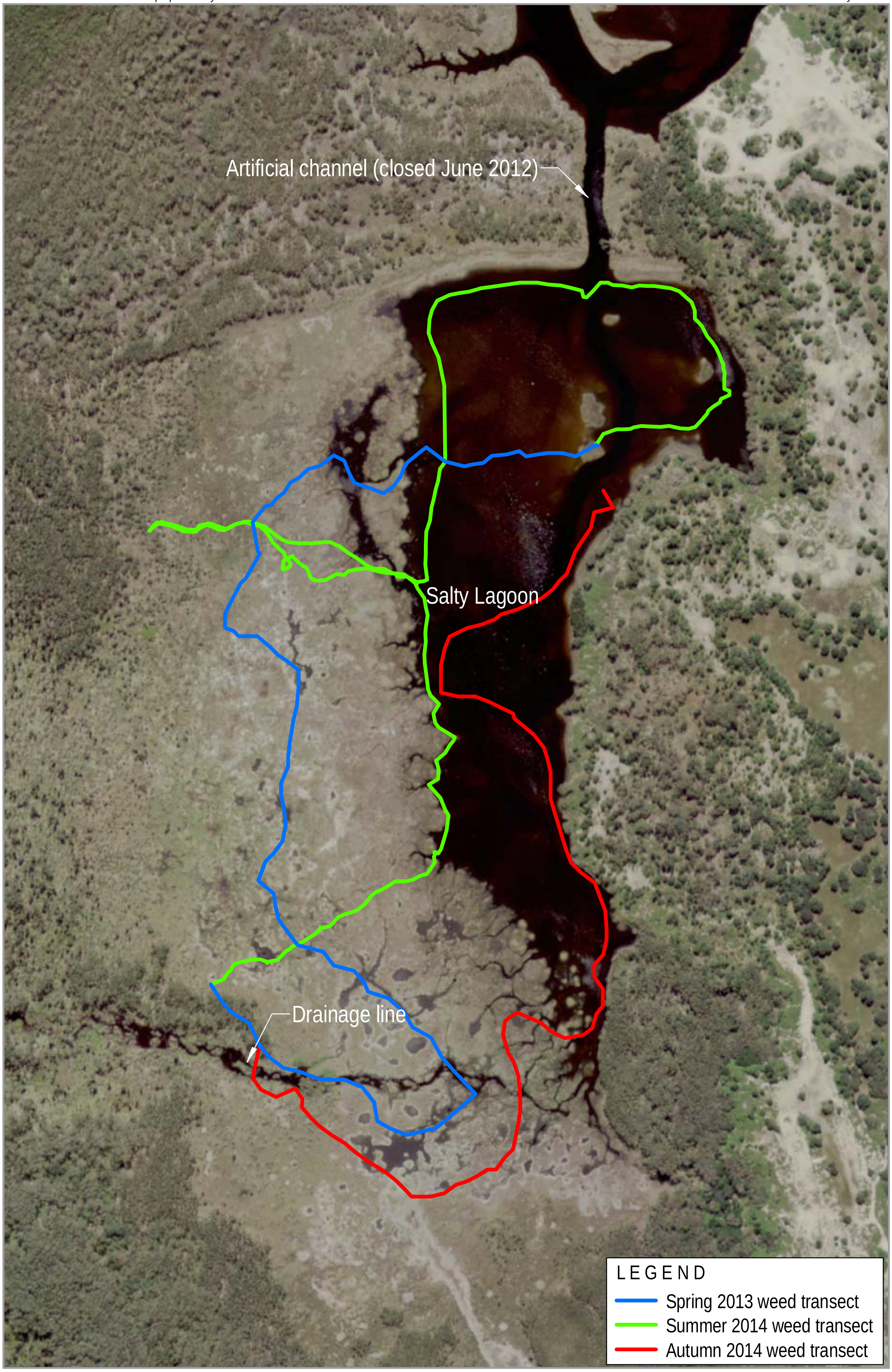
Species Name	*Common Name*	*Survey*									
		Aut ‘11	*Spr ‘11*	*Sum ‘12*	*Aut ‘12*	*Spr ‘12*	*Sum ‘13*	*Aut ‘13*	*Spr ‘13*	*Sum ‘14*	*Aut ‘14*
Avicennia marina	Grey Mangrove	UC	UC	UC	UC	UC					
Sesuvium portulacastrum	Sea Purslane	UC	UC								
*Hydrocotyle bonariensis^*	A Pennywort		UC			UC			C	UC	C
Lomandra sp.	A Mat-rush							UC			
Enydra fluctuans	Buffalo Spinach	UC	UC					UC	C	UC	C
Lobelia anceps	Angled Lobelia	UC		UC							
Sarcocornia quinqueflora	Bead Weed	UC	UC								
Suaeda australis	Seablite	UC									
Baumea articulata	Jointed Twig-rush		UC				UC	UC	UC		
Baumea sp.	A Rush								UC	C	C
Cyperus exaltatus	Giant Sedge	UC		UC							C
Cyperus difformis	Dirty Dora	UC		UC	UC		UC	UC		C	VC
Gahnia sieberiana	Red-fruit Saw-sedge						UC	UC	UC		UC
Shoenoplectus validus	River Club-rush	VC	VC	VC	VC	VC	C	C		C	C
Shoenoplectus mucronatus	A Rush	VC	VC	UC	UC						C
Juncus krausii	Sea Rush	VC	VC	VC	VC	VC	VC	C	C	C	UC
Juncus usitatus	Common Rush						UC		C		
Lemna sp.	Duckweed								UC		
Bacopa monnieri	Bacopa	C	VC	C	UC	C	C	UC	C	C	VC
Diplachne fusca	Brown Beetle Grass										VC
Paspalum vaginatum	Saltwater Couch	VC	VC	VC	VC	VC	VC	VC	VC	VC	VC
Phragmites australis	Common Reed	VC	C	C	C	C	C	C	C	C	VC
Sporobolus virginicus	Saltwater Couch	C	C	C	C						

Species Name	*Common Name*	*Survey*									
		Aut '11	*Spr '11*	*Sum '12*	*Aut '12*	*Spr '12*	*Sum '13*	*Aut '13*	*Spr '13*	*Sum '14*	*Aut '14*
Persicaria decipiens	Slender Knotweed		UC								
Rhizophora stylosa	Red Mangrove	UC									
Azolla pinnata	Ferny Azolla	UC	VC	UC	UC	UC	UC	UC	UC		
Typha orientalis	Cumbungi		UC	UC		UC	UC	UC	C	C	UC
Enteromorpha sp.	Enteromorpha					C	VC		VC		
Various	Blue Green Algae	C	C	C	UC	UC					

Note UC = Uncommon, C = Common, VC = Very Common
^ Introduced Species

Drawn by: GJM Checked by: RE Reviewed by: TJP Date: 28/10/2014
Source of base data: Richmond Valley Council

Information shown is for illustrative purposes only



Aquatic Weed Transects

Illustration 4.1

GeoLINK environmental management and design

Annual Report 2014 - Salty Lagoon Monitoring Program:
Pre-Post Closure of Artificial Channel

1731-1133

4.4 Discussion

Despite the significant disturbance to the Salty Lagoon ecosystem caused by the closure of the artificial channel, the aquatic weed surveys undertaken to date have not resulted in the detection of any introduced species of aquatic weeds. Despite this, the risk of weed invasion into Salty Lagoon remains, particularly as the system continues the transition to a freshwater ecosystem.

During this reporting period a number of species not previously observed were recorded and other species previously observed were not recorded. Of the species identified prior to, but not during, the current reporting period, the majority are saltmarsh specialists, such as Seablight, Sea Purslane, Bead Weed and Saltwater Couch. The reduced number of observations of these plants is an expected result of the increased water depths and dominance of freshwater in Salty Lagoon following closure of the artificial channel.

The targeted weed surveys, in addition to incidental observations made during normal monthly sampling, are a cost effective way to address the continuing risk of aquatic weed invasion and to assess vegetation changes over a relatively short time scale.

Plate 4.1 Flowers of the Broad-leaved paperbark (*Melaleuca quinquinerva*)

Plate 4.2 Flowers of the Giant Sedge (*Cyperus exaltatus*) in the south western part of Salty Lagoon

5 Fish

5.1 Introduction

Fish are monitored as part of the MPPC due to their iconic status, importance to ecosystems and sensitivity to environmental change. The fish populations of Salty Lagoon are expected to be impacted positively in the long term as a result of the closure of the artificial channel (Hydrosphere 2010b). The aims of sampling fish fauna throughout the MPPC project are as follows:

- To confirm predicted positive effects of closing the artificial channel upon fish fauna.
- To monitor for potential negative impacts arising from closure of the artificial channel.

Prior to the closure of the artificial channel, Salty Lagoon operated as part of an ICOLL (intermittently open and closed lakes and lagoons) and regular changes in the fish populations resulted in response to the entrance status and rainfall runoff. This is typical of ICOLLs, where fish populations are highly variable (Hadwen & Arthrington 2006).

In the first year after the closure of the artificial channel, the water level in Salty Lagoon stabilised higher and the salinity regime was less variable. However, there were still occasions where saltwater ingress led to periods of higher salinity. During this reporting period the water level in Salty Lagoon became very low as a result of drought conditions. The evaporation that caused the low water level also led to a distillation effect, increasing conductivity and nutrient concentrations. Temperature fluctuations during this time were larger than those that occur when the water level is higher. In addition to the above changes in the hydrological and water quality regime there were two occasions where saline water flowed in from Salty Creek and led to increased conductivity measurements.

Plate 5.1 Flathead gudgeons (*Philypnodon grandiceps*) found at the Salty Lagoon PWQMS

The fish populations of Salty Lagoon had been sampled on a small number of occasions prior to the beginning of the MPPC (listed in Hydrosphere 2010a & b). The results of these surveys were used to describe the impacts of physical and chemical processes operating as a result of changes to the effluent quality from the Evans Head STP and the hydrological connection to Salty Creek. A wide variety of sampling methods have been applied including bait traps, dip nets, backpack electrofishers and seine nets. Bait traps, whilst not the most effective nor representative measure have proven the most consistent in terms of their applicability across all of the available habitat types and during all phases of water quality cycles (Hydrosphere 2010b). For this reason they have been selected as the method for continuing monitoring of Salty Lagoon.

It is important to note that the structure of the sampling effort set up for the duration of the MPPC facilitates comparison of samples from individual sites over time as opposed to comparisons of results between sites.

5.2 Methods

5.2.1 Site Selection

Fish fauna are sampled at four separate sites within Salty Lagoon. The sites were selected in order to cover the major physical, chemical and ecological zones throughout the lagoon. The location of the sites is presented in **Illustration 3.1**. A brief description of each site is given in **Table 5.1**. As expected, some of the sites have changed with respect to habitat and conditions in response to the higher water levels and greater influence of freshwater since the closure of the artificial channel.

Table 5.1 A description of the fish sampling sites in Salty Lagoon being used for the duration of the MPPC.

