Annual Report 2017

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 2017) summarises the results of the MPPC monitoring undertaken between June 2016 and June 2017, which consists of the final (fifth) post-closure of the artificial channel monitoring period. Comparisons between the monitoring results and the predicted changes in Salty Lagoon would be discussed in the Final Evaluation Report.

The monitoring period was characterised by particularly dry weather in the period between September 2016 and January 2017, and very wet periods in June 2016, August 2016, March 2017 and June 2017. Key findings from the 2016/17 monitoring period are summarised below.

Water Quality (Monitored at Salty Lagoon and Salty Creek)

- Water level: The water level in Salty Lagoon was full for most of the reporting period but low water levels were recorded around January 2017.
- Conductivity: Conductivity in Salty Lagoon was relatively stable throughout the reporting period with the exception of the three-week period following saline water ingress in late February 2017. The key driving factors causing fluctuations in the conductivity during this reporting period were rainfall, evaporation and saline water inflow from Salty Creek.
- Dissolved oxygen: DO concentration measured at the Salty Lagoon PWQMS:
  - Dropped below 1 mg/L on a large number of occasions.
  - Was 6 mg/L or less on approximately 64% of occasions and 1 mg/L or less on approximately 23% of occasions.

  This is a notable increase in these statistics relative to the previous reporting period (2015/16) but similar to previous reporting periods (2011-15).
- pH: The pH measurements at the Salty Lagoon PWQMS varied mainly in response to rainfall conditions during this reporting period. The pH in Salty Lagoon drops sharply in response to heavy rainfall, when low pH water is washed out of the wetlands in the catchment. During dry times the pH measured at the Salty Lagoon PWQMS increases, in response to an unknown buffering agent.
- 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, which has been recorded previously.
- Turbidity: Turbidity measurements were relatively stable in Salty Lagoon. 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.
- Nitrogen: Concentrations of TN were relatively stable with the exception of the driest period between October 2016 and February 2017. The highest TN concentrations were measured during the lowest water levels, indicating that evaporative distillation was the key cause of those results. In general, TN concentrations reduced after heavy rainfall and increased during extended dry periods. This indicates that nitrogen stored in the sediment in Salty Lagoon is the major source of

nitrogen in the system, not rainfall runoff or the release of treated effluent upstream. If this is the case, TN concentrations should reduce over coming years as nitrogen is lost to the system in runoff.

- Phosphorus: Variation in phosphorus concentrations at the sites in Salty Lagoon did not conform precisely to a specific pattern. 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. Evaporative distillation was observed to impact on phosphorus concentrations at sites S2 and S4 immediately before drying out. The lowest measured concentrations of phosphorus occurred immediately following heavy rainfall events. Aside from the periods immediately prior to sites drying out TN and TP concentrations appear to have varied independently during this reporting period. This indicates that the processing of nitrogen and phosphorus in Salty Lagoon also occurs independently. For the majority of the results, the greater proportion of the total phosphorus present was present as orthophosphate (a bioavailable form). The relationship between available phosphorus and algal concentrations was cryptic.
- Chlorophyll-a: Chlorophyll-a concentrations in Salty Lagoon did not comply with guiding values for a large part of the reporting period. Most of the results indicated an algal bloom of small to moderate proportions with the exception of samples collected in December 2016 and February 2017, which indicated algal blooms of moderate to large proportions. The highest chlorophyll-a concentrations measured were associated with increased nutrient concentrations or bioavailable nutrient concentrations (DIN and orthophosphate).

  There has been a slight trend towards increasing chlorophyll-a concentrations over the course of the MPPC project. It is possible that the more stable freshwater conditions are contributing to a stabilisation of the microalgal population in the water column and, subsequently, more dynamic microalgal population shifts in response to environmental conditions.
- Blue green algae: Blue green algae were not detected in any samples during the reporting period.
- Faecal indicator organisms: With the exception of a few spikes in concentration the enterococcus and faecal coliform concentrations remained low at all sites during the reporting period. The major contributors to the observed variation in the concentration of faecal indicator organisms are runoff from the catchment and the presence of waterfowl. The results do not suggest that discharge from the Evans Head STP or leaks from the Evans Head sewerage system are influencing the concentrations of faecal indicator organisms.
- STP discharge monitoring: Discharge quality results for the monitoring period were within the licensing limits set for the Evans Head STP by the NSW Environmental Protection Agency (EPA), with the exception of one TN measurement and one TP measurement. STP discharge is not enough to maintain water levels and water losses due to evaporation and groundwater being larger than the input from the STP. In general, faecal coliform concentrations in discharged effluent are very low. It is highly unlikely that discharged effluent is contributing significantly to faecal coliform measurements in Salty Lagoon. 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 and is diluted by unpolluted water from around the catchment. It is possible that elevated nitrogen concentrations around Salty Lagoon may be partially maintained in the long term by the input from the Evans Head STP.

  The concentrations of TP in discharged effluent are generally comparable to those measured at S2, where the drainage channel opens out into Salty Lagoon. The increasing trend of TP concentration along the drainage channel from the STP to Salty Lagoon is 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 will continue for some time into the future.

Macroinvertebrates

- A total of 26 macroinvertebrate taxa have been recorded during the MPPC.
- There has been continued variation in the diversity, abundance and species makeup of benthic macroinvertebrates collected during seasonal surveys. However there are some signs that the numbers of individuals and the variety of species being collected are becoming more stable.
- There is a strong indication 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. This trend is reflective of a shift from an intermittently open and closed waterbody to a freshwater wetland. 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.

Aquatic Vegetation/ Weeds

- No significant introduced species of aquatic weeds have been recorded in the current monitoring period, though an introduced (naturalised) species and four 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.

Fish

- Across all surveys during the reporting period a total of four finfish species were captured. The number of species captured at each of the sites has varied over time. There is no clear pattern to the overall observed variation.
- There was wide variation in the number (abundance) of fish captured at each site over time. Patterns evident are in relation to season (with lower numbers of captures in winter) and Mosquitofish numbers.

Waterfowl

- The current reporting period observed continued and consistent high levels of both diversity and abundance of waterfowl.
- The highest recorded species diversity since the beginning of the MPPC was recorded in the autumn 2017 monitoring event.
- 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.

Frogs

- Eight frog species were recorded during the current reporting period. The diversity recorded was similar to recent MPPC monitoring. There was no obvious trend in total species diversity. All species recorded in the current monitoring had previously been recorded in the study area in both the ERMP monitoring and MPPC monitoring.

- 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. Although some overlap was recorded in the distribution of Wallum Froglet (acid frog) and Dwarf Tree Frog (habitat generalist) a broad segregation was noted based on habitat preference, with Wallum Froglet being most commonly recorded in those habitats furthest from the Open Water of Salty Lagoon and Dwarf Tree Frog being least common in these same habitats.
- Wallum Froglet distribution has remained relatively stable within the Sedge Swamp and Swamp Forest habitats, though varied throughout the MPPC along Transect 1 in the Fringing Marsh. The suitability of this habitat may vary overtime in relation to the overall water levels within the lagoon.

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. There has been an increase in the extent of Fringing Marsh since the 2015 monitoring, as freshwater sedges and rushes colonise the 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 declined since the pre-channel closure monitoring, through increased slightly since the 2015 monitoring. The overall reduction is flora diversity 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 trees continues to be good, with thick foliage throughout and no signs of stress detected on any trees. In some quadrats the small trees and trees that were recorded in 2015 have grown in height substantially.

Emerging Trends and Issues

The erosive headcut to the east of the old artificial channel continues to present a threat to the project. Ongoing monitoring has observed continued advancement of the headcut, at a rate increased in relation to the previous reporting period. 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. Remediation plans are currently being designed.

1. Introduction

1.1 Background

GeoLINK and Aquatic Science and Management (ASM) 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).

1.2 Objectives

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 ended 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.
- Close liaison with RVC, Office of Environment and Heritage (OEH) and the Salty Lagoon Stakeholder Group, as well as attendance at meetings throughout the course of the project.

This report (*Annual Report 2017)* summarises the results of the monitoring undertaken between June 2016 and June 2017 as part of the MPPC program. This comprises the fifth (and final) post-closure of the artificial channel monitoring period. Comparisons between the monitoring results and the predicted changes in Salty Lagoon would be discussed in the Final Evaluation Report.

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 multi-faceted 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 weekly to fortnightly intervals, 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 the previous 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.

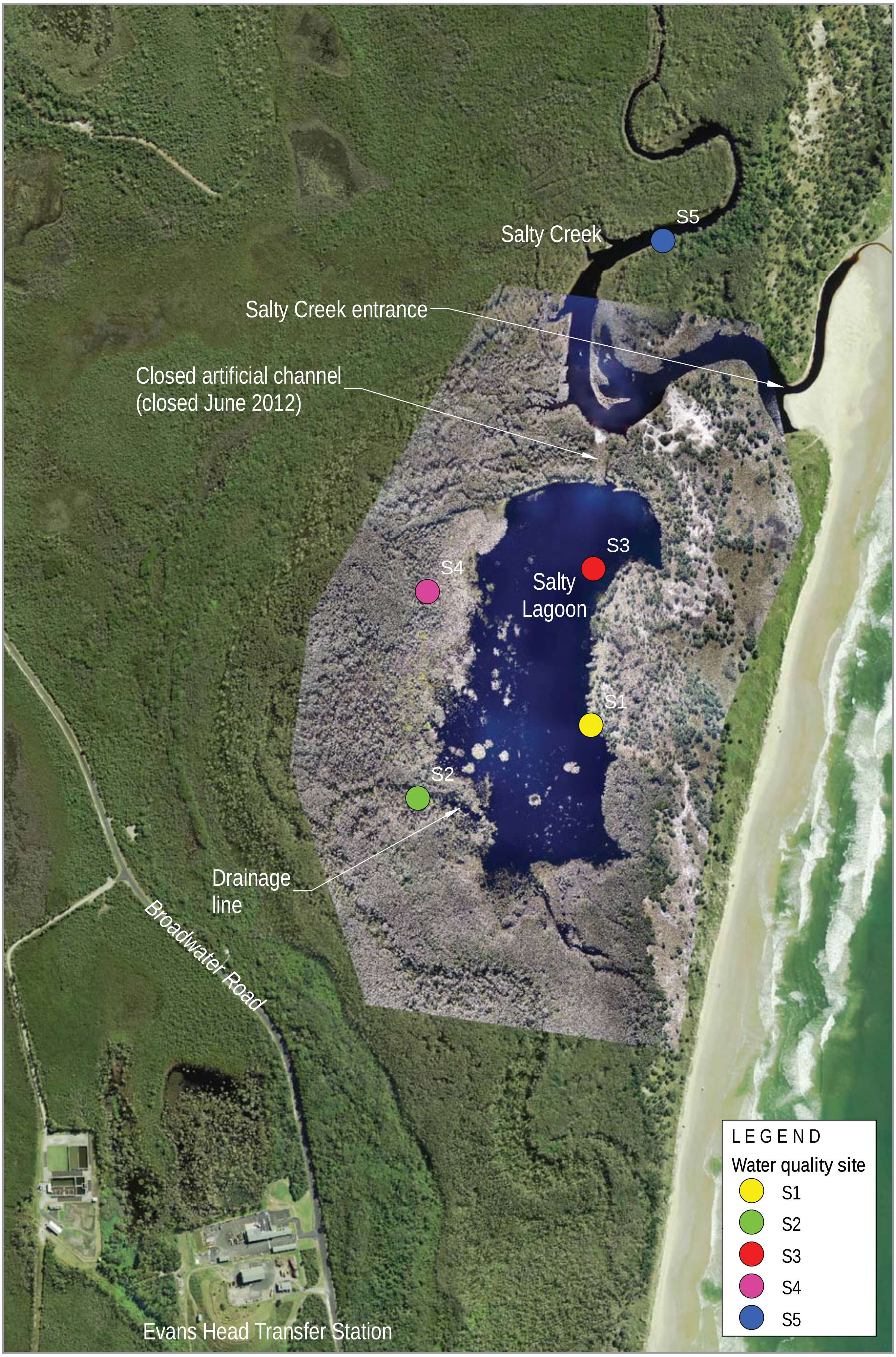
Discrete samples were collected in jars for analysis of chemical and biological parameters at the Coffs Harbour Laboratory (CHL). Sterile jars were used for bacteriological analysis and brown glass jars were used for analysis of chlorophyll-a and blue green algal (BGA) content. Samples were placed upon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

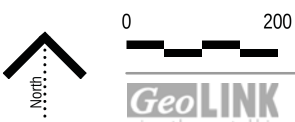
2.2.3 Adaptive Management WQ Sampling

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.

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: RE Reviewed by: DSA Date: 14/09/2017
Source of base data: Richmond Valley Council





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Location of Water Quality Sites

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Illustration 2.1

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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 (ASM) 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. For this reporting period they were:

- 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 Rainfall

Rainfall, or lack thereof, is a key factor influencing water quality in Salty Lagoon and Salty Creek. Monthly rainfall conditions for the reporting period are displayed in **Figure 2.1**. Daily rainfall for the reporting period is displayed in **Figure 2.2** and **Figure 2.3**. The monitoring period was characterised by particularly dry weather in the period between September 2016 and January 2017, and very wet periods in June 2016, August 2016, March 2017 and June 2017. It is worth noting that wet weather in August and June is uncharacteristic for this part of Australia.

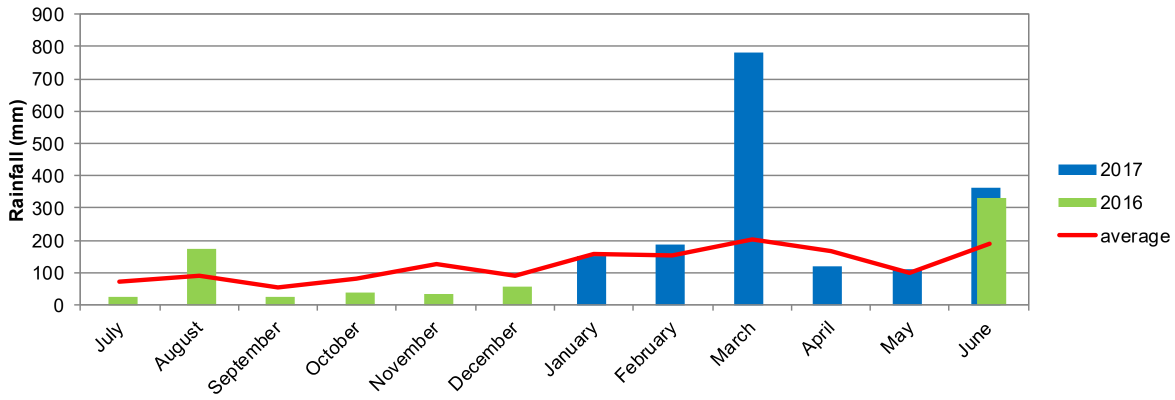

Figure 2.1 Monthly rainfall at the Evans Head BOM weather station for the reporting period displayed against average monthly rainfall (BOM 2017)

2.3.2 Permanent Water Quality Monitoring Stations

2.3.2.1 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;
- A series of gaps in the Salty Lagoon PWQMS dataset resulting from data loss; or
- Gaps where erroneous data, occurring as a result of faulty water quality probes, have been highlighted within the dataset.

Over the monitoring period from 1 June 2016 to 30 June 2017 there were 3285 (8.7%) missed data points from the Salty Lagoon PWQMS and 665 (1.8%) from the Salty Creek PWQMS. An extra 637 pH and turbidity data points were lost from the Salty Lagoon PWQMS due to a mistake in the probe deployment. Most of the missed data points from Salty Lagoon occurred in between late July and early October 2017, probably due to poor battery performance. Additional gaps in the turbidity results collected at the Salty Lagoon PWQMS occurred due to poor probe performance.

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

2.3.2.2 Key Points Arising from the Salty Lagoon Data Set

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

Water Level

Salty Lagoon remained full for most of the reporting period but low water levels were recorded around January 2017. As a result, water moved from Salty Lagoon into Salty Creek for most of the reporting period. The exception to this was in late February 2017 when water levels in Salty Creek rose rapidly in response to rainfall and saline water, stored in Salty Creek, moved upstream into Salty Lagoon. The water levels in Salty Lagoon was so low from January to March 2017 that there was no water to sample at site S4 for those 3 months and no water to sample at S2 in February 2017. The water level chart in **Figure 2.2** indicates that:

- Freshwater input from Evans Head STP does not maintain water levels in Salty Lagoon. Evaporation, groundwater drawdown and runoff into Salty Creek have a greater cumulative impact on water levels in Salty Lagoon.
- The maximum water level reached in Salty Lagoon for the reporting period was 2.34 mAHD.

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 saline water inflow from Salty Creek. Evaporation causes a gradual increase in conductivity measurements. Rainfall has the opposite effect but typically operates over shorter timeframes. Saline water inflow from Salty Creek has occurred in previous annual reporting periods and occurs when saline water trapped in Salty Creek by a high entrance berm flows into Salty Lagoon after rainfall. The water level in Salty Creek tends to respond to rainfall faster than the water level in

Salty Lagoon. Small and short term variations in the conductivity measured at the Salty Lagoon PWQMS also often result from changes in the intensity of wind and flow driven mixing of the water column. This is most apparent when water levels are low. Overall conductivity was relatively stable throughout the reporting period with the exception of the three-week period following saline water ingress in late February 2017.

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, seasonal variation relating to water temperatures and medium term fluctuations in response to rapid changes in the water quality, such as heavy rainfall runoff. 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 exchanges through diffusion. For this reason, DO concentrations tend to be higher in surface waters.
- Microalgal concentrations: Microalgae produce oxygen during the day through photosynthesis and consume it at night through respiration. Nutrient availability has an impact on DO concentrations indirectly through supporting microagal concentrations.
- Light availability: This influences the photosynthetic activity of microalgae throughout the water column and attached to the benthos. Turbidity, therefore, is a key regulator of DO concentrations.
- 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.
- Salinity: The mechanism is not certain but there have been sharp reductions in DO concentration associated with saline water ingress in previous years.

Although it is not apparent from the logged data, the water column in Salty Lagoon can be 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 2016 and 30 June 2016 are reported in **Section 2.3.3**.

During this reporting period the DO concentration measured at the Salty Lagoon PWQMS dropped below 1 mg/L on a large number of occasions. In the current reporting period the DO concentration was 6 mg/L or less on approximately 64% of occasions and 1 mg/L or less on approximately 23% of occasions. This is a notable increase in these statistics relative to the previous reporting period but similar to previous reporting periods. A significant number of the occasions where the Salty Lagoon PWQMS returned a DO concentration of less than 1 mg/L were during periods when the DO probe was malfunctioning (**Figure 2.2** Data from the Salty Lagoon PWQMS for the current reporting period).

pH

The pH measurements at the Salty Lagoon PWQMS varied mainly in response to rainfall conditions during this reporting period. The pH in Salty Lagoon drops sharply in response to heavy rainfall, when low pH water is washed out of the wetlands in the catchment. During dry times the pH measured at the Salty Lagoon PWQMS increases, in response to an unknown buffering agent. 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. There are also small daily fluctuations in pH associated with other diurnal changes in water quality such as dissolved oxygen concentration.

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 daily temperature variation. When water levels are low, temperature variation tends to be greater. This can have a large impact on the overall ecology of Salty Lagoon, particularly during hot, dry summers. 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 fluctuate in response to various other factors such as wind driven sediment suspension and microalgal growth. During the current monitoring period turbidity measurements were relatively stable. 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.

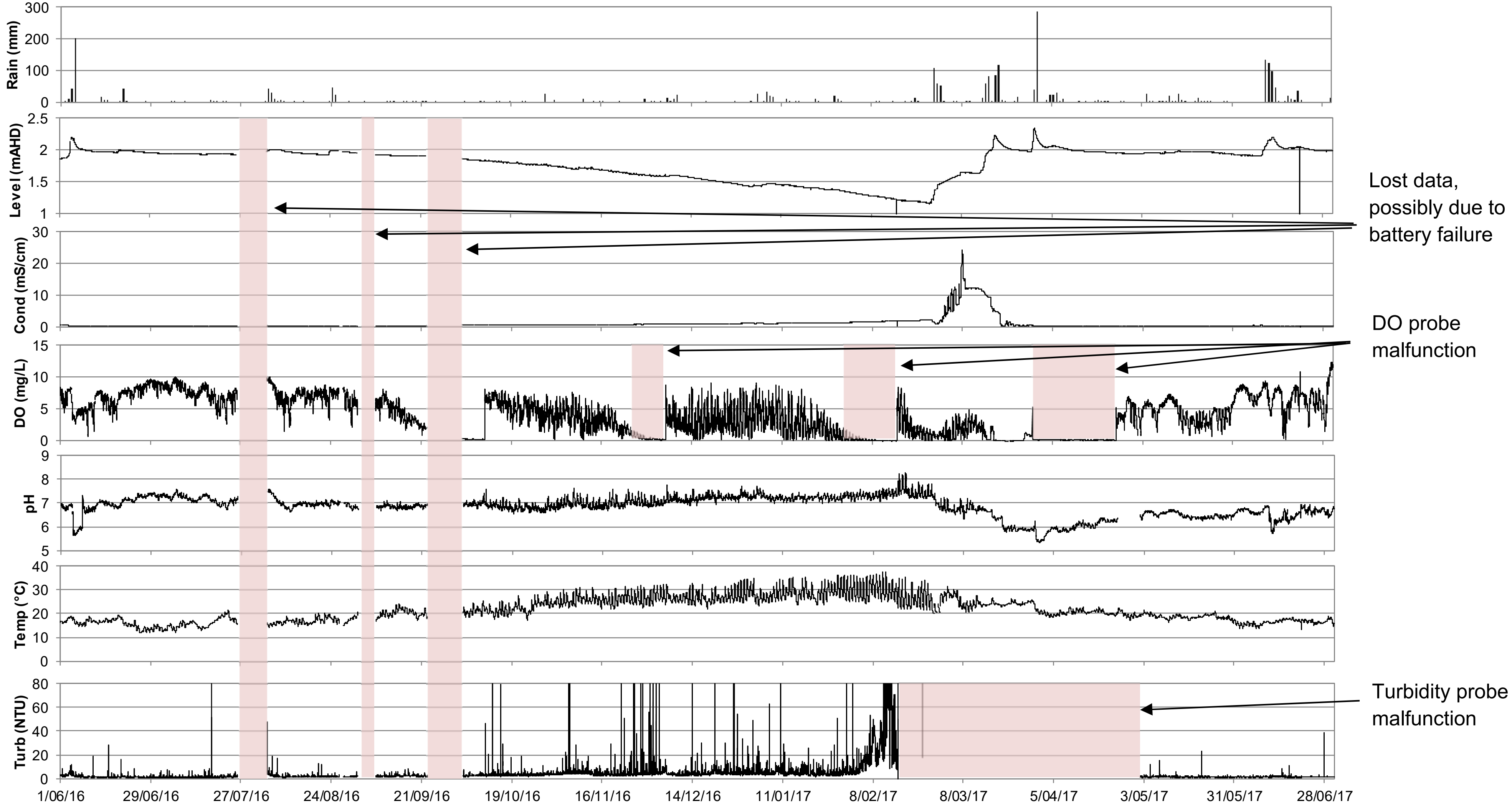

Figure 2.2 Data from the Salty Lagoon PWQMS for the current reporting period

2.3.2.3 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 2.3**.

Water Level

The most important factor affecting the water level in Salty Creek is the status of its entrance. The entrance to Salty Creek opened 6 times in the current reporting period, compared with 9 times in the previous reporting period and 17 times, 2 times, 5 times and 17 times respectively in the four reporting periods before that. Between October and March the entrance to Salty Lagoon was closed. The level of Salty Creek increased sharply on a number of occasions during the reporting period as a result of seawater ingress during large swell and storm surge conditions, and also in response to very heavy rainfall events.

