Coffs Harbour Region Ecohealth Project

Assessment of River and Estuarine Condition 2011

Final Technical Report to the Coffs Harbour City Council

Darren Ryder

Adrienne Burns, Rob Veal, John Schmidt, Malcolm Robertson, Morag Stewart and Max Osborne

Cover Photo: Bonville Estuary, Sawtell. Photo by D.Ryder 2011.

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June 2012

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Acknowledgements

This project was funded by the Coffs Harbour City Council with supporting funds from the NSW Office of Environment and Heritage, and Northern Rivers CMA. Special thanks to the Ecohealth Technical Reference Group for providing valuable information and guidance, and for their ability to help overcome hurdles along the way.

The people below provided significant support for the project, our thanks to each of them.

Malcolm Robertson, Krystle Knowles: Coffs Harbour City Council.

John Scmidt, Josh Chivers, Geoff Code, Peter Scanes and Yoshi Kobayashi: NSW OEH

Hamish Malcolm: Solitary Island Marine Parks Authority

Peter Corlis, Tony Broderick and Nigel Blake: NRCMA

Michael Healey and Tod Lockridge: NSW Office of Water

Rob Veal, Karlie McDonald, Dorothy Bell, Selina Miller, Maddeson Hardman: University of New England

This report should be cited as:

Ryder, D., Burns, A., Veal, R., Schmidt, J., Robertson, M., Stewart, M. & Osborne, M (2012). Coffs Harbour Region Ecohealth Project: Assessment of River and Estuarine Condition 2011. Final Technical Report to the Coffs Harbour City Council. University of New England, Armidale.

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Summary

The development of a standardised means of collecting, analysing and presenting riverine, coastal and estuarine assessments of ecological condition has been identified as a key need for coastal Catchment Management Authorities and Local Councils who are required to monitor natural resource condition, and water quality and quantity in these systems. This project was conducted over a 12 month period in 2011 in the Coffs Harbour Region covering Bonville/Pine Creeks, Boambee/Newports Creeks, Coffs Creek, Moonee Creek, Hearnes Lake, Darkum Creek, Arrawarra Creek, Woolgoolga Lake, and Corindi/Saltwater Creeks to contribute to the assessment of the ecological condition of the catchment. The project aimed to

- Assess the health of coastal catchments using standardised indicators and reporting for estuaries, and freshwater river reaches using hydrology, water quality, riparian vegetation and habitat quality, and macroinvertebrates assemblages as indicators of ecosystem health in streams of the Coffs Harbour region, and

- Contribute scientific information to the development of a report card system for communicating the health of the estuarine and freshwater systems in the Coffs Harbour City Council region.

Water chemistry was sampled monthly from 40 sites (10 freshwater, 30 estuarine) from 12 river systems in the Coffs Harbour LGA during 2011. The study was undertaken in a period with above average annual rainfall, with 7 months exceeding long-term monthly averages. Two events exceeding 400mm occurred during the study period and had a clear influence on many of the water quality variables. Trigger values from the ANZECC and NSW MER guidelines were used to interpret water quality data.

- Concentrations of Total Nitrogen exceeded the guideline value at some point in all river systems, with the majority of systems exceeding the value more than 50% of the time. Systems with reduced flushing such as Darkum Creek and Hearnes Lake exceeded guideline values on all sampling events, whereas larger systems with increased tidal exchange such as Coffs Creek often exceeded guideline values during high flow events. Elevated Nitrogen concentrations did not consistently result in increased primary production, requiring an investigation to determine if increased nitrogen leads to a decline in ecosystem health or if systems have adapted to increased Nitrogen loads.
- The number of times Total Phosphorus concentrations exceeded guideline values was less than 50% at all sites. The exception was Moonee Creek, where all estuary sites exceeded the guideline value on at least 80% of the sampling events. Investigations into point and diffuse sources of Phosphorus in this catchment are required to minimize impact on ecosystem health of elevated Phosphorus levels.
- Increased chlorophyll a concentrations were not directly linked to elevated Total Nitrogen concentrations. In cases where guideline values were exceeded, Total Nitrogen and Total Phosphorus concentrations were elevated, suggesting productivity in the study estuaries remain phosphorus limited. As a consequence, both Darkum Creek and Hearnes Lake had concentrations above the guideline value over 40% of the sampling events. Investigations

into nutrient concentrations, loads and hydrology (residence time and flushing) are required to determine the ecosystem responses to increased nutrients and chlorophyll concentrations.

- Low dissolved oxygen concentrations were evident at the majority of the sites, generally during periods of low flow conditions and warmer temperatures. Saturation levels were consistently below the guideline value at all sites throughout the study period, and below 10% at Darkum Creek and Hearnes Lake. Dissolved oxygen levels this low can lead to stress on biota and reduced environments in the water column promoting nutrient release.
- Faecal coliforms were clearly linked to high flow events, and therefore are a consequence of localized runoff. Coffs Creek, Moonee Creek and Darkum Creek all recorded concentrations above the primary contact threshold, and Woolgoolga Creek and Arrawarra Creek recorded concentrations almost double the secondary contact threshold.
- The poorest water quality was recorded from the sites closest to the tidal limit, highlighting their role as a depositional environment for both freshwater and estuarine contaminants, highlighting the importance of this zone being a focal point for future monitoring programs.
- Water quality issues were recorded in both high and low flow conditions, identifying the importance for sampling these coastal systems during both types of hydrologic conditions.

- Family level taxonomic richness ranged from 28 in Bonville Creek to just 12 in Coffs Creek. Similarly, the abundance of individuals ranged from 368 in Bonville Creek to 83 in Newports Creek when both sample periods were combined. The low richness and abundance of macroinvertebrates in the majority of systems suggests these sites have a level of degradation.
- SIGNAL scores ranged from a maximum of 5.6 in Woolgoolga Creek to 3.9 in Saltwater Creek. These scores are particularly low and indicate long-term degradation of water quality and instream habitat.
- The numerical dominance of macroinvertebrate individuals from pollution tolerant and generalist feeding families such as Chironomidae (midge larve) and Atyidae (freshwater shrimps) highlights that these systems are dominated by taxa resilient to long-term disturbances and poor water quality. The exception was Woolgoolga Creek that was dominated by pollution sensitive Caddis Fly larvae with high SIGNAL scores.
- There was a consistent trend among systems with a main stem and tributary of substantially higher richness, abundance and SIGNAL scores in the main stem relative to the smaller tributary. This was evident in Bonville/Pine, Boambee/Newports and Corindi/Saltwater systems.

- Riparian condition scores ranged from a maximum of 8.7/10 in Arrawarra Creek to 6.5/10 in Pine Creek.
- A number of sites such as Corindi, Coffs and Pine Creeks were dominated by the invasive Camphor Laurel as the overstory. The majority of sites had *Lantana camara* as a dominant plant in the mid- and understory layers.

- Exceptions were Saltwater creek dominated by natives such as *Angophora* and native grasses, Arrawarra Creek dominated by native *Ficus* and *Syzygium* mid-story, and Woolgoolga Creek with an overstory dominated by a Tallowood gallery forest with a diversity of native mid- and understory species.
- The majority of sites recorded excellent scores for the Bank Condition index, highlighting the current role of both native and exotic riparian species in minimizing erosion despite the number of large rainfall events during the study.

Management Priorities and Recommendations

- Investigate ecosystem responses to consistently elevated organic and inorganic nitrogen concentrations in creek and lake systems of the Coffs LGA to determine if increased nitrogen leads to a decline is ecosystem health.
- Investigate the drivers of elevated TN, Chlorophyll *a* concentrations and low DO concentrations in Darkum Creek, Hearnes Lake and Woolgoolga Creek catchments.
- Examine potential point- or diffuse-source catchment contributions of TP to Moonee Creek.
- Investigate point- and diffuse-source of elevated faecal contamination and links to stream hydrology, and remediation options for Woolgoolga, Arrawarra, Coffs, Moonee and Darkum Creeks.
- Future monitoring and assessment to acknowledge the importance of sampling freshwater and tidal reaches under a range of flow conditions.
- Review restoration priorities of stream corridors to include systems impacted by weed species such as Camphor Laurel (particularly in Coffs Creek) and Lantana (in Bonville, Boambee and Corindi systems) and at high-risk of bank erosion (identified in freshwater reaches of Woolgoolga and Corindi systems).
- Future monitoring for the Ecohealth program is recommended to retain the current macroinvertebrate and water quality variables and sampling processes, and include an on-ground estuarine riparian condition index to mirror the data from the freshwater reaches. The La Nína conditions experienced in the region during 2011 have influenced the water quality and ecological condition recorded in this study. Ecohealth sampling one out of every four years for the CHCC reporting for SoE/SoC may not reflect the long-term condition of the sites as much as the influence of short-term climate conditions of La Nína and El Níno cycles. It is recommended to consider target sampling to specific flow conditions (>80th percentile) in defined time periods (seasonal) over a multi-year timeframe. This will facilitate the capture of data from all sites under similar flow conditions and replicated temporal periods (seasons) within the four year reporting period (e.g., 1 sample/season, 4 seasons/year, for 3 years = 12 sample times).

Part 1 – Ecohealth Program and Objectives

1.1 Background

The NSW Natural Resources Monitoring Evaluation and Reporting (MER) Strategy was prepared by the Natural Resources and Environment CEO Cluster of the NSW Government in response to the Natural Resources Commission standard and targets, and was adopted in August 2006. The purpose of the Strategy is to refocus the resources of NSW natural resource and environment agencies and coordinate their efforts with CMAs, Local Governments, landholders and other natural resource managers to establish a system of monitoring, evaluation and reporting on natural resource condition.

At this time there was no consistent monitoring program for estuarine ecological condition in NSW, nor monitoring that linked freshwater and estuarine reaches within river systems. Working groups were formed to consider the most appropriate indicators and sampling designs to enable a statewide assessment of the ecological condition of rivers and estuaries. This report outlines the approach taken by stakeholders in the Coffs Harbour Local Government Area (LGA) to supplement the MER monitoring and is aligned with the objectives of regional Estuary Management Plans.

1.2 Scope

Estuarine and coastal lagoon systems are focal points for the cumulative impacts of changed catchment land-use, and increasing urbanisation and development in coastal zones (Davis and Koop 2006). As a result, these ecosystems have become sensitive to nutrient enrichment and pollution, in addition to degradation through habitat destruction and changes in biodiversity. The development of a standardised program for collecting, analysing and presenting riverine, coastal and estuarine assessments of ecological condition has been identified as a key knowledge gap for coastal Catchment Management Authorities and Local Councils who are required to monitor natural resource condition, and water quality and quantity in these systems.

This project will review and integrate information from the following sources to develop an Ecohealth framework: The NSW Monitoring, Evaluation and Reporting (MER) Program currently monitoring NSW estuaries and coastal rivers on a bi- or tri-annual basis, NSW State of Environment (SoE) and proposed State of Catchments (SoC) reports, EHMP Healthy Waterways program, proposed estuary report cards from the NLWRA (through WA D of Water), NSW Estuary Management Policy and Coastal Zone Management Manual and relevant Estuary Management Plans, and sampling protocols developed by the CRC for Coastal Zone, Estuary and Waterway Management.

The Northern Rivers Ecohealth program outlines a framework for the development of a catchment-based aquatic ecosystem health monitoring program for rivers, estuaries and near shore marine reefs in the Northern Rivers CMA with the aim of providing consistency in monitoring and reporting, and establishing partnerships required for local and regional dissemination of outcomes. This project brings together major stakeholders in the coastal management of Northern NSW; State agencies (NRCMA, OEH, NSW Fisheries, Local Council (Coffs Harbour City Council), University Researchers (UNE and SCU) and the Solitary Island marine Parks (SIMP), to develop, refine, report and promote a standardised river, estuary and marine health assessment tool for the Coffs Harbour region.

This project is a pilot program to trial designs, methods and variables that may contribute to the Ecohealth framework. The main output will be specific monitoring and management plans for the study areas, with a generic framework outlining a standardised (and trialled) set of partnership, monitoring, data management and reporting protocols for implementation in coastal catchments throughout NSW. This framework aims to facilitate an effective reporting mechanism to communicate water quality and resource condition information to the general public stakeholders and managers through a simple report card system to be developed by the NRCMA. This technical report contributes information to the production of a River Health Report Card that will be used to communicate findings to the general public.

1.3 Project Objectives

1. Assess the health of coastal catchments using standardised indicators and reporting for estuaries, and freshwater river reaches using hydrology, water quality, riparian vegetation and habitat quality, and macroinvertebrates assemblages as indicators of ecosystem health in streams of the Coffs Harbour region,

2. Contribute scientific information to the development of a report card system for communicating the health of the estuarine and freshwater systems in the Coffs Harbour region.

1.4 Report Structure

Part 2 of the report outlines the catchment characteristics of the Coffs Region as context of the need for river and estuarine monitoring, and to provide the background to study design and site selection processes.

2.1 *Study Area and Study Design* provides information on the catchment characteristics of the rivers and estuaries of the Coffs Harbour region such as area, hydrology and land-uses.

2.2 *Study Design* provides a detailed description of the study design and protocols developed for site selection are provided.

2.3 *Study Sites* section provides a detailed site description for the 44 study sites, including the range of water quality conditions measured, physical measures of channel and bank characteristics, riparian features and local disturbance issues.

Part 3 of the report provides a detailed report on the monthly water chemistry and biophysical data collected from January 2011 to December 2011. Results for water chemistry, macroinvertebrates and riparian condition are reported for each sub-catchment. *Water chemistry* identifies trends in nutrient (nitrogen and phosphorus), chlorophyll *a*, suspended solids and coliform values, as well as static variables such as pH, salinity, dissolved oxygen and temperature. Sites that exceed NSW MER or ANZECC guideline thresholds are identified. *Macroinvertebrate* assemblages collected from freshwater sites in Spring 2011 and Autumn 2011 are used to assess long-term condition of in channel habitats. The taxonomic richness, abundance and diversity are reported, as well as health indicators using SIGNAL2 scores and percent EPT. *Riparian Condition* assessments provide information for the freshwater sites on the cover, structure and habitat as indicators of a health riparian ecosystem at each site, as well as an identification of local-scale disturbances to riparian zones. All water chemistry and biophysical data are reported for each sub-catchment (Figure 2.1):

- 3.1 Bonville/Pine Creeks,
- 3.2 Boambee/Newports Creeks,
- 3.3 Coffs Creek,
- 3.4 Moonee Creek,
- 3.5 Hearnes Lake,
- 3.6 Woolgoolga Lake
- 3.7 Darkum Creek
- 3.8 Arrawarra Creek, and
- 3.9 Corindi/Saltwater Creeks

Part 4 provides a summary of findings for each sub-catchment and identifies management priorities for instream and riparian ecosystems in rivers and estuaries of the Coffs Harbour region, and identifies priorities for future monitoring within the Ecohealth framework.

PART 2 - Study Area, Design and Site Descriptions

2.1 Study Area

The Coffs Harbour Local Government Area (LGA) covers approximately 70 kilometres of coastline, extending from Pine Creek at Bundagen in the south to Station Creek in the north. The Great Dividing Range forms a well-defined escarpment that has characteristically steep hills and passes very close to the coast, resulting in the coastal plain having no major river systems, but there are numerous small creek systems. Overall there are 16 major coastal creeks plus the inland waterways of the Bobo River, Little Nymboida River, Bucca Creek and Orara River. Figure 2.1 shows all catchments and waterways within the Coffs Harbour LGA.

Coffs Harbour experiences a moderate climate, which has been classified as humid sub-tropical, characterised by warm to hot summers and mild winters. The area experiences a high average annual rainfall, averaging 1700mm, with most rain falling in late summer and early autumn. The cooler months receive much less rainfall, and dry spells are not uncommon from April to October. Landform has a strong influence on rainfall within the area, with higher rainfall occurring east of the coastal range leading to high intensity storms. These coastal systems experience regular flooding due to the steep catchments that are relatively small in area and subject to high rainfall intensities.

The underlying geology of the coastal catchments is the Late Carboniferous Coffs Harbour association metasediments. These rock groups include the Coramba Beds, Brooklana Beds and Moonbil Siltstones, all of which are dominated by the occurrence of siliceous mudstones, slates, greywackes and siltstone with minor metabasalts and felsic volcanics. Regional metamorphic grade increases from north to south with lower grade lithofeldspathic wackes in the north to higher grade black siltstones and mudstones in the south. Dominant soil types include structured Red Earths and Red Podzolic Soils. Dominant Soil Landscapes of Coffs Coast range includes the Suicide (su), Megan (me) and Ulong (ul) (Milford 1999, Potts 2002, Gilligan et al. 1992).

The clearing of native vegetation and associated indirect impacts such as sedimentation and contamination remain the single greatest threat to biodiversity in water ways in the Coffs Harbour LGA. A total of 95 taxa occurring within the Coffs Harbour LGA are recognized as threatened with the main cause of habitat clearance from urban expansion and weed infestation. Clearing and associated urban settlement adjacent to waterways has potential to adversely impact the health of these coastal streams, estuaries and the marine environment through changes to run-off, occurrence of acid sulfate soils, and erosion (Bewsher Consulting 2005).