Site	*Habitat*	*Hydrological Regime*
F1	The traps at this site were set along the eastern edge of the lagoon among sparse River Club-rush (*Shoenoplectus validus*) and Sea rush (*Juncus krausii*) and the roots of Broad-leaved Paperbark trees (*Melaleuca quinquinerva*). The banks of the lagoon at this position are relatively steep with small overhangs under the water surface. The sediment is a mixture of mud and sand.	This part of the lagoon was formerly subject to significant saltwater ingress and following this a stratified water column was common. Since closure of the artificial channel this part of the lagoon has been subject to infrequent low level saltwater ingress.
F2*	This site is an area of shallow ponded open water where the drainage channel from the STP traverses rushlands in the SW part of the lagoon. The vegetation around the pond is dominated by Jointed Rush (*Baumea articulata*), Saw Sedge (*Ghania sieberiana*) and Cumbungi (*Typha orientalis*), but also includes Sea Rush and Saltwater couch (*Paspalum vaginatum*). There are a number of snags in the channel and the bank at this point slopes gently. The sediment is a mixture of mud and coarse organic detritus.	This site has always been predominantly freshwater, dominated during most times by input from the Evans Head STP. Saltwater ingress past this point in the Lagoon has been recorded at times but very rarely since closure of the artificial channel. This site was dry between December 2013 and March 2014.
F3	The traps at this site were set along the eastern edge of the lagoon among sparse River Club-rush and overhanging branches. There are a few large snags amongst the site. The bank of the lagoon at this position is gently sloping. The sediment is a mixture of mud and sand.	This part of the lagoon was previously subject to significant saltwater ingress and following this a stratified water column was common. Since closure of the artificial channel this part of the lagoon has been subject to infrequent low level saltwater ingress.
F4	This site is a series of small pools of open water in a low lying area that drains water from a paperbark swamp forest to the NW of the lagoon. The pools are lined mostly with Common Reed (*Phragmites australis*), Sea Rush and Broad-leaved Paperbark. The sediment is a mixture of mud and coarse organic detritus.	This site was always dominated by freshwater input from the catchment. Seawater ingress at this point in the lagoon only occurred very rarely and under specific circumstances. This site was dry between November 2013 and March 2014.

* This site was sampled previously as part of the ERMP (Hydrosphere 2010b)

5.2.2 Timing

Fish fauna are sampled on a seasonal basis once during every three month period. In the current reporting period fish were surveyed on 8 July 2013, 15 October 2013, 13 January 2014 and 8 April 2014. The traps are generally set within 2.5 hours of dawn and collected within 2.5 hours of dusk. Due to license conditions imposed by Industry and Investment NSW (I&I now DPI) the traps are not able to be set through the night as they were during previous monitoring within Salty Lagoon.

5.2.3 Capture and Handling

Fish fauna were sampled under Scientific Collection Permit (P11/0012-1.0) and Animal Research Authority (11/924). Five standard bait traps were set at intervals of between 2 m and 5 m at each site, depending on the available habitat. The traps were baited with a mixture of aniseed scented fish pellets and tinned sardines and left unattended for the day. Upon collection captured fauna were identified and counted prior to being released. At least one photo of each native finfish species encountered was taken. In keeping with licence conditions non-native fauna were euthanised in ice slurry. To minimise the stress upon fauna during counting and identification, traps were left in a suitable depth of water until they were emptied and physical handling of fish was kept to a minimum.

5.3 Results

5.3.1 Conditions at the time of monitoring

Environmental variables such as water quality and depth are likely to significantly affect the distribution of fish in Salty Lagoon. The temperature, conductivity, average dissolved oxygen (DO) concentration and water depth at the Salty Lagoon PWQMS are all listed in **Table 5.2** along with the rainfall in the 72 hours prior to sampling. The water quality measurements collected at the Salty Lagoon PWQMS are not always representative of water quality conditions at all sites. In particular, DO concentrations can vary significantly at different locations and at different points in the water column. The water quality at F2 and F4 is often very different to the water quality at F1 and F3.

Table 5.2 Water quality and rainfall information at the time of surveys.

Survey	*Date*	*Temp (°C)*	*Cond (mS/cm)*	*DO (mg/L)*	*Depth (mAHD)*	*72 Hr Rain (mm)*
Winter 2013	8/07/2013	14.86	0.48	5.70	1.92	0
Spring 2013	15/10/2013	22.92	1.14	7.56	1.75	0
Summer 2014	13/01/2014	30.14	5.45	0.30	1.33*	0.4
Autumn 2014	8/04/2014	21.96	3.08	8.15	1.63	60.4

Note: Water quality and depth expressed as averages of readings taken at the Salty Lagoon PWQMS over the time of trap deployment.
* F2 and F4 dry at the time of this survey. No traps were deployed at these sites as a result.

5.3.2 Fish Diversity

The number of fish species captured at each site has been used as a measure of fish diversity. Whilst not representative of the entire fish fauna of the system, the fish captured in bait trap surveys are indicative of the broader diversity.

A variety of vertebrate and invertebrate fauna were captured during the surveys including fish, crustaceans, snails and insects. However, reporting for fish surveys will focus on the targeted finfish species and does not include the invertebrates captured. Across all surveys during the reporting period a total of four finfish species were captured. This is lower than the five species captured during the previous annual reporting period and the eight species captured during the first annual reporting period. A list of fish species captured since the beginning of the MPPC is presented in **Table 5.3**. All species on the list were also caught during bait trap fish surveys undertaken as part of the ERMP (Hydrosphere 2010a).

Variation in the diversity of fish species captured at each site since the beginning of the MPPC is displayed in **Illustration 5.1**. The number of species captured at each of the sites has varied over time. There is no clear pattern to the observed variation, with the exception of F4 where fish diversity appears to have increased over time. The diversity of captured fish at F4 was the highest since the beginning of the MPPC prior to the site drying out. No fish were captured at F2 or F4 in autumn 2014 after those sites dried out in summer 2014. Excluding the results of the summer 2014 survey, there appears to be a trend of reduced diversity at F1 and F3 since the beginning of the MPPC.

Table 5.3 A list of fish species captured during fish surveys since the beginning of the MPPC

Family	*Species*	*Common Name*	*04/11*	*07/11*	*10/11*	*01/12*	*04/12*	*07/12*	*10/12*	*01/13*	*04/13*	*07/13*	*10/13*	*01/14*	*04/14*
Anguillidae															
	Anguilla reinhardtii	Longfin Eel	*				*								
Eleotriidae															
	Gobiomorphus australis	Striped Gudgeon	*	*	*	*	*	*		*	*	*	*	*	*
	Hypseleotris compressa	Empire Gudgeon					*						*	*	
	Hypseleotris galii	Firetail Gudgeon				*									
	Philypnodon grandiceps	Flathead Gudgeon			*		*				*	*	*	*	
	Philypnodon macrostomas	Dwarf Flathead Gudgeon	*		*	*	*			*	*				
Gobiidae															
	Afurcagobius tamarensis	Tamar River Goby			*	*	*			*	*				
Poecilidae															
	Gambusia holbrooki	Mosquito Fish^	*	*	*	*	*			*	*	*	*	*	*

^ Introduced Species

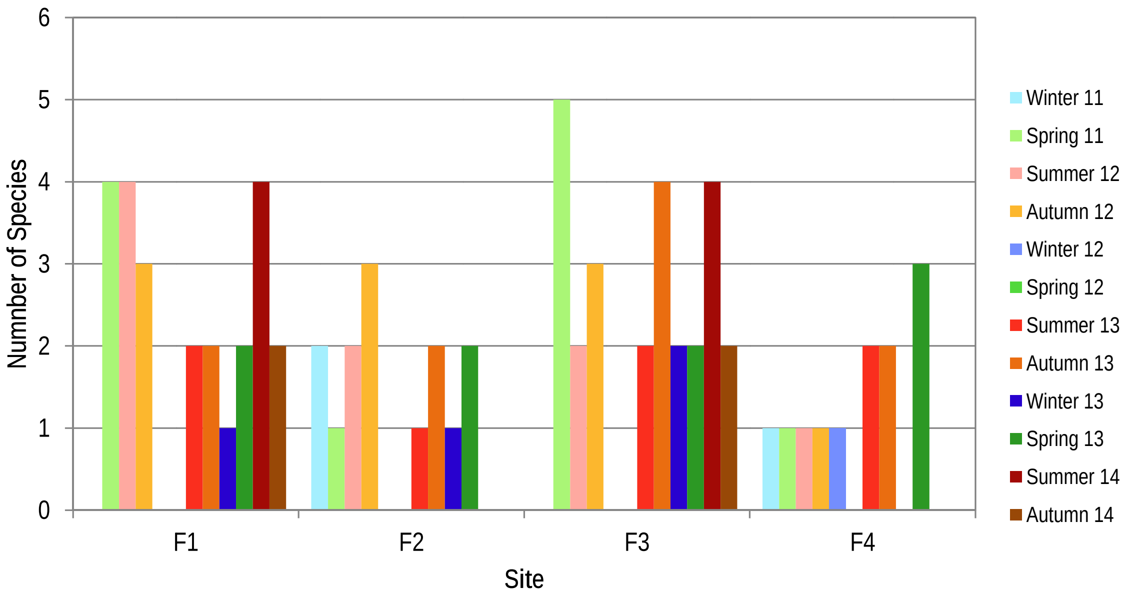


Illustration 5.1 Number of finfish species captured at each site in surveys undertaken since winter 2011.

5.3.3 Abundance

The number of individual fish captured at each site is used as a measure of abundance for the duration of the project. There was wide variation in the number of fish captured at each site over time (**Illustration 5.2**). With respect to the number of individual fish captured, the only patterns evident from the assembled data are:

- Lower numbers of fish captured during the winter surveys.
- No fish captured at F2 and F4 in the summer and autumn surveys, following six months of very dry conditions.
- Very high numbers of fish captured in the summer 2014 survey following six months of very dry conditions, particularly at F3.

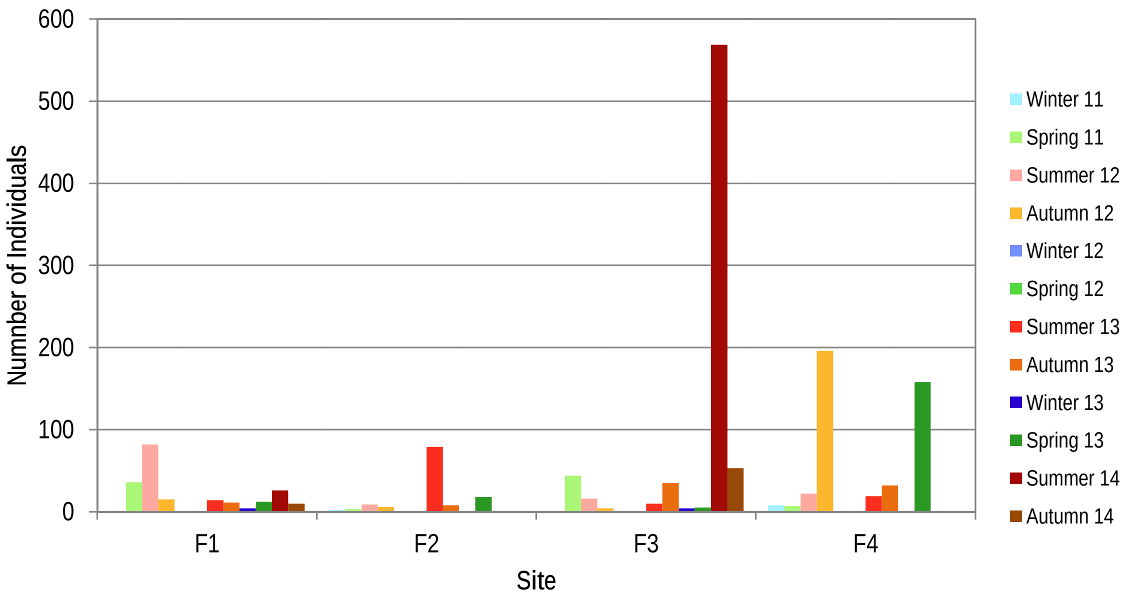


Illustration 5.2 Number of finfish individuals captured at each site over the five sampling periods undertaken since the winter 2011 survey.