Conductivity

The conductivity measurements from the Salty Creek PWQMS fluctuated widely in response to the dynamic state of the entrance and several heavy and very heavy rainfall events during this reporting period. The dataset indicates varying influences of heavy rainfall, tidal movements and seawater ingress. 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 these fluctuations tend to be weak and are most pronounced when freshwater dominates.
- 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 68% of the reporting period and 1mg/L or less for approximately 16% of the reporting period. These figures are slightly better than comparable figures reported in previous years.

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 heavy rainfall. This contrasts strongly with the pH after seawater ingress which can have the effect of increasing the pH measurements to over pH 7. The pH in Salty Creek thus tends to be either quite high or very low, depending upon the dominant source of water.

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.

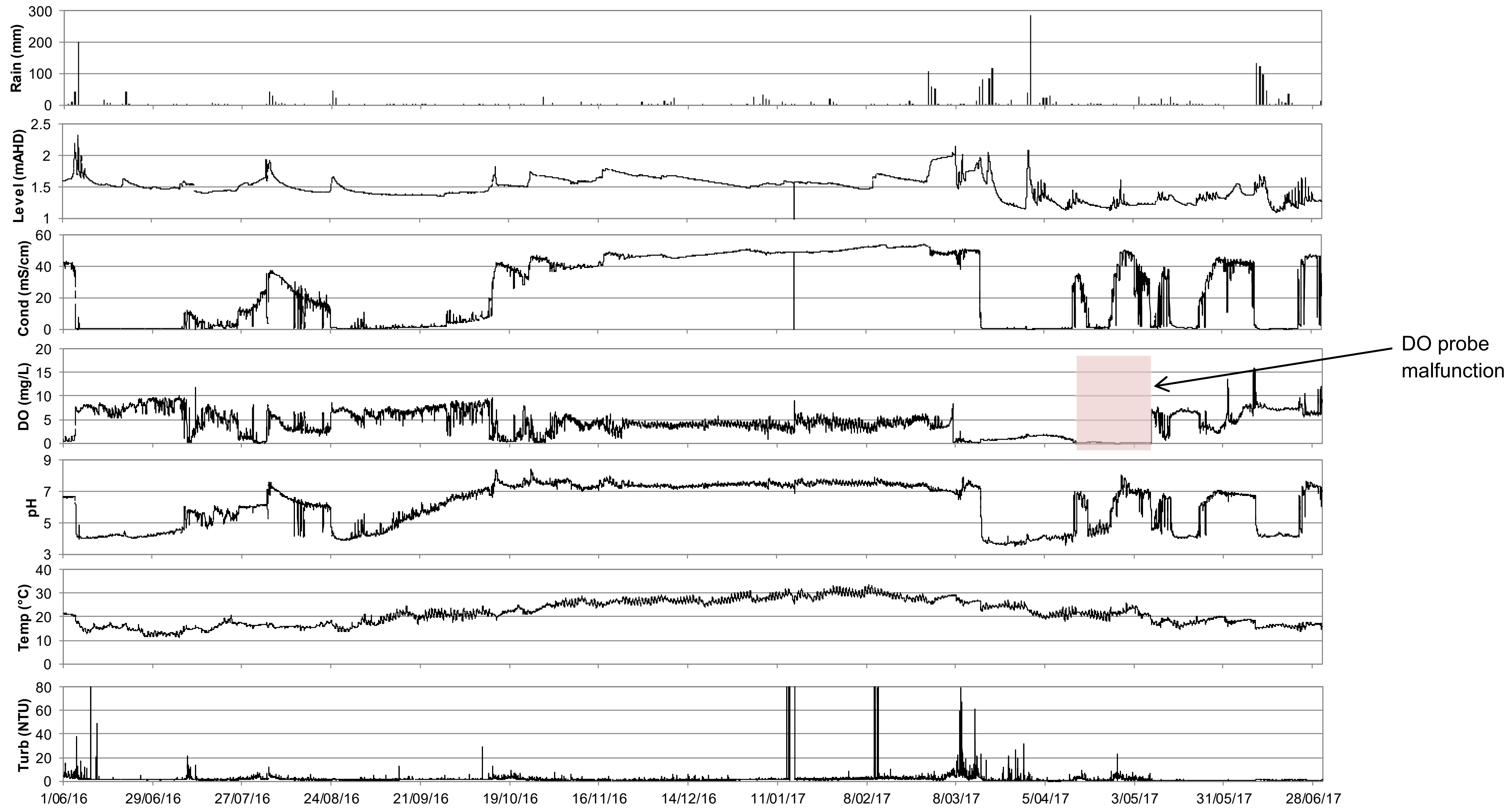

Figure 2.3 Data from the Salty Creek PWQMS for the current reporting period

2.3.3 Discrete Water Quality Samples

This section describes the results of discrete water quality samples collected during normal monthly water quality monitoring. 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 2.3.3.1** to **Section 2.3.3.5**.

Table 2.4 Median Results of Discrete Samples from Surface Waters at all Sites Between 1 June 2016 and 30 June 2017

Indicator	*Site*				
	S1	*S2*	*S3*	*S4*	*S5*
Nitrite nitrogen (mg/L)	0.00	0.00	0.00	0.00	0.00
Nitrate nitrogen (mg/L)	0.00	0.00	0.00	0.00	0.00
Oxidized nitrogen (mg/L)	0.00	0.00	0.00	0.00	0.00
Ammonia nitrogen (mg/L)	0.00	0.00	0.00	0.00	0.00
Total kjeldahl nitrogen (mg/L)	1.38	1.12	1.40	1.41	1.10
Total nitrogen (mg/L)	1.40	1.12	1.43	1.41	1.10
Total phosphorus (mg/L)	0.09	**0.13**	0.10	0.07	0.00
Orthophosphate (mg/L)	0.04	0.08	0.03	0.03	0.00
Chlorophyll-a (µg/L)	**5.00**	3.00	**10.00**	1.50	2.00
Enterococcus (CFU/100mL)	16.00	51.00	10.00	10.00	5.00
Faecal coliforms (CFU/100mL)	40.00	25.00	28.00	2.00	85.00
Blue green algae (cells/L)	0.00	0.00	0.00	0.00	0.00
Temp (˚C)	20.99	18.52	20.89	17.72	20.6
pH	6.67	6.17	6.64	5.25	4.89
ORP (mV)	180	184.5	192	215.5	230
Cond (mS/cm)	0.37	0.36	0.37	0.36	1.13
Turbidity (NTU)	2.20	1.20	2.60	0.80	0.60
DO (mg/L)	7.52	**2.09**	8.30	**2.12**	6.48
DO (% sat)	84.40	22.35	87.90	23.25	72.20
TDS (ppt)	0.24	0.23	0.24	0.24	0.72
Salinity (ppt)	0.20	0.20	0.20	0.20	0.60

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

2.3.3.1 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, evaporative distillation and rainfall runoff. Current 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 (the site closest to the STP) are often lower than those measured further downstream.

During the current reporting period the concentrations of TN were relatively stable with the exception of the driest period between October 2016 and February 2017 (**Figure 2.4**). The highest TN concentrations were measured at sites S2 and S4 shortly before those sites dried out altogether, indicating that evaporative distillation was the key cause of those results. At sites S1 and S3 the highest TN concentrations were also recorded during the lowest water levels, again resulting from evaporative distillation. The differences between the individual sites appear to have been less prominent during this reporting period, particularly when water levels were most stable. In general, TN concentrations reduced after heavy rainfall and increased during extended dry periods. This indicates that nitrogen stored in the sediment in Salty Lagoon is the major source of nitrogen in the system, not rainfall runoff or the release of treated effluent upstream. If this is the case, TN concentrations should reduce over coming years as nitrogen is lost to the system in runoff.

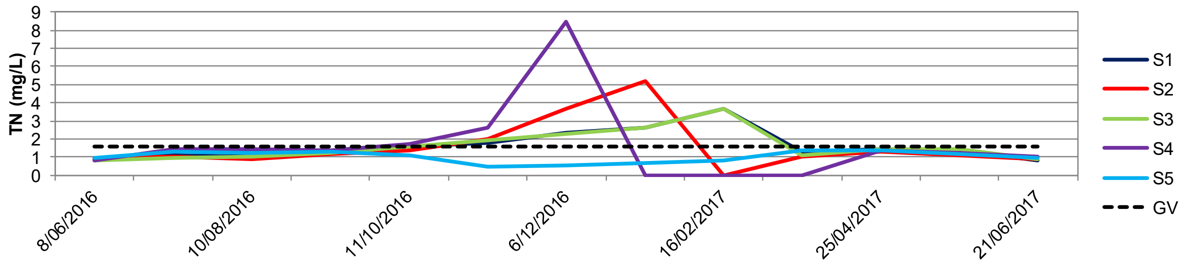

Figure 2.4 Time series of TN concentrations at all sites for the current reporting period

Aside from infrequent spikes in the concentration of nitrite, nitrate and ammonia, overall DIN concentrations remained low at all sites throughout the reporting period (**Figure 2.5**, **Figure 2.6** and **Figure 2.7**). There was no obvious trend notable in the variation observed.

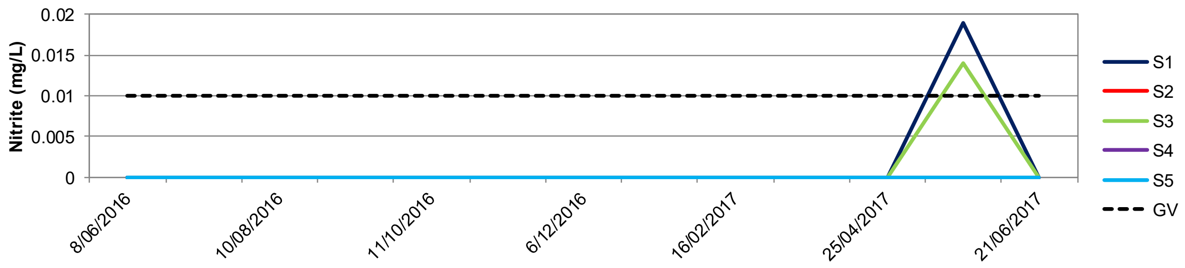

Figure 2.5 Time series of Nitrite concentrations at all sites for the current reporting period

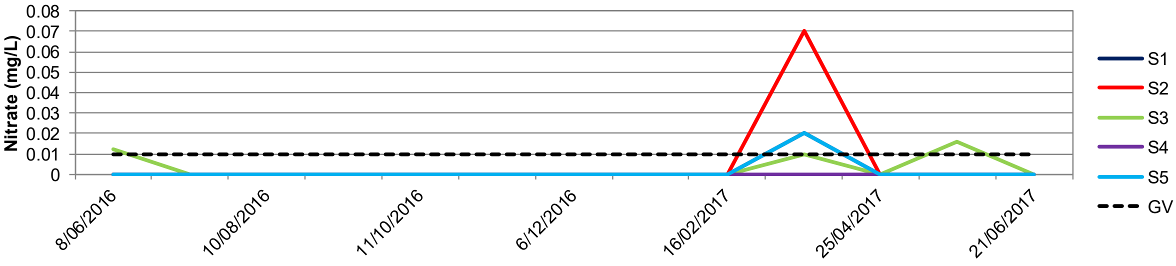

Figure 2.6 Time series of Nitrate concentrations at all sites for the current reporting period

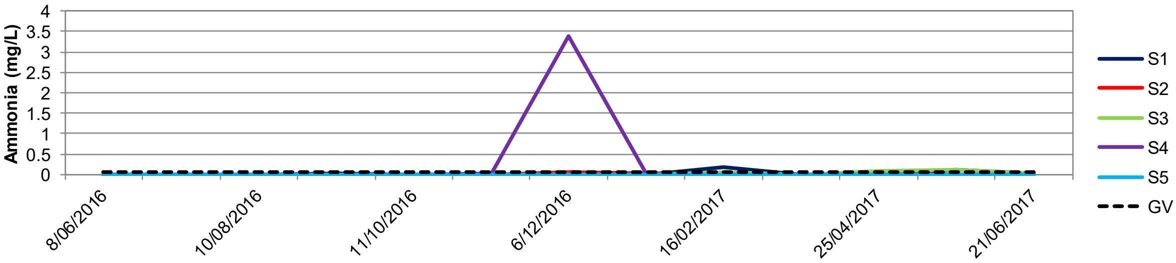

Figure 2.7 Time series of Ammonia concentrations at all sites for the current reporting period

2.3.3.2 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 variety of 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 2.8** and **Figure 2.9**). However, the data does allow for some general observations:

- Site S2 is the site most influenced by historical and current discharged effluent from the Evans Head STP and is most often the site with the highest phosphorus concentration.
- The highest measured concentrations of phosphorus occurred at sites S2 and S4 shortly before these sites dried out completely, indicating that evaporative distillation has an impact on phosphorus concentrations.
- The lowest measured concentrations of phosphorus occurred immediately following heavy rainfall events.
- Aside from the periods immediately prior to sites drying out TN and TP concentrations appear to have varied independently during this reporting period. This indicates that the processing of nitrogen and phosphorus in Salty Lagoon also occurs independently.

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. However, the relationship between available phosphorus and algal concentrations is cryptic.

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

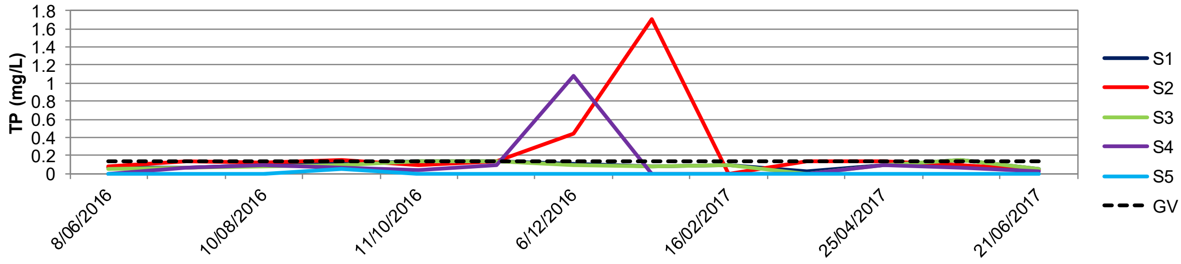

Figure 2.8 Time series of TP concentrations at all sites for the current reporting period

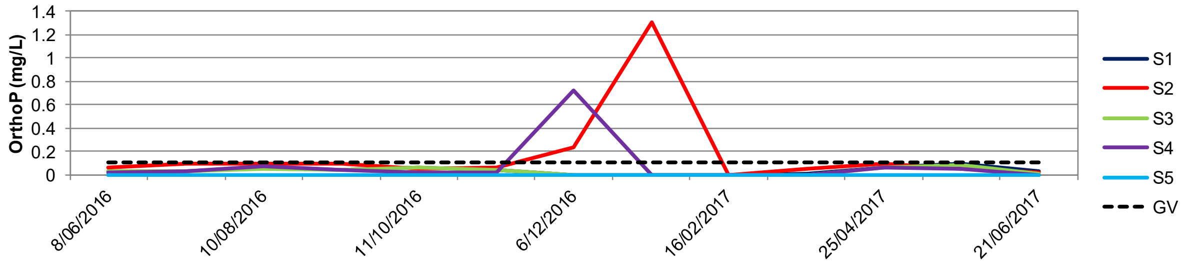

Figure 2.9 Time series of orthophosphate concentrations at all sites for current reporting period

2.3.3.3 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 in Salty Lagoon did not comply with guiding values for a large part of the reporting period (refer to **Figure 2.10**). Most of the results indicated an algal bloom of small to moderate proportions with the exception of samples collected in December 2016 and February 2017, which indicated algal blooms of moderate to large proportions.

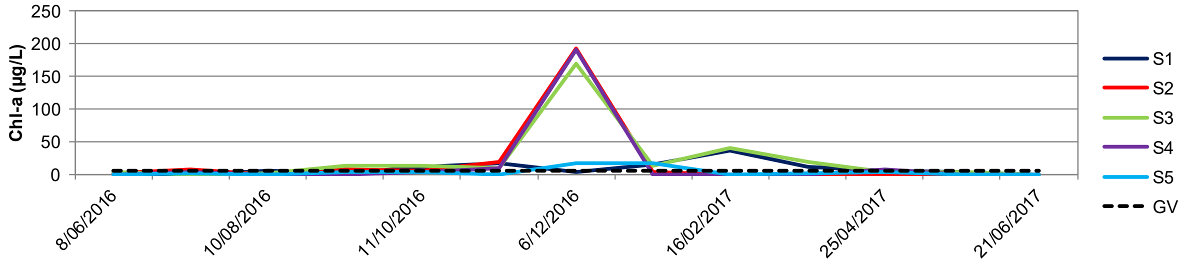

Figure 2.10 Time series of chlorophyll-a concentrations at all sites for the current reporting period

The highest chlorophyll-a concentrations measured were associated with increased nutrient concentrations or bioavailable nutrient concentrations (DIN and orthophosphate). At all of the Salty Lagoon sites there was some correlation between TN concentrations and chlorophyll-a concentrations. At S2 and S4 there was also some correlation between TP concentrations and chlorophyll-a concentrations.

There has been a slight trend towards increasing chlorophyll-a concentrations over the course of the MPPC project. It is possible that the more stable freshwater conditions are contributing to a stabilisation of the microalgal population in the water column and, subsequently, more dynamic microalgal population shifts in response to environmental conditions.

2.3.3.4 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 this reporting period.

2.3.3.5 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 remained low at all sites during the reporting period (refer to **Figure 2.11** and **Figure 2.12**).

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 influencing the concentrations of faecal indicator organisms. Faecal coliform concentrations in discharge from the Evans Head STP are routinely lower than those measured in Salty Lagoon (**Figure 2.14**)

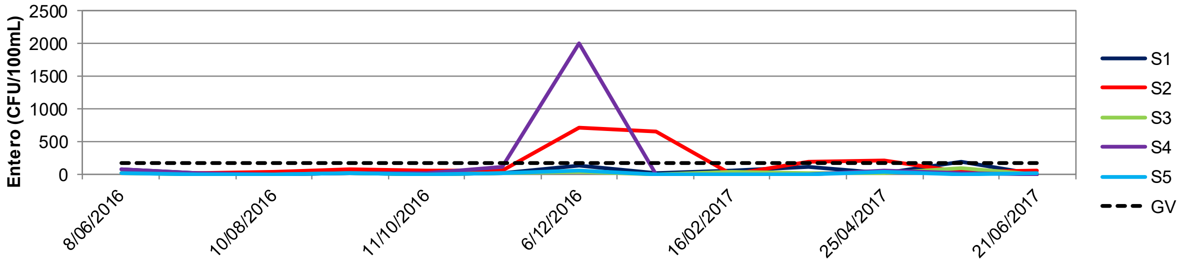

Figure 2.11 Time series of enterococcus concentrations at all sites for the current reporting period

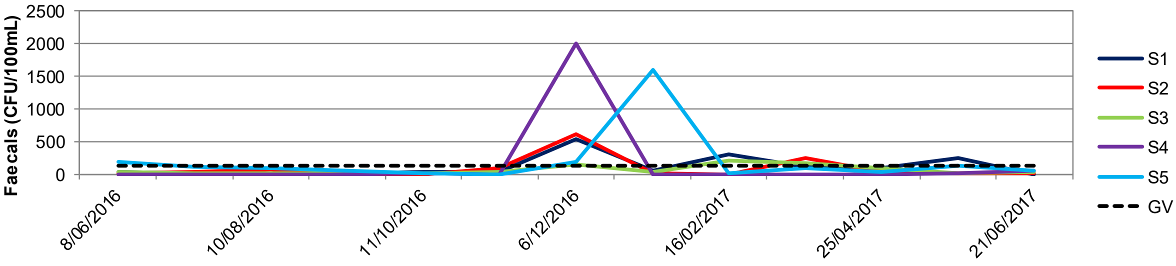

Figure 2.12 Time series of faecal coliform concentrations at all sites for current reporting period

2.3.4 STP Discharge Monitoring

As part of licensing conditions, the Evans Head STP is required to monitor discharge quality on a fortnightly basis. A suite of effluent quality parameters is 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 2.13**, **Figure 2.14**, **Figure 2.15** and **Figure 2.16**.

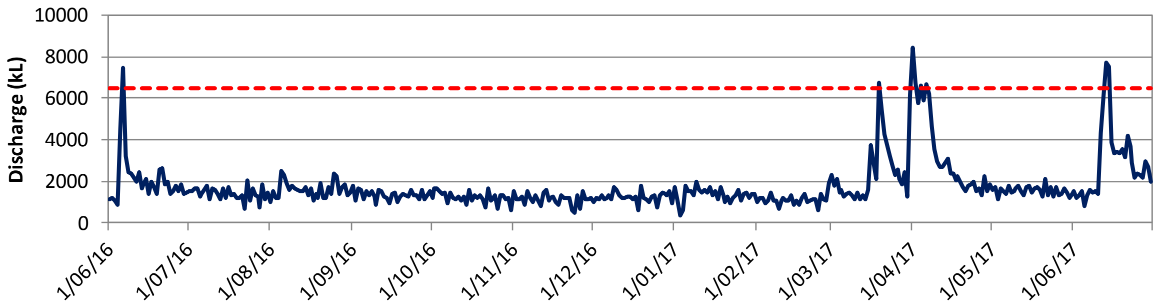

Figure 2.13 Time series of daily discharge volumes from the Evans Head STP (maximum allowed discharge volume in red)

The daily discharge volumes from the Evans Head STP exceeded the licensing limits set by the EPA on 8 occasions during this reporting period. All of the exceedances were associated with heavy rainfall events.

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. In effect, the Evans Head STP discharge is not enough to maintain water levels and water losses to evaporation and groundwater are larger than the input from the STP.

In general, faecal coliform concentrations in discharged effluent are very low and they complied with the licensing limits on all occasions during this reporting period. The measured concentrations of faecal coliforms in the discharged effluent are typically lower than those measured in samples collected from Salty Lagoon as part of the MPPC project. This, in combination with the fact that faecal coliforms do not persist in the environment for a long period of time, indicates that it is highly unlikely that discharged effluent is contributing significantly to faecal coliform measurements in Salty Lagoon.

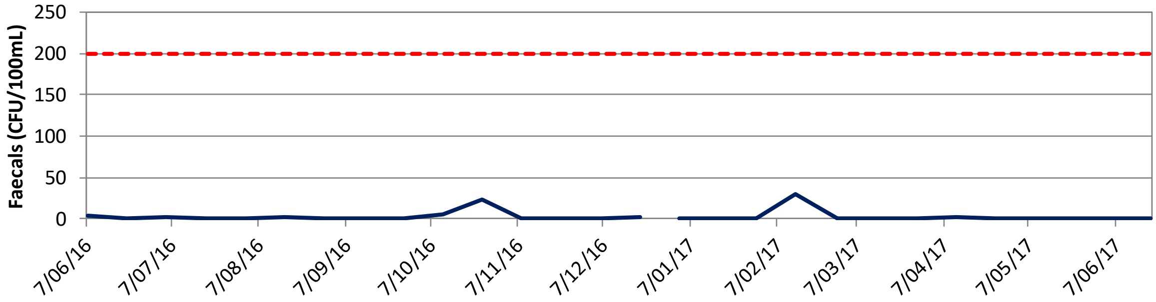

Figure 2.14 Time series of faecal coliform concentrations from the Evans Head STP discharge (90th percentile limit in red)

The TN concentrations in discharged effluent from the Evans Head STP complied with the licensing limits on most occasions through the reporting period, except for one occasion when the 90th percentile limit was exceeded.

