Annual Report 2015

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

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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 2015) summarises the results of the MPPC monitoring undertaken between June 2014 and May 2015, 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 relatively stable during the current reporting period.
- Conductivity: Saline water movement from Salty Creek into Salty Lagoon at the end of the previous reporting period meant that Salty Lagoon was slightly brackish for the first few months of the current reporting period. After a number of rainfall events the water stabilised at low conductivity levels and remained there.
- Dissolved Oxygen: During this reporting period the DO concentration measured at the Salty Lagoon permanent water quality monitoring stations (PWQMS) dropped below 1 mg/L on a large number of occasions. Due to an improved approach to adaptive management this has not resulted in a large number of non-routine site inspections. In the current reporting period the DO concentration was 6 mg/L or less on approximately 81% of occasions and the DO concentration was 1mg/L or less on approximately 19% of occasions. This is relatively similar to the two previous years. However, 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 2012a). 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 heavy rainfall. The processes that impact pH in Salty Lagoon are runoff from the catchment, effluent discharge from the Evans Head Sewage Treatment Plant (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 heavy rainfall.
- Nitrogen: During the current reporting period the concentrations of TN were most strongly influenced by evaporation and rainfall. There was no obvious trend in the concentrations of DIN. A low/moderate level 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 concentration of TP, like TN, continued to increase over the spring and summer months 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.
- Chlorophyll-a: Chlorophyll-a concentrations again remained high for the majority of the reporting period, indicating an algal bloom of small to moderate proportions for much of the 12 months. The persistent algal bloom was caused by the increased nutrient concentrations and contributed to by the high water temperatures experienced over the same period. The algal concentrations were highest during the dry period when nutrient concentrations increased as a result of evaporative distillation.
- 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 few high concentrations measured were typically associated with 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 22 macroinvertebrate taxa have been recorded during the MPPC.
- The numbers of benthic macroinvertebrates captured at each site have varied over time; however, there are no clear patterns evident in the overall abundance or diversity.
- There has been continued variation in the diversity, abundance and makeup of the benthic macroinvertebrate community collected during seasonal surveys. Some of these changes indicate an expected shift towards a freshwater dominated aquatic ecology.

Aquatic Vegetation/ Weeds

- No significant introduced species of aquatic weeds have been recorded in the current monitoring period, though an introduced (naturalised) species and two native species sometimes considered nuisance plants have been recorded.
- The risk of weed invasion into Salty Lagoon remains, particularly as the system continues the transition to a freshwater ecosystem. Plants that have not been recorded in Salty Lagoon prior to the MPPC were observed during the current reporting period, indicating pathways for recruitment of new species.

Fish

- Across all surveys during the reporting period a total of four finfish species were captured. This is lower than 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 overall observed variation.
- A considerable degree of variation within the site in fish abundance and diversity has been detected during the twelve fish surveys undertaken thus far for MPPC monitoring. Some of the changes can be related to environmental conditions.

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 summer 2015 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 a continued increase in waterbird diversity since the closure of the artificial channel.
- Waterfowl abundance has varied from season to season and across the years but there is no clear pattern to overall abundance.
- There has been a shift in the waterbird community to one dominated to a greater degree by true waterfowl such as ducks, coot and grebe.

Terrestrial Vegetation

- The main change to occur in the location of the vegetation communities occurring on the western edge of Salty Lagoon since the pre-closure baseline monitoring period in 2011 is the reduction in the extent of the Fringing Marsh community. This can be directly attributed to the closure of the artificial channel leading to higher water levels and inundation of some area previously covered by Fringing Marsh and conversion to open water.
- Species dominance in the Fringing Marsh community has changed substantially, with a decline in salt tolerate species and an increase in freshwater species. Species dominance in the Swamp Forest community and Sedge Swamp community has not changed substantially.
- The overall number of flora species recorded in the three vegetation communities along the western survey transects has continued to decline. This is associated with higher, more stable water levels and predominantly lower salinity within Salty Lagoon.

- Melaleuca dieback and recolonisation monitoring data shows little change since the pre-closure monitoring, with minimal recolonisation evident nor any further dieback occurring. The overall health of the existing Broad-leaved Paperbark was observed to be good.

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. Reduced overall species diversity during the current monitoring event was largely attributed to varying weather conditions.
- No acid frogs were recorded in the Fringing Marsh along any transects during the current monitoring event, contrasting to previous monitoring events, where the Wallum Froglet has been recorded within this habitat zone along Transect 1. This appears to be associated with the neutral pH tendency of the core waterbody at Salty Lagoon which has been largely stable (in terms of water level and pH) during the current monitoring event, creating unsuitable conditions for acid frogs.
- 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.
- 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 two 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.
  - Water quality monitoring and review.
- Environmental Status and Risk Assessment including:
  - Surface water quality and hydrology.
  - Field observations and monitoring data review.
  - Photo record for nominated sites.
- Adaptive Management Response including:
  - Water level and surface water quality.
  - 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).
  - 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 2015*) summarises the results of the monitoring undertaken between June 2014 and May 2015 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

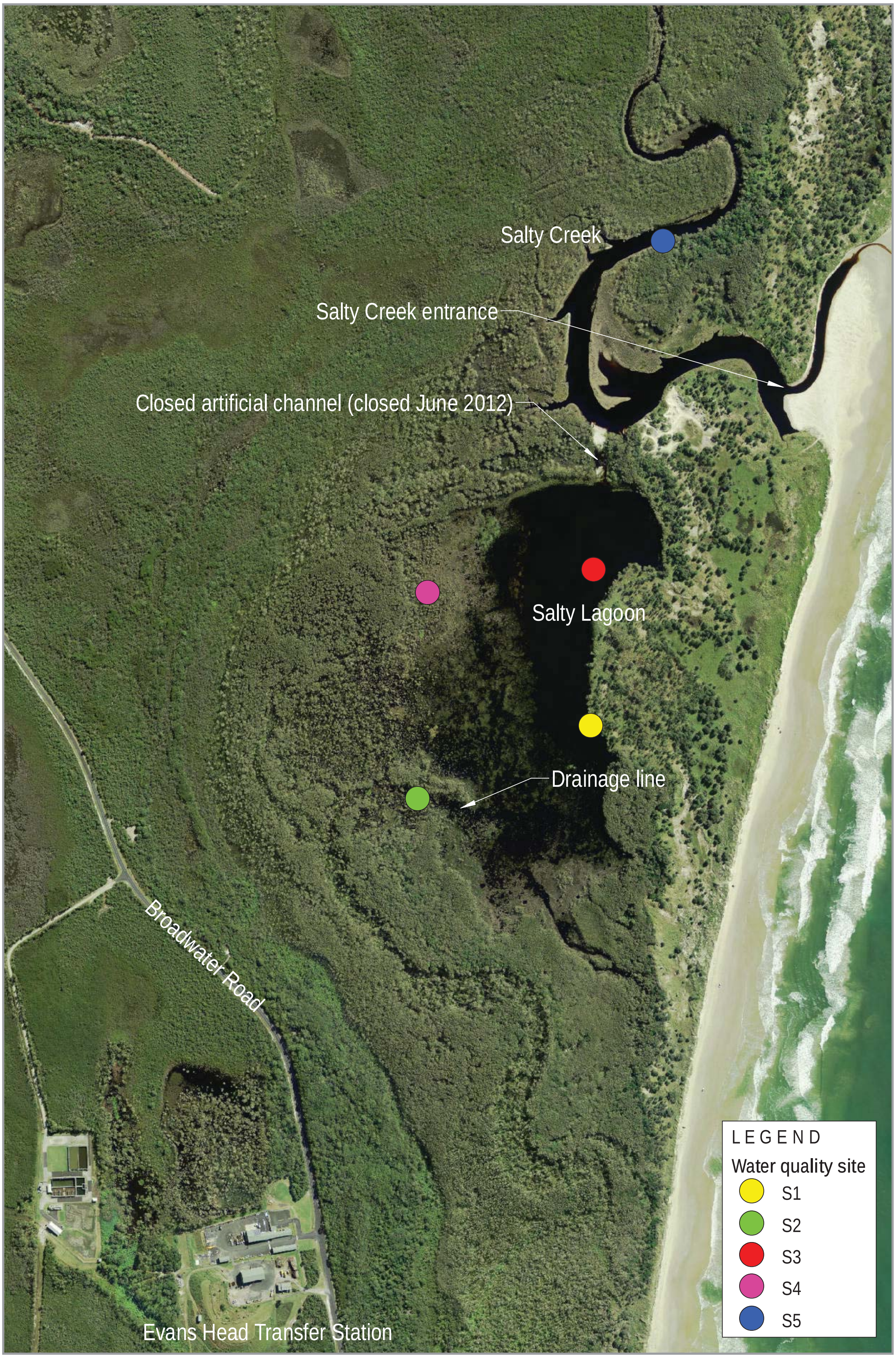
Discrete water quality samples were taken from surface water (approx. 0.2 metre depth) at four sites in Salty Lagoon (S1-S4) and a single site (S5) in Salty Creek on a monthly basis. An additional quality assurance (QA) replicate sample was collected from a randomly chosen site each month. The specific locations of all sites sampled are presented in **Table 2.2** and displayed in **Illustration 2.1**.

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 one metre 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.



0 200

North

Location of Water Quality Sites

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/ Aquatic Science and Management, 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
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 three 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 2014 to 31 May 2015 there were 2920 (8.3%) missed data points from the Salty Lagoon PWQMS and 698 (2.0%) 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 **Figure 2.1** and are discussed below.

Water Level

In comparison with the previous year the water level in Salty Lagoon was relatively stable. However, there was a period of moderately low water levels corresponding with a dry period in the early summer. The relatively high water levels resulted in water movements from Salty Lagoon into Salty Creek for the majority of the reporting period. There was only one occasion, in August 2014, where water from Salty Creek flowed into Salty Lagoon. The chart in **Figure 2.1** indicates that:

- 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 September to December 2014).
- Flow from Salty Creek into Salty Lagoon is unlikely when the entrance berm to Salty Creek remains low.
- 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. The key driving factors causing fluctuations in the conductivity of the water recorded in Salty Lagoon during this reporting period were rainfall, evaporation and, on one occasion, saltwater ingress from Salty Creek. Saltwater ingress from Salty Creek into Salty Lagoon happens because Salty Creek rises faster than Salty Lagoon in response to rainfall or as a result of storm surge and high tides. Evaporation causes a gradual increase in conductivity measurements. Rainfall has the opposite effect but typically operates over shorter timeframes. 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. The DO concentrations measured in surface waters between 1 June 2014 and 31 May 2015 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 three adaptive management site visits. In the current reporting period the DO concentration was 6 mg/L or less on approximately 81% of occasions and the DO concentrations was 1 mg/L or less on approximately 19% of occasions. This is in comparison with the previous reporting period where these values were 83% and 22% of occasions respectively. 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 2012a). 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. Other than small daily fluctuations in pH associated with other diurnal changes in water quality such as dissolved oxygen concentration, the majority of changes in pH in Salty Lagoon are closely aligned with rainfall.

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. There also appears to be a mechanism of pH buffering in Salty Lagoon resulting in a tendency towards neutral when freshwater flow ceases. It is uncertain if this buffering mechanism is associated with natural features, deposition of buffering marine salts or long term use of buffering chemicals in the Evans Head STP. This may warrant further investigation, as the wetlands around Salty Lagoon are typically low pH.

Temperature

Over the reporting period temperature fluctuated according to both daily and seasonal patterns. There is also 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 can contribute to the higher temperatures that encourage algal blooms and also increase the frequency of wind driven re-suspension of benthic material.

Plate 2.1 A Great Cormorant making use of the Salty Lagoon PWQMS infrastructure

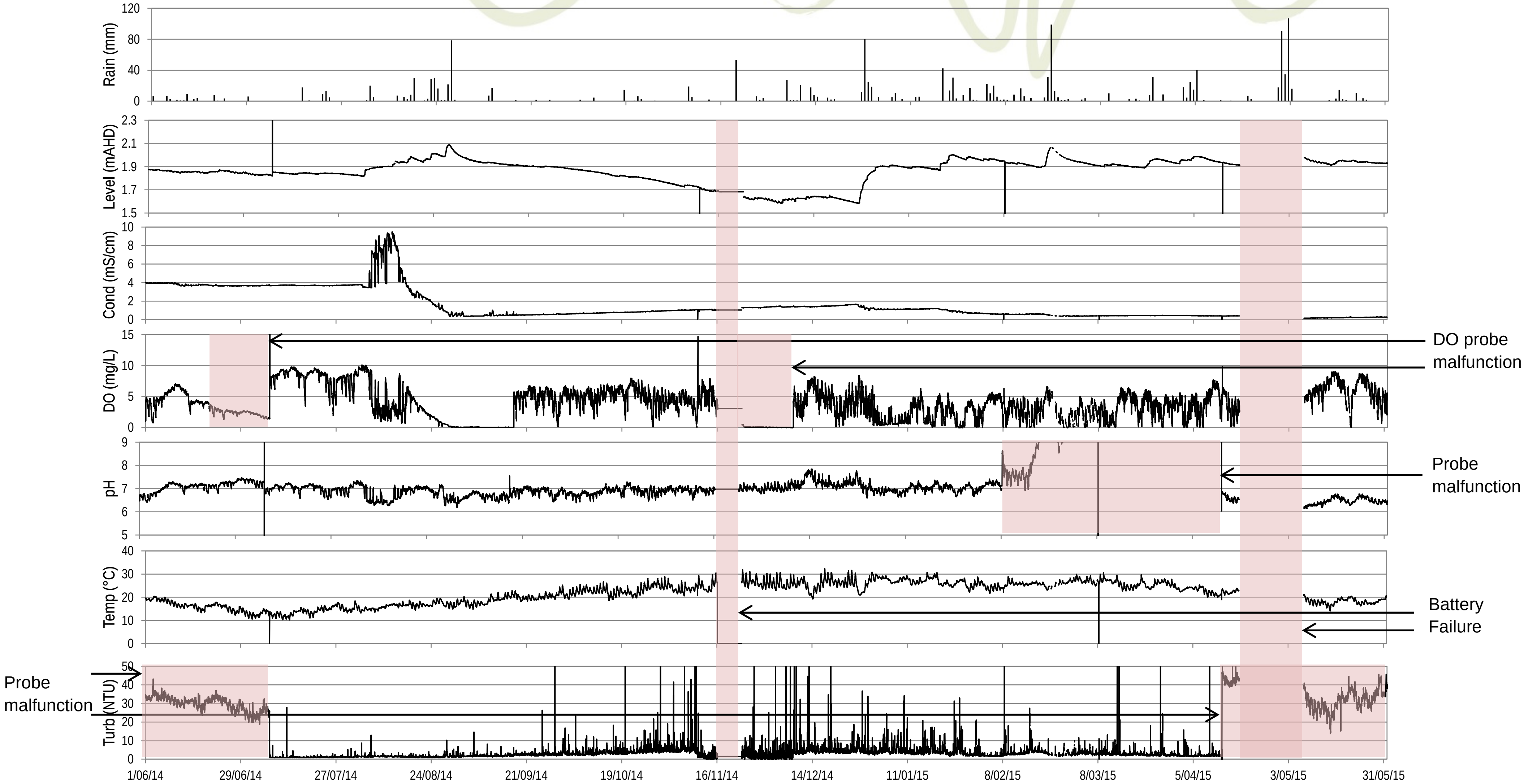


Figure 2.1 Data from the Salty Lagoon PWQMS for the current reporting period

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 **Figure 2.2**.

Water Level

The most important factor affecting the water level in Salty Creek is the status of its entrance. The entrance to Salty Creek opened 17 times in the current reporting period, compared with twice in the previous reporting period, five times and 17 times respectively in the reporting periods before that. The entrance to Salty Creek was very dynamic during the current reporting period and rarely closed over completely. 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 was only one occasion 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 fluctuated widely in response to the dynamic state of the entrance during this reporting period. The dataset indicates varying influences of heavy rainfall, tidal movements, seawater ingress and evaporation. During the times when conductive saline water dominated the readings from the Salty Creek PWQMS, discrete water quality samples from the surface of the water frequently showed that the water column was stratified into a heavy saline layer and a freshwater surface layer.

Dissolved Oxygen

Dissolved Oxygen (DO) concentrations measured at the Salty Creek PWQMS fluctuated widely throughout the year. A variety of factors influence the DO concentrations in Salty Creek. The general patterns of variation 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 91% of the reporting period and 1mg/L or less for approximately 25% of the reporting period. These figures are comparable to those reported last year and higher than the previous results.

pH

The pH measurements from the Salty Creek PWQMS fluctuated regularly during this reporting period and were closely associated with conductivity and the state of the entrance. 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 fluctuated on a daily and seasonal basis. Daily fluctuations in temperature are strongest when water levels are low. Turbidity measurements from the Salty Creek PWQMS were generally low, with periods of greater turbidity following seawater ingress and heavy rainfall.

Plate 2.2 Water quality monitoring probes are replaced with a serviced and calibrated spare at two month intervals

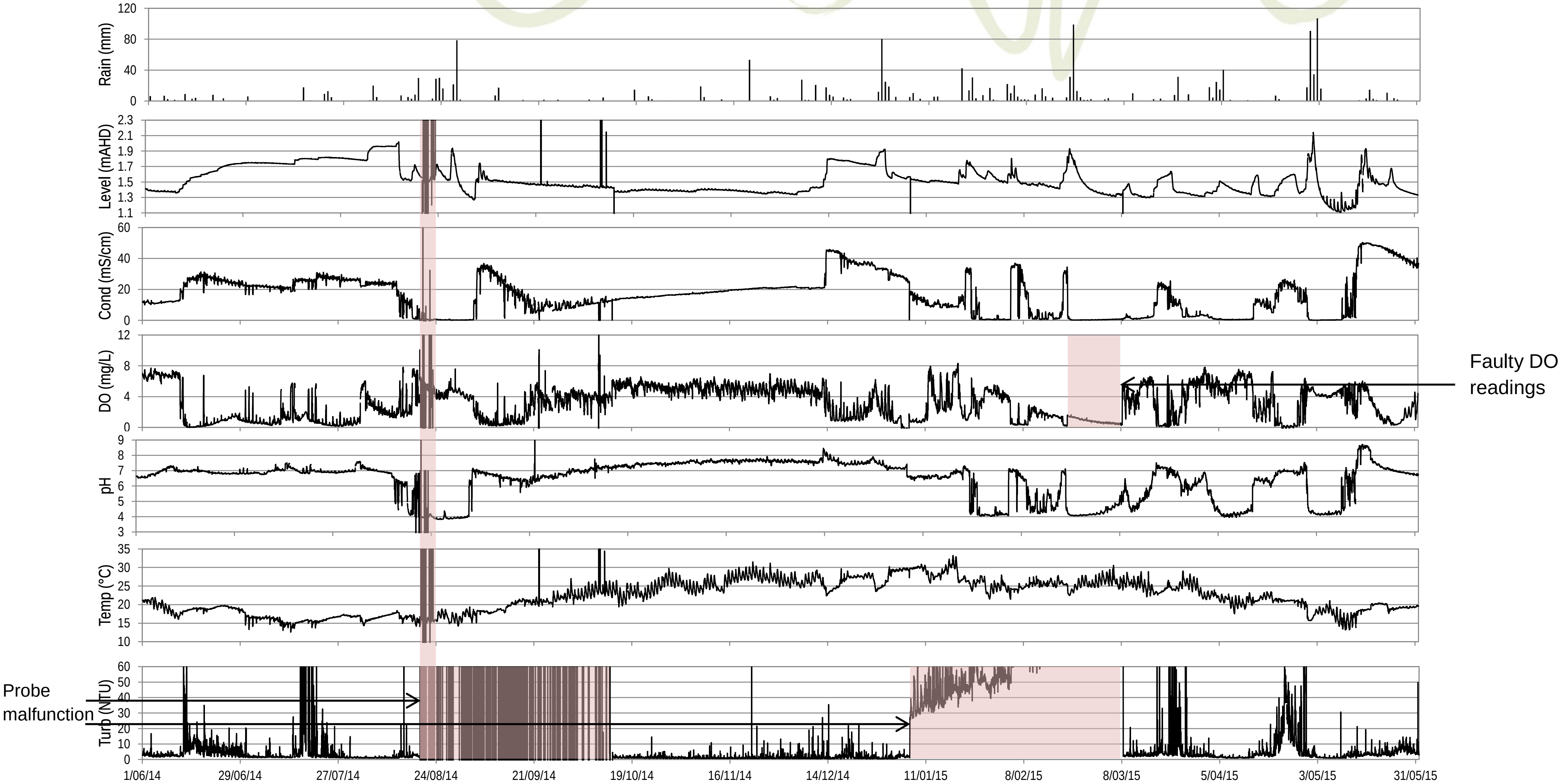


Figure 2.2 Data from the Salty Creek PWQMS for the current reporting period

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 2014 and 31 May 2015

Indicator	*Site*				
	S1	*S2*	*S3*	*S4*	*S5*
Nitrite Nitrogen (mg/L)	0	0	0	0	0
Nitrate Nitrogen (mg/L)	**0.035**	0	**0.0415**	0	0
Oxidized Nitrogen (mg/L)	0.035	0	0.0415	0	0
Ammonia Nitrogen (mg/L)	0.038	0	0.032	0	0.041
Total Kjeldahl Nitrogen (mg/L)	**1.725**	**1.75**	**1.7**	**1.68**	1.345
Total Nitrogen (mg/L)	**1.76**	**1.75**	**1.74**	**1.68**	1.355
Total Phosphorus (mg/L)	**0.14**	**0.16**	0.135	0.03	0
Orthophosphate (mg/L)	0.099	**0.125**	0.0985	0.016	0
Chlorophyll-a (µg/L)	**10.5**	3.5	**10**	2	0
Enterococcus (CFU/100mL)	4.5	25.5	9.5	25	8
Faecal Coliforms (CFU/100mL)	12	23	12	6.5	63
Blue Green Algae (cells/L)	0	0	0	0	0
Temp (˚C)	22.10	19.66	22.31	19.18	22.86
pH	6.74	6.07	6.79	5.39	5.04
ORP (mV)	142.5	151	149	167	194.5
Cond (mS/cm)	0.884	0.438	0.864	0.939	3.99
Turbidity (NTU)	2.95	2.55	2.7	1.7	2.3
DO (mg/L)	5.96	**1.53**	6.78	**2.26**	5.89
DO (% sat)	72	16.7	79.7	25.65	67.65
TDS (ppt)	0.57	0.28	0.55	0.60	2.55
Salinity (ppt)	0.4	0.2	0.4	0.45	2.1

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

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, 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 lower than those measured downstream.

During the current reporting period the concentrations of TN were most strongly influenced by evaporative distillation during the dry period up until December 2014 (**Figure 2.3**). In general, TN concentrations reduced after heavy rainfall. This indicates that nitrogen stored in the sediment in Salty Lagoon could be a significant source of nitrogen measured in the water column. If this is the case, TN concentrations should reduce over coming years as nitrogen is lost to the system in runoff.

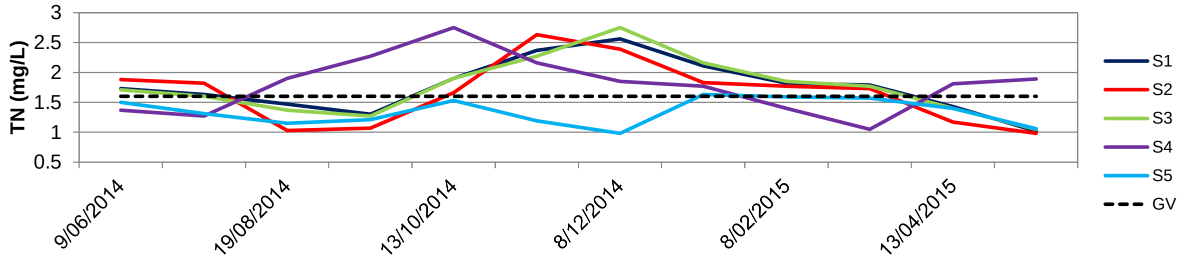


Figure 2.3 Time series of TN concentrations at all sites for the current reporting period

During the reporting period there was no obvious trend in the concentrations of DIN (**Figure 2.4**). The concentrations of ammonia and nitrate spiked at different sites at different times. 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.

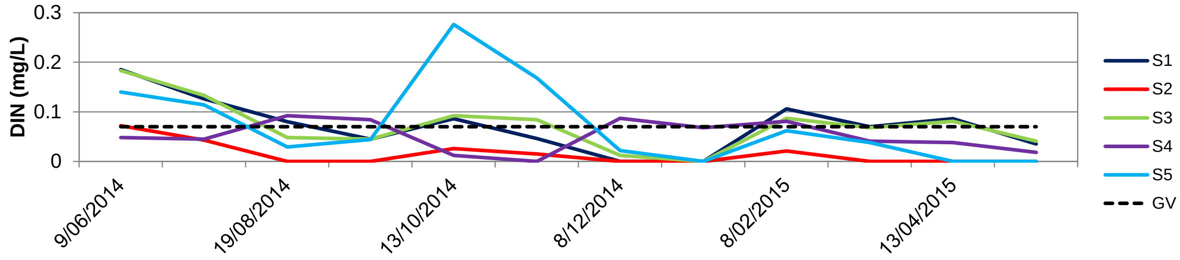


Figure 2.4 Time series of DIN concentrations at all sites for the current reporting period

A low to moderate level algal bloom persisted for much of this reporting period, particularly at S1, S2 and S3 (**Section** Error! Reference source not found.). 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.