The large fluctuations in the numbers of fish captured at F2 and F4 can be attributed to differences in the numbers of Mosquito Fish (*Gambusia holbrooki*). The very high numbers of fish captured at S3 in the summer 2014 survey were mostly Empire Gudgeon (*Hypseleotris compressa*).

5.4 Discussion

Fish monitoring provides another useful measure of the status of the Salty Lagoon system. Because of the differences between the available habitats and the water quality at each site, the fish monitoring program is designed to facilitate comparison of changes within sites over time rather than changes between sites. Whilst the responses of fish to environmental changes vary among species, due to their mobility and longer breeding cycles, fish tend to be more difficult to detect over the short term compared with benthic invertebrates. However, although the Salty Lagoon fish monitoring program is relatively small in scale, over the long term it should prove sufficient to confirm or reject predicted changes to the fish fauna.

A considerable degree of within site variation in fish abundance and diversity has been detected during the twelve fish surveys undertaken thus far. Detecting long-term trends in the variation of fish communities using the data at hand is complicated by the variation in background factors such as hydrology and water quality. For example, the drying out of the wetlands to the west of Salty Lagoon caused by the drought conditions between September 2013 and March 2014 led to Salty Lagoon being utilised as a drought refuge, as evidenced by the high numbers and greater diversity of fish captured at F1 and F3 in the summer 2014 survey. The same conditions led to a drying out of sites F2 and F4 and no fish were captured at either of these sites during the summer 2014 and autumn 2014 surveys. However, discounting these effects attributable to the drought conditions, there does appear to be a detectable trend of reduced diversity of fish captured at F1 and F3 and a detectable trend of increased diversity at F4. Both of these trends are expected results of the channel closure, as water levels stabilise at F4 and variation in the hydrological and water quality regime at F1 and F3 reduces. In keeping with this hypothesis the overall diversity of fish captured at all sites combined has decreased since the closure of the artificial channel. It would appear that there is a reduction in the number of species generally associated with brackish water utilising Salty Lagoon following the closure of the artificial channel.

Fish abundance was expected to increase at most sites as hydrological and water quality conditions stabilise in response to closure of the artificial channel. Fish abundance at each site has varied since the beginning of the MPPC but there has not been a clear trend to the observed variation. There are a number of factors that may be impacting results at the scale of the individual site in addition to the general changes to the Salty Lagoon ecosystem that have occurred since the closure of the artificial channel. These include:

- Stochastic factors associated with fish capture.
- Fluctuating water levels. This factor is particularly relevant in consideration of the results from the summer 2014 survey. At this time, most of the wetlands in Broadwater National Park were dry, as were sites F2 and F4. The results from F1 and F3 indicate that Salty Lagoon was acting as a drought refuge for fish from the surrounding wetlands as high numbers and diverse species were captured during that survey.
- Continued fluctuation in conductivity at F1 and F3. The conductivity of the water in Salty Lagoon has not been as stable as may have been expected due to a number of incidences where saline water stored in Salty Creek has flowed back into the lagoon after rainfall events. The water quality changes associated with these events may be impacting fish populations and preventing stable colonisation of the available habitats.
- Short term impacts on fish populations resulting from independent variations in DO concentration and temperature occurring immediately prior to fish surveys.
- Temporary changes in the density of fish populations at the chosen sites resulting from the fluctuations of available habitat associated with increases and decreases in the water level.

It is likely that a combination of the above factors, and others, explains the majority of the variation.

The conditions at the time of monitoring varied between the four surveys undertaken. The key variations were in the water level, water temperature, conductivity and dissolved oxygen concentration. In comparison with the previous annual reporting period, variations in water level, temperature and dissolved oxygen concentrations were larger and variations in conductivity were similar. As discussed, the variability of conditions at the time of sampling contributes significantly to the complexity of the dataset. Continued sampling over the long term will increase the capacity to draw conclusions.

The abundance and diversity of species trapped was low. The largest number of species trapped at any one site during this reporting period was four. Despite this, the results were comparable to those reported from previous surveys using bait traps (GeoLINK 2012, Hydrosphere 2010a) and are reflective of coastal lagoons and ICOLLs in general. The lowest numbers and diversity continue to be measured during the winter periods. Some of this observed variation can be attributed to seasonal changes in abundance but shallow water bodies such as Salty Lagoon typically display this type of temporal pattern of variation due to low temperatures experienced during winter and autumn. Fish, being cold blooded (poikilothermic), tend to be much less active in cold water temperatures and therefore less susceptible to trapping.

6

Waterfowl

6.1 Introduction

Waterbirds are an important part of wetland ecosystems. The particular range of species found in any one system depends on a range of physical and biological characteristics. Prior to the closure of the artificial channel Salty Lagoon provided a range of feeding and nesting habitats for waterfowl, waders and shorebirds, depending upon the water level. In the first year after channel closure the water level stabilised, leading to a dominance of waterfowl and waders. During the current reporting period the water levels have fluctuated more.

Waterbirds are included in the MPPC project because they can be monitored with relative ease and may compliment other monitoring procedures undertaken.

6.2 Methods

6.2.1 Timing

Water bird surveys were completed on a seasonal basis once every three months. The dates of surveys during the current reporting period were 14 January 2013, 15 October 2013, 13 January 2014 and 8 April 2014.

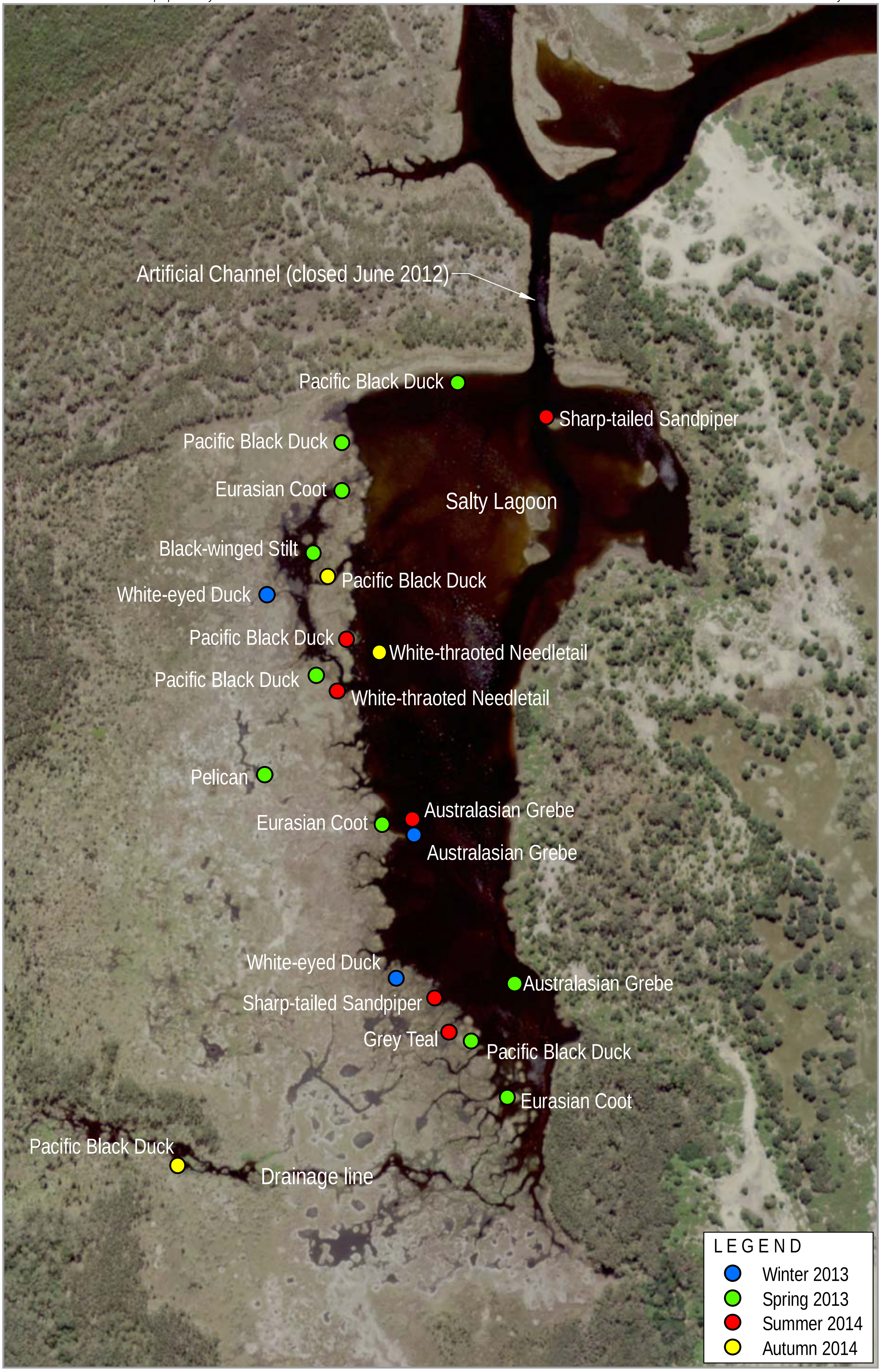
Plate 6.1 A Black-fronted Dotterel (*Elseyornis melanops*) on the banks of Salty Creek

6.2.2 Surveys

Waterbird monitoring involved a foot or canoe based traverse of open water and fringing rushlands in Salty Lagoon over the course of one hour. Water bird surveys are completed within two hours of dawn. Birds were identified using a field guide (Simpson & Day 1999) and counted using Bushnell 8 x 42 binoculars. All birds were included in the count, including non-waterbirds. However the focus of discussion relating to changes in bird assemblages on Salty Lagoon focuses on waterbirds. All possible efforts were made to avoid counting individual birds or flocks twice. Where flocks of >8 birds were observed, a GPS mark was taken. These are displayed in Illustration 6.1.

Drawn by: GJM Checked by: RE Reviewed by: TJP Date: 28/10/2014
Source of base data: Richmond Valley Council

Information shown is for illustrative purposes only



Mapped Locations of Bird Flocks

Illustration 6.1

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Pre-Post Closure of Artificial Channel

1731-1134

6.3 Results

6.3.1 Conditions at the time of Monitoring

Environmental conditions at the time of survey greatly affect the avifauna present. Water level is important to habitat availability in Salty Lagoon, the most notable example being the expansion of mud flats as water levels recede and a subsequent increase in feeding habitat for wading birds. Weather patterns prior to and during surveys are also important, as is the time of survey. The state of these factors at the time of sampling is shown below in **Table 6.1** and **Illustration 6.2**

Table 6.1 Environmental conditions at the time of waterfowl monitoring.