The concentrations of TN in discharged effluent are generally two to five 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). It is also likely that dilution with unpolluted water from around the catchment contributes to this effect. It is possible that elevated nitrogen concentrations around Salty Lagoon may be partially maintained in the long term by the input from the Evans Head STP.

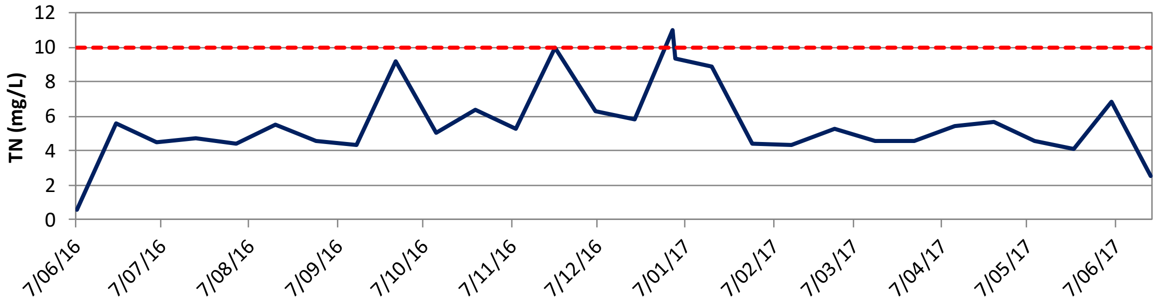

Figure 2.15 Time series of TN concentration from the Evans Head STP discharge (90th percentile limit in red)

The TP concentrations in discharged effluent from the Evans Head STP also complied with the licensing limits on most occasions through the reporting period, except for one occasion when the 90th percentile limit was exceeded.

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.

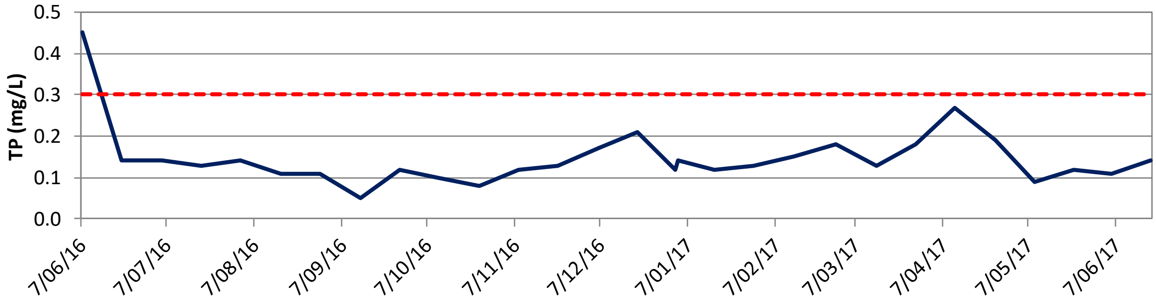

Figure 2.16 Time series of TP concentration from the Evans Head STP discharge (90th percentile limit in red)

2.3.5 Emerging Trends and Issues

The erosive headcut to the east of the old artificial channel continues to present a threat to the project. Ongoing monitoring has observed continued advancement of the headcut, at a rate increased in relation to the previous reporting period. 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. Remediation plans are currently being designed.

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**.

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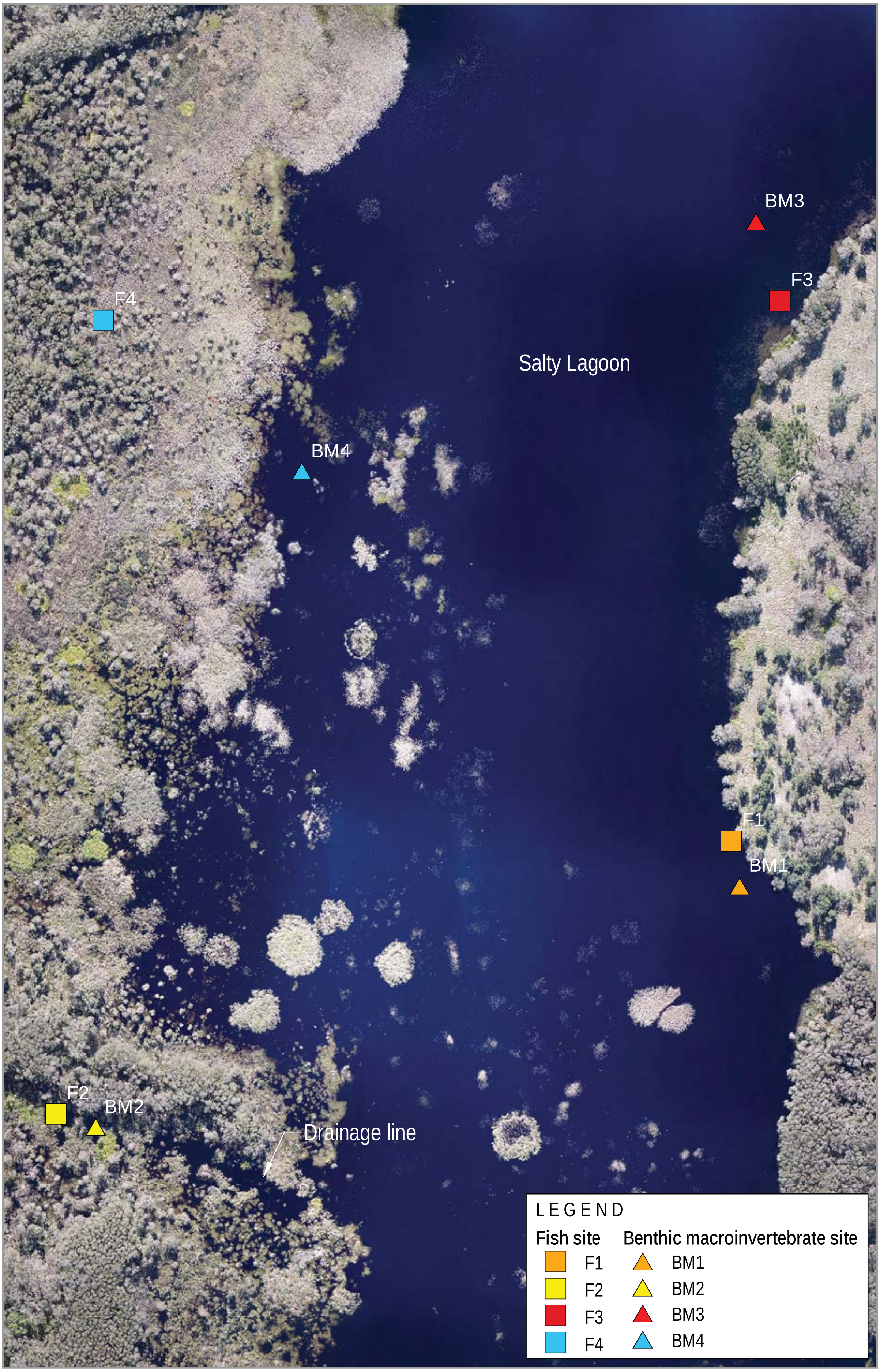
Source of base data: Richmond Valley Council

Information shown is for illustrative purposes only



Location of Benthic Macroinvertebrate and Fish Sites

GeoLINK environmental management and design

Annual Report 2017 - Salty Lagoon Monitoring Program:
Pre/Post Closure of Artificial Channel

Illustration 3.1

1731-1270

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 with the exception of the summer 2017 survey, which was characterised by saline water inflow from Salty Creek and lower water levels.	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 with the exception of the summer 2017 survey, when water levels were lower. The quality of the freshwater changes at this site in response to rainfall. When effluent discharge dominates freshwater inflow when 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 with the exception of the summer 2017 survey, which was characterised by saline water inflow from Salty Creek and lower water levels. The nearest vegetation consists of Saltwater Couch and Bacopa (*Bacopa monnieri*), which is reducing in its nearby extent. Water Snowflake (*Nymphoides indica*) has increased in its extent nearby during this reporting period.	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.	0541738	6783005

3.2.3 Sample Collection

Benthic macroinvertebrates were sampled once per season. The dates of benthic macroinvertebrate collection were 12 July 2016, 11 October 2016, 16 January 2017 and 8 May 2017. 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.

3.2.4 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 the previous reporting period the conditions at the time of sampling were diverse 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 also relatively variable between surveys with a difference of 0.52 m between the highest and lowest levels at the time of sampling. Water temperature, conductivity and nutrient concentrations also varied within sites and between sampling times.

The dry weather prior to the summer 2017 survey was a major source of variation in the conditions at the time of sampling. The dry weather led to higher nutrient (particularly total nitrogen) concentrations at most sites, higher pH and higher conductivity measurements and significantly lower water levels. There was no water at site BM4 at the time of the summer 2017 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 2016	12/07/2016	1.93	**16.52**	6.67	**0.29**	**1.09**	**0.07**
	Spring 2016	11/10/2016	1.83	20.99	**6.53**	0.46	1.55	0.14
	Summer 2017	16/01/2017	**1.42**	**26.99**	**7.60**	**1.13**	**2.65**	0.08
	Autumn 2017	8/05/2017	**1.94**	18.73	6.67	0.36	1.40	0.15
BM2	Winter 2016	12/07/2016	1.93	**14.45**	6.22	0.34	**1.01**	0.13
	Spring 2016	11/10/2016	1.83	19.53	6.16	0.42	1.36	0.10
	Summer 2017	16/01/2017	**1.42**	**27.13**	**8.20**	**1.25**	**5.16**	**1.71**
	Autumn 2017	8/05/2017	**1.94**	16.68	**5.77**	**0.29**	1.09	**0.09**
BM3	Winter 2016	12/07/2016	1.93	**16.49**	6.80	**0.30**	**0.98**	**0.07**
	Spring 2016	11/10/2016	1.83	21.02	6.61	0.46	1.61	0.14
	Summer 2017	16/01/2017	**1.42**	**26.85**	**7.71**	**1.11**	**2.60**	0.08
	Autumn 2017	8/05/2017	**1.94**	19.02	**6.43**	0.36	1.43	**0.15**
BM4	Winter 2016	12/07/2016	1.93	**14.38**	**5.25**	**0.36**	1.43	0.06
	Spring 2016	11/10/2016	1.83	**19.05**	5.06	**0.58**	**1.69**	**0.04**
	Summer 2017	16/01/2017	**1.42**	-	-	-	-	-
	Autumn 2017	8/05/2017	**1.94**	17.12	**4.92**	**0.36**	**1.26**	**0.07**

Notes: 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 26 macroinvertebrate taxa have been identified from samples collected to date. Of the 26 taxa identified, seven have only been observed in one of the 25 seasonal surveys undertaken. Only 14 of the 26 taxa were collected during the five surveys prior to channel closure. Twenty-three taxa have been collected in the 20 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 26 taxa collected (*Capitellidae*) to date has been observed in each of the 25 surveys. One of the taxa has been collected in 24 of the 25 surveys (*Chironominae*) and two in 18 of the 25 surveys (*Hydrobiidae* and *Ceratopogonidae*).

The most common taxa captured during the current reporting period were the *Chironominae, Leptoceridae* and *Ceratopogonidae*. In the previous two reporting periods respectively they were *Chironominae, Leptoceridae* and *Tanypodinae*, and then *Chironominae, Hydrobiidae* and *Capitellidae* (**Table 3.4** and **Table 3.5**). In the first annual reporting period (prior to channel closure) 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
Winter 2015	9	283
Spring 2015	9	84
Summer 2016	8	133
Autumn 2016	7	192
Winter 2016	10	425
Spring 2016	12	451

Survey	Number Taxa	Number of Individuals
Summer 2017	13	564
Autumn 2017	7	168

Table 3.4 Annual Totals of Benthic Macroinvertebrate Taxa at BM1 and BM2

Taxa	Common Name	BM1						BM2					
		2012	2013	2014	2015	2016	2017	2012	2013	2014	2015	2016	2017
Chironominae	Non biting midge	19	7	318	13	37	257	98	137	43	51	156	650
Tanypodinae	Non biting midge	0	0	0	3	16	10	0	0	0	0	2	2
Ceratopogonidae	Biting midge	10	1	0	2	0	3	0	2	2	0	3	4
Chaoboridae	Phantom midges	0	0	0	0	0	0	0	0	0	0	0	0
Sialidae	Alderfly	0	0	0	0	0	0	0	0	0	0	0	0
Libellulidae	Dragonfly	0	0	0	0	0	0	5	4	0	0	0	3
Hemiphlebidae	Damselfly	1	0	0	0	0	0	0	0	0	0	0	0
Ecnomidae	A Caddis Fly	0	0	0	0	0	4	0	0	0	0	0	0
Leptoceridae	Stick Caddis	0	0	0	1	27	16	0	0	0	0	2	0
Pyralidae	Aquatic Caterpillar	0	0	0	1	0	0	0	1	0	1	0	0
Hygrobiidae	Screech Beetle	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophiidae	Water Scavenger Beetle	0	0	1	1	0	0	0	0	5	0	0	0
Dytiscidae	Diving Beetle	0	0	0	0	0	0	0	0	1	0	1	4
Belastomatidae	Giant Water Bug	0	0	0	0	0	1	0	0	0	0	0	1
Corixidae	Water Boatmen	0	0	20	2	0	2	0	0	0	0	0	0
Veliidae	Small Water Strider	0	0	0	0	0	0	0	0	0	1	0	0
-	Springtail	2	7	2	1	3	0	1	0	4	2	2	2
Capitellidae	Polychaete	5	2	4	5	2	5	0	0	0	0	0	0
Spionidae	Polychaete	92	8	11	1	0	0	1	0	0	0	0	0
Mytilidae	Mussel	1	85	4	1	0	0	1	0	0	0	0	0
Hydrobiidae	Snail	3	4	31	22	1	0	3	20	0	0	0	0
Planorbidae	Snail	0	0	0	0	0	0	0	1	0	1	2	10
Sphaeromatidae	Isopod	0	4	5	0	0	0	3	1	0	0	0	0

Taxa	*Common Name*	*BM1*						*BM2*					
		2012	*2013*	*2014*	*2015*	*2016*	*2017*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
Hymenosomatidae	-	0	0	0	0	0	0	0	0	0	0	0	0
-	Copepod	0	0	0	0	0	0	0	0	0	0	0	0
-	Cladoceran	0	0	0	0	3	5	0	0	0	0	0	0
Total animals		**133**	**118**	**396**	**53**	**86**	**303**	**112**	**166**	**55**	**56**	**168**	**676**
Total taxa		**8**	**8**	**9**	**12**	**7**	**9**	**7**	**7**	**5**	**5**	**7**	**8**

Table 3.5 Annual Totals of Benthic Macroinvertebrate Taxa at BM3 and BM4

Taxa	*Common Name*	*BM3*						*BM4*					
		2012	*2013*	*2014*	*2015*	*2016*	*2017*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
Chironominae	Non biting midge	23	23	197	38	82	423	2	3	12	28	276	99
Tanypodinae	Non biting midge	0	0	0	0	4	10	2	1	3	0	5	4
Ceratopogonidae	Biting midge	0	1	1	1	2	13	3	0	0	0	8	15
Chaoboridae	Phantom midges	0	0	0	0	0	0	0	0	0	1	0	0
Sialidae	Alderfly	0	0	0	0	0	0	1	0	0	0	0	0
Libellulidae	Dragonfly	0	0	0	0	0	1	2	0	1	0	0	2
Hemiphlebidae	Damselfly	0	0	0	0	0	2	0	0	0	0	0	0
Ecnomidae	A Caddis Fly	0	0	0	0	1	1	0	0	0	0	0	8
Leptoceridae	Stick Caddis	0	0	0	5	23	29	0	0	0	1	0	2
Pyralidae	Aquatic Caterpillar	0	0	0	0	0	0	0	0	0	0	0	0
Hygrobiidae	Screech Beetle	0	0	0	0	0	0	1	0	0	0	0	0
Hydrophiidae	Water Scavenger Beetle	0	0	0	0	0	1	0	1	1	2	0	4
Dytiscidae	Diving Beetle	0	0	0	0	0	0	0	1	0	0	0	0
Corixidae	Water Boatmen	0	0	40	1	0	0	0	0	4	2	11	0
Veliidae	Small Water Strider	0	0	0	0	0	2	0	0	0	0	0	1

Taxa	*Common Name*	*BM3*						*BM4*					
		2012	*2013*	*2014*	*2015*	*2016*	*2017*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
-	Springtail	1	1	0	0	1	0	0	3	3	3	3	0
Capitellidae	Polychaete	42	14	17	25	7	0	0	0	0	0	0	1
Spionidae	Polychaete	11	91	26	1	0	5	2	0	0	0	0	0
Mytilidae	Mussel	3	172	56	2	0	3	0	0	0	0	0	0
Hydrobiidae	Snail	0	6	66	58	14	1	54	1	5	0	0	0
Planorbidae	Snail	0	0	0	2	0	0	0	0	4	1	1	0
Sphaeromatidae	Isopod	1	5	16	2	0	0	9	3	0	0	0	1
Hymenosomatidae	-	1	0	0	0	0	0	0	0	0	0	0	0
-	Copepod	0	0	0	0	1	0	0	0	0	0	0	0
-	Cladoceran	0	0	0	0	0	0	0	0	0	0	0	0
Total animals		**82**	**313**	**419**	**135**	**134**	**492**	**76**	**13**	**33**	**38**	**304**	**137**
Total taxa		**7**	**8**	**8**	**10**	**9**	**13**	**9**	**7**	**8**	**7**	**6**	**10**

The diversity of taxa in macroinvertebrate samples has 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. The number of macroinvertebrate taxa at all sites in all surveys since the beginning of the MPPC are represented in **Figure 3.1**. There does appear to be a slight increase in the overall diversity at each of the sites since the beginning of the MPPC.

One taxa, Giant Water Bugs (family: *Belastomatidae*), were observed for the first time since the beginning of the MPPC during this reporting period.

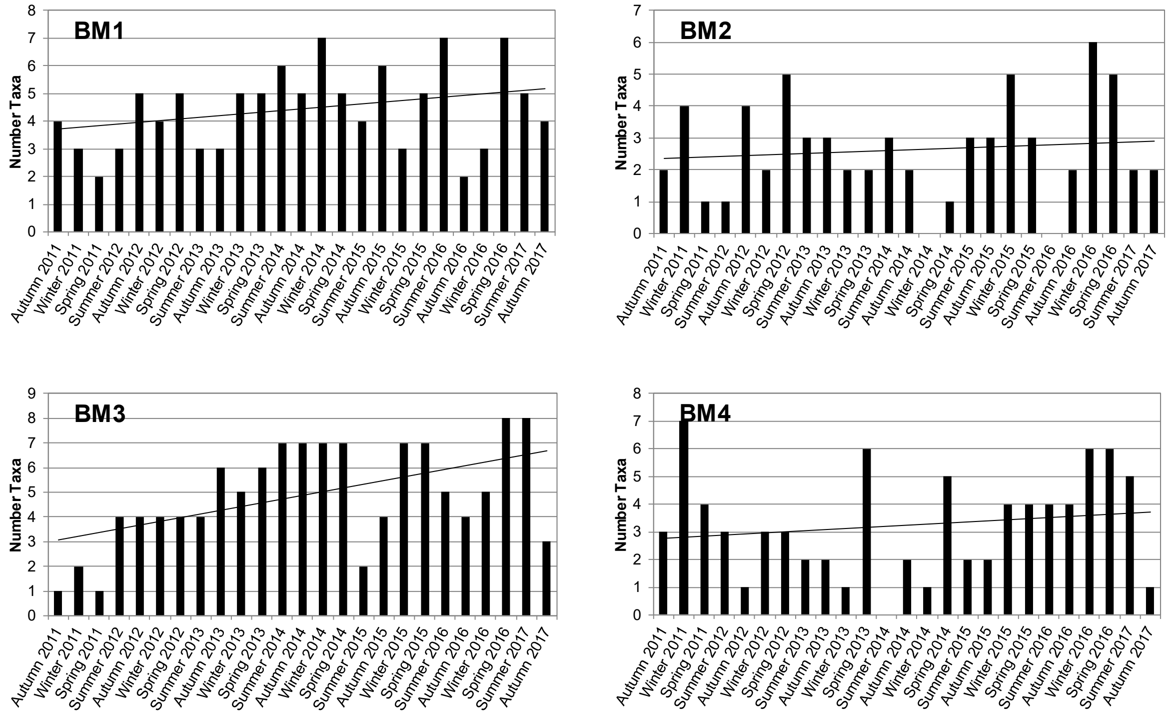


Figure 3.1 Number of macroinvertebrate taxa at all sites in all surveys since the beginning of the MPPC

3.3.3 Abundance

The numbers of benthic macroinvertebrates captured at each site have also varied over time (**Figure 3.2**). However, again there are no clear patterns evident in the data set. While at all four sites there appears to be a general trend towards increasing abundance the majority of observed variation in the total number of individuals is due to spikes in the numbers of different individual 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, autumn 2014 and summer 2017 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 has been 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*. At BM1 there have been stable or increased captures of *Tanypodinae*, *Leptoceridae* and *Chironominae* (all predominantly freshwater taxa) indicating a move towards a more stable freshwater environment.

At BM2 there is a slight increasing trend with respect to macroinvertebrate abundance but variation is very high. The majority of the variation in the total number of individuals is explained by the number of *Chironominae* captured during individual surveys. At this stage of the project the observed variation is not adequately explained by the collected environmental factors. The first collection of animals from the freshwater taxa *Tanypodinae* and *Leptoceridae* are encouraging signs that freshwater taxa are becoming more dominant.

At BM3 there is no apparent pattern to the overall variation of abundance (**Figure 3.2**). 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 *Ecnomidae* and *Leptoceridae* since the closure of the artificial channel.

At BM4 there appears to be an overall trend towards increasing abundance since the beginning of the MPPC (**Figure 3.2**), though the current reporting period was characterised by decreasing macroinvertebrate numbers. There has been a shift in the dominant taxa at BM4, from *Hydrobiidae* to *Chironominae*, since closure of the artificial channel.