The climate within the Coffs Harbour City Council (CHCC) LGA spans coastal areas with mean annual temperatures ranging from maximums of 27°C in February to 18.8°C in July, and minimums 19.1°C in February to 6.6°C in July) with a distinct summer peak, and long-term mean annual rainfall of 1647.3mm (BOM 2012). Discharge in the coastal river systems is poorly gauged, with data on water level in estuaries only available for a number of coastal systems in the CHCC. To provide indicative discharge for the coastal streams we have included data for the Orara River @ Orange Grove as this is the closest gauged system on an unregulated coastal system (NOW 2012). Although discharge rates will be different, relative changes in magnitude of discharge will be indicative of coastal streams. The Orara River demonstrates a distinct pattern of increased mean monthly discharge from November to May (Table 2.1)

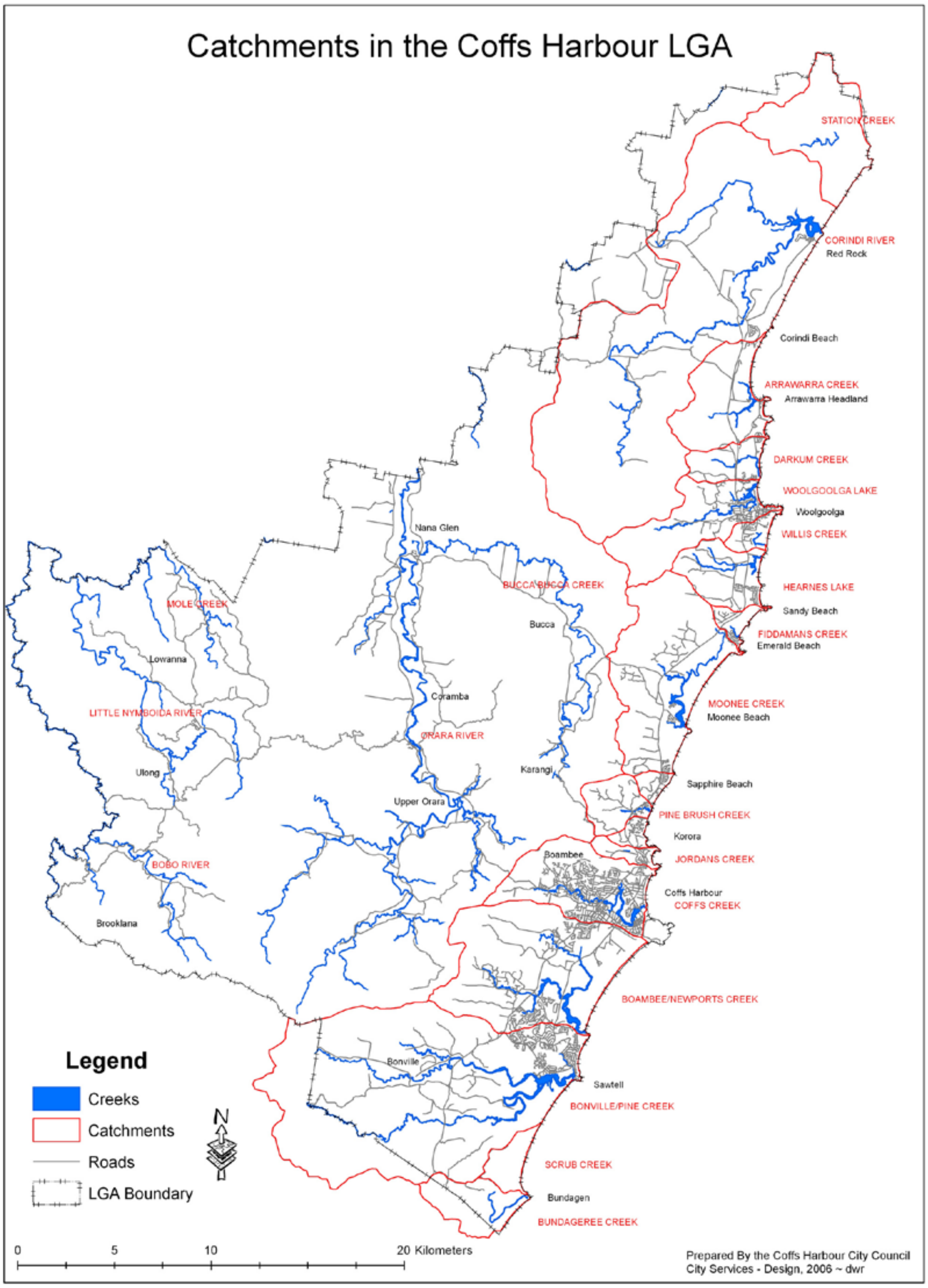

Figure 2.1 Coffs Harbour region and major stream systems (Source Northern Rivers Catchment Management Authority, 2011).

Table 2.1 Long term discharge data for the Orara River at Orange Grove (Gauge No. 204068) from 1946-2011.

	Daily				Monthly
	Max	Min	Mean	Median	Mean
Jan	12244	4	255	84	7908
Feb	18786	7	463	127	13097
Mar	21402	19	509	230	15772
Apr	25184	34	334	111	10025
May	21995	32	411	94	12741
Jun	9311	18	183	80	5492
Jul	14065	11	189	56	5851
Aug	12628	8	128	43	3844
Sep	8816	10	108	38	3122
Oct	13763	6	101	31	3139
Nov	18566	5	239	72	7158
Dec	4885	5	191	76	5814
All months	25184	4	249	73	7535

2.2 Study Design

The design of the Ecohealth freshwater/estuarine monitoring program for the Coffs Harbour region is based on the NSW Monitoring, Evaluation, Reporting (MER) protocols for Rivers and Estuaries (NSW OEH 2012), and aligned for reporting outcomes used in the South-East Queensland Ecosystem Health Monitoring program (EHMP) methodologies, as well as previous ecosystem health assessments undertaken within the local region. The number and location of sample sites has been designed to be statistically robust, and as such, will provide a data set that can be used to assess spatial and temporal variability of the system, and in time, further refinement of the monitoring program. Constraints on study design from available budgets limited the project to 44 sample locations and monthly sampling for water quality.

The location of the 10 freshwater monitoring sites (1 per river) was based on selection criteria to:

- identify longitudinal change within the main stem of each river system
- identify end of system flows from rivers entering the estuarine environment
- represent major tributaries of each river system or were identified by stakeholders as tributaries of interest for management
- facilitate comparison with historical datasets and additional information (e.g., discharge gauges)
- compare River Styles, Condition and Recovery Potential, and elevations within and across catchments, and
- locate ecological changes at the point of the tidal limit.

The location of the 30 estuarine monitoring sites was based on selection criteria to:

- identify longitudinal change within the main stem of each river system, and end of system flows
- represent multiple sites within salinity categories of 0-15ppt, 15-30ppt and 30+ppt
- compare River Styles, Condition and Recovery Potential, and elevations within and across catchments, and
- locate ecological changes at the point of the tidal limit.

2.2.1 Regional climate conditions

Rainfall in the region during the 2011 sampling period was well above the long term mean, with an annual total rainfall of 2294mm at Coffs Harbour (Figure 2.2). Monthly total rainfall ranged from 29.2mm in September to 469mm in April.

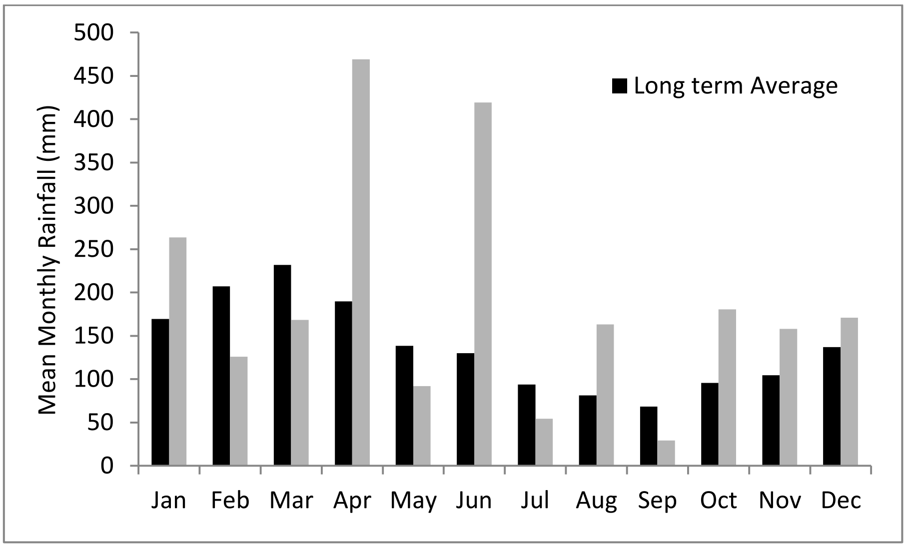

Figure 2.2 Mean monthly rainfall at Coffs Harbour for long term average and January to December 2011 (Source BOM 2012).

Discharge in the Orara River at Orange Grove reflected the above average and highly variable annual rainfall for the region in 2011 (Table 2.2). Highest mean monthly discharge of 1422 ML/day occurred in June. Similarly, peak daily discharge of 29,123 231 ML/day also occurred in June. Minimum discharge of less than 150ML/day occurred in 7 of the 12 months, and a discharge of less than 85ML/day occurred in 4 of the 12 months. These rainfall and discharge data highlight that although there was above average rainfall throughout 2011, the influence on river discharge was not persistent, with highly variable flows occurring in each sampling month.

Table 2.2: Mean, minimum and maximum monthly discharge in ML/d at Orange Grove (No. 206048) on the Orara River from January 2011 to December 2011 (Source NOW 2012).

	Discharge ML/d		
	Mean	**Min**	**Max**
Jan	1243.039	294.046	17745.037
Feb	325.107	180.352	1143.337
Mar	336.833	180.352	1301.225
Apr	374.358	168.484	1103.135
May	245.881	136.761	580.416
Jun	1422.340	212.254	29123.979
Jul	216.560	113.068	658.419
Aug	219.406	84.468	2002.512
Sep	121.979	73.299	309.356
Oct	82.254	50.059	228.660
Nov	283.762	46.123	6276.459
Dec	275.639	143.494	2389.627

2.2.2 Sampling schedule

Monthly sampling for water chemistry, bi-annual sampling for freshwater macroinvertebrates, and a once-off assessment of riparian condition were undertaken from January 2011 to December 2011 (Table 2.3).

Each water chemistry sampling event was undertaken on a single day, with multiple river/estuaries sampled within a 5-day period to ensure consistency in sampling with tidal regime. The estuarine sites were sampled consistently on an incoming high tide to maximize access to all sites via boat. The average 20 minute difference in mean high tide on consecutive days facilitates comparable data collection, and required adjusted start times for each sampling event. All estuary sites were sampled using a boat or canoe supplied by OEH or SIMP. All other sites were sampled via road access and vehicles.

Table 2.3 Sampling regime for field collection of water chemistry and biota.

Event	Date	Variables from freshwater sites	Variables from estuary sites
1	Jan 24	Water Chemistry	Water Chemistry
2	Feb 28	Water Chemistry	Water Chemistry
3	Mar 30	Water Chemistry	Water Chemistry
4	May 2	Water Chemistry, Invertebrates	Water Chemistry
5	Jun 6	Water Chemistry	Water Chemistry
6	Jul 4	Water Chemistry	Water Chemistry
7	Aug 1	Water Chemistry	Water Chemistry
8	Aug 29	Water Chemistry	Water Chemistry
9	Sep 31	Water Chemistry	Water Chemistry
10	Oct 24	Water Chemistry, Invertebrates, Riparian	Water Chemistry
11	Nov 21	Water Chemistry	Water Chemistry
12	Dec 19	Water Chemistry	Water Chemistry

2.3 Study Sites

Forty study sites were selected within the CHCC LGA, 10 freshwater sites and 30 estuarine sites spread across 9 river catchments and 12 river systems (Table 2.4). Sites were distributed as follows: Bonville/Pine Creeks (2 freshwater, 5 estuary sites), Boambee/Newports Creeks (2 freshwater, 5 estuary sites), Coffs Creek (1 freshwater, 3 estuary sites), Moonee Creek (1 freshwater, 3 estuary sites), Hearnes Lake (3 estuary sites), Darkum Creek (1 estuary site) , Woolgoolga Lake (1 freshwater, 3 estuary sites), Arrawarra Creek (1 freshwater, 2 estuary sites), Corindi/Saltwater Creeks (2 freshwater, 5 estuary sites).

Table 2.4. Location of field sample locations in the Coffs Harbour region.

River System	Site Code	Easting	Northing	Zone
Bonville Creek	BONV1	508894	6639266	Marine (30+ppt)
	BONV2	505377	6639809	Intermediate
	BONV3	503922	6640515	Tidal limit
	BONV4	501275	6639506	Freshwater
Pine Creek	PINE1	506706	6637460	Intermediate
	PINE2	505279	6637530	Tidal limit
	PINE3	502993	6637137	Freshwater
Boambee Creek	BOAM1	509287	6642989	Marine (30+ppt)
	BOAM2	508375	6644612	Intermediate
	BOAM3	507259	6643963	Tidal limit
	BOAM4	506799	6643962	Freshwater
Newport Creek	NEW1	510148	6645326	Intermediate
	NEW2	509391	6645972	Tidal limit
	NEW3	508642	6646544	Freshwater
Coffs Creek	COFFS1	513085	6648273	Marine (30+ppt)
	COFFS2	512046	6649093	Intermediate
	COFFS3	511238	6648680	Tidal limit
	COFFS4	509966	6648913	Freshwater
Moonee Creek	MOON1	515103	6658283	Marine (30+ppt)
	MOON2	515299	6659441	Intermediate
	MOON3	515747	6660553	Tidal limit
	MOON4	517470	6662155	Freshwater
Hearnes Lake	HEAR1	519304	6666448	Lagoon
	HEAR2	518952	6665629	Lagoon
	HEAR3	518719	6666120	Lagoon
Woolgoolga Creek	WOOL1	518958	6670065	Lagoon
	WOOL2	518467	6669139	Lagoon
	WOOL3	518886	6669663	Tidal limit
	WOOL4	516934	6668853	Freshwater
Darkum Creek	DARK1	519103	6671619	Lagoon
Arrawarra Creek	ARR1	518966	6674631	Lagoon
	ARR2	518390	6674042	Intermediate
	ARR3	517767	6673123	Freshwater
Corindi Creek	COR1	521831	6683164	Marine (30+ppt)
	COR2	520253	6682367	Intermediate
	COR3	518901	6681300	Tidal limit
	COR4	515408	6677577	Freshwater
Saltwater Creek	SALT1	520028	6683643	Intermediate
	SALT2	518995	6684560	Tidal limit
	SALT3	517268	6685511	Freshwater

2.4 Sampling Methods and Indicators

The indicators applied in this monitoring program focus on the condition of the system to best identify the stressors and pressures that cause change in ecological condition. The selection of indicators (and groupings of indicators) represents elements of the structure, function and composition of riverine and estuarine ecosystems.

2.4.1 Water Quality Indicators

Assessing the impacts of land-use change on the ecological health of rivers and streams is an important issue for the management of water resources in Australia. Traditionally, these assessments have been dominated by the measurement of patterns in species distribution and abundance, which contribute important information such as the status of threatened species and their habitat requirements. However, many goals of river management refer to concepts of sustainability, viability and resilience that require an implicit knowledge of ecosystem or landscape-level interactions and the processes influencing these organisms or populations.

The water chemistry of rivers and estuaries can be an ideal measure of their ecological condition by providing an integrated response to a broad range of catchment disturbances (Table 2.5). Nutrients such as nitrogen, phosphorus, and carbon can play an integral role in regulating rates of primary production in these systems. However, anthropogenic changes to catchment land-use have led to increased supply of nutrients from diffuse or point sources, and altered light and turbidity regimes through increased suspended sediment loads and loss of riparian vegetation. These landscape-level processes define the supply of contaminants to a stream and provide the framework within which other processes operate at smaller spatial scales and shorter temporal scales to regulate their supply and availability.

Table 2.5 Water chemistry measurements taken each month from all sites.

In situ measurements	Water quality samples for laboratory analysis
• Water depth • pH • Temperature • Salinity/Conductivity • Dissolved oxygen • Turbidity	• Total nutrients (nitrogen and phosphorus) • Chlorophyll *a* • Total Suspended Solids (TSS)

2.4.1.1 Field methods

At each sampling site, *insitu* water quality measurements were measured with the use of a Hydrolab Quanta, Troll 9500 or Horiba water quality multi-probe (pH, Conductivity, Dissolved Oxygen (DO), Temperature, Turbidity). The following procedural steps are outlined to standardise the collection of these data and to identify quality control.

Water Quality Probe Calibration and Use

The water quality probe(s) were calibrated each day prior to use in the field. At each sample site, field measurements for the water column profile were taken at near surface (approx. 0.2m below surface), and at 1 m intervals through the water column to a depth of 0.2m from the bottom (epibenthic). Measurements for each water quality parameter using the multi-probe were recorded at each interval. In freshwater sites that were less than 1 meter in depth, surface and epibenthic measurements were taken and maximum sampling depths noted. Data were recorded on proforma data recording sheets (Appendix 1).

Water Quality Sampling

Water samples were collected at each site for the determination of Chlorophyll *a*, total and dissolved nutrients, and total suspended solids. Samples were collected at near surface (<0.2m) and obtained with the use of a hand held sampling device to ensure sample is taken at least 1.5m from the edge of the boat or riverbank. Samples were transferred to 1L containers. The following procedures for sample collection and treatment are provided for each determination.

Chlorophyll *a*

Water column chlorophyll *a* is a measure of the photosynthetic biomass of algae/phytoplankton. These organisms are central to important nutrient and biogeochemical processes, and as such may respond to disturbance before effects on higher organisms are detected. This is because the higher organisms depend on processes mediated by algal communities. Consequently, they form the base of food webs supporting zooplankton, grazers such as crustaceans, insects, molluscs and some fish Burns and Ryder 2001). The short generation time, responsiveness to environmental condition and the availability of sound, quantitative methodologies such as chlorophyll *a* make these measures of phytoplankton ideally suited as indicators of disturbance in aquatic systems. Information can be collected, processed and analysed at time scales relevant to both scientific and management interests. In the field, a 1 litre bottle of water from a 0.2m depth was collected using the hand held sampling device at each site, labelled, and placed on ice in an esky for transport to the Coffs Harbour Water Laboratory for processing.

Total Suspended Solids

Total suspended solids is a direct measure of turbidity of the water. In the field, a 1 litre bottle of water from a 0.2m depth was collected using the hand held sampling device at each site, labelled, and placed on ice in an esky for transport to the Coffs Harbour Water Laboratory for processing.

Total Nitrogen and Total Phosphorus

Nitrogen and phosphorus are macronutrients vital for plant and animal growth. Nitrogen (N) is a key component in organic compounds such as amino acids, proteins, DNA and RNA, while phosphorus (P) is an integral component of nucleic acids, phospholipids (e.g. cell walls) and many intermediary metabolites (e.g. adenosine phosphates). As such, nitrogen and phosphorus typically limit primary productivity in rivers and estuaries (specifically, their ratio to each other and to carbon, i.e. C:N:P). Nitrogen and phosphorus are derived naturally from sources external to the river or estuary such as geological weathering, terrestrial leaf litter and oceanic upwelling, or through internal processes such as nitrogen fixation, recycling by heterotrophs, and denitrification. In the field, a 1 litre bottle of water from a 0.2m depth was collected using the hand held sampling device at each site, labelled, and placed on ice in an esky for transport to the Coffs Harbour Water Laboratory for processing.

Faecal coliforms

Members of two bacteria groups, coliforms and fecal streptococci, are used as indicators of possible sewage contamination because they are commonly found in human and animal feces. Although they are generally not harmful themselves, they indicate the possible presence of pathogenic (disease-causing) bacteria, viruses, and protozoans that also live in human and animal digestive systems. Therefore, their presence in streams suggests that pathogenic microorganisms might also be present and that swimming and eating shellfish might be a health risk. In the field, a 250mL bottle of water from a 0.2m depth was collected using the hand held sampling device at each site, labelled, and placed on ice in an esky for transport to the Coffs Harbour Water Laboratory for processing.

2.4.1.2 ANZECC and MER water quality guidelines

The ANZECC Water Quality Guidelines (the guidelines) established in 1992 under the Commonwealth's National Water Quality Management Strategy (NWQMS), provide a scientifically informed framework for the water quality objectives required to maintain current and future water resources and environmental values (ANZECC, 2000). The ANZECC guidelines were created in response to growing understanding of the potential for water quality to be a limiting factor to social and economic growth. The guidelines were derived from reviewing water quality guidelines developed overseas. However; Australian guidelines were also incorporated where available.

