Annual Report 2013

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

quality solutions sustainable future

This page has been intentionally left blank.

Annual Report 2013

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

Prepared for: Richmond Valley Council

GeoLINK
environmental management and design

PO Box 119
Lennox Head NSW 2478
T 02 6687 7666

PO Box 1446
Coffs Harbour NSW 2450
T 02 6651 7666

info@geolink.net.au

UPR	*Description*	*Date Issued*	*Issued By*
1731-1071	First issue	30/07/2013	TJP / MB
1731-1081	Second issue	20/08/2013	TJP
1731-1082	Third issue	21/08/2013	TJP

Table of Contents

Illustrations

Tables

Plates

Appendices

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 2013*) summarises the results of the MPPC monitoring undertaken between June 2012 and May 2013, which comprises the early post-closure of the artificial channel monitoring period. Key findings include:

Water Quality (monitored at Salty Lagoon and Salty Creek)

- *Water Level*: Since the artificial channel was closed permanently on 19 June 2012 the water level in Salty Lagoon has stabilised considerably. During this reporting period the entrance was relatively stable in comparison with the 2011 – 2012 reporting period (5 or 6 opening events in comparison with 17).
- *Conductivity*: the conductivity measurements from the Salty Lagoon PWQMS were much less variable throughout this reporting period as a result of the closure of the artificial channel and the reduced incidence of saltwater ingress from Salty Creek. The Salty Creek PWQMS recorded substantially wider fluctuations in conductivity, reflecting Salty Creek mouth opening events and saltwater ingress.
- *Dissolved Oxygen*: Dissolved Oxygen (DO) concentrations measured at the Salty Lagoon PWQMS fluctuated regularly throughout the year. Dissolved Oxygen (DO) concentrations measured at the Salty Creek PWQMS tended to be more stable than those measured at the Salty Lagoon PWQMS. The key processes impacting upon the DO concentration are light availability, water level, mixing and saltwater ingress. In Salty Lagoon the DO concentration was 6 mg/L or less on approximately 82% of occasions and the DO concentration was 1mg/L or less on approximately 34% of occasions. These figures are higher than the previous figures reported in the ERMP. In effect, the DO concentrations at the level of the sonde are at low levels more often than they have been in the past. There are a number of factors that may be contributing to this, including:
  - the higher water level since the closure of the artificial channel. This has led to more frequent incidences of low light penetration to the bottom of the water column and a lower likelihood that wind driven mixing will impact upon the entire water column;
  - the reduction in flow since closure of the artificial channel. This means that flow driven mixing is less likely;
  - the ecosystem changes, including vegetation decomposition, occurring in Salty Lagoon in response to the closure of the artificial channel. These changes may be resulting in increased oxygen consumption throughout the lagoon while they are occurring; and
  - a lower likelihood that saline water at the bottom of the water column, which tends to be associated with low DO concentrations in Salty Lagoon, will be flushed out in low flow events.
- *pH*: fluctuations in the pH measured at the Salty Lagoon PWQMS have not been as frequent or large as they had been prior to the closure of the artificial channel. However, the processes that drive these fluctuations remain the same. These are runoff from the catchment, effluent discharge from the Evans Head STP and seawater ingress. The pH measurements from the Salty Creek PWQMS tend to fluctuate more than those from Salty Lagoon. The key to this fluctuation is the increased influence of swamp forests in the catchment of Salty Creek.
- *Temperature*: fluctuated according to both daily and seasonal patterns, however, daily fluctuations tended to reduce in magnitude as water levels become higher following the closure of the artificial channel.
- *Turbidity*: turbidity measurements fluctuated widely throughout the monitoring period. Higher turbidity measurements tended to occur following heavy rainfall, strong winds and saltwater ingress.
- *Nitrogen*: some of the factors impacting nitrogen concentrations in Salty Lagoon and Salty Creek include seawater ingress, tidal movements and rainfall runoff. Effluent discharge from the Evans Head STP does not appear to be a factor that strongly influences nitrogen concentrations in Salty Lagoon. Results from this reporting period are not conclusive.

- *Phosphorus*: concentrations have fluctuated from month to month with no clear trend apparent. One of the major factors influencing the long term concentration of phosphorus is discharge from the Evans Head STP.
- *Chlorophyll-a*: Chlorophyll-a concentrations were low for the majority of the reporting period. Median concentrations were the same at all sites. There were no clear trends in terms of spatial variation, although the highest concentrations were generally recorded in the summer months.
- *Blue Green Algae*: despite increases in the concentrations of bioavailable phosphorus and nitrogen at some sites, blue green algae were not detected in any samples during the current reporting period.
- *Faecal Indicator Organisms*: in general, enterococcus and faecal coliform concentrations were 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 strongly influencing the concentrations of faecal indicator organisms.
- *STP Discharge Monitoring*: all results for the entire monitoring period were within the licensing limits set for the Evans Head STP by the EPA.

Macroinvertebrates

- A total of 18 macroinvertebrate taxa were recorded.
- The diversity of taxa in macroinvertebrate samples varied between sites and 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. This was also the case in the previous 2011-2012 monitoring period. As the environment stabilises following closure of the artificial channel it is forecast that benthic macroinvertebrate communities will become more robust and more diverse.

Aquatic Vegetation / Weeds

- No introduced species of aquatic weeds have been in the current monitoring period.
- Of the 26 aquatic plant types observed during the surveys, only two are considered to have the potential to become nuisance plants in Salty Lagoon: blue green algae (BGA) and Ferny Azolla.
- BGA has only been present in small scattered occurrences (Spring 2012) and there have not been any observations indicative of algal blooms.
- Following a peak of Ferny Azolla abundance recorded in the previous 2011-2012 monitoring period, this species returned to being recorded as uncommon in the current monitoring period.

Fish

- In general, the abundance and diversity (five species in total) of species trapped was low, with wide variation in the number of fish captured at each site over time. A reduction in species diversity when compared with the previous monitoring period (from 8 to 5 species) indicates that fish abundance and diversity may have reduced for a period following channel closure before beginning to recover.

Waterfowl

- The diversity of species observed in waterbird surveys undertaken during the current reporting period has been relatively consistent in terms of the number of species observed. The greatest diversity of species was observed during the summer survey. This is consistent with previous years when high species diversity has been observed in the summer and spring. In terms of changes before and after the closure of the artificial channel the average recorded species diversity has been higher following closure of the artificial channel. In addition, higher species numbers have been observed in each of the seasons (when compared with the same season in the previous 2011-2012 monitoring period, with the exception of the spring survey. As was predicted in the previous annual report, closure of the artificial channel appears to have led to stabilisation of waterbird numbers over time as fluctuations in mud-flat habitat is no longer a significant factor influencing waterbirds.

Terrestrial Vegetation

- The main change to occur in the location of the vegetation communities occurring on the western edge of Salty Lagoon since the previous monitoring period in 2011 is the reduction in the extent of the Fringing Marsh community. This can be directly attributed to the closure of the artificial channel leading to higher water levels and inundation of some area previously covered by Fringing Marsh and conversion to open water.
- Species dominance was relatively stable between monitoring events, with the same species dominating each of the 3 vegetation communities.
- A reduction in the diversity of plants in the Swamp Forest most likely reflects the proximity of this site to areas that are currently mostly open water, and the inundation of understorey herbaceous species in this part of the site since the closure of the artificial channel.
- There are some early indications of an increase in the number of Melaleuca seedlings, particularly at Transect 1. However, as the artificial channel closure occurred relatively recently, this trend will not be confirmed until more time has elapsed and the changes in the water levels have stabilised. The overall health of the existing Broad-leaved Paperbark was observed to be good, with no trees in an obvious state of decline. This would seem to indicate that the dieback event is no longer occurring and that this species should remain at its current extent or increase its extent over time.
- In relation to predicted changes the following points are noted:
  - as predicted there has been a decrease in cover of Sea Rush in the Swamp Forest and Fringing Marsh communities, but most noticeably in the Fringing Marsh (however, this trend was not apparent on the eastern shore of the lagoon). This is attributable to the greater degree of inundation closer to the lagoon.
  - A similar pattern to that seen for Sea Rush has also occurred with Saltwater Couch.
  - Shore Club-rush was not recorded in the Swamp Forest community in either the MPCC vegetation monitoring or the 2013 monitoring. This species was not recorded at a high density in the MPCC vegetation monitoring. Nonetheless, this species has generally declined in cover in the Fringing Marsh since channel closure, particularly around the eastern shore.
  - Bare Twig-rush has not increased in area in the area occupied by Fringing Marsh in the period of 2011-2013.
  - Broad-leaved Paperbark has not extended into the Fringing Marsh as yet. The next monitoring event in 2015 (or later) may show that this species has extended into the Fringing Marsh over a longer time frame than was expected.
  - At Transect 4 Saw-sedge was recorded at a slightly lower cover in 2013 that in the previous vegetation monitoring event. It is not clear whether this is due to small differences in sampling between individuals or whether this prediction will not occur. Data from future monitoring events will make this clearer.
  - As predicted, Coast Banksia has maintained a similar cover level in the Banksia Woodland between the previous vegetation monitoring event and the current monitoring event.

Frogs

- The results of the 2013 MPPC frog monitoring were broadly consistent with the results of the pre-artificial drainage channel closure frog monitoring in terms of overall species diversity, species diversity in each habitat; species distribution at Transects 2 and 3 and the absence of acid frog species in the low lying areas adjacent to Salty Lagoon.
- As was recorded in the previous monitoring events in 2012, at Transect 1 (north-west of Salty Lagoon), results differed slightly with Wallum Froglet recorded across the Swamp Forest (including Melaleuca dieback area) and adjacent Fringing Marsh. These differences are most likely to be attributed to localised differences in water quality. It is predicted that in the future Wallum Froglet will retract westward along Transect 1 out of the Fringing Marsh and into the Swamp Forest and Sedge Swamp in response to the higher water levels and conversion towards a predominantly freshwater system. If will be possible to test this prediction in the next winter frog monitoring event due in August 2013. It is recommended that along Transect 1 basic water-quality sampling be undertaken in August 2013 at frog sample sites where acid frogs are recorded within the Swamp Forest and Fringing Marsh.

This page has been intentionally left blank.

1

Introduction

1.1 Background

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

The rehabilitation strategy comprises three parts:

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

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

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

- water quality and hydrology;
- diatoms;
- macroinvertebrates;
- fish;
- frogs and waterbirds;
- flora and vegetation mapping; and
- 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 are implementing the MPPC (Hydrosphere 2010b).
The objectives of the monitoring program are summarised as follows:

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

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

- Ecosystem Health and Trend Assessment, including:
  - targeted terrestrial vertebrate survey and monitoring;
  - fish survey and monitoring;
  - macroinvertebrate survey and monitoring;

- flora survey and monitoring assessments; and
- water quality monitoring and review.

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

This report (*Annual Report 2013*) summarises the results of the monitoring undertaken between June 2012 and May 2013 as part of the MPPC program, which comprises the post-closure of the Artificial Channel monitoring period. This information is compared with the baseline monitoring results pre-closure of the Artificial Channel (GeoLINK 2012a) and the ERMP monitoring results, where appropriate.

2

Water Quality

2.1 Introduction

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

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

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

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

2.2 Methods

2.2.1 Permanent Water Quality Monitoring Stations

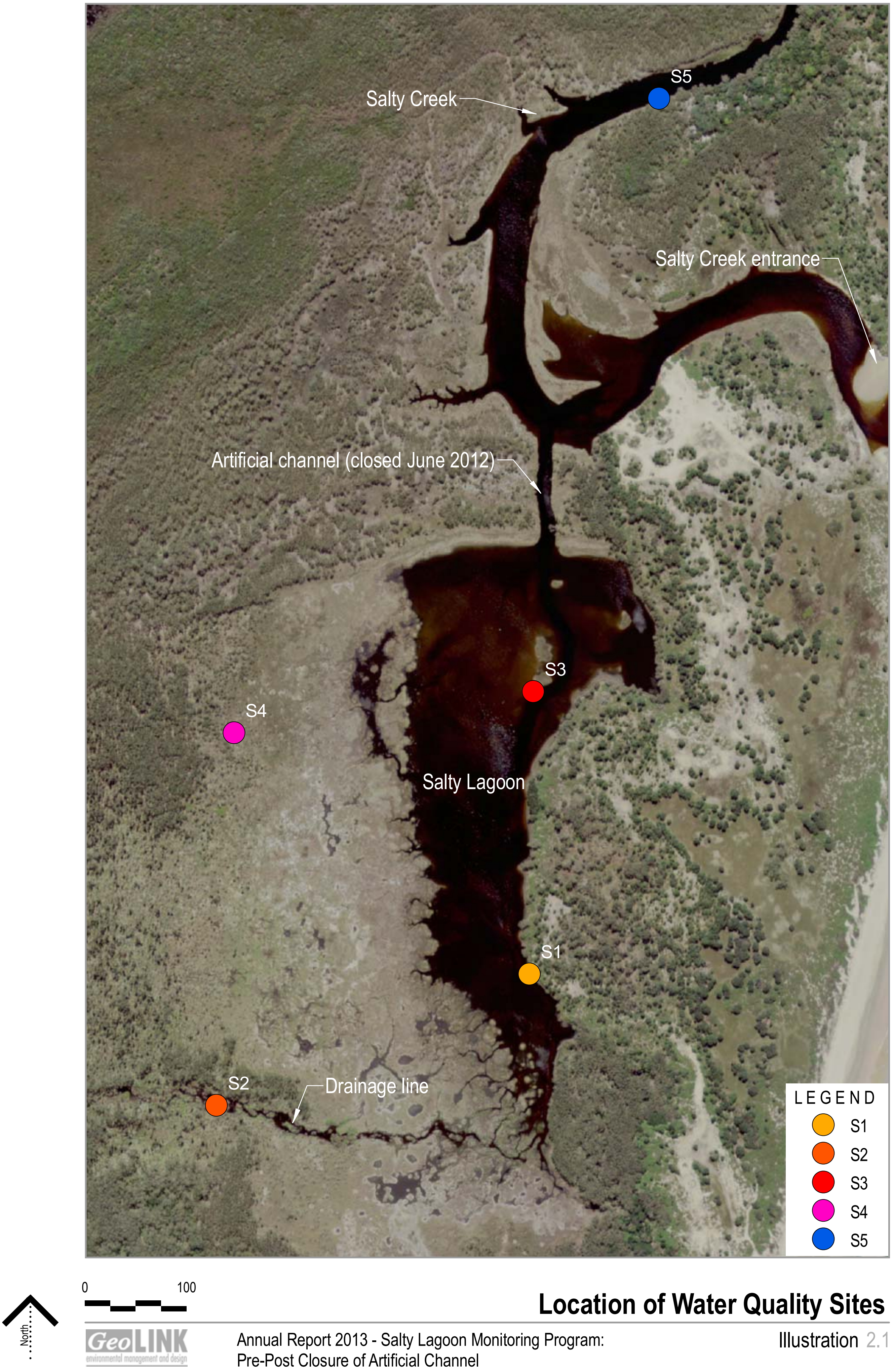
There are two permanent water quality monitoring stations (PWQMS) in place for the duration of the MPPC, measuring water level, temperature, pH, conductivity, turbidity and dissolved oxygen (DO) concentration. Each PWQMS is fitted with a YSI Series 6 sonde and a CRS 800 data logger. Data from the PWQMS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

The data from the PWQMS is used to inform the adaptive management strategy. Automatic alarms are received from the RVC server when DO concentration or water level changes at a specific rate. This is discussed further in Section 2.2.3.

This page has been intentionally left blank.

Information shown is for illustrative purposes only

Drawn by: TJP Checked by: MVE Reviewed by: GJM Date: July 2013
Source of base data: Richmond Valley Council



Location of Water Quality Sites

GeoLINK environmental management and design

Annual Report 2013 - Salty Lagoon Monitoring Program:
Pre-Post Closure of Artificial Channel

Illustration 2.1

1731-1075

This page has been intentionally left blank.

2.2.2 Routine Discrete Sampling

Discrete water quality samples were taken from surface water (approx. 0.2 m depth) at four sites in Salty Lagoon (S1-S4) and a single site (S5) in Salty Creek (refer to Illustration 2.1) 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*
Eastings	0542064	0541799	0542037	0541738	0542187
Northings	6782801	6782669	6783013	6783033	6783665
Site Description	Salty Lagoon PWQMS	SE of Drainage Channel	NE area of lagoon	NW area of lagoon	Salty Creek PWQMS

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

Discrete samples were collected in jars for analysis of chemical and biological parameters at the Coffs Harbour Laboratory (CHL). Sterile jars were used for collection of samples for bacteriological analysis and brown glass jars were used for collection of samples for analysis of chlorophyll-a and blue green algal (BGA) content. Samples were placed upon ice in an esky and typically delivered to CHL on the day 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 is currently being prepared.

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

- dissolved oxygen concentration < 1 mg/L – average over one hour;
- dissolved oxygen concentration < 1 mg/L – average over three hours;
- water temperature > 30 ˚C;
- water level change (up or down) > 0.05 m in 1 hr; and
- water level change (up or down) > 0.4 m in 24 hrs.

The new triggers are likely to be as follows:

- dissolved oxygen concentration < 1 mg/L – average over twelve hours;
- conductivity > 3 mS/cm; and
- water temperature > 30 ˚C.

For the first 18 months of the MPPC project a DO concentration of < 1 mg/L average over three hours resulted in a site inspection and extra round of water quality sampling. This resulted in a significant volume of extra data and an improved understanding of the processes operating in Salty Creek and Salty Lagoon. However, a new system of assessing the need for a site inspection has been proposed as part of the review process to better reflect the lower risk of environmental incident since the closure of the artificial channel.

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

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

Table 2.3 Guiding Values for all Water Quality Parameters

Measure		*Guiding Value*	
		Salty Lagoon	*Salty Creek*
Chemical	Total Nitrogen (mg/L)	1.6	1.64
	Ammonia (mg/L)	0.05	0.11
	Nitrate (mg/L)	0.01	0.01
	Nitrite (mg/L)	0.01	0.01
	Total Kjeldahl Nitrogen (mg/L)	1.6	1.64
	Total Phosphorus (mg/L)	0.14	0.04
	Orthophosphate (mg/L)	0.11	0.01
Biological	Chlorophyll-a (µg/L)	5	3
	Faecal Coliforms (CFU/100mL)	135	150
	Enterococci (CFU/100mL)	170	40
	Blue Green Algae (cells/mL)	0	0
Physical	Dissolved Oxygen (mg/L)	4.09	5.52
	Turbidity (NTU)	13.0	11.0
	pH	6.9	4.3 – 6.8
	Conductivity (mS/cm)	8.0	0.3 – 21.5
	Temperature (˚C)	25.9	13.1 - 28.8

2.3 Results and Discussion

2.3.1 Permanent Water Quality Monitoring Stations

2.3.1.1 Data Quality and Consistency

There are a number of gaps in the data from the PWQMS. There are two categories of data gaps consisting of:

- regular short term gaps in the data set ranging from one 15 minute interval reading to over 3 hours. Over the monitoring period from 1 June 2012 to 31 May 2013 there were 1266 missed data points from the Salty Lagoon PWQMS and 690 from the Salty Creek PWQMS; and
- a number of gaps where erroneous data, occurring as a result of faulty water quality probes, have been highlighted within the dataset. The turbidity probes have been particularly susceptible to such problems.

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

2.3.1.2 Key Points Arising from the Salty Lagoon Data Set

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

Water Level

Since the artificial channel was closed permanently on 19 June 2012 the water level in Salty Lagoon has stabilised considerably. The chart in Illustration 2.2 shows that following the closure of the artificial channel:

- the water level in Salty Lagoon responds quickly to rainfall in the catchment, particularly to events where 30 mm or more is received;
- the combined effects of groundwater drawdown and evaporation are still greater than the effect of freshwater input from the Evans Head STP (as evidenced by the dry period between July and October 2013;
- input from Salty Creek still occurs at times following heavy rainfall and or very high oceanic water levels such as those occurring when spring high tides and storm surges combine; and
- the majority of drainage into Salty Creek occurs when water levels are above approximately 1.9 m AHD.

Conductivity

Conductivity is measured to describe the concentration of salt in the water. The conductivity measurements from the Salty Lagoon PWQMS were much less variable throughout this reporting period as a result of the closure of the artificial channel and the reduced incidence of saltwater ingress from Salty Creek. However, following channel closure there were still three occasions on which saltwater ingress from Salty Creek occurred. Two of these occurred when heavy rainfall led to saline water, which was stored in Salty Creek, being pushed into Salty Lagoon. This happens because Salty Creek rises faster than Salty Lagoon in response to rainfall. The third occasion was a result of storm surge and high tides. Although it is not obvious from the logged data, the water column in Salty Lagoon is often stratified into a heavy salty layer at the bottom and a lighter freshwater layer at the surface. Small variations in the conductivity measured at the Salty Lagoon PWQMS can result from changes in the intensity of wind and flow driven mixing and thus give an indication of other processes occurring in the system generally.

Dissolved Oxygen

Dissolved Oxygen (DO) concentrations measured at the Salty Lagoon PWQMS fluctuated regularly throughout the year. The key processes impacting upon the DO concentration are light availability, water level, mixing and saltwater ingress. Diurnal fluctuations (high DO concentration in the day and low DO concentration at night) occur in response to light availability. These are most common when water levels are low and wind and flow driven mixing is not occurring. Low DO concentration also often coincides with high water levels, as light penetration to the bottom of the water column is low and the impact of wind and flow driven mixing at the bottom of the water column is reduced. Periods of stable healthy DO concentration measured from the Salty Lagoon PWQMS often coincide with periods of strong winds dominated by southerly or northerly wind directions. Windy conditions lead to mixing of the water column and bring well oxygenated water from the surface down to the bottom of the water column. Following saltwater ingress there is often a period of low DO concentration. It is possible that DO consumption at the bottom of the water column is increased when saltwater enters the system.

Although it is not apparent from the logged data, the water column in Salty Lagoon is often stratified with respect to DO concentration. The data from surface waters recorded from 1 June 2012 to 31 May 2013 is reported in Section 2.3.2. During this reporting period the DO concentration measured at the Salty Lagoon PWQMS dropped below 1 mg/L on a large number of occasions. This resulted in 9 adaptive management site visits. The percentages of DO readings below 1 mg/L and 6 mg/L at Salty Lagoon were previously reported in the ERMP (Hydrosphere 2010a & b). In the current reporting period the DO concentration was 6 mg/L or less on approximately 82% of occasions and the DO concentration was 1mg/L or less on approximately 34% of occasions. These figures are higher than the previous figures reported in the ERMP. In effect, the DO concentrations at the level of the sonde are at low levels more often than they have been in the past. There are a number of factors that may be contributing to this, including:

- the higher water level since the closure of the artificial channel. This has led to more frequent incidences of low light penetration to the bottom of the water column and a lower likelihood that wind driven mixing will impact upon the entire water column;
- the reduction in flow since closure of the artificial channel. This means that flow driven mixing is less likely;
- the ecosystem changes, including vegetation decomposition, occurring in Salty Lagoon in response to the closure of the artificial channel. These changes may be resulting in increased oxygen consumption throughout the lagoon while they are occurring; and
- a lower likelihood that saline water at the bottom of the water column, which tends to be associated with low DO concentrations in Salty Lagoon, will be flushed out in low flow events.

pH

Fluctuations in the pH measured at the Salty Lagoon PWQMS have not been as frequent or large as they had been prior to the closure of the artificial channel. However, the processes that drive these fluctuations remain the same. These are runoff from the catchment, effluent discharge from the Evans Head STP and seawater ingress. Following periods of heavy rainfall, runoff from the catchment tends to be acidic and lowers the pH at the Salty Lagoon PWQMS. During dry times, the main source of fresh water is the Evans Head STP, which releases treated water close to a neutral pH. Consequently, when effluent discharge is the dominant source of water the pH at the Salty Lagoon PWQMS tends to be close to neutral. Saltwater ingress usually has the effect of raising the pH measured at the Salty Lagoon PWQMS. However, there appears to be a mechanism of pH buffering in Salty Lagoon resulting in a tendency towards neutral following any disturbance.

Temperature

Over the reporting period temperature fluctuated according to both daily and seasonal patterns. There is a relationship between water level in Salty Lagoon and the magnitude of temperature variation. As water levels become higher the daily fluctuations in temperature tend to reduce in magnitude, indicating an increase in thermal mass relative to the surface area of the lagoon and a reduced tendency towards temperature fluctuation. In addition, higher water levels reduce light penetration at the bottom of the water column and thus lead towards thermal stratification including a stabilisation of water temperatures at the bottom of the water column.

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 suspended in the water column. Turbidity measurements fluctuated widely throughout the monitoring period. Higher turbidity measurements tended to occur following heavy rainfall, strong winds and saltwater ingress.