Survey	*Date*	*Water Depth (mAHD)*	*72 Hour Rainfall (mm)*	*Weather*	*Wind*
Winter 2013	14/07/2013	1.97	3	Light Cloud	Light WSW
Spring 2013	15/10/2013	1.76	0	Fine	Light S
Summer 2014	13/01/2014	1.33	0.4	Light Cloud	Calm
Autumn 2014	8/04/2014	1.64	60.4	Overcast	Light S

Note: Water depth expressed as an average of the depth recorded at the Salty Lagoon PWQMS during the time of the survey

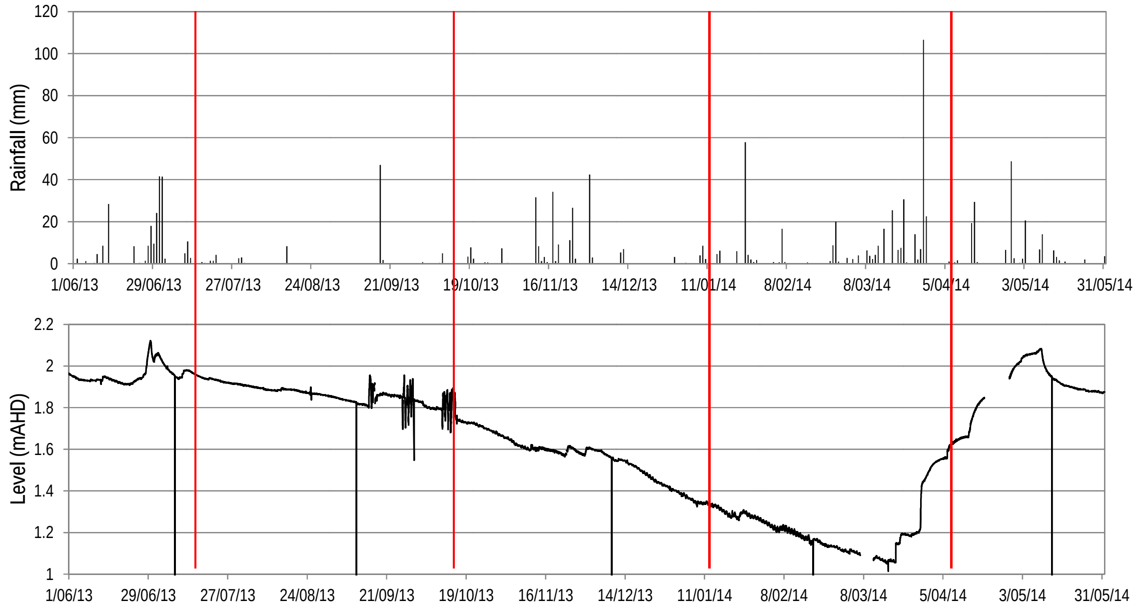

Illustration 6.2 Rainfall and water level charts for the reporting period showing bird survey times (red).

The water level at the time of sampling varied widely between sample times. The summer 2014 sample was undertaken in drought conditions when water levels were at the lowest level since the closure of the artificial channel. The effect of these conditions is a contraction in open water habitat available and an expansion of the mudflats and dry rushlands.

6.3.2 Diversity

The diversity of species observed in waterbird surveys undertaken during the current reporting period has varied from season to season. With the exception of the autumn survey each season's results for the current reporting period include the highest species diversity for that season since the beginning of the MPPC, pointing to an increase in waterbird diversity since the closure of the artificial channel.

The greatest diversity of species was observed during the summer survey. This is consistent with previous years when high species diversity has been observed in the summer and spring (**Illustration 6.3**).

During the current reporting period there have been a number of species observed for the first time since the beginning of the MPPC (**Table 6.2**). These species included Royal Spoonbill (*Platalea regia*), Black-necked Stork (*Ephippiorhynchus asiaticus*), Brolga (*Grus Rubicunda*), Sharp-tailed Sandpiper (*Calidris acuminata*), Pacific Golden Plover (*Pluvialus fulva*) and Black Kite (*Milvus migrans*). Black-necked Stork is listed as an endangered species under the NSW *Threatened Species Conservation Act 1995* (TSC Act), Brolga is listed as a vulnerable species under the TSC Act and Sharp-tailed Sandpiper and Pacific Golden Plover are listed as migratory under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). On the other hand the species that were observed in earlier surveys but not during this reporting period include Darter (*Anhinga novaehollandiae*), Purple Swamphen (*Porphyrio porphyrio*), Comb-crested Jacana (*Irediparra gallinacea*), Black Bittern (*Ixobrychus flavicollis*), Whimbrel (*Numenius phaeopus*), Black-fronted Dotterel (*Elseyornis melanops*), Rainbow Bee Eater (*Merops ornatus*), Osprey (*Pandion haliaetus*) and Little Egret (*Egretta garzetta*). The majority of these species have been observed incidentally during normal monthly monitoring outside of formal bird surveys. The details for such observations are presented in monthly reports. Comb-crested Jacana and Black Bittern are listed as vulnerable species under the TSC Act.

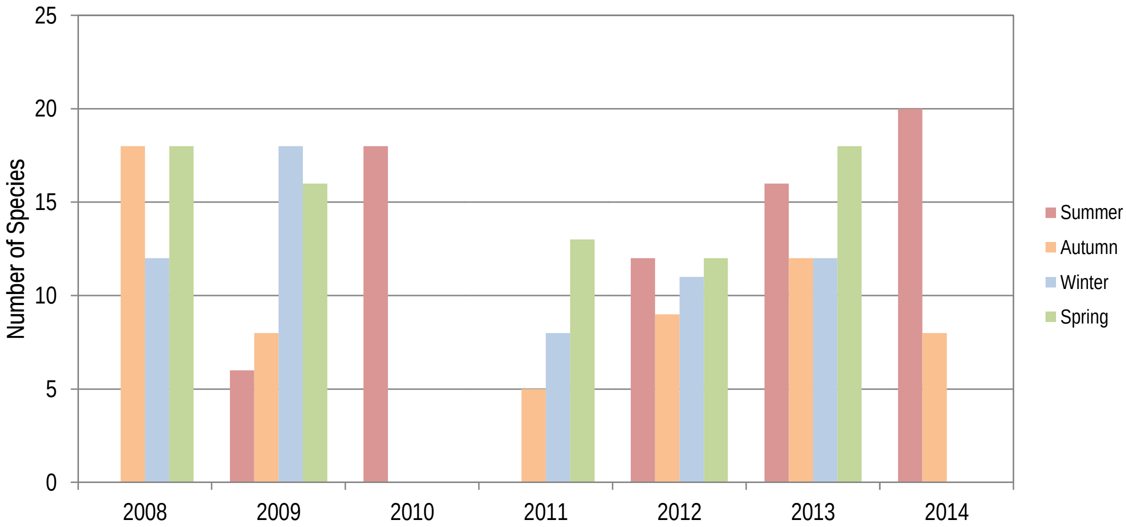

Illustration 6.3 Number of bird species observed in previous seasonal surveys on Salty Lagoon (Autumn 2008 until Summer 2010 (Hydrosphere 2010a)) and during the MPPC (Autumn 2011 until Autumn 2014)

6.3.3 Abundance

Waterbird abundance has varied since the beginning of the MPPC in autumn 2011. The greatest abundances were observed in the surveys undertaken in spring 2013 and summer 2014. With the exception of the autumn survey each season’s results for the current reporting period include the abundance for that season since the beginning of the MPPC, pointing to an increase in waterbird abundance since the closure of the artificial channel

In terms of individual species the abundances of a small number of species appear to have increased since the beginning of the MPPC. These species include Pacific Black Duck (*Anas superciliosa*), Hardhead, Australasian Grebe (*Tachybaptus novaehollandiae*) and Eurasian Coot.

Table 6.2 Results of waterbird surveys since the beginning of the MPPC

Common Name	*Autumn 2011*	*Winter 2011*	*Spring 2011*	*Summer 2012*	*Autumn 2012*	*Winter 2012*	*Spring 2012*	*Summer 2013*	*Autumn 2013*	*Winter 2013*	*Spring 2013*	*Summer 2014*	*Autumn 2014*
Little Black Cormorant			4	3			2	4	8	2	1	3	
Little Pied Cormorant	2	1		1		1				1		2	
Pied Cormorant				9	2	1		1		1			1
Great Cormorant						1			1	2	4		1
Darter				1	1	1	1	2					
Pelican		30	10						13	9	16	1	
Australasian Grebe		1		2			6	18	9	22	38	11	3
Grey Teal	1	3	29	23				16	20	5		28	
Pacific Black Duck				7	4	59	31	42	52	13	82	42	33
Chestnut Teal			1				6			2		14	
Hardhead							11		20	28			
Black Swan				2	4	2			1		4		4
Purple Swamphen								33					
Eurasian Coot								22	24	25	125	6	
Comb-crested Jacana*								3					
White Faced Heron	1	2	5		2	6	2	1	9		2	1	4
Black Bittern*			1										
White Necked Heron			2					1			4		
Little Egret			1										
Intermediate Egret							1	1			1	1	
Great Egret			3	1	1	1	4	2	1		4	2	1
White Ibis			2				1				7	12	
Royal Spoonbill											5		
Black-necked Stork*												2	
Brolga*											2		
Whimbrel								1					
Sharp-tailed Sandpiper												44	

Common Name	*Autumn 2011*	*Winter 2011*	*Spring 2011*	*Summer 2012*	*Autumn 2012*	*Winter 2012*	*Spring 2012*	*Summer 2013*	*Autumn 2013*	*Winter 2013*	*Spring 2013*	*Summer 2014*	*Autumn 2014*
Black Winged Stilt	3				2						11	13	
Masked Lapwing		2	2								2	3	
Pacific Golden Plover												12	
Black Fronted Dotterel			7										
Rainbow Bee Eater				3									
Welcome Swallow			7		3	3	3				3	3	
White-throated Needletail				15								17	22
Raven				1									
Eastern Osprey*									1				
Sea Eagle	2	1			1	1				1			
Wedge Tailed Eagle							1	1					
Black Kite											1		
Whistling Kite		1				4		2				1	
Total No. Species	5	8	13	12	9	11	12	16	12	12	18	20	8
Total No. Individuals	9	41	74	68	20	80	69	150	159	111	312	218	69