The variation in phosphorus concentrations at the sites in Salty Lagoon did not conform precisely to a specific pattern (refer to Figure 2.5 and **Figure 2.6**). However, the data does allow for some general observations:

- Site S2 is the site most influenced by discharged effluent from the Evans Head STP and is most often the site with the highest phosphorus concentration.
- Concentrations of phosphorus were highest at S1 and S3 during the warmer months. This was also true at S2 with two exceptions.
- For the most part, the variation in phosphorus concentrations was closely aligned with variation in nitrogen concentrations. This contrasts with the results from last year when 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 elevated phosphorus concentrations measured during this reporting period were most often associated with elevated chlorophyll-a concentrations.

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

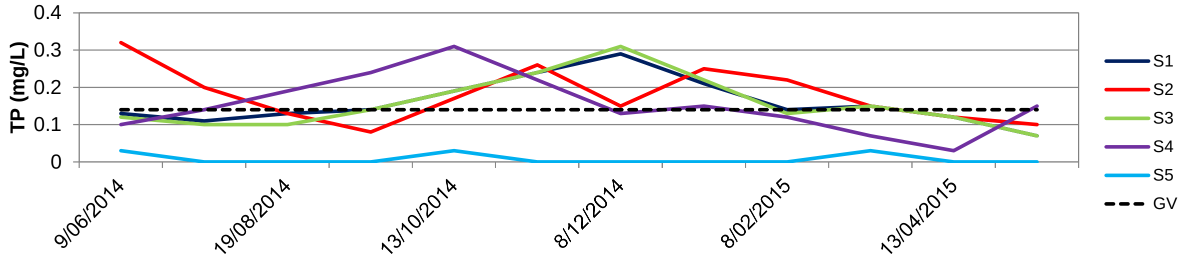


Figure 2.5 Time series of TP concentrations at all sites for the current reporting period

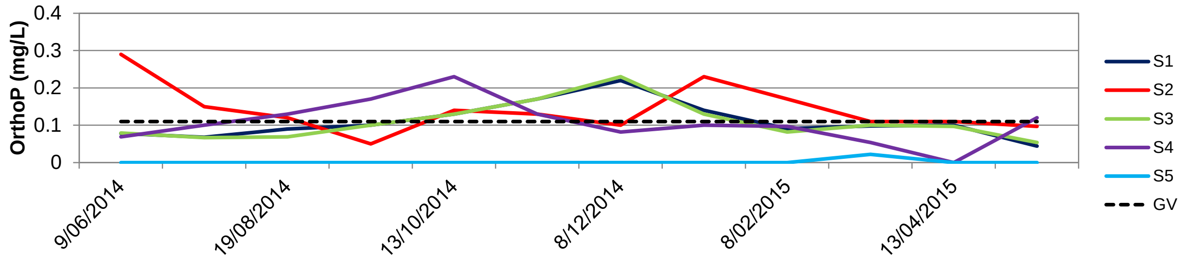


Figure 2.6 Time series of orthophosphate concentrations at all sites for current reporting period

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.

Chlorophyll-a concentrations at the sites in Salty Lagoon did not comply with guiding values for the majority of the reporting period (refer to **Figure 2.7**). Most of the results indicated an algal bloom of small to moderate proportions with the exception of samples collected in November and January, which indicated an algal bloom of moderate proportions.

The persistent algal bloom was associated with increased nutrient concentrations (that occurred as a result of the dry conditions) and contributed to by the high water temperatures experienced over the same period. As discussed in **Section 2.3.1.2** the high water temperatures are exacerbated by the low water levels that occurred as a result of the continued evaporation of water from the system. 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 non-toxic green algae from the genera *Cryptomonas* and *Euglena*.

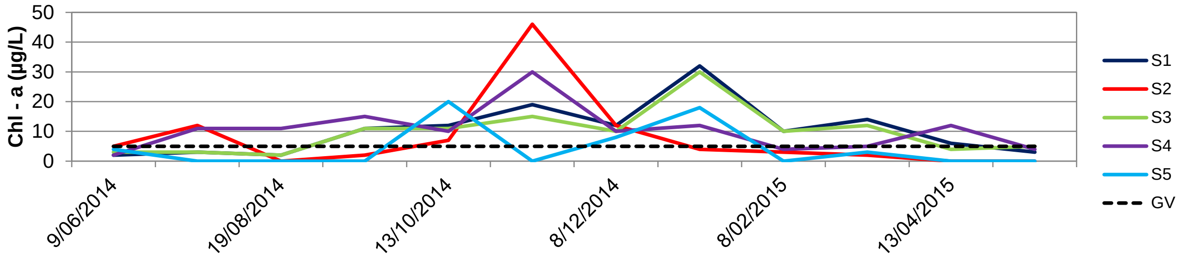


Figure 2.7 Time series of chlorophyll-a concentrations at all sites for the current reporting period

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.

With the exception of a few spikes in concentration the enterococcus and faecal coliform concentrations were low at all sites during the reporting period (refer to **Figure 2.8** and **Figure 2.9**).

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.

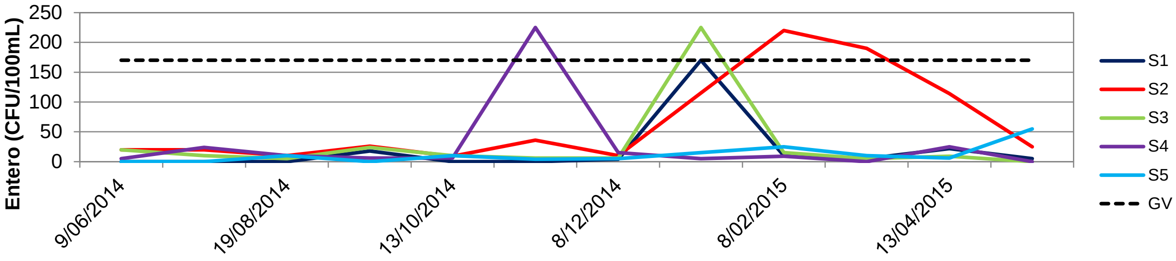


Figure 2.8 Time series of enterococcus concentrations at all sites for the current reporting period

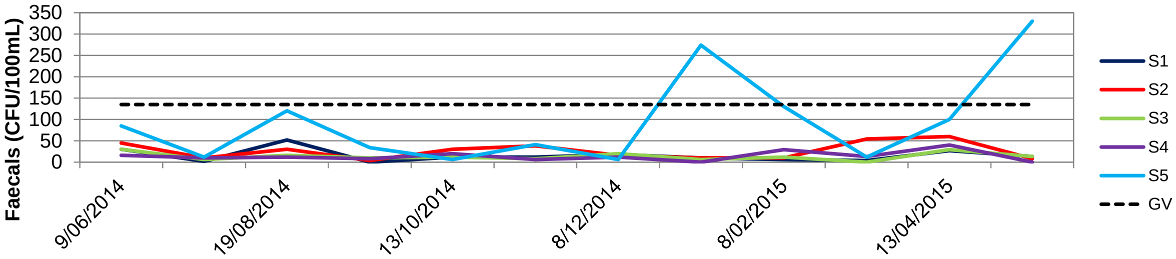


Figure 2.9 Time series of faecal coliform concentrations at all sites for current reporting period

2.3.3 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 **Figure 2.10**, **Figure 2.11**, **Figure 2.12** and **Figure 2.13**. With the exception of one TP 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.

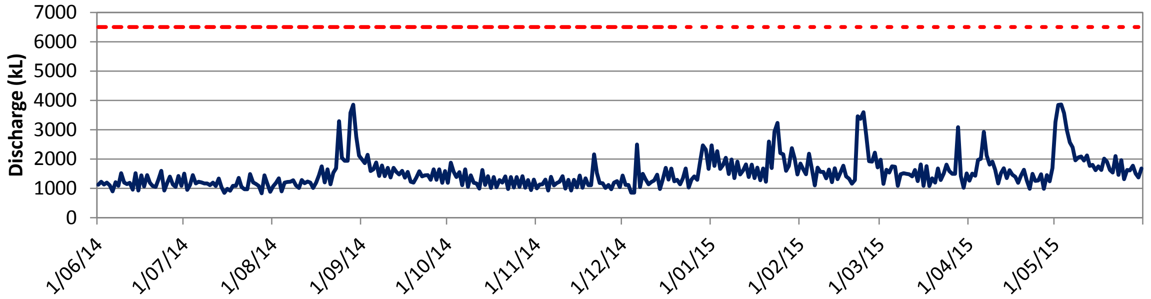


Figure 2.10 Time series of daily discharge volumes from the Evans Head STP (maximum allowed discharge volume in red)

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 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.

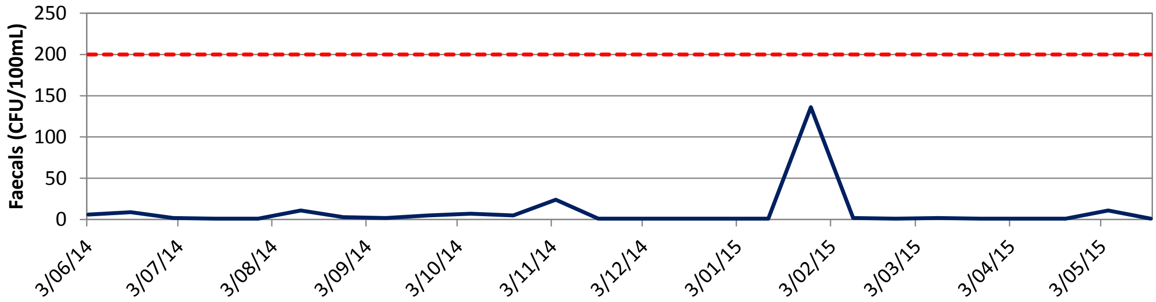


Figure 2.11 Time series of faecal coliform concentrations from the Evans Head STP discharge (90th percentile limit in red)

The concentrations of TN in discharged effluent are generally two to four 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).

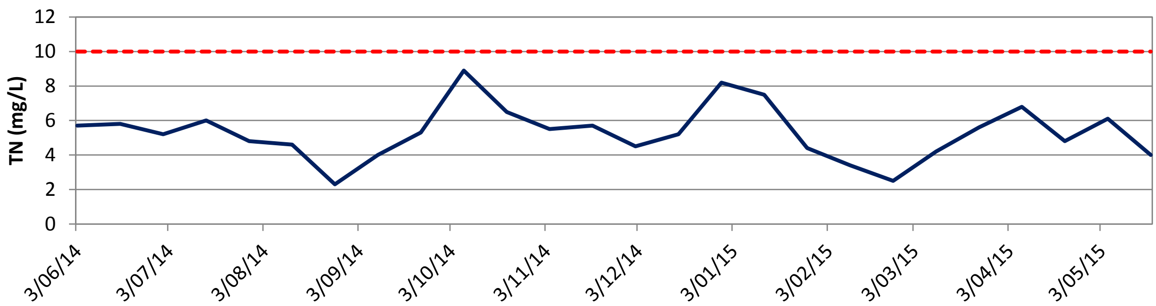


Figure 2.12 Time series of TN concentration from the Evans Head STP discharge (90th percentile limit in red)

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.

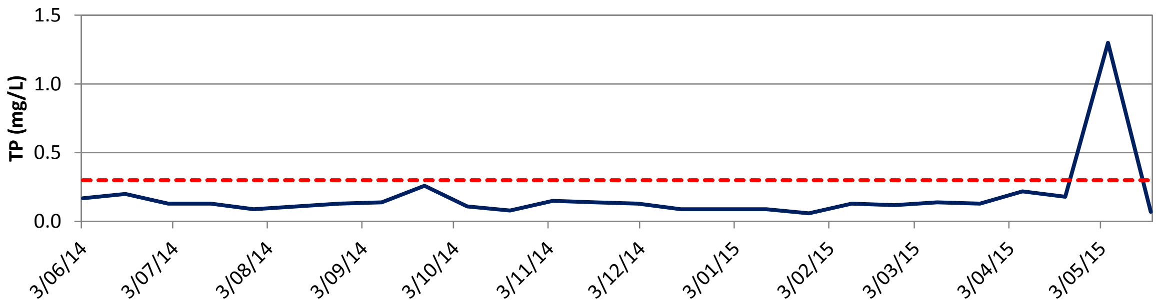


Figure 2.13 Time series of TP concentration from the Evans Head STP discharge (90th percentile limit in red)

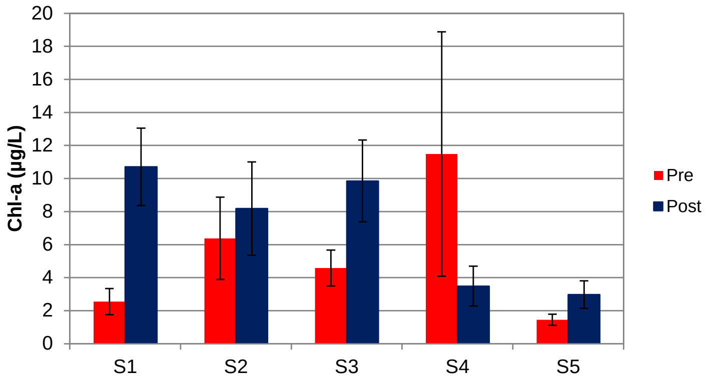
2.3.4 Comparison against Rehabilitation Targets

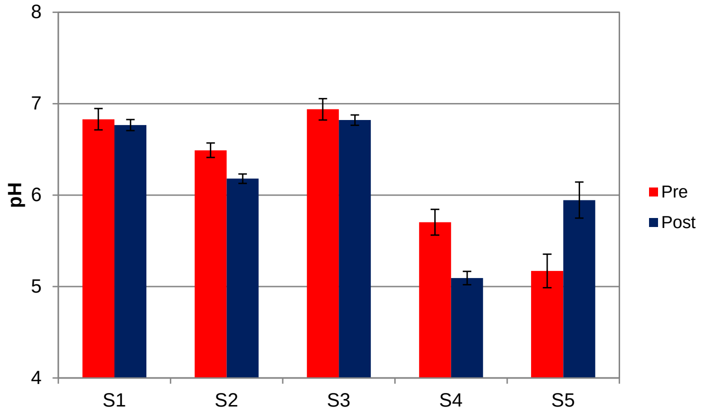
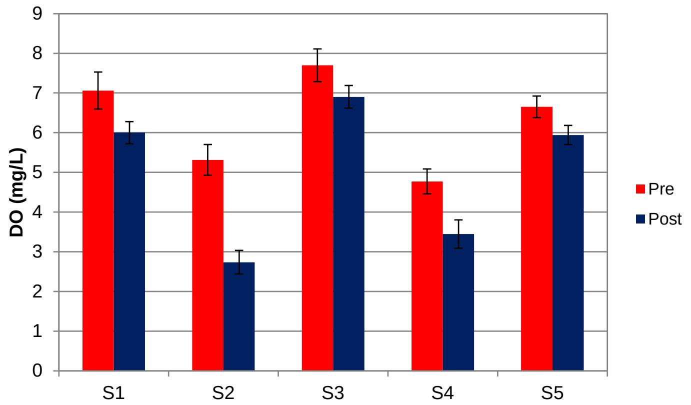
Closure of the artificial channel was anticipated to have a dramatic effect on the hydrology and water quality of Salty Lagoon (Hydrosphere 2011). Alongside the general goal of improved water quality Hydrosphere (2010 and 2011) listed a number of anticipated benefits and changes resulting from channel closure. These followed on from an ecosystem response model (ABER 2010) and are listed in Error! Reference source not found. along with a summary of the outcomes to date from data collected during the MPPC.

In general the data to date indicates that many of the predicted changes are being realised but that some are not. The data from the post-closure period are strongly affected by extreme dry weather between September 2013 and March 2014 when water quality became very poor and water levels very low. There was no comparable weather scenario during the pre-closure period. This is important to consider in the context of considering changes to water quality and hydrological conditions.

Table 2.5 Predicted Water Quality Changes and Outcomes to Date for the MPPC

Predicted Change	*Outcome to Date*
More natural hydrology and salinity regime including higher water levels – 1.9 m AHD for approximately 63% of the time.	This change has been realised. In the current reporting period the water levels in Salty Lagoon were > 1.85 m AHD for approximately 64% of the time. In the previous reporting period the respective value was 40%. The total for the period since the closure of the artificial channel is 58%. Prior to closure (from January 2011) the figure was 2%. In addition the mean water level has increased from 1.29 m AHD to 1.80 m AHD. Note that these figures include a period of extreme drought between September 2013 and March 2014.

Predicted Change	***Outcome to Date***
A reduced magnitude and rate of water level variation.	There has been a reduction in the variation of water level in Salty Lagoon. The standard deviation of the mean water level prior to channel closure was 0.25 m. Since channel closure it has been 0.24 m. However, the difference between the 10^{th} and 90^{th} percentile water levels since the closure has reduced from 0.65 m AHD to 0.44 m AHD.
Less frequent saline water ingress.	This anticipated change has been realised. There have been four occurrences of saline water ingress since the closure of the artificial channel in July 2012. In the 14 months prior to closure there were over 20. Since closure the average logged conductivity has reduced from 15.97 mS/cm to 2.83 mS/cm and the 90^{th} percentile has reduced from 44.1 mS/cm to 7.14 mS/cm.
Improved productivity of the benthic microalgal assemblage resulting in nutrient assimilation reduced algal blooms and reduced potential for deoxygenation.	It is uncertain if the productivity of the benthic macroalgal assemblage has changed since the closure of the artificial channel. The data that would be used to assess this is conflicting. For example, the average DO concentrations at the bottom of the water column have improved slightly since channel closure (and variation in DO concentrations at the bottom of the water column has reduced), turbidity has reduced and the reduced incidence of saline water ingress has created a more stable environment for benthic macroalgae. However, average DO concentrations at the surface of the water column have reduced overall since closure and nutrient concentrations have increased slightly.
Reduced water column algal biomass.	Using chlorophyll-a as a proxy for water column algal biomass there has been a significant increase in algal biomass in the open water of Salty Lagoon. This is likely to be related to a number of other changes, including increased nutrient concentrations and a more stable freshwater environment. Notably, no blue green algae have been detected in water samples since the beginning of the MPPC  **Figure 2.14 Mean ± SE chlorophyll-a concentrations at all sites before and after channel closure**
Improved water quality generally with a risk of poor water quality episodes in the period immediately following the channel closure.	With respect to nutrient and microalgal concentrations there has not been an improvement in the average water quality conditions since the closure of the artificial channel. With respect to turbidity and pH there has been an improvement and stabilisation of water quality. The risk of poor water quality episodes in the period following the channel closure was realised during the drought conditions that persisted between October 2013 and March 2014. Poor water quality conditions resulted in algal blooms but have not resulted in a fish kill or other ecological incident.

Predicted Change	Outcome to Date
Less temperature variability.	This logged data from the Salty Lagoon PWQMS indicates that this has been realised with the exception of the period between December 2013 and March 2014 when water levels were very low and temperature variability was extreme.
Reduced average and maximum pH values.	There has been a significant reduction in the average pH at sites S2 and S4 since channel closure but only slight reductions at S1 and S3. Since closure of the channel there have been no incidences of the high pH maxima that occurred with seawater ingress prior to closure.  **Figure 2.15 Mean ± SE pH at all sites before and after channel closure**
Generally higher DO concentrations with a reduction in dramatic DO crashes and more predictable diurnal variation of DO.	The DO concentrations in surface waters have not increased since channel closure. While regular periods of low DO concentrations measured at the Salty Lagoon PWQMS have continued since channel closure the DO crashes that were associated with fish kill events prior to channel closure have not eventuated. Diurnal variation in DO concentrations is evident in the data from the PWQMS but when water levels are high wind driven mixing and freshwater flow are the dominant features driving DO concentrations.  **Figure 2.16 Mean ± SE DO concentrations in discrete samples from surface waters at all sites before and after channel closure**

<table>
<tr><th>Predicted Change</th><th>Outcome to Date</th></tr>
<tr><td>Potential for low DO occurring as a result of high BOD of the marsh sediments and/or increased photo-oxidation of tannins in the warmer months</td><td>These anticipated changes have been realised to an extent and provide a good insight into the DO patterns that have been observed since channel closure. Persistent low DO concentrations at sites S2 and S4, particularly since channel closure are likely to be widely related to the BOD of the rich organic sediments at these sites, along with the naturally low DO runoff from the catchment upstream of these sites. Also, although the pattern is not entirely clear, maximum daily DO concentrations in the summer months have tended to be lower than the winter months since channel closure.</td></tr>
<tr><td>Reduced probability of wind driven turbidity increases and no draining related turbidity spikes.</td><td>Turbidity has reduced significantly at S1 and S3 since channel closure. There have been no draining related turbidity spikes and wind driven turbidity increases have been reduced with the exception of the period of very low water levels between December 2013 and March 2014.

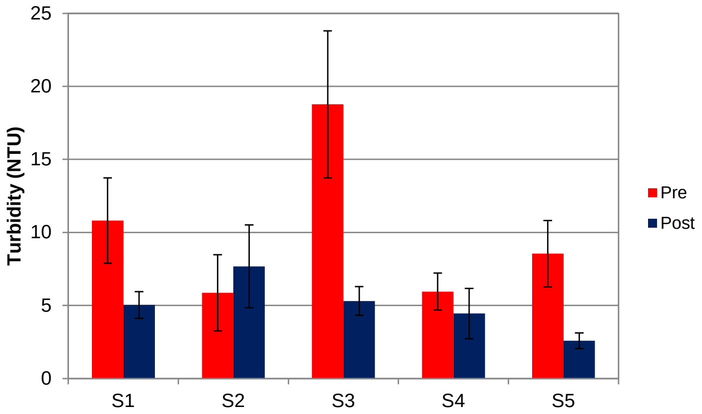


Figure 2.17 Mean ± SE turbidity measurements in discrete samples from surface waters at all sites before and after channel closure</td></tr>
<tr><td>Reduced TP concentrations over time resulting from greater benthic microbial uptake and higher burial rates.</td><td>There have been significant but small increases in the average TP concentrations at S1, S3, a larger relative increase at S4 and a small increase at S2.

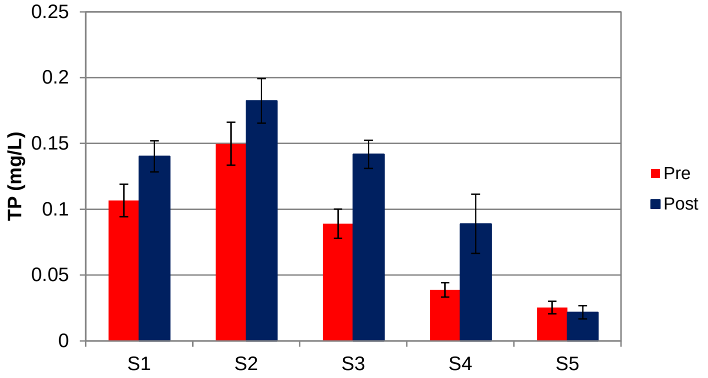


Figure 2.18 Mean ± SE TP concentrations at all sites before and after channel closure</td></tr>
<tr><td>Poor water quality episodes around high risk periods such as low water levels and high temperatures.</td><td>This predicted risk has been realised. During the summer months of 2013/2014 water quality became very poor when water levels were at extreme lows and temperatures were very high.</td></tr>
</table>

<table>
<tr><th>Predicted Change</th><th>Outcome to Date</th></tr>
<tr><td>Reduced TN concentrations and continued dominance of DON.</td><td>The predicted reduced TN concentrations have not yet been realised. However, the extreme dry conditions that have characterised a large proportion of the post closure period have clearly contributed to higher average nitrogen concentrations.

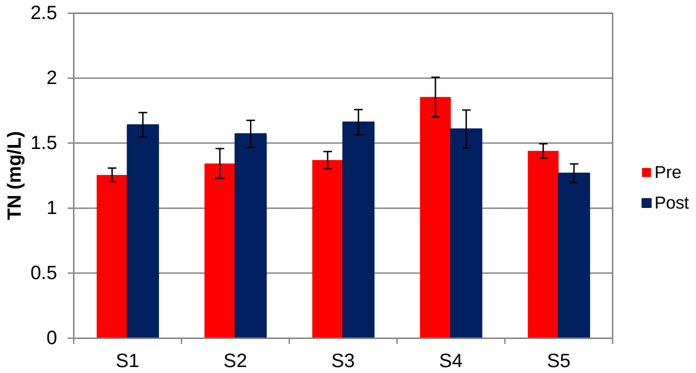


Figure 2.19 Mean ± SE TN concentrations at all sites before and after channel closure

The predicted continued dominance of DON as the major form of nitrogen in samples has continued although at S1 and S3 the proportion of TN as DIN has increased slightly in the post closure period.