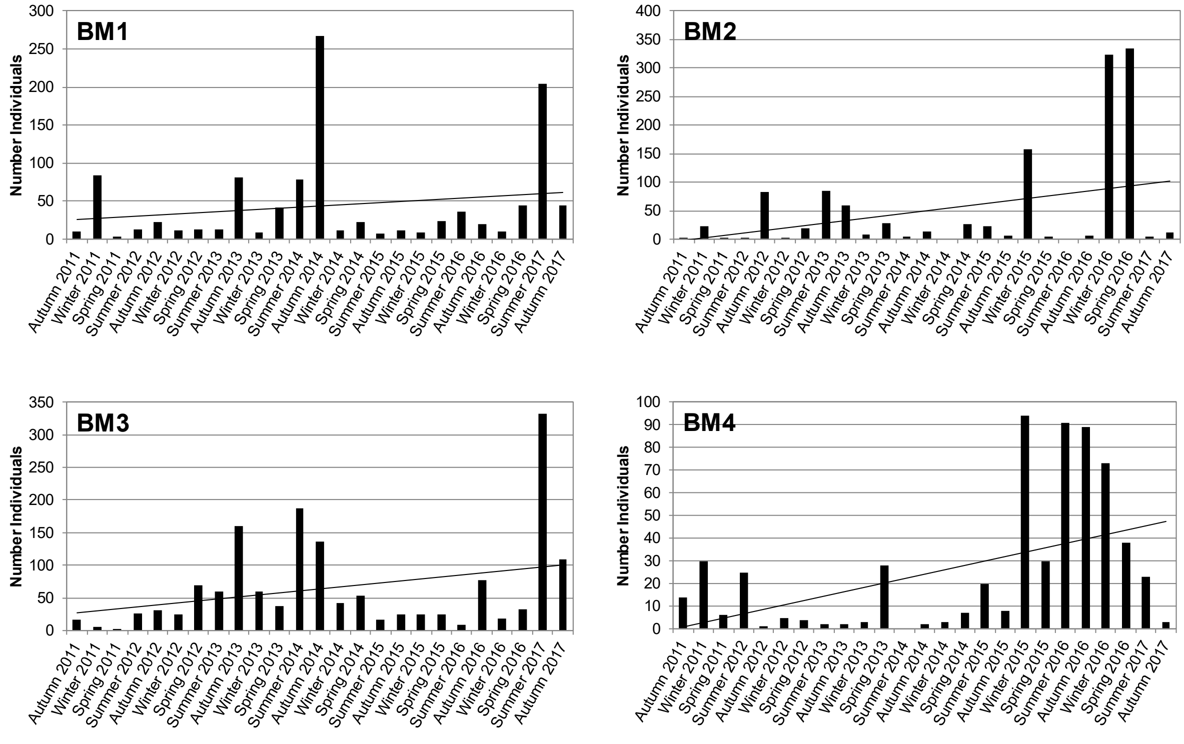


Figure 3.2 Number of macroinvertebrate individuals at all sites in all surveys since the beginning of the MPPC

3.3.4 Conclusions

There has been continued variation in the diversity, abundance and species 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 in Salty Lagoon throughout the MPPC. Most of the variation observed to date has been in the form of short term spikes in the numbers of individual taxa. However, there are some signs that the numbers of individuals and the variety of species being collected are becoming more stable.

There is a strong indication 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. This trend is reflective of a shift from an intermittently open and closed waterbody to a freshwater wetland. The reduction in the numbers of polychaetes collected and increased numbers of chironomids and trichoptera are good indicators of this.

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.

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 11 October 2016, 16 January 2017 and 8 May 2017.

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 are 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 38 plant taxa have now been observed during the aquatic weed surveys since the beginning of the MPPC. Of these, 24 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 only been detected in water samples twice during the MPPC. No BGA were observed during this reporting period. Pacifc Azolla and Duckweed have been encountered at varying densities to the west of Salty Lagoon, particularly around site S2. The abundance of these two plants tends to fluctuate in response to temperature and freshwater flow. They are less likely to be observed growing at high densities during the winter months.

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**.

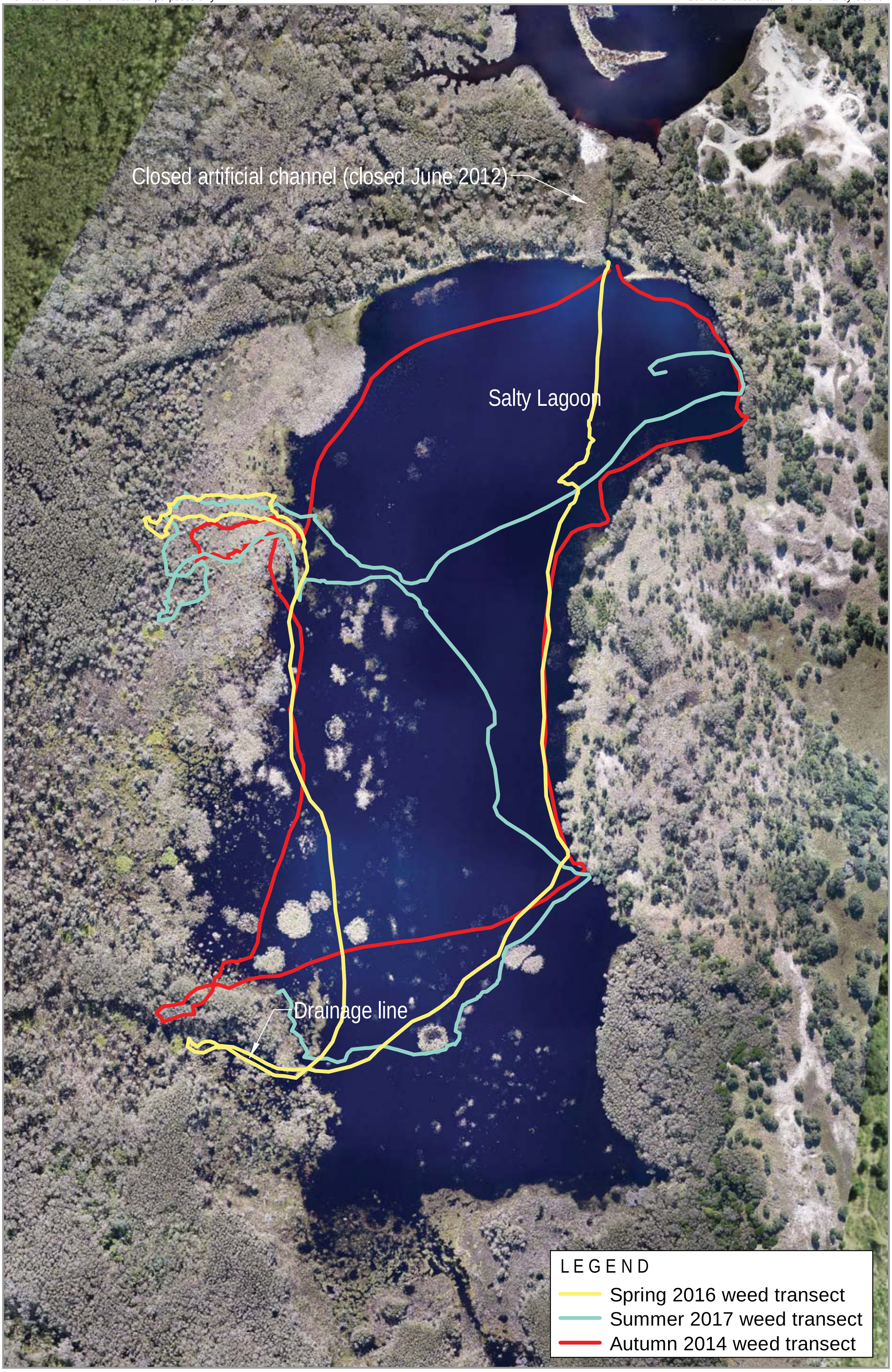
Table 4.1 List of all Aquatic Plant Species Detected During Aquatic Weed Surveys and an Assessment of Abundance

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	Spr '15	Sum '16	Aut '16	Spr '16	Sum '17	Aut '17
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	C	VC	C	C	C	UC
Lomandra sp.	A Mat-rush							UC												
Enydra fluctuans	Buffalo Spinach	UC	UC					UC	C	UC	C	C	C	C	C	C	C	UC	UC	UC
Lobelia anceps	Angled Lobelia	UC		UC											UC			UC	UC	
Ceratophyllum demersum	Hornwort																		UC	
Sarcocornia quinqueflora	Bead Weed	UC	UC																	
Suaeda australis	Seablite	UC																		
Baumea articulata	Jointed Twig-rush		UC				UC	UC	UC				UC				C	C	UC	C
Baumea sp.	A Rush								UC	C	C	C	C	C	VC	VC	VC	C	VC	VC
Baumea sp 2.	A Rush														UC			UC		
Carex appressa	Tall Sedge																		UC	
Cyperus exaltatus	Giant Sedge	UC		UC							C						UC		UC	
Cyperus difformis	Dirty Dora	UC		UC	UC		UC	UC		C	VC		C	UC		C	UC		VC	C
Ficinia nodosa	Noody Club-rush																	UC		
Gahnia sieberiana	Red-fruit Saw-sedge						UC	UC	UC		UC		C	UC	UC	C	UC	C	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	Spr '15	Sum '16	Aut '16	Spr '16	Sum '17	Aut '17
Schoenoplectus validus	River Club-rush	VC	VC	VC	VC	VC	C	C		C	C	VC	C	VC	VC	C	C	VC	VC	C
Schoenoplectiella mucronatus	Marsh Club-rush	VC	VC	UC	UC						C									
Juncus krausii	Sea Rush	VC	VC	VC	VC	VC	VC	C	C	C	UC	C	C	VC	C	C	C	UC	C	
Juncus usitatus	Common Rush						UC		C								UC			
Triglochin sp.	Water Ribbons																UC			
Lemna sp.	Duckweed								UC			C	VC	VC	VC	VC	C	UC	C	UC
Utricularia spp.	Bladderwort													VC	VC		C	C	UC	VC
Nymphoides indica	Water Snowflake												UC	C	UC	C	C	UC	C	UC
*Nymphaea capensis^*	Cape Waterlily											UC	UC	UC						UC
Bacopa monnieri	Water Hyssop	C	VC	C	UC	C	C	UC	C	C	VC	VC	C	VC	UC	VC	VC	UC	VC	UC
Diplachne (Leptochloa) fusca	Brown Beetle Grass										VC									
Paspalum vaginatum	Saltwater Couch	VC	VC	VC	VC	VC	VC	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	VC	VC	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											

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***	***Spr '15***	***Sum '16***	***Aut '16***	***Spr '16***	***Sum '17***	***Aut '17***
Azolla filiculoides	Pacific Azolla											C	VC	VC	VC	VC	C	UC	C	UC
Typha orientalis	Cumbungi		UC	UC		UC	UC	UC	C	C	UC	UC	C	C	VC	C	UC	C	VC	VC
Enteromorpha sp.	Enteromorpha					C	VC		VC				VC		VC	VC			VC	
Various	Blue Green Algae	C	C	C	UC	UC														

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



0 80

North

Aquatic Weed Transects

Illustration 4.1

4.4 Discussion

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.

The continued transition to a stable freshwater ecosystem appears to be resulting in a change to the overall aquatic plant community in Salty Lagoon. There are a variety of freshwater plants that have only been observed in the most recent surveys, including Water Ribbons (*Triglochin sp.),* Water Snowflake (*Nymphoides indica*), Cape Water Lily (*Nymphaea capensis*), Bladderwort (*Utricularia spp.*), Duckweed (*Lemna sp.),* Noddy Club-rush (*Ficinia nodosa*), Hornwort (*Ceratophyllum demersum*) and Tall Sedge (*Carex appressa*). 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 (*Rhizophora stylosa* and *Avicennia marina*), Sea Purslane (*Sesuvium portulacastrum*), Bead Weed (*Sarcocornia quinqueflora*) and Seablite (*Suaeda australis*).

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 Noddy Club-rush was observed in Salty Lagoon for the first time during this reporting period during weed surveys

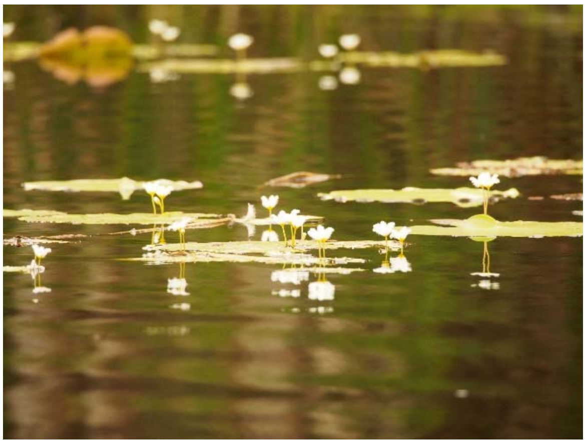


Plate 4.2 Flowers of Water Snowflake (*Nyphoides indica*)

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 at higher levels 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 next two reporting periods were characterised by more stable water levels and water quality conditions. The current reporting period saw one episode of lower water levels resulting from dry conditions between September 2016 and February 2017 in addition to a short period of higher conductivity measurements resulting from salt water flowing into Salty Lagoon from Salty Creek.

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 continued 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 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 more 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, *Baumea sp*. 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 and catchment runoff. Saltwater ingress past this point in the Lagoon has been recorded at times but barely at all since closure of the artificial channel. This site became dry at one point 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 more 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*), *Baumea sp.*, 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 became dry for a period of approximately two months between January and February 2017.

* *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 12 July 2016, 11 October 2016, 16 January 2017 and 8 May 2017. 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 2016	12/07/2016	16.62	0.25	7.46	1.93	0
Spring 2016	11/10/2016	21.05	0.44	6.62	1.83	1.4
Summer 2017	16/02/2016	27.14	1.13	1.33	1.42	1.2
Autumn 2017	8/05/2017	18.87	0.36	5.52	1.94	1.8

Note: Water quality and depth expressed as averages of readings taken at the Salty Lagoon PWQMS over the time of trap deployment.

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 greater than the two previous reporting periods, lower than the five species captured during the annual reporting period before that and lower than 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**. 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 although in the last two reporting periods there have generally been more diverse captures in Spring and Summer than in the other two seasons.

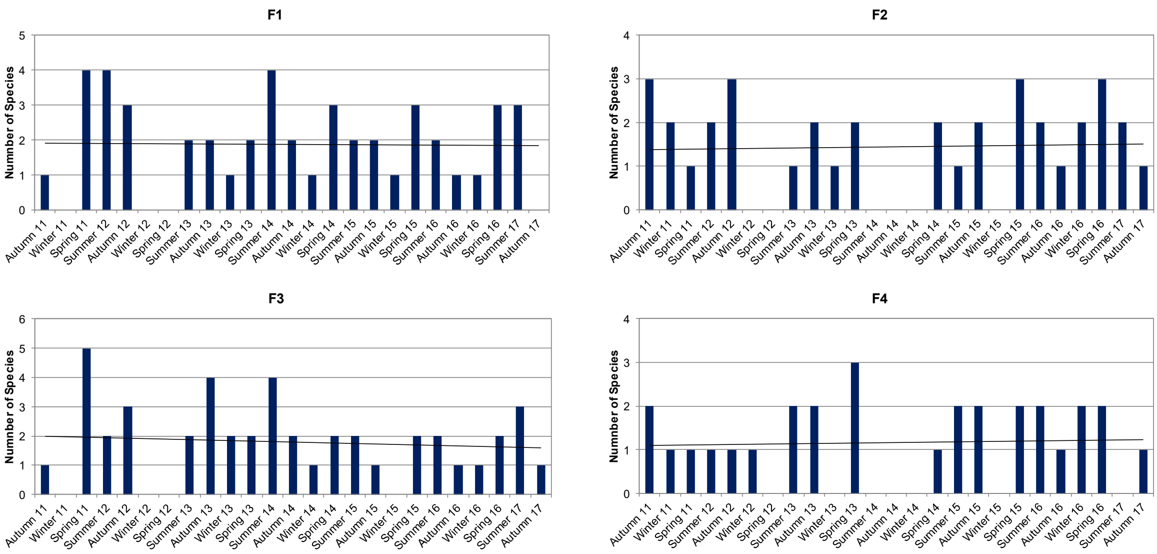


Figure 5.1 Number of fish species captured at all sites in all surveys since the beginning of the MPPC

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*	*07/ 14*	*10/ 14*	*01/ 15*	*04/ 15*	*07/ 15*	*10/ 15*	*01/ 16*	*04/ 16*	*07/ 16*	*10/16*	*01/ 17*	*05/ 17*
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.
- More variation in the numbers of fish captured at F2 and F4, mostly coinciding with the numbers of Mosquitofish captured at those sites.

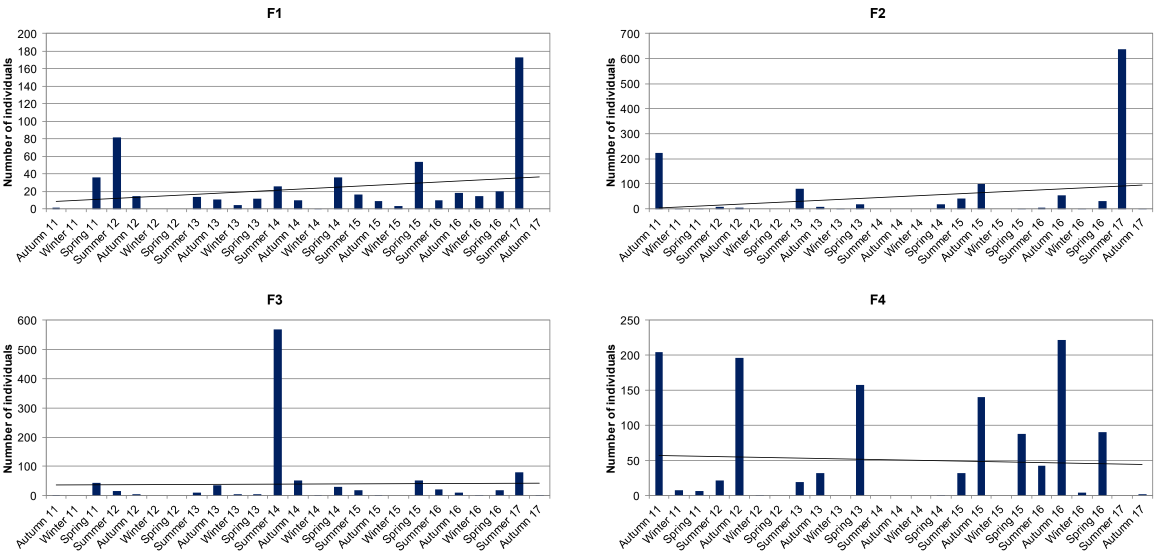


Figure 5.2 Number of individual fish captured at all sites in all surveys since the beginning of the MPPC plotted with linear trend lines

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 twenty five fish surveys undertaken. 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, and between December 2016 and February 2017 led to fish seeking drought refuge in the deeper waterholes, as evidenced by the high numbers and greater diversity of fish captured at F1 and F3 in the summer 2014 survey and the high numbers captured at F1, F2 and F3 in the summer 2017 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 and summer 2017 surveys. At these times, most of the wetlands in Broadwater National Park were dry. The results from F1, F2 and F3 indicate that Salty Lagoon was acting as a drought refuge for fish from the surrounding wetlands as high numbers (and, in some cases, diverse species) were captured during those surveys. The opposite trend is also notable; when water levels increase the available habitat increases quickly and fish become more dispersed throughout the wetlands surrounding Salty Lagoon. Water levels also impact the types of fish captured. Mosquito fish are a surface species and are more likely to be captured when water levels are low and the entrances to the fish traps are located near the surface of the water.
- Fluctuations in conductivity. The conductivity of the water in Salty Lagoon has not been as stable as may have been expected due to 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.

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 during this reporting period, with the exception of the summer 2017 survey when water levels had decreased significantly, the conductivity had increased slightly due to evaporative distillation and the dissolved oxygen was low.

The diversity of species trapped during this reporting period was low. The largest number of species trapped at any one site during any survey 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.

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 last two reporting periods have been characterised by stable water levels and consistent 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

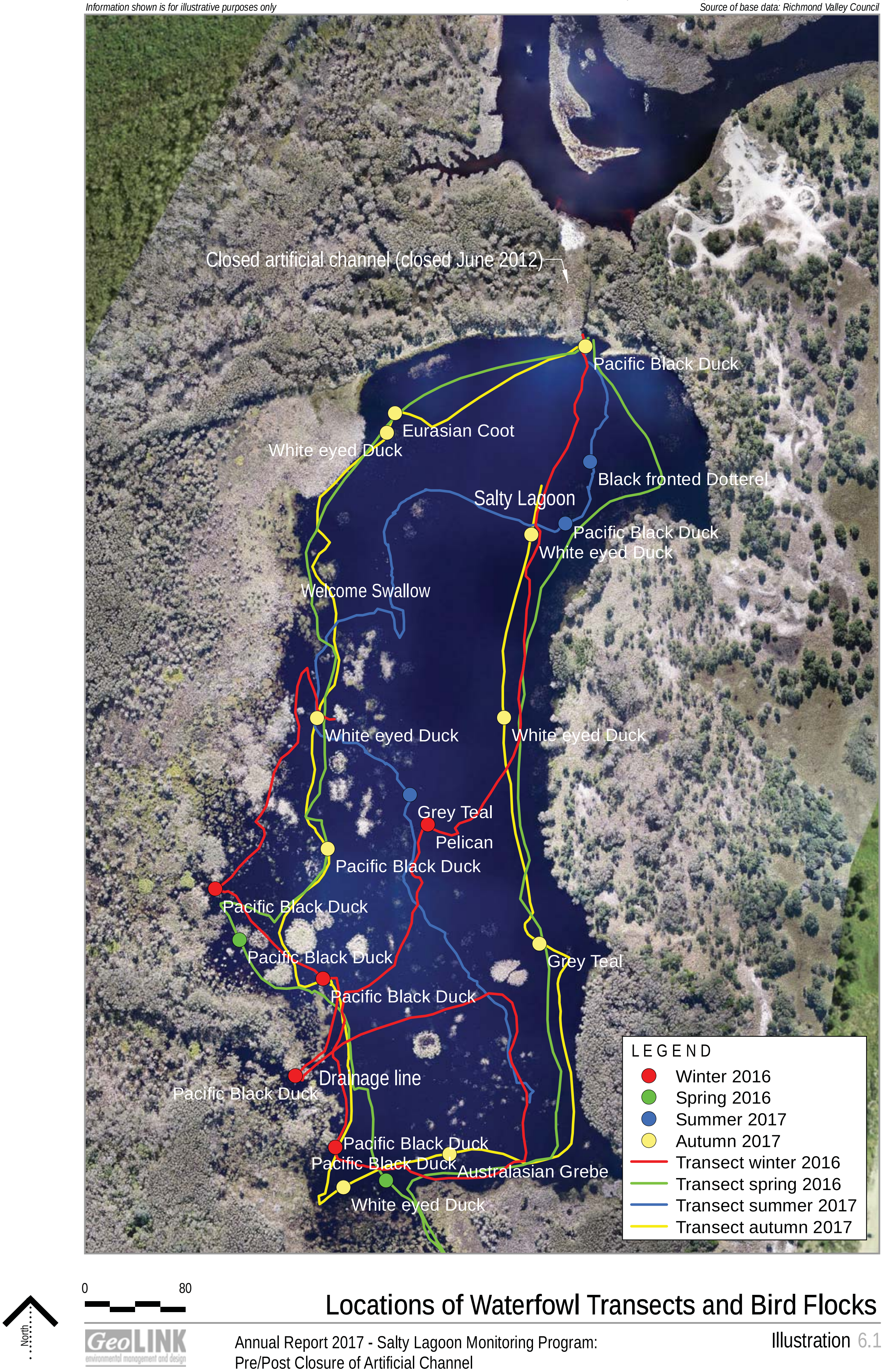
Water bird surveys were completed on a seasonal basis once every three months. The dates of surveys during the current reporting period were 12 July 2016, 11 October 2016, 16 February 2017 and 8 May 2017.