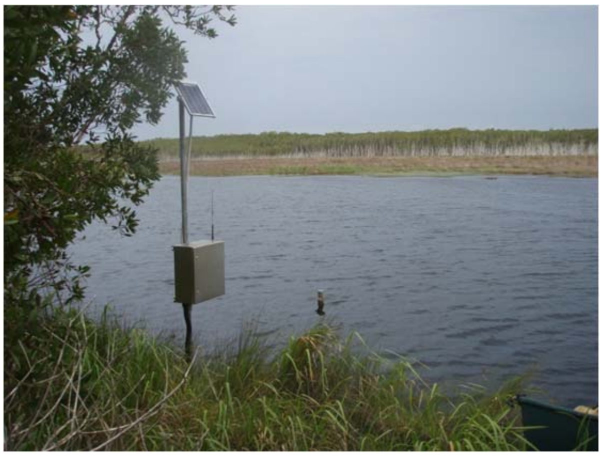


Plate 2.1 The PWQMS located at Salty Lagoon

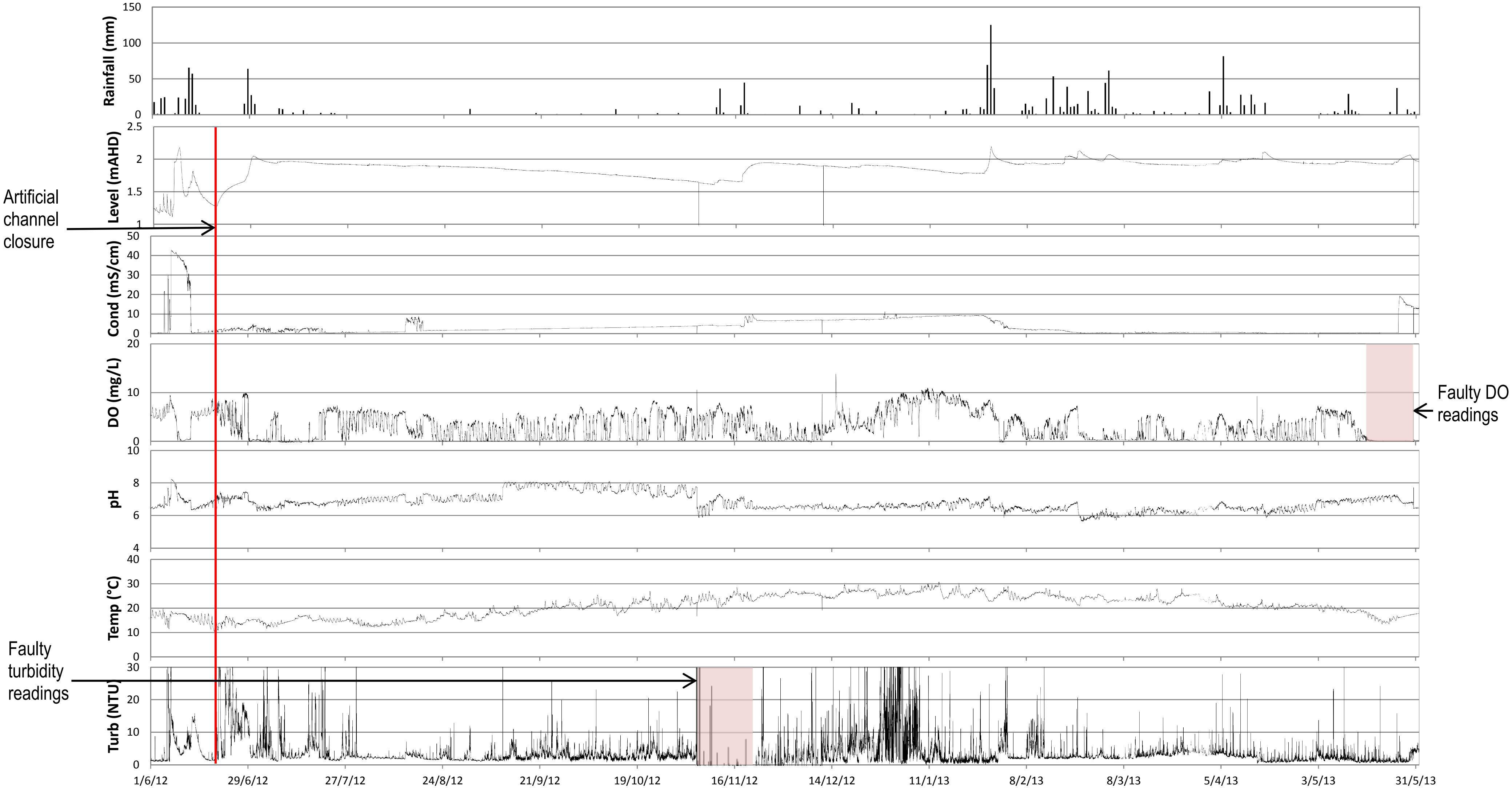


Illustration 2.2 Results from the Salty Lagoon PWQMS for the Period from 1 June 2012 until 31 May 2013.

2.3.1.3 Key Points Arising from the Salty Creek Data Set

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

Water Level

The key factor affecting the water level in Salty Creek is the status of its entrance. However, there is a very strong interaction between the status of the entrance, rainfall and tidal and oceanic wave conditions in determining the actual level. During this reporting period the entrance was relatively stable in comparison with the 2011 – 2012 reporting period (5 or 6 opening events in comparison with 17).

Conductivity

The conductivity measurements from the Salty Creek PWQMS were highly variable throughout the reporting period. The conductivity measurements were most commonly either very low, following entrance breakout, or very high, following saltwater ingress. Some of the same factors that lead to seawater ingress also tend to lead towards a closed entrance with a high entrance berm. This scenario, in combination with low rainfall between July and October 2013, resulted in a long period of very high conductivity measurements where saline water was 'trapped' in Salty Creek.

Dissolved Oxygen

Dissolved Oxygen (DO) concentrations measured at the Salty Creek PWQMS tended to be more stable than those measured at the Salty Lagoon PWQMS. The patterns of variation at the Salty Creek PWQMS were as follows:

- DO concentrations do not tend to fluctuate strongly according to diurnal cycles in Salty Creek;
- changes to stable water level and conductivity conditions tend to result in a reduction in the measured DO concentration, at least temporarily; and
- 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 69% of the reporting period and 1mg/L or less for approximately 15% of the reporting period. These figures are within the ranges of previously reported results in the ERMP.

pH

The pH measurements from the Salty Creek PWQMS tend to fluctuate more than those from Salty Lagoon. The key to this fluctuation is the increased influence of swamp forests in the catchment of Salty Creek. Runoff from these areas is strongly acidic, leading to the pH of Salty Creek following rainfall often being around pH 4. This contrasts strongly with the pH after seawater ingress which can have the effect of increasing the pH measurements to over pH 8.

Temperature and Turbidity

The temperature and turbidity measurements from the Salty Creek PWQMS fluctuated in similar fashion to the equivalent measurements from Salty Lagoon, as described in Section 2.3.1.2.

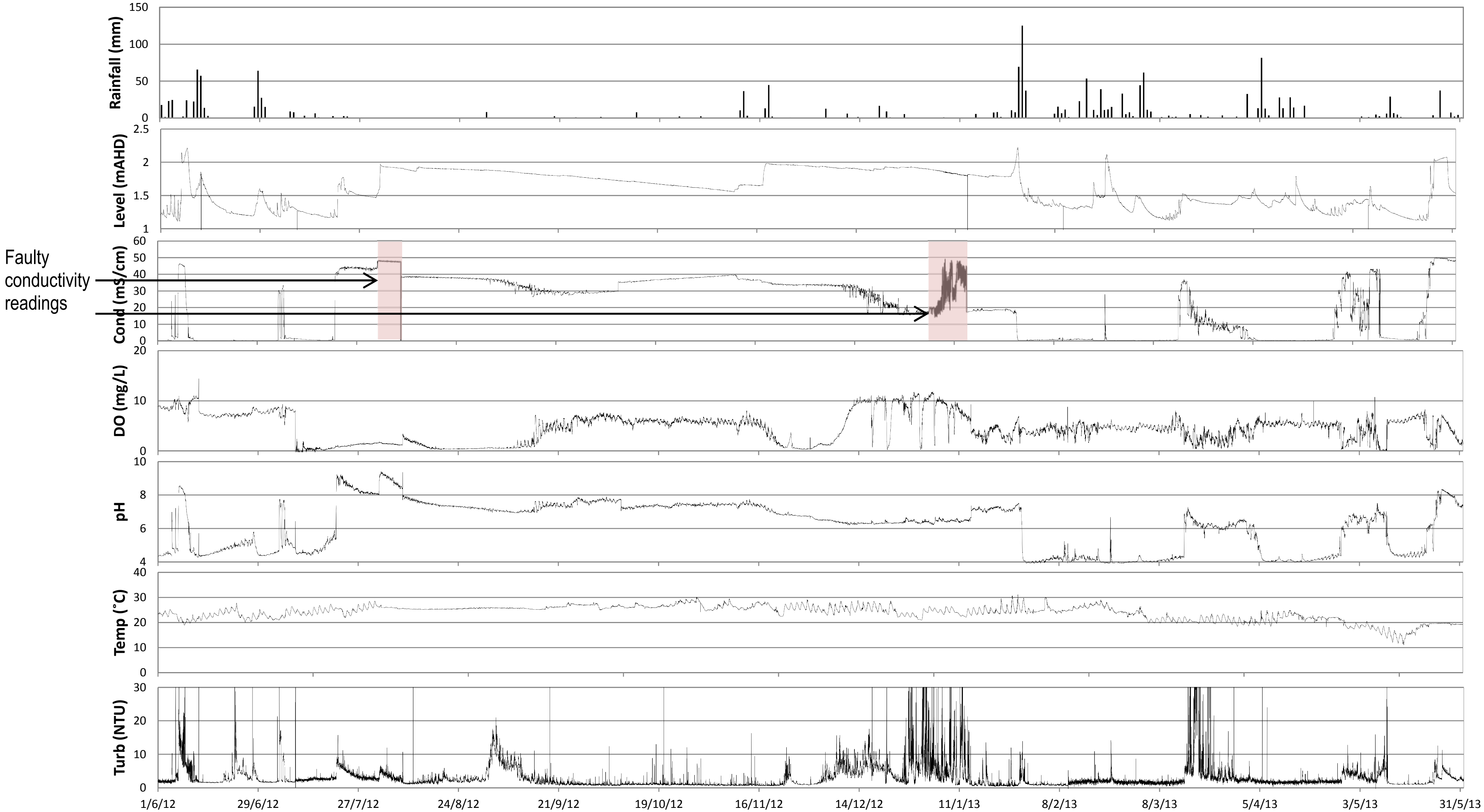


Illustration 2.3 Results from the Salty Creek PWQMS for the Period from 1 June 2012 until 31 May 2013.

2.3.2 Discrete Water Quality Samples

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

Table 2.4 Median results of discrete samples from surface waters at all sites for the reporting period

Indicator	*Site*				
	S1	*S2*	*S3*	*S4*	*S5*
Nitrite Nitrogen (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate Nitrogen (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01
Oxidized Nitrogen (mg/L)	0	0	0	0	0
Ammonia Nitrogen (mg/L)	0.05	0.01	0.07	<0.01	0.037
Dissolved Inorganic Nitrogen (mg/L)	0.05	0.01	0.07	0	0.037
Total Kjeldahl Nitrogen (mg/L)	1.24	1.15	1.23	1.21	1.14
Total Nitrogen (mg/L)	1.24	1.15	1.23	1.21	1.14
Total Phosphorus (mg/L)	0.1	0.14	0.11	0.06	0.03
Orthophosphate (mg/L)	0.048	0.07	0.05	0.011	0
Chlorophyll-a (µg/L)	<1	<1	<1	<1	<1
Enterococcus (CFU/100mL)	17	45	10	12	4
Faecal Coliforms (CFU/100mL)	10	16	5	2	30
Blue Green Algae (cells/L)	0	0	0	0	0
Temp (˚C)	21.44	20.46	22.37	20.18	22.4
pH	6.665	6.3	6.73	5.365	4.78
ORP (mV)	156.5	118.5	151.5	121	183
Cond (mS/cm)	1.9	0.321	3.47	1.335	1.465
Turbidity (NTU)	3.6	1.15	6.85	2.35	1.25
DO (mg/L)	6.385	4.265	7.59	4.415	6.14
DO (% sat)	70.55	44.55	82.45	49.25	70.1
TDS (ppt)	1.22	0.207	2.69	0.933	0.955
Salinity (ppt)	1	0.2	1.8	0.65	0.7

2.3.2.1 *Nitrogen*

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

Some of the factors impacting nitrogen concentrations in Salty Lagoon and Salty Creek include seawater ingress, tidal movements and rainfall runoff. Effluent discharge from the Evans Head STP does not appear to be a factor that strongly influences nitrogen concentrations in Salty Lagoon, as concentrations of TN at S2 are often the lowest. Concentrations of TN appeared to be highest during the summer months for most sites (Illustration 2.4). No single site consistently had the highest TN concentration. In GeoLINK 2012 it was noted that concentrations of TN tended to be highest in samples from S4 and S5, suggesting that nitrogen delivery from the catchment was higher than that from the Evans Head STP. Results from this reporting period are not conclusive.

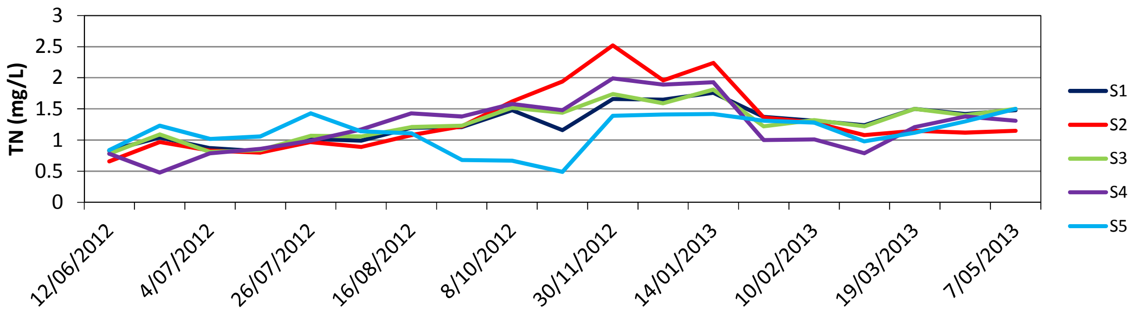


Illustration 2.4 Time series of TN concentrations from all sites for the monitoring period

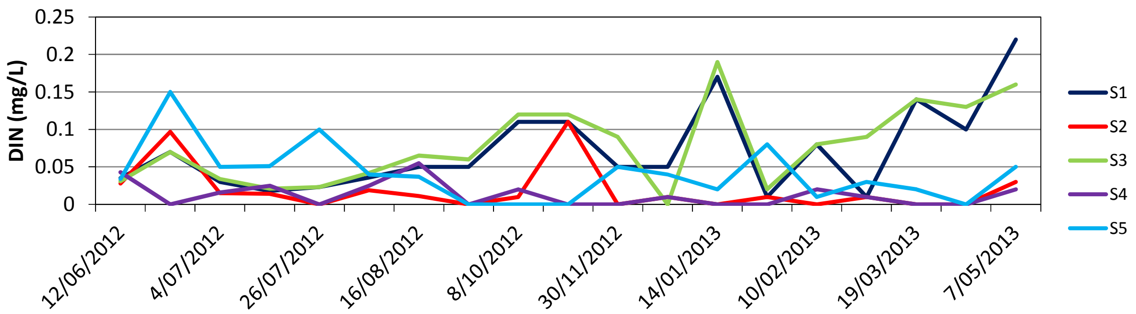


Illustration 2.5 Time series of DIN concentrations from all sites for the monitoring period

During the reporting period the concentration of DIN appeared to increase over time at S1 and S3 and decrease at the other sites (Illustration 2.5). Whilst no definitive answer is available for this trend it is likely that the increased decomposition of organic matter in Salty Lagoon and a reduction in the available pathways for oxygenation of nitrogen containing molecules are contributing factors. To date, no algal blooms have been associated with the higher concentrations of DIN. However, there is a risk that further increase in the concentration of DIN may lead to algal bloom conditions because inorganic nitrogen species, particularly nitrate, are available for biological uptake.

No definitive conclusions can be drawn from a comparison of nitrogen concentrations before and after channel closure (Illustration 2.6). However, the following patterns are apparent:

- no nitrite has been measured in any samples since the closure of the artificial channel;
- the mean concentrations of nitrate and ammonia have clearly increased at S1 and S3 since closure of the artificial channel. The degree of change shown in Illustration 2.6 indicates that this increase is likely to be statistically significant;
- the mean concentrations of nitrate and ammonia have reduced at S2, S4 and S5 since closure of the artificial channel; and
- the mean concentration of TN has increased slightly at S1, S2 and S3 but reduced at S4 and S5. However, the changes between the before and after data sets are very small.

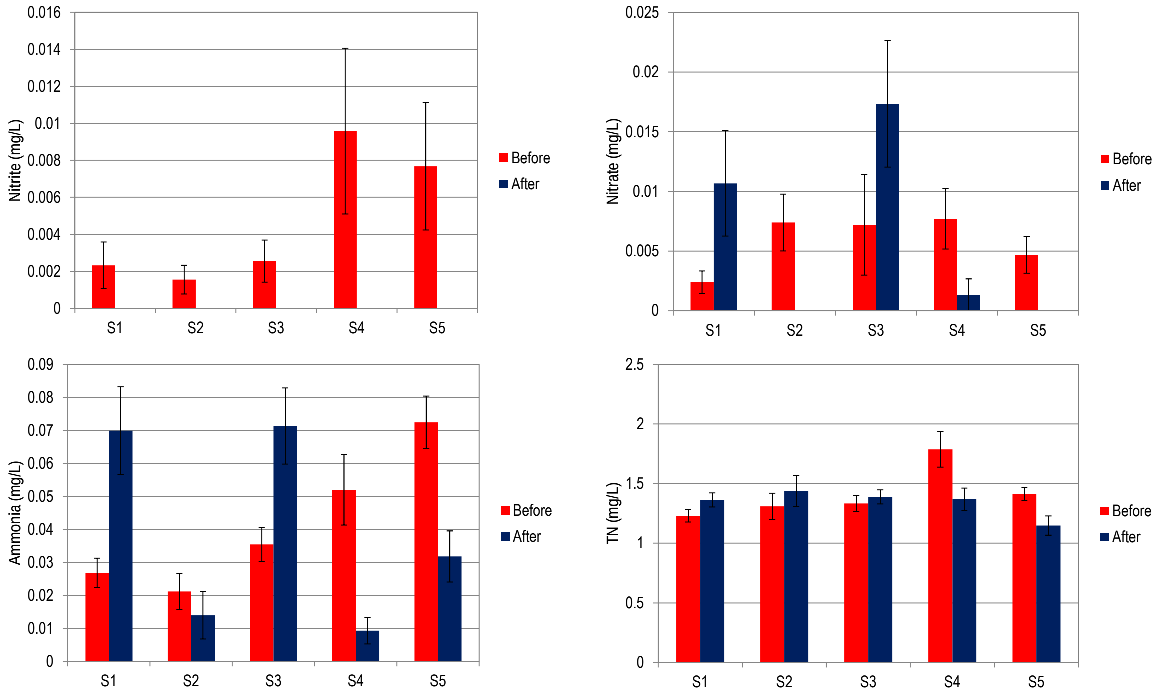


Illustration 2.6 Before and after channel closure mean concentrations of nitrogen species (±SE)

2.3.2.2 Phosphorus

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

As per the results in the previous annual report (GeoLINK 2012a), the concentrations of TP and orthophosphate tended to be highest at S2, followed by S1 and S3. Site S2 is the site most influenced by discharged effluent from the Evans Head STP. Concentrations of phosphorus were lowest at S4 and S5, which are the two sites least influenced by discharged effluent from the Evans Head STP.

The major factor influencing the long term concentration of phosphorus is discharge from the Evans Head STP. However, other key factors leading to variation in phosphorus concentrations include tidal movements, rainfall runoff and seawater ingress. The time series plot of TP concentration (Illustration 2.7) shows that over the current reporting period TP concentrations have fluctuated from month to month with no clear trend apparent. The time series plot of orthophosphate concentration indicates that there may have been a slightly increasing trend at S1, S2 and S3 (Illustration 2.8).

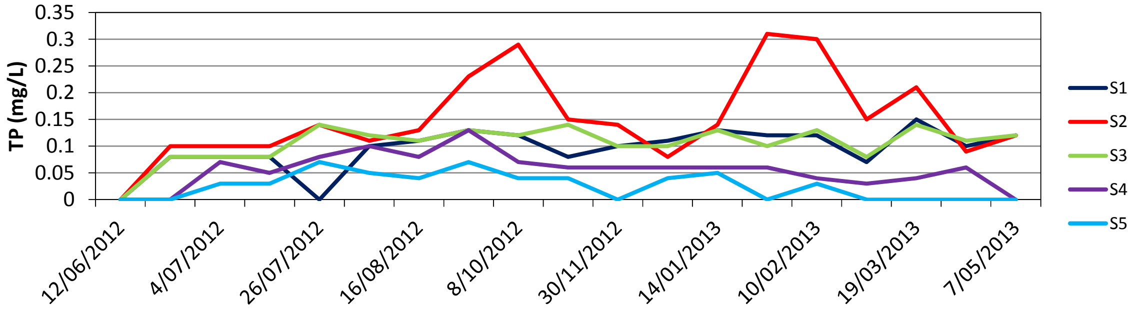


Illustration 2.7 Time series of TP concentrations from all sites for the monitoring period

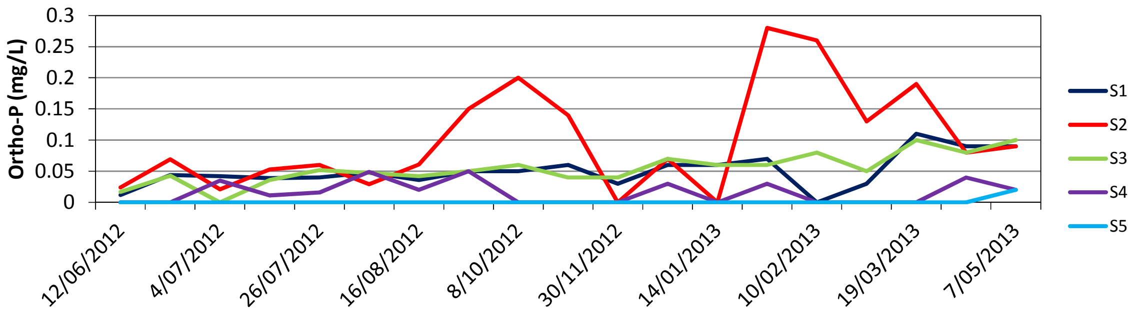


Illustration 2.8 Time series of Orthophosphate concentrations from all sites for the monitoring period

A closer look at the data indicates that since closure of the artificial channel there has been a minor increase in the mean concentration of TP at S2, S3 and S4, while concentrations at S1 and S5 were comparatively stable. A minor increase in the mean concentration of orthophosphate was also recorded at S3 and S4 (Illustration 2.9), while S1, S2, and S5 were comparatively stable. Further increases in the concentration of orthophosphate will raise the risk of algal bloom conditions. This aspect of water quality should be watched closely over the next year of monitoring.

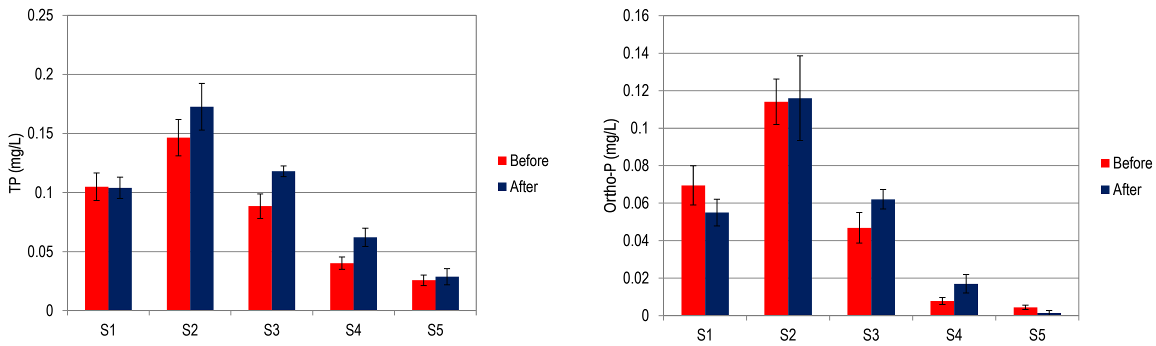


Illustration 2.9 Mean concentrations of phosphorus species (±SE) before and after channel closure

2.3.2.3 Chlorophyll-a

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

Chlorophyll-a concentrations were low for the majority of the reporting period. Median concentrations were the same at all sites. There were no clear trends in terms of spatial variation, as shown in Illustration 2.10 although the highest concentrations were generally recorded in the summer months.

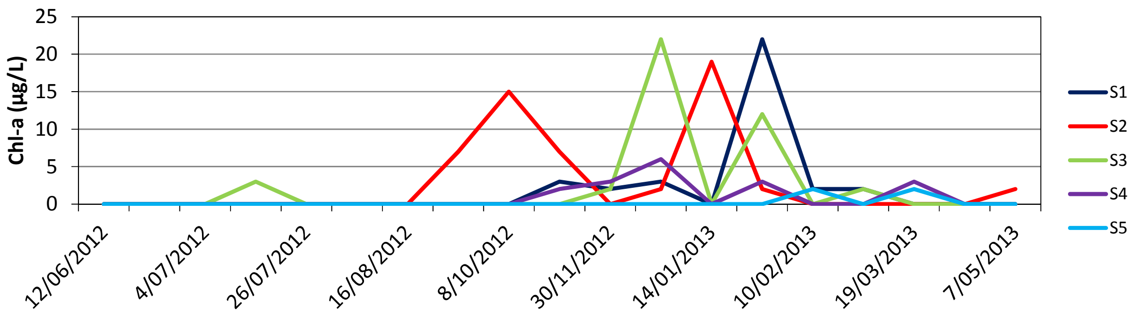


Illustration 2.10 Time series of Chlorophyll-a concentrations from all sites for the monitoring period

The mean concentration of chlorophyll-a decreased at all sites since the closure of the artificial channel, although this was most distinct at S4 and S2 (Illustration 2.11).