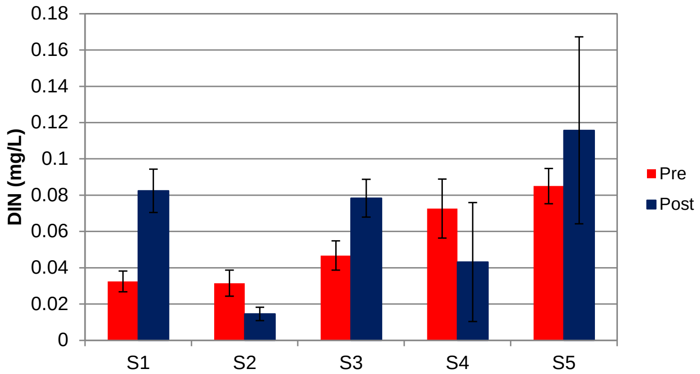


Figure 2.20 Mean ± SE DIN concentrations at all sites before and after channel closure</td></tr>
<tr><td>Reduced severity of Salty Creek drawdown during draining events.</td><td>This change has been realised. The 95th percentile values for level reduction over 15 minutes at the Salty Creek PWQMS before and after closure are 0.4 cm and 0.2 cm respectively. For level reduction over one hour the values are 1.3 cm and 0.8 cm respectively. The 98th percentile values for level reduction over 15 minutes at the Salty Creek PWQMS before and after closure are 1 cm and 0.3 cm respectively. The 98th percentile values for level reduction over one hour at the Salty Creek PWQMS before and after closure are 2.7 cm and 1.1 cm respectively.</td></tr>
<tr><td>Less protracted entrance opening of Salty Creek</td><td>This anticipated change has not been consistently realised. Although it is difficult to assess the change due to differences in the conditions that cause entrance opening and closing there appears to have been a change in the dynamics of the entrance and the trends of opening and closing. Since channel closure the entrance to Salty Creek has more often been very shallow and narrow and only very slowly draining. Prior to channel closure the entrance was more likely to close completely but when open the entrance was more likely to be deeper and/or wider.</td></tr>
</table>

2.3.5 Emerging Trends and Issues

Apart from the trends and issues described in the above subsections there have been three notable issues that have been incidentally observed during regular site inspections and reporting since channel closure. These are:

- An erosive headcut to the east of the old artificial channel that is advancing from Salty Creek towards Salty Lagoon through a naturally existing low point between the two water bodies.
- Spikes in the population of the aquatic plants Pacific Azolla (*Azolla filiculoides*) and Duckweed (*Lemna sp.*) around S2.
- A reduction in the reliability of the permanent water quality monitoring equipment.

The advancement of the headcut to the east of the old artificial channel has been monitored via the positioning of survey stakes and fixed point photography since it was first noted in May 2014. The total advance of the headcut position in the year following the initial observation was approximately 2.2 m. Advance, and occasional widening, occurs during times of heavy rain. During dry times it does not tend to change, even when Salty Lagoon is consistently flowing out into Salty Creek. The position and continued advance of the headcut could potentially lead to a new channel between Salty Lagoon and Salty Creek supporting flow in both directions and return Salty Lagoon to the pre-closure state.

Plate 2.3 Water flowing from Salty Lagoon to Salty Creek has created a headcut that is advancing between the two waterways

The first spike in the populations of Pacific Azolla and Duckweed was noted in October 2011, before closure of the artificial channel. Another major spike occurred in February 2015. It is uncertain if this is a new trend or if these plants have been irregularly blooming over the long term. There has not been a clear correlation between the timing of the increased growth in these plants and other occurrences such as poor water quality or high water temperatures. Further monitoring may provide a greater insight into this issue.

The permanent water quality monitoring equipment is aging and beginning to require more regular maintenance. A number of strategies have been put in place to manage this and to continue to receive reliable data from this system.

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 2010). 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

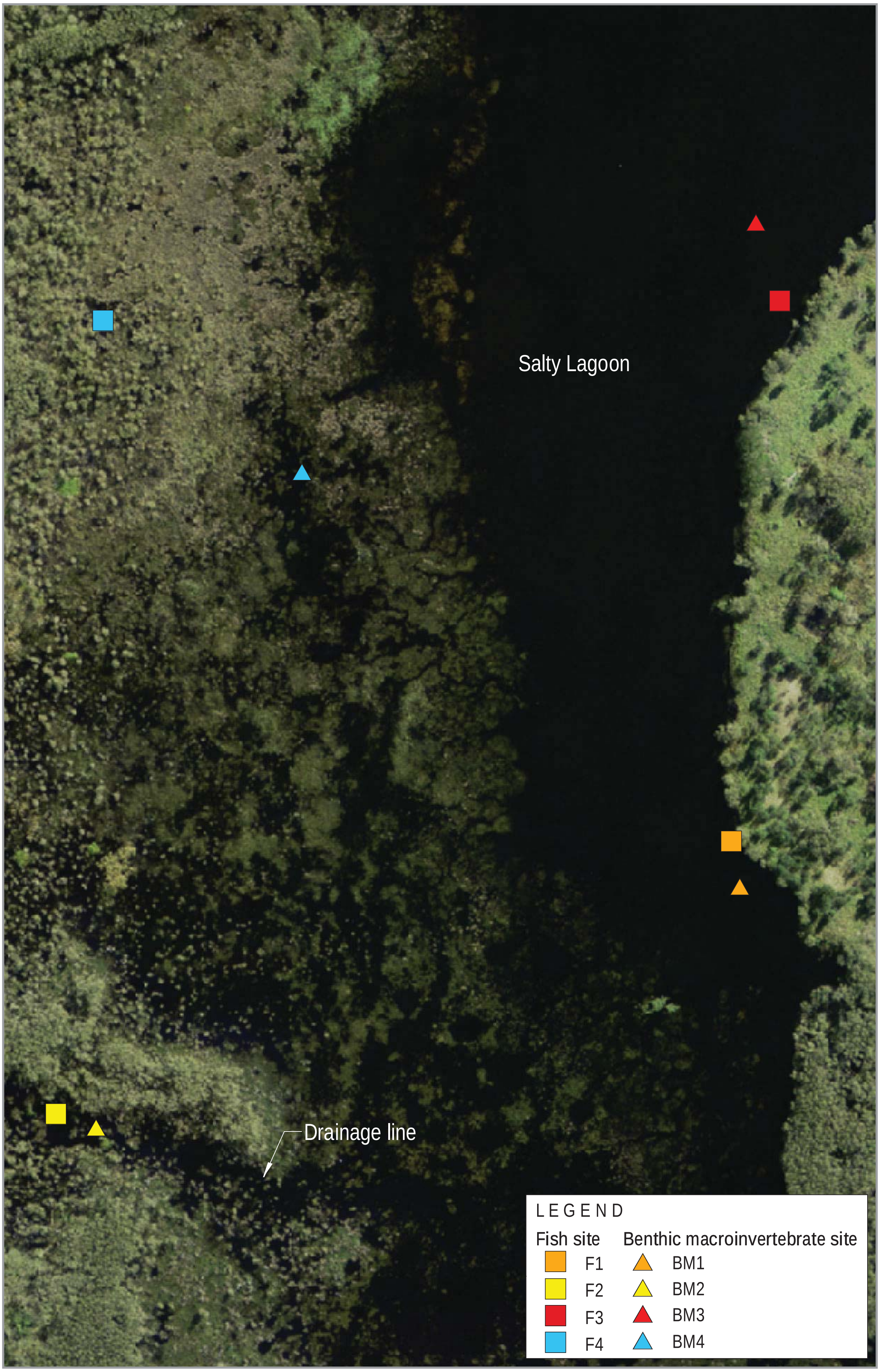
3.2.1 Site Location

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**.

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



Location of Benthic Macroinvertebrate and Fish Sites

GeoLINK environmental management and design

Annual Report 2015 - Salty Lagoon Monitoring Program:
Pre-Post Closure of Artificial Channel
1731-1174

Illustration 3.1

Table 3.1 Description of Benthic Macroinvertebrate Sites and 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. Water quality and water level at this site were relatively consistent during the current monitoring period.	0542065	6782781
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 freshwater for the duration of the current reporting period and experienced relatively stable water levels and water quality. The quality of the freshwater changes at this site in response to rainfall. When effluent discharge dominates freshwater inflow higher pH values are recorded. During wet times lower pH values are recorded.	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. Water levels and water quality were relatively stable at this site during the current reporting period. The nearest vegetation consists of Saltwater Couch and Bacopa (*Bacopa monnieri*), 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 and a variety of rushes. The water quality in this part of the lagoon is dominated by freshwater runoff from the catchment and generally has a low pH. Water levels and water quality were relatively consistent during the current reporting period.	0541738	6783005

3.2.2 Sample Collection

Benthic macroinvertebrates were sampled once per season. The dates of benthic macroinvertebrate collection were 7 July 2014, 13 October 2014, 6 January 2015 and 13 April 2015. At each of four sites, three benthic cores were collected at horizontal intervals of between one and two metres. The cores were taken using a 10 cm diameter round corer inserted to a depth of 10 cm. Cores were field rinsed over a one millimetre 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 one millimetre 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.

3.3 Results and Discussion

3.3.1 Conditions at the Time of Sampling

In comparison to recent years the conditions at the time of sampling were relatively stable 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 were consistent between surveys with a difference of 0.08 m between the highest and lowest levels. However, water temperature, conductivity and nutrient concentrations varied within sites and between sampling times.

The main water quality factor providing background environmental variation during the benthic macroinvertebrate sampling events was seawater ingress that occurred outside of this reporting period but was still evident at the time of the first macroinvertebrate survey.

Table 3.2 Water Quality at all Sites at the Time of Benthic Macroinvertebrates Sample Collection

Site	Survey	Date	Water Level (mAHD)	Temp (˚C)	pH	Cond (mS/cm)	TN (mg/L)	TP (mg/L)
BM1	Winter 2014	7/07/2013	1.84	**13.36**	**6.91**	**3.72**	1.63	**0.11**
	Spring 2014	13/10/2013	**1.84**	22.49	6.6	0.71	1.9	0.19
	Summer 2015	6/01/2014	1.91	**27.63**	**6.5**	1.11	**2.11**	**0.21**
	Autumn 2015	13/04/2014	**1.92**	21.7	6.74	**0.38**	**1.43**	0.12
BM2	Winter 2014	7/07/2013	1.84	**9.41**	6.09	**2.22**	1.82	0.20
	Spring 2014	13/10/2013	**1.84**	19.84	5.99	0.57	1.66	0.17
	Summer 2015	6/01/2014	1.91	**23.77**	**5.83**	0.46	**1.83**	**0.25**
	Autumn 2015	13/04/2014	**1.92**	19.47	**6.23**	**0.31**	**1.17**	**0.12**
BM3	Winter 2014	7/07/2013	1.84	**12.88**	6.75	**3.75**	1.60	**0.10**
	Spring 2014	13/10/2013	**1.84**	22.95	**6.72**	0.69	1.90	0.19
	Summer 2015	6/01/2014	1.91	**27.75**	**7.0**	1.11	**2.16**	**0.22**
	Autumn 2015	13/04/2014	**1.92**	21.67	6.83	**0.39**	**1.40**	0.12
BM4	Winter 2014	7/07/2013	1.84	**9.90**	5.47	**1.62**	**1.89**	**0.15**
	Spring 2014	13/10/2013	**1.84**	19.08	5.31	1.05	1.85	**<0.03**
	Summer 2015	6/01/2014	1.91	**23.94**	**5.27**	1.57	1.65	0.04
	Autumn 2015	13/04/2014	**1.92**	19.28	**5.54**	**0.35**	**1.31**	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.

3.3.2 Diversity

A total of 22 macroinvertebrate taxa have been identified from samples collected to date. Of the 22 taxa identified, six have only been observed in one of the 13 seasonal surveys undertaken. Only 14 of the 22 taxa were collected during the five surveys prior to channel closure. Eighteen taxa have been collected in the 12 surveys since channel closure. 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 17 surveys.

The most common taxa captured during the current reporting period were the *Chironominae, Hydrobiidae* and *Capitellidae* (**Table 3.4** and Table 3.5). In the previous reporting period the most common taxa collected were the *Chironominae, Hydrobiidae* and *Corixidae*. 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
Winter 2014	10	56
Spring 2014	10	110
Summer 2015	8	66
Autumn 2015	8	50

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 *Spionidae* and *Capitellidae*. 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 at S1 and S2

		BM1				BM2			
Taxa	***Common Name***	***2012***	***2013***	***2014***	***2015***	***2012***	***2013***	***2014***	***2015***
Chironominae	Non biting midge	19	7	318	13	98	137	43	51
Tanypodinae	Non biting midge	0	0	0	3	0	0	0	0
Ceratopogonidae	Biting midge	10	1	0	2	0	2	2	0
Chaoboridae	Phantom midges	0	0	0	0	0	0	0	0
Sialidae		0	0	0	0	0	0	0	0
Libellulidae	Dragonfly	0	0	0	0	5	4	0	0
Hemiphlebidae	Damselfly	1	0	0	0	0	0	0	0
Leptoceridae	Stick Caddis	0	0	0	1	0	0	0	0
Pyralidae	Aquatic Caterpillar	0	0	0	1	0	1	0	1
Hygrobiidae	Screech Beetle	0	0	0	0	0	0	0	0
Hydrophilidae	Water Scavenger Beetle	0	0	1	1	0	0	5	0
Dytiscidae	Diving Beetle	0	0	0	0	0	0	1	0
Corixidae	Water Boatmen	0	0	20	2	0	0	0	0
Veliidae	Small Water Strider	0	0	0	0	0	0	0	1
	Springtail	2	7	2	1	1	0	4	2
Capitellidae	Polychaete	5	2	4	5	0	0	0	0
Spionidae	Polychaete	92	8	11	1	1	0	0	0
Mytilidae	Mussel	1	85	4	1	1	0	0	0
Hydrobiidae	Snail	3	4	31	22	3	20	0	0
Planorbidae	Snail	0	0	0	0	0	1	0	1
Sphaeromatidae	Isopod	0	4	5	0	3	1	0	0
Hymenosomatidae		0	0	0	0	0	0	0	0
Total animals		133	118	396	53	112	166	55	56
Total taxa		8	8	9	12	7	7	5	5

Table 3.5 Annual Totals of Benthic Macroinvertebrate Taxa at S3 and S4

		BM3				*BM4*			
Taxa	***Common Name***	***2012***	***2013***	***2014***	***2015***	***2012***	***2013***	***2014***	***2015***
Chironominae	Non biting midge	23	23	197	38	2	3	12	28
Tanypodinae	Non biting midge	0	0	0	0	2	1	3	0
Ceratopogonidae	Biting midge	0	1	1	1	3	0	0	0
Chaoboridae	Phantom midges	0	0	0	0	0	0	0	1
Sialidae		0	0	0	0	1	0	0	0
Libellulidae	Dragonfly	0	0	0	0	2	0	1	0
Hemiphlebidae	Damselfly	0	0	0	0	0	0	0	0
Leptoceridae	Stick Caddis	0	0	0	5	0	0	0	1
Pyralidae	Aquatic Caterpillar	0	0	0	0	0	0	0	0
Hygrobiidae	Screech Beetle	0	0	0	0	1	0	0	0
Hydrophilidae	Water Scavenger Beetle	0	0	0	0	0	1	1	2
Dytiscidae	Diving Beetle	0	0	0	0	0	1	0	0
Corixidae	Water Boatmen	0	0	40	1	0	0	4	2
Veliidae	Small Water Strider	0	0	0	0	0	0	0	0
	Springtail	1	1	0	0	0	3	3	3
Capitellidae	Polychaete	42	14	17	25	0	0	0	0
Spionidae	Polychaete	11	91	26	1	2	0	0	0
Mytilidae	Mussel	3	172	56	2	0	0	0	0
Hydrobiidae	Snail	0	6	66	58	54	1	5	0
Planorbidae	Snail	0	0	0	2	0	0	4	1
Sphaeromatidae	Isopod	1	5	16	2	9	3	0	0
Hymenosomatidae		1	0	0	0	0	0	0	0
Total animals		82	313	419	135	76	13	33	38
Total taxa		7	8	8	10	9	7	8	7

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 (**Figure 3.1**Figure 2.1Error! Reference source not found.). At BM2 and BM4 there are no apparent trends overall. The lower numbers of animals captured at these sites (see **Section 3.3.3**) contribute to difficulties in determining any changes or patterns that are occurring.

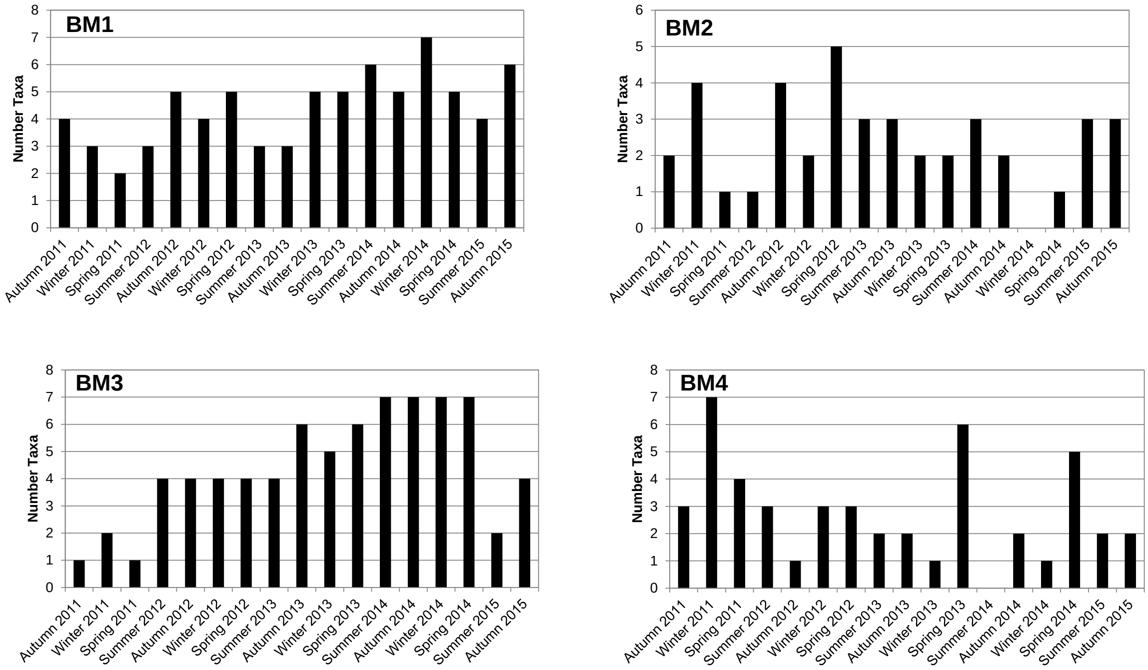


Figure 3.1 Number of macroinvertebrate taxa at all sites in all surveys since the beginning of the MPPC

3.3.3 Abundance

The numbers of benthic macroinvertebrates captured at each site have varied over time (**Figure 3.2**). However, there are no clear patterns evident in the data set. A closer look at the available data indicates that the majority of variation in total individuals is due to spikes in different taxa at different times.

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*. There have been some encouraging signs at BM1 in the current reporting period with the first collections of individuals from the *Tanypodinae*, *Leptoceridae*, *Hydrophilidae* and *Pyralidae* (all predominantly freshwater taxa) indicating a move towards a more stable freshwater environment.

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, to a lesser extent, *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 overall variation of abundance (Error! Reference source not found.). As with the other sites the variation is mostly explained by short term spikes in the numbers of individual taxa. However, there are some indications of a return to a more stable freshwater ecology, such as a reduction in the number of saltwater tolerant taxa such as *Spionidae* and *Capitellidae* and an increase in the numbers of freshwater taxa such as *Hydrobiidae* and *Chironominae* since the closure of the artificial channel. In addition, during the current reporting period the first individuals were collected from the predominantly freshwater taxa *Leptoceridae* and *Planorbidae*.

At BM4 there is a clear trend with respect to overall abundance (Error! Reference source not found.), though abundances have generally been low since the beginning of the MPPC. There has been a shift in the dominant taxa, from *Hydrobiidae* to *Chironominae* since closure of the artificial channel and during the current reporting period the first individuals were collected from the *Leptoceridae* and *Chaoboridae*.

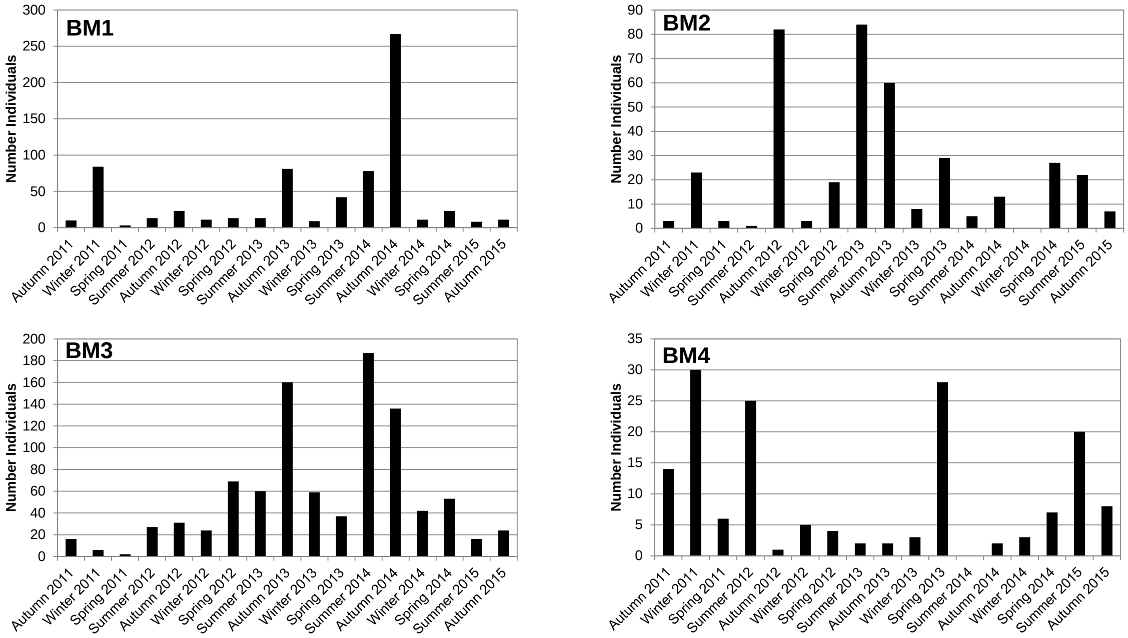


Figure 3.2 Number of macroinvertebrate individuals at all sites in all surveys since the beginning of the MPPC

3.3.4 Conclusions

There has been continued variation in the diversity, abundance and makeup of benthic macroinvertebrates collected during seasonal surveys. Some of the changes observed 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 macroinvertebrates captured at each site over time, indicating that macroinvertebrate abundance has fluctuated throughout Salty Lagoon throughout the MPPC. 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. Most of the variation observed to date has been in the form of short term spikes in the numbers of individual taxa. In general the numbers of individuals collected during the current reporting period have been more stable. 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. 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. There have also been a number of freshwater taxa collected for the first time during this reporting period, a positive sign. 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.

3.3.5 Comparison against Rehabilitation Targets

Closure of the artificial channel was anticipated to have an impact on the ecology of Salty Lagoon (Hydrosphere 2011). With respect to macroinvertebrates the key change specified was a return to a freshwater dominated, more robust, more diverse aquatic ecology. The data to date indicates that this predicted change is happening to an extent. Although there has not been a consistent overall increase in the diversity of the system there has been an increase in the number of freshwater taxa collected and a number of freshwater taxa were collected for the first time during the current reporting period. There has also been an (inconsistent) reduction in the abundance and diversity of the salt water tolerant taxa that have been captured, particularly in the current reporting period. With respect to the robustness of the macroinvertebrate ecology the changes have been inconsistent, though the short-term spikes in the populations of individual taxa that have characterised data from previous reporting periods were not evident in the current reporting period.

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 13 October 2014, 6 January 2015 and 13 April 2015.

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 notable aquatic weeds observed during the current reporting period. An individual species of introduced plant, Cape Waterlily (*Nymphaea capensis*) was identified, but this is widely considered to be naturalised to the area and is seldom thought of as a weed. A total of 33 plant taxa have now been observed during the aquatic weed surveys since the beginning of the MPPC. Of these, 19 were observed during the current reporting period (refer to **Table 4.1**). Four types of native aquatic plant sometimes regarded as nuisance plants have been encountered. These were blue green algae (BGA, various species), Ferny and Pacific Azolla (*Azolla pinnata* and *A. flilculoides*) and Duckweed (*Lemna sp.*). BGA have not been observed since the early surveys prior to channel closure and have never been detected in water samples. Pacifc Azolla and Duckweed have been encountered at varying densities to the west of Salty Lagoon, particularly around site S2.