* Species listed as vulnerable under the TSC Act

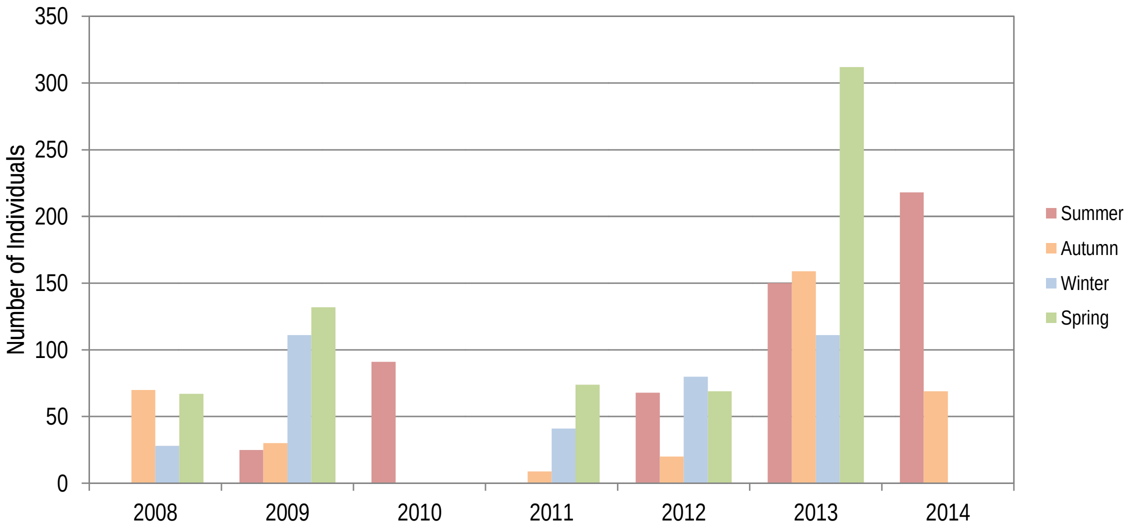

Illustration 6.4 Number of individual birds observed in previous seasonal surveys on Salty Lagoon (Autumn 2008 until Summer 2010 (Hydrosphere 2010a)) and during the MPPC (Autumn 2011 until Autumn 2014)

6.4 Discussion

Waterbird surveys continue to be a cost effective means of assessing an ecological aspect of the Salty Lagoon ecosystem.

Waterbird abundance and diversity have fluctuated since the beginning of the MPPC. The results of waterbird surveys indicate that there has been an increase in species diversity and waterbird abundance since the closure of the artificial channel. However, the very high species diversity observed in spring 2013 and summer 2014 may be related to the drought conditions and the lack of water elsewhere, as opposed to improved conditions at Salty Lagoon. The drought conditions also have the effect of diversifying the available habitats as dry rushland and mudflats become more available when water levels recede. This is likely to impact on species diversity as shorebirds and wading birds increasingly utilise Salty Lagoon when mudflats and dry rushlands are available.

The data captures a seasonal effect of increased abundance and diversity in summer and spring when more migratory species are utilising Salty Lagoon. The results of previous surveys (Hydrosphere 2010a) suggest that variation in the numbers and diversity of waterbirds does not only occur as a result of seasonal change, though it is undoubtedly a major factor accounting for diversity. Much of the variation in previous results has been explained by the varying availability of mud flats in Salty Lagoon caused by changes in the water level.

Plate 6.2 Pelicans (*Pelecanus conspicillatus*) among the rushes to the West of Salty Lagoon

7 Frogs

7.1 Introduction

7.1.1 General

Frogs are good indicators of ecosystem health, particularly in relation to water quality (Robinson 1998). They are a prominent component of coastal wetlands, including Salty Lagoon which supports both habitat generalists and specialist 'acid' frog species (Hydrosphere 2010a; Sandpiper 2010). Their responsiveness to changes in water quality (including salinity and nutrient levels) and the variability of microhabitat requirements between species/species groups known at the site makes them a valuable indicator of ecosystem change for the Salty Lagoon MPPC program.

It was predicted that closure of the artificial channel between Salty Creek and Salty Lagoon would lead to changes in the frog community from a number of interacting factors such as water level, salinity, pH and competition between species. In particular it was predicted that there will be an expansion of usable habitat for frogs at the site, including expansion of the area suitable for acid frog (Hydrosphere 2010b).

Acid frogs previously recorded include the Wallum Froglet (*Crinia tinnula*), Wallum Rocket Frog (*Litoria freycineti*) and Wallum Sedge Frog (*Litoria oblongburensis*). The Wallum Froglet and Wallum Sedge Frog are listed as Vulnerable species under the *Threatened Species Conservation Act 1995* (TSC Act). The latter is also listed as Vulnerable under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act).

7.1.2 ERMP Frog Monitoring Results

Frog monitoring was a key part of the ERMP between 2008 and 2010 (Hydrosphere 2010a), with previous ecological baseline surveys undertaken by GHD (2006). The ERMP covered a larger study area than that of this MPPC monitoring program (the former having included sites at Salty Creek and adjacent to the Sewage Treatment Plant) and the frog monitoring locations varied from those of this program. Notwithstanding, the ERMP frog sampling methodology was the same as the sampling methodology used in this program and provides useful baseline data for the general trends that were recorded. Key findings from the ERMP which will assist in identifying changes in species composition and distribution include:

- Fourteen species of amphibian were recorded within the Salty Lagoon study area between 2008-2010, including:
  - seven species of tree frogs (Family Hylidae);
  - six species of burrowing frogs (Family Myobatrachidae); and
  - one species of toad (Family Bufoniadae).
- Three 'acid' frog species were recorded including:
  - Wallum Froglet: Recorded in Sedge Swamp, Swamp Forest and (upper parts of) the drainage line habitats;
  - Wallum Rocket Frog: Recorded only once in the Swamp Forest habitat; and
  - Wallum Sedge Frog: Recorded only in the Sedge Swamp habitat.
- No acidic frogs were recorded in the Fringing Marsh, the Melaleuca dieback area or south of the lagoon and drainage channel.
- The Striped Marsh Frog (Limnodynastes peronii), Common Froglet (Crinia signifera), Dwarf Tree Frog (Litoria fallax), Rocket Frog (Litoria nasuta) and Tyler's Tree Frog (Litoria tyleri) were the most widely distributed species recorded at four of the six habitats within the study area (Sandpiper 2010).

- Comparisons were made of the distribution of the Wallum Froglet (acid frog) and Dwarf Tree Frog (habitat generalist). These species were selected as they rarely co-exist in undisturbed environments due to the differences in preferred habitat. Comparisons found that:
  - Wallum Froglets were:
    - recorded predominantly within Swamp Forest with a sedge understorey and Sedge Swamp along the upper part of the drainage line and adjoining Salty Creek; and
    - not recorded in the Fringing Marsh, areas of Melaleuca dieback or along the drainage line east of from approximately 100 m east of Evans Head-Broadwater Road culvert; area with an understorey of Salt Couch or Juncus spp. in the vicinity of Salty Lagoon.
  - Dwarf Tree Frogs were:
    - recorded in all habitats except in Sedge Swamp with emergent Paperbarks. They occurred throughout the Marshland and drainage line habitats and parts of the Swamp Forest, including the Melaleuca dieback area; and
    - not recorded in 'undisturbed' Swamp Forest and Sedge Swamp.
- An overlap in distribution was found along much of the drainage line and adjacent Swamp Forest (Hydrosphere, 2010a).

7.2 Methods

7.2.1 Surveys

Frogs were sampled using two methods:

- Point counts undertaken at six fixed points along three fixed transects.
- Transect traverses undertaken along three fixed transects which corresponded with the point counts.

The point count methodology was as described in Hydrosphere (2010a and 2010b). Point counts were undertaken at six fixed sites along the three frog transects located on the western side of Salty Lagoon (refer to Illustration 7.1). Habitats sampled include Sedge Swamp, Fringing Marsh and Swamp Forest, and ecotones between these communities. Approximate transect lengths and average distance between the fixed point count sites were:

- Transect 1 – 440 m long with an average distance of 73 m between point count sites.
- Transect 2 – 575 m long with an average distance of 96 m between point count sites.
- Transect 3 – 580 m long with an average distance of 97 m between point count sites.

Since the closure of the artificial channel in June 2012 the water level of Salty Lagoon has fluctuated over time with an initial increase followed by a reduction in water levels due to drought. One consequence of the closure of the artificial channel has been conversion from Fringing Marsh to open water at the three fixed monitoring points closest to the lagoon. Consequently, frog monitoring was not undertaken at these localities due to a lack of suitable vegetated habitat for frogs. However, if future changes occur that are conducive to supporting frogs (e.g. establishment of Water Lilies *Nymphaea* sp.), sampling at these points will be resumed.

The location of the point count sites is shown in Table 7.1.

Point count surveys involved:

- A two minute settling period after reaching each site, followed by;
- A five minute listening period during which the number of calling frogs within a 20 m radius were recorded independently by two observers; and
- After five minutes, counts were discussed between observers and a consensus reached on abundance and diversity. Frogs calling within 20-50 m of point count sites were recorded as 'off-site' recordings.

The transect traverse involved walking along the fixed transect between point count site surveys. Data recorded along each transect included:

- The location of individual or groups of Dwarf Tree Frogs and Wallum Froglet using a GPS. Data was collected at 20 m intervals and involved recording the presence of any individuals of this species within a 20 m radius of the point.
- Any additional species not recorded during the point count surveys.

The transect data that was used to determine the distribution of the Dwarf Tree Frog (a 'habitat generalist') and Wallum Froglet (an 'acid' frog species) in the study area. As mentioned previously, these species rarely co-exist in undisturbed environments due to the differences in preferred habitat, hence their presence is considered indicative of habitat conditions (Hydrosphere 2010a). Further information on why these species were selected for comparison is provided in Hydrosphere (2010a).

Frogs were identified using Robinson (1998) and Nature Sound (2001). They were primarily identified by call identification, with 30Watt head torches used to actively find frogs if confirmation was needed and during transverse transect surveys to opportunistically observe frogs while moving along each transect.

Frog sampling was undertaken twice per season (excluding autumn) during appropriate weather conditions (refer to Hydrosphere 2010a) on non-consecutive nights. Weather conditions (rainfall, air temperature, cloud cover, relative humidity and wind speed) and water depth at each fixed point transect site was recorded during each survey event.