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. The pathways traversed are presented in **Illustration 6.1**. 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 observed 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: 14/09/2017
Source of base data: Richmond Valley Council



Locations of Waterfowl Transects and Bird Flocks

GeoLINK environmental management and design

Annual Report 2017 - Salty Lagoon Monitoring Program:
Pre/Post Closure of Artificial Channel

1731-1272

Illustration 6.1

6.3 Results

6.3.1 Conditions at the Time of Monitoring

Environmental conditions at the time of survey have an impact upon the avifauna present. Water level is particularly 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 2016	12/07/2016	1.93	0	Overcast	Calm
Spring 2016	11/10/2016	1.83	1.4	Overcast	Moderate SSE
Summer 2017	16/02/2017	1.21	1	Fine	Calm
Autumn 2017	8/05/2017	1.95	1.8	Fine	Moderate SSW

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

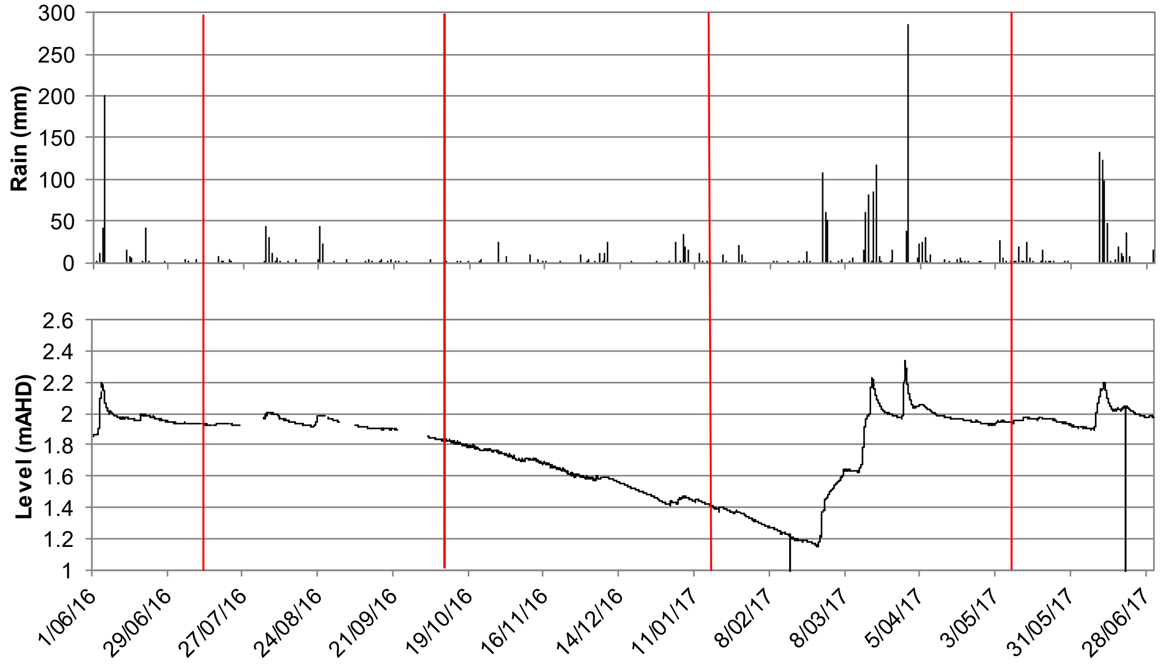


Figure 6.1 Rainfall and water level charts for the reporting period showing bird survey times (red)

The water level at the time of sampling was relatively high for three of the bird surveys but relatively low during the summer 2017 survey. The other key differences among the conditions present at the times of sampling were seasonal temperature variations and windy conditions during the spring 2016 and winter 2017 surveys.

6.3.2 Diversity

The diversity of species observed in waterbird surveys undertaken during the current reporting period only varied slightly from season to season, with the exception of the winter survey, which returned a relatively low number of species. The current reporting period returned the highest recorded species diversity in autumn since the beginning of the MPPC (**Figure 6.2**).

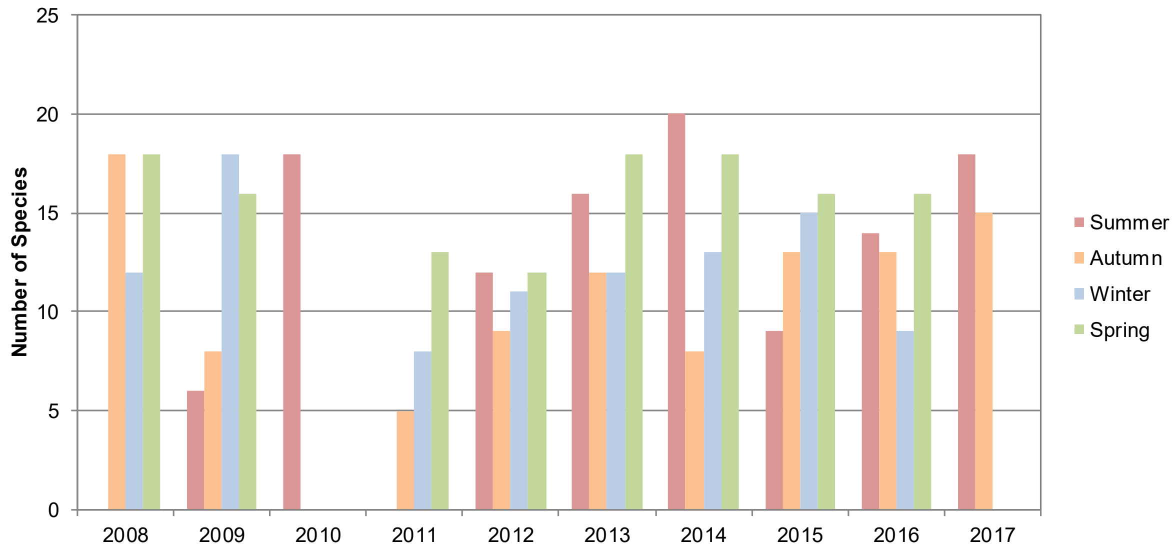


Figure 6.2 Number of bird species observed in previous seasonal surveys on Salty Lagoon (autumn 2008 until summer 2010 [Hydrosphere 2010a]) and during the MPPC (Autumn 2011 until autumn 2017)

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 Lathams Snipe (*Gallinago hardwickii*), Pied Oystercatcher (*Haematopus longirostris*), and the Tree Martin (*Hirundo nigricans*). Alternately, there were a variety of species that were observed in earlier surveys but not during this reporting period, including Chestnut Teal (*Anas castanea*), Australasian Shoveler (*Anas rhynchotis*), Musk Duck (*Biziura lobata*), Australian Spotted Craike (*Porzana fluminea*), Comb-crested Jacana (*Irediparra gallinacea*), Black Bittern (*Ixobrychus flavicollis*), White-necked Heron (*Ardea pacifica*), Royal Spoonbill (*Platelea regia*), Whimbrel (*Numenius phaeopus*), Black-winged Stilt (*Himantopus himantopus*), Pacific Golden Plover (*Pluvialus fulva*), Rainbow Bee-eater (*Merops ornatus*), Welcome Swallow (*Hirundo neoxena*), White throated Needletail (*Hirundapus caudacutus*) and Osprey (*Pandion haliaetus*).

It is notable that the majority of these species are waders and shore-birds or birds that were seldom observed in previous surveys at Salty Lagoon. The waders and shore-birds are less likely to be seen in Salty Lagoon now that water levels have stabilised at higher levels and there is less foraging habitat available to them.

6.3.3 Abundance

Overall waterbird abundance has varied since the beginning of the MPPC. The numbers of individual birds observed during the current reporting period were comparable to those from previous years' surveys with the exception of the spring 2016 survey, which had lower than usual numbers. The numbers of individual birds observed during the autumn 2017 survey were the highest for those seasons since the beginning of the MPPC.

In terms of individual species the abundances of a small number of species appear to have stabilised at higher numbers or more frequent sightings since closure of the artificial channel (**Figure 6.3**). These species include Pacific Black Duck (*Anas superciliosa*), Hardhead (*Aythya australis*), Black Swan (*Cygnus atratus*), Eurasian Coot (*Fulica atra*) and Australasian Grebe (*Tachybaptus novaehollandiae*).

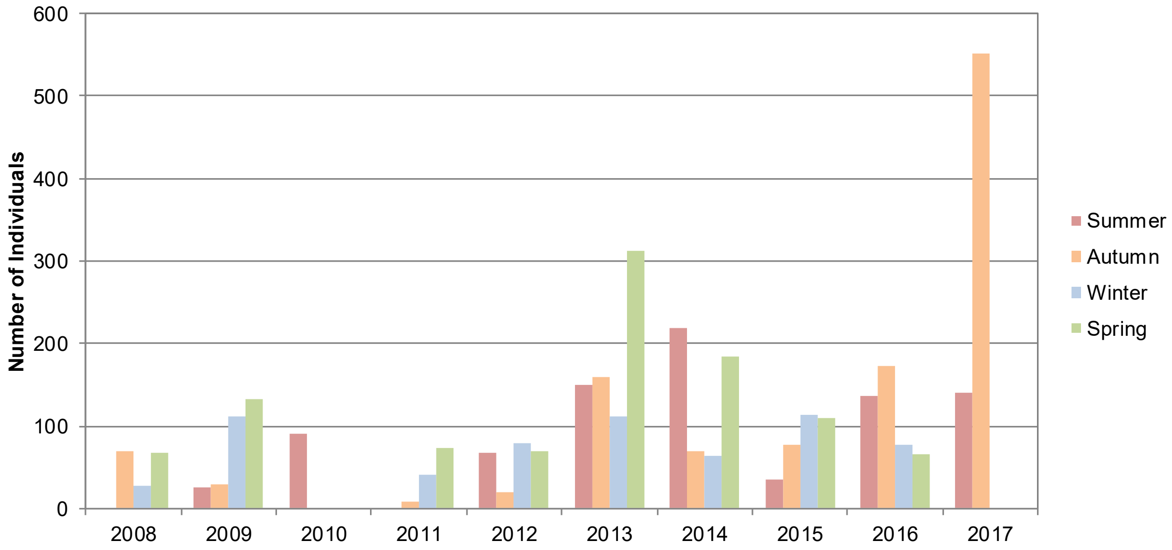


Figure 6.3 Number of individual birds observed in previous seasonal surveys on Salty Lagoon (Autumn 2008 until Summer 2010 (Hydrosphere 2010a)) and during the MPPC (Autumn 2011 until Autumn 2017)

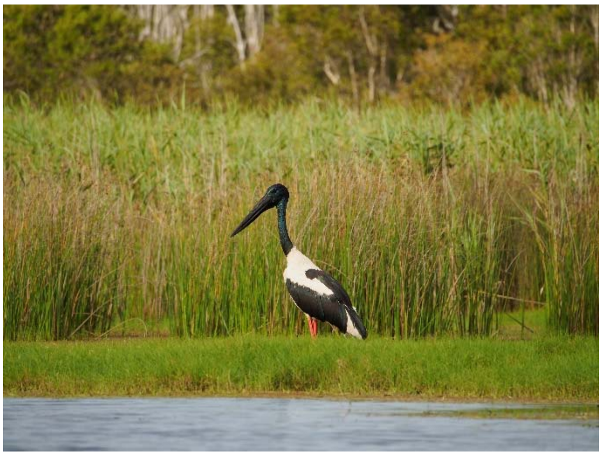


Plate 6.1 A Black-necked Stork on the margins of Salty Lagoon

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

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	07/14	10/14	01/15	04/15	07/15	10/15	01/16	04/16	07/16	10/16	01/17	05/17
Little Black Cormorant			4	3			2	4	8	2	1	3			4	2	2		7	4	1		4		
Little Pied Cormorant	2	1		1		1				1		2			2				3	1		1		7	
Pied Cormorant				9	2	1		1		1			1		4		1	2		6			2		4
Great Cormorant						1			1	2	4		1	1	6	1				1			1		
Darter				1	1	1	1	2							1		1	1	2	1	1		3		2
Pelican		30	10						13	9	16	1		8	7			1	1			8	3		
Australasian Grebe		1		2			6	18	9	22	38	11	3	7	19	2	8	5	20		2	4			11
Grey Teal	1	3	29	23				16	20	5		28			2					2	5	2	3	10	35
Pacific Black Duck				7	4	59	31	42	52	13	82	42	33	7	44	25	24	41	48	108	46	58	29	20	49
Chestnut Teal			1				6			2		14						2	7						
Australasian Shoveler														25				7							
Hardhead							11		20	28					33			12	7			1			397
Musk Duck																		1							
Black Swan				2	4	2			1		4		4	3		2	2	2	2	3	2		2	2	6
Dusky Moorhen																					1				1
Australian Spotted Crake															1										
Purple Swamphen								33														2			
Eurasian Coot								22	24	25	125	6			29		33	35			1				36
Comb-crested Jacana*								3									1			1	1				
White-faced Heron	1	2	5		2	6	2	1	9		2	1	4	7	3		1		1		2			7	1

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	07/ 14	10/ 14	01/ 15	04/ 15	07/ 15	10/ 15	01/ 16	04/ 16	07/ 16	10/ 16	01/ 17	05/ 17
Black Bittern*			1																						
White-necked Heron			2					1			4			1				1	1						
Little Egret			1																					1	
Intermediate Egret							1	1			1	1		1	1	1		1	1				1		1
Great Egret			3	1	1	1	4	2	1		4	2	1	1	1		2	1	2		30	1	5		
White Ibis			2				1				7	12			2				2					1	
Royal Spoonbill											5			1					5						
Black-necked Stork*												2								1				2	
Brolga*											2													1	
Whimbrel								1																	
Lathams Snipe																								2	
Sharp-tailed Sandpiper												44												2	
Black-winged Stilt	3				2						11	13													
Pied Oystercatcher*																							5		
Masked Lapwing		2	2								2	3			3								1	4	
Pacific Golden Plover												12													
Black-fronted Dotterel			7																					20	
Common Tern																				1				1	
Crested Tern																1							1		
Rainbow Bee Eater				3																1					
Forest Kingfisher																					1	1			2

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***	***07/ 14***	***10/ 14***	***01/ 15***	***04/ 15***	***07/ 15***	***10/ 15***	***01/ 16***	***04/ 16***	***07/ 16***	***10/ 16***	***01/ 17***	***05/ 17***
Welcome Swallow			7		3	3	3				3	3			22					4					
Tree Martin																								50	
White-throated Needletail				15								17	22								80				
Raven				1																				6	
Eastern Osprey*									1							1									
White-bellied Sea- Eagle*	2	1			1	1				1				1		1	1		1	2					
Wedge-tailed Eagle							1	1															3	2	4
Black Kite											1						1	2						2	
Brahminy Kite																	1						1		
Whistling Kite		1				4		2				1		1											1
Red Goshawk^																							1		
Total No. Species	**5**	**8**	**13**	**12**	**9**	**11**	**12**	**16**	**12**	**12**	**18**	**20**	**8**	**13**	**18**	**9**	**13**	**15**	**16**	**14**	**13**	**9**	**16**	**18**	**15**
Total No. Individuals	**9**	**41**	**74**	**68**	**20**	**80**	**69**	**150**	**159**	**111**	**312**	**218**	**69**	**64**	**184**	**36**	**78**	**114**	**110**	**136**	**173**	**78**	**65**	**140**	**551**

* *Species listed as vulnerable under the Biodiversity Conservation Act 2016.*

^ *Tentative recordings only. Species listed as Critically Endangered under the Biodiversity Conservation Act 2016 and Vulnerable under the Environment Protection and Biodiversity Conservation Act 1999*

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 both species diversity and waterbird abundance since the closure of the artificial channel. In the current reporting period we observed continued and consistent high levels of both diversity and abundance. Some individual species of waterfowl, such as Pacific Black Duck and Australasian Grebe have stabilised at high numbers relative to those observed prior to channel closure.

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.

7. Frogs

7.1 Introduction

7.1.1 General

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

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

Acid frogs previously recorded 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).

7.1.2 ERMP Frog Monitoring Results

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

7.1.3 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.

7.2 Methods

7.2.1 Surveys

Frogs were sampled using two methods:

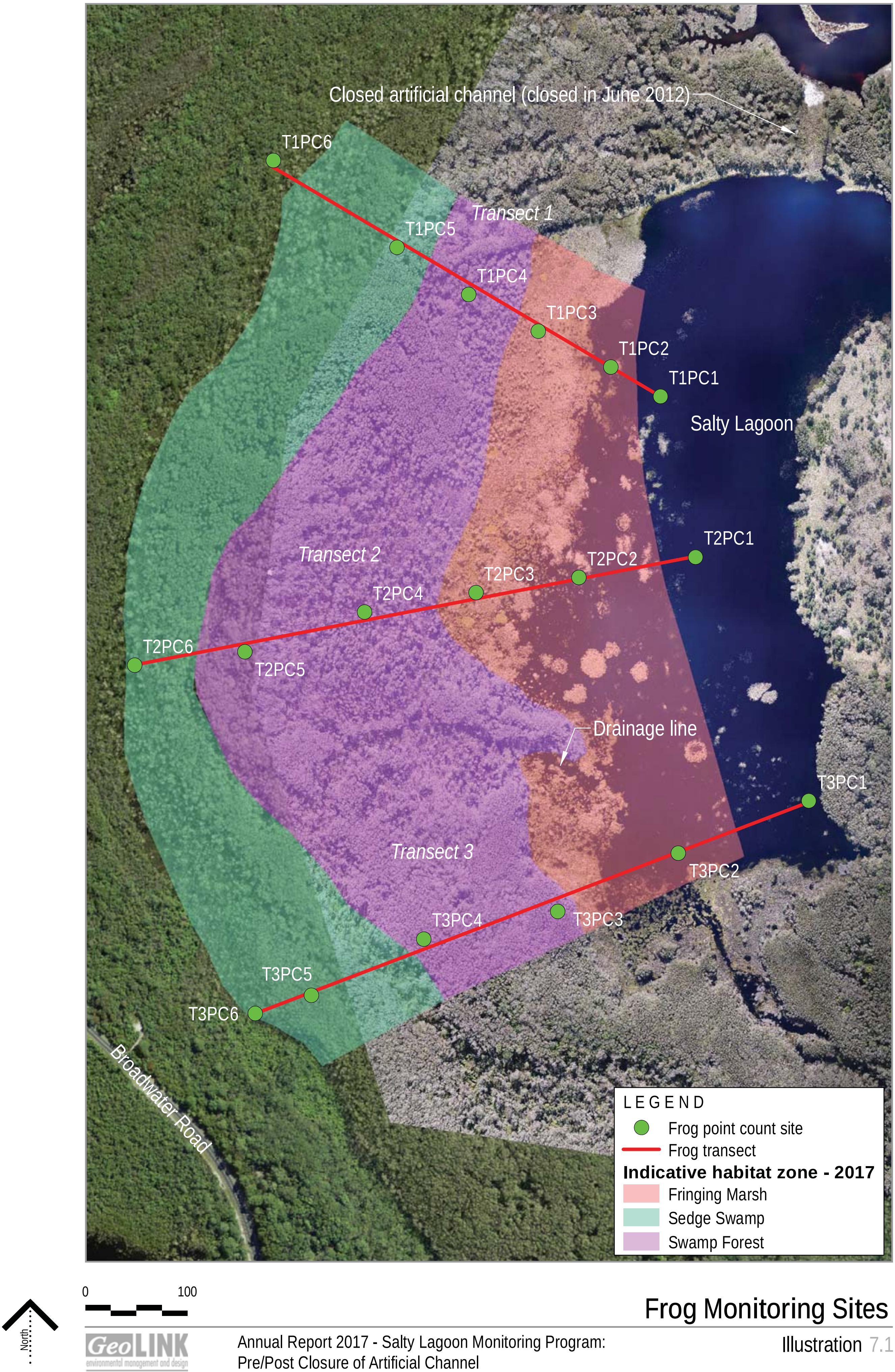
- Point counts undertaken at six fixed points along three fixed transects.
- Transect traverses undertaken along three fixed transects which corresponded with the point counts.

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

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

Since the closure of the artificial channel in June 2012 the water level of Salty Lagoon 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. All fixed monitoring points were surveyed within the current monitoring period due to the presence of emergent vegetation. Previous frog monitoring was not undertaken at the three fixed monitoring points closest to the lagoon due to a lack of suitable vegetated habitat for frogs.

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



Frog Monitoring Sites

Illustration 7.1

Table 7.1 **Point Count Locations (GDA 84)**

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

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.

7.2.2 Timing

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

- Winter 2016 surveys: 25 August and 1 September 2016.
- Spring 2016 surveys: 6 December and 8 December 2016.
- Summer 2017 surveys: 6 March and 14 March 2017.

Minor seasonal delays in survey timing were undertaken so surveys could be undertaken during the best conditions possible.

7.2.3 Conditions at the Time of Monitoring

The call behaviour of frogs is highly variable and associated with season, weather conditions and behavioural patterns. Weather conditions during the post artificial channel closure frog monitoring events are provided in **Table A.1** of **Appendix A**.

Weather conditions varied across monitoring events. Overcast and fine conditions were observed during the winter monitoring event, thunder storms and intermittent light rain was experienced in the spring monitoring event and fine/ overcast conditions were experienced in the summer monitoring event. Nearly all monitoring events had rain in the 24 hours prior to monitoring being undertaken, the second winter monitoring event (1/09/16) being the only exception with no rain prior to monitoring. Temperature generally ranged from mild to warm during most monitoring events. Winds were variable across seasons and ranged from calm to moderate. Relative humidity was moderate to high during the winter and first summer (6/03/17) monitoring events ranging between 64 – 70% relative humidity. Relative humidity during the spring and second summer (6/03/217) monitoring events was high to very high ranging between 76 – 100% relative humidity.

7.3 Results

7.3.1 Point Count

7.3.1.1 Species Richness and Abundance

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

- Five species recorded during the winter monitoring events, comprising 115 ‘on-site’ specimens.

- Six species recorded during the spring monitoring events, comprising 142 'on-site' specimens.
- Four species recorded during the summer monitoring events, comprising 60 'on-site' specimens.

The Dwarf Tree Frog was consistently the most commonly recorded species in all of the monitoring seasons. The acid frog species Wallum Froglet was also recorded in all monitoring seasons, but at a lower abundance compared to the Dwarf Tree Frog.

An abundance of Striped Marsh Frog and Rocket Frog were recorded in the summer monitoring season and Tyler's Tree Frog was recorded in high numbers in the winter monitoring season.

In general, results varied between habitats and transects. Frog species recorded 'on-site' at point count sites within each habitat are shown in **Table 7.2**. The highest diversity of species at point count sites was recorded within the Fringing Marsh/ Swamp Forest Ecotone and the least diversity was recorded in the Swamp Forest/ Sedge Swamp.

The species with the overall highest abundance recorded 'on-site' during the point count surveys were:

- Dwarf Tree Frog – 187 individuals;
- Rocket Frog – 45 individuals; and
- Wallum Froglet – 45 individuals.

The least abundant species recorded were Wallum Sedge Frog and Bleating Tree Frog (*Litoria dentata*), with one individual each.

7.3.1.2 Distribution

The habitats for 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 (with emergent rushes). 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 was inundated following closure of the artificial channel.

As shown in **Table 7.2**, the most widely distributed species were the Dwarf Tree Frog and Striped Marsh Frog (both recorded in all five of the habitats). The Wallum Froglet, Common Eastern Froglet and Wallum Sedge Frog were not recorded in the Fringing Marsh or the Fringing Marsh/ Open Water ecotone.

Six frog species were recorded in the Fringing Marsh/ Swamp Forest ecotone, five species were recorded in the Sedge Swamp and Swamp Forest habitats, and four species were recorded in the Fringing Marsh and Fringing Marsh/ Open Water Ecotone and the Open Water (with emergent rushes) habitats.