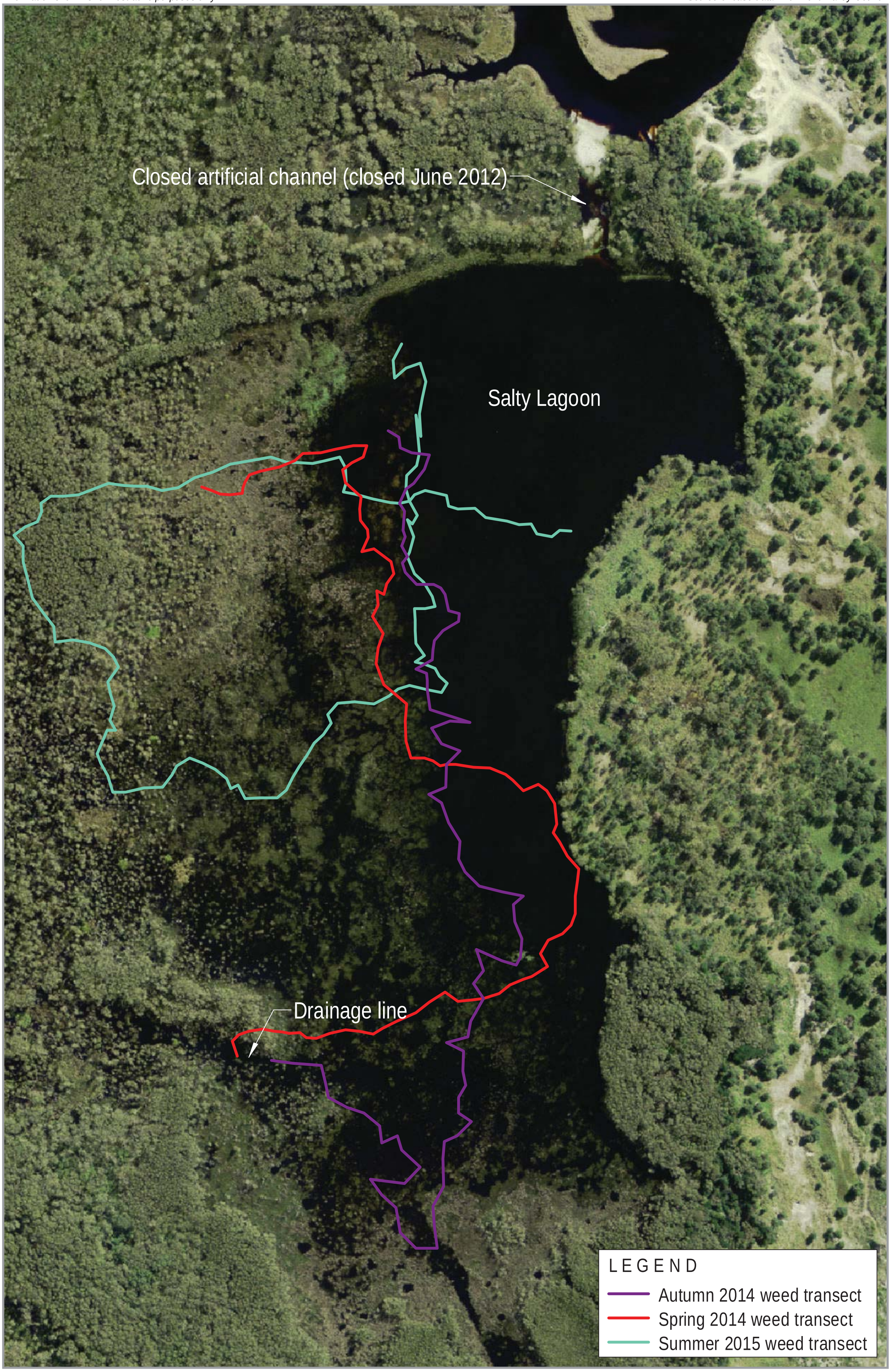
During the aquatic weed surveys a list of all aquatic plant species encountered was collected and a basic estimate of their abundance made. The list of aquatic plant species encountered is shown in **Table 4.1**.

Table 4.1 List of all Aquatic Plant Species Detected During Aquatic Weed Surveys and an Assessment of 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	Spr '14	Sum '15	Aut '15
Avicennia marina	Grey Mangrove	UC	UC	UC	UC	UC								
Sesuvium portulacastrum	Sea Purslane	UC	UC											
Hydrocotyle verticillata	Shield Pennywort		UC			UC			C	UC	C	C	UC	UC
Lomandra sp.	A Mat-rush							UC						
Enydra fluctuans	Buffalo Spinach	UC	UC					UC	C	UC	C	C	C	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				UC	
Baumea sp.	A Rush								UC	C	C	C	C	C
Cyperus exaltatus	Giant Sedge	UC		UC							C			
Cyperus difformis	Dirty Dora	UC		UC	UC		UC	UC		C	VC		C	UC
Gahnia sieberiana	Red-fruit Saw-sedge						UC	UC	UC		UC		C	UC
Shoenoplectus validus	River Club-rush	VC	VC	VC	VC	VC	C	C		C	C	VC	C	VC
Shoenoplectus mucronatus	A Rush	VC	VC	UC	UC						C			
Juncus krausii	Sea Rush	VC	VC	VC	VC	VC	VC	C	C	C	UC	C	C	VC
Juncus usitatus	Common Rush						UC		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	Spr '14	Sum '15	Aut '15
Lemna sp.	Duckweed								UC			C	VC	VC
Utricularia spp.	Bladderwort													VC
Nymphoides indica	Water Snowflake												UC	C
Nymphaea capensis^	Cape Waterlily											UC	UC	UC
Bacopa monnieri	Water Hyssop	C	VC	C	UC	C	C	UC	C	C	VC	VC	C	VC
Diplachne (Leptochloa) fusca	Brown Beetle Grass										VC			
Paspalum vaginatum	Saltwater Couch	VC	VC	VC	VC	VC	VC	VC	VC	VC	VC	VC	VC	
Phragmites australis	Common Reed	VC	C	C	C	C	C	C	C	C	VC	VC	VC	VC
Sporobolus virginicus	Saltwater Couch	C	C	C	C									VC
Persicaria decipiens	Slender Knotweed		UC											
Rhizophora stylosa	Red Mangrove	UC												
Azolla pinnata	Ferny Azolla	UC	VC	UC	UC	UC	UC	UC	UC					
Azolla filiculoides	Pacific Azolla											C	VC	VC
Typha orientalis	Cumbungi		UC	UC		UC	UC	UC	C	C	UC	UC	C	C
Enteromorpha sp.	Enteromorpha					C	VC		VC				VC	
Various	Blue Green Algae	C	C	C	UC	UC								

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



Aquatic Weed Transects

Illustration 4.1

4.4 Discussion

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

In the current reporting period there were a variety of plant species observed for the first time since the MPPC began, including Water Snowflake, Cape Water Lily, Bladderwort and Duckweed. There have also been a variety of plants previously observed that were not recorded during this reporting period. The majority of these were plants usually associated with saline or brackish water such as Mangroves, Sea Purslane, Bead Weed, Seablight and Angled Lobelia. This is indicative of the move towards freshwater ecosystems expected with the 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 Cape Waterlily (*Nymphaea capensis*)

Plate 4.2 Flowers of the Water Snowflake (*Nymphoides indica*)

4.4.1 Comparison against Rehabilitation Targets

With respect to aquatic plant life there was one relevant predicted change and one risk identified prior to the start of the MPPC. The predicted change to a freshwater dominated, more robust, more diverse aquatic ecology is being consistently realised with respect to the aquatic plants being identified. There have been a number of specialist freshwater plants observed since the closure of the artificial channel that were not observed in the pre-closure surveys. The risk of aquatic weed invasion has not been realised to date. There have been no significant freshwater weeds observed since the closure of the artificial channel.

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. In the second year after closure the water level in Salty Lagoon became very low as a result of drought conditions leading to higher conductivity and nutrient concentrations, and large temperature fluctuations. The current reporting period has been characterised by more stable water level and water quality conditions.

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; 2010b). 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 quinquenerva*). 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. In the current monitoring period this site has had more stable water levels and consistently low conductivity.
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 margins 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 had stable water levels during the current reporting period.
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. In the current monitoring period this site has had more stable water levels and consistently low conductivity.
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 had stable water levels during the current monitoring period.

* *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 7 July 2014, 13 October 2014, 6 January 2015 and 13 April 2015. 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 (P13/0035-1.0) and Animal Research Authority (14/1357). Five standard bait traps were set at intervals of between two and five metres at each site, depending on the available habitat. The traps were baited with pilchards 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 euthanased 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	7/07/2014	12.77	3.70	8.06	1.83	0
Spring 2013	13/10/2014	23.37	0.73	4.87	1.84	0
Summer 2014	6/01/2015	25.99	1.12	0.86*	1.91	15.6
Autumn 2014	13/04/2015	22.30	0.38	5.82	1.91	1.2

Note: Water quality and depth expressed as averages of readings taken at the Salty Lagoon PWQMS over the time of trap deployment.
** The water column was poorly mixed at this time. The surface waters had healthy DO concentrations.*

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 have been 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 the same as the previous reporting period, lower than both the five species captured during the annual reporting period before that 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**.

Variation in the diversity of fish species captured at each site since the beginning of the MPPC is displayed in **Figure 5.1**Error! Reference source not found.. The number of species captured at each of the sites has varied over time. There is no clear pattern to the observed variation in overall captured fish diversity.

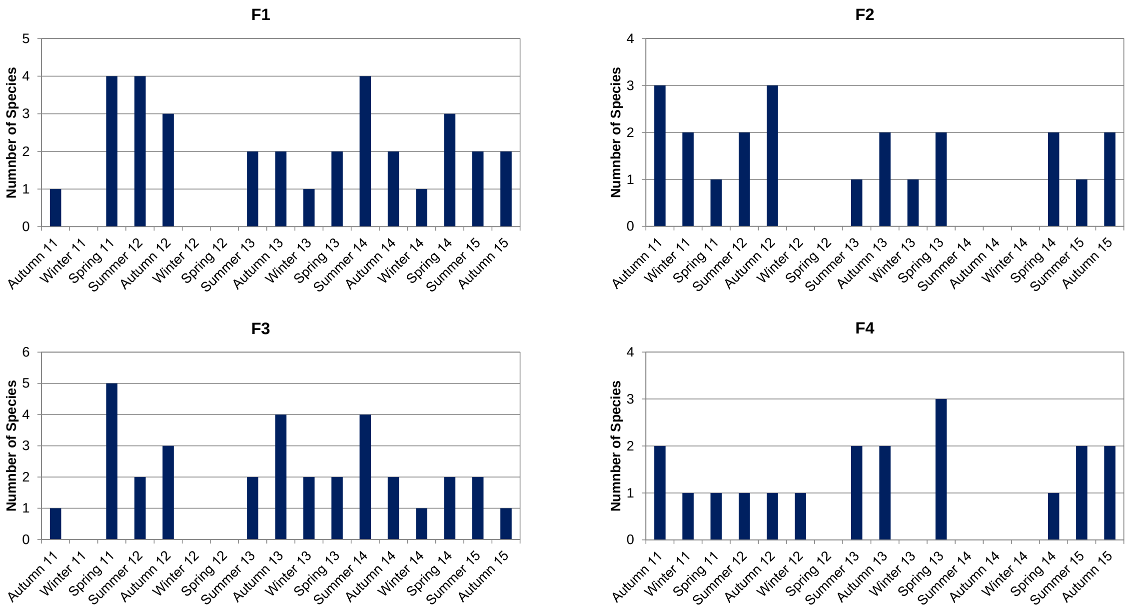


Figure 5.1 Number of fish species captured at all sites in all surveys since the beginning of the MPPC

Table 5.3 A List of Fish Species Captured During Fish Surveys since 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*

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 (**Figure 5.2**). With respect to the overall number of individual fish captured at each site, 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.

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*).

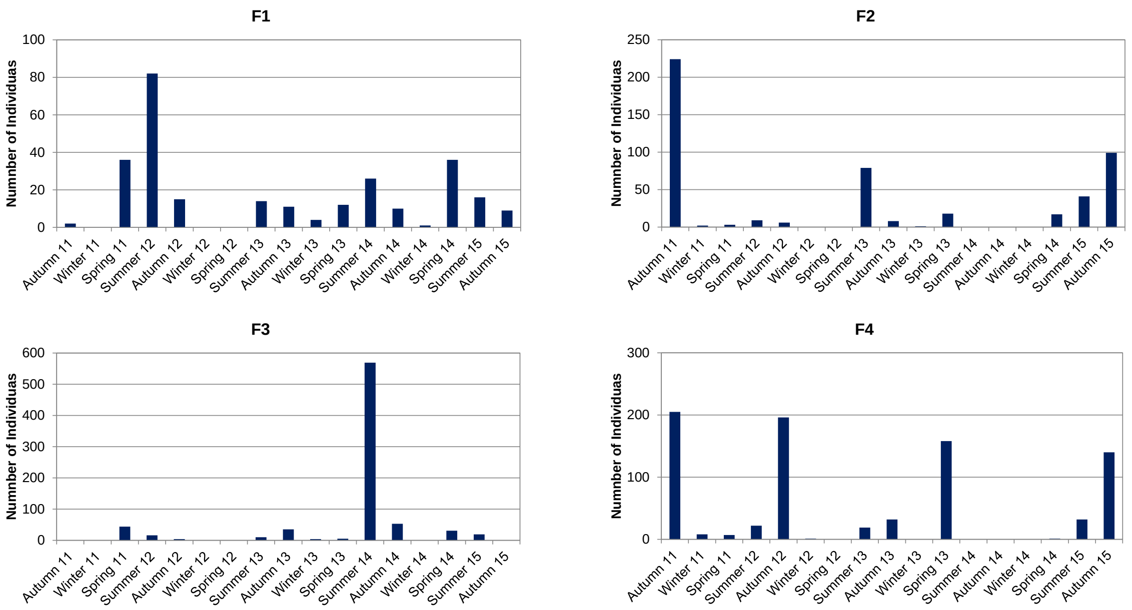


Figure 5.2 Number of individual fish captured at all sites in all surveys since the beginning of the MPPC

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, variation in fish communities tends 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. 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. As an example, the Tamar River Goby has not been captured at any site since the autumn 2013 survey.

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.
- Fluctuations in conductivity at F1 and F3 in the previous reporting period. 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 explains the majority of the variation.

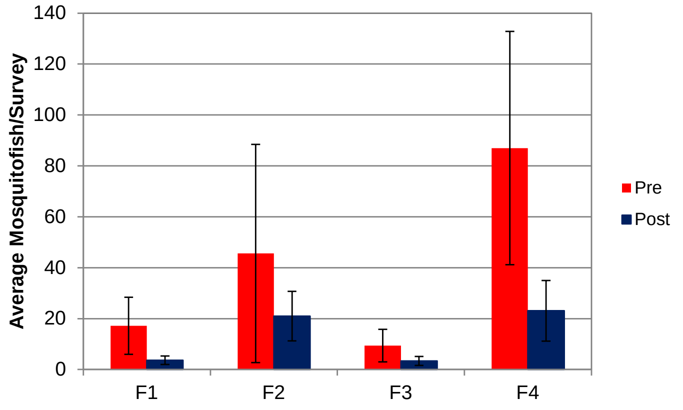
The conditions at the time of monitoring were relatively stable between the four surveys undertaken, with the exception of the conductivity, which was higher in the winter 2014 survey. In comparison with the previous annual reporting period, variations in water level, temperature and dissolved oxygen concentrations were much smaller. It is expected that water quality will stabilise further and that continued sampling over the long term will increase the capacity to draw conclusions.

The abundance and diversity of species trapped during this reporting period was low. The largest number of species trapped at any one site was three. Despite this, the results were comparable to those reported from previous surveys using bait traps (GeoLINK 2012a, GeoLINK 2013a, 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.

5.4.1 Comparison against Rehabilitation Targets

There were a variety of predicted changes to fish fauna resulting from closure of the artificial channel made prior to the MPPC. In general the data to date indicates that many of the predicted changes are being realised but that some are not. Predicted changes and the outcomes to date are listed in **Table 5.4**.

Table 5.4 Predicted Changes to Fish Fauna and Outcomes to Date for the MPPC

Predicted Change	***Outcome to Date***
Reduced risk of fish kills.	This anticipated change has been realised. There have been no fish kill events since closure of the artificial channel and many of the conditions that were related to fish kills in the past have not eventuated or have eventuated to a lesser extent.
Increased Mosquitofish dominance	This perceived risk has not been realised. The average mosquito fish capture per survey has reduced since the closure of the artificial channel. However, variation in this dataset is very large and it is difficult to draw strong conclusions about a reduction in the Mosquitofish population.  **Figure 5.3 Average ± SE Mosquitofish capture per survey in the pre and post-closure periods**
Potential for reduced freshwater eel migration to Salty Lagoon.	It is not certain whether this predicted risk has been realised or not. Freshwater eel capture has been very low throughout the MPPC. The potential for upstream migration of recruiting freshwater eels into Salty Lagoon has been very good in the current reporting period with water flowing from Salty Lagoon into Salty Creek for the majority of the time.

Predicted Change	Outcome to Date
A dominance of freshwater fish species, a larger fish population and reduced fish diversity.	This anticipated change has not been consistently realised. There has been a dominance of freshwater fish species, though the Flathead Gudgeon (a brackish water tolerant species) is still the most commonly encountered native fish in traps. There is no clear evidence of an increase or decrease in the fish population. There is some evidence, though not yet consistent, that fish diversity has reduced, as expected.

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. In the second year after closure the water levels fluctuated strongly but the current reporting period has seen fairly stable water levels and habitat availability.

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 7 July 2014, 13 October 2014, 6 January 2015 and 13 April 2015.

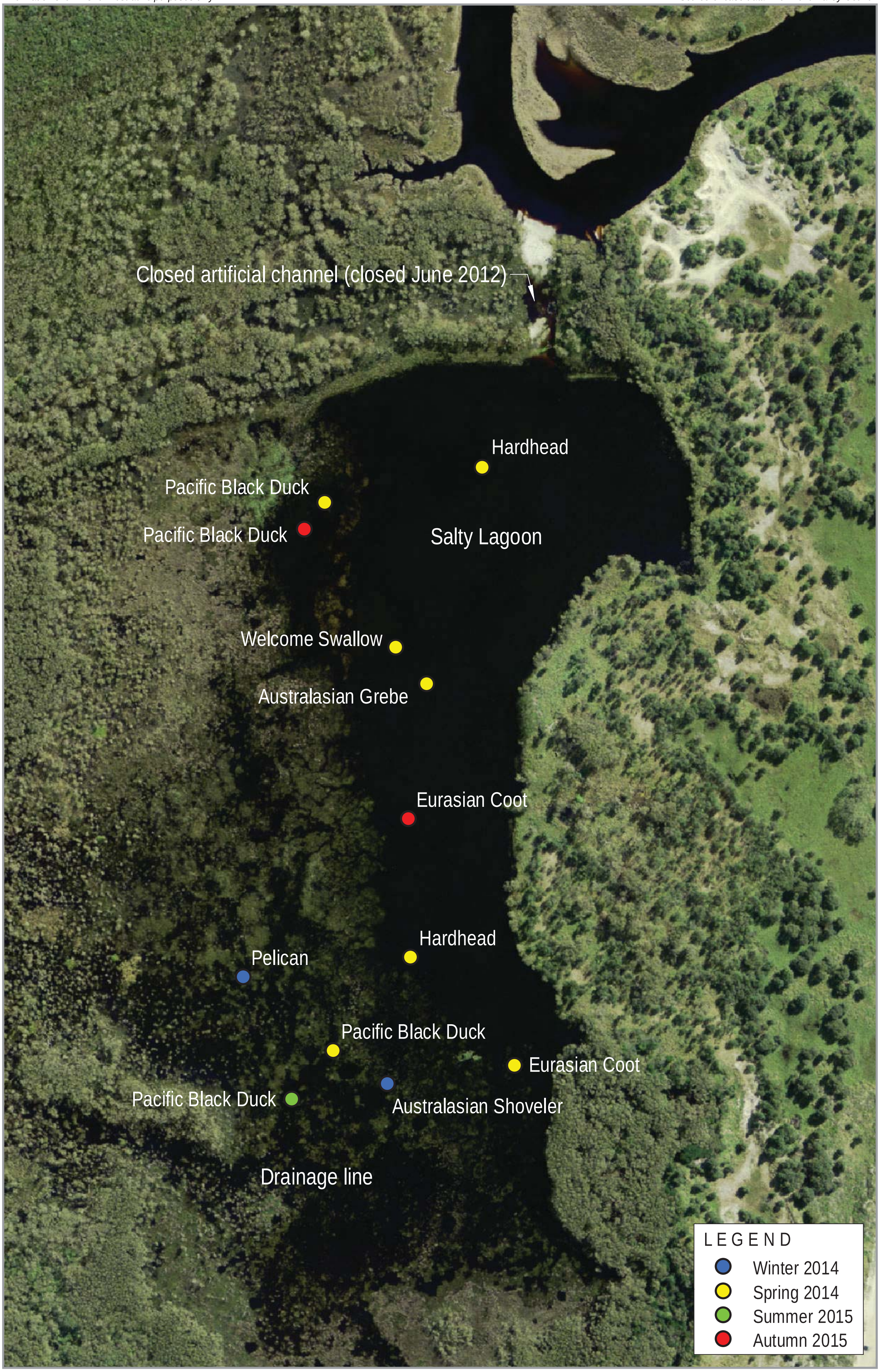
Plate 6.1 Flocks of birds are a common sight over Salty Lagoon

6.2.2 Surveys

Waterbird monitoring involved a foot and/or canoe based traverse of open water and fringing rushlands in Salty Lagoon over the course of one hour. Waterbird surveys are completed within two hours of dawn. Birds were identified using a field guide (Simpson and Day 2010) 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, waders and shorebirds. 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**.

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: RE Reviewed by: DSA Date: 20/10/2015
Source of base data: Richmond Valley Council



North

0 80

GeoLINK environmental management and design

Mapped Locations of Bird Flocks

Illustration 6.1

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Pre-Post Closure of Artificial Channel
1731-1176

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 **Figure 6.1**.

Table 6.1 Environmental Conditions at the Time of Waterfowl Monitoring

Survey	*Date*	*Water Depth (mAHD)*	*72 Hour Rainfall (mm)*	*Weather*	*Wind*
Winter 2014	7/07/2014	1.82	0	Fine	Calm
Spring 2014	13/10/2014	1.84	0	Fine	Calm
Summer 2015	6/01/2015	1.91	15.6	Overcast	Calm
Autumn 2015	13/04/2015	1.94	1.2	Overcast	Moderate SSW

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

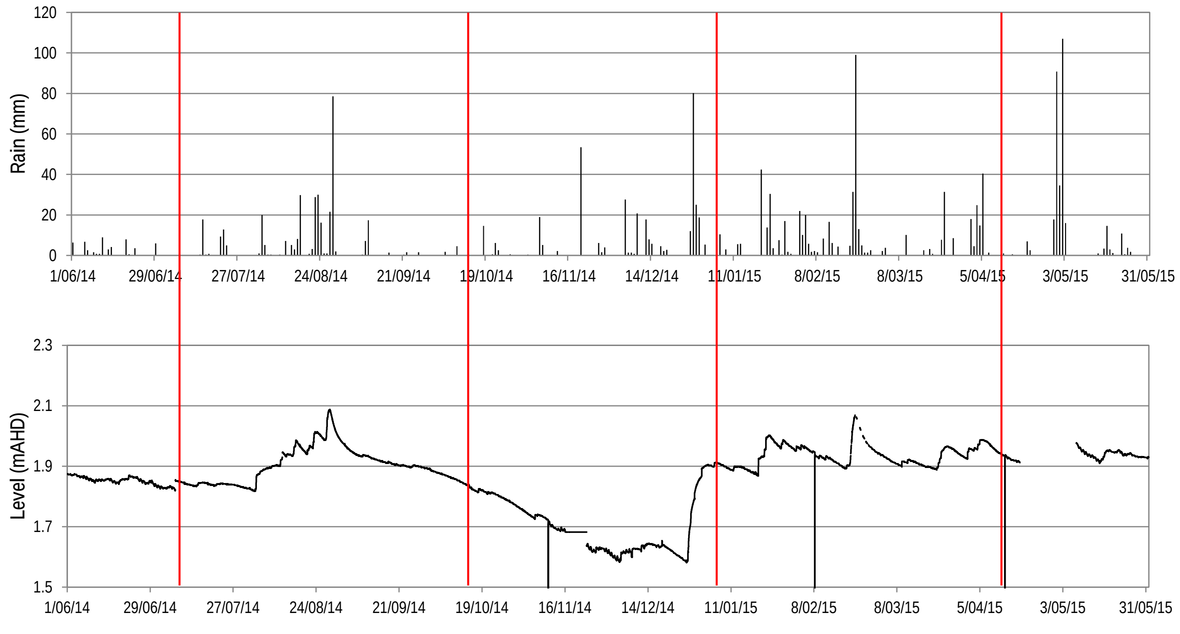


Figure 6.1 Rainfall and water level charts for the reporting period showing bird survey times (red)

The water level at the time of sampling was relatively consistent between sample times. Apart from normal seasonal variations in temperature the key differences between the conditions present at the times of sampling were moderate wind conditions during the summer 2015 survey and moderate rainfall in the days leading up to that survey.

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 summer 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 a continued increase in waterbird diversity since the closure of the artificial channel.

Atypically, the lowest diversity of species was observed during the summer survey (**Figure 6.1**). This may be related to the rainfall prior to the survey and the windy conditions experienced during the survey. In any case, the low species count is an outlying result.