The ANZECC *Australian Water Quality Guidelines for Fresh and Marine Waters* was released in 1992, and developed using two approaches:

1. an empirical approach which used the Precautionary Principle to create conservative trigger values from all available and acceptable national and international data. This method implemented data from only the most sensitive taxa in order to ensure the protection of these species.
2. the modeling of all available and acceptable national and international data into a statistical distribution with the confidence intervals of 90% and 50%.

Trigger values are conservative thresholds or desired concentration levels for different water quality indicators. When an indicator is below the trigger value there is a low risk present to the protection of that environment. However, when an indicator is above the trigger value there is a risk that the ecosystem will not be protected from a desired ecological condition. In cases where the trigger value is exceeded further research and remediation of the risk identified should be conducted. Where a numerical value cannot be derived for a water quality indicator a target load may be set, for example the salinity guideline, or a descriptive statement for example for oil there should be no visible surface film, or an index of ecosystem health for example percentage cover of an algal bloom. The

Australian and New Zealand Environment Conservation Council (ANZECC) Guidelines (2000 and 2006) provide threshold values for freshwater and estuarine systems for pH, dissolved oxygen (DO), electrical conductivity (EC), salinity and nutrients such as nitrogen (N) and phosphorus (P). In addition, we used region-based trigger values for estuarine chlorophyll and turbidity developed by DECCW as part of the MER program.

A combination of ANZECC (2000,2006) and NSW MER developed trigger values were used to explore water quality across sites and sampling occasions (Table 2.6). For water quality variables with only upper limits for trigger values, the number of times each indicator recorded a value between 1-1.5 times, and greater than 1.5 times each month was used to examine changes in water quality. Exceedence of trigger values by less than 0.5 times or between 1-1.5 times, and greater than 1.5 times each month was used for variables that have both upper and lower thresholds.

Table 2.6 ANZECC water quality guidelines and trigger values for freshwater (above and below 150m elevation) and estuarine systems of south-east Australia.

	ANZECC Guidelines (2000) and NSW MER - Min. and Max Values								
	pH		DO %	EC µScm	Turbidity NTU	Chl a µgL	TN µgL	TP µgL	Coliforms
Freshwater sites <150m	6.5	8	80-110	125-2200	50	4	500	50	150cells/100mL primary contact 1000cells/100ML secondary contact
Estuary sites	7	8.5	80-110	no ANZECC values	10	3.3	300	30	150cells/100mL primary contact 1000cells/100ML secondary contact

2.4.2 Macroinvertebrates

Aquatic macroinvertebrates are non-vertebrate aquatic animals (e.g., insects, crustaceans, snails and worms) that are visible to the naked eye and which live at least part of their life within a body of freshwater. Freshwater macroinvertebrates are important members of aquatic foodwebs. They feed on a wide range of food sources such as detritus (dead organic matter), bacteria, algal and plant material, and other animals. They in turn provide food for other animals such as fish and aquatic birds. Macroinvertebrates are useful as bio-indicators as many taxa are sensitive to stress and respond to changes in environmental conditions. Because many macroinvertebrates live in a river reach for an extended period of time they can integrate the impacts on the ecosystem over an extended period of time, rather than just at the time of sampling. In addition, many macroinvertebrates have widespread distributions, they are reasonably easy to collect and their taxonomy is reasonably well known.

Macroinvertebrates have been widely used in broad scale assessments of ‘river health’. The most common approach adopted for environmental monitoring has involved the analysis of the taxonomic richness of macroinvertebrates. SIGNAL ‘Stream Invertebrate Grade Number – Average Level’ (Chessman 2003), is a simple scoring system for macroinvertebrate samples from Australian rivers. A SIGNAL score gives an indication of water quality in the river from which the sample was collected. Rivers with high SIGNAL scores are likely to have low levels of salinity, turbidity and nutrients such as nitrogen and phosphorus. They are also likely to be high in dissolved oxygen. When considered together with macroinvertebrate richness (the number of types of macroinvertebrates), SIGNAL can provide indications of the types of pollution and other physical and chemical factors that are affecting the macroinvertebrate community. SIGNAL Scores range from 1 (pollution tolerant) to 10 (pollution intolerant). Another classification systems uses the EPT index (Growns et al. 1997). The basis for this index lies in different insect taxa varying widely in their sensitivity to sedimentation, the taxa from the orders Ephemeroptera (E), Plecoptera (P), and Trichoptera (T) behave similarly. However, a taxonomic group can exhibit a great deal of heterogeneity, so an assessment method like the EPT may be insensitive to changes in species composition unless composition is altered along with overall taxa richness. Multimetric and multivariate approaches can increase a model's accuracy. These models evaluate the sampled community by comparing observed conditions to what conditions or taxa are expected to occur in the absence of disturbance.

2.4.2.1 Field and laboratory methods

Macroinvertebrates were sampled bi-annually (Autumn and Spring 2011) at the freshwater sites to align with the MER protocols. Kick net samples (250µm mesh) that comprise 10 linear meters of each of pool, riffle and edge habitats were taken from each of the 10 freshwater sites on each of the 2 sampling occasions. Only those habitats present at the time were sampled. Invertebrates were immediately preserved in 70% ethanol on site and transported to the laboratory for analysis. Each sample was passed through 2mm, 1mm and 250um sieves. All taxa from the 2mm and 1mm sieves were recorded, with material retained on the 250um sieve sorted for a standardized 30 minute period. Macroinvertebrates were identified to Family/genera level and assigned a SIGNAL2 score for pollution tolerance, and EPT score calculated. Metrics of abundance, richness, diversity and composition were recorded. Data for each river, sites within rivers and season were collated to produce summary data on the abundance of macroinvertebrates, number of families, number of taxa, median signal score and EPT score.

2.4.3 Riparian assessment of freshwater sites

A riparian zone is found where any body of water directly influences, or is influenced by adjacent land (Boulton & Brock 1999).Riparian zones are dynamic environments regularly influenced by freshwater, and characterised by strong energy regimes, considerable habitat diversity, a variety of ecological processes and multidimensional gradients (Naiman et al. 2005). The riparian land is an intermediary semi-terrestrial zone with boundaries that extend outward from the waters edges to the limits of flooding and upward into the canopy of the riverside vegetation (Naiman et al. 2005).

The area within a riparian zone contains valuable water resources, highly fertile soil and supports high levels of biodiversity (Jansen et al. 2007). In regards to natural ecosystems and agricultural production, riparian land is often considered the most productive and fertile area in a landscape and hence they are considered to be a vital element of an ecosystem. Riparian zones contribute to numerous ecological functions as well as fulfill many social and economic functions, both directly and indirectly. The ecological functions of a riparian zone can be grouped into four main categories: nutrient flux, geomorphology, temperature and light, and litter input (Boulton & Brock 1999). Each of the four categories involves different attributes of the riparian zone and may encompass significantly different areas of channel bank.

2.4.3.1 Rapid Assessment of Riparian Condition

The sub-tropical rapid appraisal for riparian condition (STRARC) is a multi-metric index of riparian condition, which has been modified from the original Rapid Appraisal for Riparian Condition (RARC) (Jansen et al. 2007a) and the adapted Tropical Rapid Appraisal of Riparian Condition (TRARC) (Dixon et al. 2006). The STRARC is comprised of 24 indicators which are grouped into four sub-indices which when combined; calculate to an overall index of riparian condition. The four sub-indices help to identify the general components that contribute to the condition of a site (Dixon et al. 2006). These sub-indices and their indicators are listed below in Table 9. In summary the four sub-indices describe:

1. The overall condition of the riparian vegetation (VEGETATION CONDITION).
2. The extent of habitat found within the riparian zone (HABITAT).
3. The degree of bank stability along the channel (BANK CONDITION).
4. The amount of overall disturbance to the riparian zone (DISTURBANCES).

Riparian condition

The percentage cover of each vegetation layer (midstorey, understorey, grass and organic litter) and the number of vegetation layers present is used as an indicator of the overall presence of riparian vegetation. This was chosen as it provides a well-rounded representation of the vegetation within the site and its distribution among different strata, as well as resilience to major flood events. The percentage of weeds within each stratum was measured as they pose threats to the ecological integrity and productivity of many Australia vegetation communities. The abundance of large trees was chosen as an indicator of riparian condition as the presence of such trees represents mature growth and undisturbed conditions. This is a particularly important indicator considering the history of logging and land clearing within the upper catchments. Vines were included as an indicator of riparian condition as they can contribute to the vegetation strata. However, it was desirable that the vines were natives as exotic species tend to outcompete the original vegetation.

Habitat

Riparian zones occupy only a small fraction of the landscape, but they frequently have high levels of biodiversity. Habitats within riparian zones are an important characteristic of condition as they represent the presence of food, water, shelter from predators and harsh physical conditions, and safe sites for nesting and roosting. Organic litter is an indicator of habitat as it provides shelter for smaller invertebrates, nesting materials for birds and is a source of course particulate organic matter. Standing dead trees, fallen trees and large trees provide hollows in which approximately 15% of all Australian terrestrial vertebrate fauna use as habitat at some point in time (Gibbons et al. 2002). Fallen trees and logs provide in-stream habitat for spawning sites and areas for fish to hide from predators, and to avoid intense sunlight and high current velocities (Crook and Robertson 1999). Logs also provide habitat for biofilm and invertebrates that maintain essential links in the food web for fish (Ryder 2004).

Table 2.7 Sub-indices and their indicators (each given a score of 1(poor) -5 (good)).

Sub-indices and their indicators	Assessment (each given a score of 1-5)
VEGETATION CONDITION	
- Midstorey cover	Percentage cover of vegetation 1.5-5m tall
- Midstorey weeds	Percentage of weeds in midstorey cover
- Understorey cover	Percentage cover of vegetation <1.5m tall
- Understorey weeds	Percentage of weeds in understorey cover
- Grass cover	Percentage cover of grass
- Grass weeds	Percentage of weeds in grass cover
- Organic litter	Percentage cover of leaves and fallen branches <10cm in diameter
- Organic weeds	Percentage of weeds in organic litter
- Vines	Present native, present exotic, absent
- Vegetation layers	Number of layers
- Canopy cover	Percentage cover of trees >5m tall
- Large trees	Number of large trees with >30cm trunk diameter at 1.3m from base
HABITAT	
- Organic litter	Percentage cover of leaves and fallen branches <10cm in diameter
- Organic weeds	Percentage of weeds in organic cover
- Standing dead trees	Number of standing dead trees >30cm trunk diameter at 1.3m from base
- Fallen trees	Number of fallen trees (i.e as a result of flooding)
- Large trees	Number of large trees with >30cm trunk diameter at 1.3m from base
- Reeds	Present native, present exotic, absent.
- Logs	Abundance of logs >10cm diameter
- Proximity	Nearest patch of native vegetation
BANK CONDITION	
- Bank slope	>70 degrees, 45-75 degrees, <45 degrees
- Undercutting	Combined width of undercutting
- Slumping	Combined width of slumping
- Exposed tree roots	Extent of exposed tree roots due to erosion
DISTURBANCES	
- Tree clearing	Present, absent
- Fencing	Present, absent
- Livestock	Evidence of livestock
- Proximity	Nearest patch of native vegetation

Bank condition

Bank condition is a measure of the overall bank stability of a river. The sub-tropical rivers of the Coffs Region catchment are prone to irregular flooding therefore the stream banks that have been cleared of vegetation are more susceptible to erosion. The indicators used include undercutting, slumping and exposed tree roots. These attributes are essential in the sub-tropical regions of the Coffs catchments that have a history of forestry and agricultural land clearing and features steep asymmetrical floodplains.

Disturbances

Vegetation clearing and the presence of livestock continue to accelerate the deterioration of riparian condition within the Coffs catchments. The presence of fencing indicates that there has been an attempt made to exclude livestock from the site. The evidence of livestock within a site was used as an indicator to determine whether fencing attempts had failed or if none existed then measured the extent of livestock disturbance. The vegetation surround was chosen as an indicator or disturbance as it is seen as an anthropogenic impact on riparian zones. Furthermore, the proximity of the nearest patch of native vegetation was noted in an attempt to measure the extent of tree clearing within the area in question.

2.4.3.3 Field methods

All 10 freshwater sites in the Coffs Harbour LGA catchments were sampled in October 2011 using the STRARC method developed for the Ecohealth project. Data for each of the four indices were collected at the reach (200m) scale as well as within 3, 25m^2 quadrats within each study reach.

Complete details of the STRARC methods are available in Southwell, E (2010) Development and application of a sub-tropical rapid assessment of riparian condition. Unpublished Honours Thesis, University of New England, Armidale NSW. A score out of 5 is recorded for each index, totaled to record a score out of 20 for the four indices, and converted to a score out of 10 to align with other reporting in this report.

Part 3 – Water Chemistry, Macroinvertebrates and Riparian Condition

This section of the report provides a detailed report on the monthly water chemistry and biophysical data collected from January 2011 to December 2011. Results for water chemistry, macroinvertebrates and riparian condition are reported for each sub-catchment. *Water chemistry* identifies trends in nutrient (nitrogen and phosphorus), chlorophyll *a*, suspended solids and coliform values, as well as static variables such as pH, salinity, dissolved oxygen and temperature measured from water column profiles from each site. Attributes within each site that exceed NSW MER or ANZECC guideline thresholds (Table 2.6) are identified. *Macroinvertebrate* assemblages collected from freshwater sites only in Spring 2011 and Autumn 2011 are used to assess long-term condition of channel habitats and water quality. The taxonomic richness, abundance and diversity are reported, as well as health indicators using SIGNAL2 scores and percent EPT. *Riparian Condition* assessments provide information for the freshwater sites on the cover, structure and habitat as indicators of a health riparian ecosystem at each site, as well as an identification of local-scale disturbances to riparian zones. All water chemistry and biophysical data are reported for each sub-catchment:

- 3.1 Bonville/Pine Creeks,
- 3.2 Boambee/Newports Creeks,
- 3.3 Coffs Creek,
- 3.4 Moonee Creek,
- 3.5 Hearnes Lake,
- 3.6 Woolgoolga Lake
- 3.7 Darkum Creek
- 3.8 Arrawarra Creek, and
- 3.9 Corindi/Saltwater Creeks

3.1 BONVILLE AND PINE CREEKS

3.1.1 Catchment description

The Bonville Creek catchment extends more than 15km inland from the coast, rising to Tuckers Nob with an elevation of 920m above sea level. The northern section of the upper catchment is within Tuckers Nob State Forest, and is characterized by extremely steep terrain with slopes exceeding 30% undulating to low rolling hills on metasediments exhibiting strongly acid soils with moderately low to low fertility (Milford 1999). The valley floor is typically below 60m above sea level. Bonville Creek flows southeasterly through an area of predominantly agricultural land. Pine Creek also drains the lower slopes of the Tuckers Nob State Forest, with its headwaters at an elevation of 567m above sea level. Pine Creek meanders through pine plantations and pasture before entering native forest and productive fields in its lower reaches. Pine Creek flows into Bonville Creek approximately 2km from the mouth of the estuary (Patterson-Britton 2003).

The Bonville-Pine Creek estuary is situated south of Sawtell, approximately 9km south of Coffs Harbour. The estuary drains a catchment area approximately 115 km^2 and opens to the ocean to the south of Sawtell Headland (Patterson-Britton 2003). The entrance is shallow and untrained but generally remains open (Fig. 3.1.1). Most of the lower reaches of the estuary are within Bongil Bongil National Park, which has an area of 978ha, most of which extends to the south of the estuary and along the coastal fringe (Patterson-Britton 2003).

Urban expansion in the Sawtell area has seen the development of new residential areas that extend from Middle Creek (that runs through Sawtell) to the catchment divide. As such, nearly the entire urban and industrial development along the estuary is located within the Middle Creek catchment. Pollution levels in the creek have been reported to be elevated due to catchment runoff (Patterson-Britton 2003). This has the potential to threaten the water quality of the lower estuary as Middle Creek enters the estuary approximately 1km from the ocean.

Small acreage holdings along the lowlands adjacent to the estuary are typically concentrated east from the Pacific Highway. This transition in land-use has seen an increase in clearing and conversion of the land for grazing, modified hydrology through floodplain drainage, and increasing the chance of fish kills associated with runoff from areas of oxidized acid sulfate soils (Patterson-Britton 2003). This is particularly apparent along the northern banks of Pine Creek upstream from the National Park boundary. Severe rainfall over the upper sections of the Bonville and Pine Creeks catchments often causes flooding in the lower reaches and along the estuary. Since European settlement, flooding has occurred on numerous occasions, with bank erosion in most locations where these activities exist (Patterson-Britton 2003).

3.1.2 Site description

Four sites were selected along Bonville Creek and three sites were selected along Pine Creek (Table 3.1.1). The most upstream sites are represented by PINE3 in Pine Creek (Fig 3.1.2a) and BONV4 in Bonville Creek (Fig 3.1.2b), which are both within freshwater zones and in a River Style defined as Fine-grained Meandering. The next most upstream sites, BONV3 and PINE2, are both within the tidal limit zone, while sites BONV2 and PINE1 (Fig 3.1.3a) are within zones of intermediate salinity. Site PINE1 is the most downstream site on Pine Creek and is located approximately 7km upstream of the confluence of Pine Creek with Bonville Creek. Site BONV1 (Fig 3.1.3b) is located after the confluence and is considered to be in a marine zone with a salinity range of 30+ ppt. Site BONV1, was the only site on Bonville and Pine Creeks that was sampled for faecal coliform to represent the total outflow from both systems. All sites were sampled each month from January to December 2011 for water chemistry.