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

Scientific Name	***Common Name***	***Sedge Swamp***			***Swamp Forest***			***Fringing Marsh/ Swamp Forest Ecotone***			***Fringing Marsh and Fringing Marsh/ Open Water Ecotone***			***Open Water (with emergent rushes)***		
		T1	T2	T3	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	x			x								
Striped Marsh Frog	*Limnodynastes peroni*		x			x	x	x	x				x	x	x	
Dwarf Tree Frog	*Litoria fallax*	x	x	x	x	x	x	x	x		x		x	x	x	x
Wallum Sedge Frog	*Litoria olongburensis*			x												
Rocket Frog	*Litoria nasuta*								x				x	x	x	x
Tyler's Tree Frog	*Litoria tyleri*				x	x			x		x				x	
Bleating Tree Frog	*Litoria dentata*			x												

7.3.2 Transect Traverse

7.3.2.1 Occurrence and Distribution of Wallum Froglet and Dwarf Tree Frog

The transect traverse Wallum Froglet and Dwarf Tree Frog comparison results are shown in **Illustration 7.2** and **Table A3** of **Appendix A**. Along Transect 1 Wallum Froglet was commonly recorded within Sedge Swamp and Swamp Forest, with a lesser occurrence further east in the Melaleuca dieback area and a single record within Fringing Marsh. Along Transect 2 Wallum Froglet was recorded in the Sedge Swamp and Swamp Forest and was only recorded in the Sedge Swamp along Transect 3.

Along Transect 1 and 3 Dwarf Tree Frog was recorded in all three habitats with the majority of observations being in the Fringing Marsh/ Open Water and Melaleuca dieback area. Along Transect 2 Dwarf Tree Frog was recorded in both the Fringing Marsh and Swamp Forest (including the Melaleuca dieback area).

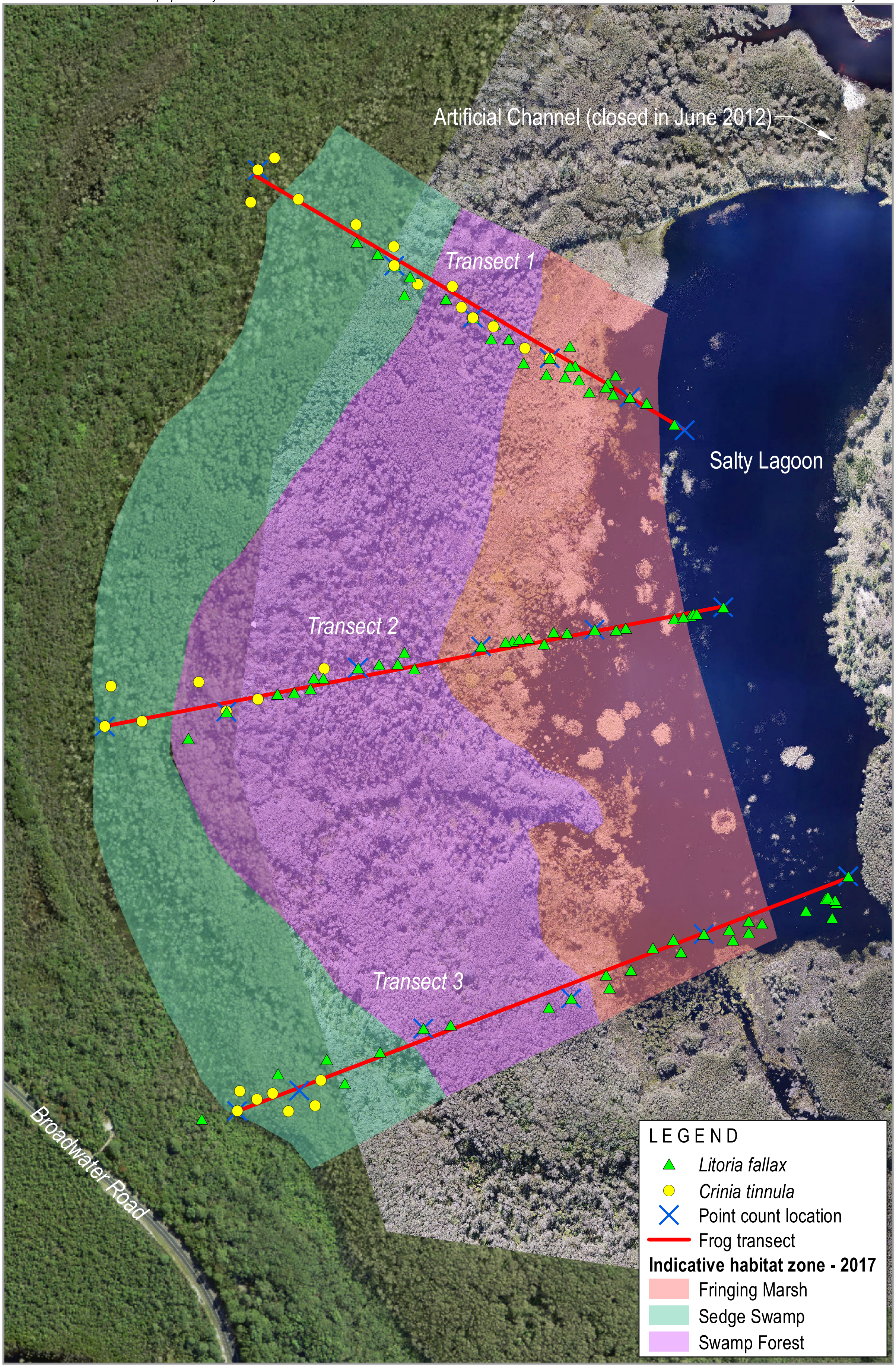
The following summary can be made relating to the distribution of the Wallum Froglet and Dwarf Tree Frog in the study area:

- 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.
- Wallum Froglet was observed in Swamp Forest habitat, however Dwarf Tree Frog was the dominant species.
- Only a minor occurrence of Wallum Froglet was recorded in Fringing Marsh habitat and only a minor occurrence of Dwarf Tree Frog was recorded in Sedge Swamp habitat.
- The broadest distribution of Wallum Froglet was recorded within habitats along Transect 1 and the narrowest distribution was along Transect 3 where this species only occurred in Sedge Swamp.

The location of records of the two species displayed some overlap in the current monitoring period but a preference for those habitats further from Open Water for Wallum Froglet was noted.

Drawn by: GJM Checked by: RE Reviewed by: DSA Date: 14/09/2017
Information shown is for illustrative purposes only
Source of base data: Richmond Valley Council



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

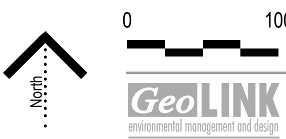


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Illustration 7.2

7.4 Discussion

The findings of the current monitoring period are discussed in **Section 7.4.1** to **Section 7.4.4**. Where trends are evident in the MPPC frog monitoring data collected thus far (for the period of mid-2011 to early-2017, and subsequently referred to as: baseline monitoring [GeoLINK 2012a], 2012-2013 monitoring [GeoLINK 2013a], 2013-2014 monitoring [GeoLINK 2014], 2014-2015 monitoring (GeoLINK 2015a), 2015-2016 monitoring (GeoLINK 2016) and the current monitoring [2016-2017]), 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) would be provided in the Final Evaluation Report.

7.4.1 Overall Species Diversity

The overall amphibian species diversity was similar in the current monitoring period when compared with recent MPPC monitoring. Eight species were recorded in the current monitoring period, seven species were recorded in 2016-2017 and six species in 2014-2015. Similar counts of nine species in 2013-2014, eight species in 2012-2013 and nine species in the baseline monitoring were recorded. There is no obvious trend in total species diversity to date. Fluctuations in overall amphibian species diversity are likely to be associated with climatic conditions (e.g. dry summer conditions) and general survey limitations (e.g. 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 Broad-palmed Rocket Frog (*Litoria latopalmata*) and Dainty Green Tree Frog (*L. gracilenta*).

7.4.2 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 spring in both 2015-2016 and 2012-2013 monitoring, in summer in both 2014-2015 and baseline monitoring, and winter in 2013-2014 monitoring.

The species with the highest abundance in the current monitoring was the Dwarf Tree Frog, with a total of 187 individuals recorded at point counts. This is equal to the highest number recorded in 2015-2015 monitoring. This species has consistently been the most abundant species recorded at Salty Lagoon, with 187 individuals recorded in 2015-2016, 85 individuals recorded in 2014-2015 monitoring, 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. The current monitoring period recorded the highest abundance of Wallum Froglet, with a total of 45 individuals recorded at point counts. Other Wallum Froglet numbers include 28 individuals recorded in the 2015-2016 monitoring, 12 individuals recorded in the 2014-2015 monitoring, 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 in response to variable environmental factors (e.g. seasonal weather conditions/ water level) and is displaying no clear trend.

7.4.3 Species Diversity by Vegetation Habitat Zone

Six species were recorded in the Swamp Forest and Swamp Forest/ Fringing Marsh ecotone (Melaleuca dieback area) in the current monitoring as was also the case in the 2015-2016 and 2014-2015 monitoring, compared with seven species in 2013-2014 monitoring, eight species in 2012-2013 monitoring and eight species in baseline monitoring.

Four species were recorded in the Fringing Marsh/ Open Water ecotone and Open water (with emergent rushes) habitats as was also the case with 2015-2016 monitoring, five species were recorded in the 2014-2015 monitoring, 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 these habitats over the 2014-2015 and 2015-2016 monitoring periods was likely due to increased water levels and less vegetation around the periphery of the lagoon. 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) during these events. For the current monitoring event however, water levels where lower and the extent vegetation was greater than these previous years within this zone. The lower species diversity may be attributed to the uniform habitat value within this zone, accommodating for a limit diversity of species.

Wallum Froglet was recorded onsite in the Fringing Marsh/ Swamp Forest Ecotone as well as offsite in the Fringing Marsh habitat along Transect 1 during the current monitoring event. With the exception of the 2014-2015 monitoring, Wallum Froglet has also previously been recorded within this habitat zone along Transect 1 (GeoLINK 2012a, 2013a, 2014, 2016). Water quality monitoring has shown a buffering pH tendency towards neutral within the core water body. Despite this, it appears that the remaining sedgeland habitat along Transect 1 provided by the Fringing Marsh is still broadly suitable for Wallum Froglets. The suitability of this habitat may vary overtime in relation to the overall water levels within the lagoon.

Five species were recorded in the Sedge Swamp habitat as was also the case with 2015-2016 monitoring, The trend of a comparatively low diversity of frog species being recorded in the Sedge Swamp in the 2013-2014 monitoring and 2014-2015 monitoring (Wallum Froglet being the only recorded species) has not continued. This increase in frog species diversity supports the assertion that any variability reflects environmental factors such as seasonal weather conditions rather than a change in salinity or water quality attributable to the closure of the artificial channel.

7.4.4 Habitat Segregation and Distribution Patterns

A primary segregating factor for the frog species at Salty Lagoon is the acid water tolerance of individual species. In general, this has the effect of limiting ‘acid’ frog species to Sedge Swamp and Swamp Forest habitats at Salty Lagoon. Although some overlap was recorded in the distribution of Wallum Froglet (acid frog) and Dwarf Tree Frog (habitat generalist) a broad segregation was noted based on habitat preference, with Wallum Froglet being most commonly recorded in those habitats furthest from the Open Water of Salty Lagoon and Dwarf Tree Frog being least common in these same habitats (refer to **Section 7.4.3** and **Illustration 7.2**).

As has been recorded in previous MPPC monitoring (except for 2014-2015 monitoring), the Wallum Froglet was recorded in the western section of Fringing Marsh along Transect 1 'onsite'. This observation was recorded on 14/03/17 and coincided with a slight increase in Salty Lagoon water levels (resulting from heavy falls in late February/early March) after a particularly dry weather period (water levels in Salty Lagoon reached their lowest point between January 2017 and early March 2017). The observation also coincided with a drop in pH (from around 7 to between 5-6 pH). The monitoring has shown that the Fringing Marsh habitat bordering the swamp forest habitat along Transect 1 remains at least periodically suitable for Wallum Froglets when environmental conditions are suitable.

8. Terrestrial Vegetation

8.1 Introduction

8.1.1 General

This section of the annual report summarises the methods, data, observations and conclusions relating to vegetation monitoring during the 2017 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 (2017). 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.

8.1.2 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).

8.2 Methods

The following section details the methodology used for the 2017 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).

8.2.1 Vegetation Transects

8.2.1.1 Timing

Vegetation sampling was undertaken over two days on 23 March and 24 March 2017. Water levels at the time of sampling were very high, as a result of significant rainfall in the week prior to sampling.

8.2.2 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).

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.

8.2.3 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.

8.2.4 Melaleuca Diebank/ Recolonisation

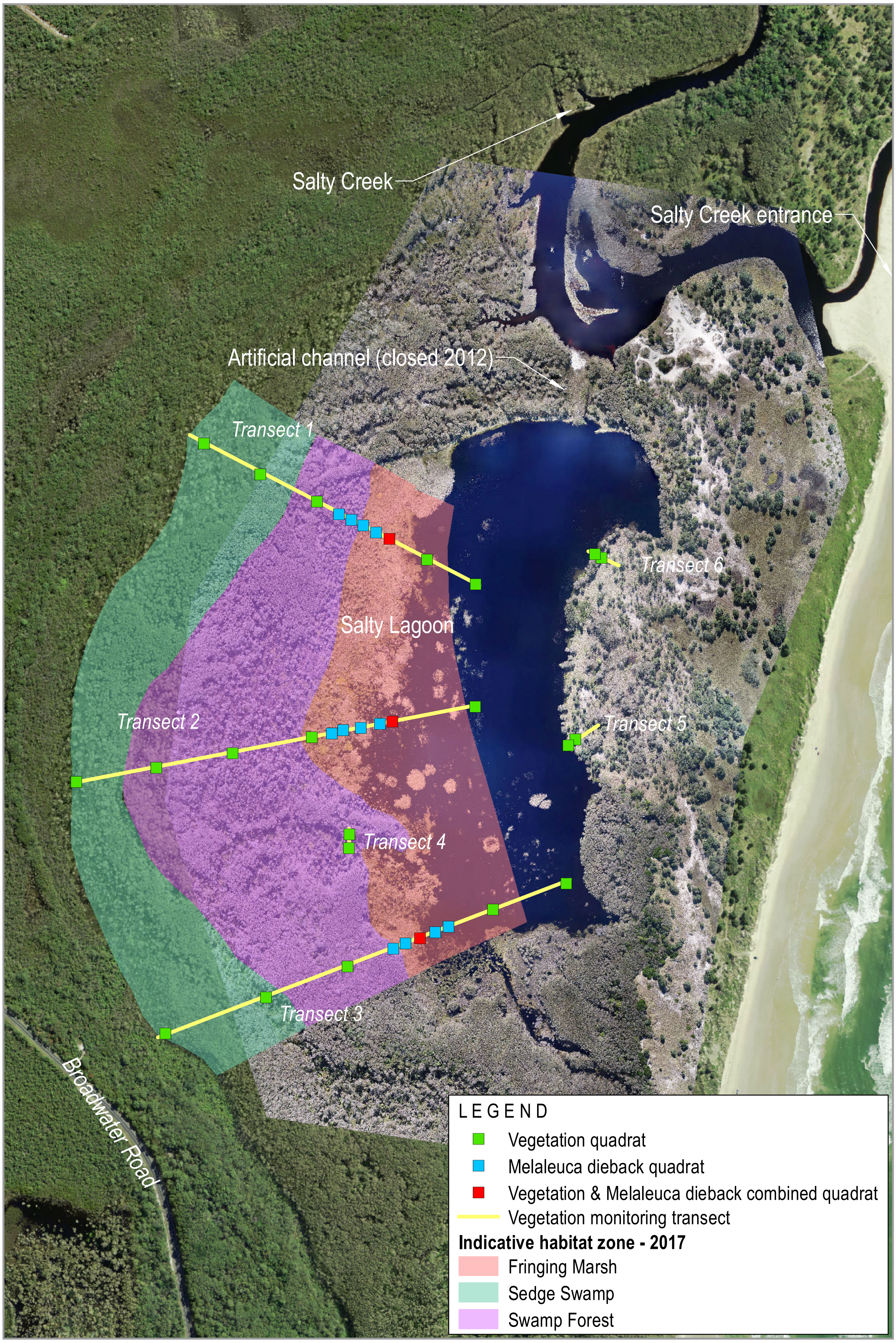
Melaleuca dieback transects and quadrats (10 m x 10 m) were established according to the proposed methodology outlined in Hydrosphere (2010b). Three transects were established corresponding with those previously established for the ERMP sampling and correspond with Transects 1-3 established to measure vegetation habitat zone changes (refer to **Illustration 8.1**). 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.

Drawn by: GJM Checked by: DSA Reviewed by: DSA Date: 14/09/2017
Source of base data: Richmond Valley Council
Information shown is for illustrative purposes only



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North

Indicative Vegetation Sampling Sites selected for the Monitoring Program

8.3 Results and Discussion

8.3.1 Transects 1 – 3

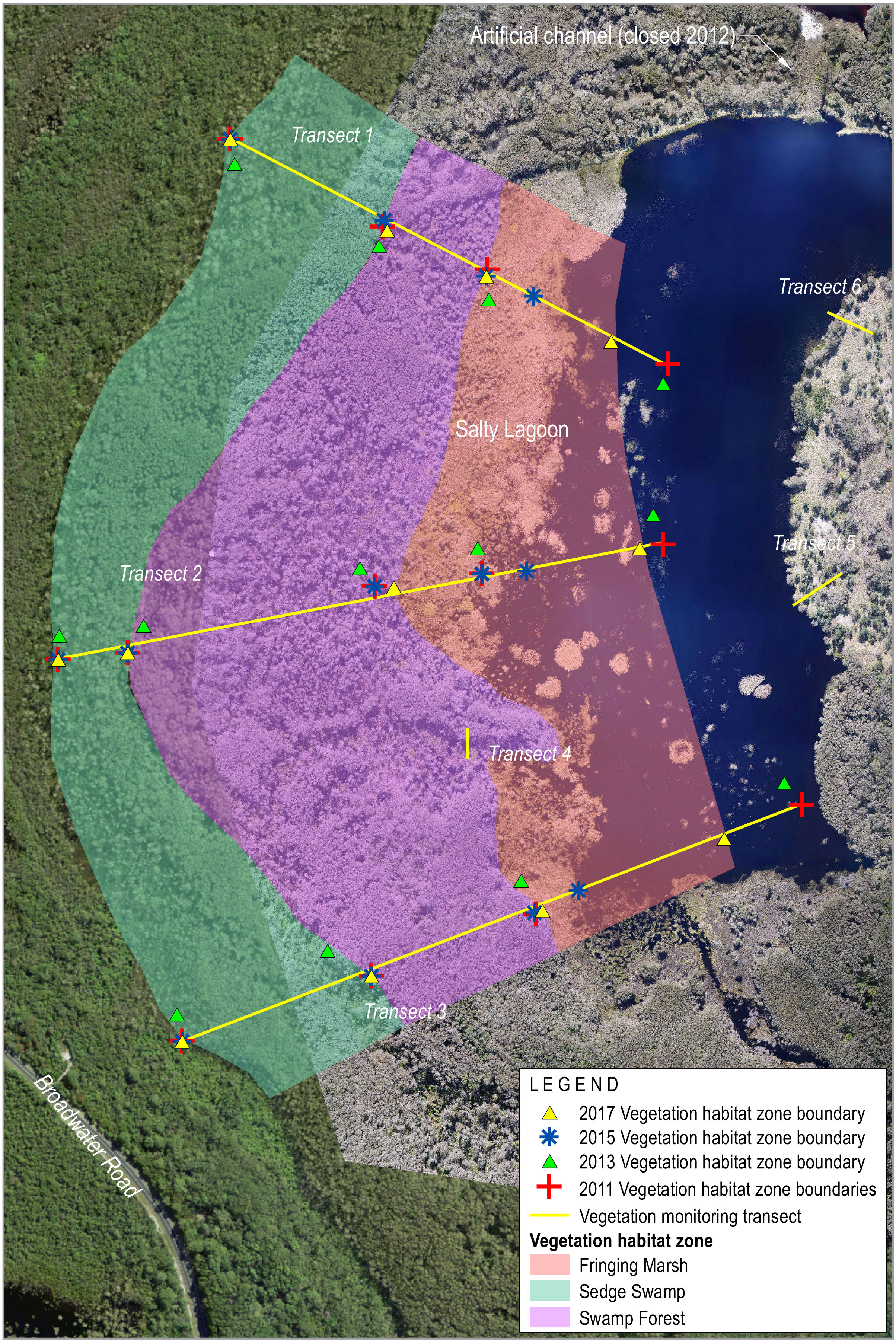
Transects 1-3 extend across the three distinct vegetation habitat zones of Fringing Marsh, Swamp Forest and Sedge Swamp. The location of vegetation habitat zones boundaries along each transect is shown **Illustration 8.2**. Since the baseline vegetation monitoring the total length occupied by the vegetation habitat zones along the transects has varied, though overall 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.

In total, 58 flora species (both native and exotic) were recorded from the three vegetation habitat zones. This presents a areduction from the 73 species recorded in 2011, though a minor increase from the 55 and 47 species recorded in 2013 and 2015 respectively. The breakdown of total number of species by vegetation habitat zones is shown in **Table 8.1**.

Table 8.1 Flora Species Numbers

Vegetation Habitat Zone	Total Number of Species			
	2011	2013 (Change since 2011)	2015 (Change since 2011)	2017 (Change since 2011)
Fringing Marsh	28	7 (-21)	11 (-17)	16 (-12)
Swamp Forest	36	30 (-6)	27 (-9)	29 (-7)
Sedge Swamp	40	32 (-8)	26 (-14)	31 (-9)
Total Flora Species	73	55 (-18)	47 (-26)	58 (-15)

Drawn by: GJM Checked by: DSA Reviewed by: DSA Date: 14/09/2017
Source of base data: Richmond Valley Council
Information shown is for illustrative purposes only



Vegetation Habitat Zone Boundaries

GeoLINK environmental management and design

Annual Report 2017 - Salty Lagoon Monitoring Program:
Pre/Post Closure of the Artificial Channel
1731-1276

Illustration 8.2

8.3.1.1 Vegetation Habitat Zone Descriptions

Fringing Marsh

Dominant flora species within the Fringing Marsh quadrats consisted of:

- *Cyperus polystachyos* and Brown Beetle Grass (*Diplachne fusca*); occurring at a moderate density in five out of six quadrats.
- Fringe Rush (*Fibrostylus ferruginea*); occurring at moderate density in three out of six quadrats.
- Saltwater Couch (*Paspalum vaginatum*); occurring at a moderate density in two out of six quadrats.
- Common Reed (*Phragmites australis*); occurring at a moderate to high density in two out of six quadrats.
- Sea Rush (*Juncus kraussii* subsp. *australiensis*), Shore Club-rush (*Schoenoplectus subulatus*), Broadleaf Cumbungi (*Typha orientalis*) and Enydra (*Enydra fluctuans*); occurring at a moderate density in one out of six quadrats.

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 five out of six quadrats.
- Tall Sedge (*Carex appressa*); occurring at a moderate density in two out of six quadrats.
- Groundsel Bush (*Baccharis halimifolia**), Water Hyssop (*Bacopa monnieri*), Jointed Twig-rush (*Baumea articulata*), Enydra (*Enydra fluctuans*); *Hydrocotyle peduncularis*; Spiny-headed Mat-rush (*Lomandra longifolia*); Common Reed (*Phragmites australis*); *Schoenus brevifolius* 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.
- Zig-zag Bog-rush (*Schoenus brevifolius*); occurring in a moderate to very high density in three 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.
- Bare Twig-rush (*Baumea juncea*); occurring at a high density in one out of six quadrats; Weeping Baeckea (*Baeckea frutescens*) and Cassytha (*Cassythea filiformis*); occurring at a moderate density in two out of six quadrats.
- Dillwinia (*Dillwinia retorta*); Red-fruited Sword-sedge (*Gahnia seiberana*), Grass Tree (*Xanthorrhoea* sp.), Pouched Coral Fern (*Gleichenia dicarpa*), Tantoon (*Leptospermum polygalifolium*), Selaginella (*Selaginella uligonosa*) and Saltwater Couch (*Paspalum vaginatum*);

occurring at a moderate density in one out of six quadrats.