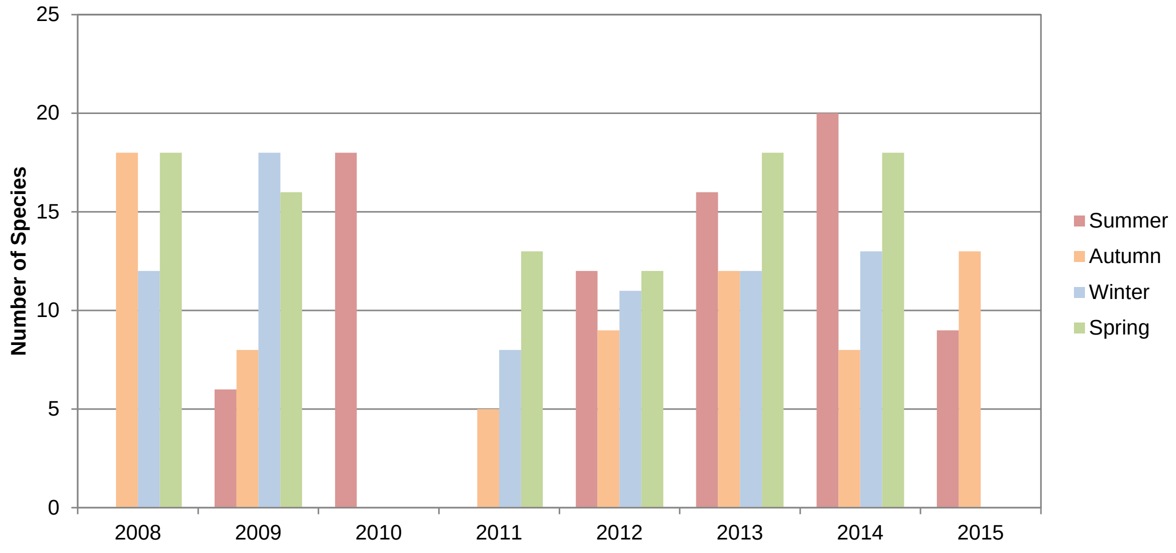


Figure 6.1 Number of bird species observed in previous seasonal surveys on Salty Lagoon (autumn 2008 until summer 2010 (Hydrosphere 2010a)) and during the MPPC (Autumn 2011 until autumn 2015)

During the current reporting period there were a small number of species observed for the first time since the beginning of the MPPC (**Table 6.2**). These were the Australasian Shoveler (*Anas rhynchotis*), Australian Spotted Crake (*Porzana fluminea*), Crested Tern (*Thallasseus bergii*) and the Brahminy Kite (*Haliastur indus*). On the other hand the species that were observed in earlier surveys but not during this reporting period include Chestnut Teal (*Anas castanea*), Purple Swamphen (*Porphyrio porphyrio*), Black Bittern (*Ixobrychus flavicollis*), Little Egret (*Ardea garzetta*), Black-necked Stork (*Ephippiorhynchus asiaticus*), Brolga (*Grus rubicunda*), Whimbrel (*Numenius phaeopus*), Sharp-tailed Sandpiper (*Calidris acuminata*) Black-winged Stilt (*Himantopus himantopus*), Pacific Golden Plover (*Pluvialus fulva*), Black-fronted Dotterel (*Elseyornis melanops*), Rainbow Bee-eater (*Merops ornatus*) and Wedge-tailed Eagle (*Aquila audax*). It is notable that the majority of these species are waders and shore-birds. While some of these species have been observed incidentally during normal monthly monitoring outside of formal bird surveys many are much less likely to visit Salty Lagoon when water levels are high because they rely on mud-flats for foraging.

6.3.3 Abundance

Overall waterbird abundance has varied since the beginning of the MPPC in autumn 2011. The numbers of individual birds observed during the current reporting period were lower than those from the previous reporting period but comparable to those from the years before that. The exception was the count from summer 2015, which was low, possibly due to the conditions prior to and during the survey.

In terms of individual species the abundances of a small number of species appear to have stabilised at higher numbers since closure of the artificial channel (**Figure 6.2**). These species include Pacific Black Duck (*Anas superciliosa*), Hardhead (*Aythya australis*), Australasian Grebe (*Tachybaptus novaehollandiae*) and Eurasian Coot (*Fulica atra*).

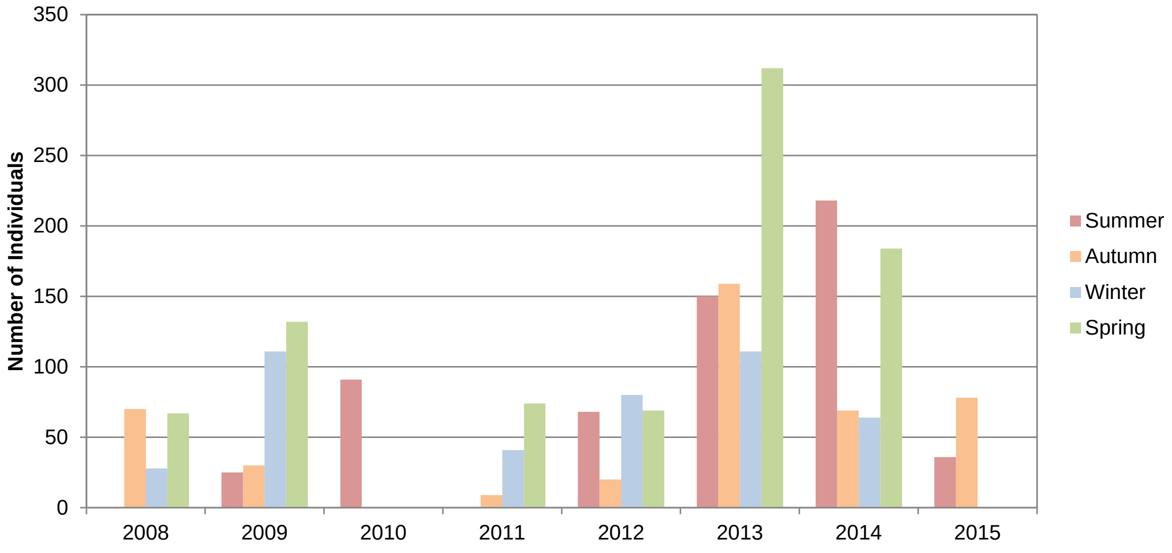


Figure 6.2 Number of individual birds observed in previous seasonal surveys on Salty Lagoon (Autumn 2008 until Summer 2010 (Hydrosphere 2010a)) and during the MPPC (Autumn 2011 until Autumn 2015)

Table 6.2 Results of Waterbird Surveys since the Beginning of the MPPC

Common Name	Aut 11	Win 11	Spr 11	Sum 12	Aut 12	Win 12	Spr 12	Sum 13	Aut 13	Win 13	Spr 13	Sum 14	Aut 14	Win 14	Spr 14	Sum 15	Aut 15
Little Black Cormorant			4	3			2	4	8	2	1	3			4	2	2
Little Pied Cormorant	2	1		1		1				1		2			2		
Pied Cormorant				9	2	1		1		1			1		4		1
Great Cormorant						1			1	2	4		1	1	6	1	
Darter				1	1	1	1	2							1		1
Pelican		30	10						13	9	16	1		8	7		
Australasian Grebe		1		2			6	18	9	22	38	11	3	7	19	2	8
Grey Teal	1	3	29	23				16	20	5		28			2		
Pacific Black Duck				7	4	59	31	42	52	13	82	42	33	7	44	25	24
Chestnut Teal			1				6			2		14					
Australasian Shoveler														25			
Hardhead							11		20	28					33		
Black Swan				2	4	2			1		4		4	3		2	2
Australian Spotted Crake															1		
Purple Swamphen								33									
Eurasian Coot								22	24	25	125	6			29		33
Comb-crested Jacana*								3									1
White-faced Heron	1	2	5		2	6	2	1	9		2	1	4	7	3		1
Black Bittern*			1														
White-necked Heron			2					1			4			1			
Little Egret			1														
Intermediate Egret							1	1			1	1		1	1	1	
Great Egret			3	1	1	1	4	2	1		4	2	1	1	1		2
White Ibis			2				1				7	12			2		

Common Name	Aut 11	Win 11	Spr 11	Sum 12	Aut 12	Win 12	Spr 12	Sum 13	Aut 13	Win 13	Spr 13	Sum 14	Aut 14	Win 14	Spr 14	Sum 15	Aut 15
Royal Spoonbill											5			1			
Black-necked Stork*												2					
Brolga*											2						
Whimbrel								1									
Sharp-tailed Sandpiper												44					
Black-winged Stilt	3				2						11	13					
Masked Lapwing		2	2								2	3			3		
Pacific Golden Plover												12					
Black-fronted Dotterel			7														
Crested Tern																1	
Rainbow Bee Eater				3													
Welcome Swallow			7		3	3	3				3	3			22		
White-throated Needletail				15								17	22				
Raven				1													
Eastern Osprey*									1							1	
Sea Eagle	2	1			1	1				1				1		1	1
Wedge-tailed Eagle							1	1									
Black Kite											1						1
Brahminy Kite																	1
Whistling Kite		1				4		2				1		1			
Total No. Species	**5**	**8**	**13**	**12**	**9**	**11**	**12**	**16**	**12**	**12**	**18**	**20**	**8**	**13**	**18**	**9**	**13**
Total No. Individuals	**9**	**41**	**74**	**68**	**20**	**80**	**69**	**150**	**159**	**111**	**312**	**218**	**69**	**64**	**184**	**36**	**78**

* *Species listed as vulnerable under the TSC Act.*

6.4 Discussion

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

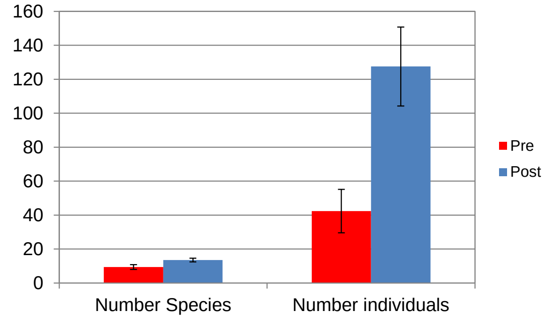
Waterbird abundance and diversity have fluctuated since the beginning of the MPPC. The results of waterbird surveys indicate that there has been an increase in species diversity and waterbird abundance since the closure of the artificial channel. In the current reporting period we observed continued high levels of diversity (with the exception of the summer survey) but a greater fluctuation in abundance than previous years. Some individual species of waterfowl, such as Pacific Black Duck, Eurasian Coot and Australasian Grebe have stabilised at high numbers relative to those observed prior to channel closure. The drought conditions observed during the previous reporting period are thought to have led to increased abundance and diversity (GeoLINK 2014). In this context, the lower numbers observed this year may be a return to the 'normal' post-closure waterfowl community. Continued monitoring should improve our capacity to make firmer conclusions.

The data shows a relatively consistent increase in abundance and diversity in summer and spring when more migratory species are utilising Salty Lagoon. With more stable water levels and less variation occurring as a result of changes in habitat availability this pattern is expected to continue.

6.4.1 Comparison against Rehabilitation Targets

In general the data to date indicates that the predicted changes with respect to waterfowl are being realised. The predicted changes are listed in **Table 6.3** along with the outcomes to date.

Table 6.3 Predicted Waterfowl Changes and Outcomes to Date for the MPPC

Predicted Change	*Outcome to date*
A positive impact on bird populations with an increased abundance of waterfowl but a reduction in opportunistic waders.	This anticipated change has been realised. The average diversity and abundance of waterbirds observed during surveys has increased post-channel closure (**Figure 6.3**).  **Figure 6.3 Average ± SE of bird species and individuals in surveys pre and post-channel closure** There has also been a consistent shift in the observed bird community towards a community dominated by waterfowl from the families *Anatidae* and *Rallidae* with fewer observations of shorebirds from the families *Scolopacidae* and *Charadriidae*.

Predicted Change	***Outcome to date***
Reduction in area of wading bird habitat	This anticipated change has also been realised. With the exception of the low water levels in spring 2014 and summer 2015 the area of mudflats available to wading birds has greatly reduced and the majority of habitat available in Salty Lagoon is now open water or permanently wet rushlands.

Plate 6.2 A Little Black Cormorant (*Phalacrocorax sulcirostris*) on well-used roost in Salty Creek

7. Terrestrial Vegetation

7.1 Introduction

7.1.1 General

This section of the annual report summarises the methods, data, observations and conclusions relating to vegetation monitoring during the 2015 season undertaken after the closure of the artificial channel in June 2012. This vegetation monitoring is part of the Ecosystem Health and Trend Assessment portion of the Salty Lagoon Ecosystem Recovery MPPC. For a detailed account of the results of latest vegetation monitoring refer to GeoLINK (2015). Previous baseline vegetation monitoring for the MPPC has also been undertaken in 2011, prior to the closure of the artificial channel. A comprehensive account of the methods and results of the baseline vegetation monitoring are contained in GeoLINK (2012c).

Prior to this current engagement, RVC implemented the Salty Lagoon Ecosystem Recovery Monitoring Program (ERMP). In brief, the ERMP aimed to monitor the ecological health of the system for a two 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. This work included a flora and vegetation mapping component and was completed in March 2010 (Hydrosphere 2010a), and a comprehensive description of methods and results from the ERMP monitoring is provided in that report.

Vegetation monitoring for the MPPC is less intensive than that implemented for the ERMP as a major component of the ERMP was to document baseline data over a broader area than that covered in the MPPC. The focus for the vegetation component of the MPPC monitoring is identifying and documenting the occurrence of the predicted changes in the vegetation habitat zone boundaries below 2 m AHD. The other major component is to document any re-colonisation or reduction within the Melaleuca dieback zone on the western side of the lagoon.

7.1.2 Predicted Changes to Vegetation Habitat Zones

Vegetation communities are anticipated to change in response to the closure of the artificial channel. A description of the potential changes is described in Hydrosphere (2010b) and Hydrosphere (2011). The three main vegetation habitat zones potentially affected by the closure of the channel are located predominantly on the western side of Salty Lagoon and consist of:

- Fringing Marsh
- Swamp Forest
- Sedge Swamp.

Predictions of expected changes in Hydrosphere (2010b) and Hydrosphere (2011) include:

- An increase in the area of open water.
- Colonisation of the central portions of the lagoon by Giant Waterlilies (*Nymphaea gigantea*) and also on the fringes.

- Domination by mixed sedges and rushes such as Juncus spp. and Baumea spp. in the western area currently occupied by Fringing Marsh.
- Expansion of Broad-leaved Paperbark (*Melaleuca quinquenervia*) to the east. Historical information and evidence on site (i.e. several large tree stumps in the lagoon) indicates that Broad-leaved Paperbark once occurred further east, closer to the lagoon.
- Establishment of Gahnia spp. and Cumbungi (*Typha orientalis*) in the deeper depressions that occur on the western shore.
- Drier extremities of the lagoon, where water levels will be less than 0.1 metre deep to remain largely unchanged.
- Other vegetation habitat zones that occur below 2.0 m AHD to be potentially affected along the drainage channel (Sedge Swamp/ open water) and along the eastern edge of the lagoon (Fringing Marsh and Banksia Woodland).

7.2 Methodology

The following section details the methodology used for the 2015 vegetation monitoring. This methodology follows the methods used for the baseline vegetation monitoring and is summarised where appropriate to reduce repetition with the baseline vegetation report. More detail on methodology can be found in that report (GeoLINK 2012c).

7.2.1 Vegetation Transects

7.2.1.1 Timing

Vegetation sampling was undertaken over two days on 19 March and 20 March 2015.

Water levels at the time of sampling were relatively high, as a result of significant rainfall experienced in February. As was noted at the time of the 2013 vegetation monitoring, some of the monitoring quadrats on the fringe of Salty Lagoon were covered by open water at the time of sampling and the water level was substantially higher than that in the 2011 vegetation monitoring event prior to closure of the artificial channel.

7.2.2 Vegetation Habitat Zones

The boundaries of the vegetation were evidenced in the field by the following criteria:

- **Sedge Swamp/ Swamp Forest**: Sedge Swamp has a clearly defined edge and generally comprises a dense thicket dominated by *Gahnia sieberiana*, which occurs in all strata including the upper stratum (generally <3 metres in height). Emergent Broad-leaved Paperbark and Tea Tree can be present; and

- **Swamp Forest/ Fringing Marsh**: The edge of the Swamp Forest is poorly defined due to the zone dominated by dead/ dying Broad-leaved Paperbark. The point at which the boundary was defined was where percentage foliage cover (PFC) of the Broad-leaved Paperbark greater than three metres in height was >10%.

Transects in which data was collected for this monitoring are the same as those used for baseline vegetation monitoring, as outlined below.

Transects 1-3 are 400-600 metres in length and each extends across the three distinct vegetation habitat zones of Fringing Marsh, Swamp Forest and Sedge Swamp. Two quadrats (10 m x 10 m) are located in each pre-channel closure vegetation habitat zone along each transect (i.e. total of six quadrats per transect). Quadrats are orientated generally in an east-west direction and run from the open water at the eastern end through the Sedge Swamp to the heathland boundary to the west. The location of the boundary of each of the vegetation habitat zones was recorded via global positioning system (GPS).

Transects 4-6 are between 20-60 metres in length and each comprise two distinct pre-channel closure vegetation habitat zones. One quadrat (10 m x 10 m) is located in each pre-channel closure vegetation habitat zone along each of these transects (i.e. total of two quadrats per transect).

Data recorded for vegetation quadrats included:

- Description of vegetation by stratum (height and total percentage cover) (modified Braun-Blanquet scale).
- Floristic composition with cover abundance for each species.
- Diameter at breast height (DBH - recorded at 1.25 metres above the ground) for each stem greater than 10 cm DBH.
- Description of vegetation health.
- Photos taken from the north-east corner of each quadrat.

7.2.3 Selection of Indicator Species

Indicator flora species were identified in the baseline vegetation monitoring on the basis that will be useful for identifying changes that may occur in vegetation habitat zones once closure of the artificial channel has occurred. These indicator species were selected based on the following methodology:

- Identified in the predicted changes to the Salty Lagoon flora in Hydrosphere (2010b); and/ or
- Dominant in a vegetation habitat zone, as identified in the cover abundance data collected; and
- Primarily associated with a single habitat vegetation zone.

7.2.4 Melaleuca Diebank/ Recolonisation

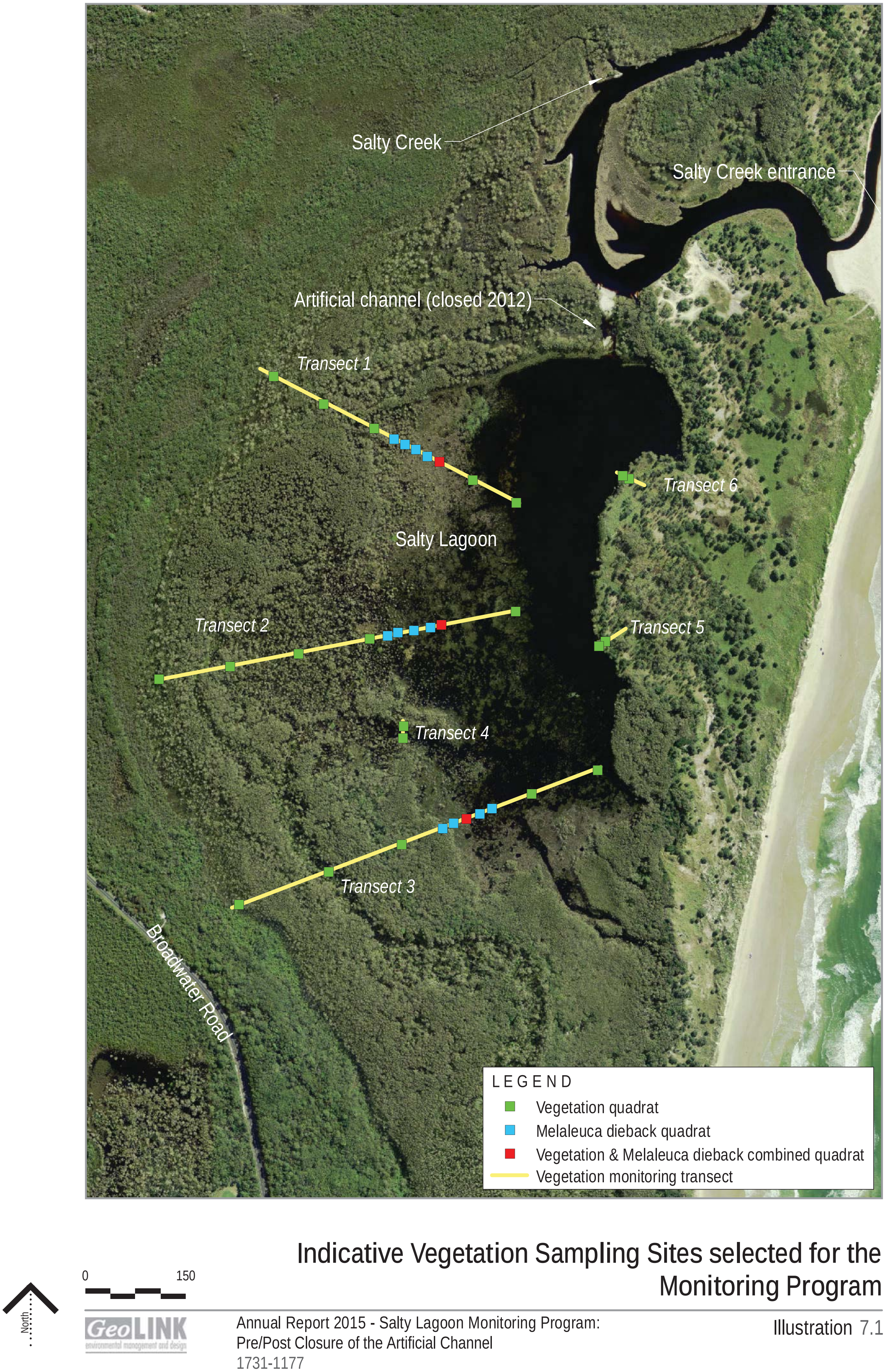
Melaleuca dieback transects and quadrats (10 m x 10 m) were established according to the proposed methodology outlined in Hydrosphere (2010b). Three transects were established corresponding with those previously established for the ERMP sampling. These transects correspond with Transects 1-3 established to measure vegetation habitat zone changes (refer to **Illustration 7.1**). Quadrats were established along these transects corresponding with the pre-channel closure Fringing Marsh/ Swamp Forest boundary.

Data recorded at Melaleuca dieback quadrats includes:

- Vegetation description by stratum (height and total percentage cover).
- Floristic composition with cover abundance for each species (modified Braun-Blanquet scale).
- Description of vegetation health (presence of necrotic spots on leaves, galls on small branches).
- Photos taken from the north-east corner of each quadrat.
- Number of trees with >10 cm DBH (and the DBH of each stem >10cm).
- Number of small trees (i.e. height <1.5 m and DBH >5 cm).
- Number of seedlings (i.e. height <0.5 m).
- Condition of trees within the quadrat using the following categories:
  - Unaffected/ full recovery.
  - Resprouting.
  - Dead.

Information shown is for illustrative purposes only

Drawn by: DSA Checked by: VJS Reviewed by: GJM Date: 20/10/2015
Source of base data: Richmond Valley Council



Indicative Vegetation Sampling Sites selected for the Monitoring Program

GeoLINK environmental management and design

Annual Report 2015 - Salty Lagoon Monitoring Program:
Pre/Post Closure of the Artificial Channel
1731-1177

Illustration 7.1

7.3 Results and Discussion

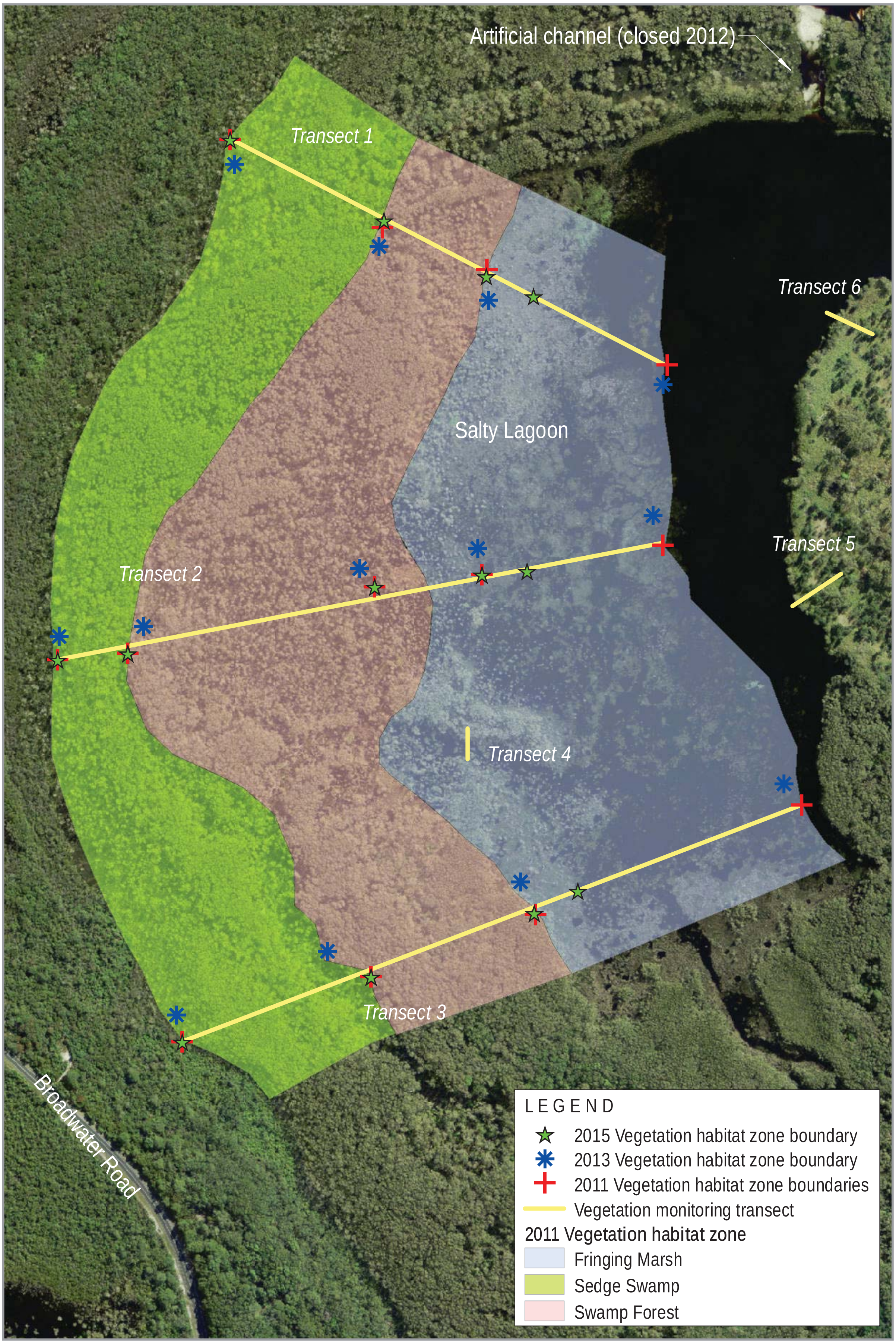
7.3.1 Transects 1 – 3

Transects 1-3 extend across the three distinct vegetation habitat zones of Fringing Marsh, Swamp Forest and Sedge Swamp. The location of vegetation habitat zones boundaries along each transect is shown **Illustration 7.2**. Since the baseline vegetation monitoring the total length occupied by the vegetation habitat zones along the transects has decreased primarily due to fringing marsh being converted to open water as water levels in the lagoon have raised since closure of the artificial channel in 2012. *Note: 2015 Vegetation Habitat Zone Boundaries supersede those shown in GeoLINK (2015), with a mapping error corrected for the habitat zone boundary between the Sedge Swamp and Swamp Forest on Transect 1.*

In total, 47 flora species (both native and exotic) were recorded from the three vegetation habitat zones (a reduction from 73 in 2011 and 55 in 2013). The breakdown of total number of species by vegetation habitat zones is shown in **Table 7.1**.