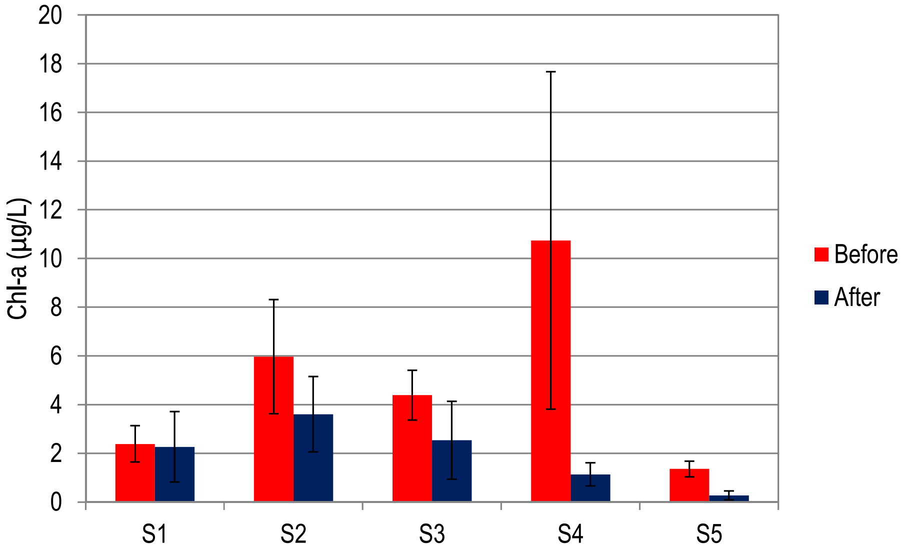


Illustration 2.11 Mean concentrations of chlorophyll-a (±SE) before and after channel closure

2.3.2.4 Blue Green Algae

Blue green algae are naturally occurring photosynthetic bacteria. Under bloom conditions they can be toxic to humans and aquatic fauna and can cause other problems related to deoxygenation of the water column and reduced light penetration.

Despite increases in the concentrations of bioavailable phosphorus and nitrogen at some sites, blue green algae were not detected in any samples during the current reporting period.

2.3.2.5 Faecal Indicator Organisms

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

The median Enterococcus concentration was highest at S2 but the median faecal coliform concentration was highest at S5. In general, enterococcus and faecal coliform concentrations were low at all sites during the reporting period. Time series plots indicate that concentrations of both indicator organisms are frequently highest at S2, with a spike in very high concentrations occurring at S5 (Illustration 2.12 and Illustration 2.13).

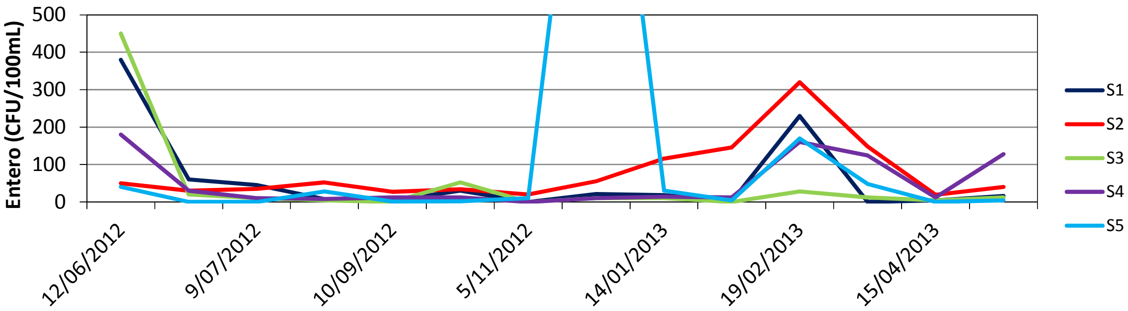


Illustration 2.12 Time series of enterococcus concentrations from all sites for the monitoring period

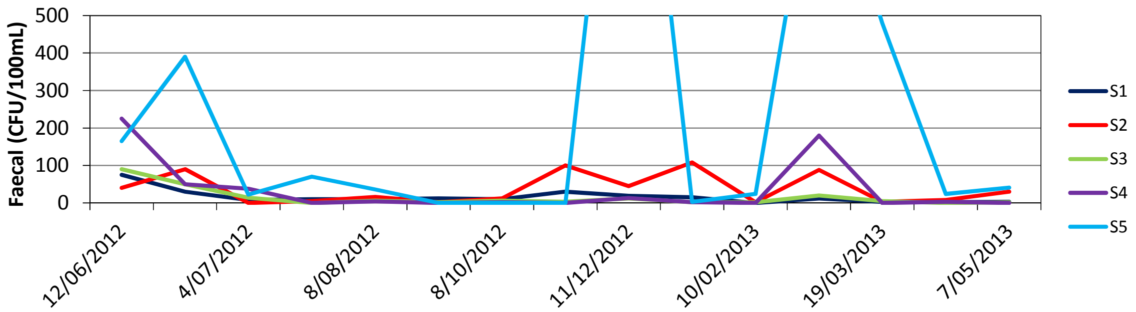


Illustration 2.13 Time series of faecal coliform concentrations from all sites for the monitoring period

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

Since the closure of the artificial channel the mean concentrations of faecal indicator organisms have reduced at all sites except S2 and S5, where occasional very high concentrations have led to increases in the mean and the standard error of the mean (Illustration 2.14).

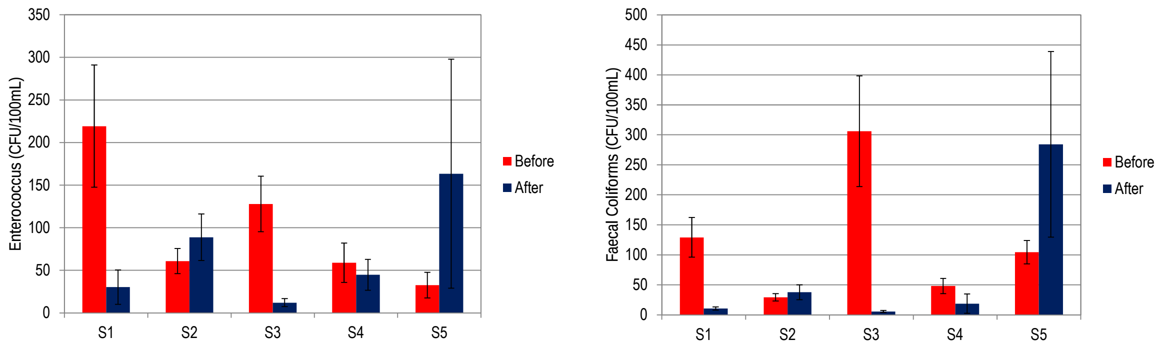


Illustration 2.14 Mean concentrations of faecal indicator organisms (±SE) before and after channel closure

2.4 STP Discharge Monitoring

As part of their licensing conditions the Evans Head STP is required to monitor discharge quality on a fortnightly basis. Among the suite of effluent quality parameters sampled are faecal coliform, TN and TP concentrations. The data collected from the Evans Head STP is used to contextualise results collected during the MPPC and inform any pollution incidents that may occur during the project. Monitoring results from the Evans Head STP are presented in Illustration 2.15, Illustration 2.16, Illustration 2.17 and Illustration 2.18. All results for the entire monitoring period were within the licensing limits set for the Evans Head STP by the EPA.

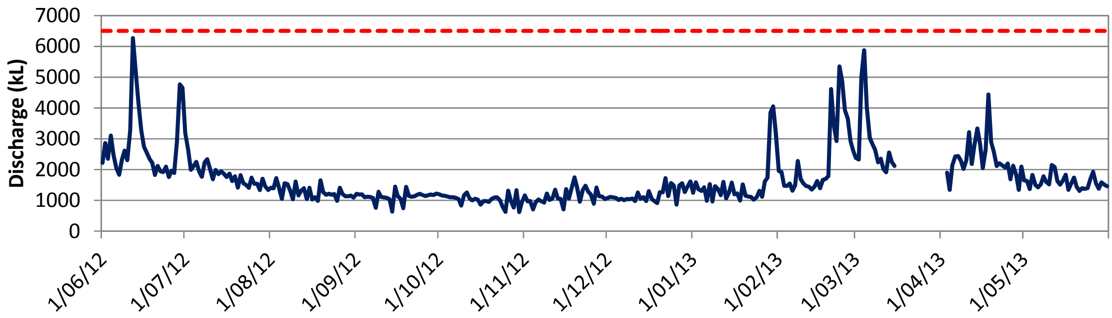


Illustration 2.15 Time series of daily discharge volumes from the Evans Head STP (maximum allowed discharge volume in red)

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

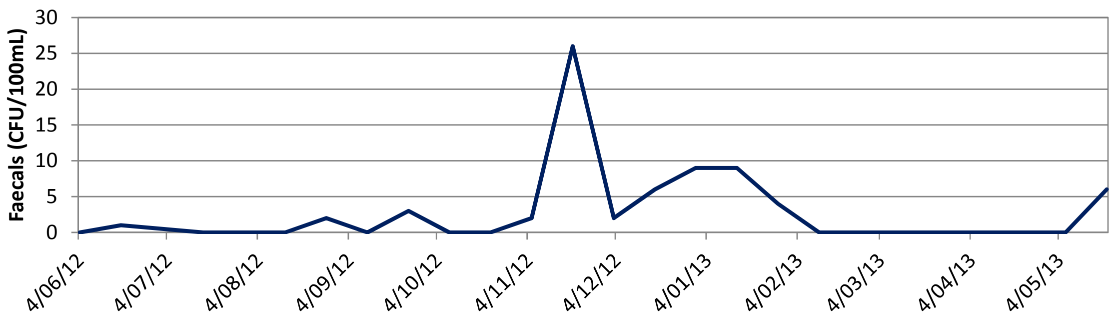


Illustration 2.16 Time series of faecal coliform concentrations from the Evans Head STP discharge

The concentrations of TN in discharged effluent are generally 2 to 3 times higher than those measured at any site within 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 (as described in the ERMP project, Hydrosphere 2010a).

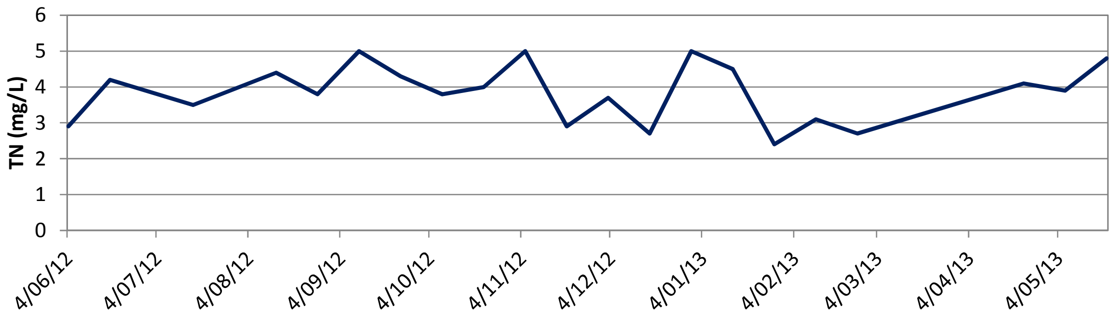


Illustration 2.17 Time series of TN concentration from the Evans Head STP discharge

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

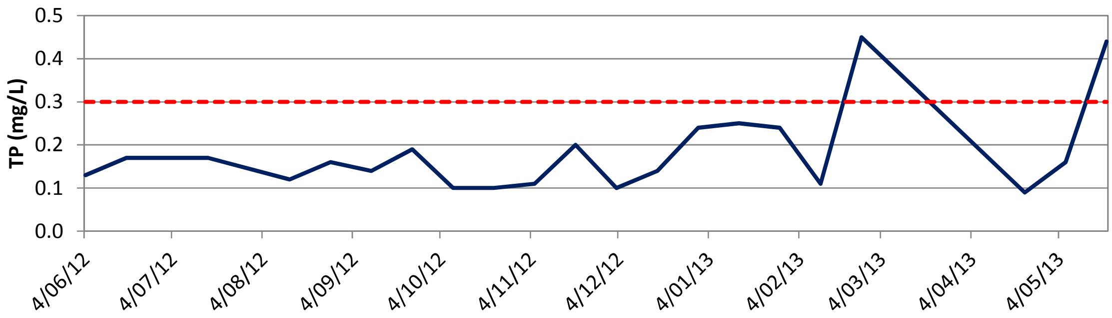


Illustration 2.18 Time series of TP concentration from the Evans Head STP discharge (80th percentile limit in red)

3

Macroinvertebrates

3.1 Introduction

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

In Salty Lagoon, benthic macroinvertebrate communities have previously been monitored to assess the effects of improvements to the operation and discharge from the Evans Head STP (Hydrosphere 2010a). It was hypothesised that as nutrient loads and effluent flow reduced over time the makeup of benthic communities would change in response. In order to avoid the confounding effects of salinity and variation in water levels experienced in Salty Lagoon the collection sites utilised during the ERMP were all located in the drainage channel. The study found high levels of variation in abundance and diversity of benthic macroinvertebrates, but concluded that there were no apparent trends and no significant change had occurred in the nutrient status of the drainage channel.

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

3.2 Methods

3.2.1 Site Location

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

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

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

Site	*Description*	*Eastings*	*Northings*
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 nearest vegetation is Saltwater Couch (*Paspalum vaginatum*), although the nearby extent of this is reducing. The water levels at this site have increased significantly since the closure of the artificial channel.	0542065	6782781

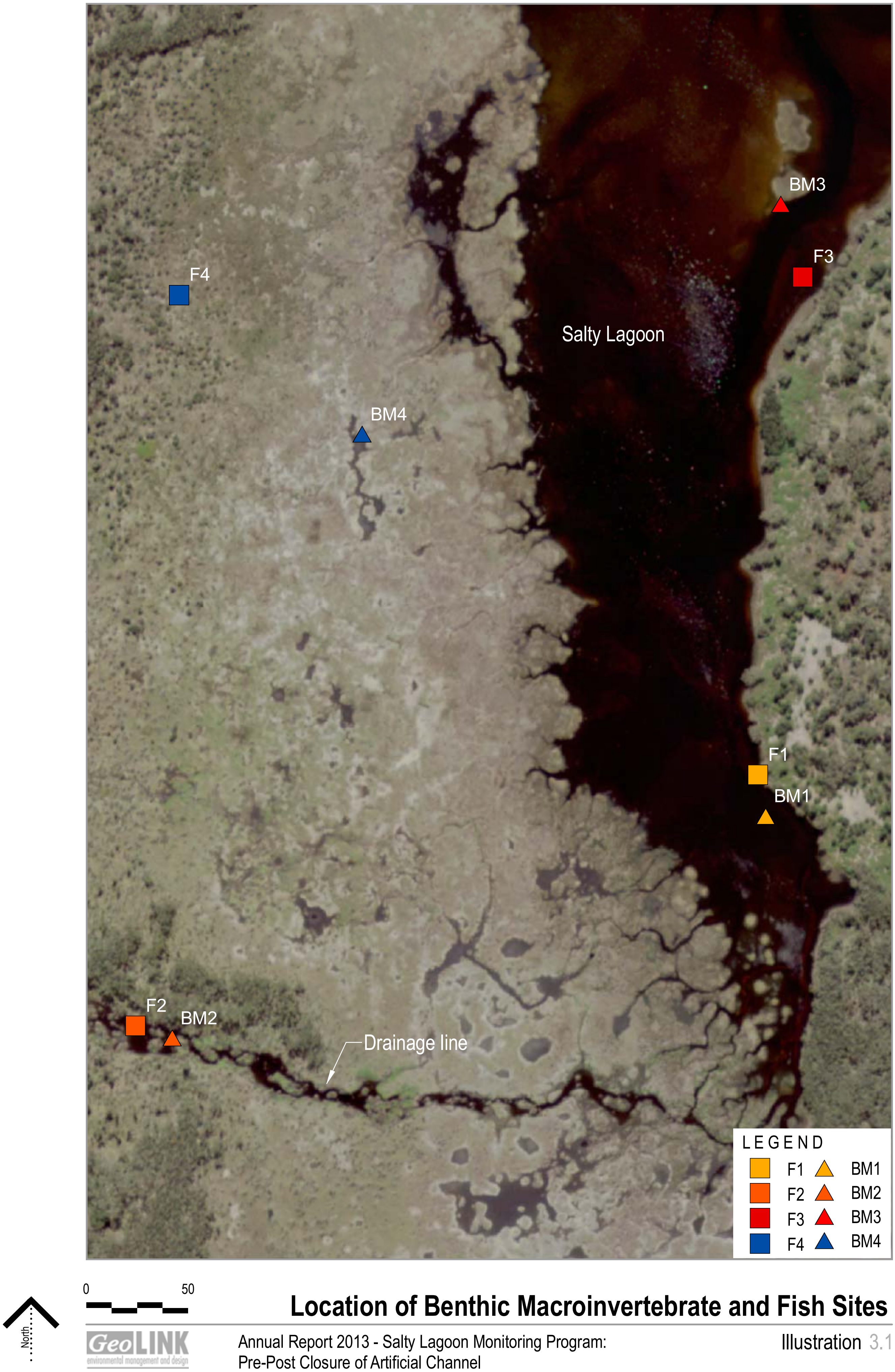
Site	Description	Eastings	Northings
BM2	This site is located near to where the drainage channel from the STP opens out into Salty Lagoon. The benthos at this site is dominated by coarse organic material bound by a low percentage of mud. Fallen branches from overhanging vegetation are common. The vegetation at this site is dominated by Cumbungi (*Typha orientalis*), Common Reed (*Phragmites australis*), Jointed Twig-rush (*Baumea articulata*), and Broad-leaved Paperbark (*Melalueca quinquenervia*). Twigs, leaves, matted algae and fungal hyphae dominate sieved samples from this site. This site was mostly freshwater during the reporting period though prior to and after the Summer 2013 sampling event brackish water persisted at the site for approximately 2 months. The quality of the freshwater changes at this site between dry times when effluent discharge dominates and wet times when catchment runoff dominates.	0541981	6782659
BM3	This site is located in open water towards the northern end of Salty Lagoon. The benthic material consists of sand and silt, organic matter is uncommon at this site. This site is affected the most by saltwater flow from Salty Lagoon. Saline water persisted at this site before and after the spring 2012 (approx. 5% seawater) and summer 2013 (approx. 10% seawater) sampling events. The nearest vegetation is Saltwater Couch, which is reducing in its nearby extent.	0542073	6783082
BM4	This site is located in the rushlands in the north-western part of Salty Lagoon. The benthic material is primarily coarse organic material bound by a low percentage of mud. Leaves, fungal hyphae and matted algae dominate sieved samples. The surrounding vegetation is in a state of rapid flux, with nearby saltmarsh vegetation receding rapidly and being replaced slowly by freshwater tolerant vegetation. The water quality in this part of the lagoon is dominated by freshwater runoff from the catchment and generally has a low pH. However, prior to and after the Summer 2013 sampling event brackish water persisted at the site for approximately 2 months.	0541738	6783005

3.2.2 Collection

Benthic macroinvertebrates were sampled once per season. The exact dates of benthic macroinvertebrate collection were 9 July 2012, 8 October 2012, 14 January 2013 and 15 April 2013. At each of four sites 3 benthic cores were collected at intervals of between 1 m and 2 m. The cores were taken using a 10 cm diameter round corer inserted to a depth of 10 cm. Cores were field rinsed over a 1 mm sieve using water from the immediate environment prior to being transferred into a labelled sample bag with minimal water. Once all samples had been collected they were fixed with 70% ethanol solution and transported to the laboratory.

3.2.3 Processing

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



Location of Benthic Macroinvertebrate and Fish Sites

Annual Report 2013 - Salty Lagoon Monitoring Program:
Pre-Post Closure of Artificial Channel

Illustration 3.1

1731-1076

This page has been intentionally left blank.

3.3 Results and Discussion

3.3.1 Conditions at the time of sampling.

The conditions at the time of sampling were highly variable between seasons at each of the four sites. Water quality is among the most important environmental factors driving variability in benthic macroinvertebrate communities and a summary of water quality results collected from all sites on the survey days is presented in Table 3.2. The water levels were relatively stable between surveys with a difference of 0.24 m between the highest and lowest levels.

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

Site	*Survey*	*Date*	*Water Level (mAHD)*	*Temp (˚C)*	*pH*	*Cond (mS/cm)*	*TN (mg/L)*	*TP (mg/L)*
BM1	Winter 2012	9/07/2012	1.96	16.44	6.16	0.33	0.82	0.08
	Spring 2012	8/10/2012	1.77	22.84	7.01	2.93	1.48	0.12
	Summer 2013	14/01/2013	1.81	27.53	6.56	8.55	1.76	0.13
	Autumn 2013	15/04.2013	2.01	20.96	6.47	0.35	1.42	0.10
BM2	Winter 2012	9/07/2012	1.96	11.49	6.00	0.19	0.80	0.10
	Spring 2012	8/10/2012	1.77	19.9	6.07	1.35	1.62	0.29
	Summer 2013	14/01/2013	1.81	28.0	6.24	7.35	2.24	0.14
	Autumn 2013	15/04.2013	2.01	19.31	5.8	0.23	1.12	0.09
BM3	Winter 2012	9/07/2012	1.96	17.17	6.50	0.54	0.84	0.08
	Spring 2012	8/10/2012	1.77	21.87	6.71	2.93	1.52	0.12
	Summer 2013	14/01/2013	1.81	27.21	6.65	8.56	1.81	0.13
	Autumn 2013	15/04.2013	2.01	21.33	6.35	0.40	1.40	0.11
BM4	Winter 2012	9/07/2012	1.96	11.3	4.51	0.30	0.86	0.05
	Spring 2012	8/10/2012	1.77	18.59	4.73	2.54	1.58	0.07
	Summer 2013	14/01/2013	1.81	25.66	5.5	6.27	1.93	0.06
	Autumn 2013	15/04.2013	2.01	19.37	4.85	0.28	1.38	0.06

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

The most notable differences in water quality between seasons are as follows:

BM1 – The winter 2012 survey period was significantly affected by heavy rainfall with the lowest temperature, pH, conductivity and nutrient concentrations. The summer 2013 survey period was heavily impacted by saltwater ingress with the highest temperature, conductivity and nutrient concentrations. Water levels were much less variable between survey periods as a result of channel infill, but the lowest water levels occurred in spring 2012 and the highest in autumn 2013.

BM2 – There was a higher degree of variability between survey periods at this site when compared with the previous annual reporting period (GeoLINK 2012a). Saltwater ingress prior to the summer survey was evident in the high temperatures, pH, conductivity and nitrogen concentration. Freshwater flow prior to the winter survey contributed to low conductivities and nutrient concentrations. Water levels were much less variable between survey periods as a result of channel infill, but the lowest water levels occurred in spring 2012 and the highest in autumn 2013.

BM3 – The winter 2012 survey period was significantly affected by heavy rainfall with the lowest temperature and nutrient concentrations. The summer 2013 survey period was heavily impacted by saltwater ingress with the highest temperature, conductivity and nutrient concentrations. Water levels were much less variable between survey periods as a result of channel infill, but the lowest water levels occurred in spring 2012 and the highest in autumn 2013.

BM4 – Again, the freshwater flow prior to the winter survey and seawater ingress prior to the summer survey impacted water quality at this site. The lowest water levels occurred in spring 2012 and the highest in autumn 2013.

3.3.2 Diversity

Coastal freshwater lakes and intermittently open estuaries are known to generally be low in macroinvertebrate diversity. However, the surveys to date have identified adequate diversity and abundance for assessing future changes. Overall, there has been a fair degree of variation between the species numbers and individual animal numbers encountered during the surveys since the beginning of the MPPC (see Table 3.3). Although some of the variation in the dataset is lost by comparing the seasonal surveys in this way, it is clear that there is no obvious seasonal pattern in the variation between surveys.

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

A total of 18 macroinvertebrate taxa have been identified from samples collected to date. Of the 18 taxa identified, 8 have only been observed in one of the nine seasonal surveys undertaken. Only fourteen of the 18 taxa were collected during the first five surveys of the MPPC. The list of all taxa collected and their presence throughout the various surveys is presented in Table 3.4. Only 1 of the 18 taxa collected to date has been observed in each of the nine surveys. One other has been collected in 8 of the 9 surveys and two others in 7 of the nine surveys.

The most common taxa captured to during the current reporting period were *Chironominae*, *Mytilidae* and *Spionidae* (Table 3.4). These were followed by the *Hydrobiidae*, *Capitellidae*, *Sphaeromatidae* and *Collembola*. In the previous reporting period (GeoLINK 2012a) the most common taxa were the *Chironominae*, *Spionidae*, *Hydrobiidae* and *Capitellidae*. With respect to the whole system, the major changes between the previous and current monitoring periods have been the increase in the number of *Mytilidae* and the reduction in the numbers of *Capitellidae* and *Hydrobiidae*. The *Mytilidae* have been almost exclusively encountered at S1 and S3, and are likely to have entered the system with salt water inflow from Salty Creek. The *Capitellidae* are found mostly at S3 and the reduction in observed abundance is likely to reflect the greater depths and more stable lower salinity since the closure of the artificial channel. The reduction in the numbers of *Hydrobiidae* in recent surveys is due to a reduction in the numbers observed in samples from S4. At the other sites they have been steady or increased in numbers.

A number of taxa have now been observed in numbers at all four sites, including the *Chironominae*, *Hydrobiidae* and *Sphaeromatidae* (see Table 3.4). These taxa appear to be adapting well to changing conditions.