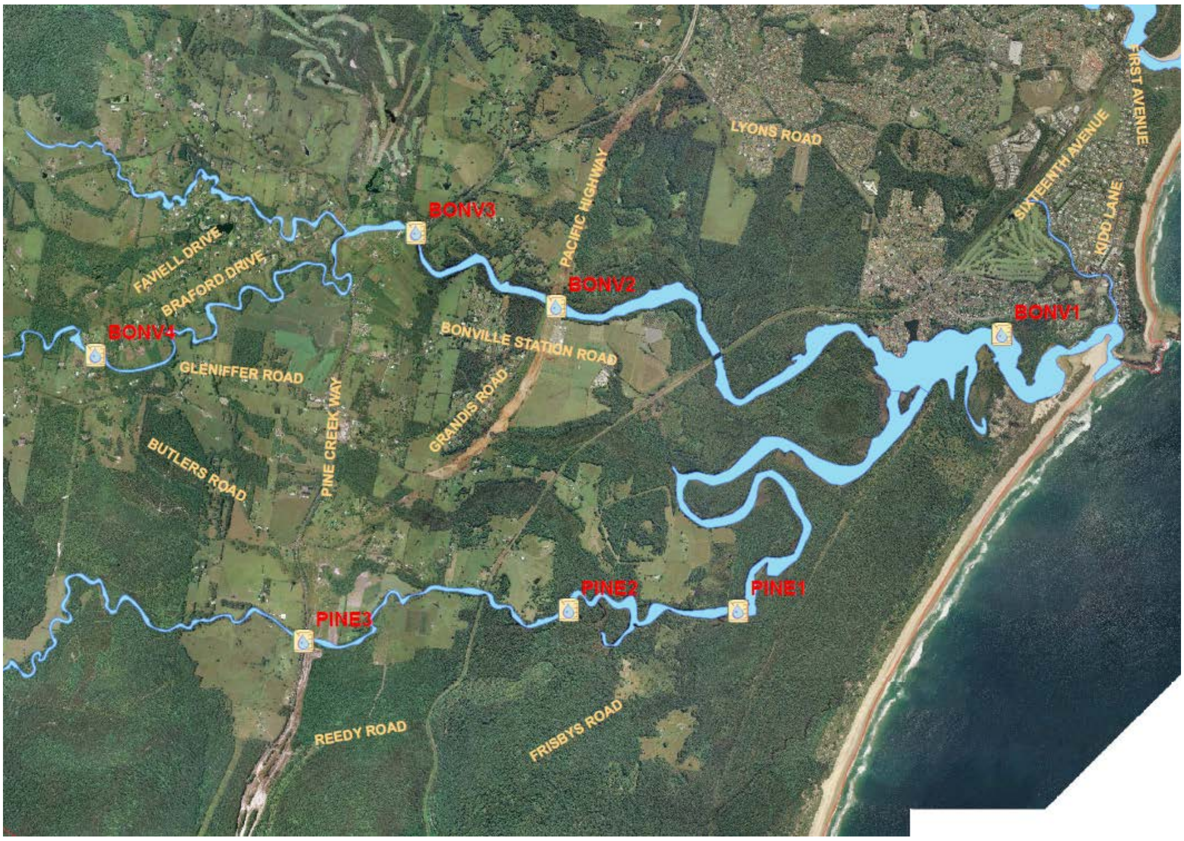

Figure 3.1.1 Dominant land-use and location of sites in Bonville and Pine Creeks in the Coffs Harbour catchment (Source CHCC).

Table 3.1.1 Location of sampling sites, River Style and Condition in Bonville and Pine Creeks.

River System – Site Code	Easting	Northing	Zone	Organisation collecting	Samples collected
Bonville Creek 1 (BONV1)	508894 m E	6639266 m S	Marine (30+ppt)	UNE	Faecal, Nutrients, TSS & Chl *a*
Bonville Creek 2 (BONV2)	505377 m E	6639809 m S	Intermediate salinity	UNE	Nutrients, TSS & Chl *a*
Bonville Creek 3 (BONV3)	503922 m E	6640515 m S	Tidal limit	UNE	Nutrients, TSS & Chl *a*
Bonville Creek 4 (BONV4)	501275 m E	6639506 m S	Freshwater	UNE/CHCC	Nutrients, TSS Chl *a*, Macroinverts
Pine Creek 1 (PINE1)	506706 m E	6637460 m S	Intermediate salinity	UNE	Nutrients, TSS & Chl *a*
Pine Creek 2 (PINE2)	505279 m E	6637530 m S	Tidal limit	UNE	Nutrients, TSS & Chl *a*
Pine Creek 3 (PINE3)	502993 m E	6637137 m S	Freshwater	UNE/CHCC	Nutrients, TSS Chl *a*, Macroinverts

Figure 3.1.2a Site PINE3 in Pine Creek looking downstream from crossing.

Figure 3.1.2b Site BONV4 in Bonville Creek looking upstream from crossing.

Figure 3.1.3a Site PINE1 in Pine Creek looking upstream

Figure 3.1.3b Site BOAM1 in Boambee estuary looking upstream towards boat ramp.

3.1.3 Water Chemistry

Chlorophyll *a*

The mean chlorophyll *a* concentration in Bonville Creek ranged from 1.46µg/L at site BONV1 to 3.93µg/L at site BONV4 (Fig. 3.1.4). At the Pine Creek sites, the mean chlorophyll *a* concentrations ranged from 2.66µg/L at PINE1 to 8.94µg/L at PINE3. The minimum chlorophyll *a* concentration at Bonville Creek sites BONV1, BONV2 and BONV3 was 0.90µg/L from March to June. The minimum concentration at BONV4 was also 0.90µg/L during May to July, and November and December 2011. The maximum chlorophyll *a* concentrations in Bonville Creek were 13µg/L and 10µg/L during September 2011 at sites BONV1 and BONV3, respectively. At sites BONV2 and BONV4 the maximum concentrations were 11µg/L and 4µg/L during January 2011. The minimum concentrations at Pine Creek ranged from 0.9µg/L at PINE1, 2 and 3 for up to 7 months of 2011.

All of the chlorophyll *a* samples from site BONV4 and PINE3 had concentrations that fell below the prescribed trigger value of 4µg/L. At site BONV3, 42% of chlorophyll *a* samples had concentrations that exceeded the trigger value. At sites BONV2 and PINE1, 25% of samples had concentrations that also exceeded the trigger value, while 8 to 16% of samples from BONV1, BONV3 and PINE2 had concentrations that exceeded the trigger value (Table 3.2.2).

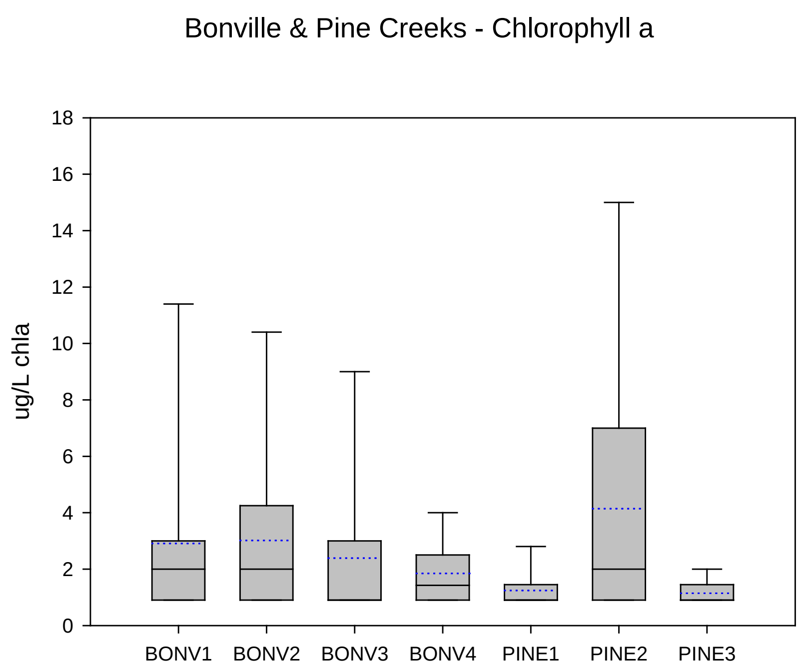

Figure 3.1.4 Mean, median, 25th and 75th percentiles, and range of chlorophyll *a* concentrations from Bonville Creek and Pine Creek sites, BONV1 to BONV4 and PINE1, PINE2 and PINE3, from January to December 2011.

Table 3.1.2 Proportion of monthly chlorophyll *a* samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum µg/L	Month
BONV1	0.46	0.34	0.00	0.20	12	13	Sep
BONV2	0.40	0.40	0.10	0.10	12	11	Jan
BONV3	0.64	0.18	0.00	0.18	12	10	Sep
PINE1	0.82	0.18	0.00	0.00	12	3	
PINE2	0.36	0.28	0.00	0.36	12	17	Jan
BONV4	0.80	0.20	0.00	0.00	12	4	Jan
PINE3	1.00	0.00	0.00	0.00	12	2	

Total Nitrogen (TN)

The mean TN concentration in Bonville Creek ranged from 298.6µg/L at site BONV4 to 479.1µg/L at site BONV1 (Fig. 3.1.5). At the Pine Creek sites, the mean TN concentrations ranged from 353.9µg/L at PINE3 to 420.45µg/L at PINE1. The minimum TN concentrations across all Bonville Creek sites ranged from 160µg/L at BONV4 during September to 280µg/L at BONV2 during October and December 2011. The maximum concentrations detected at Bonville Creek sites were 880µg/L at BONV1 during November, 640µg/L at BONV2 and 660µg/L at BONV3 during July, and 530µg/L at BONV4 during August 2011. The minimum TN concentrations at the Pine Creek sites ranged from 140µg/L at PINE3 during September to 340µg/L at PINE1 during January 2011. The maximum concentrations at Pine Creek were 510µg/L at PINE1 in August, 610µg/L at PINE2 in January, and 780µg/L at PINE3 during April 2011. All of the TN samples from PINE1 had concentrations that exceeded the prescribed trigger value, with BONV1, BONV2 and PINE2, between 82% and 90% of TN samples had concentrations that exceeded the trigger value, while 73%, 22% and 9% of samples from BONV3, PINE3 and BONV4, respectively had concentrations that exceeded the trigger value (Table 3.1.3).

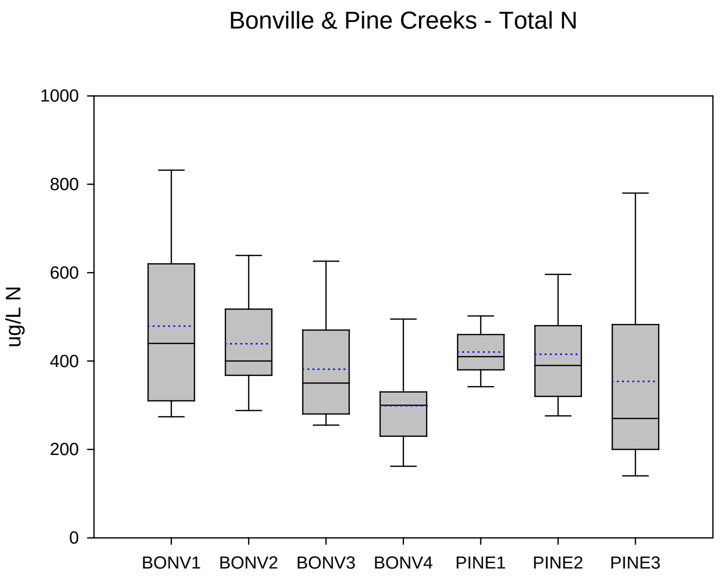

Figure 3.1.5 Mean, median, 25th and 75th percentiles, and range of TN concentrations from Bonville Creek and Pine Creek sites, BONV1 to BONV4 and PINE1, PINE2 and PINE3, from January to December 2011.

Table 3.1.3 Proportion of monthly TN samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
BONV1	0.00	0.18	0.36	0.46	11	880	Nov
BONV2	0.00	0.10	0.50	0.40	10	640	Jul
BONV3	0.00	0.27	0.46	0.27	11	660	Jul
PINE1	0.00	0.00	0.73	0.27	11	510	Aug
PINE2	0.00	0.18	0.46	0.36	11	610	Jan
BONV4	0.27	0.64	0.09	0.00	11	530	Aug
PINE3	0.44	0.34	0.11	0.11	9	780	Apr

Total Phosphorous (TP)

The mean TP concentration in Bonville Creek ranged from 36.36µg/L at site BONV1 to 41.36µg/L at site BONV3 (Fig. 3.1.6). At the Pine Creek sites, the mean TP concentrations ranged from 31.18µg/L at PINE1 to 44.55µg/L at PINE2. The minimum TP concentrations across all Bonville Creek and Pine Creek sites were all 30µg/L, and detected on more than one occasion at all sites during 2011. The maximum concentrations detected at Bonville Creek sites were 100µg/L at BONV1 and BONV2 during May 2011, 90µg/L at BONV3 during May 2011, and 100µg/L at BONV4 during December 2011. The maximum concentrations at Pine Creek were 110µg/L at PINE1 and PINE2 in May 2011, and 100µg/L at PINE3 during December 2011. Between 36% and 45% of the TP samples from BONV2, BONV3 and PINE2 had concentrations that exceeded the prescribed trigger value. At sites PINE1 and BONV4, 18% and 27% of TP samples, respectively, had concentrations that exceeded the trigger value, while 10% of samples from BONV1 and PINE3 had concentrations that also exceeded the trigger value (Table 3.1.4).

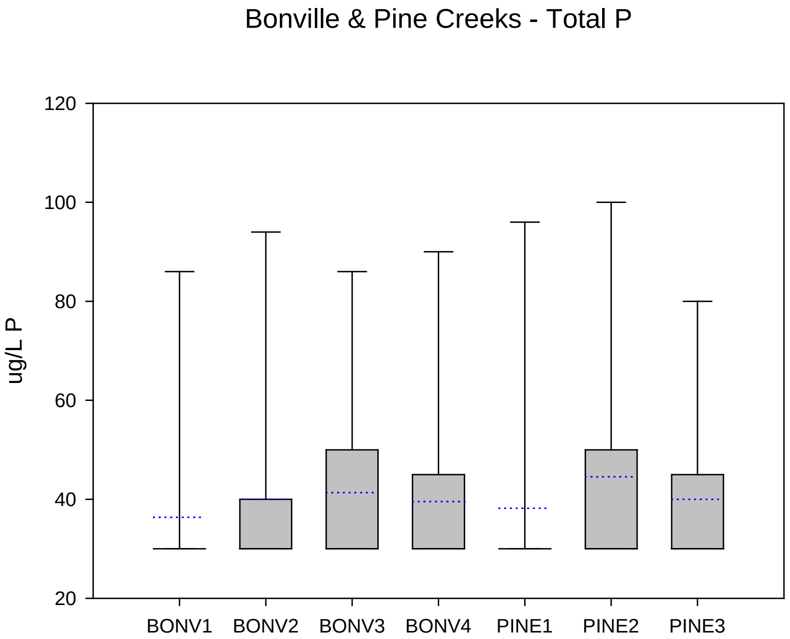

Figure 3.1.6 Mean, median, 25th and 75th percentiles, and range of TP concentrations from Bonville Creek and Pine Creek sites, BONV1 to BONV4 and PINE1, PINE2 and PINE3, from January to December 2011.

Table 3.1.4 Proportion of monthly TP samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
BONV1	0.00	0.90	0.05	0.05	11	100	May
BONV2	0.00	0.60	0.30	0.10	10	100	May
BONV3	0.00	0.64	0.00	0.36	11	90	May
PINE1	0.00	0.82	0.09	0.09	11	110	May
PINE2	0.00	0.55	0.18	0.27	11	110	May
BONV4	0.00	0.73	0.14	0.13	11	100	Dec
PINE3	0.00	0.90	0.00	0.10	9	80	Dec

Turbidity

The mean turbidity values in Bonville Creek ranged from 1.46NTU at site BONV1 to 3.32 NTU at site BONV3 (Fig. 3.1.7). At the Pine Creek sites, the mean turbidity values ranged from 2.66 NTU at PINE1 to 8.94 NTU at PINE2. The minimum turbidity values across the three most downstream sites on Bonville Creek, BONV1, BONV2 and BONV3, were 0 NTU during February 2011, while the minimum value at BONV4 was 0.90NTU during November 2011. The maximum values detected at Bonville Creek sites were 8.2 NTU at BONV1, 13.4 NTU at BONV2, and 9.6NTU at BONV3 all recorded during September 2011, and 10.9 NTU at BONV4 during August 2011. Minimum turbidity values observed at Pine Creek sites were 0 NTU at PINE1 and 0.6 NTU at PINE2 during February 2011, and 4.5NTU during October 2011. The maximum values at Pine Creek were 19.8 NTU at PINE1, 25.6 NTU at PINE2, and 17.9 NTU at PINE3 all recorded during September 2011. All of the turbidity samples collected from BONV1, BONV3, BONV4 and PINE3 during 2011, had values that fell below the prescribed trigger value, while between 2 and 7% of the samples collected from sites BONV2, PINE1 and PINE2 had values that exceeded this trigger value (Table 3.1.5).

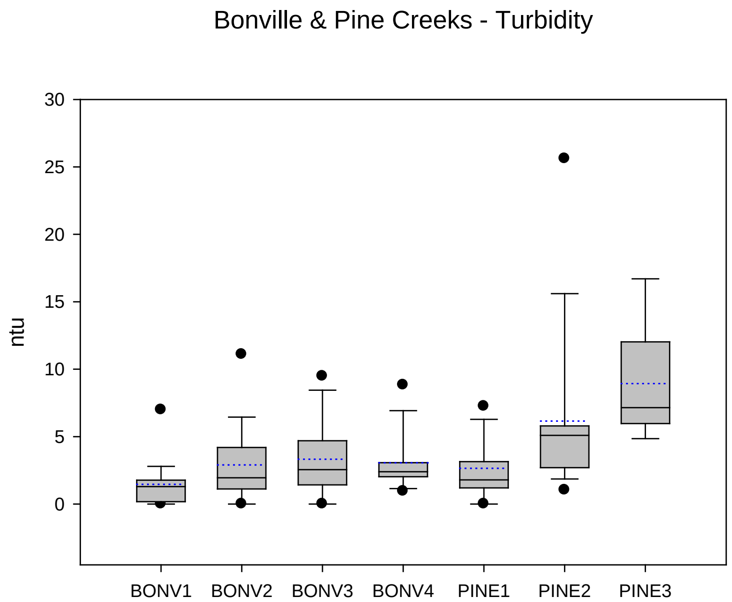

Figure 3.1.7 Mean, median, 25th and 75th percentiles, and range of turbidity values from Bonville Creek and Pine Creek sites, BONV1 to BONV4 and PINE1, PINE2 and PINE3, from January to December 2011.

Table 3.1.5 Proportion of monthly turbidity samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
BONV1	0.93	0.07	0.00	0.00	28	8.2	
BONV2	0.84	0.12	0.04	0.00	26	13.4	Sep (0.1m)
BONV3	0.79	0.21	0.00	0.00	24	9.6	
PINE1	0.93	0.05	0.00	0.02	41	16.8	Sep (0.1m)
PINE2	0.48	0.41	0.04	0.07	27	25.6	Sep (0.1/1m)
BONV4	0.96	0.04	0.00	0.00	28	27	
PINE3	1.00	0.00	0.00	0.00	14	17.9	

pH

The mean pH values in Bonville Creek ranged from 6.20 at site BONV4 to 8.05 at site BONV1 (Fig. 3.1.8). At the Pine Creek sites, the mean pH values ranged from 6.16 at PINE3 to 7.28 at PINE1. The minimum pH values at the Bonville Creek sites ranged from 5.31 at BONV4 during July 2011 to 6.92 at BONV1 during September 2011. The maximum values detected at Bonville Creek sites were 9.11 at BONV1, 8.23 at BONV2, and 8.06 at BONV3 all recorded during October 2011, and 7.30 at BONV4 during November 2011. Minimum pH values at Pine Creek sites were 6.04 at PINE1 during May 2011, 6.23 at PINE2 during September 2011, and 5.53 during July 2011. The maximum values recorded at Pine Creek were 8.43 at PINE1 and 8.77 at PINE2 during October 2011, and 7.18 at PINE3 during November 2011. At sites BONV4 and PINE3, 86% of pH samples collected during 2011 had values that fell below the prescribed trigger value. Between 50 and 57% of the samples from BONV2, BONV3 and PINE2 had values that fell below the 6.5 lower limit, while 3% and 26% of pH samples from BONV1 and PINE1, respectively, also fell below this range. At BONV1 and PINE2, 20% and 3% of pH samples, respectively, had values that exceeded the 8.0 upper limit (Table 3.1.6).