Table 7.1 Flora Species Numbers

Vegetation Habitat Zone	***Total Number of Species***		
	2011	***2013 (Change since 2011)***	***2015 (Change since 2011)***
Fringing Marsh	28	7 (-21)	11 (-17)
Swamp Forest	36	30 (-6)	27 (-9)
Sedge Swamp	40	32 (-8)	26 (-14)
Total Flora Species	73	55 (-18)	47 (-26)



Vegetation Habitat Zone Boundaries

7.3.1.1 Vegetation Habitat Zone Descriptions

Fringing Marsh

Dominant flora species within the Fringing Marsh quadrats consisted of:

- Shore Club-rush (*Schoenoplectus subulatus*), Azolla (*Azolla filiculoides*) and Duckweed (*Lemna* sp.); all occurring at a moderate density in three out of six quadrats.
- Common Reed (*Phragmites australis*); occurring at a moderate to high density in two out of six quadrats.
- Saltwater Couch (*Paspalum vaginatum*); occurring at a moderate density in two out of six quadrats.
- Sea Rush (*Juncus kraussii* subsp. *australiensis*) and Bare Twig-rush (*Baumea juncea*); both occurring at a moderate density in one out of six quadrats.

Two of the Fringing Marsh quadrats supported no dominant flora species, as these quadrats are now open water devoid of vegetation.

Swamp Forest

Dominant flora species within the Swamp Marsh quadrats consisted of:

- Broad-leaved Paperbark (*Melaleuca quinquenervia*); occurring in a moderate density in all quadrats.
- Bare Twig-rush (*Baumea juncea*); occurring at a moderate to high density in four out of six quadrats.
- Tall Sedge (*Carex appressa*); occurring at a moderate density in two out of six quadrats.
- Sea Rush (*Juncus kraussii* subsp. *kraussii*), Native Violet (*Viola* sp.), Spiny-headed Mat-rush (*Lomandra longifolia*), Azolla (*Azolla filiculoides*), Duckweed (*Lemna* sp.) and Red-fruited Saw-sedge (*Gahnia sieberiana*); all occurring at a moderate density in one out of six quadrats.

Sedge Swamp

Dominant flora species within the Sedge Swamp quadrats consisted of:

- Broad-leaved Paperbark (*Melaleuca quinquenervia*); occurring in a moderate density in five out of six quadrats.
- Swamp Twig-Rush (*Baumea arthrophylla*); occurring in a high density in two out of six quadrats.
- Plume Rush (*Baloskion tetraphyllum*); occurring at a moderate to high density in two out of six quadrats.
- Weeping Baeckea (*Baeckea frutescens*) and Bryophyte (a moss sp.); both occurring at a moderate density in two out of six quadrats.
- Bare Twig-rush (*Baumea juncea*); occurring at a high density in one out of six quadrats.
- Grass Tree (*Xanthorrhoea* sp.), Pouched Coral Fern (*Gleichenia dicarpa*), Sand Couch (*Sporobolus virginicus*), Zig-zag Bog-rush (*Schoenus brevifolius*) and Didgery Sticks (*Baloskion pallens*); occurring at a moderate to high density in one out of six quadrats.

Indicator Species

Based on the expected changes to vegetation identified in Hydrosphere (2010b and 2011) and previous monitoring reports by GeoLINK (2012c and 2013b), the following species were identified as indicator species for transects 1-3:

- Sea Rush (*Juncus krausii subsp. australiensis*): expected to decrease in the area currently occupied by Fringing Marsh and Swamp Forest.
- Saltwater Couch (*Paspalum vaginatum*): expected to decrease in the area currently occupied by Fringing Marsh and Swamp Forest.
- Bare Twig-rush (*Baumea juncea*): expected to increase in the area currently occupied by Fringing Marsh.
- Broad-leaved Paperbark (*Melaleuca quinquenervia*): expected to increase in the area currently occupied by Fringing Marsh.

The average cover abundance value for each of these indicator species in the vegetation habitat zones is graphically represented in **Figure 7.1**. Plume Rush is also shown. The results of the monitoring indicate that Plume Rush is a prominent feature of the Sedge Swamp community and Bare Twig Rush is a prominent species of the Swamp Forest. Sea Rush occurs across both the Fringing Marsh and Swamp Forest communities and Saltwater Couch is restricted to the Fringing Marsh community.

Vegetation characteristics recorded within quadrats along Transects 1-3 were recorded and are detailed in GeoLINK (2015).

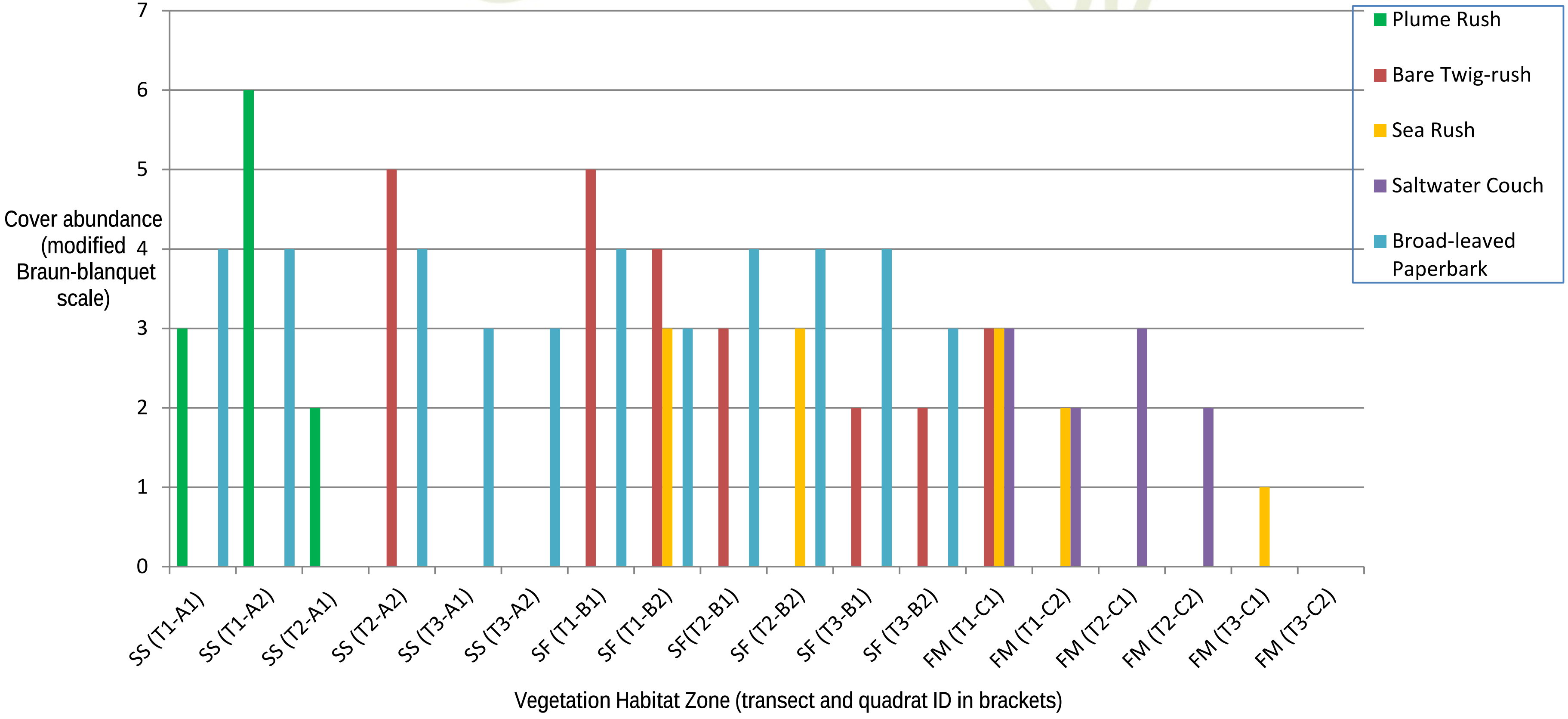


Figure 7.1 Cover abundance scores for indicator species in vegetation habitat zones of transects 1 – 3

Figure abbreviations – SS = Sedge Swamp, SF = Swamp Forest, FM = Fringing Marsh, T = Transect number, A, B etc. =Quadrat ID)

7.3.2 Transects 4 – 6

Transects 4-6 each traverse the following two distinct vegetation habitat zones:

- Transect 4: Sedge Swamp/ open water and Swamp Forest.
- Transect 5 and 6: Fringing Marsh and Banksia Woodland.

The location of the monitoring transects is shown in Error! Reference source not found..

No quantifiable changes are evident at Transect 4 as habitat zone boundaries. The vegetation habitat zone boundaries along Transects 5 and 6 were fairly well defined in the field at the time of survey. As the water level of the lagoon has increased following the artificial channel closure, the extent of the Fringing Marsh community has decreased substantially, being replaced by open water.

7.3.2.1 Species Composition of Vegetation Habitat Zones

In total, 28 flora species (both native and exotic) were recorded from the four vegetation habitat zones (a reduction from 32 in 2011 and 38 in 2013). The breakdown of total number of species by vegetation habitat zones is shown in **Table 7.2**.

Table 7.2 Flora Species Numbers

Vegetation Habitat Zone	***Total number of Species***		
	2011	***2013 (Change since 2011)***	***2015 (Change since 2011)***
Fringing Marsh	14	20 (+6)	17 (+3)
Swamp Forest	13	6 (-7)	10 (-3)
Sedge Swamp/ Open Water	15	12 (-3)	13 (-2)
Banksia Woodland	14	17 (+3)	14 (0)
Total Flora Species	32	38 (+6)	28 (-4)

7.3.2.2 Vegetation Habitat Zone Descriptions

<u>Transect 4</u>

Dominant flora species within the Sedge Swamp/ Open Water quadrat consisted of:

- Sea Rush (*Juncus kraussii* subsp. *australiensis*), Bare Twig-rush (*Baumea juncea*), Shore Club-rush (*Schoenoplectus subulatus*), and Saltwater Couch (*Paspalum vaginatum*); all occurring at a moderate density.

Swamp Forest

Dominant flora species within the Swamp Forest quadrat consisted of:

- Azolla (*Azolla filiculoides*) occurring at a high density.
- Duckweed (*Lemna* sp.), Bare Twig-rush (*Baumea juncea*), Saltwater Couch (*Paspalum vaginatum*), and Broad-leaved Paperbark (*Melaleuca quinquenervia*); all occurring at a moderate density.

Transects 5

Fringing Marsh

Dominant flora species within the Fringing Marsh quadrat consisted of:

- Broad-leaved Paperbark (*Melaleuca quinquenervia*), Bare Twig-rush (*Baumea juncea*) and Blady Grass (*Imperata cylindrica*); all occurring at a moderate density.

Banksia Woodland

Dominant flora species within the Banksia Woodland quadrat consisted of:

- Coast Banksia (*Banksia integrifolia* subsp. *integrifolia*), Blady Grass (*Imperata cylindrica*) and Snake Vine (*Stephania japonica*); all occurring at a moderate density.

Transect 6

Fringing Marsh

Dominant flora species within the Fringing Marsh quadrat consisted of:

- Broad-leaved Paperbark (*Melaleuca quinquenervia*) and Bare Twig-rush (*Baumea juncea*); each occurring at a moderate density.

Banksia Woodland

Dominant flora species within the Banksia Woodland quadrat consisted of:

- Blady Grass (*Imperata cylindrica*), occurring at a high density.
- Coast Banksia (*Banksia integrifolia* subsp. *integrifolia*), occurring at a moderate density.

Indicator Species

7.3.2.3 Indicator Species

Based on the expected changes to vegetation identified in Hydrosphere (2010b and 2011) and previous monitoring reports by GeoLINK (2011 and 2013b), the following species were identified as indicator species for transects 4-6:

- Sea Rush (*Juncus krausii* subsp. *australiensis*) (prediction was that this species will decrease in the area currently occupied by the Gahnia sedge/ open water habitat zone along Transect 4).

- Saltwater Couch (*Paspalum vaginatum*) (prediction was that this species is expected to decrease in the area currently occupied by the Swamp Forest along Transect 4 and Fringing Marsh along Transect 5).
- Shore Club-rush (*Schoenoplectus subulatus*) (prediction was that this species is expected to decrease in the area currently occupied by Fringing Marsh vegetation habitat zone along Transects 5 and 6).
- Saw-sedge (*Gahnia* spp.) (prediction was that this species is expected to increase in the area currently occupied by Sedge Swamp/ open water in Transect 4).
- Coast Banksia (*Banksia integrifolia* subsp. *integrifolia*) (prediction was that this species is expected to retain current density within the Banksia Woodland with expected water level changes).

The average cover abundance value for each of these indicator species in the vegetation habitat zones is shown in **Figure 7.2**.

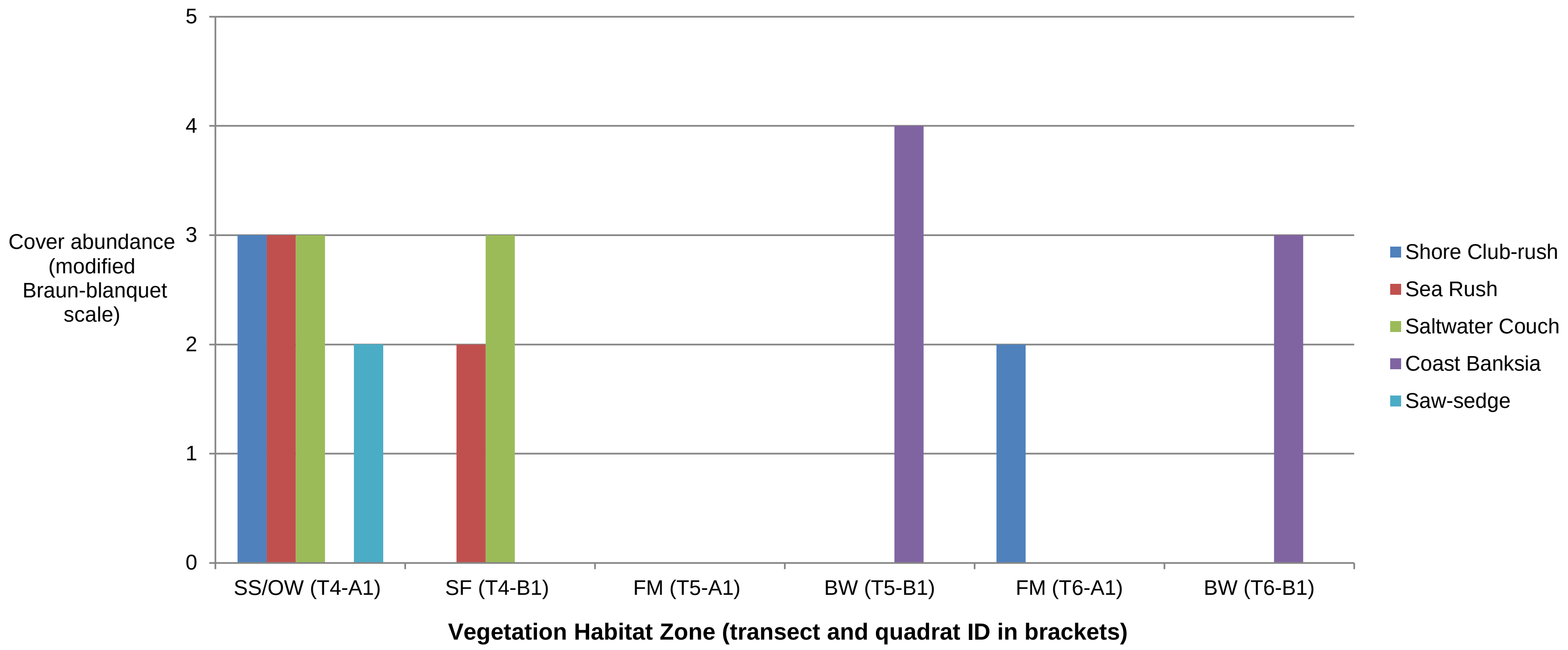


Figure 7.2 Cover Abundance Scores for Indicator Species in Vegetation Habitat Zones of Transects 4-6

Figure abbreviations – SS = Sedge Swamp, OW = Open Water, SF = Swamp Forest, FM = Fringing Marsh, BW =Banksia Woodland, T = Transects number, A, B etc. = Quadrat ID

7.3.3 Melaleuca Dieback/ Recolonisation Monitoring

Results from the Melaleuca dieback quadrats are provided in detail in GeoLINK (2015). Less than half of the quadrats contained dead Melaleuca individuals (six out of 15), with the least dieback being recorded in the quadrats located along Transect 1. This reflects a very low general occurrence of Melaleuca (living or dead) in Melaleuca dieback quadrats along this transect. Most of the Melaleuca dieback recorded was in quadrats furthest from the edge of the lagoon, where Melaleuca dominance was also greatest.

A relatively low proportion of quadrats contained regenerating Melaleuca seedlings (four out of 15) or saplings (five out of 15).

Where living Melaleuca was present, in general the health appeared good, with thick foliage, flowering and no presence of necrotic spots on leaves or galls on small branches.

7.3.4 Photo-point Monitoring

All photos taken at photo monitoring points for the current monitoring period are displayed in GeoLINK (2015). These photos showed obvious changes in the vegetation since 2011, particularly in the fringing marsh community where water levels have increased substantially following the closure of the artificial channel.

7.4 Discussion and Comparison with Previous Monitoring

7.4.1 Transect 1 – 3

7.4.1.1 Vegetation Habitat Zonation

A reduction in the extent of the Fringing Marsh community around the western edge of Salty Lagoon has continued since the artificial channel was closed in 2012. Much of the area previously occupied by this community prior to the channel closure is now open water. When compared with the extent of this community recorded in baseline monitoring the reduction in extent has been between 137 metres and 216 metres, with the greatest reduction in this community occurring in the southern section of Salty Lagoon along Transect 3.

Variation in the extent of Sedge Swamp and Swamp Forest since baseline monitoring has not been significant, reflecting that the primary driving factor for vegetation change to date is related to the rising water level in Salty Lagoon and associated lowering of salinity levels as the system changes to being more freshwater dominated.

7.4.1.2 Species Composition of Vegetation Habitat Zones

The overall number of flora species recorded in the three vegetation communities along Transects 1-3 has continued to decline, with only 47 species recorded in the current monitoring, compared with 55 in 2013 and 73 in 2011 prior to the closure of the artificial channel. The major factor contributing to this decrease in the number of species recorded was the closure of the artificial channel and the resulting expansion of open water covering previously exposed ground in the Fringing Marsh. Twenty-eight flora species were recorded in the Fringing Marsh in 2011 compared with a count of seven species in 2013 and 11 in the current monitoring. A relatively large proportion of the flora species occurring in the Fringing Marsh community were low-growing herbaceous species that are intolerant of submersion for an extended period.

Reduction in species diversity in Sedge Swamp and Swamp Forest has also been apparent since 2011. Despite being further from the new edge of open water in Salty Lagoon, nonetheless a substantial area of the Swamp Forest community is now regularly inundated (particularly following heavy rainfall events), and similar to the Fringing Marsh community, these inundation events may be having the overall effect of reducing flora diversity in the herbaceous understorey. However, the reason why a reduction in species diversity since 2011 has occurred in the Sedge Swamp community (which is generally not as prone to inundation) remains unclear.

7.4.1.3 Species Dominance

Since monitoring in 2011 the species dominance in the Fringing Marsh community has changed substantially, with a decline in the cover of Sea Rush (*Juncus kraussii* subsp. *australiensis*) and Saltwater Couch (*Paspalum vaginatum*) and an increase in the cover of Common Reed (*Phragmites australis*) and Shore Club-rush (*Schoenoplectus subulatus*).

In contrast, the dominant flora species has not substantially changed since 2011, consisting of Broad-leaved Paperbark (*Melaleuca quinquenervia*) and Bare Twig-rush (*Baumea juncea*) in the Swamp Forest community and Broad-leaved Paperbark, Plume Rush (*Baloskion tetraphyllum*) and Swamp Twig-rush (*Baumea arthrophylla*) in the Sedge Swamp community.

7.4.1.4 Predicted Changes and Indicator Species

The following predicted changes were listed in the baseline vegetation monitoring report. These are discussed in turn.

1. Sea Rush (*Juncus krausii subsp. australiensis*): expected to decrease in the area currently occupied by Fringing Marsh and Swamp Forest.

The decrease in cover of Sea Rush in both of these communities that was recorded in the 2013 monitoring has continued, with the reduction most prominent in the Fringing Marsh community (refer to **Plate 7.1** and **Plate 7.2**. This is attributable to the greater degree of inundation that has occurred in the Fringing Marsh community since channel closure.

Plate 7.1 Open-water along Transect 3 in 2015

Plate 7.2 Sea Rush dominated the same area along Transect 3 in 2011

2. Saltwater Couch (*Paspalum vaginatum*): expected to decrease in the area currently occupied by Fringing Marsh and Swamp Forest.

A similar pattern to that seen for Sea Rush has also occurred with Saltwater Couch. There has been a decrease in cover of this species in both of these communities, with the most notable reduction occurring in the Swamp Forest community in which no Saltwater Couch was recorded in the 2015 monitoring. This absence may be a response to inundation and lower salinity levels in the Swamp Forest community as Salty Lagoon transitions to a more freshwater-dominated system following channel closure.

3. Shore Club-rush (*Schoenoplectus subulatus*): expected to decrease in the area currently occupied by Fringing Marsh and Swamp Forest.

In the MPCC vegetation monitoring report, Shore Club-rush (*Schoenoplectus subulatus*) was identified as a potential indicator species that was expected to decrease in the area currently occupied by Fringing Marsh and Swamp Forest. This species has been recorded at a low density in the Swamp Forest community in all previous monitoring events and at a low to moderate density in the Fringing Marsh community, with no substantial decrease occurring in the area currently occupied by this species since channel closure.

4. Bare Twig-rush (*Baumea juncea*): expected to increase in the area currently occupied by Fringing Marsh.

The monitoring results indicate that Bare Twig-rush has not substantially increased in the Fringing Marsh community since 2011.

5. Broad-leaved Paperbark (*Melaleuca quinquenervia*): expected to increase in the area currently occupied by Fringing Marsh.

Broad-leaved Paperbark has not substantially extended into the Fringing Marsh as yet. The cover of this species has also remained relatively stable in and around the edge of the Swamp Forest community with neither an obvious decline in the health of Broad-leaved Paperbark occurring, nor a substantial increase in recruitment. However, this may be a reflection that the time since the closure of the artificial channel has been insufficient for changes to woody vegetation to become apparent. Future vegetation monitoring in 2017 may show that this species has extended into the Fringing Marsh over a longer time frame.

7.4.2 Transect 4 – 6

7.4.2.1 Vegetation Habitat Zonation

At transect 4, while the water level is greater, there has been no noticeable change in vegetation habitat zone boundaries to date.

The major influencing factor on the extent of the vegetation communities in transects 5 and 6 was also related to increased water levels caused by the closure of the artificial channel. This is most apparent when a comparison is made between the monitoring photos for the Fringing Marsh/ Open Water quadrats in 2011 and the current monitoring event (refer to **Plate 7.3** and **Plate 7.4**).

Plate 7.3 Transect 6, quadrat A1 in 2011

Plate 7.4 Transect 6, quadrat A1 in 2015

7.4.2.2 Species Composition of Vegetation Habitat Zones

The overall number of species recorded in the vegetation communities along these transects was relatively not substantially changed in the period of 2011 to 2015, with 32 species recorded in 2011 and 28 species in 2015.

7.4.2.3 Species Dominance

Species dominance was relatively stable between monitoring events, with the exception of the Fringing Marsh community in which the dominant species have shifted from Saltwater Couch and Shore Club-rush in 2011 to Bare Twig-rush in fringing areas. This reflects the higher water levels (and associated freshwater-influence) following channel closure.

Blady Grass and Coast Banksia remain dominant species in the Banksia Woodland community.

7.4.2.4 Predicted Changes and Indicator Species

The following predicted changes were listed in the baseline vegetation monitoring report. These are discussed in turn.

1. Sea Rush (*Juncus krausii* subsp. *australiensis*) (expected to decrease in the area currently occupied by the Gahnia sedge/ open water habitat zone along Transect 4).

Sea Rush has shown no significant difference in cover between the 2011 and 2015 monitoring events. Although Sea Rush has decreased substantially overall within the Fringing Marsh community surrounding Salty Lagoon, this species still occurs at a low to moderate density in some areas, including the fringe of the drainage channel that Transect 4 crosses.

2. Saltwater Couch (*Paspalum vaginatum*) (expected to decrease in the area currently occupied by the Swamp Forest along Transect 4 and Fringing Marsh along Transect 5).