The diversity of taxa in macroinvertebrate samples varied between sites and over time. However, there are no obvious patterns in the variation of species diversity with respect to either seasonal changes or environmental conditions at the time of sampling. At BM1, BM2 and BM3 there are no clear trends with respect to the observed macroinvertebrate diversity. In each case, however, the lowest recorded diversity in a single survey occurred prior to the closure of the artificial channel. At BM4 the diversity appears to be decreasing overall, though again, the lowest recorded diversity from any single survey period occurred prior to the channel closure (Illustration 3.2).

Table 3.4 A comparison of benthic macroinvertebrate taxa captured at all sites during surveys before and after the channel closure

Taxa	*Common Name*	*BM1*			*BM2*			*BM3*			*BM4*		
		Pre	*Post*	*Total*	*Pre*	*Post*	*Total*	*Pre*	*Post*	*Total*	*Pre*	*Post*	*Total*
Chironominae	Midge	19	7	26	98	137	235	23	23	46	2	3	5
Tanypodinae	Midge	0	0	0	0	0	0	0	0	0	2	1	3
Ceratopogonidae	Biting midge	10	1	11	0	2	2	0	1	1	3	0	3
Sialidae	Toebiters	0	0	0	0	0	0	0	0	0	1	0	1
Libellulidae	Dragonfly	0	0	0	5	4	9	0	0	0	2	0	2
Hemiphlebidae	Damselfly	1	0	1	0	0	0	0	0	0	0	0	0
Crambidae	Caterpillar	0	0	0	0	1	1	0	0	0	0	0	0
Hygrobiidae	Screech Beetle	0	0	0	0	0	0	0	0	0	1	0	1
Hydrophiidae	Water Beetle	0	0	0	0	0	0	0	0	0	0	1	1
Dytiscidae	Diving Beetle	0	0	0	0	0	0	0	0	0	0	1	1
Collembola	Springtail	2	7	9	1	0	1	1	1	2	0	3	3
Capitellidae	Polychaete	5	2	7	0	0	0	42	14	56	0	0	0
Spionidae	Polychaete	92	8	100	1	0	1	11	91	102	2	0	2
Mytilidae	Mussel	1	85	86	1	0	1	3	172	175	0	0	0
Hydrobiidae	Snail	3	4	7	3	20	23	0	6	6	54	1	55
Planorbidae	Snail	0	0	0	0	1	1	0	0	0	0	0	0
Sphaeromatidae	Isopod	0	4	4	3	1	4	1	5	6	9	3	12
Hymenosomatidae	Crab	0	0	0	0	0	0	1	0	1	0	0	0
Total animals		133	118	251	112	166	278	82	313	395	76	13	89

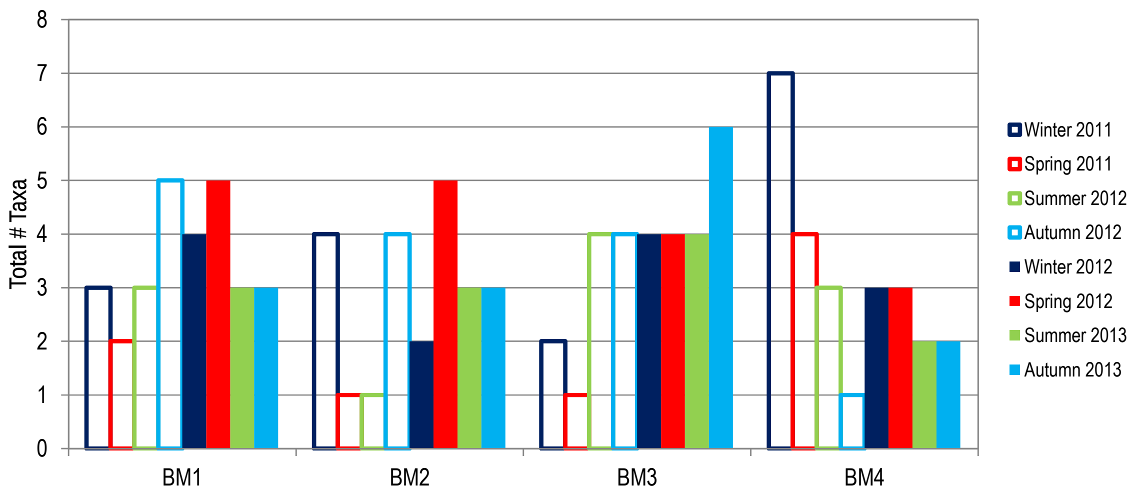


Illustration 3.2 Total number of taxa captured at each of the four sites in surveys since winter 2011

With consideration of how macroinvertebrate diversity has changed in response to channel closure, results of the average number of taxa per sample at each site indicate that diversity has remained relatively steady with no large increases or decreases noted. The direction of change in the number of taxa was for a small increase at BM1 and BM2, an increase at BM3 and a small decrease at BM4 (**Illustration 3.3**).

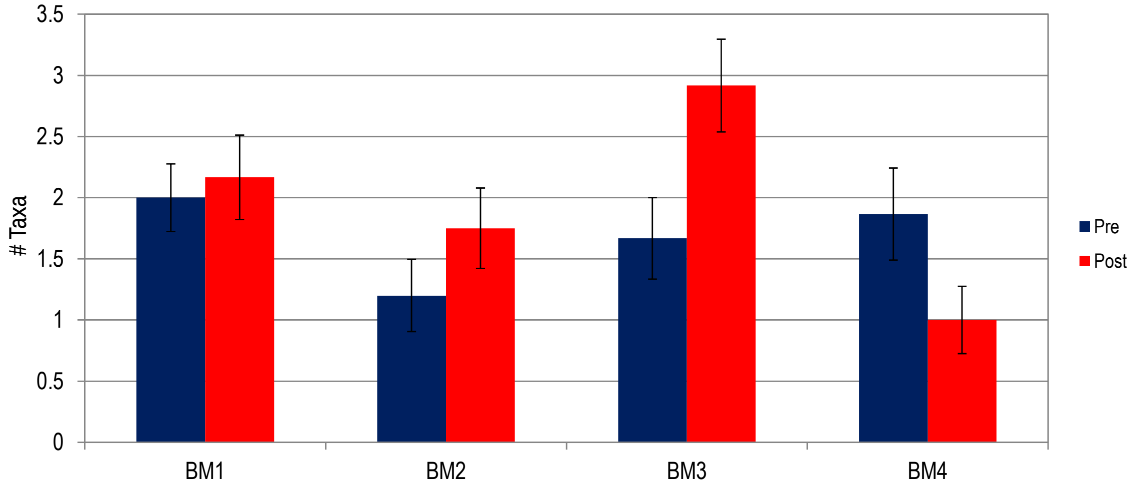


Illustration 3.3 Average (±SE) number of taxa per sample at each of the four sites prior to and after the closure of the artificial channel

3.3.3 Abundance

There was a great deal of variation in the total number of individual benthic macroinvertebrate captured between seasons during the current reporting period (**Table 3.3**). The lowest abundances were observed in the winter 2012 survey and the highest abundances in autumn 2013. There was also considerable variation in the total number of individuals captured at individual sites between seasons at BM1, BM2 and BM3. The abundance at S4 was low for the entire monitoring period (**Illustration 3.4**).

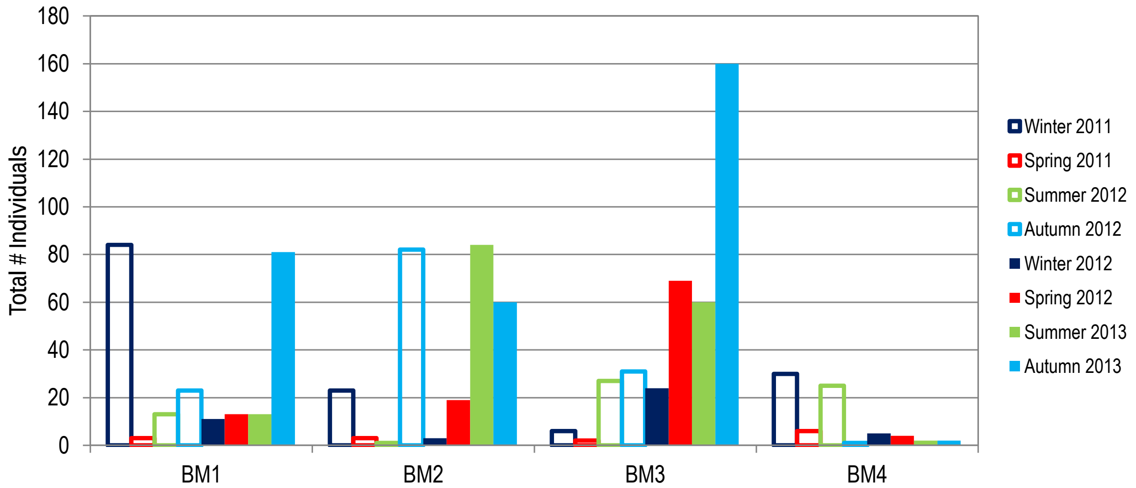


Illustration 3.4 Total number of animals captured at each of the four sites during surveys in the current reporting period

At BM1 there does not appear to be a trend with respect to abundance. However, apart from large numbers of *Spionidae* observed in the winter 2011 survey and large numbers of *Mytilidae* observed in the autumn 2013 sample, numbers have been relatively stable since the beginning of the MPPC. There is no clear seasonal pattern nor is there a close correlation between the variation in the number of individuals trapped and the observed variation in water quality. There has been no real change in the total abundance of animals since the closure of the artificial channel but there has been an increase in the number of *Mytilidae* and a decrease in the numbers of *Spionidae*.

At BM2 there does not appear to be a trend with respect to abundance. The majority of the variation in the total number of individuals is explained by the number of Chironominae captured. The variation cannot be attributed to seasonal factors at this stage of the project, nor is it adequately explained by the collected environmental factors. On average there appears to have been a slight increase in abundance since the closure of the artificial channel (though there has not been a clear shift in the species makeup at this site).

At BM3 there appears to be a general trend towards increasing abundance since the winter 2011 survey (Illustration 3.4). There has definitely been an increase in the average number of animals per sample since the closure of the artificial channel (Illustration 3.5). Although the highest numbers of animals in the pre-closure and post-closure periods have been captured in the autumn surveys there is not an obvious seasonal trend apparent. A closer look at the available data shows that the key changes resulting in different abundance between surveys occurs are the recent increase in the numbers of *Mytilidae*, a one-off sharp increase in the numbers of *Chironominae* and occasional short-term fluctuations in the numbers of *Capitellidae* and *Spionidae*.

At BM4 there appears to be a general trend towards decreasing abundance (Illustration 3.4) though abundances have generally been low since the beginning of the MPPC. The average number of animals per sample has clearly decreased since the closure of the artificial channel (Illustration 3.5). The key difference appears to be decreasing numbers of *Hydrobiidae* and *Sphaeromatidae*.

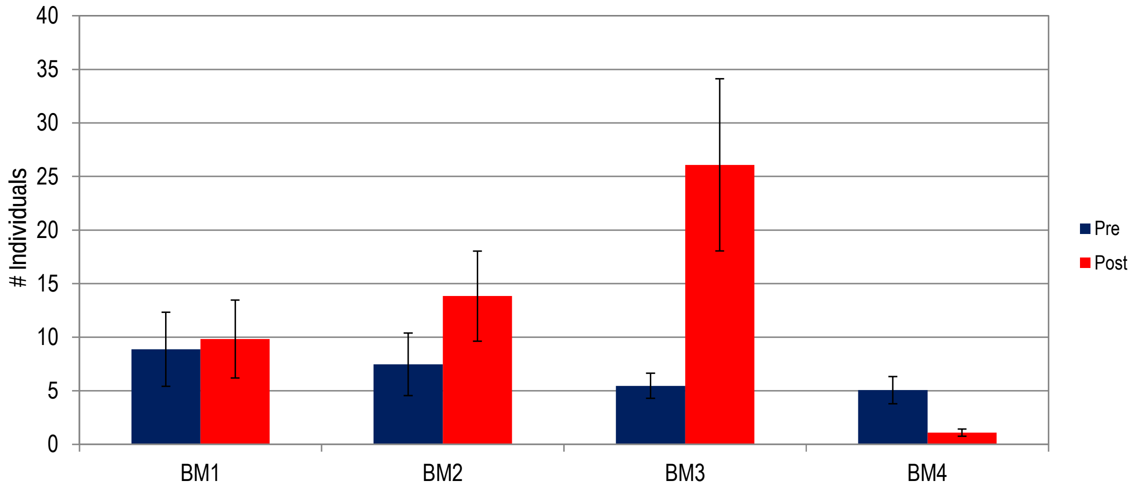


Illustration 3.5 Average (± SE) numbers of individual animals per sample at each of the four sites prior to and since the closure of the artificial channel

3.3.4 Conclusions

The benthic macroinvertebrate surveys have shown a large degree of variation and have provided a useful insight into the changes occurring in Salty Lagoon, both on a short term basis and 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 last reporting period there were no clear patterns of association with seasonal or measured environmental changes that can be concluded with certainty.

There has also been considerable variation in the numbers of individual macroinvertebrate captured at each site over time, indicating that macroinvertebrate abundance has fluctuated throughout Salty Lagoon during the reporting period. The direction of change has varied over time and between sites. For example the changes seem to have been random at BM1 and BM2 whilst abundance at BM3 has increased over time and decreased at BM4 over time. There is no clear evidence that the variation is strongly linked to either seasonal changes or short term water quality changes. Evidence for changes in abundance since the closure of the artificial channel is building at BM3 and BM4 but not at the other sites. However, there is no indication of causality at either of these sites. Continued monitoring should allow for stronger conclusions to be made.

The observed variation in abundance and diversity may be occurring in response to a combination of a large number of factors. Some of these 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 stabilised, higher water levels in Salty Lagoon and reduced variation in salinity;
- short term changes to the environment resulting from seasonal changes and the weather; and
- high levels of oxygen consumption and nutrient release from decaying vegetation matter, particularly around BM4.

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

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 specific dates of the aquatic weed surveys undertaken to date are 5 November 2012, 14 January 2013 and 15 April 2013.

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

The pathway of the meandering transect was recorded using the tracking feature of a handheld GPS set to track points at intervals of 20 seconds. The approximate transect pathways used during weed surveys and the location and species of all aquatic weeds encountered is displayed in Illustration 1.1.

4.3 Results

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

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

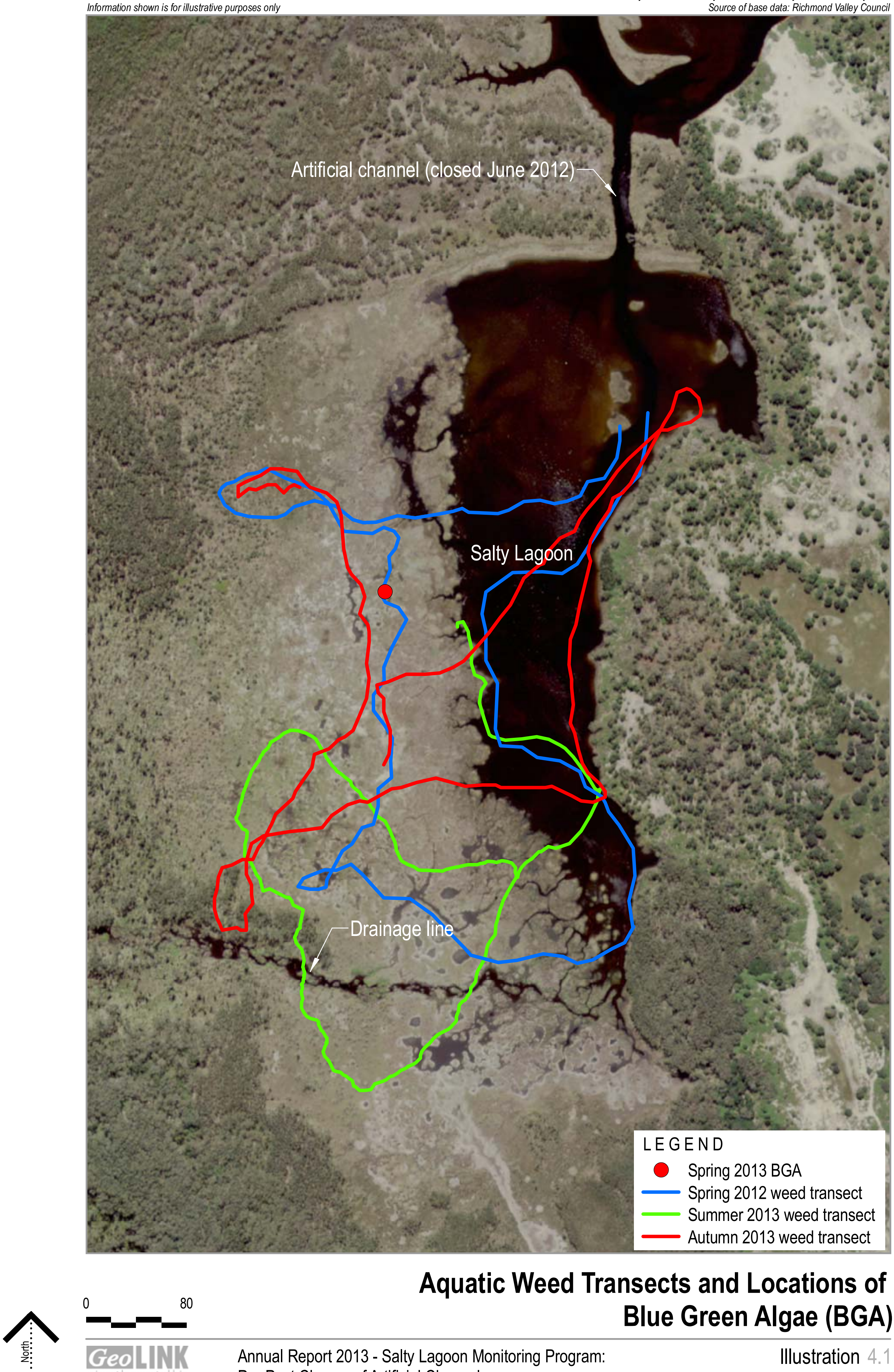
Table 4.1 List of all aquatic plant species detected during aquatic weed surveys and an assessment of their abundance.

Species Name	*Common Name*	*Survey*						
		Aut '11	*Spr '11*	*Sum '12*	*Aut '12*	*Spr '12*	*Sum '13*	*Aut '13*
Avicennia marina	Grey Mangrove	UC	UC	UC	UC	UC		
Sesuvium portulacastrum	Sea Purslane	UC	UC					
Hydrocotyle bonariensis^	A Pennywort		UC			UC		
Lomandra sp.	A Mat-rush							UC
Enydra fluctuans	Buffalo Spinach	UC	UC					UC
Lobelia anceps	Angled Lobelia	UC		UC				
Sarcocornia quinqueflora	Bead Weed	UC	UC					
Suaeda australis	Seablite	UC						
Baumea articulata	Jointed Twig-rush		UC				UC	UC
Cyperus exaltatus	Giant Sedge	UC		UC				
Cyperus difformis	Dirty Dora	UC		UC	UC		UC	UC
Gahnia sieberiana	Red-fruit Saw-sedge						UC	UC
Shoenoplectus validus	River Club-rush	VC	VC	VC	VC	VC	C	C
Shoenoplectus mucronatus	A Rush	VC	VC	UC	UC			
Juncus krausii	Sea Rush	VC	VC	VC	VC	VC	VC	C
Juncus usitatus	Common Rush						UC	
Bacopa monnieri	Bacopa	C	VC	C	UC	C	C	UC
Paspalum vaginatum	Saltwater Couch	VC	VC	VC	VC	VC	VC	VC
Phragmites australis	Common Reed	VC	C	C	C	C	C	C
Sporobolus virginicus	Saltwater Couch	C	C	C	C			
Persicaria decipiens	Slender Knotweed		UC					
Rhizophora stylosa	Red Mangrove	UC						
Azolla pinnata	Ferny Azolla	UC	VC	UC	UC	UC	UC	UC
Typha orientalis	Cumbungi		UC	UC		UC	UC	UC
Enteromorpha sp.	Enteromorpha					C	VC	
Various	Blue Green Algae	C	C	C	UC	UC		

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

Drawn by: TJP Checked by: MVE Reviewed by: GJM Date: July 2013
Source of base data: Richmond Valley Council

Information shown is for illustrative purposes only



Aquatic Weed Transects and Locations of Blue Green Algae (BGA)

GeoLINK environmental management and design

Annual Report 2013 - Salty Lagoon Monitoring Program:
Pre-Post Closure of Artificial Channel

1731-1077

Illustration 4.1

This page has been intentionally left blank.

4.4 Discussion

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

Observed incidences of BGA and Ferny Azolla, the two potentially nuisance plants observed in the past have reduced since the previous annual report (GeoLINK 2012a). BGA are naturally occurring and become a nuisance under bloom conditions when they can be toxic to fauna and humans and lead to deoxygenation of the water column. Ferny Azolla is a native plant that under certain conditions can cover large areas of the surface of water bodies, hindering light penetration into, and potentially leading to deoxygenation of, the water column. The reduced occurrence of these plants is a positive change.

During this reporting period a number of species not previously observed were recorded and other species previously observed were not recorded. Of the species identified prior to, but not during, the current reporting period, the majority are saltmarsh specialists, such as Seablight, Sea Purslane, Bead Weed and Saltwater Couch. The reduced number of observations of these plants is no surprise given the increased water depths and dominance of freshwater in Salty Lagoon following closure of the artificial channel.

A more in depth analysis of vegetation changes, based upon a quantitative sampling regime is given in Section 8. However, 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 shorter time scale than the quantitative vegetation surveys.

Plate 4.1 Flowers of Red-fruit Saw-sedge (*Gahnia sieberiana*) in the south western part of Salty Lagoon

Plate 4.2 A stand of Jointed Twig-rush (*Baumea articulata*) in the south western part of Salty Lagoon

This page has been intentionally left blank.

5

Fish

5.1 Introduction

Fish populations in intermittently closed and open lakes and lagoons (ICOLLS), such as the Salty Creek system, tend to be highly variable in response to the regular changes in environmental variables such as water quality, depth and habitat availability (Hadwen & Arthrington 2006). Fish distribution, diversity and abundance all change throughout ICOLLS in relation to aspects such as salinity and the entrance opening and closing regime. Two key factors driving fish distribution, diversity and abundance in ICOLLS are:

- the interaction between the timing and frequency of entrance opening events and seasonal events in the life cycle of fish species; and
- the salinity tolerance of freshwater/brackish species and their ability to move and exploit a variety of habitats under changing salinity regimes.

Prior to the closure of the artificial channel, Salty Lagoon operated as part of an ICOLL and regular changes in the fish populations resulted in response to the entrance status and rainfall runoff. Since the closure of the artificial channel, the water levels in Salty Lagoon have stabilised at higher levels and the salinity regime is much less variable. The fish populations of Salty Lagoon are expected to be impacted positively in the long terms as a result of the closure of the artificial channel (Hydrosphere 2010b).

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

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

Fish are monitored as part of the MPPC due to their iconic status, importance to ecosystems and sensitivity to environmental change. The aims of sampling fish fauna throughout the MPPC project are as follows:

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

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 at specific times.

5.2 Methods

5.2.1 Site Selection

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

Site	*Habitat*	*Salinity 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 and 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 a stratified water column was common at this site following seawater ingress.
F2*	This site is an area of shallow ponded open water where the drainage channel from the STP traverses rushlands in the SW part of the lagoon. The vegetation around the pond is dominated by River Club-rush and Cumbungi (*Typha orientalis*) but also includes Sea Rush and Saltwater couch (*Paspalum vaginatum*). There are a number of snags in the channel, the bank at this point slopes gently and the sediment is a mixture of mud and coarse organic detritus.	This site has always been predominantly fresh water, dominated during most times by input from the Evans Head STP. However, salt water ingress past this point in the Lagoon has been recorded at times.
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 a stratified water column was common at this site following seawater ingress.
F4	This site is a series of small pools of open water in a low lying area that drains water from a paperbark swamp forest to the NW of the lagoon. The pools are lined mostly with Common Reed (*Phragmites australis*) and Broad-leaved Paperbark. The sediment is a mixture of mud and coarse organic detritus.	This site was always dominated by freshwater input from the catchment. Seawater ingress at this point in the lagoon only occurred very rarely and under specific circumstances.

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

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.

5.2.2 Timing

Fish fauna are sampled on a seasonal basis, in effect, once during every three month period. In the current reporting period fish were surveyed on 9 July 2012, 8 October 2012, 14 January 2013 and 15 April 2013. The traps are generally set within 2.5 hours of dawn and collected within 2.5 hours of dusk. Due to license conditions imposed by Industry and Investment NSW (I&I now DPI) the traps are not able to be set through the night as they were during previous monitoring within Salty Lagoon.

5.2.3 Capture and Handling

Fish fauna were sampled under Scientific Collection Permit (P11/0012-1.0) and Animal Research Authority (11/924). Five standard bait traps were set at intervals of between 2 m and 5 m at each site, depending on the available habitat. The traps were baited with a mixture of aniseed scented fish pellets and tinned sardines and left unattended for the day. Upon collection captured fauna were identified and counted prior to being released. At least one photo of each native finfish species encountered was taken. In keeping with licence conditions non-native fauna were 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

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 2012	9/07/2012	14.02	1.50	0.15	1.96	18
Spring 2012	8/10/2012	22.04	2.97	5.12	1.77	0
Summer 2013	14/01/2013	26.93	9.11	9.98	1.81	0
Autumn 2013	15/04/2013	20.70	0.37	2.03	1.98	42.2

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

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.