Table 7.1 Point Count Locations (GDA 84)

Point Count Reference	*Easting*	*Northing*
T1PC1	541930	6783016
T1PC2	541881	6783045
T1PC3	541810	6783080
T1PC4	541742	6783116
T1PC5	541672	6783162
T1PC6	541551	6783247
T2PC1	541964	6782859
T2PC2	541850	6782839
T2PC3	541749	6782824
T2PC4	541640	6782805
T2PC5	541523	6782766
T2PC6	541415	6782753
T3PC1	542075	6782620
T3PC2	541947	6782569
T3PC3	541829	6782512
T3PC4	541698	6782485
T3PC5	541588	6782430
T3PC6	541533	6782412

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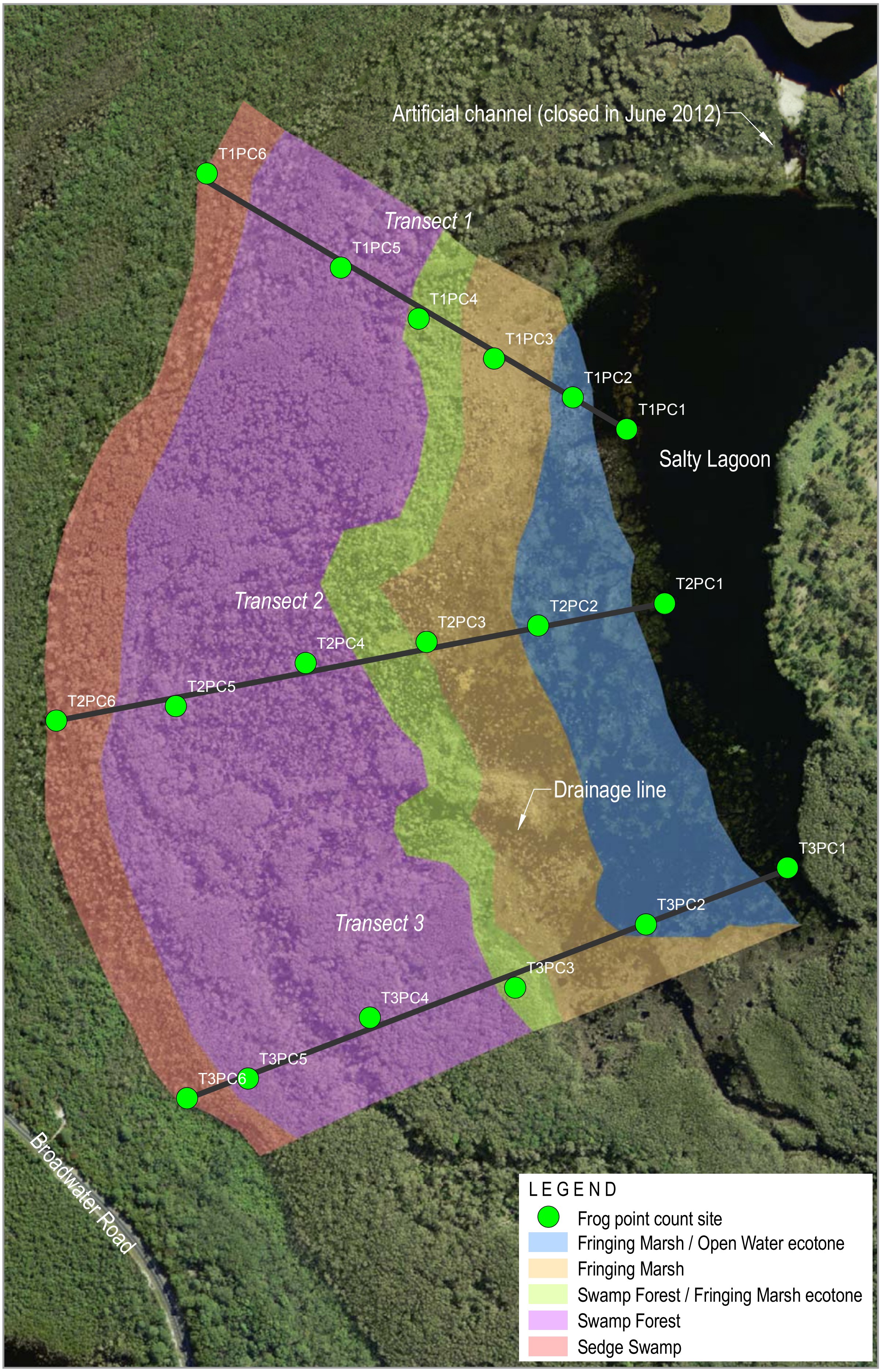
Drawn by: TJP Checked by: GJM Reviewed by: DGH Date: August 2014
Source of base data: Richmond Valley Council



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North

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Frog Monitoring Sites

Illustration 7.1

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7.2.2 Timing

The post-closure frog monitoring events were undertaken on the following dates:

- Winter 2013 surveys: 22 August 2013 and 28 August 2013.
- Spring 2013 surveys: 19 November and 25 November 2013.
- Summer 2014 surveys: 18 February and 19 March 2014.

7.2.3 Conditions at the Time of Monitoring

The call behaviour of frogs is highly variable and associated with season, weather conditions and behavioural patterns. Weather conditions during the post artificial channel closure frog monitoring events are provided in Table A.1, Appendix A. Conditions were dry for the winter, spring, and 1st summer monitoring events, and wet during the 2nd summer monitoring event. Both the spring and summer monitoring events had rain in the days prior to monitoring. Temperature ranged from mild to warm for each monitoring event, except for the first monitoring event in winter which coincided with a relatively cold night. Winds varied between calm and moderate across all seasons. Relative humidity was generally moderate to high during monitoring events. The Salty Creek mouth was naturally open just prior to the August monitoring period but closed for the winter survey dates. The creek mouth was also closed for during both the spring and summer surveys periods.

Conditions were very dry during the 2013/2014 summer period and therefore the 2nd monitoring event was delayed until March 2014 to coincide with better rainfall.

7.3 Results

7.3.1 Point Count

7.3.1.1 Species Richness and Abundance

The raw frog point count results are provided in Table A.2 - Appendix A. Eight amphibian species were recorded in total, with:

- Five species recorded during the winter monitoring events, comprising 76 'on-site' specimens.
- Six species recorded during the spring monitoring events, comprising 21 'on-site' specimens.
- Five species recorded during the summer monitoring events, comprising 31 'on-site' specimens.

Wallum Froglet, Common Eastern Froglet and Dwarf Tree Frog were consistently common, and were recorded during all of the monitoring seasons. No 'acid' frog species were recorded across all monitoring seasons.

All species recorded had previously been recorded in the study area during the ERMP monitoring (Sandpiper 2010) with the exception of The Dainty Tree Frog (*Litoria gracilenta*), which was recorded during census 2 of the 2014 summer monitoring period and has not been recorded in previous monitoring events. Two species were recorded during the pre-closure frog monitoring surveys but have not been detected since the closure of the artificial channel. They were the Broad-palmed Rocket Frog and the Bleating Tree Frog.

In general, results varied between habitats and transects. Frog species recorded 'on-site' at point count sites within each habitat are shown in Table 7.2. The highest diversity of species at point counts sites was recorded within the Swamp Forest while the least diversity was recorded in the Sedge Swamp. This result is consistent with the results of the 2012/2013 monitoring period.

The species with the overall highest abundance recorded 'on-site' during the point count surveys were the Dwarf Tree Frog (*Litoria fallax* – 64 individuals), Wallum Froglet (*Crinia tinnula* - 26) and Tyler's Tree Frog (*Litoria tyleri* – 16 individuals).

The least abundant species were Common Eastern Froglet (*Crinia signifera* – 8 individuals), Striped Rocket Frog (*Litoria nasuta* – 6 individuals) and Wallum Sedge Frog (*Litoria olongburensis* – 1 individual).

7.3.1.2 Distribution

The habitats along the subject frog monitoring sites comprised Sedge Swamp, Swamp Forest, Fringing Marsh (with a broad ecotone between the Swamp Forest and Fringing Marsh along Transects 2 and 3) and open water. An additional habitat was defined as ‘Fringing Marsh/ Open Water ecotone’, corresponding to the zone around the edge of Salty Lagoon that has been inundated since closure of the artificial channel, consisting of widely scattered clumps of Sea Rush (in a state of decline) within open water.

Wallum Froglet was the only species recorded within the Sedge Swamp across all transects for this monitoring period. This species was also recorded within the Swamp Forest and Fringing Marsh/Swamp Forest Ecotone.

As shown in Table 7.2, The most widely distributed species were Common Eastern Froglet, Dwarf Tree Frog, and Tyler’s Tree Frog, which were recorded across multiple transects and in four vegetation communities including the Swamp Forest, Fringing Marsh/ Swamp Forest Ecotone, Fringing Marsh, and Fringing Marsh/ Open Water Ecotone. A number of species, including Wallum Froglet, Striped Marsh Frog, Rocket Frog, Wallum Sedge Frog, did not occur in the Fringing Marsh or the Fringing Marsh/ Open Water Ecotone.

Table 7.2 Frog Occurrence at 'On-site' Point Counts

Scientific Name	*Common Name*	*Sedge Swamp*			*Swamp Forest*			*Fringing Marsh/ Swamp Forest Ecotone*			*Fringing Marsh and Fringing Marsh/ Open Water Ecotone*		
		T1	*T2*	*T3*	*T1*	*T2*	*T3*	*T1*	*T2*	*T3*	*T1*	*T2*	*T3*
Common Eastern Froglet	*Crinia signifera*					x			x		x	x	x
Wallum Froglet	*Crinia tinnula*	x	x	x	x	x	x	x					
Striped Marsh Frog	*Limnodynastes peroni*					x		x					
Dwarf Tree Frog	*Litoria fallax*				x	x	x	x			x	x	x
Rocket Frog	*Litoria nasuta*				x				x				
Wallum Sedge Frog	*Litoria olongburensis*				x			x					
Tyler’s Tree Frog	*Litoria tyleri*					x		x			x		x

As shown in Table 7.2 one frog species were recorded in the Sedge Swamp, seven species were recorded in the Swamp Forest and Fringing Marsh/ Swamp Forest Ecotone, and three species were recorded in the Fringing Marsh and Fringing Marsh/ Open Forest ecotone.

7.3.2 Transect Traverse

7.3.2.1 Occurrence and Distribution of Wallum Froglet and Dwarf Tree Frog

The transect traverse Wallum Froglet and Dwarf Tree Frog comparison results are shown in Illustration 7.2.

Along Transect 1 Wallum Froglet was commonly recorded within Swamp Forest, with 1 record ‘off site’ within the Melaleuca dieback area. One Wallum Froglet was also recorded in the adjacent Fringing Marsh during summer 2014 monitoring.

Along Transect 2 and Transect 3 Wallum Froglet was only recorded in the Sedge Swamp and Swamp forest habitats.