This prediction appears to have been borne out, with a lower cover being recorded in the Swamp Forest community along Transect 4 in the current monitoring and an absence from the Fringing Marsh community along Transect 5. As was discussed for Transects 1-3, this decrease in cover of Saltwater Couch is likely to be related to inundation and lower salinity levels in the Swamp Forest community as Salty Lagoon transitions to a more freshwater-dominated system following channel closure.

3. Shore Club-rush (*Schoenoplectus subulatus*) (expected to decrease in the area currently occupied by Fringing Marsh vegetation habitat zone along Transects 5 and 6).

As predicted this Shore Club-rush has decreased in cover within the Fringing Marsh community along Transect 5 and Transect 6 between 2011 and the current monitoring event. It is interesting that this species has not undergone a similar decrease in cover on the western margin of Salty Lagoon (Fringing Marsh quadrats along Transects 1-3) over the same monitoring period. This may be related to the water depth along the eastern fringe of Salty Lagoon now being relatively deep since closure of the artificial channel. On this eastern fringe there is currently a relatively distinct boundary between dry ground occupied by Banksia woodland and open water, while the transition from dryland heath communities to open water is much more gradual along the western fringe of Salty Lagoon. Consequently, the shallower water depth may be allowing Shore Club-rush to persist on the western fringe of Salty Lagoon.

4. Saw-sedge (*Gahnia* spp.) expected to increase in the area currently occupied by Sedge Swamp/ open water in Transect 4).

Along Transect 4 Saw-sedge has not undergone a substantial increase in cover between the 2011 monitoring and the current monitoring event. However, opportunistic observations of this species in areas not covered by quadrats elsewhere (e.g. fringing small areas of deeper water along channels/ mini lagoons within the Swamp Forest community) seem to indicate that an increase in the prominence of this species has occurred since 2011 (however, this observation is not backed up by systematically collected quadrat data).

5. Coast Banksia (*Banksia integrifolia* subsp*. integrifolia*) (expected to retain current density within the Banksia Woodland with expected water level changes).

As predicted, Coast Banksia has maintained a similar cover level in the Banksia Woodland between the 2011 monitoring and the current monitoring event.

7.4.3 Melaleuca Dieback/ Recolonisation Monitoring

Data recorded in the 2011 monitoring and the 2015 monitoring is broadly consistent, with little recolonisation evident nor any further dieback occurring. The overall health of the existing Broad-leaved Paperbark was observed to be good, with thick foliage and flowering observed at the time of the current monitoring.

It is postulated that with the generally elevated water level in Salty Lagoon following closure of the artificial channel, suitable conditions for recolonisation by Broad-leaved Paperbark may now occur less frequently (assuming that for germination to occur, seeds much be able to contact with moist, bare soil). Suitable conditions for germination may now occur only during prolonged dry periods when the lagoon recedes. Such prolonged dry conditions would be expected to occur relatively infrequently, and consequently, substantial recolonisation of the lagoon edge by Broad-leaved Paperbark may only be apparent after several years or even decades have elapsed (significantly longer than the timeframe of the monitoring program which ends in 2017).

7.4.4 Comparison against Rehabilitation Targets

In Hydroshpere (2010a) it was discussed that vegetation communities around Salty Lagoon are anticipated to change in response to water level and salinity changes. The main changes were that there would be a replacement of Saltmarsh communities on the western shore of the Lagoon with freshwater macrophyte community, and potential for *Melaleuca* recolinisation within the dieback area.

Specific predicted outcomes on vegetation following the closure of the artificial channel (Hydrosphere 2010a) and comparison with the findings of the MPPC terrestrial vegetation monitoring are shown in **Table 7.3**.

Table 7.3 Predicted Terrestrial Vegetation Changes and Outcomes to Date for the MPPC

Predicted Major Changes to the System	*MPPC Monitoring Findings*
Change of saltmarsh community to freshwater macrophyte/ macro algae in Salty Lagoon with change to freshwater	This change has been realised. Since closure of the artificial channel the Saltmarsh community has been converted to freshwater dominated Fringing Marsh. An overall reduction in the cover of salt-tolerant species Sea Rush (*Juncus kraussii*) and Saltwater Couch (*Paspalum vaginatum*) around the lagoon has occurred. The prediction that Bare Twig-rush (*Baumea juncea*) would increase in cover around the lagoon is not apparent. However, other predicted freshwater loving species such as Common Reed (*Phragmites australis*) have increased in cover substantially in the Fringing Marsh.
Melaleuca re-colonisation & reduction in area of dieback	Predicted change may have occurred (but longer monitoring is required to establish this). Some positive changes have been noted including observation of low numbers of regenerating seedlings and improved canopy cover of Broad-leaved Paperbark (*Melaleuca quinquenervia*) at the edge of the Swamp Forest/ dieback zone interface. However, no obvious substantial recolonisation of the dieback area with Broad-leaved Paperbark has occurred yet.

7.4.5 Future Monitoring

The results of the 2015 vegetation monitoring indicate that vegetation change has occurred around the lagoon, particularly in the Fringing Marsh community, where both the extent of this community has decreased and the dominant species have shifted in relation to inundation and changes in salinity. Some of the vegetation changes that have been observed are broadly consistent with the predictions made in Hydrosphere (2010b and 2011). Other changes may only become apparent as more time elapses since the closure of the artificial channel, such as substantial recolonisation of the western lagoon edge by Broad-leaved Paperbark.

8. Frogs

8.1 Introduction

8.1.1 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 at Salty Lagoon 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).

8.1.2 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 that 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).
  - 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.
  - 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.
    - Not recorded in the Fringing Marsh, areas of Melaleuca dieback or along the drainage line east of from approximately 100 metres 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.
    - 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).

8.1.3 Baseline (Pre Channel-closure) Frog Monitoring Results

Frog sampling was undertaken at Salty Lagoon in mid-2011 to mid-2012, to establish a baseline against which potential changes to frog assemblages following the closure of the artificial channel could be assessed (GeoLINK 2012a). Key findings from this baseline frog monitoring that were used in identifying changes in species composition and distribution included:

- Ten amphibian species were recorded in total, with:
  - Four species recorded during the winter monitoring events, comprising 44 'onsite' specimens.
  - Seven species recorded during the spring monitoring events, comprising 67 'onsite' specimens.
  - Eight species recorded during the summer monitoring events, comprising 81 'onsite' specimens.
- Two 'acid' frog species were recorded consisting of:
  - Wallum Froglet: Recorded in Sedge Swamp, Swamp Forest and Fringing Marsh (one point count location).
  - Wallum Sedge Frog: Recorded in the Sedge Swamp and Swamp Forest habitats.
- The species with the overall highest numbers of individuals recorded 'onsite' during the point count surveys were the Stripped Marsh Frog, Dwarf Tree Frog, Common Eastern Froglet and Wallum Froglet.

- Striped Marsh Frog and Tyler's Tree Frog were the most widely distributed species occurring in all four habitats in the study area, while Common Eastern Froglet, Dwarf Tree Frog, Rocket Frog, Wallum Froglet and Wallum Sedge Frog were recorded in three out of four habitats.
- 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:
  - The comparison in distribution of the Wallum Froglet and Dwarf Tree Frog varied between Transect 1 and Transect 2 and 3. At Transects 2 and 3.
  - Only the Dwarf Tree Frog was recorded east of transect point count site T2PC5 and T3PC4 which comprises Fringing Marsh and Swamp Forest (including the Melaleuca dieback areas).
  - An overlap in distribution was recorded along the western portion of the Swamp Forest and adjacent edge of Sedge Swamp (the latter at Transect 3 only).
  - The Wallum Froglet was the dominant species within the Sedge Swamp.

8.2 Methods

8.2.1 Surveys

Frogs were sampled using two methods:

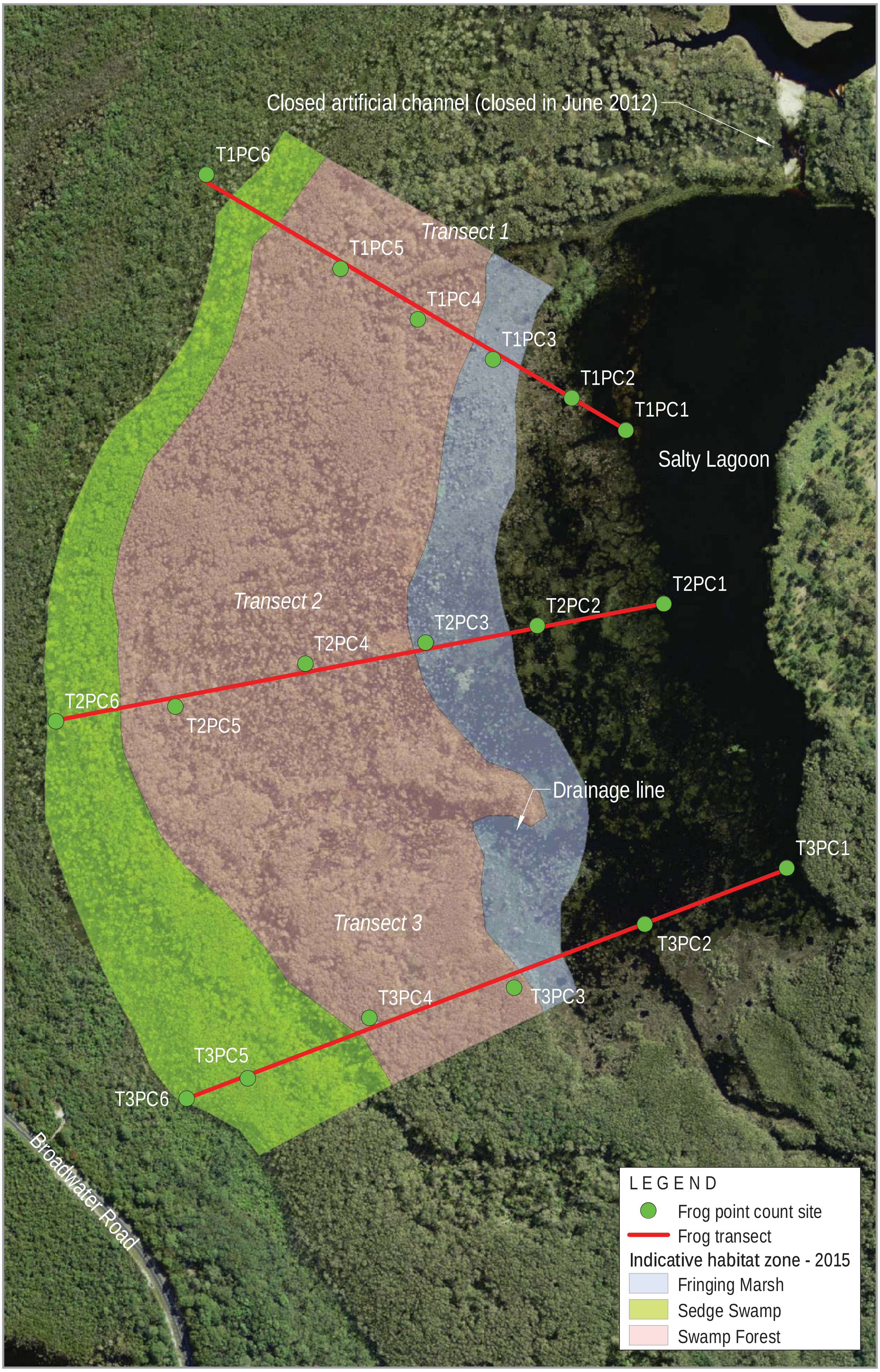
- Point counts undertaken at six fixed points along three fixed transects.
- Transect traverses undertaken along three fixed transects which corresponded with the point counts.

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 8.1**). 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 initially increased and has subsequently fluctuated according to seasonal rainfall/ drought and related run-off input. 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*. and other emergent vegetation), sampling at these points will be resumed.

The location of the point count sites is shown in **Table 8.1**.



Frog Monitoring Sites

Illustration 8.1

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Table 8.1 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

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 metre 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 metres 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 metre intervals and involved recording the presence of any individuals of this species within a 20 metre 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 30-Watt head torches used to actively find frogs if confirmation was needed and during transverse transect surveys to opportunistically observe frogs.

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.

8.2.2 Timing

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

- Winter 2014 surveys: 19 August 2014 and 4 September 2014.
- Spring 2014 surveys: 17 November and 19 November 2014.
- Summer 2015 surveys: 24 February and 26 February 2014.

8.2.3 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** of **Appendix A**. Conditions were dry for the winter and spring monitoring events. Light rain and wet conditions were experienced for the summer monitoring events. Both the first winter and both summer monitoring events had rain in the days prior to monitoring. Temperature ranged from mild to warm for the spring and summer monitoring events, while the winter monitoring events coincided with cool evenings. Winds were variable across seasons ranging from no wind to moderate. Relative humidity was generally moderate to high during monitoring events.

8.3 Results

8.3.1 Point Count

8.3.1.1 Species Richness and Abundance

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

- Five species recorded during the winter monitoring events, comprising 94 'on-site' specimens.
- Four species recorded during the spring monitoring events, comprising 71 'on-site' specimens.
- Four species recorded during the summer monitoring events, comprising 121 'on-site' specimens.

The Dwarf Tree Frog was consistently common, and was recorded during all of the monitoring seasons. Rocket Frog and Tyler's Tree Frog were also relatively common in spring and summer but not during winter. The acid frog species Wallum Froglet was recorded across all monitoring seasons but was rare in summer.

In general, results varied between habitats and transects. Frog species recorded 'on-site' at point count sites within each habitat are shown in **Table 8.2**. The highest diversity of species at point counts sites was generally recorded within the Swamp Forest while the least diversity was recorded in the Sedge Swamp.

The species with the overall highest abundance recorded 'on-site' during the point count surveys were the Dwarf Tree Frog (*Litoria fallax*) - 166 individuals, Rocket Frog (*Litoria nasuta*) – 40 individuals, and Tyler's Tree Frog (*Litoria tyleri*) – 36 individuals.

The least abundant species recorded were Striped Marsh Frog (*Limnodynastes peronii*) - 8 individuals, and Wallum Froglet (*Crinia tinnula*) – 12 individuals.

8.3.1.2 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 area of ex-Fringing Marsh around the edge of Salty Lagoon that has now been inundated following closure of the artificial channel and is mostly open water with occasional clumps of rushes.

Wallum Froglet was the only species recorded within the Sedge Swamp across Transects 1 and 2 (no species were recorded in the Sedge Swamp along Transect 3) for this monitoring period. This species was also recorded within the Swamp Forest.

As shown in **Table 8.2**, the most widely distributed species were Striped Marsh Frog, Dwarf Tree Frog, and Tyler's Tree Frog, which were recorded across multiple transects and in three out of four of the vegetation communities. The Wallum Froglet and Common Eastern Froglet were not recorded in the Fringing Marsh or the Fringing Marsh/ Open Water Ecotone. Only Wallum Froglet was recorded in the Sedge Swamp community. One frog species was recorded in the Sedge Swamp, six species were recorded in the Swamp Forest and Fringing Marsh/ Swamp Forest Ecotone, and four species were recorded in the Fringing Marsh and Fringing Marsh/ Open Forest ecotone.

Table 8.2 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				
Wallum Froglet	*Crinia tinnula*	x	x		x								
Striped Marsh Frog	*Limnodynastes peroni*					x			x		x		
Dwarf Tree Frog	*Litoria fallax*				x	x	x		x		x	x	x
Rocket Frog	*Litoria nasuta*								x			x	x
Tyler's Tree Frog	*Litoria tyleri*				x	x			x				x

8.3.2 Transect Traverse

8.3.2.1 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 8.2** and **Table A3** of **Appendix A**. Along Transect 1 Wallum Froglet was commonly recorded within Sedge Swamp and Swamp Forest, with an additional two records further east in the Melaleuca dieback area. Along Transect 2 Wallum Froglet was recorded in the Sedge Swamp and Swamp forest, and along Transect 3 Wallum Froglet was only recorded in the Sedge Swamp. No Wallum Froglets were recorded in the Fringing Marsh along any transect in the current monitoring period.

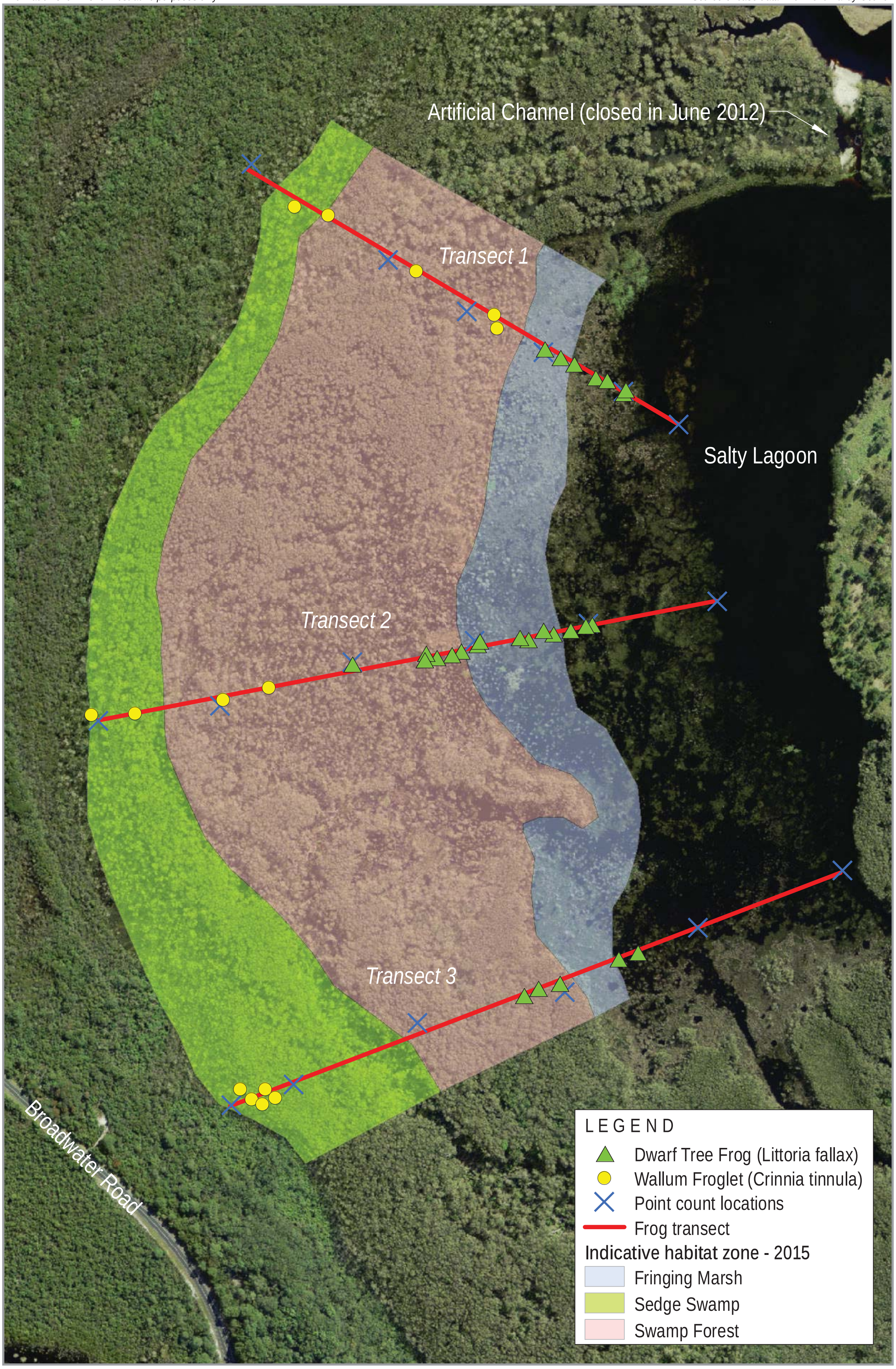
Along Transect 1 Dwarf Tree Frog was recorded predominantly in the Fringing Marsh with a few records also being made in the Melaleuca dieback area. Along Transect 2 and Transect 3 Dwarf Tree Frog was recorded in both the Fringing Marsh and Swamp Forest (including the Melaleuca dieback area). No Dwarf Tree Frogs were recorded in the Sedge Swamp habitat zone in the current monitoring period.

The following summary can be made relating to the distribution of the Wallum Froglet and Dwarf Tree Frog in the study area:

- Dwarf Tree Frogs were particularly dominant in the Fringing Marsh and Swamp Forest habitats; including the Melaleuca dieback area.
- Wallum Froglet was dominant in the Sedge Swamp habitat, and to a lesser extent in the Swamp Forest habitat.
- Wallum Froglet did not occur in the Fringing Marsh habitat and Dwarf Tree Frog did not occur in the Sedge Swamp habitat.
- The location of records of the two species did not overlap in the current monitoring period.

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: RE Reviewed by: DSA Date: 20/10/2015
Source of base data: Richmond Valley Council



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

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Pre-Post Closure of Artificial Channel
1731-1180

Illustration 8.2

8.4 Discussion and Comparison with Pre-channel Closure Monitoring

The findings of the current monitoring period are discussed in **Section 8.4.1** to **Section 8.4.4**. Where trends are evident in the MPPC frog monitoring data collected thus far (for the period of mid-2011 to mid-2015, and subsequently referred to as: baseline monitoring [GeoLINK 2012a], 2012-2013 monitoring [GeoLINK 2013a], 2013-2014 monitoring [GeoLINK 2014], and the current monitoring [2014-2015]) this is noted. Particular focus is given to any apparent differences between the current monitoring and the baseline monitoring undertaken immediately prior to the closure of the artificial channel (GeoLINK 2012a).

An evaluation of the frog monitoring data from the current monitoring period in relation to predictions from the ERMP monitoring (Hydrosphere 2010a) is also provided in **Section 8.4.5**.

8.4.1 Overall Species Diversity

The overall amphibian species diversity has reduced in the current monitoring period when compared with previous MPPC monitoring, with only six species recorded in the current monitoring period, compared with nine species in 2013-2014, eight species in 2012-2013 and nine species in the baseline monitoring. There is no obvious trend in total species diversity to date suggesting that the current reduction is likely to be associated with climatic conditions (eg. the dry period in early summer) and general survey limitations (eg. species not occurring or calling from the survey footprint).

All species recorded in the current monitoring had previously been recorded in the study area in both the ERMP monitoring (Sandpiper 2010) and MPPC monitoring. A number of species recorded in previous monitoring were not recorded in the current monitoring, including Wallum Sedge Frog (*Litoria olongburensis*), Broad-palmed Rocket Frog (*L. latopalmata*), Bleating Tree Frog (*L. dentata*) and Dainty Green Tree Frog (*L. gracilenta*). It should be noted that although not recorded along any of the sampling transects, the Wallum Sedge Frog was recorded off-site in the Sedge Swamp community between Transect 2 and Transect 3.

8.4.2 Frog Seasonal Abundance

The highest abundance of frogs for the current monitoring was recorded during summer. Frog seasonal abundance has been very variable throughout MPPC monitoring, with the highest abundance recorded in winter in 2013-2014 monitoring, in spring in 2012-2013 monitoring, and in summer in baseline monitoring.

The species with the highest abundance in the current monitoring was the Dwarf Tree Frog, with a total of 85 individuals recorded at point counts. This species has consistently been the most abundant species recorded at Salty Lagoon, with 64 individuals recorded in 2013-2014 monitoring, 169 individuals recording in 2012-2013 monitoring, and 78 individuals recorded in baseline monitoring.

Abundance of the threatened Wallum Froglet (acid frog) has been variable throughout the MPPC monitoring, with 12 individuals recorded in the current monitoring compared with 26 individuals recorded in 2013-2014 monitoring, 19 individuals recorded in 2012-2013 monitoring and 29 individuals recorded in baseline monitoring. The yearly abundance of this species appears to be fluctuating rather than showing a strong trend. These fluctuations appear to be associated with variability of environmental factors such as varying/ seasonal weather conditions, as well as water levels.

8.4.3 Species Diversity by Vegetation Habitat Zone

The comparatively low diversity of frog species recorded in the Sedge Swamp in the current monitoring is in line with results from the 2013-2014 monitoring. Only one species (Wallum Froglet) was recorded in this habitat zone in both of these monitoring events. However, the Wallum Sedge Frog was recorded off-site in the Sedge Swamp community between Transect 2 and Transect 3. Considering the Sedge Swamp (core acid frog habitat) is located a considerable distance from the edge of Salty Lagoon, it is unlikely that the closure of the artificial channel is a significant influencing factor leading to a reduction in species diversity in this habitat zone. It is more likely that this variability reflects environmental factors such as seasonal weather conditions.

Six species were recorded in the Swamp Forest and Swamp Forest/ Fringing Marsh ecotone (Melaleuca dieback area) in the current monitoring, compared with seven species in 2013-2014 monitoring, eight species in 2012-2013 monitoring and eight species in baseline monitoring. Five species were recorded in the Fringing Marsh and Fringing Marsh/ Open Water ecotone, compared with eight species in 2013-2014 monitoring, seven species in the 2012-2013 monitoring, and eight species in baseline monitoring.

Comparatively low species diversity recorded in the Fringing Marsh and Fringing Marsh/ Open Water ecotone in the current monitoring may be a reflection of changes to water levels and vegetation around the edge of the lagoon and hence habitat availability for frogs. Sedgeland fringing the lagoon has been converted to open water as the water level has increased in the lagoon, resulting in both a narrowing in the width of the fringing marsh habitat and a reduction in the availability of structural habitat for frogs (emergent vegetation).