Indicator Species

The average cover abundance value for each of these indicator species in the vegetation habitat zones is graphically represented in Figure **8.1**. The results of the monitoring indicate the following:

- Sea Rush (*Juncus krausii* subsp. *australiensis*): Continues to occur in the Swamp Forest however the number of quadrats in which it was recorded and cover abundance has reduced. Continues to occur in only one quadrat within the Fringing Marsh. Not recorded in the Sedge Swamp.
- Saltwater Couch (*Paspalum vaginatum*): Continues to occur at low-moderate density in two of the six quadrats in both the Sedge Swamp and Swamp Forest. Occurring at a low-moderate density in four out of six quadrats in the Fringing Swamp.
- Bare Twig-rush (*Baumea juncea*): Occurring in all quadrats in the Swamp Forest, predominantly at a moderate to high density (i.e. five out of six quadrats). Occurring in one quadrat only in the Sedge Swamp, and at very high density. Not recorded in the Fringing Swamp.
- Broad-leaved Paperbark (*Melaleuca quinquenervia*): Continues to persist in all quadrats in the Sedge Swamp and Swamp Forest, however only occurs in one quadrat within the Fringing Marsh.
- Plume Rush (*Baloskion tetraphyllum*): Persists at very high density in the Sedge swamp in Transect 1 and to a lesser degree in the Swamp Forest, however no longer detected in the quadrat on Transects 2 or 3.

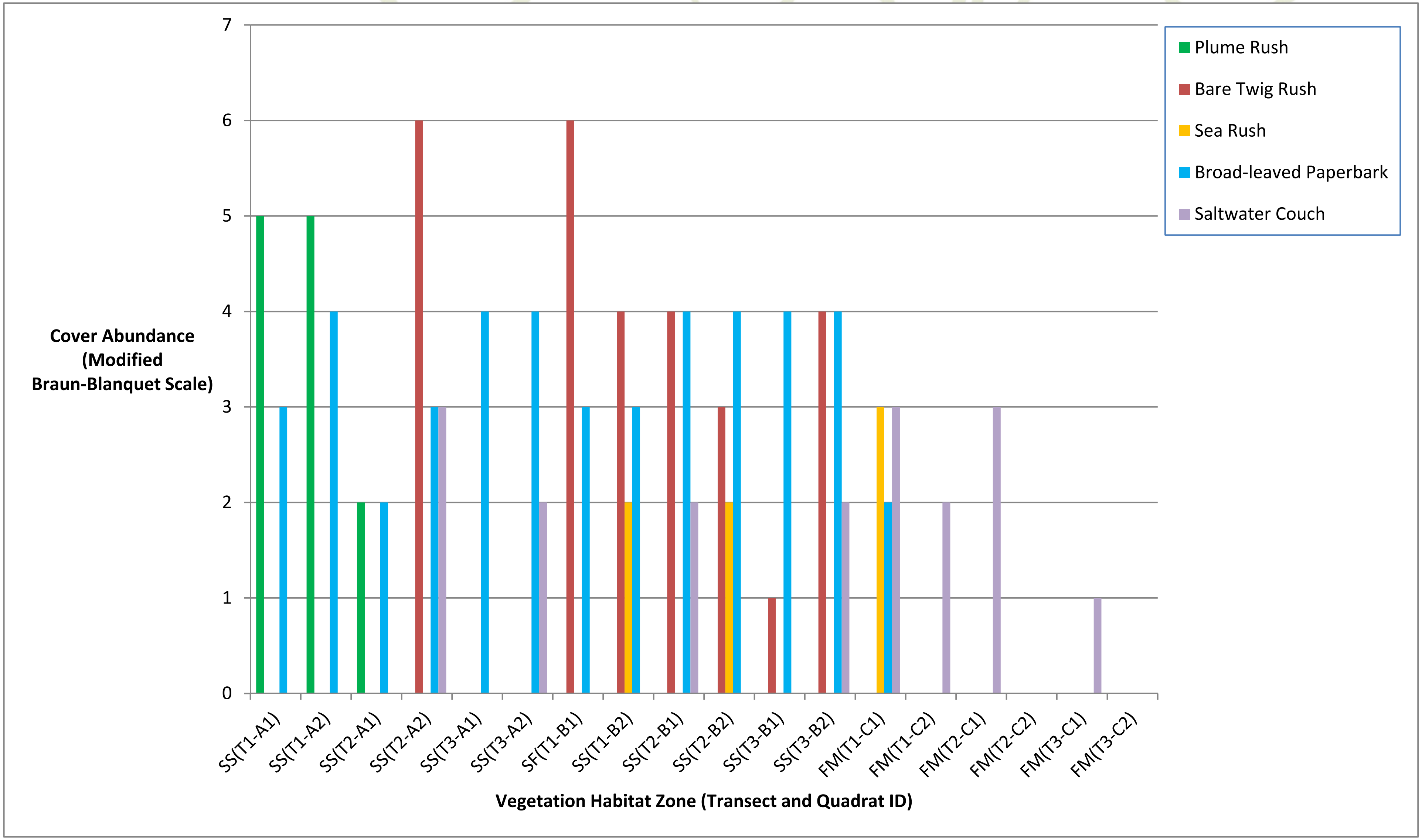


Figure 8.1 Cover abundance scores for indicator species in vegetation habitat zones of transects 1 – 3

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

8.3.2 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 **Illustration 8.1**.

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.

8.3.2.1 Species Composition of Vegetation Habitat Zones

In total, 41 flora species (both native and exotic) were recorded from the four vegetation habitat zones (an increase from other MPPC events). The breakdown of the total number of species by vegetation habitat zones is shown in **Table 8.2**.

Table 8.2 Flora Species Numbers

Vegetation Habitat Zone	*Total number of Species*			
	2011	*2013 (Change since 2011)*	*2015 (Change since 2011)*	*2017 (Change since 2011)*
Fringing Marsh	14	20 (+6)	17 (+3)	20 (+6)
Swamp Forest	13	6 (-7)	10 (-3)	13 (0)
Sedge Swamp/ Open Water	15	12 (-3)	13 (-2)	7 (-8)
Banksia Woodland	14	17 (+3)	14 (0)	24 (10)
Total Flora Species	32	38 (+6)	28 (-4)	41 (+9)

8.3.2.2 Vegetation Habitat Zone Descriptions

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 Shore Club-rush (*Schoenoplectus subulatus*) in fringing areas. This reflects the higher water levels and associated stronger freshwater influence following channel closure.

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

Indicator Species

8.3.2.3 Indicator Species

Results for indicator species identified in the 2011 monitoring include:

- Sea Rush: This species was no longer occurring in the Swamp Forest community and had reduced in cover density from medium to low during the current monitoring period.
- Saltwater Couch continues to occur at medium density within the Swamp Forest community in Transect 4, although it appears that there was some reduction in its density cover during the previous monitoring in 2015. Saltwater Couch was not detected in the Fringing Marsh community of Transect 5.
- Shore Club-rush was not detected within the Fringing Marsh community along Transect 5, however it has re-established since the 2015 monitoring at a moderate density at Transect 6.
- Saw-sedge has not changed in density along Transect 4, however appears to be increasing in distribution in both the Sedge Swamp and Swamp Forest communities.
- Coast Banksia cover at Transects 5 and 6 has remained similar between the 2011 monitoring and the current monitoring event.

8.3.3 Melaleuca Dieback/ Recolonisation Monitoring

Results from the Melaleuca dieback quadrats are provided in detail in GeoLINK (2017). Less than half of the quadrats contained dead Melaleuca individuals (four out of 15).

A relatively low proportion of quadrats contained regenerating Melaleuca seedlings (four out of 15), saplings (six out of 15) or small trees (five out of 15); similar to the 2015 results.

Where living Melaleuca was present, in general the health appeared good, with thick foliage and no presence of necrotic spots on leaves or galls on small branches. Although recruitment is not significant, in some quadrats the existing small trees and trees that were known recorded in 2015 have grown in height substantially and now form part of the upper stratum.

8.3.4 Photo-point Monitoring

All photos taken at photo monitoring points for the current monitoring period are displayed in GeoLINK (2017). 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. Colonisation and/or growth of freshwater species within the Fringing Marsh post closure and initial conversion to open water is also evident.

8.4 Discussion and Comparison with Previous Monitoring

8.4.1 Transect 1 – 3

8.4.1.1 Vegetation Habitat Zonation

Large areas of Fringing Marsh have been replaced by open water as a result closing of the artificial channel in 2012. While still less than the pre-closure extent, the Fringing Marsh has increased since the 2015 monitoring, with freshwater sedges and rushes colonising the open water along the western edge of Salty Lagoon.

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.

8.4.1.2 Species Composition of Vegetation Habitat Zones

There was a minor increase in the overall number of flora species recorded in the three vegetation communities along Transects 1-3 with 58 species detected overall. This is the first increase in species diversity since the baseline monitoring was undertaken in 2011 and is attributed to the lower water levels during the current monitoring event. Total species diversity is still lower than the pre-channel closure monitoring (73 species).

8.4.1.3 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*), Shore Club-rush (*Schoenoplectus subulatus*), Fringe Rush (*Fibrostylus ferruginea*), Broadleaf Cumbungi (*Typha orientalis*) and Enydra (*Enydra fluctuans*), *Cyperus polystachyos* and Brown Beetle Grass (*Diplachne fusca*).

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

8.4.2 Transect 4 – 6

8.4.2.1 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 has caused a shift in species composition of the Fringing Marsh communities in these transects. The Banksia Woodland communities however have been far less affected by comparison, as would be expected.

8.4.2.2 Species Composition of Vegetation Habitat Zones

The overall number of species recorded in the vegetation communities along these transects increased substantially to 41 species (both native and exotic). In comparison 32 species were recorded in 2011 and 28 species in 2015.

8.4.2.3 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 Shore Club-rush (*Schoenoplectus subulatus*) in fringing areas. This reflects the higher water levels and associated stronger freshwater influence following channel closure.

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

8.4.3 Melaleuca Dieback/ Recolonisation Monitoring

There is little evidence of recolonisation of Broad-leaved Paperbark or any further dieback occurring. The overall health of the trees continues to be good, with thick foliage throughout and no signs of stress detected on any trees.

Although recruitment is not significant, in some quadrats the small trees and trees that were recorded in 2015 have grown in height substantially.

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 MPPC program).

9. Conclusion

9.1 Conclusion

This report (Annual Report 2017) summarises the results of the MPPC monitoring undertaken between June 2016 and June 2017, which consists of the final (fifth) post-closure of the artificial channel monitoring period. The monitoring period was subject to atypical climatic periods, characterised by particularly dry weather in spring/summer and very wet periods at other times. This adds to the diverse climatic conditions experienced in the region throughout the MPPC program, allowing for a compressive monitoring program dataset.

The 2016/17 monitoring results has shown that the Salty Lagoon system has continued to move towards a predominantly freshwater lagoon system. Relatively stable water quality conditions were recorded and overall improved system health when compared to pre-channel closure results were recorded. Comparisons between the monitoring results and the predicted changes in Salty Lagoon would be discussed in the Final Evaluation Report.

The erosive headcut to the east of the old artificial channel continues to present a threat to the project. Remediation plans are currently being designed.

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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 (ºC)	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 2016	25/08/16	1	Overcast	20.3 - 22.6	67%	Calm	Yes, 49.6 mm in previous 24 hours	Yes, 49.6 mm in previous 24 hours	Very dark - half moon and cloud	1100	500	400	350	150	50	Closed
	25/08/16	2	Overcast	20.3 - 22.6	67%	Calm	Yes, 49.6 mm in previous 24 hours	Yes, 49.6 mm in previous 24 hours	Very dark - half moon and cloud	700	600	500	400	150	0	Closed
	25/08/16	3	Overcast	20.3 - 22.6	67%	Light	Yes, 49.6 mm in previous 24 hours	Yes, 49.6 mm in previous 24 hours	Very dark - half moon and cloud	700	600	100	50	50	0	Closed
	1/09/16	1	Fine	14.1 - 27.2	70%	Light	No	No	Very dark - no moon	650	500	450	400	250	0	Closed
	1/09/16	2	Fine	14.1 - 27.2	70%	Light	No	No	Very dark - no moon	700	550	550	100	100	0	Closed
	1/09/16	3	Fine	14.1 - 27.2	70%	Light	No	No	Very dark - no moon	700	650	100	100	50	0	Closed

Season	Date	Transect	Weather	Temperature (ºC)	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	
Spring 2016	6/12/16	1	Thunder storms and intermittent light rain during survey.	20.6-37.3 (22.3-23.4 during survey)	97-98 during survey	Calm to moderate (variable during survey: N, S, calm, NW, SSW, NNW - 0 to 20km/ hour)	Light rain during survey. 12.4 mm in previous 24 hours	14.0 mm in previous 72 hours	dark (1/4 moon and overcast)	40	10	10	0	0	0	Closed
	6/12/16	2	Thunder storms and intermittent light rain during survey.	20.6-37.3 (22.3-23.4 during survey)	97-98 during survey	Calm to moderate (variable during survey: N, S, calm, NW, SSW, NNW - 0 to 20km/ hour)	Light rain during survey. 12.4 mm in previous 24 hours	14.0 mm in previous 72 hours	dark (1/4 moon and overcast)	40	15	0	5	0	0	Closed
	6/12/16	3	Thunder storms and intermittent light rain during survey.	20.6-37.3 (22.3-23.4 during survey)	97-98 during survey	Calm to moderate (variable during survey: N, S, calm, NW, SSW, NNW - 0 to 20km/ hour)	Light rain during survey. 12.4 mm in previous 24 hours	14.0 mm in previous 72 hours	dark (1/4 moon and overcast)	50	25	0	0	0	0	Closed
	8/12/16	1	Overcast (pre-storm)	19.5-31.4 (21.0-24.0 during survey)	98-100 during survey	Calm to moderate (variable during survey:	Storm passed mid-survey (11.4 mm).	14.0 mm in previous hours	dark (1/2 moon and overcast)	40	10	10	0	0	0	

Season	Date	Transect	Weather	Temperature (ºC)	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	
						NNE, N, NW, SW, WSW) - 9 to 33km/ hour)	1.6 mm in previous 24 hours									
	8/12/16	2	Thunder storms and intermittent light rain during survey.	19.5-31.4 (21.0-24.0 during survey)	98-100 during survey	Calm to moderate (variable during survey: NNE, N, NW, SW, WSW) - 9 to 33km/ hour)	Storm passed mid-survey (11.4 mm). 1.6 mm in previous 24 hours	14.0 mm in previous hours	dark (1/2 moon and overcast)	40	15	0	5	0	0	
	8/12/16	3	Overcast (post-storm)	19.5-31.4 (21.0-24.0 during survey)	98-100 during survey	Calm to moderate (variable during survey: NNE, N, NW, SW, WSW) - 9 to 33km/ hour)	Storm passed mid-survey (11.4 mm). 1.6 mm in previous 24 hours	14.0 mm in previous hours	dark (1/2 moon and overcast)	50	25	0	0	0	0	
Summer 2017	6/03/17	1	Fine	18.8 - 28.4 (24.3 - 22.6 during survey)	64 - 70 during survey	Moderate (variable during survey: S, SSW - 30 - 39 km/hour)	Yes, however no rain during survey. 4 mm in previous 24 hours	7.0 mm in previous 72 hours	Detail seen - moon and clear sky	50	5	0	0	0	0	Closed

Season	Date	Transect	Weather	Temperature (ºC)	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	
	6/03/17	2	Fine	18.8 - 28.4 (24.3 - 22.6 during survey)	64 - 70 during survey	Moderate (variable during survey: S, SSW - 30 - 39 km/hour)	Yes, however no rain during survey. 4 mm in previous 24 hours	7.0 mm in previous 72 hours	Detail seen - moon and clear sky	45	15	1	0	0	0	Closed
	6/03/17	3	Fine	18.8 - 28.4 (24.3 - 22.6 during survey)	64 - 70 during survey	Moderate (variable during survey: S, SSW - 30 - 39 km/hour)	Yes, however no rain during survey. 4 mm in previous 24 hours	7.0 mm in previous 72 hours	Detail seen - moon and clear sky	40	15	0	0	0	0	Closed
	14/03/17	1	Overcast; rain during the day and immediately prior to survey	19.6 - 25.0 (21.5 - 24.0 during survey)	76 to 95 during survey	Light to moderate (during survey - E to SE 17-30 km/hour)	Yes, no rain during survey and shower immediatel y prior to survey. 52 mm in previous 24 hours	52.4 mm in previous 72 hours	Detail seen - full moon but overcast	60	20	15	5	5	0	Closed
	14/03/17	2	Overcast; rain during the day and immediately prior to	19.6 - 25.0 (21.5 - 24.0 during survey)	76 to 95 during survey	Light to moderate (during survey - E to SE 17-30	Yes, no rain during survey and shower	52.4 mm in previous 72 hours	Detail seen - full moon but overcast	60	35	5	10	0	0	Closed

Season	Date	Transect	Weather	Temperature (ºC)	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	
			survey			km/hour)	immediately prior to survey. 52 mm in previous 24 hours									
	14/03/17	3	Overcast; rain during the day and immediately prior to survey	19.6 - 25.0 (21.5 - 24.0 during survey)	76 to 95 during survey	Light to moderate (during survey - E to SE 17-30 km/hour)	Yes, no rain during survey and shower immediately prior to survey. 52 mm in previous 24 hours	52.4 mm in previous 72 hours	Detail seen - full moon but overcast	60	35	0	0	0	0	Closed

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

Table A2 Point Count Survey Results

Transect No. and Survey Data	Point Count No.	Habitat Type	Species Count																						
Species Name			*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peroni*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		*Litoria gracilenta*		**Total**
Winter																									
Census 1:			Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	**Total**
T1: 25/08/16 6:12 pm - 7:15 pm	1	Open Water	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T1: 25/08/16 6:12 pm - 7:15 pm	2	Open Water (with emergent rushes)	0	No	0	No	0	No	0	No	2	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**2**
T1: 25/08/16 6:12 pm - 7:15 pm	3	Open Water / Fringing Marsh Ecotone	0	No	0	No	0	No	0	No	4	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**4**
T1: 25/08/16 6:12 pm - 7:15 pm	4	Swamp Forest	0	No	0	No	0	No	0	No	2	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**2**
T1: 25/08/16 6:12 pm - 7:15 pm	5	Sedge Swamp	2	Yes	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**2**
T1: 25/08/16 6:12 pm - 7:15 pm	6	Sedge Swamp	0	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T2 25/08/16 7:30 pm - 8:40 pm	1	Open Water	0	No	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T2 25/08/16 7:30 pm - 8:40 pm	2	Open Water (with emergent rushes)	0	No	0	No	0	No	0	No	2	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**2**
T2 25/08/16 7:30 pm - 8:40 pm	3	Fringing Marsh/ Swamp Forest Ecotone	0	No	0	No	0	No	0	No	5	Yes	0	Yes	0	No	0	No	0	No	0	No	0	No	**5**
T2 25/08/16 7:30 pm - 8:40 pm	4	Swamp Forest	0	No	0	No	0	No	0	No	0	Yes	0	Yes	0	No	0	No	0	No	0	No	0	No	**0**
T2 25/08/16 7:30 pm - 8:40 pm	5	Sedge Swamp	0	No	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T2 25/08/16 7:30 pm - 8:40 pm	6	Sedge Swamp	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T3 25/08/16 9:10 pm - 10.00 pm	1	Open Water	0	No	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**0**

Transect No. and Survey Data	Point Count No.	Habitat Type	Species Count																						
Species Name			***Crinia tinnula***		***Litoria peronii***		***Crinia signifera***		***Limnodynastes peroni***		***Litoria fallax***		***Litoria tyleri***		***Litoria olongburensis***		***Litoria latopalmata***		***Litoria nasuta***		***Litoria dentata***		***Litoria gracilenta***		**Total**
T3 25/08/16 9:10 pm - 10.00 pm	2	Open Water / Fringing Marsh Ecotone	0	No	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T3 25/08/16 9:10 pm - 10.00 pm	3	Swamp Forest	0	No	0	No	1	Yes	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**1**
T3 25/08/16 9:10 pm - 10.00 pm	4	Swamp Forest	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T3 25/08/16 9:10 pm - 10.00 pm	5	Sedge Swamp	0	No	0	No	0	No	0	No	1	No	0	No	0	No	0	No	0	No	0	No	0	No	**1**
T3 25/08/16 9:10 pm - 10.00 pm	6	Sedge Swamp	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
C1 Total			**2**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**16**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**19**
Species Name			***Crinia tinnula***		***Litoria peronii***		***Crinia signifera***		***Limnodynastes peroni***		***Litoria fallax***		***Litoria tyleri***		***Litoria olongburensis***		***Litoria latopalmata***		***Litoria nasuta***		***Litoria dentata***		***Litoria gracilenta***		
Census 2:			Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	**Total**
T1: 1/09/16 6pm - 7:10pm	1	Open Water	0	No	0	No	0	No	0	No	0	Yes	0	Yes	0	No	0	No	0	No	0	No	0	No	**0**
T1: 1/09/16 6pm - 7:10pm	2	Open Water (with emergent rushes)	0	No	0	No	0	No	0	Yes	2	Yes	0	Yes	0	No	0	No	0	No	0	No	0	No	**2**
T1: 1/09/16 6pm - 7:10pm	3	Open Water / Fringing Marsh Ecotone	0	No	0	No	0	No	0	No	8	Yes	7	Yes	0	No	0	No	0	No	0	No	0	No	**15**
T1: 1/09/16 6pm - 7:10pm	4	Swamp Forest	0	No	0	No	0	No	0	No	2	Yes	2	Yes	0	No	0	No	0	No	0	No	0	No	**4**
T1: 1/09/16 6pm - 7:10pm	5	Sedge Swamp	4	Yes	0	No	0	No	0	No	2	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**6**
T1: 1/09/16 6pm - 7:10pm	6	Sedge Swamp	0	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T2: 1/09/16 7.30pm - 9.00 pm	1	Open Water	0	No	0	No	0	No	0	No	0	Yes	0	Yes	0	No	0	No	0	No	0	No	0	No	**n/a**
T2: 1/09/16 7.30pm - 9.00 pm	2	Open Water (with emergent rushes)	0	No	0	No	0	No	0	No	3	Yes	2	Yes	0	No	0	No	0	No	0	No	0	No	**5**
T2: 1/09/16 7.30pm - 9.00 pm	3	Fringing Marsh/ Swamp Forest Ecotone	0	No	0	No	0	No	0	No	14	Yes	7	Yes	0	No	0	No	0	No	0	No	0	No	**21**