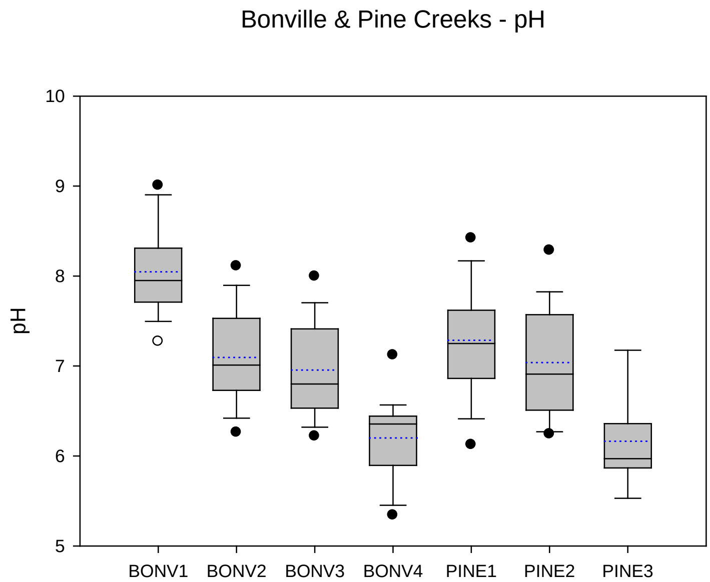

Figure 3.1.8 Mean, median, 25th and 75th percentiles, and range of pH values from Bonville Creek and Pine Creek sites, BONV1 to BONV4 and PINE1, PINE2 and PINE3, from January to December 2011.

Table 3.1.6 Proportion of monthly turbidity samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0.5-1	1-1.5	>1.5	*n*	Minimum	Maximum
BONV1	0.03	0.77	0.20	35	6.92	9.11
BONV2	0.50	0.50	0.00	30	6.09	8.23
BONV3	0.57	0.43	0.00	28	6.21	8.06
PINE1	0.26	0.74	0.00	46	6.04	8.43
PINE2	0.52	0.45	0.03	31	6.23	8.77
BONV4	0.86	0.14	0.00	28	5.31	7.3
PINE3	0.86	0.14	0.00	13	5.53	7.18

Faecal coliform

Cell counts of coliforms were below the 100cells/mL primary contact threshold for all sample periods. The highest value recorded of 148cells/100mL in September was very close to the trigger value (Table 3.1.7).

Table 3.1.7 Monthly faecal coliform values (fc/100mL) from Bonville Creek at site BONV1. Concentrations more than 1 times the trigger value are highlighted in red.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BONV1	33	2		23	17	44	54		148	2	0	20

Water chemistry variables

The range of water temperatures, salinity and measures of Secchi depth from Bonville and Pine Creek sites, BONV1 to BONV4, PINE1, PINE2 and PINE3 are outlined in Table 3.1.8. Water temperatures in both creeks reflected seasonal climatic changes. In Bonville Creek, the summer maximum temperatures ranged from 23°C to 31.78°C and winter minimum temperatures ranged from 13.12°C to 15.66°C. In Pine Creek, the summer maximum temperatures ranged from 22.7°C to 30.44°C and winter minimum temperatures ranged from 8.24°C to 13.18°C. Conductivity at the most upstream sites BONV4 and PINE3 had consistently low conductivity with a maximum of 0.10 mS/cm recorded throughout the study period. At sites BONV2, BONV3, PINE1 and PINE2, minimum conductivities ranged from 0.13 mS/cm to 1.19 mS/cm and maximum conductivities ranged from 47.6 mS/cm to 54.1 mS/cm. Conductivity ranged from 22.1 mS/cm to a maximum of 56.1 mS/cm at site BONV1. Minimum secchi depths across the Bonville Creek sites ranged from 0.5 m to 1.1 m, while maximum values ranged from 1.9m to 4.0m. Minimum secchi depths across the Pine Creek sites ranged from 0.4m to 0.7m, while maximum values ranged from 1.0m to 2.3m. Dissolved oxygen concentrations varied substantially over the sampling period, with all sites recorded very low concentrations that generally decreased with distance upstream in Bonville Creek, but the opposite trend was apparent in Pine Creek. Lower dissolved oxygen values were also generally found at the base of the water column at all sites.

Table 3.1.8 Summary of range of water chemistry variables including water temperature, conductivity, secchi depth and dissolved oxygen for Bonville Creek and Pine Creek sites, BONV1 to BONV4 and PINE1, PINE2 and PINE3.

Site	Water temp (°C)	Conductivity (mS/cm)	Secchi Depth (m)	Dissolved Oxygen %
BONV1	15.66 - 25.31	22.1 - 56.1	0.8 - 4	85.9-104
BONV2	13.12 - 30.61	1.19 - 48.4	0.8 - 2	31.9 – 107.2
BONV3	13.89 - 31.78	0.36 - 47.6	1.1 - 2.3	20.3 - 103
BONV4	13.44 – 23.00	0.06 - 0.08	0.5 - 1.9	55.4 - 104
PINE1	13.06 - 30.30	1.02 - 48.5	0.7 - 2.3	9-106.4
PINE2	8.24 - 30.44	0.13 - 54.1	0.5 - 2	12.7-101
PINE3	13.18 - 22.70	0.08 - 0.10	0.4 - 1	51-105

3.1.4 Macroinvertebrates

Bonville Creek

Twenty-eight macroinvertebrate families were recorded from Bonville Creek during the Autumn and Spring sampling in 2011, dominated by Trichoptera (Caddis Flies) with 8 families, and Odonata (Dragon Flies) with 6 families present (Tables 3.1.9, 3.1.10). Family level richness was higher in Autumn than Spring, driven by the presence of Odonatas (Table 3.1.9). The EPT index identifies approximately 40% of the families and 36% of the individuals recorded are from these families that require flowing water, and good habitat and water quality condition.

The abundance of individuals was also higher in Autumn (220) compared to Spring (148). There were a number of families that contributed to the larger abundances in Autumn including Psephenidae (30), Leptophlebiidae (20), Baetidae (20) and Hydropsychidae (19). In Spring, the abundance of individuals was biased by the presence of Chironomidae (43), Leptophlebiidae (26) and Calamoceratidae (18). Equally, there were a number of taxa that were rare in the catchment, with ten taxa having less than five individuals recorded in both seasons.

Mean SIGNAL2 score for Bonville Creek was 5.3 in Spring and 5.6 in Autumn with little difference between the range of scores recorded. The two most abundant species were from Chironomidae and Leptophledbiidae, which have SIGNAL2 scores of 3 and 8, respectively, suggesting the system has water quality and habitat suitable for a diversity of taxa.

Table 3.1.9 Summary of macroinvertebrate data for Bonville Creek.

	Spring	Autumn
Family Richness	22	24
Total Abundance	148	220
EPT richness	10	10
EPT abundance	76	88
Mean Signal score	5.3	5.6
Signal score range	2-8	2-9

Table 3.1.10 Summary of macroinvertebrate abundance and SIGNAL2 grade scores for Bonville Creek.

Order	Family	SIGNAL grade	Spring	Autumn
			BONV4	BONV4
Ephemeroptera	Leptophlebiidae	8	26	20
Ephemeroptera	Baetidae	5	3	20
Ephemeroptera	Caenidae	4	1	0
Trichoptera	IF	8	1	6
Trichoptera	Calamoceratidae	7	18	1
Trichoptera	Glossomatidae	9	0	2
Trichoptera	Hydropsychidae	6	14	19
Trichoptera	Philopotamidae	8	6	10
Trichoptera	Ecnomidae	4	5	2
Trichoptera	Hydrobiosidae	8	1	3
Trichoptera	Leptoceridae	6	1	5
Odonata	Indeterminate	3	1	0
Odonata	Ashnidae	5	0	1
Odonata	Gomphidae	5	0	4
Odonata	Corduliidae	5	2	10
Odonata	Protonuridae	4	5	7
Odonata	Diphlebiidae	6	0	1
Coleoptera	Elmidae	7	3	12
Coleoptera	Psephenidae	6	3	30
Coleoptera	Dytiscidae	2	2	0
Coleoptera	Gyrinidae	4	1	0
Coleoptera	Hydrophilidae	2	0	1
Lepidoptera	Pyralidae	3	1	5
Megaloptera	Corydalidae	7	2	15
Decapoda	Atyidae	3	3	13
Diptera	Simuliidae	5	0	16
Diptera	Tipulidae	5	1	11
Diptera	Chironomidae	3	43	15

Pine Creek

Twelve macroinvertebrate families were recorded from Pine Creek during the Autumn and Spring sampling in 2011, dominated by Trichoptera (Caddis Flies) with 4 families present (Tables 3.1.11, 3.1.12). Family level richness was slightly higher in Spring (10) compared to Autumn (9) (Table 3.1.11). The EPT index identifies approximately 40% of the families and 36% of the individuals recorded are from these families that require good habitat and water quality condition.

Conversely, the abundance of individuals was higher in Autumn (79) compared to Spring (64), but considerably lower than the freshwater site BONV4 on Bonville Creek. Although there were a number of different taxa present in both Autumn and Spring, the abundance of individuals was biased by the presence of Chrinomidae during Autumn (61) and Spring (35). There were a number of taxa that were rare in the catchment, with seven of the twelve taxa having less than five individuals recorded in both seasons.

Mean SIGNAL2 score for Pine Creek was 5.1 in Spring and 5.4 in Autumn with little difference between the range of scores recorded. The most abundant species were from Chironomidae with SIGNAL2 score of 3 suggesting predominantly poor water quality and habitat conditions.

Table 3.1.11 Summary of macroinvertebrate data for Pine Creek.

	Spring	Autumn
Family Richness	10	9
Total Abundance	64	79
EPT richness	5	5
EPT abundance	17	12
Mean Signal score	5.1	5.4
Signal score range	2-8	3-8

Table 3.1.12 Summary of macroinvertebrate abundance and SIGNAL grade scores for Pine Creek.

Order	Family	SIGNAL grade	Spring	Autumn
			PINE3	PINE3
Ephemeroptera	Leptophlebiidae	8	4	6
Ephemeroptera	Baetidae	5	2	2
Trichoptera	IF	8	2	1
Trichoptera	Ecnomidae	4	5	2
Trichoptera	Hydrobiosidae	8	0	1
Trichoptera	Leptoceridae	6	4	0
Odonata	IF	3	0	1
Odonata	Gomphidae	5	1	0
Coleoptera	Elmidae	7	4	3
Oligocheata	Tubificidae	2	1	0
Decapoda	Atyidae	3	6	2
Diptera	Chironnomidae	3	35	61

3.1.5 Riparian condition

The riparian condition assessments for the most upstream sites on Bonville and Pine Creeks showed that PINE3 had a condition score of 7.24/10, while BONV4 had a score of 6.50/10 (Table 3.1.13). Site PINE3 had higher scores in the vegetation bank condition indices, which contributed to the higher overall riparian condition score. Site BONV4 had higher scores in the riparian habitat and site-based disturbance indices.

Table 3.1.13 Site level summary of riparian condition scores for Bonville and Pine Creeks. Individual scores maximum of 5, total score out of 10.

	VEGETATION	BANK CONDITION	HABITAT	DISTURBANCE	Total/10
PINE3	2.77	4.00	3.38	4.33	7.24
BONV4	2.00	3.00	3.50	4.50	6.50
Mean	**2.38**	**3.50**	**3.44**	**4.42**	**6.87**

The vegetation at PINE3 is described as Flooded Gum and Brush Cherry Forest, with an index score of 2.77/5 (Table 3.1.14; 15). The mid-storey also consisted of the natives *Tristaniopsis laurina*, *Aphlitonia excels*, *Wilkiea huegeliana*, *Glochidion ferdinandi var. ferdinandi*, *Cryptocarya glaucescens*, and the exotic, *Lantana camara*. The understorey at PINE3 consisted of the native grasses, *Microlaena stipoides* and *Ottochloa gracillima*, as well as the exotic species, *Paspalum mandiocanum* and *Tradescantia fluminensis*. Site BONV4 had a vegetation index score of 2.00/5, and was described as Flooded Gum forest. There were a limited number of large trees in the riparian zone and the only species present in the mid-storey was the exotic, *Ligustrum sinense*. In the understorey, the only native species present was the grass, *Ottochloa gracillima*, while the exotic species present included *Ageratum houstonianum*, *Bidens pilosa*, *Sida rhombifolia*, and the grass, *Paspalum mandiocanum*. The higher index score at PINE3 was also attributed to the presence of the native vines, *Smilax australis* and *Ripogonum discolour*.

Site PINE3 also had a higher bank condition score of 4.00/5, compared to a score of 3.00/5 at site BONV4. Both sites had bank slopes with scores of 2.00/5, indicating the potential for increased bank erosion at these sites, however, only site BONV4 had evidence of bank undercutting. A positive feature of both sites was the limited number of exposed tree roots and reduced bank slumping.

The riparian habitat condition scores were 3.50/5 for BONV4 and 3.38/5 for PINE3. There was a large number of standing dead tree habitat at both sites. There were a limited number of fallen tree and log habitats within both sites. Both sites had reduced amounts of weed litter present in the riparian zone. Site PINE3 was located with Tuckers Nob State Forest area and therefore was in closer proximity to patches of remnant native vegetation compared to site BONV4.

Site BONV4 had a slightly higher site-based disturbance score of 4.50/5, compared to site PINE3, which had a score of 4.33/5. There was limited evidence of tree removal, fences and livestock movement within the riparian zone of BONV4. In contrast, there was some evidence of tree removal and livestock movement at site PINE3, however, this site did have good connectivity with patches of remnant vegetation.

Table 3.1.14 Site level summary of riparian condition scores for each sub-index for PINE3 and BONV4 sites. Individual scores maximum of 5.

	PINE3	BONV4
Vegetation		
Large trees	1.00	1.67
Canopy Cover	4.67	2.00
Mid-storey Cover	3.00	1.00
Mid-storey Weeds	3.67	3.67
Grass Cover	4.00	4.67
Grass Weeds	2.33	2.00
Understorey Cover	2.33	1.00
Understorey Weeds	1.00	1.00
Vines	2.33	1.00
Vegetation Layers	3.33	2.00
Total/5	**2.77**	**2.00**
Bank Condition		
Slope score	2.00	2.00
Undercutting	5.00	1.00
Exposed Tree Roots	4.00	4.00
Slumping	5.00	5.00
Total/5	**4.00**	**3.00**
Habitat		
Standing Dead Trees	5.00	5.00
Logs	3.00	2.00
Fallen Trees	0.00	0.00
Reeds	3.00	5.00
Large Trees	1.00	5.00
Organic Litter	5.00	3.00
Weed Litter	5.00	5.00
Proximity to remnant	5.00	3.00
Total/5	**3.38**	**3.50**
Disturbance		
Tree Clearing	3.67	5.00
Fencing	5.00	5.00
Livestock	3.67	5.00
Connectivity to vegetation	5.00	3.00
Total/5	**4.33**	**4.50**

Table 3.1.15 Dominant riparian vegetation for each strata at PINE3 and BONV4 sites.

Vegetation Description	PINE3	BONV4
Left/Right bank (facing downstream)	L	R
Dominant Large Trees A	*Eucalyptus grandis*	*Eucalyptus grandis*
Dominant Large Trees B	no large trees	no large trees
Dominant Large Trees C	*Syzygium australe*	*Eucalyptus grandis*
Dominant Mid-storey Cover (native)	*Syzygium australe*	
	Tristaniopsis laurina	
	Aphlitonia excelsa	
	Wilkiea huegeliana	
	Glochidion ferdinandi var. ferdinandi	
	Cryptocarya glaucescens	
Dominant Mid-storey Cover (weeds)	*Lantana camara*	*Ligustrum sinense*
Dominant Grass Cover (native)	*Microlaena stipoides*	*Ottochloa gracillima*
	Ottochloa gracillima	
Dominant Grass Cover (weeds)	*Paspalum mandiocanum*	*Paspalum mandiocanum*
Dominant Understorey Cover (native)		
Dominant Understorey Cover (weeds)	*Tradescantia fluminensis*	*Ageratum houstonianum*
		Bidens pilosa
		Sida rhombifolia
Dominant Organic Litter (natives)	*Eucalyptus grandis*	*Eucalyptus grandis*
	Syzygium australe	*Lophostemon confertus*
Dominant Organic Litter (weeds)	no weeds	
Dominant Vines	*Smilax australis*	no vines
	Ripogonum discolor	

3.2 BOAMBEE and NEWPORTS CREEKS

3.2.1 Catchment description

The Boambee-Newports Estuary is located between the city of Coffs Harbour (to the north) and the town of Sawtell (to the south). The estuary has a roughly rectangular shape catchment area of approximately 49 km^2, extending approximately 8 km from the coast with a coastal floodplain of approximately 3 km wide (GHD 2010). The headwaters consist of steep hills with slopes 33-56% on metasediments of Coffs Harbour association (Brooklana Beds consisting of silicious mudstones and siltstones typically highly fractured, cleaved and deformed) exhibiting strongly acid stony soils with strong subsoil acidity and low fertility (Milford 1999). The drainage network consists of two main tributaries: the largest being Newports Creek in the north; Boambee Creek is next largest and drains the middle portion of the catchment. The Boambee/Newports Estuary is permanently open to the ocean and has no artificial entrance training works, as it is naturally trained by Boambee Headland (GHD 2012) (Fig. 3.2.1).

The hydraulic processes in the estuary are characterised by the semi-diurnal ocean tide in conjunction with hydrologic surface runoff contributed by the Boambee/Newports Creek catchment. Tidal velocities and discharges are greatest at the mouth followed by Boambee Creek and then Newports Creek. The 100 year recurrence interval flood level ranges from 2.6m AHD at the railway line crossing of Boambee Creek to 6m AHD at the Pacific Highway crossing of Newports Creek (GHD 2010).

Much of the catchment is affected by urban growth. Large industrial areas in the mid-catchment include a sewage treatment plant and the Coffs Harbour airport. Significant land use changes are expected to continue within the catchment with residential, rural and industrial development. Upper catchment condition has improved as areas of banana plantations have decreased since the 1980s, however urban development has increased which may lead to altered run-off patterns (GHD 2010).