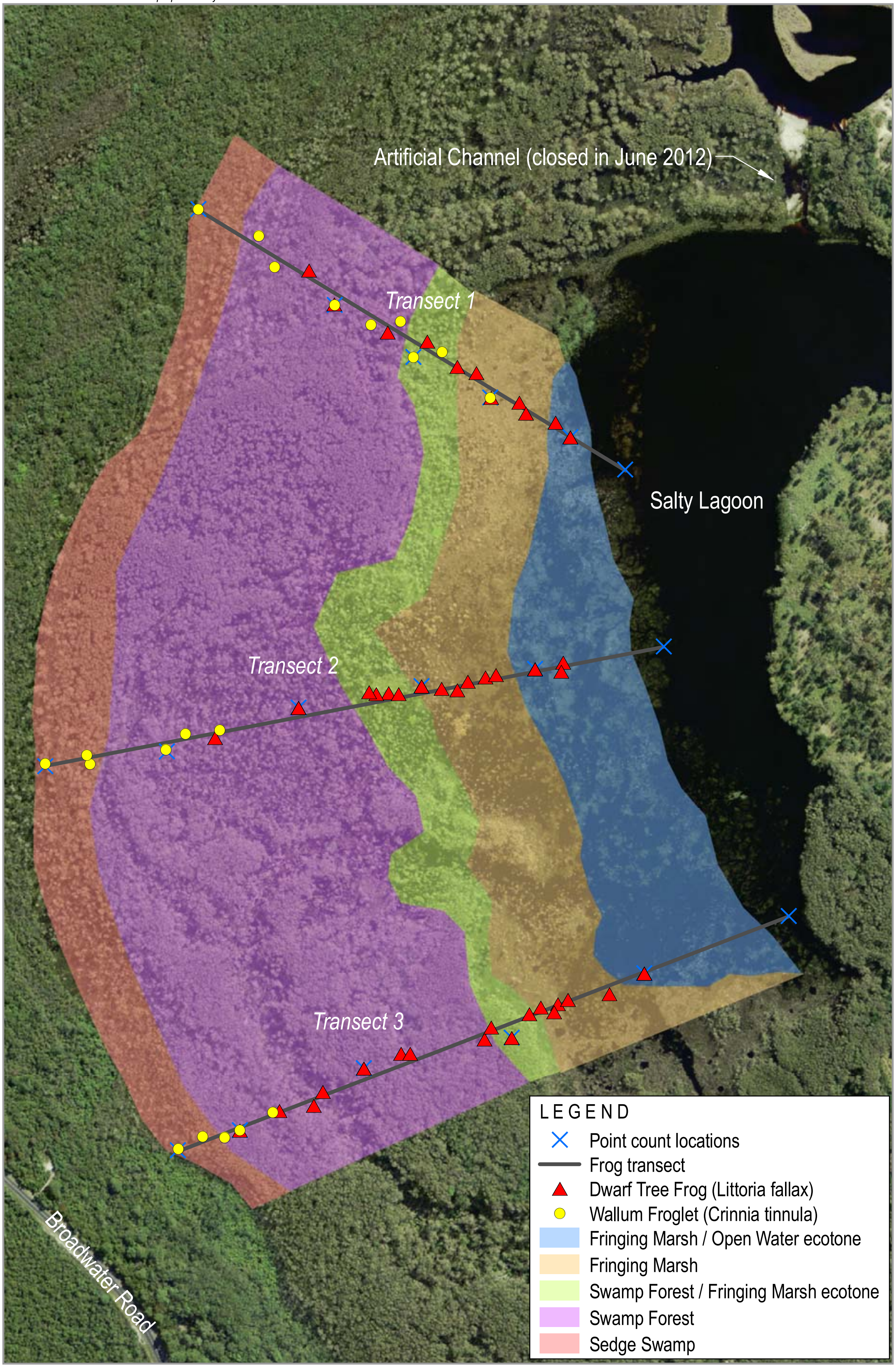
The Dwarf Tree Frog was mainly recorded in the Fringing Marsh and Swamp Forest habitats, mostly along Transects 2 and 3, with a few records in Sedge Swamp habitat along Transect 2 and Transect 3.

No additional species to those recorded during point count surveys were recorded during transect traverse surveys.

The following summary can be made relating to the distribution of the Wallum Froglet and Dwarf Tree Frog occupying the western habitats adjacent to Salty Lagoon:

- Dwarf Tree Frogs were particularly dominant in the Fringing Marsh and Swamp Forest habitats; including the Melaleuca dieback area.
- Wallum Froglet was recorded in Sedge Swamp along all 3 transects.
- Wallum Froglet also occurred in Swamp Forest and Fringing Marsh along Transect 1.
- The two species overlapped along all three of the Swamp Forest transects and Fringing Marsh along Transect 1.

Information shown is for illustrative purposes only



Distribution of the Wallum Froglet (Crinia tinnula) and Dwarf Tree Frog (Litoria fallax)

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Illustration 7.2

7.4 Discussion and Comparison with Previous Monitoring

7.4.1 Overall Species Diversity

The overall species diversity of frog species has been relatively stable since the beginning of the MPPC monitoring, with nine species recorded in 2011-2012 monitoring and the same number of species recorded during the current monitoring period. Eight species were recorded in 2012-2013 monitoring.

7.4.2 Frog Seasonal Abundance

Highest frog abundance for the current monitoring period was during winter, compared with the highest abundance occurring in spring during 2012-2013 monitoring. The species with the highest abundance was Dwarf Tree Frog, with a total of 55 individuals recorded at point counts compared 78 during the 2011-2012 monitoring period. This species has consistently been the most abundant species recorded at Salty Lagoon.

The second most abundant species for the current monitoring period is the Wallum Froglet with 26 records; consisting of 16 during the summer monitoring event and 10 during the spring monitoring event.

7.4.3 Species Diversity by Vegetation Habitat Zone

A decrease in the number of frog species recorded in the Sedge Swamp is apparent when compared with 2011-2012 and 2012- 2013 monitoring. In the current monitoring period only one frog species was recorded in the Sedge Swamp, seven species were recorded in the Swamp Forest and eight species were recorded in the Fringing Marsh. In the 2012-13 monitoring three frog species were recorded in the Sedge Swamp, eight species were recorded in the Swamp Forest and seven species were recorded in the Fringing Marsh, while in the 2011-1012 monitoring five species in the Sedge Swamp, and eight species in both the Swamp Forest and Fringing Marsh for the pre-closure 2012 MPPC monitoring.

This decrease in species diversity is unlikely to be related to changes in the environment that can be attributed to the channel-closure, considering that the Sedge Swamp community is furthest from the edge of the lagoon. As the water conditions within Sedge Swamp are predominantly acidic, many non-acid tolerant species naturally do not occur in this vegetation community. Dry conditions during this monitoring period may have also affected the diversity of species this year. The results of future monitoring will assist in determining whether this is due to natural variability.

7.4.4 Habitat Segregation and Distribution Patterns

A primary segregating factor for the frog species at Salty Lagoon is the acid water tolerance of individual species. In general, this has the effect of limiting 'acid' frog species to Sedge Swamp and Swamp Forest habitats at Salty Lagoon. However, Wallum Froglet was recorded in Fringing Marsh along Transect 1 in the current monitoring period, as has been recorded in other monitoring since the beginning of the MPPC. This differs from the distribution trends of acid frog species recorded during monitoring for the ERMP (Hydrosphere, 2010a – however, surveying in this particular location was not undertaken during the ERMP monitoring).

The presence of Wallum Froglet in the Fringing Marsh community may relate to localised differences in water quality. It was predicted that Wallum Froglet would retract westward along Transect 1 out of the Fringing Marsh and into the Swamp Forest and Sedge Swamp in response to the higher water levels and conversion towards a predominantly freshwater system following the closure of the artificial channel. However, this has not been the case, with Wallum Froglet being recorded in Fringing Marsh along Transect 1 in the summer monitoring event during the current monitoring period. It is possible that the drought conditions that were experienced over much of the monitoring period may have influenced the acidity of the waters in this location, and that given higher water levels and more freshwater input this area may not have been suitable for Wallum Froglet. Provided that rainfall conditions return to near-normal levels, this hypothesis will be able to be tested in the next monitoring period.

8

Conclusion

8.1 Conclusion

The results of the MPPC to date consist of both pre-closure of the Artificial Channel baseline set and the early results of post-closure monitoring. The data for all monitored environmental attributes appear adequate for allowing pre-closure and post-closure comparisons, though it is apparent that the system is still in a state of flux as it moves towards a predominantly freshwater lagoon system. This variability is apparent in many of the environmental variables that are being monitored, including water quality parameters, distribution and composition of vegetation communities, distribution of acid frog species, and waterbird usage of the lagoon. Early indications are that many of the predicted changes are occurring. However, as the current monitoring period only extends over a small post-closure period, the exact nature of the changes will only become apparent over time. It is expected that it will be possible to draw more definite conclusions in the 2015 Annual Report.

The results of the current monitoring period support previous findings that the Salty Lagoon system is highly dynamic and provides a dataset that will allow testing of the prediction that environmental conditions will stabilise post-closure of the Artificial Channel.

Project Team

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Appendix A

Frog Monitoring Data

Table A1: Environmental Conditions at the Time of Frog Monitoring

Season	*Date*	*Transect*	*Weather*	*Temperature*	*Relative Humidity (3 pm)*	*Wind km/hr*	*Evidence of rain in 24 hrs*	*Rain in last 72 hours (mm)*	*Night Light*	*Approximate Depth of Surface Water (mm)*						*Artificial Channel Open or closed*
										PC 1	*PC 2*	*PC 3*	*PC 4*	*PC 5*	*PC 6*	
Winter 2013	22/08/13	1	Dry	5.3 - 20.2	42	light	no	0	Bright -half moon	>500 mm	400	300	150	50	0	Closed
	22/08/13	2	Dry	5.3 - 20.2	42	light	no	0	Bright -half moon	>500 mm	400	250	200	50	0	Closed
	22/08/13	3	Dry	5.3 - 20.2	42	light	no	0	Bright -half moon	>500 mm	400	150	0	25	0	Closed
	28/08/13	1	Dry	12.1 - 25.2	43	light	no	0	Dark - quarter moon	>500 mm	500	100	20	5	0	Closed
	28/08/13	2	Dry	12.1 - 25.2	43	light	no	0	Dark - quarter moon	>500 mm	500	250	100	100	55	Closed
	28/08/13	3	Dry	12.1 - 25.2	43	light	no	0	Dark - quarter moon	>500 mm	400	250	200	100	55	Closed
Spring 2013	19/11/13	1	Dry	12.6-24.6	59	moderate	Yes	44.6	Dark - quarter moon	400	150	50	0	0	0	Closed
	19/11/13	2	Dry	12.6-24.6	59	moderate	Yes	44.6	Bright - half moon	500	150	0	0	0	0	Closed
	19/11/13	3	Dry	12.6-24.6	59	moderate	Yes	44.6	Bright - half moon	500	300	0	0	0	0	Closed
	25/11/13	1	Dry	17.4-25.5	64	calm	No	40.2	Very dark (no moon)	not sampled	150	50	0	0	0	Closed
	25/11/13	2	Dry	17.4-25.5	64	light	No	40.2	Very dark (no moon)	not sampled	100	0	0	0	0	Closed
	25/11/13	3	Dry	17.4-25.5	64	calm	No	40.2	Very dark (no moon)	not sampled	200	0	0	0	0	Closed
Summer 2014	18/02/14	1	Dry	21.3-29.0	82	light	No	0	Dark - moon not risen, clear sky	0	0	0	0	0	0	Closed
	18/02/14	2	Dry	21.3-29.0	82	light	No	0	Dark - moon not risen, clear sky	0	0	0	0	0	0	Closed
	18/02/14	3	Dry	21.3-29.0	82	light	No	0	Bright - half moon or more no cloud	10	0	0	0	0	0	Closed
	19/03/14	1	Wet - rain during the week	19.8-26.5	95	moderate	yes	32	Full moon partly cloudy	0	0	0	0	0	0	Closed
	19/03/14	2	Wet - rain during the	19.8-26.5	95	moderate	yes	32	Moon rising during transect up at P3	0	0	0	0	0	0	Closed

Season	Date	Transect	Weather	Temperature	Relative Humidity (3 pm)	Wind km/hr	Evidence of rain in 24 hrs	Rain in last 72 hours (mm)	Night Light	Approximate Depth of Surface Water (mm)						Artificial Channel Open or closed
										PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	
			week													
	19/03/14	3	Wet - rain during the week	19.8-26.5	95	moderate	yes	32	Moon not risen yet	0	0	0	0	0	0	Closed