5.3.2 Fish Diversity

The numbers of fish species captured at each site have 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.

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

Family	*Species*	*Common Name*	*04/11*	*07/11*	*10/11*	*01/12*	*04/12*	*07/12*	*10/12*	*01/13*	*04/13*
Anguillidae											
Anguilla reinhardtii		Longfin Eel	*				*				
Eleotriidae											
Gobiomorphus australis		Striped Gudgeon	*	*	*	*	*	*		*	*
Hypseleotris compressa		Empire Gudgeon					*				
Hypseleotris galii		Firetail Gudgeon				*					
Philypnodon grandiceps		Flathead Gudgeon			*		*				*

Family	Species	Common Name	04/11	07/11	10/11	01/12	04/12	07/12	10/12	01/13	04/13
Philypnodon macrostomas		Dwarf Flathead Gudgeon	*		*	*	*			*	*
Gobiidae											
Afurcagobius tamarensis		Tamar River Goby			*	*	*			*	*
Poecilidae											
Gambusia holbrooki		Mosquito Fish^	*	*	*	*	*			*	*

^ Introduced Species

A variety of vertebrate and invertebrate fauna were captured during the surveys including fish, crustaceans, snails and insects. However, reporting for fish surveys will focus on the targeted finfish species only rather than the invertebrates captured. Across all surveys during the reporting period a total of five finfish species were captured. This is lower than the eight species captured during the previous reporting period (GeoLINK 2012a). A list of fish species captured since the beginning of the MPPC is presented in Table 5.3. All species on the list were also caught during bait trap fish surveys undertaken as part of the ERMP (Hydrosphere 2010a).

Variation in the diversity of fish species captured at each site since the beginning of the MPPC is displayed in Illustration 5.1. The number of species captured over time occurred at each of the sites showed some variation. No finfish were captured at any sites during the spring 2012 survey and only one species was captured during the winter 2012 survey. At the other sites there is no clear pattern with the exception of S4 where native fish (Striped Gudgeon) were captured for the first time since the beginning of the MPPC during the summer 2013 and autumn 2013 surveys.

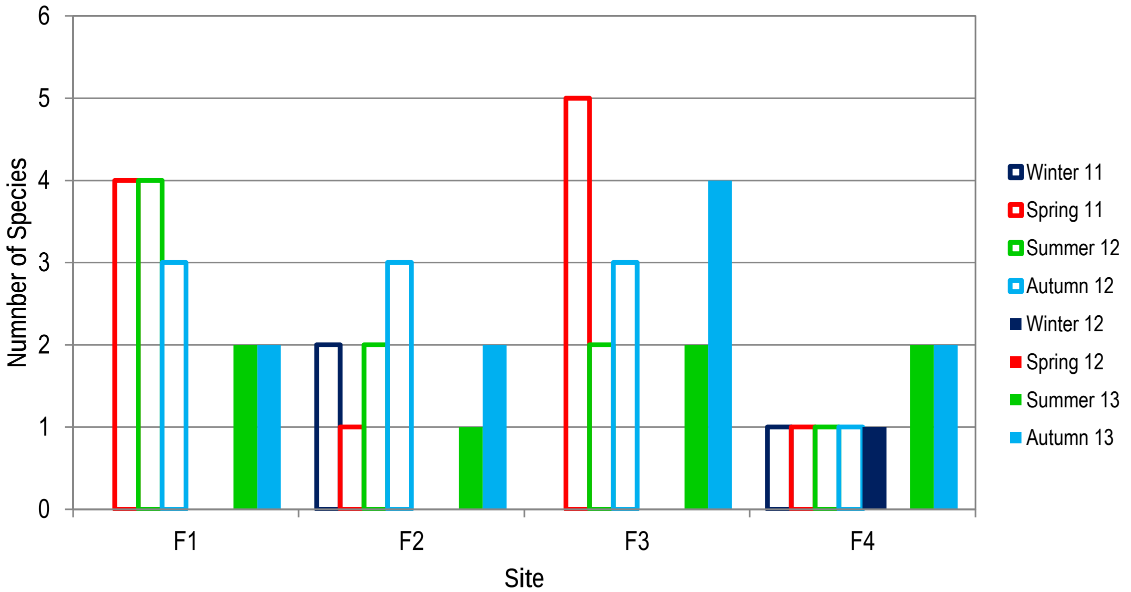


Illustration 5.1 Number of finfish species captured at each site in surveys undertaken since winter 2011.

5.3.3 Abundance

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

- a reduction in numbers of fish captured at S1 during the current reporting period when compared with the previous reporting period (GeoLINK 2012a); and
- a general reduction in the numbers of captured fish during the winter surveys.

The large fluctuations in the numbers of fish captured at S2 and S4 can be attributed to differences in the numbers of Mosquito Fish (*Gambusia holbrooki*).

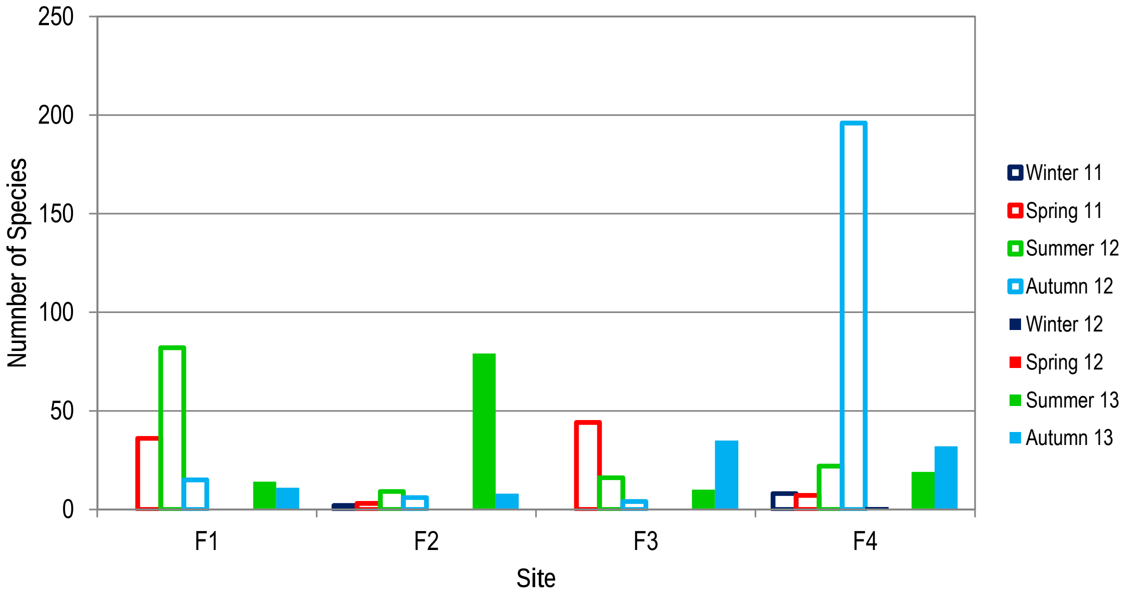


Illustration 5.2 Number of finfish individuals captured at each site over the five sampling periods undertaken since the winter 2011 survey.

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, they tend to be more difficult to detect over the short term than 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 predicted changes to the fish fauna.

A considerable degree of variation in fish abundance and diversity has been detected during the nine fish surveys undertaken thus far. In general, fish diversity and abundance appears to have decreased since the closure of the artificial channel. This observation was most obvious during the two surveys taken after the channel closure in winter 2012 and spring 2012 when a total of one fish was caught for the two surveys. Despite this there were progressive increases in either abundance, diversity or both at all sites except S1 during the summer 2013 and autumn 2013 surveys. This indicates that fish abundance and diversity may have reduced for a period following channel closure before beginning to recover. Some possible explanations for the reduction in captures and the subsequent increase include:

- stochastic factors associated with fish capture;
- a temporary negative impact on fish populations resulting from the direct changes to the Salty Lagoon ecosystem, such as permanently higher water levels and dieback of rushlands, followed by a period of recovery;
- short term impacts on fish populations resulting from independent variations in conductivity, DO concentration and temperature occurring immediately prior to fish surveys; and
- a temporary reduction in the density of fish populations resulting from the great increase in permanently available habitat, followed by an increase in density as breeding-driven recruitment occurs.

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

The conditions at the time of monitoring varied between the five surveys undertaken. The key variations were in the water temperature, conductivity and dissolved oxygen concentration. However, in comparison with the previous annual reporting period (GeoLINK 2012a) variations in water level and conductivity were much smaller. The variability of conditions at the time of sampling contributes significantly to the complexity of the dataset. Continued sampling over the long term will increase the capacity to draw conclusions.

In general the abundance and diversity of species trapped was low. The largest number of species trapped at any one site during any one survey was 5. Despite this the results were comparable to those reported from previous surveys using bait traps (GeoLINK 2012a, 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. Following closure of the artificial channel water levels have stabilised, resulting in changes to the availability of different habitat types.

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, in effect once every three months. The dates of surveys during the current reporting period were 9 July 2012, 9 October 2012, 14 January 2013 and 15 April 2013.

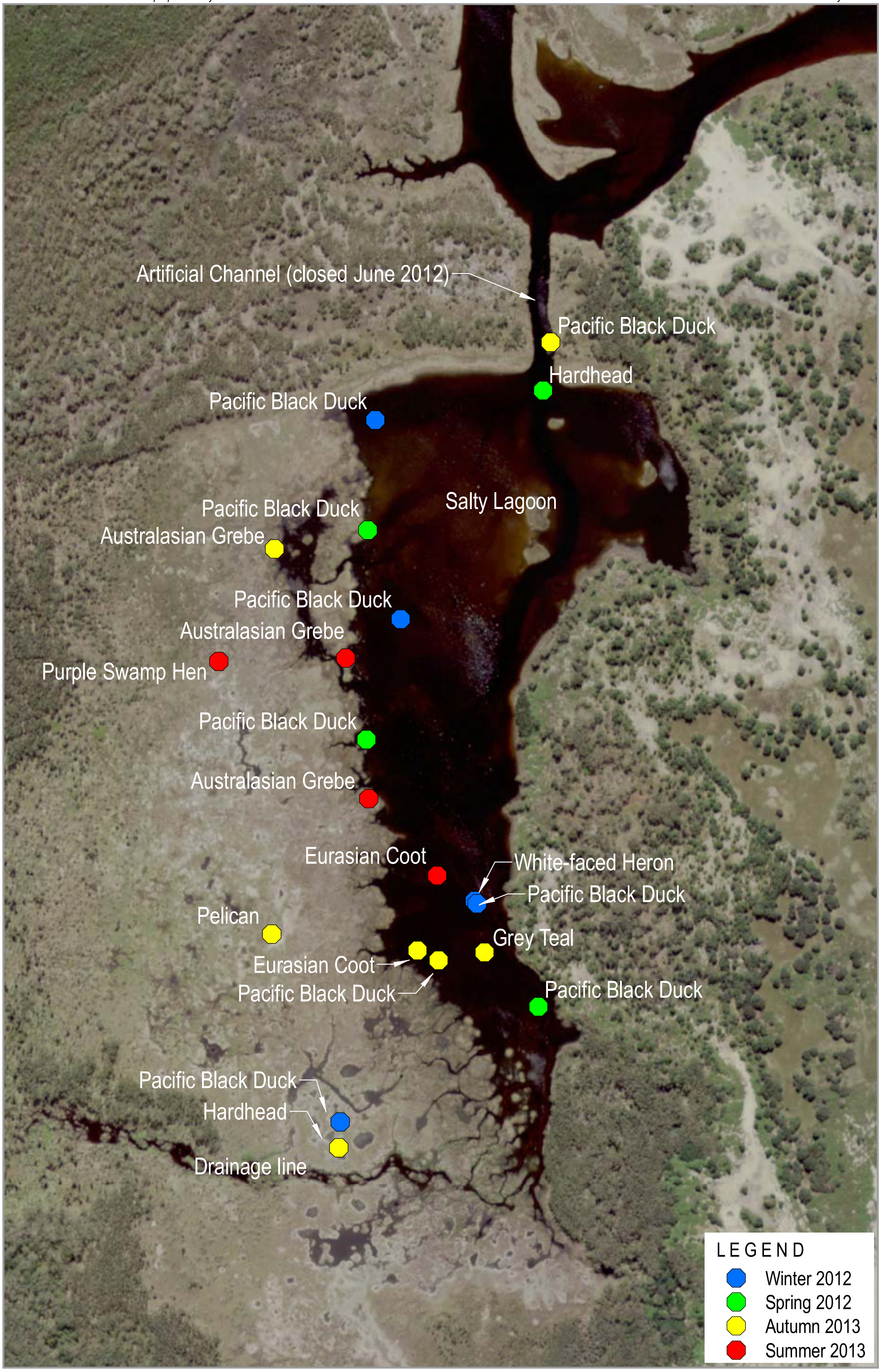
Plate 6.1 A Great Egret (*Ardea alba*) along the margins of Salty Creek

6.2.2 Surveys

Waterbird monitoring involved a foot or canoe based traverse of open water and fringing rushlands in Salty Lagoon over the course of 1 hour. Water bird surveys are completed within 2 hours of dawn. Birds were identified using a field guide (Simpson & Day 1999) and counted using Bushnell 8 x 42 binoculars. All birds were included in the count, including non-waterbirds. However the focus of discussion relating to changes in bird assemblages on Salty Lagoon focuses on waterbirds. All possible efforts were made to avoid counting individual birds or flocks twice. Where flocks of >8 birds were observed, a GPS mark was taken. These are reproduced in Illustration 1.1.

This page has been intentionally left blank.

Drawn by: TJP Checked by: MVE Reviewed by: GJM Date: July 2013
Source of base data: Richmond Valley Council
Information shown is for illustrative purposes only



GeoLINK environmental management and design

Mapped Locations of Bird Flocks

Annual Report 2013 - Salty Lagoon Monitoring Program:
Pre-Post Closure of Artificial Channel
1731-1078

Illustration 6.1

This page has been intentionally left blank.

6.3 Results

6.3.1 Conditions at the time of Monitoring

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

Table 6.1 Environmental condition at the time of waterfowl monitoring.

Survey	*Date*	*Water Depth (mAHD)*	*72 Hour Rainfall (mm)*	*Weather*	*Wind*
Winter 2012	9/07/2012	1.96	18	Light Cloud	Light W
Spring 2012	9/10/2012	1.77	0	Fine	Light NW
Summer 2013	14/01/2013	1.81	0	Overcast	Moderate S
Autumn 2013	15/04/2013	2.01	42.2	Overcast	Light NW

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

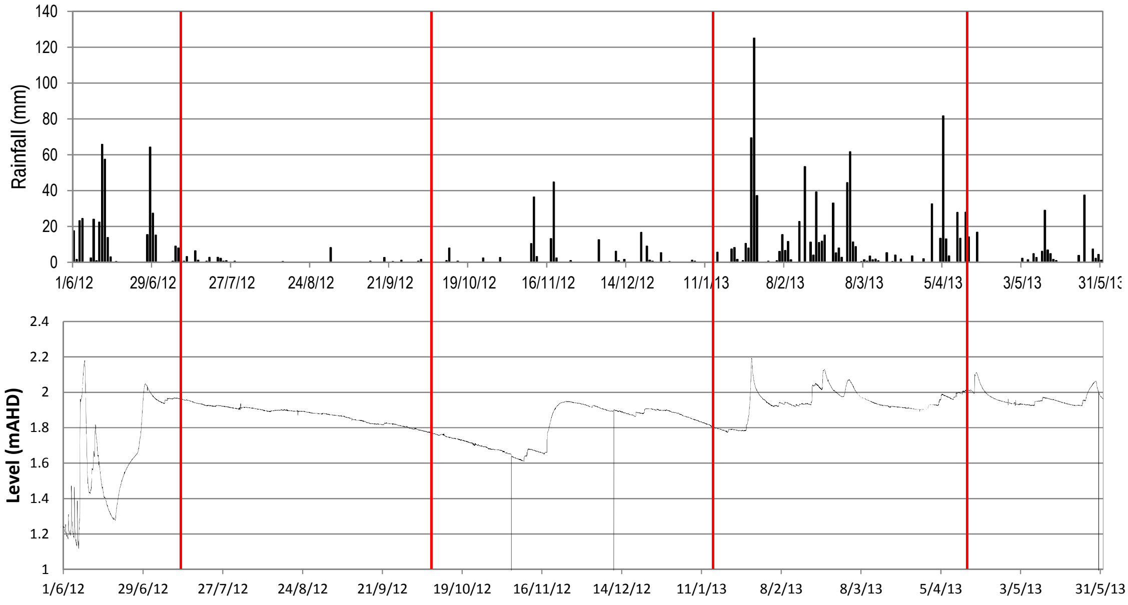


Illustration 6.2 Rainfall and water level charts for the reporting period showing bird survey times (red).

The water level at the time of sampling was high to very high for all samples. Low water levels are unlikely to be observed in Salty Lagoon following the closure of the artificial channel. The higher water levels experienced during the winter 2012 and autumn 2013 surveys translate to more open water habitat available. Antecedent rainfall and weather during monitoring varied widely among the seasons. The autumn 2013 survey was undertaken after a number of days of consistent moderate rainfall. Rainfall prior to the other surveys was relatively light.

6.3.2 Diversity

The diversity of species observed in waterbird surveys undertaken during the current reporting period has been relatively consistent in terms of the number of species observed. The greatest diversity of species was observed during the summer survey. This is consistent with previous years when high species diversity has been observed in the summer and spring (Illustration 6.3). In terms of changes before and after the closure of the artificial channel the average recorded species diversity has been higher following closure of the artificial channel. In addition, higher species numbers have been observed in each of the seasons (when compared with the same season in the previous monitoring period [GeoLINK 2012a]) with the exception of the spring survey.

Although changes in the number of species observed have not been large since the closure of the artificial channel there have been some notable changes in which species were observed (Table 6.2). In particular, a number of species have only been observed during the MPPC in the post channel closure surveys. These species included Hardhead (*Aythya australis*), Eurasian Coot (*Fulica atra*), Purple Swamphen (*Porphyrio porphyria*) and Comb-crested Jacana (*Irediparra gallinacea*). Comb-crested Jacana is listed as a vulnerable species under the NSW *Threatened Species Act 1995* (TSC Act). Species that were observed prior to channel closure, but not since the channel closure, include Black Bittern (*Ixobrychus flavicollis*) (also listed as vulnerable under the TSA Act) and Little Egret (*Egretta garzetta*).

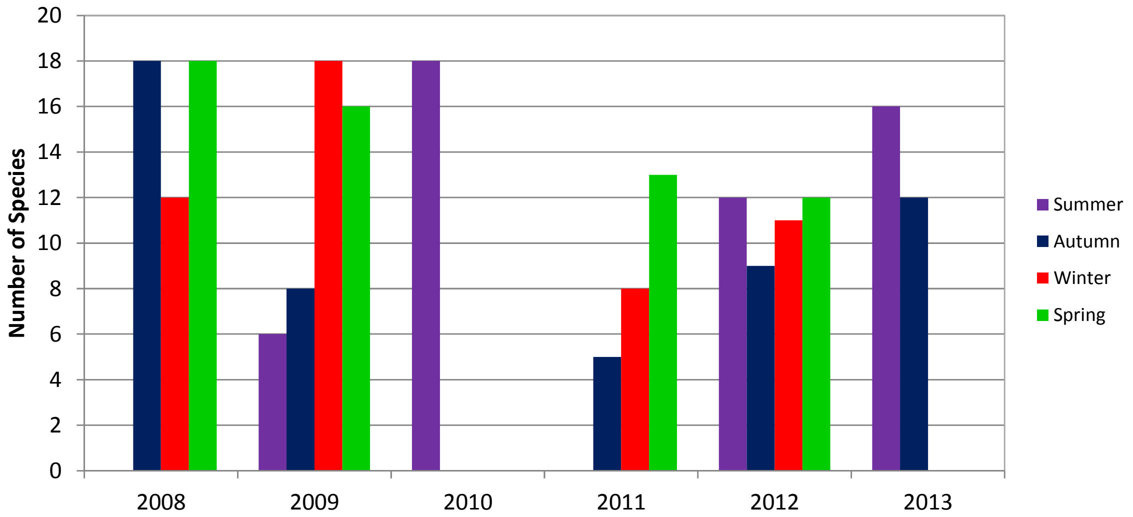


Illustration 6.3 Number of bird species observed in previous seasonal surveys on Salty Lagoon (Autumn 2008 until Summer 2010 (Hydrosphere 2010a)) and during the MPPC (Autumn 2011 until Autumn 2013)

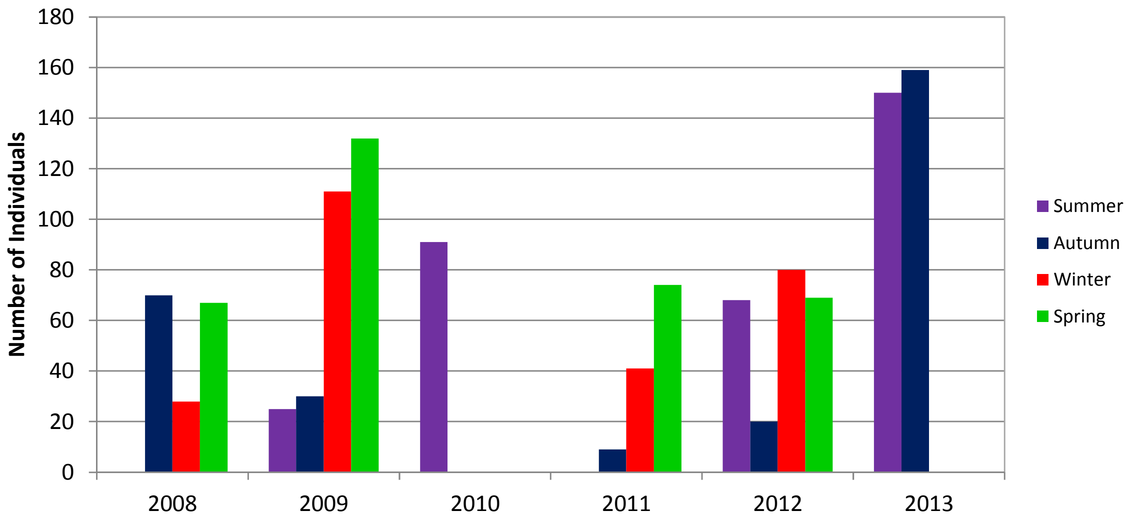


Illustration 6.4 Number of individual birds observed in previous seasonal surveys on Salty Lagoon (Autumn 2008 until Summer 2010 (Hydrosphere 2010a)) and during the MPPC (Autumn 2011 until Autumn 2013)

6.3.3 Abundance

Waterbird abundance has varied since the beginning of the MPPC in autumn 2011. The greatest abundances observed have clearly been in the last two surveys undertaken in summer and autumn 2013. The average observed abundance has increased since the closure of the artificial channel. In addition, the abundances observed since the closure of the artificial channel have been greater each season in comparison with the equivalent seasons prior to channel closure.

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

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

Common Name	*Aut 2011*	*Win 2011*	*Spr 2011*	*Sum 2012*	*Aut 2012*	*Win 2012*	*Spr 2012*	*Sum 2013*	*Aut 2013*
Little Black Cormorant			4	3			2	4	8
Little Pied Cormorant	2	1		1		1			
Pied Cormorant				9	2	1		1	
Great Cormorant						1			1
Darter				1	1	1	1	2	
Pelican		30	10						13
Australasian Grebe		1		2			6	18	9
Grey Teal	1	3	29	23				16	20
Pacific Black Duck				7	4	59	31	42	52
Chestnut Teal			1				6		
Hardhead							11		20
Black Swan				2	4	2			1
Purple Swamphen								33	
Eurasian Coot								22	24
Comb-crested Jacana*								3	
White Faced Heron	1	2	5		2	6	2	1	9
Black Bittern*			1						
White Necked Heron			2					1	
Little Egret			1						
Intermediate Egret							1	1	
Great Egret			3	1	1	1	4	2	1
White Ibis			2				1		
Whimbrel								1	
Black Winged Stilt	3				2				
Masked Lapwing		2	2						
Black Fronted Dotterel			7						
Rainbow Bee Eater				3					
Welcome Swallow			7		3	3	3		
White-throated Needletail				15					
Raven				1					
Eastern Osprey*									1
Sea Eagle	2	1			1	1			
Wedge Tailed Eagle							1	1	
Whistling Kite		1				4		2	
Total No. Species	5	8	13	12	9	11	12	16	12
Total No. Individuals	9	41	74	68	20	80	69	150	159

* Species listed as vulnerable under the TSC Act

6.4 Discussion

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

Waterbird abundance and diversity have fluctuated since the beginning of the MPPC (refer to GeoLINK 2012a). Although the general trend appears to be towards increased diversity and abundance since closure of the artificial channel the results are not conclusive at this point in time. The results of previous surveys (Hydrosphere 2010a) suggest that variation in the numbers and diversity of waterbirds does not only occur as a result of seasonal change, though it is undoubtedly a major factor accounting for diversity. Much of the variation in previous results has been explained by the varying availability of mud flats in Salty Lagoon caused by changes in the water level. Since the closure of the artificial channel mud flats have not been available in Salty Lagoon and this has been reflected in increased numbers of Pacific Black Ducks, Hardheads, Australasian Grebe and Eurasian Coot, all birds that favour open water habitats and rushlands. It is likely that these changes will be permanent.