3.2.2 Site description

Four sites were selected along Boambee Creek and three sites were selected along Newport Creek (Table 3.2.1). The most upstream sites are represented by BOAM4 in Boambee Creek (Fig 3.2.2a) and NEW3 in Newport Creek (Fig 3.2.2b), which are both within freshwater zones and in a River Style defined as Fine-grained Meandering. The next most upstream sites, BOAM3 and NEW2, are both within the tidal limit zone, while sites BOAM2 and NEW1 (Fig 3.2.3) are within zones of intermediate salinity. Site NEW1 is the most downstream site on Newport Creek and is located approximately 4.5km upstream of the confluence of Newport Creek with Boambee Creek. Site BOAM1 (Fig 3.2.4) is located after the confluence and is considered to be in a marine zone with a salinity range of 30+ ppt. Site BOAM1, was the only site on Boambee and Newport Creeks that was sampled for faecal coliform. All sites were sampled each month from January to December 2011 for water chemistry.

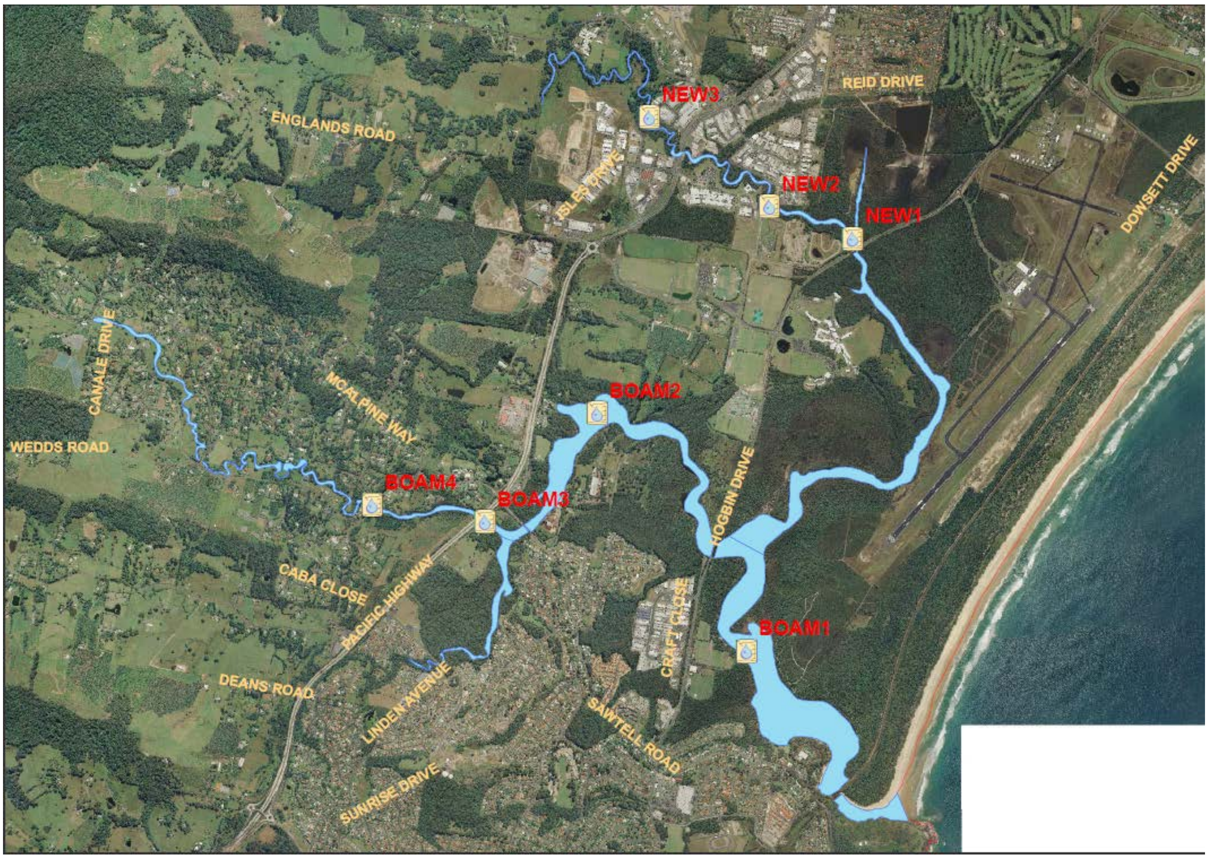

Figure 3.2.1 Dominant land-use and location of sites in Boambee and Newport Creeks in the Coffs Harbour catchment (Source CHCC).

Table 3.2.1 Location of sampling sites, River Style and Condition in Boambee and Newports Creeks.

River System – Site Code	Easting	Northing	Zone	Organisation collecting	Samples collected
Boambee Creek 1 (BOAM1)	509287 m E	6642989 m S	Marine (30+ppt)	UNE	Faecal, Nutrients, TSS & Chl *a*
Boambee Creek 2 (BOAM2)	508375 m E	6644612 m S	Intermediate salinity	UNE	Nutrients, TSS & Chl *a*
Boambee Creek 3 (BOAM3)	507259 m E	6643963 m S	Tidal limit	UNE	Nutrients, TSS & Chl *a*
Boambee Creek 4 (BOAM4)	506799 m E	6643962 m S	Freshwater	CHCC	Nutrients, TSS Chl *a*, Macroinverts
Newports Creek 1 (NEW1)	510148 m E	6645326 m S	Intermediate salinity	UNE	Nutrients, TSS & Chl *a*
Newports Creek 2 (NEW2)	509391 m E	6645972 m S	Tidal limit	UNE	Nutrients, TSS & Chl *a*
Newports Creek 3 (NEW3)	508642 m E	6646544 m S	Freshwater	CHCC	Nutrients, TSS Chl *a*, Macroinverts

Figure 3.2.2a Site BOAM4 in Boambee Creek looking downstream from crossing.

Figure 3.2.2b Site NEW3 in Newports Creek looking upstream from crossing.

Figure 3.2.3 Site NEW1 in Newports Creek looking upstream.

Figure 3.2.4 Site BOAM1 in Boambee Creek looking upstream.

3.2.3 Water Chemistry

Chlorophyll *a*

The mean chlorophyll *a* concentration in Boambee Creek ranged from 1.97µg/L at site BOAM4 to 4.17µg/L at site BOAM2 (Fig. 3.2.5). At the Newports Creek sites, the mean chlorophyll *a* concentrations ranged from 2.18µg/L at NEW3 to 3.08µg/L at NEW1. The minimum chlorophyll *a* concentration across all Boambee and Newports Creek sites was 0.90µg/L, and was detected during more than one sampling occasion at each site. The maximum chlorophyll *a* concentrations in Boambee Creek were 5.00 µg/L and 10.00 µg/L during November 2011 at sites BOAM1 and BOAM2, respectively. At site BOAM3 the maximum concentration was 9µg/L during July 2011, while at site BOAM4 the maximum concentration was 3µg/L during the October and November 2011. The maximum concentrations at Newports Creek were 8µg/L at NEW1 during July, 5µg/L at NEW2 during November, and 6µg/L at NEW3 during February. All chlorophyll *a* samples from BOAM4 had concentrations that fell below the prescribed trigger value. At site BOAM3, 42% of chlorophyll *a* samples had concentrations that exceeded the trigger value. At sites BOAM2 and NEW1, 25% of samples had concentrations that also exceeded the trigger value, while 8 to 16% of samples from BOAM1, NEW2 and NEW3 had concentrations that exceeded the trigger value (Table 3.2.2).

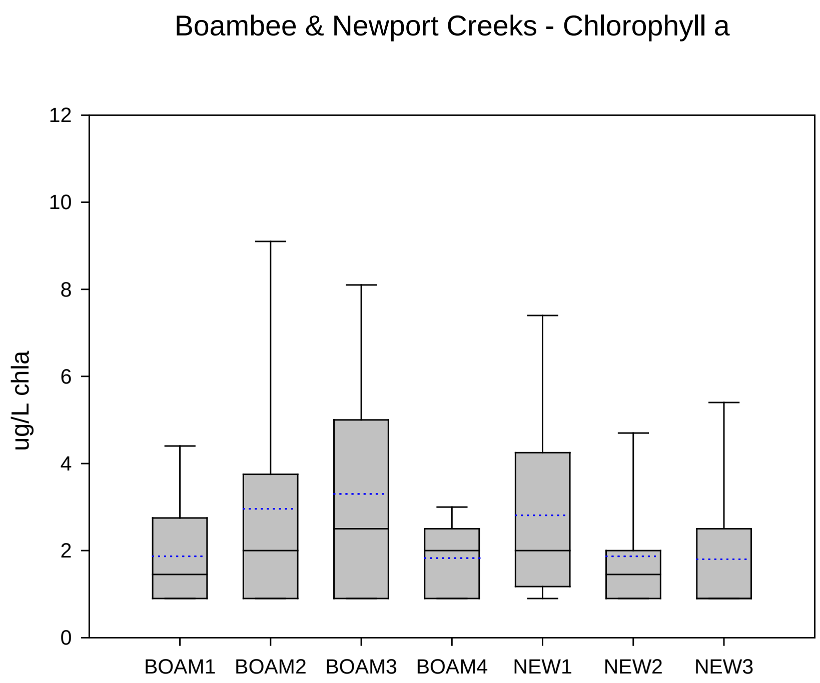

Figure 3.2.5 Mean, median, 25th and 75th percentiles, and range of chlorophyll *a* concentrations from Boambee Creek and Newport Creek sites, BOAM1 to BOAM4, NEW1, NEW2 and NEW3, from January to December 2011.

Table 3.2.2 Proportion of monthly chlorophyll *a* samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum µg/L	Month
BOAM1	0.50	0.42	0.00	0.08	12	5	Nov
BOAM2	0.42	0.33	0.00	0.25	12	10	Nov
BOAM3	0.33	0.25	0.09	0.33	12	9	Jul
NEW1	0.25	0.50	0.00	0.25	12	8	Jul
NEW2	0.50	0.34	0.08	0.08	12	5	Nov
BOAM4	0.91	0.09	0.00	0.00	11	3	Oct/Nov
NEW3	0.82	0.10	0.08	0.00	11	6	Feb

Total Nitrogen (TN)

The mean TN concentration in Boambee Creek ranged from 655.91µg/L at site BOAM1 to 729.55µg/L at site BOAM4 (Fig. 3.2.6). At Newports Creek sites, mean TN concentrations ranged from 551.1µg/L at NEW3 to 578.18µg/L at NEW2. The minimum TN concentrations across all Boambee Creek sites ranged from 30µg/L at BOAM4 during June to 460µg/L at BOAM3 during March. The maximum concentrations detected at Boambee Creek sites were 640µg/ at BOAM1 during October, 810µg/L at BOAM2 during July, 1030µg/L at BOAM3 during July, and 1060µg/L at BOAM4 also during July 2011. The minimum TN concentrations at the Newports Creek sites ranged from 81µg/L at NEW3 during June to 430µg/L at NEW2 during December. The maximum concentrations at Newport Creek were 850µg/L at NEW1, 760µg/L at NEW2, and 750µg/L at NEW3, all recorded during July 2011. All of the TN samples from sites BOAM2, BOAM3, NEW1 and NEW2 had concentrations that exceeded the prescribed trigger value. At site BOAM4, 91% of TN samples had concentrations that exceeded the trigger value, while 73% and 70% of samples from BOAM1 and NEW3, respectively, had concentrations that exceeded the trigger value (Table 3.2.3).

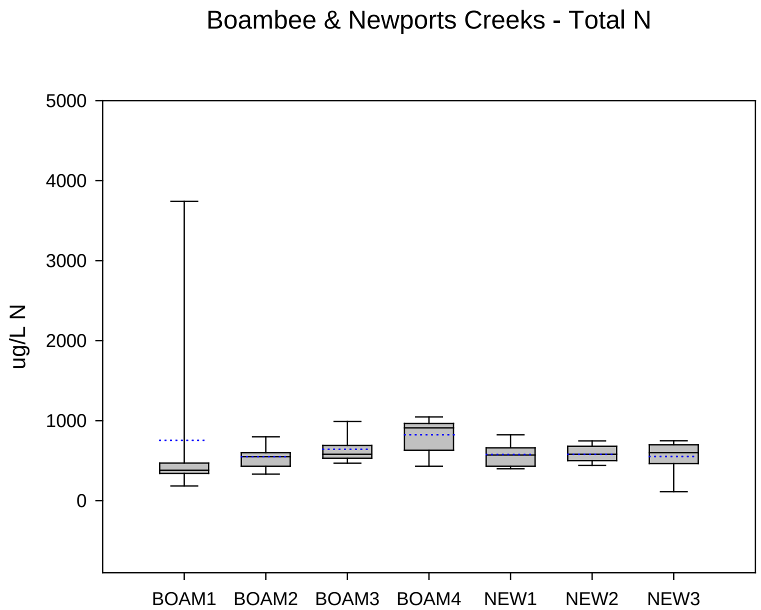

Figure 3.2.6 Mean, median, 25th and 75th percentiles, and range of TN concentrations from Boambee Creek and Newport Creek sites, BOAM1 to BOAM4, NEW1, NEW2 and NEW3, from January to December 2011.

Table 3.2.3 Proportion of monthly TN samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
BOAM1	0.09	0.18	0.55	0.18	11	640.0	Oct
BOAM2	0.00	0.00	0.27	0.73	11	810.0	JuL
BOAM3	0.00	0.00	0.00	1.00	11	1030.0	Jul
NEW1	0.00	0.00	0.27	0.73	11	850.0	Jul
NEW2	0.00	0.00	0.09	0.91	11	760.0	Jul
BOAM4	0.00	0.09	0.18	0.73	11	1060.0	Jul
NEW3	0.10	0.20	0.70	0.00	10	750.0	Jul

Total Phosphorous (TP)

The mean TP concentration in Boambee Creek ranged from 37.27µg/L at site BOAM2 to 439.55µg/L at site BOAM1 (Fig. 3.2.7). At the Newports Creek sites, mean TP concentrations ranged from 38.5µg/L at NEW3 to 42.73µg/L at NEW2. The minimum TP concentrations across all Boambee Creek and Newport Creek sites were 30µg/L, and detected on more than one sampling occasion. Maximum concentrations detected at Boambee Creek sites were 145µg/L at BOAM1 during October, 100µg/L at BOAM2 and 110µg/L at BOAM3 during May, and 70µg/L at BOAM4 during December 2011. The maximum concentrations at Newports Creek were 100µg/L at NEW1 and 110µg/L at NEW2 during May, and 80µg/L at NEW3 during December 2011. At site BOAM3, 45% of TP samples collected during 2011 had concentrations that exceeded the prescribed trigger value, while 36% of samples from sites NEW1 and NEW2, 18% of samples from sites BOAM1, BOAM2 and BOAM3, and 10% of samples from NEW3, also had concentrations that exceeded the trigger value (Table 3.2.4).

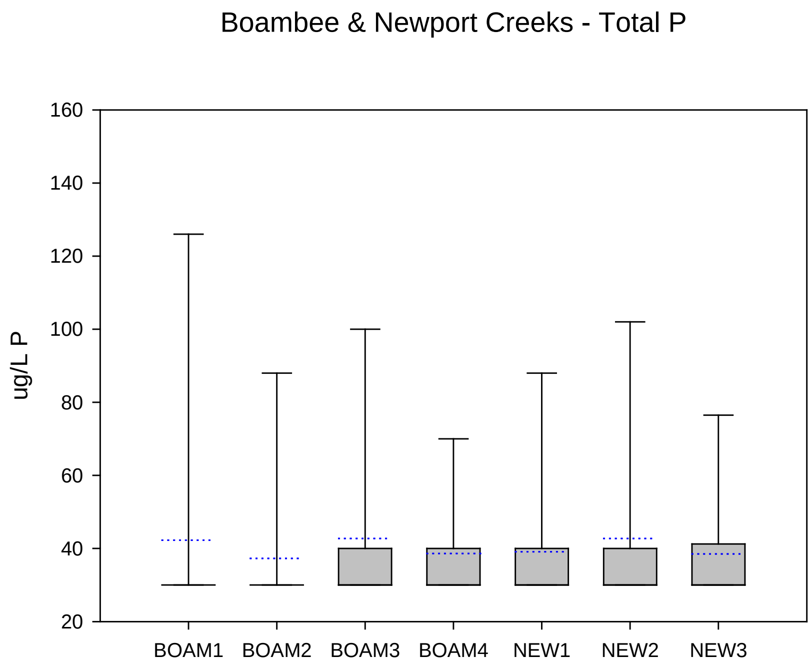

Figure 3.2.7 Mean, median, 25th and 75th percentiles, and range of TP concentrations from Boambee Creek and Newport Creek sites, BOAM1 to BOAM4, NEW1, NEW2 and NEW3, from January to December 2011.

Table 3.2.4 Proportion of monthly TP samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
BOAM1	0.00	0.82	0.00	0.18	11	145	Oct
BOAM2	0.00	0.82	0.09	0.09	11	100	May
BOAM3	0.00	0.55	0.27	0.18	11	110	May
NEW1	0.00	0.64	0.27	0.09	11	100	May
NEW2	0.00	0.64	0.27	0.09	11	110	May
BOAM4	0.00	0.82	0.18	0.00	11	70	Dec
NEW3	0.00	0.90	0.00	0.10	10	80	Dec

Turbidity

The mean turbidity values in Boambee Creek ranged from 1.72NTU at site BOAM1 to 8.42NYU at site BOAM2 (Fig. 3.2.8). At the Newport Creek sites, the mean turbidity values ranged from 6NTU at NEW3 to 12.69NTU at NEW1. The minimum values detected within Boambee Creek ranged from 0 NTU at BOAM1 during January, February and August to 1.5NTU at BOAM2 during February 2011. The maximum turbidity values detected at Boambee Creek sites were 10NTU at BOAM1 during October, 20NTU at BOAM2 during June, 21.8NTU at BOAM3 during September, and 42.9NTU at BOAM4 during August 2011. At Newports Creek, the minimum values ranged from 1.9NTU at NEW2 during February to 4.7NTU at NEW1 during August 2011. The maximum values were 25.2NTU at NEW1 during October, 19NTU at NEW2 during September, and 9.5NTU at NEW3 during December 2011. At site NEW1, 54% of turbidity samples collected during 2011 had values that exceeded the prescribed trigger value of 10NTU, while 33% of samples from BOAM2, 26% of samples from sites NEW2, and 8% of samples from BOAM3, also had values that exceeded the trigger value (Table 3.2.5).