Transect No. and Survey Data	Point Count No.	Habitat Type	Species Count																						
Species Name			*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peroni*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		*Litoria gracilenta*		**Total**
T2: 1/09/16 7.30pm - 9.00 pm	4	Swamp Forest	0	No	0	No	0	No	0	No	4	Yes	6	Yes	0	No	0	No	0	No	0	No	0	No	**10**
T2: 1/09/16 7.30pm - 9.00 pm	5	Sedge Swamp	0	No	0	No	0	No	2	No	2	Yes	0	Yes	0	No	0	No	0	No	0	No	0	No	**4**
T2: 1/09/16 7.30pm - 9.00 pm	6	Sedge Swamp	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T3: 1/09/16 9:40pm - 10:55 pm	1	Open Water	0	No	0	No	0	No	0	No	0	Yes	0	Yes	0	No	0	No	0	No	0	No	0	No	**0**
T3: 1/09/16 9:40pm - 10:55 pm	2	Open Water / Fringing Marsh Ecotone	0	No	0	No	0	No	0	No	3	Yes	0	Yes	0	No	0	No	0	No	0	No	0	No	**3**
T3: 1/09/16 9:40pm - 10:55 pm	3	Swamp Forest	0	No	0	No	0	No	0	No	3	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**3**
T3: 1/09/16 9:40pm - 10:55 pm	4	Swamp Forest	0	No	0	No	2	No	1	Yes	1	Yes	0	Yes	0	No	0	No	0	No	0	No	0	No	**4**
T3: 1/09/16 9:40pm - 10:55 pm	5	Sedge Swamp	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T3: 1/09/16 9:40pm - 10:55 pm	6	Sedge Swamp	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
C2 Total			**4**	**0**	**0**	**0**	**2**	**0**	**3**	**0**	**44**	**0**	**24**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**77**
Winter Total			**6**	**0**	**0**	**0**	**3**	**0**	**3**	**0**	**60**	**0**	**24**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**96**
Spring																									
Census 1:			Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	**Total**
T1: 06/12/16 7.40 pm	1	Open Water	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T1: 06/12/16 7:50 pm	2	Open Water (with emergent rushes)	0	No	0	No	0	No	0	No	1	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**1**
T1: 06/12/16 8:05 pm	3	Open Water / Fringing Marsh Ecotone	0	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T1: 06/12/16 8:15 pm	4	Swamp Forest	0	Yes	0	No	0	No	0	No	2	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**2**

Transect No. and Survey Data	Point Count No.	Habitat Type	Species Count																						
Species Name			*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peroni*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		*Litoria gracilenta*		**Total**
T1: 06/12/16 8:25 pm	5	Sedge Swamp	1	Yes	0	No	0	No	0	No	2	Yes	0	Yes	0	No	0	No	0	No	0	No	0	No	**3**
T1: 06/12/16 68:40 pm	6	Sedge Swamp	1	Yes	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**1**
T2 06/12/16 10:50 pm	1	Open Water	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T2 06/12/16 10:40 pm	2	Open Water (with emergent rushes)	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	3	Yes	0	No	0	No	**3**
T2 06/12/16 10:10 pm	3	Fringing Marsh/ Swamp Forest Ecotone	0	No	0	No	0	No	0	No	1	Yes	0	No	0	No	0	No	1	Yes	0	No	0	No	**2**
T2 06/12/16 9:50 pm	4	Swamp Forest	0	No	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T2 06/12/16 9:30 pm	5	Sedge Swamp	0	No	0	No	0	No	0	No	2	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**2**
T2 06/12/16 9:10 pm	6	Sedge Swamp	0	No	0	No	0	No	0	No	4	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**4**
T3 06/12/16 10:50 pm	1	Open Water	0	No	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	**0**
T3 06/12/16 11:00 pm	2	Open Water / Fringing Marsh Ecotone	0	No	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T3 06/12/16 11:10 pm	3	Swamp Forest	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T3 06/12/16 11:20 pm	4	Swamp Forest	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T3 06/12/16 11:40 pm	5	Sedge Swamp	0	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T3 06/12/16 11:50 pm	6	Sedge Swamp	0	Yes	0	No	0	No	0	No	0	Yes	0	No	1	No	0	No	0	No	0	No	0	No	**1**
C1 TOTAL			**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**12**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**4**	**0**	**0**	**0**	**0**	**0**	**19**
Species Name			*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peroni*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		*Litoria gracilenta*		
Census 2:			Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	**Total**
T1: 8/12/16 7:35 pm	1	Open Water	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T1: 8/12/16 7:44 pm	2	Open Water (with emergent rushes)	0	No	0	No	0	No	0	No	1	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**1**

Transect No. and Survey Data	Point Count No.	Habitat Type	Species Count																						
Species Name			***Crinia tinnula***		***Litoria peronii***		***Crinia signifera***		***Limnodynastes peroni***		***Litoria fallax***		***Litoria tyleri***		***Litoria olongburensis***		***Litoria latopalmata***		***Litoria nasuta***		***Litoria dentata***		***Litoria gracilenta***		**Total**
T1: 8/12/16 7:55 pm	3	Open Water / Fringing Marsh Ecotone	0	No	0	No	0	No	0	No	1	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	**1**
T1: 8/12/16 8:05 pm	4	Swamp Forest	0	No	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	**0**
T1: 8/12/16 8:20 pm	5	Sedge Swamp	1	Yes	0	No	0	No	0	No	0	Yes	0	No	0	Yes	0	No	0	Yes	0	No	0	No	**1**
T1: 8/12/16 8:30 pm	6	Sedge Swamp	2	Yes	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**2**
T2: 24/11/15 10:15 pm	1	Open Water	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T2: 8/12/16 10:00 pm	2	Open Water (with emergent rushes)	0	No	0	No	0	No	0	Yes	0	Yes	0	No	0	No	0	No	1	Yes	0	No	0	No	**1**
T2: 8/12/16 9:50 pm	3	Fringing Marsh/ Swamp Forest Ecotone	0	No	0	No	0	No	0	No	2	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	**2**
T2: 8/12/16 9:40 pm	4	Swamp Forest	0	No	0	No	0	No	0	No	8	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**8**
T2: 8/12/16 9:30 pm	5	Sedge Swamp	2	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**2**
T2: 8/12/16 9:05 pm	6	Sedge Swamp	2	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**2**
T3: 8/12/16 10:30 pm	1	Open Water	0	No	0	No	0	No	0	Yes	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T3: 8/12/16 10:40 pm	2	Open Water / Fringing Marsh Ecotone	0	No	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	**0**
T3: 8/12/16 10:50 pm	3	Swamp Forest	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T3: 8/12/16 11:10 pm	4	Swamp Forest	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T3: 8/12/16 11:20 pm	5	Sedge Swamp	0	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T3: 8/12/16 11:30 pm	6	Sedge Swamp	2	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**2**
C2 Total			**9**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**12**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**22**
SPRING TOTAL			**18**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**24**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**44**

Transect No. and Survey Data	Point Count No.	Habitat Type	Species Count																						
Species Name			***Crinia tinnula***		***Litoria peronii***		***Crinia signifera***		***Limnodynastes peroni***		***Litoria fallax***		***Litoria tyleri***		***Litoria olongburensis***		***Litoria latopalmata***		***Litoria nasuta***		***Litoria dentata***		***Litoria gracilenta***		**Total**
Summer																									
Species Name		**fringe**	***Crinia tinnula***		***Litoria peronii***		***Crinia signifera***		***Limnodynastes peroni***		***Litoria fallax***		***Litoria tyleri***		***Litoria olongburensis***		***Litoria latopalmata***		***Litoria nasuta***		***Litoria dentata***		***Litoria gracilenta***		
Census 1:			Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	**Total**
T1:06/03/17 7:35 pm	1	Open Water	0	No	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	**0**
T1:06/03/17 7:50 pm	2	Open Water (with emergent rushes)	0	No	0	No	0	No	1	Yes	7	Yes	0	No	0	No	0	No	3	Yes	0	No	0	No	**11**
T1:06/03/17 8:00 pm	3	Fringing Marsh/ Swamp Forest Ecotone	0	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	**0**
T1:06/03/17 8:10 pm	4	Swamp Forest/Sedge Swamp	1	No	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	**1**
T1:06/03/17 8:20 pm	5	Sedge Swamp	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T1:06/03/17 8:55 pm	6	Sedge Swamp	1	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**1**
T2: 06/03/17 10:15 pm	1	Open Water (with emergent rushes)	0	No	0	No	0	No	0	No	3	Yes	0	No	0	No	0	No	3	Yes	0	No	0	No	**6**
T2: 06/03/17 9:46 pm	2	Open Water (with emergent rushes and fringing marsh)	0	No	0	No	0	No	6	Yes	15	Yes	0	No	0	No	0	No	13	Yes	0	No	0	No	**34**
T2: 06/03/17 9:35 pm	3	Fringing Marsh/ Swamp Forest Ecotone	0	No	0	No	0	No	3	Yes	4	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	**7**
T2: 06/03/17 9:20 pm	4	Swamp Forest	0	No	0	No	0	No	2	Yes	0	Yes	0	Yes	0	No	0	No	0	No	0	No	0	No	**2**
T2: 06/03/17 9:10 pm	5	Sedge Swamp	1	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**1**
T2: 06/03/17 8:55 pm	6	Sedge Swamp	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T3: 06/03/17 10:30 pm	1	Open Water (with emergent rushes and fringing marsh)	0	No	0	No	0	No	0	No	8	Yes	0	No	0	No	0	No	9	Yes	0	No	0	No	**17**
T3: 06/03/17 10:43 pm	2	Open Water / Fringing Marsh Ecotone	0	No	0	No	0	No	1	No	11	Yes	0	No	0	No	0	No	8	Yes	0	No	0	No	**20**

Transect No. and Survey Data	Point Count No.	Habitat Type	Species Count																						
Species Name			*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peroni*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		*Litoria gracilenta*		**Total**
T3: 06/03/17 10:55 pm	3	Swamp Forest	0	No	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T3: 06/03/17 11:05 pm	4	Swamp Forest	0	No	0	No	0	No	0	No	2	No	0	No	0	No	0	No	0	No	0	No	0	No	**2**
T3: 06/03/17 11:18 pm	5	Sedge Swamp	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T3: 06/03/17 11:27 pm	6	Sedge Swamp	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
C2 Total			**3**	**0**	**0**	**0**	**0**	**0**	**13**	**0**	**50**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**36**	**0**	**0**	**0**	**0**	**0**	**102**
Species Name			*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peroni*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		*Litoria gracilenta*		
Census 2:			Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	Within 20 m	20 - 50 m	**Total**
T1: 14/03/17 11:25 pm	1	Open Water	0	No	0	No	0	No	0	No	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T1: 14/03/17 11:15 pm	2	Open Water (with emergent rushes)	0	No	0	No	0	No	0	No	8	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**8**
T1: 14/03/17 11:05 pm	3	Fringing Marsh/ Swamp Forest Ecotone	4	Yes	0	No	1	Yes	3	Yes	2	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**10**
T1: 14/03/17 10:50 pm	4	Swamp Forest/Sedge Swamp	7	Yes	0	No	2	Yes	0	No	1	No	0	No	0	No	0	No	0	No	0	No	0	No	**10**
T1: 14/03/17 10:40 pm	5	Sedge Swamp	4	Yes	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**4**
T1: 14/03/17 10:30 pm	6	Sedge Swamp	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T2: 14/03/17 8:50 pm	1	Open Water (with emergent rushes)	0	No	0	No	0	No	0	No	3	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	**3**
T2: 14/03/17 9:05 pm	2	Open Water (with emergent rushes and fringing marsh)	0	No	0	No	0	No	2	No	13	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	**15**
T2: 14/03/17 9:20 pm	3	Fringing Marsh/ Swamp Forest Ecotone	0	No	0	No	2	Yes	2	No	6	Yes	3	Yes	0	No	0	No	0	No	0	No	0	No	**13**
T2: 14/03/17 9:35 pm	4	Swamp Forest	0	No	0	No	0	No	1	Yes	3	Yes	0	Yes	0	No	0	No	0	No	0	No	0	No	**4**
T2: 14/03/17 9:50 pm	5	Sedge Swamp	4	Yes	0	No	0	No	0	No	1	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**5**

Transect No. and Survey Data	Point Count No.	Habitat Type	Species Count																						
Species Name			***Crinia tinnula***		***Litoria peronii***		***Crinia signifera***		***Limnodynastes peroni***		***Litoria fallax***		***Litoria tyleri***		***Litoria olongburensis***		***Litoria latopalmata***		***Litoria nasuta***		***Litoria dentata***		***Litoria gracilenta***		**Total**
T2: 14/03/17 10:00 pm	6	Sedge Swamp	3	Yes	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**3**
T3: 14/03/17 8:30 pm	1	Open Water (with emergent rushes and fringing marsh)	0	No	0	No	0	No	0	No	5	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**5**
T3: 14/03/17 8:20 pm	2	Open Water / Fringing Marsh Ecotone	0	No	0	No	0	No	0	No	7	Yes	0	No	0	No	0	No	4	Yes	0	No	0	No	**11**
T3: 14/03/17 8:10 pm	3	Swamp Forest	0	No	0	No	1	No	0	No	2	Yes	0	No	0	No	0	No	0	Yes	0	No	0	No	**3**
T3: 14/03/17 7:55 pm	4	Swamp Forest	0	No	0	No	0	No	0	No	2	Yes	0	No	0	No	0	No	0	No	0	No	0	No	**2**
T3: 14/03/17 7:40 pm	5	Sedge Swamp	0	Yes	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	**0**
T3: 14/03/17 7:30 pm	6	Sedge Swamp	3	Yes	0	No	0	No	0	No	0	No	0	No	0	No	0	No	0	No	1	Yes	0	No	**4**
C2 Total			**25**	**0**	**0**	**0**	**6**	**0**	**8**	**0**	**53**	**0**	**3**	**0**	**0**	**0**	**0**	**0**	**4**	**0**	**1**	**0**	**0**	**0**	**100**
SUMMER TOTAL			**28**	**0**	**0**	**0**	**6**	**0**	**21**	**0**	**103**	**0**	**3**	**0**	**0**	**0**	**0**	**0**	**40**	**0**	**1**	**0**	**0**	**0**	**202**
Overall Total			**45**	**0**	**0**	**0**	**9**	**0**	**24**	**0**	**187**	**0**	**27**	**0**	**1**	**0**	**0**	**0**	**45**	**0**	**1**	**0**	**0**	**0**	**339**

Table A3 Wallum Froglet and Dwarf Tree Frog Comparison Results

Date	*Species*	*Transect*	*Season*	*Easting*	*Northing*
25/08/2016	*Crinia tinnula*	1	Winter	541693	6783150
25/08/2016	*Crinia tinnula*	1	Winter	541587	6783220
25/08/2016	*Litoria fallax*	1	Winter	541860	6783050
25/08/2016	*Litoria fallax*	1	Winter	541836	6783060
25/08/2016	*Litoria fallax*	1	Winter	541639	6783180
25/08/2016	*Litoria fallax*	1	Winter	541774	6783100
25/08/2016	*Litoria fallax*	2	Winter	541771	6782830
25/08/2016	*Litoria fallax*	2	Winter	541938	6782850
25/08/2016	*Litoria fallax*	2	Winter	541825	6782840
25/08/2016	*Litoria fallax*	2	Winter	541583	6782780
25/08/2016	*Litoria fallax*	2	Winter	541659	6782810
25/08/2016	*Litoria fallax*	3	Winter	542063	6782600
25/08/2016	*Litoria fallax*	3	Winter	541969	6782570
1/09/2016	*Crinia tinnula*	3	Winter	541607	6782440
1/09/2016	*Litoria fallax*	1	Winter	541920	6783020
1/09/2016	*Litoria fallax*	1	Winter	541866	6783050
1/09/2016	*Litoria fallax*	1	Winter	541824	6783060
1/09/2016	*Litoria fallax*	1	Winter	541686	6783150
1/09/2016	*Litoria fallax*	1	Winter	541657	6783170
1/09/2016	*Litoria fallax*	1	Winter	541787	6783080
1/09/2016	*Litoria fallax*	2	Winter	541783	6782830
1/09/2016	*Litoria fallax*	2	Winter	541940	6782850
1/09/2016	*Litoria fallax*	2	Winter	541828	6783070
1/09/2016	*Litoria fallax*	2	Winter	541569	6782780
1/09/2016	*Litoria fallax*	2	Winter	541681	6782820
1/09/2016	*Litoria fallax*	3	Winter	542057	6782600

Date	Species	Transect	Season	Easting	Northing
1/09/2016	*Litoria fallax*	3	Winter	541987	6782570
1/09/2016	*Litoria fallax*	3	Winter	541809	6782500
1/09/2016	*Litoria fallax*	3	Winter	541722	6782490
6/12/2016	*Crinia tinnula*	1	Spring	541566	6783260
6/12/2016	*Crinia tinnula*	1	Spring	541551	6783250
6/12/2016	*Crinia tinnula*	1	Spring	541672	6783160
6/12/2016	*Crinia tinnula*	1	Spring	541724	6783140
6/12/2016	*Crinia tinnula*	1	Spring	541638	6783200
6/12/2016	*Crinia tinnula*	3	Spring	541535	6782430
6/12/2016	*Crinia tinnula*	3	Spring	541602	6782420
6/12/2016	*Litoria fallax*	1	Spring	541881	6783050
6/12/2016	*Litoria fallax*	1	Spring	541868	6783060
6/12/2016	*Litoria fallax*	1	Spring	541807	6783070
6/12/2016	*Litoria fallax*	1	Spring	541742	6783120
6/12/2016	*Litoria fallax*	1	Spring	541758	6783100
6/12/2016	*Litoria fallax*	1	Spring	541672	6783160
6/12/2016	*Litoria fallax*	1	Spring	541681	6783140
6/12/2016	*Litoria fallax*	3	Spring	541987	6782580
6/12/2016	*Litoria fallax*	3	Spring	541569	6782450
6/12/2016	*Litoria fallax*	3	Spring	541612	6782460
6/12/2016	*Litoria fallax*	3	Spring	542064	6782600
8/12/2016	*Crinia tinnula*	1	Spring	541672	6783160
8/12/2016	*Crinia tinnula*	1	Spring	541551	6783250
8/12/2016	*Crinia tinnula*	1	Spring	541545	6783220
8/12/2016	*Crinia tinnula*	1	Spring	541672	6783180
8/12/2016	*Crinia tinnula*	2	Spring	541415	6782750
8/12/2016	*Crinia tinnula*	2	Spring	541523	6782770

Date	Species	Transect	Season	Easting	Northing
8/12/2016	*Crinia tinnula*	2	Spring	541610	6782800
8/12/2016	*Crinia tinnula*	2	Spring	541421	6782790
8/12/2016	*Crinia tinnula*	2	Spring	541499	6782790
8/12/2016	*Crinia tinnula*	3	Spring	541533	6782410
8/12/2016	*Crinia tinnula*	3	Spring	541550	6782420
8/12/2016	*Crinia tinnula*	3	Spring	541578	6782410
8/12/2016	*Litoria fallax*	1	Spring	541881	6783050
8/12/2016	*Litoria fallax*	1	Spring	541845	6783050
8/12/2016	*Litoria fallax*	1	Spring	541810	6783080
8/12/2016	*Litoria fallax*	1	Spring	541828	6783090
8/12/2016	*Litoria fallax*	1	Spring	541761	6783110
8/12/2016	*Litoria fallax*	1	Spring	541718	6783130
8/12/2016	*Litoria fallax*	2	Spring	541749	6782820
8/12/2016	*Litoria fallax*	2	Spring	541690	6782800
8/12/2016	*Litoria fallax*	2	Spring	541598	6782790
8/12/2016	*Litoria fallax*	2	Spring	541489	6782740
8/12/2016	*Litoria fallax*	2	Spring	541921	6782850
8/12/2016	*Litoria fallax*	2	Spring	541850	6782840
8/12/2016	*Litoria fallax*	2	Spring	541805	6782830
8/12/2016	*Litoria fallax*	3	Spring	541501	6782410
8/12/2016	*Litoria fallax*	3	Spring	541628	6782440
8/12/2016	*Litoria fallax*	3	Spring	541920	6782560
8/12/2016	*Litoria fallax*	3	Spring	542061	6782580
6/03/2017	*Crinia tinnula*	1	Summer	541551	6783250
6/03/2017	*Crinia tinnula*	1	Summer	541742	6783120
6/03/2017	*Crinia tinnula*	2	Summer	541415	6782750
6/03/2017	*Litoria fallax*	1	Summer	541881	6783050

Date	Species	Transect	Season	Easting	Northing
6/03/2017	*Litoria fallax*	1	Summer	541896	6783040
6/03/2017	*Litoria fallax*	2	Summer	541935	6782850
6/03/2017	*Litoria fallax*	2	Summer	541601	6782800
6/03/2017	*Litoria fallax*	2	Summer	541964	6782860
6/03/2017	*Litoria fallax*	2	Summer	541929	6782850
6/03/2017	*Litoria fallax*	2	Summer	541869	6782840
6/03/2017	*Litoria fallax*	2	Summer	541850	6782840
6/03/2017	*Litoria fallax*	2	Summer	541791	6782830
6/03/2017	*Litoria fallax*	2	Summer	541749	6782820
6/03/2017	*Litoria fallax*	3	Summer	541973	6782560
6/03/2017	*Litoria fallax*	3	Summer	542037	6782590
6/03/2017	*Litoria fallax*	3	Summer	542075	6782620
6/03/2017	*Litoria fallax*	3	Summer	541698	6782490
6/03/2017	*Litoria fallax*	3	Summer	541829	6782510
6/03/2017	*Litoria fallax*	3	Summer	541860	6782530
6/03/2017	*Litoria fallax*	3	Summer	541902	6782560
6/03/2017	*Litoria fallax*	3	Summer	541947	6782570
14/03/2017	*Crinia tinnula*	1	Summer	541732	6783130
14/03/2017	*Crinia tinnula*	1	Summer	541788	6783090
14/03/2017	*Crinia tinnula*	2	Summer	541415	6782750
14/03/2017	*Crinia tinnula*	2	Summer	541448	6782760
14/03/2017	*Crinia tinnula*	2	Summer	541523	6782770
14/03/2017	*Crinia tinnula*	2	Summer	541551	6782780
14/03/2017	*Crinia tinnula*	3	Summer	541533	6782410
14/03/2017	*Crinia tinnula*	3	Summer	541564	6782430
14/03/2017	*Crinia tinnula*	3	Summer	541672	6783160
14/03/2017	*Crinia tinnula*	3	Summer	541742	6783120

Date	Species	Transect	Season	Easting	Northing
14/03/2017	*Crinia tinnula*	3	Summer	541810	6783080
14/03/2017	*Crinia tinnula*	3	Summer	541760	6783110
14/03/2017	*Litoria fallax*	2	Summer	541609	6782800
14/03/2017	*Litoria fallax*	2	Summer	541964	6782860
14/03/2017	*Litoria fallax*	2	Summer	541850	6782840
14/03/2017	*Litoria fallax*	2	Summer	541749	6782820
14/03/2017	*Litoria fallax*	2	Summer	541523	6782770
14/03/2017	*Litoria fallax*	2	Summer	541640	6782810
14/03/2017	*Litoria fallax*	2	Summer	541675	6782810
14/03/2017	*Litoria fallax*	2	Summer	541777	6782830
14/03/2017	*Litoria fallax*	2	Summer	541813	6782840
14/03/2017	*Litoria fallax*	2	Summer	541878	6782840
14/03/2017	*Litoria fallax*	3	Summer	541863	6782520
14/03/2017	*Litoria fallax*	3	Summer	542075	6782620
14/03/2017	*Litoria fallax*	3	Summer	542055	6782600
14/03/2017	*Litoria fallax*	3	Summer	541999	6782580
14/03/2017	*Litoria fallax*	3	Summer	541947	6782570
14/03/2017	*Litoria fallax*	3	Summer	541926	6782550
14/03/2017	*Litoria fallax*	3	Summer	541882	6782540
14/03/2017	*Litoria fallax*	3	Summer	541829	6782510
14/03/2017	*Litoria fallax*	3	Summer	541698	6782490
14/03/2017	*Litoria fallax*	3	Summer	541660	6782460
14/03/2017	*Litoria fallax*	3	Summer	541742	6783120
14/03/2017	*Litoria fallax*	3	Summer	541810	6783080
14/03/2017	*Litoria fallax*	3	Summer	541881	6783050
14/03/2017	*Litoria fallax*	3	Summer	541862	6783060
14/03/2017	*Litoria fallax*	3	Summer	541833	6783070