Plate 6.2 Pelicans (*Pelecanus conspicillatus*) are regular visitors to Salty Lagoon

7

Terrestrial Vegetation

7.1 Introduction

This section of the annual report summarises the methods, data, observations and conclusions relating to vegetation monitoring during the 2013 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 (2013). 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 (2012b).

Prior to this current engagement, RVC implemented the Salty Lagoon Ecosystem Recovery Monitoring Program (ERMP). In brief, the ERMP aimed to monitor the ecological health of the system for a two year period, and to collect data across a range of disciplines to allow for further planning to be undertaken in accordance with the broader aims of the rehabilitation strategy. This work included a flora and vegetation mapping component and was completed in March 2010 (Hydrosphere 2010a), and a comprehensive description of methods and results from the ERMP monitoring is provided in that report.

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

7.1.1 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; and
- 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 m deep to remain largely unchanged; and

- other vegetation habitat zones that occur below 2 m AHD to be potentially affected along the drainage channel (Sedge Swamp/ open water) and along the eastern edge of the lagoon (Fringing Marsh and Banksia Woodland).

7.2 Methodology

The following section details the methodology used for the 2013 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 2012b).

7.2.1 Vegetation Transects

7.2.1.1 Timing

Vegetation sampling was undertaken over three days on 6 March, 12 March and 27 March 2013.

Water levels at the time of sampling were relatively high, as a result of the combined effects of closure of the artificial channel linking Salty Lagoon with Salty Creek in June 2012 and a wet summer/ early autumn period experienced just prior to sampling in 2012-2013. Some of the monitoring quadrats closest to the pre-closure edge of the lagoon were covered by up to 60 cm of water at the time of sampling, and were in the process of converting from fringing marsh to open water as vegetation died from inundation. Water levels in Swamp Forest and Sedge Swamp were lower, but nonetheless were higher than previously recorded during the 2011 monitoring event, as influenced from rainfall runoff and accumulation after the wet weather, compared with previous monitoring events.

7.2.2 Vegetation Habitat Zones

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

- Sedge Swamp/ Swamp Forest: Sedge Swamp has a clearly defined edge and generally comprises a dense thicket dominated by Gahnia sieberiana, which occurs in all strata including the upper stratum (generally <3 m 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 3 m 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 m 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 vegetation habitat zone along each transect (i.e. total of six quadrats per transect). Quadrats are orientated generally in an east-west direction and run from the open water at the eastern end through the Sedge Swamp to the heathland boundary to the west. The location of the boundary of each of the vegetation habitat zones was recorded via global positioning system (GPS).

Transects 4-6 are between 20-60 m in length and each comprise two distinct vegetation habitat zones. One quadrat (10 m x 10 m) is located in each 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 m above the ground) for each stem greater than 10 cm DBH;
- description of vegetation health; and
- photos taken from the north-east corner of each quadrat.

7.2.3 Selection of Indicator Species

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

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

7.2.4 Melaleuca Dieback / Recolonisation

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

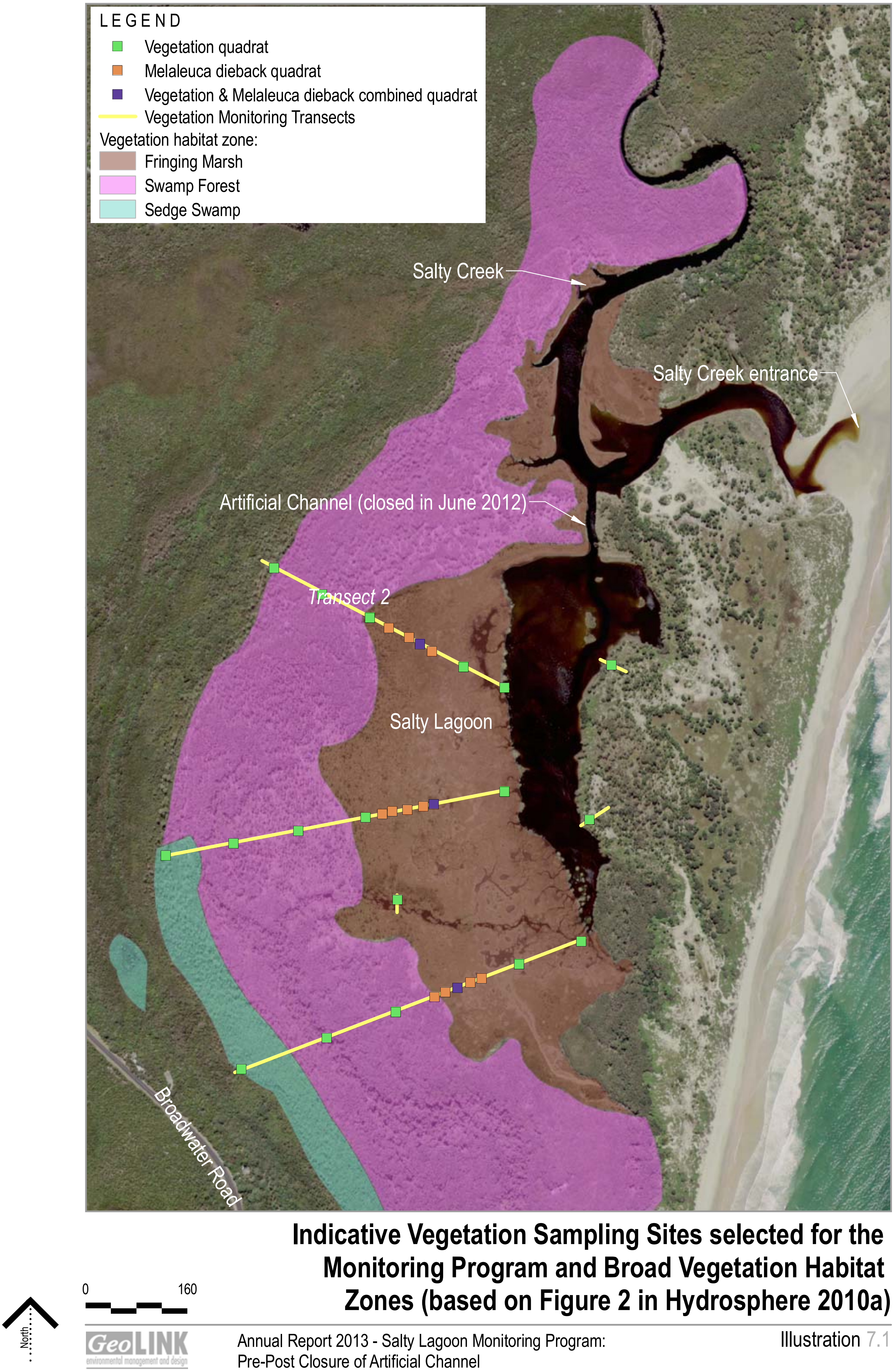
Data recorded at Melaleuca dieback quadrats includes:

- 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); and
- condition of trees within the quadrat using the following categories:
  - unaffected/ full recovery;
  - resprouting; and
  - dead.

This page has been intentionally left blank.

Drawn by: TJP Checked by: MVE Reviewed by: DSA Date: August 2013
Source of base data: Richmond Valley Council

Information shown is for illustrative purposes only



Indicative Vegetation Sampling Sites selected for the Monitoring Program and Broad Vegetation Habitat Zones (based on Figure 2 in Hydrosphere 2010a)

This page has been intentionally left blank.

7.3 Results and Discussion

7.3.1 Transects 1-3

Transects 1-3 extend across the three distinct vegetation habitat zones of Fringing Marsh, Swamp Forest and Sedge Swamp. The location of the boundary between these vegetation habitat zones was established and recorded by GPS. The relative distance occupied by the vegetation habitat zones along each transect is detailed in Table 7.1.

Table 7.1 Extent of Vegetation Habitat Zones along Transects 1-3

Transect	*Extent of Fringing Marsh (m)*	*Extent of Swamp Forest (m)*	*Extent of Sedge Swamp (m)*	*Total Length (m)*
Transect 1	102	121	152	375
Transect 2	151-195	185-265	84	544
Transect 3	225	198	133	556

In total, 55 flora species (both native and exotic) were recorded from the three vegetation habitat zones. The breakdown of species by vegetation habitat zones was as follows:

- Fringing Swamp - 7 species;
- Swamp Forest – 30 species; and
- Sedge Swamp – 32 species.

7.3.1.2 Vegetation Habitat Zone Descriptions

Fringing Marsh

At the time of the survey, the Fringing Marsh community was dominated by Saltwater Couch (*Paspalum vaginatum*) and Sea Rush (*Juncus kraussii* subsp. *australiensis*), with these species occurring in moderate density in all six quadrats. Shore Club-rush (*Schoenoplectus subulatus*) also occurs commonly, being recorded in low-moderate density in three out of six quadrats.

Swamp Forest

The Swamp Forest community was dominated by Broad-leaved Paperbark and Bare Twig-rush (*Baumea juncea*). Saltwater Couch and Sea Rush were also present in low-moderate abundance in four quadrats each. Groundsel Bush (*Baccharis halimifolia* - an exotic weed), Tall Sedge (*Carex apressa*), Blady Grass (Imperata cylindrica var. *major*), Spiny-headed Mat-rush (*Lomandra longifolia*) and Native Violet (*Viola* sp.) were all present in moderate density in one or more of the quadrats in this community.

Sedge Swamp

Sedge Swamp was dominated by Plume Rush (*Baloskion tetraphyllum*), which occurred at moderate to high density in five out of six of the quadrats. Swamp Twig-rush (*Baumea arthrophylla*) also occurred at a high density in two quadrats. Red-fruit Saw-sedge (*Gahnia sieberiana*), Weeping Baeckea (*Baeckea frutescens*), Grass Tree (*Xanthorrhoea* sp.) and Broad-leaved Paperbark were also present in moderate abundance, each being present in three to four quadrats.

Indicator Species

Based on the expected changes from Hydrosphere (2010b and 2011) and the quadrat data collected along Transects 1-3 the following species were identified as indicator species:

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

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

The average cover abundance value for each of these indicator species in the vegetation habitat zones is graphically represented in Illustration 7.2.

It is apparent that Plume Rush is a prominent feature of the Sedge Swamp community and Bare Twig Rush is a prominent species of the Swamp Forest. Broad-leaved Paperbark occurs broadly across both the Sedge Swamp and Swamp Forest communities and Sea Rush and Saltwater Couch occur across both Fringing Marsh and Swamp Forest. However, Saltwater Couch occurs most frequently in the Fringing Marsh.

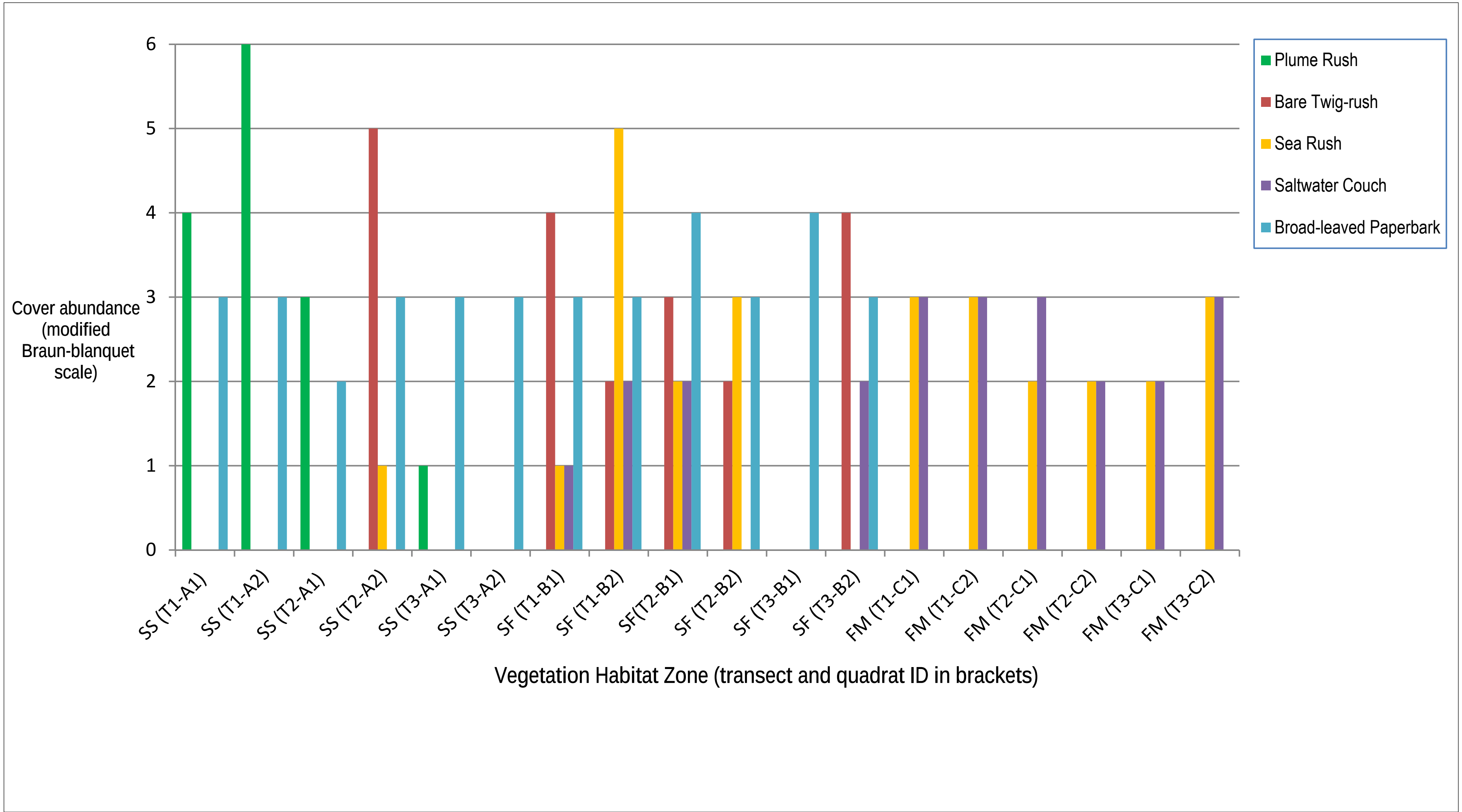


Illustration 7.2 Cover Abundance Scores for Indicator Species in Vegetation Habitat Zones of Transects 1-3

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

Vegetation characteristics recorded within quadrats along Transects 1-3 were recorded and are detailed in GeoLINK (2013).

7.3.2 Transects 4-6

7.3.2.1 Vegetation Habitat Zone Boundaries

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

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

The location of the monitoring transects is shown in Illustration 7.1.

The vegetation habitat zone boundaries along Transects 5 and 6 were fairly well defined in the field at the time of survey. However, as the level of the lagoon has increased following the artificial channel closure, the extent of the Fringing Marsh community has decreased substantially.

7.3.2.2 Species Composition of Vegetation Habitat Zones

In total, 38 flora species (both native and exotic) were recorded from the four vegetation habitat zones. The breakdown of species by vegetation habitat zones was as follows:

- Sedge Swamp/ Open Water – 12 species;
- Swamp Forest – 6 species;
- Fringing Marsh – 20 species; and
- Banksia Woodland – 17 species.

7.3.2.3 Vegetation Habitat Zone Descriptions

<u>Transect 4</u>

Sedge Swamp/ Open Water

Sedge Swamp/ open water supports a mixture of rushes and sedges and has a moderate density of Sea Rush. Saw-sedge (*Gahnia clarkei*) and Cumbungi (*Typha orientalis*) are present in this community at a low density.

Swamp Forest

Swamp Forest in this location is dominated by Broad-leaved Paperbark in the upper stratum and Saltwater Couch and Sea Rush in the lower stratum.

<u>Transects 5 and 6</u>

Fringing Marsh

Fringing Marsh at this location consists of an understorey dominated by Blady Grass along with a variety of rushes. Bare Twig-rush was the most prominent rush species recorded. Broad-leaved Paperbark is scattered in the overstorey. No indicator species were recorded as dominant flora along these transects.

Banksia Woodland

This relatively low diversity vegetation habitat zone consists of an open canopy of Coast Banksia with an understorey dominated by Blady Grass along with Bare Twig-rush. The quadrats were significantly infested with the exotic weed Bitou Bush.

7.3.2.4 Indicator Species

Based on the expected changes from Hydrosphere (2010b and 2011) and the results of the baseline vegetation monitoring, indicator species selected consisted of:

- Sea Rush (*Juncus krausii* subsp. *australiensis*) (prediction is that this species will decrease in the area currently occupied by the Gahnia sedge/ open water habitat zone along Transect 4);
- Saltwater Couch (*Paspalum vaginatum*) (prediction is that this species is expected to decrease in the area currently occupied by the Swamp Forest along Transect 4 and Fringing Marsh along Transect 5);

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

The average cover abundance value for each of these indicator species in the vegetation habitat zones is shown in Illustration 7.3.

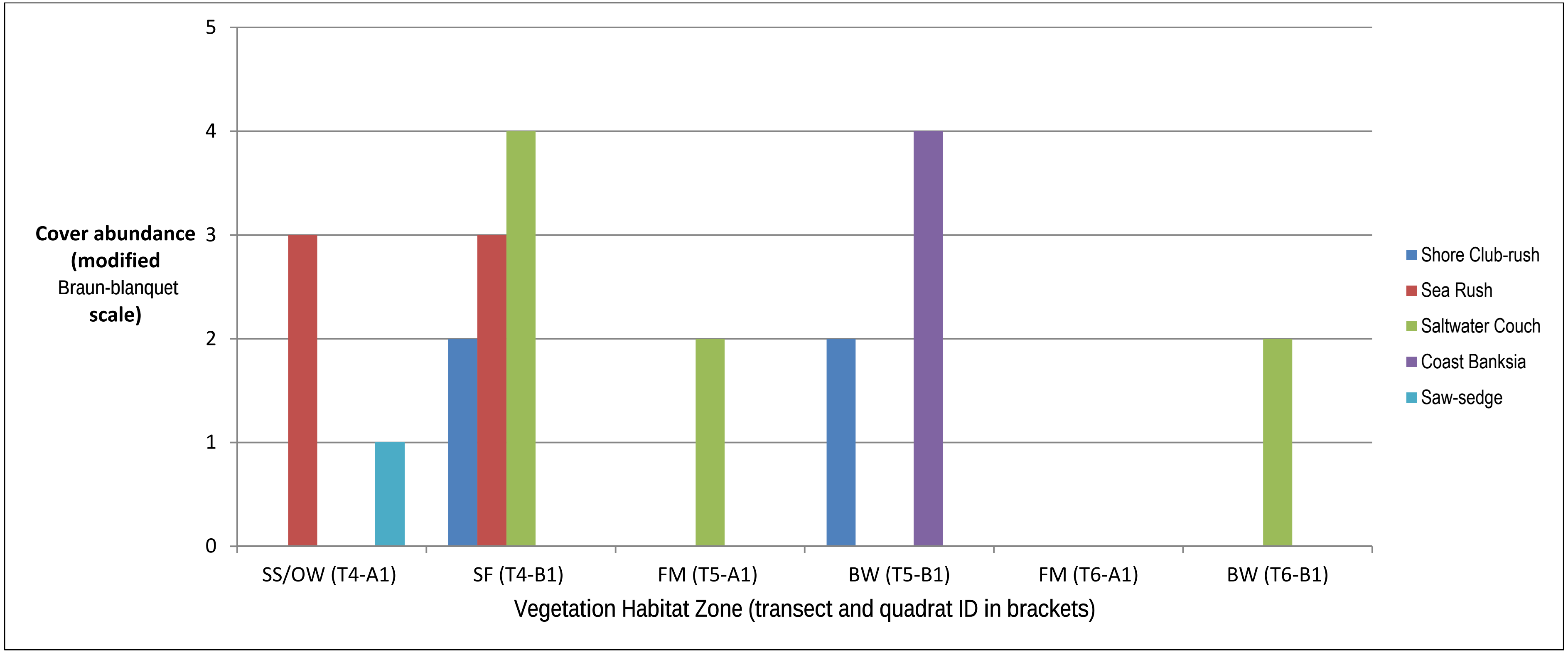


Illustration 7.3 Cover Abundance Scores for Indicator Species in Vegetation Habitat Zones of Transects 4-6

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

7.3.3 Melaleuca Dieback / Recolonisation Monitoring

Results from the Melaleuca dieback quadrats are provided in detail in GeoLINK (2013). Less than half of the quadrats contained dead Melaleuca individuals (7 out of 15), with the least dieback being recorded in the quadrats located along Transect 1. This reflects a very low general occurrence of Melaleuca (living or dead) in Melaleuca dieback quadrats along this transect. Most of the Melaleuca dieback recorded was in quadrats furthest from the edge of the lagoon, where Melaleuca dominance was also greatest.

Where applicable, observations of vegetation health (presence of necrotic spots on leaves, galls on small branches) for Broad-leaved Paperbark at the Salty Lagoon site was recorded as part of the vegetation zonation quadrats along Transects 1-3. In general, the observations taken indicated that Broad-leaved Paperbark health was good, with no discernible substantial necrosis of leaves or galls.

7.3.4 Photo-point Monitoring

All photos taken at photo monitoring points for the current monitoring period are displayed in GeoLINK (2013). These photos showed obvious changes in the vegetation over the last 2 years, particularly in the fringing marsh community where water levels have increased substantially following the closure of the artificial channel.

7.4 Discussion and Comparison with Previous Monitoring

7.4.1 Vegetation Habitat Zonation

7.4.1.1 Transects 1-3

The main change to occur in the location of the vegetation communities occurring on the western edge of Salty Lagoon since the baseline vegetation monitoring 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. Discerning the boundary between the Fringing Marsh and open water is practically challenging as some isolated clumps of rushes (primarily Sea Rush) have not yet fully died and decomposed and are therefore scattered across areas that will become open water sometime in the future.

The greatest reduction in Fringing Marsh occurred in the northern part of Salty Lagoon where the measured extent reduced by 80 m over the period since baseline vegetation monitoring.

7.4.1.2 Species Composition of Vegetation Habitat Zones

The overall number of species recorded in the 3 vegetation communities is less in 2013 compared with the results of the baseline vegetation monitoring. The major factor contributing to this decrease in the number of species recorded was the closure of the artificial channel and the resulting expansion of open water covering previously exposed ground in the fringing marsh. Twenty-eight flora species were recorded in the Fringing Marsh in 2011 compared with a count of 7 species in 2013. A relatively large proportion of the flora species occurring in the Fringing Marsh community were low-growing herbaceous species that are intolerant of submersion for an extended period.

7.4.1.3 Species Dominance

Species dominance was relatively stable between monitoring events, with the same species dominating each of the 3 vegetation communities.

7.4.1.4 Predicted Changes and Indicator Species

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

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

There has been a decrease in cover of Sea Rush in both of these communities. More of a reduction has occurred in the Fringing Marsh community when compared with the Swamp Forest. This may be attributable to the greater degree of inundation closer to the lagoon.

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

A similar pattern to that seen for Sea Rush has also occurred with Saltwater Couch. There has been a decrease in cover of this species in both of these communities, with the most notable reduction occurring in the Fringing Marsh community. Once again, this is likely to be the result of inundation of the Fringing Marsh community after closure of the artificial channel.

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

In the MPCC vegetation monitoring report, Shore Club-rush was identified as a potential indicator species that was expected to decrease in the area currently occupied by Fringing Marsh and Swamp Forest. This species was not recorded in the Swamp Forest community in either the MPCC vegetation monitoring or the 2013 monitoring. This species was not recorded at a high density in the MPCC vegetation monitoring. Nonetheless, this species has generally declined in cover in the Fringing Marsh since channel closure.

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

The monitoring results indicate that Bare Twig-rush has not increased in area in the area occupied by Fringing Marsh in the period of 2011-2013. As the closure of the artificial channel is a relatively recent event, it is too soon to form a judgement on whether this prediction has been proven to have not occurred at Salty Lagoon. Data from the next monitoring event in 2015 may show that this species has extended into the Fringing Marsh over a longer time frame.

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

Broad-leaved Paperbark has not extended into the Fringing Marsh as yet. The cover of this species has also remained relatively stable in and around the edge of the Swamp Forest community. As for Bare Twig-rush the timeframe since the closure of the artificial channel is likely to be insufficient to determine if this prediction will be borne out. The next monitoring event in 2015 (or later) may show that this species has extended into the Fringing Marsh over a longer time frame than was expected

7.4.2 Transects 4-6

The major influencing factor on the extent of the vegetation communities in transects 5 and 6 was also related to increased water levels caused by the closure of the artificial channel. This is most apparent when a comparison is made between the monitoring photos for the fringing marsh/ open water quadrats in the baseline vegetation monitoring report and the current monitoring event (refer to Plate 7.1).

Plate 7.1	Comparison between Transect 6, quadrat A1 in 2011 (left) and 2013 (right), showing a conversion from Fringing Marsh to open water.

7.4.3 Species Composition of Vegetation Habitat Zones

The overall number of species recorded in the vegetation communities along these transects was relatively stable over the period of 2011 to 2013, with 32 species recorded in the baseline vegetation monitoring and 38 species recorded in 2013. One major change was a decrease from 13 species to 6 in the Swamp Forest at Transect 4 (drainage channel). This most likely reflects the proximity of this site to areas that are currently mostly open water, and the inundation of understorey herbaceous species in this part of the site since the closure of the artificial channel. This change can be seen in a comparison of the monitoring photos for the Swamp Forest along Transect 4 taken for the baseline vegetation monitoring and the current monitoring event (refer to Plate 7.2).

Plate 7.2	Comparison between Transect 4, quadrat B1 in 2011 (left) and 2013 (right), showing inundated ground since artificial channel closure.