No acid frogs were recorded in the Fringing Marsh along any transects during the current monitoring event. This contrasts to previous monitoring events, where the Wallum Froglet has been recorded within this habitat zone along Transect 1 (GeoLINK 2012a, 2013a, 2014a). Water quality monitoring during the current monitoring period has shown stable increased water levels within Salty Lagoon, with have a buffering pH tendency towards neutral within the core water body. It appears that the Fringing Marsh along Transect 1 has subsequently becoming unsuitable for the Wallum Froglet, and the species distribution is now restricted to the Sedge Swamp and Swamp Forest (similar to Transect 2 and 3).

8.4.4 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. This segregated pattern of distribution was observed for Wallum Froglet and Dwarf Tree Frog (refer to **Section 8.4.3**).

In previous MPPC monitoring a small number of Wallum Froglet records were made in the western section of Fringing Marsh along Transect 1. However, no similar records were made in the current monitoring period in line with the expected distribution according to the acid water preference of this species as described above.

8.4.5 Comparison against Rehabilitation Targets

The ERMP data indicated that the main threat to specialist wallum species habitat (i.e. Wallum Froglet and Wallum Sedge Frog) in the Lagoon is from saline intrusion enabled by the Artificial Channel. Therefore, as the closure of the Artificial Channel effectively prevented large-scale salinity intrusion, it was predicted that the distribution of suitable habitat for these species might expand (Hydrosphere 2010a).

In Hydrosphere (2010a) it was predicted that:

"Changes in frog communities as a result of closure will be impacted by interacting factors, such as water level, salinity, pH and competition between species. It is likely that due to hydrological and water chemistry changes (specifically reduced saline intrusion) there will be an expansion in the usable habitat for species present at the site, including potential expansion in the area suitable for acid frogs".

Specific predicted outcomes on frogs following the closure of the artificial channel (Hydrosphere 2010a) and comparison with the findings of the MPPC frog monitoring are shown in **Table 8.3**.

Table 8.3 Predicted Frog Changes and Outcomes to Date for the MPPC

Predicted Major Changes to the System	*MPPC Monitoring Findings*
Increase in acid frog (*Crinia tinnula, L. freycineti* and L. *olongburensis*) distribution.	Comparison of the distribution maps for Wallum Froglet over the MPPC monitoring period does not support this prediction. Additionally the core water body of Salty Lagoon has a pH unsuitable for acid frogs, also not concurring with this prediction. Wallum Froglet distribution has remained relatively stable within the Sedge Swamp and Swamp Forest habitats, though has retracted westward along Transect 1 from the Fringing Marsh. *L. freycineti* and *L. olongburensis* have been recorded in such low numbers in the MPPC monitoring as to make it impossible to detect any changes in relation to these species, though *L. olongburensis* occurrences within the Sedge Swamp appear stable.

This may indicate that the overriding factor determining acid frog distribution is acidic influence on water quality from adjacent wallum vegetation rather than a cessation of saline intrusion the system through the artificial channel. It is possible that the generally higher water level within Salty Lagoon following closure of the artificial channel has effectively limited any expansion of suitable acidic habitat out from the Sedge Swamp/ Swamp Forest towards the lagoon edge by diluting any low pH runoff or groundwater that may reach areas closer to the lagoon that have higher water levels.

9. Conclusion

9.1 Conclusion

Results of the MPPC to date consist of pre-closure of the Artificial Channel baseline dataset and three years of post-closure monitoring. The post-closure monitoring has included both typical and atypical climatic events (including above average wet and dry weather periods); allowing the dataset to cover broad climatic variation. The current monitoring period comprised relatively 'normal' climatic conditions for the region.

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 and stabilises.

To date, early indications are that many of the predicted changes are occurring. This includes positive predicted changes such as a more natural hydrology and salinity regime; reduced magnitude, rate of water level variation; less frequent saline water ingress; and reduced risk of fish kill. Conversely, other monitoring attributes have recorded no clear trend (e.g. improved productivity of the benthic microalgal assemblage resulting in nutrient assimilation) or negative trends (e.g. Wallum Froglet distribution has decreased).

Three notable additional issues that have been observed during the current monitoring period:

- An erosive headcut to the east of the old artificial that is advancing from Salty Creek towards Salty Lagoon through a naturally existing low point between the two water bodies. The position and continued advance of the headcut could potentially lead to a new channel between Salty Lagoon and Salty Creek supporting flow in both directions and return Salty Lagoon to the pre-closure state.
- Spikes in the population of the aquatic plants Pacific Azolla (*Azolla filiculoides*) and Duckweed (*Lemna sp.*) around S2 Further monitoring may provide a greater insight into this issue.
- A reduction in the reliability of the permanent water quality monitoring equipment. A number of strategies have been put in place to manage this and to continue to receive reliable data from this system.

As the monitoring period increases, the exact nature of the changes within Salty Lagoon will become more apparent over time.

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Appendix A

Frog Monitoring Data

Table A1 Environmental Conditions at the Time of the Frog Monitoring

Season	Date	Transect	Weather	Temperature	Relative Humidity (3 pm)	Wind km/hr	Evidence of Rain in 24 hrs	Rain in 72 hrs (mm)	Night Light	Approximate Depth of Surface Water (mm)						Artificial Channel Open or Closed
										PC1	PC2	PC3	PC 4	PC5	PC6	
Winter 2014	19/08/14	1	Dry	12.5-23.1	67%	no wind	yes	29.8	Very Dark	Open water - no measurement recorded	350	300	200	20	0	Closed
	19/08/14	2	Dry	12.5-23.1	67%	light	yes	29.8	Very Dark	Open water - no measurement recorded	400	300	100	50	20	Closed
	19/08/14	3	Dry	12.5-23.1	67%	no wind	yes	29.8	Very Dark	Open water - no measurement recorded	450	100	50	20	0	Closed
	4/09/14	1	Dry	9.3-20.1	48%	light to moderate	no	0	1/2 moon	Open water - no measurement recorded	450	400	400	150	0	Closed
	4/09/14	2	Dry	9.3-20.1	48%	light to moderate	no	0	1/2 moon	Open water - no measurement recorded	550	300	50	50	0	Closed
	4/09/14	3	Dry	9.3-20.1	48%	light to moderate	no	0	1/2 moon	Open water	500	100	50	0	0	Closed
Spring 2014	17/11/14	1	Dry	20.3 - no data	78	light	no	0	Very Dark	Open water	200	100	0	0	0	Closed
	17/11/14	2	Dry	20.3 - no data	78	light	no	0	Very Dark	Open water	300	50	0	0	0	Closed
	17/11/14	3	Dry	20.3 - no data	78	light	no	0	Very Dark	Open water	300	0	0	0	0	Closed
	19/11/14	1	Dry	21.9 - 28.3	74	light	no	0	Very Dark	Open water	200	100	0	0	0	Closed
	19/11/14	2	Dry	21.9 - 28.3	74	light	no	0	Very Dark	Open water	300	50	0	0	0	Closed
	19/11/14	3	Dry	21.9 - 28.3	74	light	no	0	Very Dark	Open water	300	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 72 hrs (mm)	Night Light	Approximate Depth of Surface Water (mm)						Artificial Channel Open or Closed
										PC1	PC2	PC3	PC 4	PC5	PC6	
Summer 2015	24/02/15	1	Dry	21.3 - 28.5	77	light	yes	19.4	1/4 moon	Open water	500	500	400	250	0	Closed
	24/02/15	2	light rain	21.3 - 28.5	77	no wind	yes	19.4	dark	Open water	600	450	200	200	25	Closed
	24/02/15	3	light rain	21.3 - 28.5	77	light to moderate	yes	19.4	dark	Open water	600	250	250	25	0	Closed
	26/02/15	1	overcast	19.9 - 27.4	67	calm	yes	5.4	dark	Open water	450	450	300	250	0	Closed
	26/02/15	2	overcast	19.9 - 27.4	67	calm	yes	5.4	dark	Open water	600	300	50	250	0	Closed
	26/02/15	3	overcast	19.9 - 27.4	67	calm	yes	5.4	dark	Open water	600	250	200	25	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*		*Crinia signifera*		*Limnodynastes peronii*		*Litoria fallax*		*Litoria tyleri*		*Litoria nasuta*		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)	
WINTER 2014															
Census 1															
T1: 19/08/14 6:30 pm	1	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	**0**
	2	Fringing Marsh	0	no	0	no	0	no	4	yes	0	no	0	no	**4**
	3	Fringing Marsh	0	no	1	no	0	no	0	no	0	no	0	no	**1**
	4	Swamp Forest	0	no	1	no	0	no	0	no	0	no	0	no	**1**
	5	Swamp Forest	2	yes	0	no	0	no	0	no	0	no	0	no	**2**
	6	Sedge Swamp	0	yes	0	no	0	no	0	no	0	no	0	no	**0**
T2 19/08/14 7:45 pm	1	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	**0**
	2	Fringing Marsh	0	no	0	no	0	no	20	yes	0	no	0	no	**20**
	3	Fringing Marsh/ Swamp Forest Ecotone	0	no	1	no	0	no	9	yes	0	yes	0	no	**10**
	4	Swamp Forest	0	no	4	no	0	no	2	no	1	yes	0	no	**7**
	5	Swamp Forest	0	yes	1	yes	0	no	0	no	0	yes	0	no	**1**
	6	Sedge Swamp	2	no	0	no	0	no	0	no	0	no	0	no	**2**
T3 19/08/14 9:15 pm	1	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	**0**
	2	Open Water / Fringing Marsh Ecotone	0	no	0	no	0	no	5	yes	0	no	0	no	**5**
	3	Swamp Forest	0	no	2	yes	0	no	1	yes	0	yes	0	no	**3**
	4	Swamp Forest	0	no	4	yes	0	no	0	no	0	no	0	no	**4**
	5	Swamp Forest	0	yes	0	yes	0	no	0	no	0	no	0	no	**0**
	6	Sedge Swamp	0	yes	0	no	0	no	0	no	0	no	0	no	**0**
Census 1 TOTAL			**4**	**0**	**14**	**0**	**0**	**0**	**41**	**0**	**1**	**0**	**0**	**0**	**60**

Transect No. and Survey Date	*Point Count No.*	*Habitat Type*	*Crinia tinnula*		*Crinia signifera*		*Limnodynastes peronii*		*Litoria fallax*		*Litoria tyleri*		*Litoria nasuta*		*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)*	
							Census 2								
T1: 04/09/14 6:20 pm	1	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	**0**
	2	Fringing Marsh	0	no	0	no	0	no	5	yes	0	no	0	no	**5**
	3	Fringing Marsh	0	yes	no	yes	0	no	1	yes	0	no	0	no	**1**
	4	Swamp Forest	1	yes	0	yes	0	no	0	no	1	yes	0	no	**2**
	5	Swamp Forest	1	yes	0	no	0	no	0	no	0	no	0	no	**1**
	6	Sedge Swamp	o	no	0	no	0	no	0	no	0	no	0	no	**0**
T2: 04/09/14 7:30 pm	1	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	**0**
	2	Fringing Marsh	0	no	0	no	0	no	7	yes	0	no	0	no	**7**
	3	Fringing Marsh/ Swamp Forest Ecotone	0	no	0	no	0	no	6	yes	0	no	0	no	**6**
	4	Swamp Forest	0	no	1	yes	0	no	0	yes	0	no	0	no	**1**
	5	Swamp Forest	1	yes	1	yes	1	yes	0	no	0	no	0	no	**3**
	6	Sedge Swamp	0	yes	0	no	0	yes	0	no	0	no	0	no	**0**
T3: 04/09/14 8:50 pm	1	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	**0**
	2	Open Water / Fringing Marsh Ecotone	0	no	0	no	0	no	0	yes	0	no	0	no	**0**
	3	Swamp Forest	0	no	5	yes	0	no	0	yes	0	no	0	no	**5**
	4	Swamp Forest	0	no	3	yes	0	no	0	no	0	no	0	no	**3**
	5	Swamp Forest	0	yes	0	yes	0	no	0	no	0	no	0	no	**0**
	6	Sedge Swamp	0	yes	0	yes	0	no	0	no	0	no	0	no	**0**
Census 2 TOTAL			**3**	**0**	**10**	**0**	**1**	**0**	**19**	**0**	**1**	**0**	**0**	**0**	**34**
WINTER TOTAL			**7**	**0**	**24**	**0**	**1**	**0**	**60**	**0**	**2**	**0**	**0**	**0**	**94**
							SPRING 2014								

Transect No. and Survey Date	Point Count No.	Habitat Type	Crinia tinnula		Crinia signifera		Limnodynastes peronii		Litoria fallax		Litoria tyleri		Litoria nasuta		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)	
						Census 1									
T1: 17/11/14 8:00 pm	1	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	**0**
	2	Fringing Marsh	0	no	0	no	0	no	1	yes	0	no	0	no	**1**
	3	Fringing Marsh	0	no	0	no	0	no	0	no	0	no	0	no	**0**
	4	Swamp Forest	0	no	0	no	0	no	0	yes	0	no	0	yes	**0**
	5	Swamp Forest	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**
T2 17/11/14 9:15 pm	1	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	**0**
	2	Fringing Marsh	0	no	0	no	0	no	3	yes	0	no	10	yes	**13**
	3	Fringing Marsh/ Swamp Forest Ecotone	0	no	0	no	0	no	0	yes	0	no	0	yes	**0**
	4	Swamp Forest	0	no	0	no	0	no	0	no	0	no	0	no	**0**
	5	Swamp Forest	0	no	0	no	0	no	2	yes	3	no	0	yes	**5**
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	**0**
T3 17/11/14 10:55 pm	1	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	**0**
	2	Open Water / Fringing Marsh Ecotone	0	no	0	no	0	no	2	yes	0	no	4	yes	**6**
	3	Swamp Forest	0	no	0	no	0	no	0	yes	0	no	0	yes	**0**
	4	Swamp Forest	0	no	0	no	0	no	0	yes	0	no	0	no	**0**
	5	Swamp Forest	0	no	0	no	0	no	0	yes	0	no	0	no	**0**
	6	Sedge Swamp	0	yes	0	no	0	no	0	no	0	no	0	no	**0**
Census 1 TOTAL			**0**	**0**	**0**	**0**	**0**	**0**	**8**	**0**	**3**	**0**	**14**	**0**	**25**
						Census 2									
T1: 19/11/14 7:55 pm	1	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	**0**

Transect No. and Survey Date	Point Count No.	Habitat Type	Crinia tinnula		Crinia signifera		Limnodynastes peronii		Litoria fallax		Litoria tyleri		Litoria nasuta		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)	
	2	Fringing Marsh	0	yes	0	no	0	no	0	yes	0	no	0	yes	**0**
	3	Fringing Marsh	0	yes	0	no	0	no	0	yes	0	no	0	no	**0**
	4	Swamp Forest	0	yes	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**
	6	Sedge Swamp	1	yes	0	no	0	no	0	no	0	no	0	no	**1**
T1: 19/11/14 8:55 pm	1	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	**0**
	2	Fringing Marsh	0	no	0	no	0	no	3	yes	0	no	10	yes	**13**
	3	Fringing Marsh/ Swamp Forest Ecotone	0	no	0	no	0	no	1	yes	0	no	0	yes	**1**
	4	Swamp Forest	0	no	0	no	0	no	1	yes	3	no	0	no	**4**
	5	Swamp Forest	0	no	0	no	0	no	1	yes	6	y	0	no	**7**
	6	Sedge Swamp	3	yes	0	no	0	no	0	no	0	no	0	no	**3**
T1: 19/11/14 10:15 pm	1	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	**0**
	2	Open Water / Fringing Marsh Ecotone	0	no	0	no	0	no	5	yes	0	no	10	yes	**15**
	3	Swamp Forest	0	no	0	no	0	no	2	yes	0	no	0	yes	**2**
	4	Swamp Forest	0	no	0	no	0	no	0	yes	0	no	0	no	**0**
	5	Swamp Forest	0	yes	0	no	0	no	0	no	0	no	0	no	**0**
	6	Sedge Swamp	0	yes	0	no	0	no	0	no	0	no	0	no	**0**
Census 2 TOTAL			**4**	**0**	**0**	**0**	**0**	**0**	**13**	**0**	**9**	**0**	**20**	**0**	**46**
SPRING TOTAL			**4**	**0**	**0**	**0**	**0**	**0**	**21**	**0**	**12**	**0**	**34**	**0**	**71**

Transect No. and Survey Date	*Point Count No.*	*Habitat Type*	*Crinia tinnula*		*Crinia signifera*		*Limnodynastes peronii*		*Litoria fallax*		*Litoria tyleri*		*Litoria nasuta*		*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)*	
SUMMER 2015															
Census 1															
T1: 24/02/15 8:00 pm	**1**	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	**0**
	2	Fringing Marsh	0	no	0	no	0	yes	10	yes	0	no	0	yes	**10**
	3	Fringing Marsh	0	no	0	no	0	yes	6	no	0	no	0	no	**6**
	4	Swamp Forest	0	no	0	no	0	no	1	yes	3	yes	0	no	**4**
	5	Swamp Forest	0	no	0	no	0	no	0	no	3	yes	0	no	**3**
	6	Sedge Swamp	0	no	0	no	0	no	0	yes	0	no	0	no	**0**
T2: 24/02/15 9:25 pm	**1**	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	**0**
	2	Fringing Marsh	0	no	0	no	0	yes	8	yes	0	no	0	no	**8**
	3	Fringing Marsh/ Swamp Forest Ecotone	0	no	0	no	1	no	10	yes	2	yes	0	no	**13**
	4	Swamp Forest	0	no	0	no	0	no	5	yes	6	no	0	no	**11**
	5	Swamp Forest	0	no	0	no	0	no	0	yes	1	yes	0	no	**1**
	6	Sedge Swamp	1	yes	0	no	0	no	0	no	0	yes	0	no	**1**
T3: 24/02/15 10:45 pm	**1**	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	**0**
	2	Open Water / Fringing Marsh Ecotone	0	no	0	no	0	no	10	yes	0	no	0	no	**10**
	3	Swamp Forest	0	no	0	no	0	yes	0	yes	0	yes	0	no	**0**
	4	Swamp Forest	0	no	0	no	0	yes	0	yes	0	no	0	no	**0**
	5	Swamp Forest	0	no	0	no	0	no	0	yes	0	no	0	no	**0**
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	**0**
Census 1 TOTAL			**1**	**0**	**0**	**0**	**1**	**0**	**50**	**0**	**15**	**0**	**0**	**0**	**67**

Transect No. and Survey Date	Point Count No.	Habitat Type	Crinia tinnula		Crinia signifera		Limnodynastes peronii		Litoria fallax		Litoria tyleri		Litoria nasuta		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)	
						Census 2									
T1: 26/02/15 8:00 pm	1	Open Water	0	no	7	no	0	no	0	no	0	no	0	no	**0**
	2	Fringing Marsh	0	no	0	no	0	no	1	yes	0	no	0	no	**1**
	3	Fringing Marsh	0	no	0	no	2	yes	2	yes	0	yes	0	yes	**4**
	4	Swamp Forest	0	no	0	no	0	no	0	yes	1	yes	0	no	**1**
	5	Swamp Forest	0	no	0	no	0	no	0	yes	1	yes	0	no	**1**
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	**0**
T2: 26/02/15 8:55 pm	1	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	**0**
	2	Fringing Marsh	0	no	0	no	0	no	7	yes	0	no	0	no	**7**
	3	Fringing Marsh/ Swamp Forest Ecotone	0	no	0	no	0	no	8	yes	0	yes	2	no	**10**
	4	Swamp Forest	0	no	0	no	0	no	3	yes	5	yes	0	no	**8**
	5	Swamp Forest	0	no	0	no	0	no	1	yes	0	yes	0	no	**1**
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	**0**
T3: 26/02/15 10:00 pm	1	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	**0**
	2	Open Water / Fringing Marsh Ecotone	0	no	0	no	0	no	10	yes	0	no	4	yes	**14**
	3	Swamp Forest	0	no	0	no	2	no	2	yes	0	yes	0	yes	**4**
	4	Swamp Forest	0	no	0	no	2	yes	1	yes	0	no	0	no	**3**
	5	Swamp Forest	0	no	0	no	0	no	0	yes	0	no	0	no	**0**
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	**0**
Census 2 Total			0	0	0	0	6	0	35	0	7	0	6	0	**54**
SUMMER TOTAL			1	0	0	0	7	0	85	0	22	0	6	0	**121**
OVERALL TOTAL			**12**	**0**	**24**	**0**	**8**	**0**	**166**	**0**	**36**	**0**	**40**	**0**	**286**

Table A3 Wallum Froglet and Dwarf Tree Frog Comparison Results

ID	Easting	Northing	Species	Habitat	Transect
WF1	541588	6783209	Wallum Froglet	Sedge Swamp	T1PC5
WF2	541619	6783202	Wallum Froglet	Sedge Swamp	Between T1PC6 and T1PC5
WF3	541697	6783152	Wallum Froglet	Sedge Swamp	Between T1PC6 and T1PC5
WF4	541766	6783113	Wallum Froglet	Swamp Forest	between T1PC5 and T1PC4
WF5	541769	6783101	Wallum Froglet	Swamp Forest	Between T1PC4 and T1PC3
WF6	541408	6782759	Wallum Froglet	Swamp Forest	Between T1PC4 and T1PC3
WF7	541525	6782772	Wallum Froglet	Sedge Swamp	T2PC6
WF8	541447	6782760	Wallum Froglet	Sedge Swamp	T2PC5
WF9	541566	6782783	Wallum Froglet	Sedge Swamp	Between T2PC6 and T1PC5
WF10	541551	6782417	Wallum Froglet	Sedge Swamp	Between T2PC5 and T1PC4
WF11	541540	6782426	Wallum Froglet	Sedge Swamp	Between T3PC6 and T3PC5
WF12	541563	6782426	Wallum Froglet	Sedge Swamp	Between T3PC6 and T3PC5
WF13	541572	6782419	Wallum Froglet	Sedge Swamp	Between T3PC6 and T3PC5
WF14	541560	6782413	Wallum Froglet	Sedge Swamp	Between T3PC6 and T3PC5
DTF1	541881	6783044	Dwarf Tree Frog (*Litoria fallax*)	Fringing Marsh	T1PC2
DTF2	541883	6783047	Dwarf Tree Frog (*Litoria fallax*)	Fringing Marsh	T1PC2
DTF3	541856	6783057	Dwarf Tree Frog (*Litoria fallax*)	Fringing Marsh	Between T1PC2 and T2PC3
DTF4	541866	6783055	Dwarf Tree Frog (*Litoria fallax*)	Fringing Marsh	Between T1PC2 and T2PC3
DTF5	541837	6783070	Dwarf Tree Frog (*Litoria fallax*)	Fringing Marsh	Between T1PC2 and T2PC3
DTF6	541811	6783083	Dwarf Tree Frog (*Litoria fallax*)	Swamp Forest	T1PC3

ID	Easting	Northing	Species	Habitat	Transect
DTF7	541825	6783075	Dwarf Tree Frog (*Litoria fallax*)	Swamp Forest	Between T1PC2 and T2PC3
DTF8	541853	6782839	Dwarf Tree Frog (*Litoria fallax*)	Fringing Marsh	T2PC2
DTF9	541847	6782837	Dwarf Tree Frog (*Litoria fallax*)	Fringing Marsh	T2PC2
DTF10	541834	6782833	Dwarf Tree Frog (*Litoria fallax*)	Fringing Marsh	Between T2PC2 and T2PC3
DTF11	541819	6782830	Dwarf Tree Frog (*Litoria fallax*)	Fringing Marsh	Between T2PC2 and T2PC3
DTF12	541810	6782833	Dwarf Tree Frog (*Litoria fallax*)	Swamp Forest	Between T2PC2 and T2PC3
DTF13	541796	6782825	Dwarf Tree Frog (*Litoria fallax*)	Swamp Forest	Between T2PC2 and T2PC3
DTF14	541789	6782827	Dwarf Tree Frog (*Litoria fallax*)	Swamp Forest	Between T2PC2 and T2PC3
DTF15	541751	6782820	Dwarf Tree Frog (*Litoria fallax*)	Swamp Forest	T2PC3
DTF16	541753	6782824	Dwarf Tree Frog (*Litoria fallax*)	Swamp Forest	T2PC3
DTF17	541737	6782815	Dwarf Tree Frog (*Litoria fallax*)	Swamp Forest	Between T2PC3 and T2PC4
DTF18	541728	6782812	Dwarf Tree Frog (*Litoria fallax*)	Swamp Forest	Between T2PC3 and T2PC4
DTF19	541715	6782809	Dwarf Tree Frog (*Litoria fallax*)	Swamp Forest	Between T2PC3 and T2PC4
DTF20	541705	6782813	Dwarf Tree Frog (*Litoria fallax*)	Swamp Forest	Between T2PC3 and T2PC4
DTF21	541704	6782807	Dwarf Tree Frog (*Litoria fallax*)	Swamp Forest	Between T2PC3 and T2PC4
DTF22	541640	6782803	Dwarf Tree Frog (*Litoria fallax*)	Fringing Marsh	T2PC4
DTF23	541894	6782548	Dwarf Tree Frog (*Litoria fallax*)	Fringing Marsh	Between T3PC2 and T3PC3
DTF24	541876	6782542	Dwarf Tree Frog (*Litoria fallax*)	Fringing Marsh	Between T3PC2 and T3PC3
DTF25	541825	6782521	Dwarf Tree Frog (*Litoria fallax*)	Swamp Forest	T3PC3
DTF26	541805	6782516	Dwarf Tree Frog (*Litoria fallax*)	Swamp Forest	Between T3PC3 and T3PC4
DTF27	541793	6782509	Dwarf Tree Frog (*Litoria fallax*)	Swamp Forest	Between T3PC3 and T3PC4