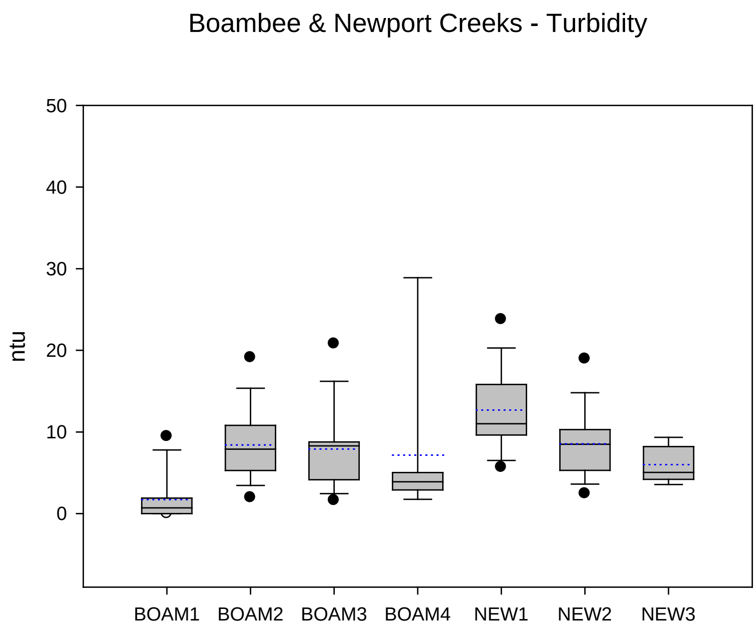

Figure 3.2.8 Mean, median, 25th and 75th percentiles, and range of turbidity values from Boambee Creek and Newport Creek sites, BOAM1 to BOAM4, NEW1, NEW2 and NEW3, from January to December 2011.

Table 3.2.5 Proportion of monthly turbidity samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
BOAM1	0.89	0.11	0.00	0.00	27	10	Oct
BOAM2	0.17	0.50	0.25	0.08	24	20	Jun (1.5m)
BOAM3	0.25	0.58	0.04	0.04	24	21.8	Sep (1.5m)
NEW1	0.00	0.46	0.29	0.25		25.2	Oct
NEW2	0.19	0.55	0.16	0.10		19	Sep
BOAM4	0.86	0.07	0.07	0.00	14	42.9	Aug
NEW3	1.00	0.00	0.00	0.00		9.5	Dec

pH

The mean pH values in Boambee Creek ranged from 6.49 at site BOAM4 to 8.31 at site BOAM1 (Fig. 3.2.9). At Newports Creek sites, the mean turbidity values ranged from 6.55 at NEW3 to 7.66 at NEW1. The minimum values detected within Boambee Creek ranged from 5.73 at BOAM4 during July 2011 to 7.71 at BOAM1 during March 2011. The maximum pH values detected at Boambee Creek sites ranged from 7.4 at BOAM4 during November to 9.50 at BOAM2 during October 2011. At Newports Creek, the minimum values ranged from 5.84 at NEW3 during July to 6.71 at NEW1 during May 2011. The maximum values were 8.68 at NEW1 during October, 8.25 at NEW2 during October, and 6.93 at NEW3 during November 2011. At sites BOAM1 and BOAM2, 10% of pH samples collected during 2011 had values that exceeded the prescribed trigger value range, while 3% of the samples from NEW1 also exceeded the upper limit. At site BOAM4, 29% of the pH values fell below the lower limit. Between 3 to 14% of the samples from sites BOAM2, BOAM3, NEW1, NEW2 and NEW3, had values that also fell above the upper limit (Table 3.2.6).

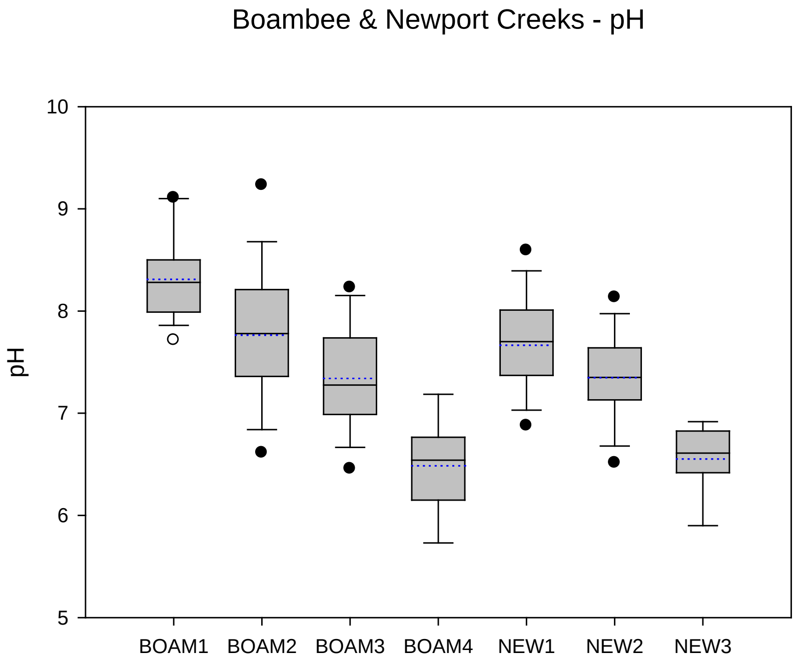

Figure 3.2.9 Mean, median, 25th and 75th percentiles, and range of pH values from Boambee Creek and Newport Creek sites, BOAM1 to BOAM4, NEW1, NEW2 and NEW3, from January to December 2011.

Table 3.2.6 Proportion of monthly pH samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0.5-1	1-1.5	>1.5	*n*	Minimum	Maximum
BOAM1	0.00	0.90	0.10	29	7.71	9.11
BOAM2	0.10	0.80	0.10	27	6.46	9.50
BOAM3	0.12	0.88	0.00	26	6.41	8.27
NEW1	0.03	0.94	0.03	31	6.71	8.68
NEW2	0.14	0.86	0.00	35	6.41	8.25
BOAM4	0.29	0.71	0.00	14	5.73	7.40
NEW3	0.08	0.92	0.00	12	5.84	6.93

Faecal coliform

Cell counts of coliforms were below the 100cells/mL primary contact threshold for all sample periods (Table 3.2.7). The maximum value recorded was 110cells/100mL was recorded in May 2011.

Table 3.2.7 Monthly faecal coliform values (fc/100mL) from Boambee Creek at site BOAM1. Concentrations more than 1 times the trigger value are highlighted in red.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BOAM1		14		17	110	2	0		3	1	0	0

Water chemistry variables

Table 3.2.8 outlines the range of water temperatures, salinity and measures of Secchi depth from Boambee and Newports Creek sites, BOAM1 to BOAM4, NEW1, NEW2 and NEW3. Water temperatures in both creeks reflected seasonal climatic changes. In Boambee Creek, the summer maximum temperatures ranged from 23.3°C to 27.78°C and winter minimum temperatures ranged from 13.62°C to 19.01°C. In Newports Creek, the summer maximum temperatures ranged from 22.96°C to 27.22°C and winter minimum temperatures ranged from 13.23°C to 16.54°C. Conductivity at the most upstream sites BOAM4 and NEW3 had consistently low conductivity with a maximum of 0.29mS/cm recorded throughout the study period. At sites BOAM2, BOAM3, NEW1 and NEW2, minimum conductivities ranged from 0.908mS/cm to 5.24mS/cm and maximum conductivities ranged from 45.5mS/cm to 53.4mS/cm. Conductivity ranged from 35.8mS/cm to a maximum of 55.4mS/cm at site BOAM1. Minimum secchi depths across the Boambee Creek sites ranged from 0.2m to 1.0m, while maximum values ranged from 0.5m to 2.8m. Minimum secchi depths across the Newports Creek sites ranged from 0.4m to 0.7m, while maximum values ranged from 0.6m to 3.1 m. Dissolved oxygen concentrations varied substantially over the sampling period, with all sites recorded very low concentrations that generally decreased with distance upstream. Lower dissolved oxygen values were also generally found at the base of the water column at all sites.

Table 3.2.8 Summary of range of water chemistry variables including water temperature, conductivity, secchi depth and dissolved oxygen for Boambee Creek and Newports Creek sites, BOAM1 to BOAM4, NEW1, NEW2 and NEW3.

Site	Water temp (°C)	Conductivity (mS/cm)	Secchi Depth (m)	Dissolved Oxygen %
BOAM1	19.01 - 26.7	35.88 - 55.4	1 - 2.8	74.4 – 108.2
BOAM2	16.92 - 27.66	3.61 - 53.4	0.6 - 2.4	57.8 – 103.5
BOAM3	15.69 - 27.78	1.02 - 47.2	0.8 - 1.8	35.2 – 102.3
BOAM4	13.62 - 23.3	0.02 - 0.29	0.2 - 0.5	33.1 – 104.1
NEW1	16.54 - 27.22	5.24 - 47.6	0.7 - 2	61 - 103
NEW2	15.56 - 26.97	0.908 - 45.5	0.6 - 3.1	15.5 - 103
NEW3	13.23 - 22.96	0.11 - 0.15	0.4 - 0.6	5.29 - 104

3.2.4 Macroinvertebrates

Boambee Creek

Twenty-two macroinvertebrate families were recorded from Boambee Creek during the Autumn and Spring sampling in 2011, dominated by Trichoptera (Caddis Flies) with 5 families, and Odonata (Dragon Flies), Diptera (Flies) and Coleoptera (Aquatic Beetles) with 4 families each recorded (Tables 3.2.9, 3.2.10). Family level richness was higher in Autumn than Spring, driven by the presence of Odonatas and Dipterans (Table 3.2.9). The EPT index identifies approximately 40% of the families and 36% of the individuals recorded are from these families that require good habitat and water quality condition.

The abundance of individuals was also higher in Autumn (120) compared to Spring (77). Although there were a number of families represented in Autumn, abundances were biased by a few taxa including Elmidae (36), Psephenidae (19) and Chrinomidae (19). In Spring, the abundance of individuals was biased by the presence of Chrinomidae individuals (51). Equally, there were a number of taxa that were rare in the catchment, with fourteen taxa having less than five individuals recorded in both seasons.

Mean SIGNAL2 score for Boambee Creek was 4.6 in Spring and 4.8 in Autumn with no difference between the range of scores recorded. The two most abundant species were Chrinomidae (midge larvae) and Elmidae (riffle beetles), which have signal scores of 3 and 7, respectively, suggesting that these systems have the water quality and habitat to support a diversity of macroinvertebrate fauna.

Table 3.2.9 Summary of macroinvertebrate data for Boambee Creek.

	Spring	Autumn
Family Richness	10	19
Total Abundance	77	120
EPT richness	6	6
EPT abundance	15	15
Mean Signal score	4.6	4.8
Signal score range	2-8	2-8

Table 3.2.10 Summary of macroinvertebrate abundance and SIGNAL grade scores for Boambee Creek.

Order	Family	SIGNAL grade	Spring	Autumn
			BOAM4	BOAM4
Ephemeroptera	Leptophlebiidae	8	2	0
Ephemeroptera	Baetidae	5	1	5
Ephemeroptera	Caenidae	4	1	0
Plecoptera	Gripopterygidae	8	0	1
Trichoptera	Indeterminate	8	0	1
Trichoptera	Calamoceratidae	7	6	1
Trichoptera	Ecnomidae	4	0	3
Trichoptera	Hydroptidae	4	2	0
Trichoptera	Leptoceridae	6	3	4
Odonata	Indeterminate	3	0	1
Odonata	Gomphidae	5	0	7
Odonata	Corduliidae	5	0	2
Odonata	Protonuridae	4	3	1
Coleoptera	Elmidae	7	0	36
Coleoptera	Psephenidae	6	0	19
Coleoptera	Dytiscidae	2	3	2
Coleoptera	Hydrophilidae	2	0	2
Decapoda	Atyidae	3	5	10
Diptera	Indeterminate	3	0	1
Diptera	Simuliidae	5	0	4
Diptera	Tipulidae	5	0	1
Diptera	Chironnomidae	3	51	19

Newports Creek

Ten macroinvertebrate families were recorded from Newports Creek during the Autumn and Spring sampling in 2011, dominated by the order, Coleoptera (Aquatic Beetles), with 3 families (Tables 3.2.11, 3.2.12). Family level richness was slightly higher in Autumn than Spring (Table 3.2.11).

The abundance of individuals was very low compared to Boambee Creek and almost equal between Autumn (42) and Spring (41). Although there were a number of families represented in Autumn, abundances were biased by a few taxa including Atyidae (13), Chironomidae (10) and Baetidae (9). In Spring, the abundance of individuals was biased by the presence of Chironomidae individuals (30). Equally, there were a number of taxa that were rare in the catchment, with six of the ten taxa having less than five individuals recorded in both seasons.

Mean SIGNAL2 score for Newports Creek was 4.6 in Spring and 4 in Autumn with no difference between the range of scores recorded. The two most abundant species were from Chironomidae (midge larvae) and Atyidae (freshwater shrimp), which have signal scores of 3. The low mean score and dominance of taxa with low SIGNAL2 scores suggests the water quality and habitat conditions in the freshwater reaches of Newports Creek are in poor condition.

Table 3.2.11 Summary of macroinvertebrate data for Newports Creek.

	Spring	Autumn
Family Richness	5	7
Total Abundance	42	41
EPT richness	1	2
EPT abundance	1	10
Mean Signal score	4.6	4
Signal score range	2-7	2-7

Table 3.2.12 Summary of macroinvertebrate abundance and SIGNAL grade scores for Newport Creek.

Order	Family	SIGNAL grade	Spring	Autumn
			NEW4	NEW4
Ephemeroptera	Amelitopsidae	7	1	0
Ephemeroptera	Baetidae	5	0	9
Trichoptera	Hydropsychidae	6	0	1
Odonata	Protonuridae	4	3	0
Coleoptera	Elmidae	7	7	6
Coleoptera	Dytiscidae	2	0	1
Coleoptera	Hydrophilidae	2	0	1
Hemiptera	Corixidae	2	1	0
Decapoda	Atyidae	3	0	13
Diptera	Chironnomidae	3	30	10

3.2.5 Riparian condition

The riparian condition scores for the Boambee and Newport Creek sites, BOAM4 and NEW4, were 6.42/10 and 7.26/10, respectively (Table 3.2.13). The Newport Creek site, NEW4, had higher individual scores for the vegetation, riparian habitat and site-based disturbance indices, compared to site BOAM4. Both sites had similar bank condition scores of 3.25/5.

Table 3.2.13 – Site level summary of riparian condition scores for Boambee and Newport Creeks. Individual scores maximum of 5, total score out of 10.

	VEGETATION	BANK CONDITION	HABITAT	DISTURBANCE	Total/10
BOAM4	2.87	3.25	2.71	4.00	6.42
NEW4	3.60	3.25	3.17	4.50	7.26
Mean	**3.23**	**3.25**	**2.94**	**4.25**	**6.84**

The vegetation at site BOAM4 was described as a Camphor Laurel Forest mixed with planted *Eucalypt spp.* and Cocos Palms, and was given a vegetation score of 2.87/5 (Table 3.2.14; 15). The mid-storey was dominated by the natives, *Glochidion ferdinandi* var. *ferdinandi*, *Sambucus gaudichaudiana*, *Endiandra sieberi*, and the exotic species, *Senna pendula* var. *glabrata*. Native species that dominated the understorey included *Jagera pseudorhus*, *Ficus coronata*, *Cordyline stricta*, *Lomandra hystrix*, and the grass, *Ottochloa gracillima*. The exotic species that were also present in the understorey included *Lantana camara*, *Bidens pilosa*, *Ageratum houstonianum*, *Galinsoga parviflora*, and the grass, *Paspalum mandiocanum*.

Site NEW4 scored 3.60/5 for the vegetation index, and was described as having a Brush Box, Flooded Gum and Brush Cherry Forest. Other native species that were present in the mid-storey included *Aphlitonia excelsa*, *Cryptocarya meissneriana*, *Mischocarpus pyriformis*, *Wilkiea huegeliana*, *Schizomeria ovata*, and *Endiandra pubens*. The exotic species *Senna pendula* var. *glabrata*, *Ligustrum sinense*, and *Lantana camara* were also present in the mid-storey of NEW4. There were only a few species present in the understorey of NEW4 and included that natives *Blechnum cartilagineum* and *Oplismenus imbecillis*, as well as the exotic grass, *Paspalum mandiocanum*. In contrast, there were a number native species of vines present in the mid-storey and tree canopy of NEW4 including *Smilax australis*, *Ripogonum discolor*, *Flagellaria indica* and *Morinda jasminoides*. Site BOAM4 had only a single native vine species present (*Cissus antarctica*) present in the tree canopy.

The bank condition scores were similar for both the BOAM4 and NEW4 sites. There was some evidence of increased bank slope and bank undercutting at both sites. However, a positive feature of BOAM4 and NEW4 was the limited number of exposed tree roots and reduced evidence of bank slumping in the riparian zone.

Site NEW4 had a higher riparian habitat score of 3.17/5, compared to site BOAM4, which had a score of 2.71/5. Both sites had a large number of standing dead tree habitats and several fallen log habitats in their riparian zones. The higher score at site NEW4 was attributed to a larger number of standing large tree habitats. The location of both sites in residential and light industrial areas meant that there was limited proximity to patches of remnant native vegetation.

The site-based disturbance scores were recorded as 4.00/5 for site BOAM4 and 4.50/5 for site NEW4. There was limited evidence of tree removal, fences or livestock movement in the riparian zones at both sites, which increased their scores. However, there was reduced connectivity of the vegetation to patches of remnant vegetation at both sites, with BOAM4 scoring 1.00/5 and NEW4 scoring 3.00/5 for this index.

Table 3.2.14 Site level summary of riparian condition scores for each sub-index for BOAM4 and NEW4. Individual scores maximum of 5.

	BOAM4	NEW4
Vegetation		
Large trees	1.00	2.00
Canopy Cover	2.67	3.67
Mid-storey Cover	2.33	3.67
Mid-storey Weeds	5.00	4.33
Grass Cover	2.00	2.00
Grass Weeds	2.67	4.00
Understorey Cover	4.33	3.00
Understorey Weeds	3.00	4.33
Vines	2.33	5.00
Vegetation Layers	3.33	4.00
Total/5	**2.87**	**3.60**
Bank Condition		
Slope score	3.00	3.00
Undercutting	2.00	1.00
Exposed Tree Roots	4.00	4.00
Slumping	4.00	5.00
Total/5	**3.25**	**3.25**
Habitat		
Standing Dead Trees	5.00	5.00
Logs	2.00	3.00
Fallen Trees	0.00	0.00
Reeds	5.00	3.00
Large Trees	1.00	4.00
Organic Litter	4.00	4.33
Weed Litter	3.67	5.00
Proximity to remnant	1.00	1.00
Total/5	**2.71**	**3.17**
Disturbance		
Tree Clearing	5.00	5.00
Fencing	5.00	5.00
Livestock	5.00	5.00
Connectivity to vegetation	1.00	3.00
Total/5	**4.00**	**4.50**

Table 3.2.15 Dominant riparian vegetation for each strata at sites, BOAM4 and NEW4.