Night Light Key: Very Dark = No moon
Dark = Quarter moon or moon with heavy cloud
Detail Seen = moon and clear sky
Bright = Half-moon or more and no cloud

Table A2: Point Count Survey Results

Transect No. and Survey Date	Point Count No.	Habitat Type	*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peronii*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		*Litoria gracilenta*		TOTAL
			Point Count	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	
WINTER 2013																									
Census 1																									
T1: 22/08/13 6:15 pm	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	*no*	*n/a*
	2	Open Water/ Fringing Marsh	0	no	0	no	0	yes	0	no	0	yes	0	no	0	no	0	no	0	no	0	no	0	*no*	*0*
	3	Fringing Marsh	0	no	0	no	0	no	0	no	2	yes	0	no	0	no	0	no	0	no	0	no	0	*no*	*2*
	4	Swamp Forest (dieback zone)	0	no	0	no	0	no	0	no	0	yes	0	no	0	no	0	no	0	no	0	no	0	*no*	*0*
	5	Swamp Forest	0	no	0	no	0	no	0	no	1	yes	0	no	0	no	0	no	0	no	0	no	0	*no*	*1*
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	*no*	*0*
T2: 22/08/13 7:30 pm	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	*no*	*n/a*
	2	Open Water/ Fringing Marsh	0	no	0	no	0	yes	0	no	2	yes	0	no	0	no	0	no	0	no	0	no	0	*no*	*2*
	3	Swamp Forest	0	no	0	no	0	yes	0	no	2	yes	0	no	0	no	0	no	0	no	0	no	0	*no*	*2*
	4	Swamp Forest	0	no	0	no	0	yes	0	no	0	yes	0	no	0	no	0	no	0	no	0	no	0	*no*	*0*
	5	Swamp Forest	0	no	0	no	0	yes	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	*no*	*0*
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	*no*	*0*
T3: 22/08/13 6:15 pm	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	*no*	*n/a*

Transect No. and Survey Date	Point Count No.	Habitat Type	*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peronii*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		*Litoria gracilenta*		TOTAL
			Point Count	Off Site (no/ yes)	Point Count	Off Site (no/ yes)	Point Count	Off Site (no/ yes)	Point Count	Off Site (no/ yes)	Point Count	Off Site (no/ yes)	Point Count	Off Site (no/ yes)	Point Count	Off Site (no/ yes)	Point Count	Off Site (no/ yes)	Point Count	Off Site (no/ yes)	Point Count	Off Site (no/ yes)	Point Count	Off Site (no/ yes)	
	2	Open Water/ Fringing Marsh	0	no	0	no	0	no	0	no	0	yes	0	no	0	no	0	no	0	no	0	no	0	*no*	*0*
	3	Swamp Forest	0	no	0	no	0	yes	0	no	0	yes	0	no	0	no	0	no	0	no	0	no	0	*no*	*0*
	4	Swamp Forest	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	*no*	*0*
	5	Swamp Forest	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	*no*	*0*
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	*no*	*0*
TOTAL			0		0		0		0		7		0		0		0		0		0		0		*7*
Census 2																									
T1: 28/08/13 6:00 pm	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	*no*	n/a
	2	Open Water/ Fringing Marsh	0	no	0	no	0	no	0	no	7	yes	0	yes	0	no	0	no	0	no	0	no	0	*no*	7
	3	Fringing Marsh	0	no	0	no	0	no	2	yes	2	yes	1	yes	0	no	0	no	0	no	0	no	0	*no*	5
	4	Swamp Forest (dieback zone)	0	no	0	no	0	no	0	no	0	yes	0	no	0	no	0	no	0	no	0	no	0	*no*	0
	5	Swamp Forest	0	yes	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	*no*	0
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	*no*	0
T2: 28/08/13 7:00 pm	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	*no*	n/a
	2	Open Water/ Fringing Marsh	0	no	0	no	0	no	0	no	7	yes	0	no	0	no	0	no	0	no	0	no	0	*no*	7
	3	Swamp Forest	0	no	0	no	0	no	3	no	10	yes	5	yes	0	no	0	no	0	no	0	no	0	*no*	18
	4	Swamp Forest	0	no	0	no	0	no	0	no	10	yes	10	yes	0	no	0	no	0	no	0	no	0	*no*	20

Transect No. and Survey Date	Point Count No.	Habitat Type	*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peronii*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		*Litoria gracilenta*		TOTAL
			Point Count	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	
	5	Swamp Forest	0	no	0	no	0	no	0	no	0	yes	0	yes	0	no	0	no	0	no	0	no	0	*no*	0
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	*no*	0
T2: 22/08/13 7:30 pm	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	*no*	n/a
	2	Open Water/ Fringing Marsh	0	no	0	no	0	no	0	no	10	yes	0	yes	0	no	0	no	0	no	0	no	0	*no*	10
	3	Swamp Forest	0	no	0	no	0	no	0	no	2	yes	0	yes	0	no	0	no	0	no	0	no	0	*no*	2
	4	Swamp Forest	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	*no*	0
	5	Swamp Forest	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	*no*	0
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	*no*	0
			0	0	0	0	0	0	5	0	48	0	16	0	0	0	0	0	0	0	0	0	0	*no*	69
WINTER TOTAL			0		0		0		5		55		16		0		0		0		0		0		76
SPRING 2013																									
Census 1																									
T1: 19/11/13 7:30 pm	1	Open Water	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	2	Fringing Marsh	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	3	Swamp Forest	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	4	Swamp Forest	2	yes	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	2
	5	Swamp Forest	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	6	Sedge Swamp	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
T2 19/11/13 8:45 pm	1	Open Water	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	2	Fringing Marsh	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0

Transect No. and Survey Date	*Point Count No.*	*Habitat Type*	*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peronii*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		*Litoria gracilenta*		TOTAL
			Point Count	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	
	3	Swamp Forest Dieback zone	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	4	Swamp Forest	0	n	0	n	0	n	0	n	0	yes	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	5	Swamp Forest	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	6	Sedge Swamp	1	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	1
T3 19/11/13 10:00 pm	1	Open Water	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	2	Open Water	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	3	Swamp Forest	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	4	Swamp Forest	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	5	Swamp Forest	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	6	Sedge Swamp	0	yes	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
TOTAL			3		0		0		0		0		0		0		0		0		0		0		3
Census 2																									
T1 25/11/13 7:45 pm	1	Open Water (not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	*no*	n/a
	2	Fringing Marsh	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	3	Swamp Forest Fringing Marsh Ecotone	0	n	0	n	0	n	0	n	0	n	0	n	0	yes	0	n	0	n	0	n	0	*no*	0
	4	Swamp Forest	2	yes	0	n	0	n	0	n	0	n	0	yes	1	n	0	n	5	yes	0	n	0	*no*	8
	5	Swamp Forest	1	yes	0	n	0	n	0	n	0	n	0	yes	0	n	0	n	0	yes	0	n	0	*no*	1

Transect No. and Survey Date	*Point Count No.*	*Habitat Type*	*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peronii*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		*Litoria gracilenta*		TOTAL
			Point Count	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	
	6	Sedge Swamp	2	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	2
T2 25/11/13 8:55 pm	1	Open Water (not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	*no*	n/a
	2	Fringing Marsh	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	1	n	0	n	0	*no*	1
	3	Fringing Marsh dieback zone	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	4	Swamp Forest	0	n	0	n	0	n	0	n	3	n	0	n	0	n	0	n	0	n	0	n	0	*no*	3
	5	Swamp Forest	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	6	Sedge Swamp	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
T3 25/11/13 10:15 pm	1	Open Water (not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	*no*	n/a
	2	Fringing Marsh	0	n	0	n	0	yes	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	3	Swamp Forest	0	n	0	n	0	yes	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	4	Swamp Forest	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	5	Swamp Forest	2	n	0	n	0	n	0	n	1	yes	0	n	0	n	0	n	0	n	0	n	0	*no*	3
	6	Sedge Swamp Swamp Forest Ecotone	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
TOTAL			7	0	0	0	0	0	0	0	4	0	0	0	1	0	0	0	6	0	0	0	0	*no*	18
SPRING TOTAL			10		0		0		0		4		0		1		0		6		0				21

Transect No. and Survey Date	Point Count No.	Habitat Type	*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peronii*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		*Litoria gracilenta*		TOTAL
			Point Count	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	
SUMMER 2014																									
Census 1																									
T1 18/02/2014 9.00 pm	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	*no*	n/a
	2	Fringing Marsh	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	3	Fringing Marsh	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	4	Swamp Forest (Dieback zone)	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	5	Swamp Forest	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	6	Sedge Swamp	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
T2 18/02/2014 9.50 pm	1	Open Water (>50cm not sampled)	0	n	0	n	0	n	0	n	0	yes	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	2	Fringing Marsh	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	3	Fringing Marsh Dieback Zone	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	4	Swamp Forest	0	n	0	n	0	n	0	n	3	yes	0	n	0	n	0	n	0	n	0	n	0	*no*	3
	5	Swamp Forest	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	6	Sedge Swamp	1	yes	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	1
T3 18/02/2014 22.10 pm	1	Open Water (>50cm not sampled)	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	2	Fringing Marsh / Open Water	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0

Transect No. and Survey Date	*Point Count No.*	*Habitat Type*	*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peronii*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		*Litoria gracilenta*		TOTAL
			Point Count	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	
	3	Swmap Forest	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	4	Swamp Forest	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	5	Swamp Forest	3	yes	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	3
	6	Sedge Swamp	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
TOTAL			4	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0		7
Census 2																									
T1 19/03/2014 9.35 pm	1	Open Water (>50cm not sampled)	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	n/a
	2	Fringing Marsh	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	3	Fringing Marsh	1	Yes	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	1
	4	Swamp Forest (Dieback zone)	2	yes	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	2
	5	Swamp Forest	0	yes	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	6	Sedge Swamp	2	yes	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	2
T2 19/03/2014 8.30 pm	1	Open Water (>50cm not sampled)	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	2	Fringing Marsh	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	3	Fringing Marsh Dieback Zone	0	n	0	n	3	yes	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	3
	4	Swamp Forest	0	n	0	n	3	yes	1	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	4
	5	Swamp Forest	1	yes	0	n	0	yes	1	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	2

Transect No. and Survey Date	*Point Count No.*	*Habitat Type*	*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peronii*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		*Litoria gracilenta*		TOTAL
			Point Count	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	
	6	Sedge Swamp	1	yes	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	1
T3 19/03/2014 7.20 pm	1	Open Water (>50cm not sampled)	0	n	0	n	2	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	yes	0
	2	Fringing Marsh / Open Water	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	0
	3	Swmap Forest	0	n	0	n	2	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	2
	4	Swamp Forest	0	n	0	n	0	yes	0	n	2	n	0	n	0	n	0	n	0	n	0	n	0	*no*	2
	5	Swamp Forest	2	yes	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	2
	6	Sedge Swamp	3	yes	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	n	0	*no*	3
TOTAL			12	0	0	0	8	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	*no*	24
SUMMER TOTAL			16		0		8		2		5		0		0		0		0		0		0		31
OVERALL TOTAL			26		0		8		7		64		16		1		0		6		0				128