7.4.3.2 Species Dominance

Species dominance was relatively stable between monitoring events, with the exception of the Fringing Marsh community in which the dominant species have shifted from Saltwater Couch and Shore Club-rush in 2011 to Bare Twig-rush in fringing areas and Blady Grass where the transect crossed well-drained land just above the water level.

7.4.3.3 Predicted Changes and Indicator Species

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

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

Sea Rush showed no significant difference in cover between the baseline vegetation monitoring and the current monitoring event in 2013. As the closure of the artificial channel is a relatively recent event, it is too soon to form a judgement on whether this prediction has been proven to have not occurred at Salty Lagoon. Data from the next monitoring event in 2015 may show that this species has decreased in extent in this community over a longer time frame.

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

This species has experienced a slight decrease in cover in these communities but not to a great degree. As mentioned previously this change may become more apparent in future monitoring events over a longer time frame.

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

As predicted this species has decreased substantially in this vegetation community (no longer recorded in quadrat data in 2013).

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

Saw-sedge was recorded at a slightly lower cover in 2013 that in the baseline vegetation monitoring. It is not clear whether this is due to small differences in sampling between individuals or whether this prediction will not occur. Data from future monitoring events will make this clearer.

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

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

7.4.4 Melaleuca Dieback / Recolonisation Monitoring

Data on Melaleuca dieback recorded in the baseline vegetation monitoring and the current monitoring is broadly consistent. There are some early indications of an increase in the number of seedlings, particularly at Transect 1. However, as the artificial channel closure occurred relatively recently, this trend will not be confirmed until more time has elapsed and the changes in the water levels have stabilised. The overall health of the existing Broad-leaved Paperbark was observed to be good, with no trees in an obvious state of decline. This would seem to indicate that the dieback event is no longer occurring and that this species should remain at its current extent or increase its extent over time.

7.4.5 Future Monitoring

The results of the 2013 vegetation monitoring indicate early signs of vegetation change, particularly in relation to the Fringing Marsh community, which is decreasing in overall extent due to inundation. The changes that have been observed at Salty Lagoon since 2011are broadly consistent with the predictions made in Hydrosphere (2010b and 2011). Other changes may only become apparent as more time elapses since the closure of the artificial channel, and as such it will be necessary to wait until at least the next round of vegetation monitoring in 2015 to draw conclusions on whether these predicted vegetation changes have occurred or not.

8 Frogs

8.1 Introduction

8.1.1 General

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

It is predicted that closure of the artificial channel will 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 is 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 known at the site include the Wallum Froglet (*Crinia tinnula*), Wallum Rocket Frog (*Litoria freycineti*) and Wallum Sedge Frog (*Litoria oblongburensis*). The Wallum Froglet and Wallum Sedge Frog are listed as Vulnerable species under the *Threatened Species Conservation Act 1995* (TSC Act). The latter is also listed as Vulnerable under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act).

8.1.2 ERMP Frog Monitoring Results

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

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

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

8.2 Methods

8.2.1 Surveys

Frogs were sampled using two methods:

- point counts undertaken at six fixed points along three fixed transects; and
- transect traverses undertaken along three fixed transects which corresponded with the point counts.

The point count methodology was as described in Hydrosphere (2010a and 2010b). Point counts were undertaken at six fixed sites along the three frog transects located on the western side of Salty Lagoon (refer to Illustration 8.1). Habitats sampled include Sedge Swamp, Fringing Marsh and Swamp Forest. 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; and
- Transect 3 – 580 m long with an average distance of 97 m between point count sites.

Since the closure of the artificial channel in June 2012 the water level of Salty Lagoon has increased substantially. This has resulted in 3 of the fixed sites closest to the lagoon converting from Fringing Marsh to open water. Consequently, frog monitoring was not undertaken at these localities in spring 2012 and summer 2013 due to a lack of suitable vegetated habitat for frogs. However, if future changes occur that are conducive to supporting frogs (e.g. establishment of Water Lilies *Nymphaea* sp.), sampling at these points will be resumed.

The centre of each point count site was marked with reflective tape, the habitat type determined, and the location recorded using a GPS (refer to Table 8.1). Point count surveys involved:

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

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

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

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

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

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

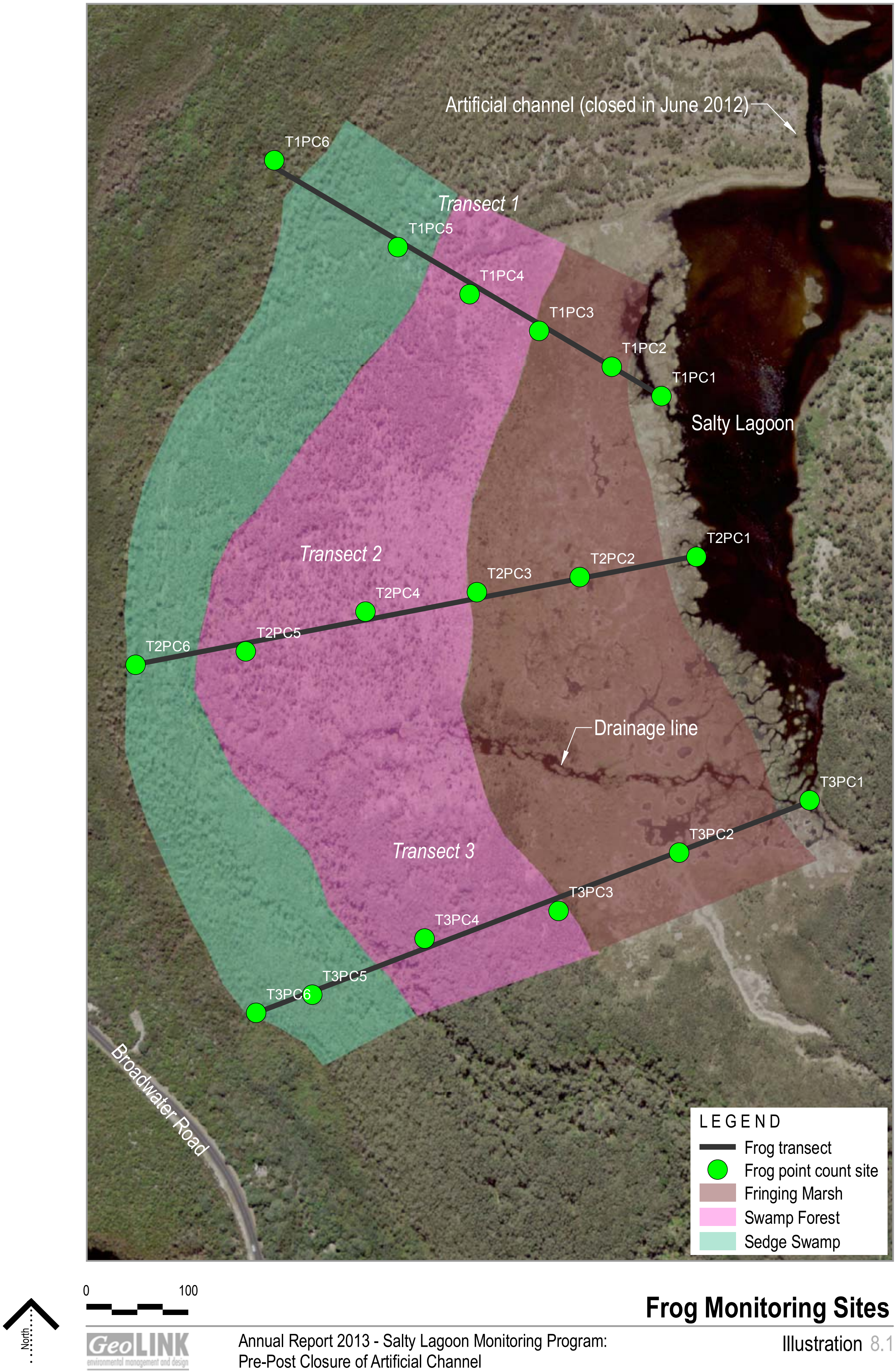
Table 8.1 Point Count Locations (GDA 84)

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

This page has been intentionally left blank.

Information shown is for illustrative purposes only

Drawn by: DSA Checked by: TJP Reviewed by: DGH Date: July 2013
Source of base data: Richmond Valley Council



Frog Monitoring Sites

GeoLINK environmental management and design

Annual Report 2013 - Salty Lagoon Monitoring Program:
Pre-Post Closure of Artificial Channel
1731-1074

Illustration 8.1

This page has been intentionally left blank.

8.2.2 Timing

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

- winter 2012 surveys: 21 August 2012 and 23 August 2012;
- spring 2012 surveys: 13 November and 15 November 2012; and
- summer 2013 surveys: 8 February and 12 February 2013.

8.2.3 Conditions at the Time of Monitoring

The call behaviour of frogs is highly variable and associated with season, weather conditions and behavioural patterns. Weather conditions during the post artificial channel closure frog monitoring events are provided in Table A.1, Appendix A. Conditions were dry for the winter and spring monitoring events and wet during the summer monitoring. Temperature ranged from mild to warm and each monitoring event followed a rain event in the preceding days. Winds varied between calm and moderate across all seasons. Relative humidity was generally high to very high ranging between 71 to 98% except during one spring monitoring event when it dropped to approximately 58%. The Salty Creek mouth was closed during all monitoring events.

8.3 Results

8.3.1 Point Count

8.3.1.1 Species Richness and Abundance

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

- six species recorded during the winter monitoring events, comprising 108 'on-site' specimens;
- four species recorded during the spring monitoring events, comprising 178 'on-site' specimens; and
- six species recorded during the summer monitoring events, comprising 122 'on-site' specimens.

Dwarf Tree Frog, Striped Marsh Frog, Tyler's Tree Frog and Striped Rocket Frog were recorded during all monitoring seasons. No 'acid' frog species were recorded during all seasons.

All species recorded had previously been recorded in the study area during the ERMP monitoring (Sandpiper 2010). Two species recorded during the pre-closure frog monitoring were not recorded, including the Broad-palmed Rocket Frog and the Bleating Tree Frog.

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

The species with the overall highest abundance recorded 'on-site' during the point count surveys were the Dwarf Tree Frog (*Litoria fallax* – 169 individuals), Striped Rocket Frog (*Litoria nasuta* – 88 individuals) and Tyler's Tree Frog (*Litoria tyleri* – 55 individuals).

The least abundant species were the Peron's Tree Frog (*Litoria peronii* – 14 individuals), Striped Marsh Frog (*Limnodynastes peronii* – 11 individuals) and Wallum Sedge Frog (*Litoria olongburensis* – 4 individuals).

8.3.1.2 Distribution

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

Wallum Sedge Frog and Wallum Froglet (acid frogs) were dominant within the Sedge Swamp. They were both recorded within the Swamp Forest at Transect 1, while the Wallum Froglet was also recorded within the Swamp Forest at Transect 3, in the Fringing Marsh/ Swamp Forest Ecotone at Transect 3 and in Fringing Marsh at Transect 1 in close proximity to Swamp Forest (refer to Illustration 1.1).

Table 8.2 Frog Occurrence at 'On-site' Point Counts

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

As shown in Table 8.2 three frog species were recorded in the Sedge Swamp, eight species were recorded in the Swamp Forest and seven species were recorded in the Fringing Marsh.

8.3.2 Transect Traverse

8.3.2.1 Occurrence and Distribution of Wallum Froglet and Dwarf Tree Frog

The transect traverse Wallum Froglet and Dwarf Tree Frog comparison results are provided in Table A.2 - Appendix A, and Illustration 1.1.

Along Transect 1 Wallum Froglet was commonly recorded within Swamp Forest, including within the Melaleuca dieback area. Three Wallum Froglets were also recorded in the adjacent Fringing Marsh during winter 2012 monitoring.

Along Transect 2 and Transect 3 Wallum Froglet was only recorded in the Sedge Swamp habitat. These were 'off-site' records (between 20-50 m from the centre of the point count site).

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

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

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

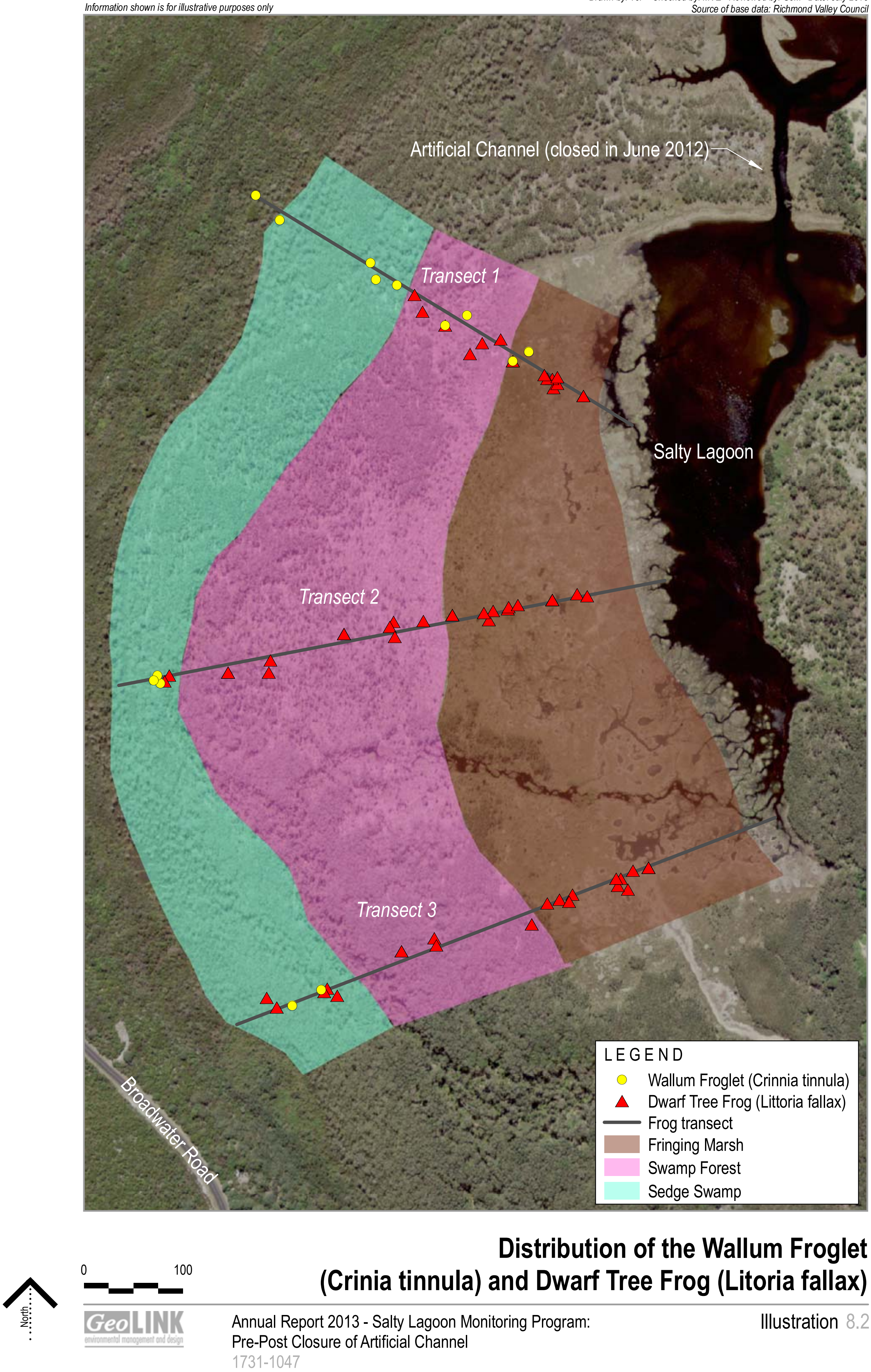
- Dwarf Tree Frogs were particularly dominant in the Fringing Marsh and Swamp Forest habitats; including the Melaleuca dieback area, but also extended into the Sedge Swamp in Transects 2 and 3;
- Wallum Froglet was recorded in Sedge Swamp along all 3 transects;
- Wallum Froglet also occurred in Swamp Forest and Fringing Marsh along Transect 1; and

- overlapping of species occurred in the Sedge Swamp, and also along the Swamp Forest and Fringing Marsh along Transect 1.

This page has been intentionally left blank.

Information shown is for illustrative purposes only

Drawn by: TJP Checked by: MVE Reviewed by: GJM Date: July 2013
Source of base data: Richmond Valley Council



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

GeoLINK environmental management and design

Annual Report 2013 - Salty Lagoon Monitoring Program:
Pre-Post Closure of Artificial Channel
1731-1047

Illustration 8.2

This page has been intentionally left blank.

8.4 Discussion and Comparison with Previous Monitoring

The results of the 2013 MPPC frog monitoring were broadly consistent with the results of the pre-artificial drainage channel closure MPPC frog monitoring conducted in 2012 (GeoLINK 2012a) as discussed below.

8.4.1 Overall Species Diversity

Comparison with pre-channel monitoring shows that the overall species diversity of frog species has been relatively stable with nine species recorded in the pre- closure 2012 MPPC monitoring and eight in the current monitoring period.

8.4.2 Species Diversity by Vegetation Habitat Zone

In the current monitoring period three frog species were recorded in the Sedge Swamp, eight species were recorded in the Swamp Forest and seven species were recorded in the Fringing Marsh. This compares with five species in the Sedge Swamp, and eight species in both the Swamp Forest and Fringing Marsh for the pre-closure 2012 MPPC monitoring. The relatively low-diversity of frog species in this community can be attributed to the water conditions within Sedge Swamp being predominantly acidic, thereby excluding many non-acid tolerant species.

A minor decrease in the number of frog species recorded in the Sedge Swamp is apparent between the two monitoring events, with neither Peron's Tree Frog nor Tyler's Tree Frog being recorded in the current monitoring period at point count sites. However, Tyler's Tree Frog was recorded 'off-site' (between 20-50 m from the centre of the point count site) in Sedge Swamp. This minor decrease is unlikely to be related to changes in the environment that can be attributed to the channel-closure, considering that the Sedge Swamp community is furthest from the edge of the lagoon. The results of future monitoring will assist in determining whether this is due to natural variability.

8.4.3 Habitat Segregation and Distribution Patterns

A primary segregating factor for the frog species at Salty Lagoon is the acid water tolerance of individual species. In general, this has the effect of limiting 'acid' frog species to Sedge Swamp and Swamp Forest habitats at Salty Lagoon. However, Wallum Froglet was recorded in Fringing Marsh along Transect 1 in the current monitoring period, and in previous pre-closure frog monitoring undertaken in 2012 (GeoLINK 2012a). This differs from the distribution trends of acid frog species recorded during monitoring for the ERMP (Hydrosphere, 2010a - noting that surveying in this particular location was not undertaken during the ERMP monitoring).

As described in GeoLINK 2012 the presence of Wallum Froglet in the Fringing Marsh community may relate to localised differences in water quality. One possible influencing factor is the distance between each transect and the drainage line. Effluent from the STP enters the drainage line and accounts for >50% of freshwater inflow into Salty Lagoon (Hydrosphere 2010a). Transect 1 is located approximately 400 m from the drainage line and there are no other proximal drainage lines. Transects 2 and 3 are within approximately 100 m of the drainage line, which may influence the pH in this locality. The water inputs to Transect 1 may be more 'natural', coming from surface and groundwater movements from the west and north and is of a suitable pH for acid frogs.

It should be noted that Wallum Froglet was only recorded in Fringing Marsh of Transect 1 in August 2012, which was approximately 2 months after the closure of the artificial channel. It is predicted that in the future Wallum Froglet will retract westward along Transect 1 out of the Fringing Marsh and into the Swamp Forest and Sedge Swamp in response to the higher water levels and conversion towards a predominantly freshwater system. It will be possible to test this prediction in the next winter frog monitoring event due in August 2013.

8.5 Recommendations

In the upcoming monitoring event in August 2013, basic water-quality sampling will be undertaken at frog sample sites where acid frogs have been recorded, including in the Fringing Marsh along Transect 1. This will provide additional information relating to distributional changes in Wallum Froglet and the relationship with the closure of the artificial channel.

9

Conclusion

9.1 Conclusion

The results of the MPPC to date consist of both pre-closure of the Artificial Channel baseline set and the early results of post-closure monitoring. The data for all monitored environmental attributes appear adequate for allowing pre-closure and post-closure comparisons, though it is apparent that the system is still in a state of flux as it moves towards a predominantly freshwater lagoon system. This variability is apparent in many of the environmental variables that are being monitored, including water quality parameters, distribution and composition of vegetation communities, distribution of acid frog species, and waterbird usage of the lagoon. Early indications are that many of the predicted changes are occurring. However, as the current monitoring period only extends over a small post-closure period, the exact nature of the changes will only become apparent over time. It is expected that it will be possible to draw more definite conclusions in the 2013-2014 Annual Report.

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

This page has been intentionally left blank.

Project Team

The project team members included:

Tom Pollard
Ecologist / Project Manager / Field Work and Report Writing
GeoLINK

Mathew Birch
Aquatic Ecologist / Field Work and Report Writing
Aquatic Science and Management

Grant McLean
Environmental Scientist / Assistant Ecologist / Field Work and Data Analysis
GeoLINK

David Andrighetto
Ecologist / Field Work
GeoLINK

David Havilah
Ecologist / Field Work
GeoLINK

This page has been intentionally left blank.

References

Boulton, A. J. & Brock, M. A. (1999). *Australian Freshwater Ecology – Processes and Management*. Gleneagles Publishing, Glen Osmond, Australia.

GeoLINK (2012a). *Salty Lagoon – Annual Report 2012.* Unpublished report to Richmond Valley Council. GeoLINK, Lennox Head.

GeoLINK (2012b). *Vegetation Monitoring Report – Baseline: Salty Lagoon.* Unpublished report to Richmond Valley Council. GeoLINK, Lennox Head.

GeoLINK (2013). *Vegetation Monitoring Report – Salty Lagoon: May 2013*. Unpublished report to Richmond Valley Council. GeoLINK, Lennox Head.

GHD (2006). *Report for Woodburn-Evans Head Wastewater Management Scheme: Salty Lagoon and Ebb Tide Release Investigations – Baseline Ecological Assessment. Report prepared for Richmond Valley Council.*

Hadwen, W. & Arthrington, A. (2006). *Ecology, Threats and Management Options for Small Estuaries and ICOLLS*. Report for CRC for Sustainable Tourism Pty Ltd, [Online]. Available: http://www.crctourism.com.au/wms/upload/resources/bookshop/hadwen_icolls.pdf

Hydrosphere (2009). *Salty Lagoon Ecosystem Recovery Monitoring Program – Environmental Incident Response Protocol.* Report to Richmond Valley Council. Unpublished report to Hydrosphere Consulting, Ballina.

Hydrosphere (2010a). *Salty Lagoon Ecosystem Recovery Monitoring Program: Final Report.* Unpublished report to Richmond Valley Council. Hydrosphere Consulting, Ballina.

Hydrosphere (2010b) *Salty Lagoon Monitoring Program Pre/Post Closure of the Artificial Channel*. Unpublished report to Richmond Valley Council. Hydrosphere Consulting, Ballina.

Hydrosphere (2011). *Salty Lagoon Rehabilitation Plan: Part C Implementation Plan. Unpublished report to Richmond Valley Council. Hydrosphere Consulting, Ballina.*

Nature Sound (2001). *Australian Frog Calls: Subtropical East*. Audio CD. Nature Sound, Mullumbimby.

Robinson, M. (1998). *A Field Guide to Frogs of Australia.* Reed New Holland.

Sandpiper (2010). *Salty Lagoon Ecosystem Recovery Monitoring Program Status Report – Birds and Frogs.* Unpublished report to Hydrosphere Consulting. Sandpiper Ecological Surveys, Alstonville.

Simpson, K. and Day, N. (1999). *Field Guide to the Birds of Australia.* Penguin, Australia.

This page has been intentionally left blank.

Copyright and Usage

The information provided on illustrations is for illustrative and communication purposes only. Illustrations are typically a compilation of data supplied by others and created by GeoLINK. Illustrations have been prepared in good faith, but their accuracy and completeness are not guaranteed. There may be errors or omissions in the information presented. In particular, illustrations cannot be relied upon to determine the locations of infrastructure, property boundaries, zone boundaries, etc. To locate these items accurately, advice needs to be obtained from a surveyor or other suitably-qualified professional.

Topographic information presented on the drawings is suitable only for the purpose of the document as stated above. No reliance should be placed upon topographic information contained in this report for any purpose other than that stated above.

This page has been intentionally left blank.

Appendix A

Frog Monitoring Data

This page has been intentionally left blank.

Table A1: Environmental Conditions at the Time of Frog Monitoring

Season	*Date*	*Transect*	*Weather*	*Temperature*	*Relative Humidity (3 pm)*	*Wind km/hr*	*Evidence of rain in 24 hrs*	*Rain in last 72 hours (mm)*	*Night Light*	*Approximate Depth of Surface Water (mm)*						*Artificial Channel Open or closed*
										PC 1	*PC 2*	*PC 3*	*PC 4*	*PC 5*	*PC 6*	
Winter 2012	21/08/12	1	Dry	9.8 - 21.3	64	calm	no	0	Dark quarter moon	not sampled	400	400	300	100	0	Closed
	21/08/12	2	Dry	9.8 - 21.3	64	Calm to light	no	0	Dark quarter moon	not sampled	400	500	200	100	550	Closed
	21/08/12	3	Dry	9.8 - 21.3	64	Calm	no	0	Dark quarter moon	not sampled	500	100	50	50	0	Closed
	23/08/12	1	Dry	16.4-29.3	57	calm	no	0	Bright -half moon	not sampled	500	100	20	5	0	Closed
	23/08/12	2	Dry	16.4-29.4	57	moderate	no	0	Bright - half moon	not sampled	500	250	100	100	55	Closed
	23/08/12	3	Dry	16.4-29.5	57	moderate	no	0	Bright - half moon	not sampled	400	250	200	100	55	Closed
Spring 2012	13/11/12	1	Dry	16.4-29.6	51	moderate	Yes	50	Very dark (no moon)	not sampled	200	100	0	0	0	Closed
	13/11/12	2	Dry	16.4-29.7	51	moderate	Yes	50	Very dark (no moon)	not sampled	200	50	50	0	0	Closed
	13/11/12	3	Dry	16.4-29.8	51	calm	Yes	50	Very dark (no moon)	not sampled	200	0	0	0	0	Closed
	15/11/12	1	Dry	18.9-31.4	54	light	Yes	3.2	Very dark (no moon)	not sampled	200	100	50	0	0	Closed
	15/11/12	2	Dry	18.9-31.4	54	light	Yes	3.2	Very dark (no moon)	not sampled	150	50	0	0	0	Closed
	15/11/12	3	Dry	18.9-31.4	54	calm	Yes	3.2	Very dark (no moon)	not sampled	200	0	0	0	0	Closed

Season	Date	Transect	Weather	Temperature	Relative Humidity (3 pm)	Wind km/hr	Evidence of rain in 24 hrs	Rain in last 72 hours (mm)	Night Light	Approximate Depth of Surface Water (mm)						Artificial Channel Open or closed
										PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	
Summer 2012/13	08/02/13	1	Wet - large rain event in week prior	18.3-27.3	67	calm	Yes	28	Very dark (no moon)	not sampled	>500	500	250	150	0	Closed
	08/02/13	2	Wet - large rain event in week prior	18.3-27.3	67	light	yes	28	Very dark (no moon)	not sampled	>500	300	200	150	0	Closed
	08/02/13	3	Wet - large rain event in week prior	18.3-27.3	67	calm	yes	28	Very dark (no moon)	not sampled	500	150	100	0.5	0.3	Closed
	12/02/13	1	Wet - large rain event in week prior	19.3-27.9	63	light	yes	1.4	Very dark (no moon)	not sampled	500	500	200	100	0	Closed
	12/02/13	2	Wet - large rain event in week prior	19.3-27.9	63	moderate	yes	1.4	Very dark (no moon)	not sampled	>500	400	200	100	0	Closed
	12/02/13	3	Wet - large rain event in week prior	19.3-27.9	63	calm	yes	1.4	Very dark (no moon)	not sampled	>500	100	0.5	0	0	Closed

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

Table A2: Point Count Survey Results

Transect No. and Survey Date	*Point Count No.*	*Habitat Type*	*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peronii*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		TOTAL
			Point Count	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	
WINTER 2012																							
Census 1																							
T1: 21/08/2012	1	Fringing Marsh_Open Water Ecotone	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	*0*
	2	Fringing Marsh/ Open Water	0	no	5	no	1	no	0	no	0	yes	0	no	0	no	0	no	0	no	0	no	*6*
	3	Fringing Marsh/ Swamp Forest ecotone	2	no	5	yes	1	no	0	no	0	no	0	yes	0	no	0	no	0	no	0	no	*8*
	4	Swamp Forest	4	no	0	no	2	no	0	no	0	no	1	no	0	no	0	no	0	no	0	no	*7*
	5	Swamp Forest	1	no	0	no	0	yes	0	no	0	no	0	yes	0	no	0	no	0	no	0	no	*1*
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	*0*
T2: 21/08/2012	1	Fringing Marsh_Open Water Ecotone	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	*0*
	2	Fringing Marsh/ Open Water	0	no	0	no	0	no	0	no	4	yes	0	yes	0	no	0	no	0	no	0	no	*0*
	3	Fringing Marsh_Swamp Forest Ecotone	0	no	0	no	3	no	0	no	0	no	0	yes	0	no	0	no	0	no	0	no	*3*
	4	Swamp Forest	0	no	0	no	2	yes	0	no	0	no	0	no	0	no	0	no	0	no	0	no	*2*
	5	Swamp Forest	0	no	0	no	0	yes	0	no	0	yes	0	no	0	no	0	no	0	no	0	no	*0*
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	yes	0	no	0	no	0	no	0	no	*0*
T3: 21/08/2012	1	Fringing Marsh_Open Water Ecotone	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	*0*
	2	Fringing Marsh/ Open Water	0	no	0	no	0	no	0	no	4	yes	0	yes	0	no	0	no	0	no	0	no	*4*
	3	Swamp Forest	0	no	0	no	3	no	0	no	0	no	0	yes	0	no	0	no	0	no	0	no	*0*
	4	Swamp Forest	0	no	0	no	2	yes	0	no	0	no	0	no	0	no	0	no	0	no	0	no	*2*

Transect No. and Survey Date	*Point Count No.*	*Habitat Type*	*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peronii*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		TOTAL
			Point Count	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	
	5	Swamp Forest	0	no	0	no	0	yes	0	no	0	yes	0	no	0	no	0	no	0	no	0	no	*0*
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	yes	0	yes	0	no	0	no	0	no	0	no	*0*
TOTAL			*7*		*10*		*14*		*0*		*8*		*1*		*0*		*0*		*0*		*0*		*40*
Census 2																							
T1: 23/08/2012	1	Open Water	0	no	0	yes	1	no	0	no	3	no	0	no	0	no	0	no	0	no	0	no	*0*
	2	Fringing Marsh/ Open Water Ecotone	0	no	0	no	0	no	0	no	1	no	0	yes	0	no	0	no	0	no	0	no	*0*
	3	Swamp Forest	3	no	3	no	0	no	0	no	0	no	3	yes	0	no	0	no	0	no	0	no	*6*
	4	Swamp Forest	7	no	0	no	0	no	0	no	0	no	0	yes	0	no	0	no	0	no	0	no	*5*
	5	Swamp Forest	1	yes	0	no	0	no	0	no	0	no	0	yes	0	no	0	no	0	no	0	no	*0*
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	*0*
T2: 23/08/2012	1	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	*0*
	2	Fringing Marsh/ Open Water Ecotone	0	no	0	no	0	no	0	no	5	no	0	yes	0	no	0	no	0	no	0	no	*5*
	3	Fringing Marsh/ Swamp Forest Ecotone	0	no	0	no	0	no	2	no	3	no	2	yes	0	no	0	no	0	no	0	no	*7*
	4	Swamp Forest	0	no	0	no	0	no	2	no	5	no	7	no	0	no	0	no	0	no	0	no	*14*
	5	Swamp Forest	0	no	0	no	6	no	3	no	0	no	0	yes	0	no	0	no	0	no	0	no	*9*
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	*0*
T3: 23/08/2012	1	Open Water	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	*0*
	2	Fringing Marsh/ Open Water Ecotone	0	no	0	no	0	no	0	no	0	yes	0	yes	0	no	0	no	0	no	0	no	*1*
	3	Fringing Marsh	0	no	0	no	2	no	0	no	1	no	3	yes	0	no	0	no	0	no	0	no	*9*
	4	Swamp Forest	0	no	1	no	1	no	1	no	0	no	2	yes	0	no	0	no	0	no	0	no	*7*

Transect No. and Survey Date	*Point Count No.*	*Habitat Type*	*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peronii*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		TOTAL
			Point Count	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	
	5	Swamp Forest	0	yes	0	no	0	yes	0	no	0	no	0	no	0	no	0	no	0	no	0	no	*1*
	6	Sedge Swamp	0	yes	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	*0*
TOTAL			*11*		*4*		*10*		*8*		*18*		*17*		*0*		*0*		*0*		*0*		*68*
WINTER TOTAL			*18*		*14*		*24*		*8*		*26*		*18*		*0*		*0*		*0*		*0*		*108*
SPRING 2012																							
Census 1																							
T1: 13/11/12	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	2	Fringing Marsh	0	no	0	no	0	yes	0	no	4	no	0	no	0	no	0	no	3	no	0	no	7
	3	Fringing Marsh	0	no	0	no	0	yes	0	yes	0	yes	0	no	0	no	0	no	0	no	0	no	0
	4	Swamp Forest	0	no	0	no	0	yes	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0
	5	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	n	0
T2 13/11/12	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	2	Fringing Marsh	0	no	0	no	0	no	1	no	4	yes	0	no	0	no	0	no	6	yes	0	noo	11
	3	Fringing Marsh_Swamp Forest Ecotone	0	no	0	no	0	no	2	no	2	yes	0	no	0	no	0	no	3	yes	0	no	7
	4	Swamp Forest	0	no	0	no	0	no	1	no	3	no	3	yes	0	no	0	no	2	no	0	no	9
	5	Swamp Forest	0	no	0	no	0	no	0	no	2	no	4	yes	0	no	0	no	0	no	0	no	6
	6	Sedge Swamp	0	yes	0	no	0	no	0	no	0	no	0	yes	0	no	0	no	0	no	0	no	0
T3 13/11/12	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	2	Fringing Marsh_Open water	0	no	0	no	0	no	0	no	6	yes	0	no	0	no	0	no	0	no	0	no	6

Transect No. and Survey Date	Point Count No.	Habitat Type	*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peronii*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		TOTAL
			Point Count	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	
	3	Swamp Forest	0	no	0	no	0	no	0	no	0	yes	0	no	0	no	0	no	0	yes	0	no	0
	4	Swamp Forest	0	no	0	no	0	no	0	no	1	no	0	no	0	no	0	no	0	no	0	no	1
	5	Swamp Forest	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0
TOTAL			0		0		0		4		22		7		0		0		14		0		47
Census 2																							
T1 15/11/12	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	2	Fringing Marsh	0	no	0	no	0	no	0	no	2	yes	0	no	0	no	0	no	4	yes	0	no	6
	3	Fringing Marsh	0	no	0	no	0	no	4	no	0	yes	0	no	0	no	0	no	0	yes	0	no	4
	4	Fringing Marsh_Swamp Forest Ecotone	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0
	5	Swamp Forest	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0
T2 15/11/12	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	2	Fringing Marsh	0	no	0	no	0	no	0	no	2	yes	0	no	0	no	0	no	10	yes	0	no	12
	3	Fringing Marsh_Swamp Forest Ecotone	0	no	0	no	0	no	0	no	1	yes	0	no	0	no	0	no	0	yes	0	no	1
	4	Swamp Forest	0	no	0	no	0	no	0	no	2	yes	1	no	0	no	0	no	5	yes	0	no	8
	5	Swamp Forest	0	no	0	no	0	no	0	no	0	no	1	yes	0	no	0	no	0	no	0	no	1
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	yes	0	no	0	no	0	no	0	no	0
T3 15/11/12	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	2	Fringing Marsh	0	no	0	no	0	no	0	no	10	yes	0	no	0	no	0	no	0	yes	0	no	10

Transect No. and Survey Date	*Point Count No.*	*Habitat Type*	*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peronii*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		TOTAL
			Point Count	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	
	3	Swamp Forest	0	no	0	no	0	no	0	no	0	yes	0	no	0	no	0	no	0	yes	0	no	0
	4	Swamp Forest	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0
	5	Swamp Forest	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0	no	0
TOTAL			0	0	0	0	0	0	4	0	17	0	2	0	0	0	0	0	19	0	0	0	42
SPRING TOTAL			0		0		0		16		78		18		0		0		66		0		178
SUMMER 2012/13																							
Census 1																							
T1 08/02/13	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	2	Fringing Marsh	0	no	0	no	0	no	0	no	4	no	0	no	0	no	0	no	7	no	0	no	11
	3	Fringing Marsh	0	no	0	no	0	no	0	no	3	yes	0	no	0	no	0	no	0	no	0	no	3
	4	Swamp Forest (Dieback zone)	0	no	0	no	0	no	0	no	2	yes	2	no	0	no	0	no	0	yes	0	no	4
	5	Swamp Forest	0	yes	0	no	0	no	0	no	0	no	0	yes	1	yes	0	no	0	no	0	no	1
	6	Sedge Swamp	1	no	0	no	0	no	0	no	0	no	0	no	1	no	0	no	0	no	0	no	2
T2 08/02/13	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	2	Fringing Marsh	0	no	0	no	0	no	0	no	8	yes	0	no	0	no	0	no	4	yes	0	no	12
	3	Swamp Forest (Dieback zone)	0	no	0	no	0	no	0	no	3	yes	0	no	0	no	0	no	4	yes	0	no	7
	4	Swamp Forest	0	no	0	no	0	no	1	no	3	yes	4	yes	0	no	0	no	0	no	0	no	8
	5	Swamp Forest	0	no	0	no	0	no	1	no	1	yes	3	yes	0	no	0	no	0	no	0	no	5
	6	Sedge Swamp	0	yes	0	no	0	no	0	yes	0	yes	0	yes	0	yes	0	no	0	no	0	no	0

Transect No. and Survey Date	Point Count No.	Habitat Type	*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peronii*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		TOTAL
			Point Count	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	
T3 08/02/13	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	2	Fringing Marsh	0	no	0	no	0	no	0	no	6	yes	0	no	0	no	0	no	0	yes	0	no	6
	3	Fringing Marsh_Swamp Forest Ecotone	0	no	0	no	0	no	0	no	4	no	0	yes	0	no	0	no	0	yes	0	no	4
	4	Swamp Forest	0	no	0	no	0	no	1	yes	4	yes	0	no	0	no	0	no	0	no	0	no	5
	5	Sedge Swamp	0	no	0	no	0	no	0	no	0	yes	0	no	0	no	0	no	0	no	0	no	0
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	no	1	yes	0	no	0	no	0	no	1
TOTAL			1	0	0	0	0	0	3	0	38	0	9	0	3	0	0	0	15	0	0	0	69
Census 2																							
T1: 12/02/2013	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	2	Fringing Marsh	0	no	0	no	0	no	0	yes	1	yes	0	no	0	no	0	no	0	yes	0	no	1
	3	Fringing Marsh	0	no	0	no	0	no	4	no	5	yes	0	no	0	no	0	no	2	yes	0	no	11
	4	Swamp Forest (Dieback zone)	0	no	0	no	0	no	0	no	0	yes	1	no	0	no	0	no	0	no	0	no	1
	5	Swamp Forest	0	no	0	no	0	no	0	no	0	yes	0	yes	0	no	0	no	0	no	0	no	0
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	no	0	yes	0	no	0	no	0	no	0	no	0
T2: 12/02/2013	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	2	Fringing Marsh	0	no	0	no	0	no	0	no	4	yes	0	no	0	no	0	no	4	yes	0	no	8
	3	Swamp Forest (Dieback zone)	0	no	0	no	0	no	0	no	4	yes	0	yes	0	no	0	no	1	yes	0	no	5
	4	Swamp Forest	0	no	0	no	0	no	0	no	1	yes	3	yes	0	no	0	no	0	no	0	no	4
	5	Swamp Forest	0	no	0	no	0	no	0	no	2	no	5	yes	0	no	0	no	0	no	0	no	7
	6	Sedge Swamp	0	yes	0	no	0	no	1	no	0	yes	0	yes	1	yes	0	no	0	no	0	no	2

Transect No. and Survey Date	*Point Count No.*	*Habitat Type*	*Crinia tinnula*		*Litoria peronii*		*Crinia signifera*		*Limnodynastes peronii*		*Litoria fallax*		*Litoria tyleri*		*Litoria olongburensis*		*Litoria latopalmata*		*Litoria nasuta*		*Litoria dentata*		TOTAL
			Point Count	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	*Point Count*	*Off Site (no/ yes)*	
T3: 12/02/2013	1	Open Water (>50cm not sampled)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	2	Fringing Marsh	0	no	0	no	0	no	0	no	2	yes	0	no	0	no	0	no	0	no	0	no	2
	3	Fringing Marsh_Swamp Forest Ecotone	0	no	0	no	0	no	1	yes	4	yes	1	y	0	no	0	no	0	yes	0	no	6
	4	Swamp Forest	0	no	0	no	0	no	2	no	4	yes	0	n	0	no	0	no	0	no	0	no	6
	5	Sedge Swamp	0	no	0	no	0	no	0	no	0	yes	0	y	0	no	0	no	0	no	0	no	0
	6	Sedge Swamp	0	no	0	no	0	no	0	no	0	yes	0	no	0	yes	0	no	0	no	0	no	0
TOTAL			0	0	0	0	0	0	8	0	27	0	10	0	1	0	0	0	7	0	0	no	53
SUMMER TOTAL			1		0		0		11		65		19		4		0		22		0		122
OVERALL TOTAL			19		14		24		35		169		55		4		0		88		0		408

Table A3: Wallum Froglet and Dwarf Tree Frog Comparison Results

Reference	*Easting*	*Northing*	*Species*	*Date of Recording*	*Habitat*	*Transect*
DTF1	541851	6783053	Dwarf Tree Frog (*Litoria fallax*)	21.08.2012	Fringing Marsh	T1
DTF2	541850	6782839	Dwarf Tree Frog (*Litoria fallax*)	21.08.2012	Fringing Marsh	T2PC2
DTF3	541875	6782845	Dwarf Tree Frog (*Litoria fallax*)	21.08.2012	Fringing Marsh	T2
DTF4	541564	6782766	Dwarf Tree Frog (*Litoria fallax*)	21.08.2012	Swamp Forest	T2
DTF5	541947	6782569	Dwarf Tree Frog (*Litoria fallax*)	21.08.2012	Fringing Marsh	T3PC2
DTF6	541926	6782547	Dwarf Tree Frog (*Litoria fallax*)	21.08.2012	Fringing Marsh	T3
DTF7	541633	6782440	Dwarf Tree Frog (*Litoria fallax*)	21.08.2012	Sedge Swamp	T3
DTF8	541562	6782438	Dwarf Tree Frog (*Litoria fallax*)	21.08.2012	Sedge Swamp	T3
DTF9	541855	6783057	Dwarf Tree Frog (*Litoria fallax*)	23.08.2012	Fringing Marsh	T1
DTF10	541810	6783080	Dwarf Tree Frog (*Litoria fallax*)	23.08.2012	Fringing Marsh	T1PC3
DTF11	541850	6782839	Dwarf Tree Frog (*Litoria fallax*)	23.08.2012	Fringing Marsh	T2PC2
DTF12	541749	6782824	Dwarf Tree Frog (*Litoria fallax*)	23.08.2012	Fringing Marsh/ Swamp Forest Ecotone	T2PC3
DTF13	541640	6782805	Dwarf Tree Frog (*Litoria fallax*)	23.08.2012	Swamp Forest	T2PC4
DTF14	542075	6782620	Dwarf Tree Frog (*Litoria fallax*)	23.08.2012	Fringing Marsh Open Water Ecotone	T3PC1
DTF15	541947	6782569	Dwarf Tree Frog (*Litoria fallax*)	23.08.2012	Fringing Marsh	T3PC2
DTF16	541881	6783045	Dwarf Tree Frog (*Litoria fallax*)	13.11.2012	Fringing Marsh	T1PC2
DTF17	541850	6783062	Dwarf Tree Frog (*Litoria fallax*)	13.11.2012	Fringing Marsh	T1
DTF18	541850	6782839	Dwarf Tree Frog (*Litoria fallax*)	13.11.2012	Fringing Marsh	T2PC2
DTF19	541749	6782824	Dwarf Tree Frog (*Litoria fallax*)	13.11.2012	Fringing Marsh/ Swamp Forest Ecotone	T2PC3
DTF20	541640	6782805	Dwarf Tree Frog (*Litoria fallax*)	13.11.2012	Swamp Forest	T2PC4
DTF21	541523	6782766	Dwarf Tree Frog (*Litoria fallax*)	13.11.2012	Swamp Forest	T2PC5
DTF22	541805	6782830	Dwarf Tree Frog (*Litoria fallax*)	13.11.2012	Fringing Marsh	T2
DTF23	541720	6782818	Dwarf Tree Frog (*Litoria fallax*)	13.11.2012	Fringing Marsh/ Open Water Ecotone	T2
DTF24	541947	6782569	Dwarf Tree Frog (*Litoria fallax*)	13.11.2012	Fringing Marsh/ Open Water Ecotone	T3PC2
DTF25	541698	6782485	Dwarf Tree Frog (*Litoria fallax*)	13.11.2012	Swamp Forest	T3PC4
DTF26	541870	6782542	Dwarf Tree Frog (*Litoria fallax*)	13.11.2012	Fringing Marsh/ Open Water Ecotone	T3
DTF27	541845	6782533	Dwarf Tree Frog (*Litoria fallax*)	13.11.2012	Swamp Forest	T3
DTF28	541881	6783045	Dwarf Tree Frog (*Litoria fallax*)	15.11.2012	Fringing Marsh	T1PC2
DTF29	541845	6783062	Dwarf Tree Frog (*Litoria fallax*)	15.11.2012	Fringing Marsh	T1
DTF30	541798	6783102	Dwarf Tree Frog (*Litoria fallax*)	15.11.2012	Fringing Marsh	T1
DTF31	541850	6782839	Dwarf Tree Frog (*Litoria fallax*)	15.11.2012	Fringing Marsh	T2PC2
DTF32	541749	6782824	Dwarf Tree Frog (*Litoria fallax*)	15.11.2012	Fringing Marsh	T2PC3
DTF33	541640	6782805	Dwarf Tree Frog (*Litoria fallax*)	15.11.2012	Fringing Marsh/ Swamp Forest Ecotone	T2PC4
DTF34	541806	6782832	Dwarf Tree Frog (*Litoria fallax*)	15.11.2012	Fringing Marsh	T2

Reference	*Easting*	*Northing*	*Species*	*Date of Recording*	*Habitat*	*Transect*
DTF36	541786	6782819	Dwarf Tree Frog (*Litoria fallax*)	15.11.2012	Fringing Marsh/ Swamp Forest Ecotone	T2
DTF35	541690	6782817	Dwarf Tree Frog (*Litoria fallax*)	15.11.2012	Swamp Forest	T2
DTF36	541947	6782569	Dwarf Tree Frog (*Litoria fallax*)	15.11.2012	Fringing Marsh	T3PC2
DTF37	541916	6782551	Dwarf Tree Frog (*Litoria fallax*)	15.11.2012	Fringing Marsh	T3
DTF38	541857	6782537	Dwarf Tree Frog (*Litoria fallax*)	15.11.2012	Swamp Forest	T3
DTF39	541881	6783045	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Fringing Marsh	T1PC2
DTF40	541810	6783080	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Fringing Marsh	T1PC3
DTF41	541742	6783116	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Fringing Marsh/ Swamp Forest Ecotone	T1PC4
DTF42	541842	6783066	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Fringing Marsh	T1
DTF43	541779	6783098	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Fringing Marsh/ Swamp Forest Ecotone	T1
DTF44	541850	6782839	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Fringing Marsh	T2PC2
DTF45	541749	6782824	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Fringing Marsh/ Swamp Forest Ecotone	T2PC3
DTF46	541640	6782805	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Swamp Forest	T2PC4
DTF47	541523	6782766	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Swamp Forest	T2PC5
DTF48	541885	6782843	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Fringing Marsh	T2
DTF49	541790	6782828	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Fringing Marsh/ Swamp Forest Ecotone	T2
DTF50	541686	6782812	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Swamp Forest	T2
DTF51	541566	6782778	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Swamp Forest	T2
DTF52	541464	6782763	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Sedge Swamp	T2
DTF53	541947	6782569	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Fringing Marsh/ Swamp Forest Ecotone	T3PC2
DTF54	541829	6782512	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Swamp Forest	T3PC3
DTF55	541698	6782485	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Swamp Forest	T3PC4
DTF56	541919	6782558	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Fringing Marsh / Open Water	T3
DTF57	541731	6782498	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Swamp Forest	T3
DTF58	541623	6782447	Dwarf Tree Frog (*Litoria fallax*)	08.02.2013	Swamp Forest	T3
DTF59	541881	6783045	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Fringing Marsh	T1PC2
DTF60	541810	6783080	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Fringing Marsh	T1PC3
DTF61	541855	6783064	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Fringing Marsh	T1
DTF62	541767	6783087	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Fringing Marsh	T1
DTF63	541719	6783130	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Fringing Marsh/ Swamp Forest Ecotone	T1
DTF64	541711	6783147	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Swamp Forest	T1

Reference	*Easting*	*Northing*	*Species*	*Date of Recording*	*Habitat*	*Transect*
DTF65	541850	6782839	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Fringing Marsh	T2PC2
DTF66	541749	6782824	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Fringing Marsh/ Swamp Forest Ecotone	T2PC3
DTF67	541640	6782805	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Swamp Forest	T2PC4
DTF68	541523	6782766	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Swamp Forest	T2PC5
DTF69	541815	6782834	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Fringing Marsh	T2
DTF70	541781	6782826	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Fringing Marsh/ Swamp Forest Ecotone	T2
DTF71	541691	6782802	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Swamp Forest	T2
DTF72	541459	6782757	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Sedge Swamp	T2
DTF73	541947	6782569	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Fringing Marsh	T3PC2
DTF74	541829	6782512	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Fringing Marsh/ Swamp Forest Ecotone	T3PC3
DTF75	541698	6782485	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Swamp Forest	T3PC4
DTF76	541914	6782558	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Fringing Marsh	T3
DTF77	541867	6782535	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Fringing Marsh/ Swamp Forest Ecotone	T3
DTF78	541733	6782491	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Swamp Forest	T3
DTF79	541620	6782444	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Sedge Swamp	T3
DTF80	541572	6782428	Dwarf Tree Frog (*Litoria fallax*)	12.02.2013	Sedge Swamp	T3