Vegetation Description	BOAM4	NEW4
Dominant Large Trees A	*Cinnamomum camphora*	no large trees
Dominant Large Trees B	no large trees	*Lophostemon confertus*
Dominant Large Trees C	eucalypt (planted)	*Eucalyptus grandis*
	Cocos Palms (planted)	*Syzygium australe*
Midstorey Cover (native) dominants	*Glochidion ferdinandi* var. *ferdinandi*	*Aphlitonia excelsa*
	Sambucus gaudichaudiana	*Cryptocarya meissneriana*
	Endiandra sieberi	*Mischocarpus pyriformis*
		Wilkiea huegeliana
		Schizomeria ovata
Midstorey Cover (weeds) dominants	*Senna pendula* var. *glabrata*	*Senna pendula* var. *glabrata*
		Ligustrum sinense
		Lantana camara
Grass Cover (native) dominants	*Ottochloa gracillima*	*Oplismenus imbecillis*
Grass Cover (weeds) dominants	*Paspalum mandiocanum*	*Paspalum mandiocanum*
	Setaria sphacelata	
Understorey Cover (native) dominants	*Jagera pseudorhus*	*Blechnum cartilagineum*
	Ficus coronata	
	Sambucus gaudichaudiana	
	Cordyline stricta	
	Lomandra hystrix	
Understorey Cover (weeds) dominants	*Lantana camara*	
	Bidens pilosa	
	Ageratum houstonianum	
	Galinsoga parviflora	
Organic Litter (natives) dominants	various Rf	*Syzygium australe*
		Eucalyptus grandis
Organic Litter (weeds) dominants	*Cinnamomum camphora*	
Vines dominants	*Cissus antarctica*	*Smilax australis*
		Ripogonum discolor
		Flagellaria indica
		Morinda jasminoides

3.3 COFFS CREEK

3.3.1 Catchment description

Coffs Creek is a relatively small, but highly populated catchment on the mid-north coast extending through the main town of Coffs Harbour. The creek is approximately 12 km long, and has a catchment area (excluding its northern tributaries) of 24 km^2 (Bewsher Consulting 2005). Coffs Creek is located within the Coramba Beds of the Coffs Harbour association consisting of slates, siliceuos mudstone, lamainated greywackes, silstone and mudstone, minor cherts and jasper. Headwater soils are often steep with slopes 33-56% exhibiting strongly acid stony soils with strong acid subsoil acidity. Lower rolling hills are highly fertile with moderately deep well-drained soils that are strongly acid, of high erodibilty with localised mass movement hazard, aluminum toxicity potential and low subsoil fertility (Milford 1999).

The creek was once pivotal in the transport of logged cedar to the Coffs Harbour Jetty for export and is now utilised for recreational pastimes such as fishing and kayaking (Bewsher Consulting 2005). For these reasons and its proximity within urban areas, the condition of the creek ecosystem comes under heavy public scrutiny. The quality of the Coffs Creek water and ecosystem is also of importance due to its location within the Solitary Islands Marine Park.

There is a long history of flooding in Coffs Creek, with recent flooding in 2011 resulting in major damage to infrastructure. Following major flooding in 1996, the CHCC has produced a detailed Floodplain Risk Management Plan including 'flood risk' mapping for Coffs Harbour (Bewsher Consulting 2005). Stormwater from impervious surfaces in urban areas is a major issue in this catchment because of localized flooding, and the pollutant load it can deliver to receiving water bodies. Coffs Creek has 47 storm water catchments draining into it east of the Pacific Highway, comprising four dominant land use types – recreational, residential, commercial and industrial. Nutrients, sediment, petrochemicals, animal waste, and gross pollutants can all be transported into Coffs Creek during high flow events. Of particular concern are remnant pollutants from agricultural and horticultural activities from the upper catchments (Bewsher Consulting 2005).

The Coffs Creek Coastal Zone Management Plan (CHCC 2012) identified a number of major issues in the catchment including:

- Poor water quality resulting from runoff in developed and agricultural areas
- Riverbank erosion and sedimentation and its effects on habitat and water quality
- Management of the estuary entrance and water depth
- Decline in riverbank and aquatic vegetation and habitat
- Climate Change, flooding and sea level rise
- Fishing and the impact on fish stocks
- Increasing demands for improved recreational use and public access, and
- Pressures from urban expansion on natural and cultural values.

3.3.2 Site description

Four sites were selected for Coffs Creek and represent a headwater site (COFFS4, Fig 3.3.2) located in the freshwater zone and considered to be in a River Style defined as Fine-Grained Meandering

(Table 3.3.1). The downstream sites, COFFS3 and COFFS2, are located within the tidal limit and intermediate salinity zones, respectively. Site COFFS1 (Fig 3.3.3) is the most downstream site and is located in the marine zone, which has a salinity range of 30+ ppt. This most downstream site (COFFS1) was the only site on Coffs Creek that was sampled for faecal coliform. All Coffs Creek sites were sampled each month from January to December 2011 for water chemistry.

Figure 3.3.1 Dominant land-use and location of sites in Coffs Creek within the Coffs Harbour catchment (Source CHCC).

Table 3.3.1 Location of sampling sites, River Style and Condition in Coffs Creek. Data collected by CHCC and UNE.

River System – Site Code	Easting	Northing	Zone	Organisation collecting	Samples collected
Coffs Creek 1 (COFFS1)	513085 m E	6648273 m S	Marine (30+ppt)	CHCC	Faecal, Nutrients, TSS & Chl *a*
Coffs Creek 2 (COFFS2)	512046 m E	6649093 m S	Intermediate salinity	CHCC	Nutrients, TSS & Chl *a*, salinity
Coffs Creek 3 (COFFS3)	511238 m E	6648680 m S	Tidal limit	CHCC	Nutrients, TSS & Chl *a*
Coffs Creek 4 (COFFS4)	509966 m E	6648913 m S	Freshwater	CHCC/UNE	Nutrients, TSS Chl *a*, Macroinverts

Figure 3.3.2 Site COFFS4 in Coffs Creek looking upstream from crossing.

Figure 3.3.3 Site COFFS1 in Coffs Creek looking downstream from crossing.

3.3.3 Water Chemistry

Chlorophyll *a*

Mean chlorophyll *a* concentrations in Coffs Creek ranged from 1.64µg/L at site COFFS1 to 6.60µg/L at site COFFS3 (Figure 3.3.4). All four Coffs Creek sites had minimum concentrations of 0.90µg/L on more than one occasion during 2011. The maximum chlorophyll *a* concentrations were 3.00µg/L at COFFS1 during June and October, 26µg/L at COFFS2 during September, 28µg/L at COFFS3 during January, and 2µg/L at COFFS4 during January, February, April and August 2011. All chlorophyll *a* samples collected from sites COFFS1 and COFFS4 during 2011, had concentrations that fell below the prescribed trigger value. At site COFFS2 and COFFS3, 55% and 46% of chlorophyll *a* samples had concentrations that exceeded the trigger value (Table 3.3.2).

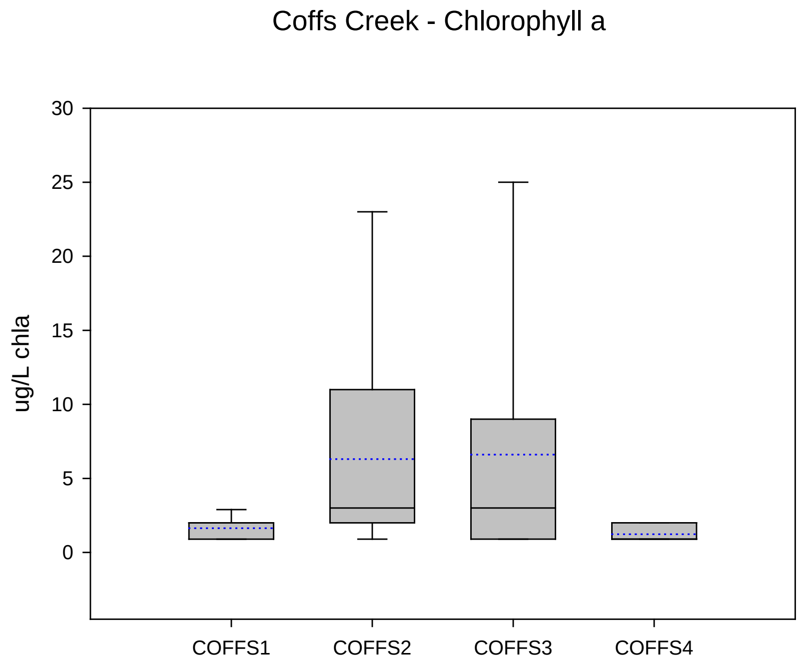

Figure 3.3.4 Mean, median, 25th and 75th percentiles, and range of chlorophyll *a* concentrations from Coffs Creek sites, COFFS1 to COFFS4, from January to December 2011.

Table 3.3.2 Proportion of monthly chlorophyll *a* samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
COFFS1	0.45	0.55	0.00	0.00	11	3.00	
COFFS2	0.18	0.27	0.10	0.45	11	26.00	Sep
COFFS3	0.27	0.27	0.00	0.46	11	28.00	Jan
COFFS4	1.00	0.00	0.00	0.00	10	2.00	

Total Nitrogen (TN)

Mean TN concentrations in Coffs Creek ranged from 418.18µg/L at site COFFS1 to 918µg/L at site COFFS4 (Figure 3.3.5). The minimum concentrations detected ranged from 90µg/L at COFFS1 during April to 330µg/L at COFFS4 during March 2011. The maximum TN concentrations were 860µg/L at COFFS1 during July, and 1200µg/L at COFFS2, 1190µg/L at COFFS3 and 1270µg/L at COFFS4 during December 2011. All TN samples collected from sites COFFS2 and COFFS3 during 2011 had concentrations that exceeded the prescribed trigger value. At site COFFS1 and COFFS4, 72% and 90% of TN samples had concentrations that exceeded the trigger value (Table 3.3.3).

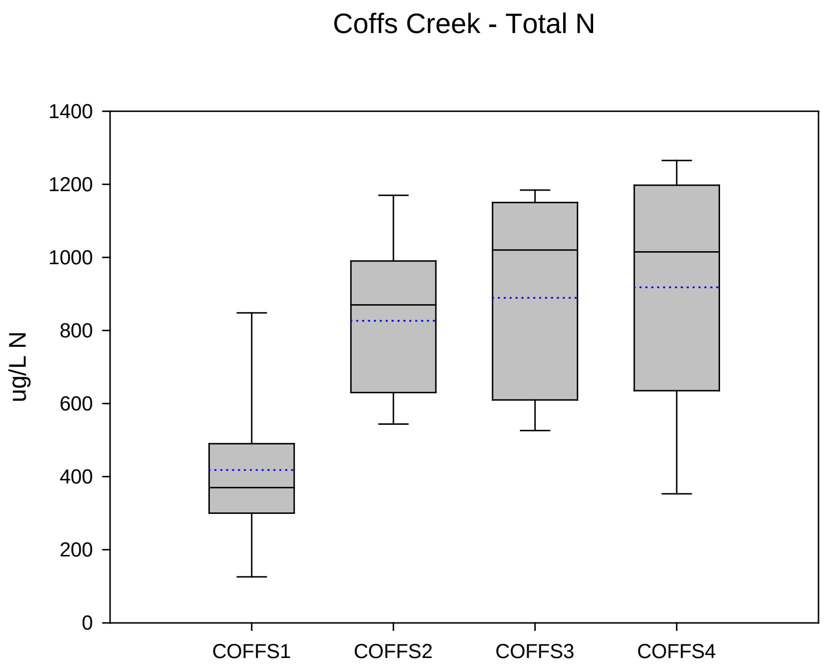

Figure 3.3.5 Mean, median, 25th and 75th percentiles, and range of TN concentrations from Coffs Creek sites, COFFS1 to COFFS4, from January to December 2011.

Table 3.3.3 Proportion of monthly TN samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
COFFS1	0.00	0.27	0.36	0.36	11	860	Jul
COFFS2	0.00	0.00	0.00	1.00	11	1200	Dec
COFFS3	0.00	0.00	0.00	1.00	11	1190	Dec
COFFS4	0.00	0.10	0.20	0.70	10	1270	Dec

Total Phosphorous (TP)

The mean TP concentrations in Coffs Creek ranged from 37.50µg/L at site COFFS4 to 58.64µg/L at site COFFS1 (Figure 3.3.6). The minimum TP concentration across all Coffs Creek sites was 30µg/L, and was recorded at each site on more than one occasion during 2011. The maximum TP concentrations were 330µg/L at COFFS1, 110µg/L at COFFS2 and 120µg/L at COFFS3 all recorded during May, and 55µg/L at COFFS4 during November 2011. At site COFFS3, 64% of TP samples collected during 2011 had concentrations that exceeded the prescribed trigger value. At sites COFFS1, COFFS2 and COFFS4, 18%, 27% and 10% of samples, respectively, had concentrations that exceeded the trigger value (Table 3.3.4).

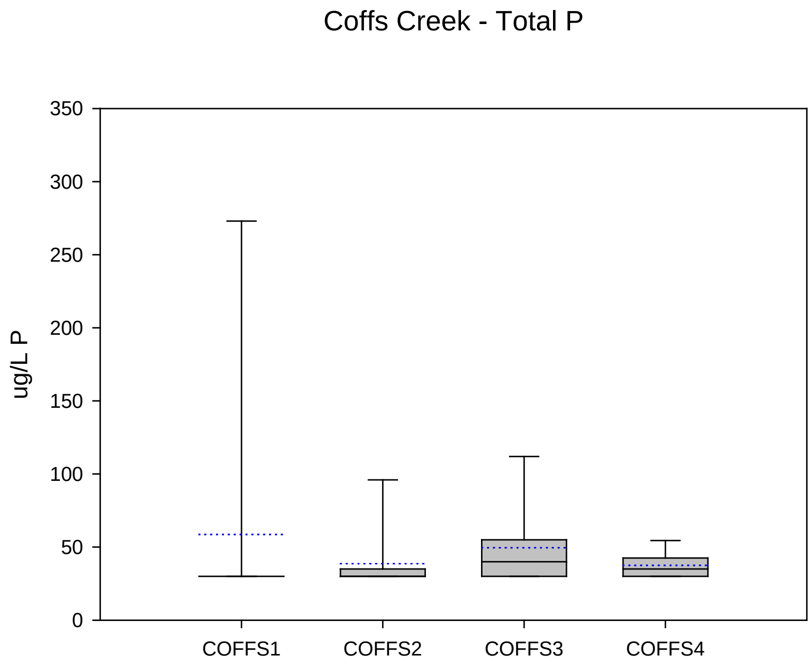

Figure 3.3.6 Mean, median, 25th and 75th percentiles, and range of TP concentrations from Coffs Creek sites, COFFS1 to COFFS4, from January to December 2011.

Table 3.3.4 Proportion of monthly TP samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
COFFS1	0.00	0.82	0.09	0.09	11	330	May
COFFS2	0.00	0.73	0.18	0.09	11	110	May
COFFS3	0.00	0.36	0.28	0.36	11	120	May
COFFS4	0.00	0.90	0.10	0.00	10	55	Nov

Turbidity

The mean turbidity values in Coffs Creek ranged from 6.20NTU at site COFFS1 to 13.04NTU at site COFFS2 (Figure 3.3.7). The minimum values ranged from 2.80NTU at COFFS1 during August to 4.60NTU at COFFS3 during September 2011. The maximum turbidity values were 10.10NTU at COFFS1 during December, 25NTU at COFFS2 during September, 15NTU at COFFS3 during February, and 8.40NTU at COFFS4 during March 2011. All samples collected from COFFS4 during 2011 had values that fell below the prescribed trigger value of 10NTU, whereas 33% of samples from COFFS1 and 25% of samples from COFFS2 and COFFS3 had values that exceeded the trigger value (Table 3.3.5).

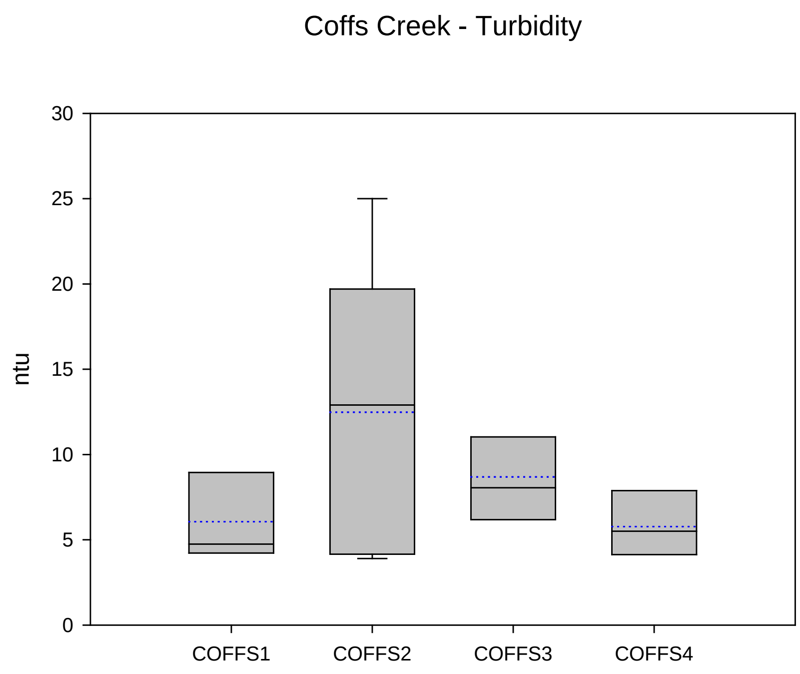

Figure 3.3.7 Mean, median, 25th and 75th percentiles, and range of turbidity values from Coffs Creek sites, COFFS1 to COFFS4, from January to December 2011.

Table 3.3.5 Proportion of monthly turbidity samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
COFFS1	0.50	0.75	0.33	0.00	8	10.1	Dec (0.1m)
COFFS2	0.25	0.50	0.20	0.05	8	25	Sep (0.1m)
COFFS3	0.17	4.00	0.25	0.00	6	15	Feb (0.7m)
COFFS4	1.00	0.00	0.00	0.00	6	8.4	

pH

The mean pH values in Coffs Creek ranged from 6.60 at site COFFS4 to 7.91 at site COFFS1 (Figure 3.3.8). The minimum values ranged from 5.86 at COFFS4 during July to 7.63 at COFFS1 during August 2011. The maximum pH values were 8.17 at COFFS1 during May, 7.88 at COFFS2 during August, 8.07 at COFFS3 during October, and 7.40 at COFFS4 during January 2011. All samples collected from COFFS1 during 2011 had values that fell within the prescribed trigger value range of 7.0 to 8.5, whereas 8% of samples COFFS2 had values that fell below the 7.0 lower limit. At sites COFFS3 and COFFS4, 43% and 33% of pH samples had values that also fell below the 7.0 lower limit (Table 3.3.6).

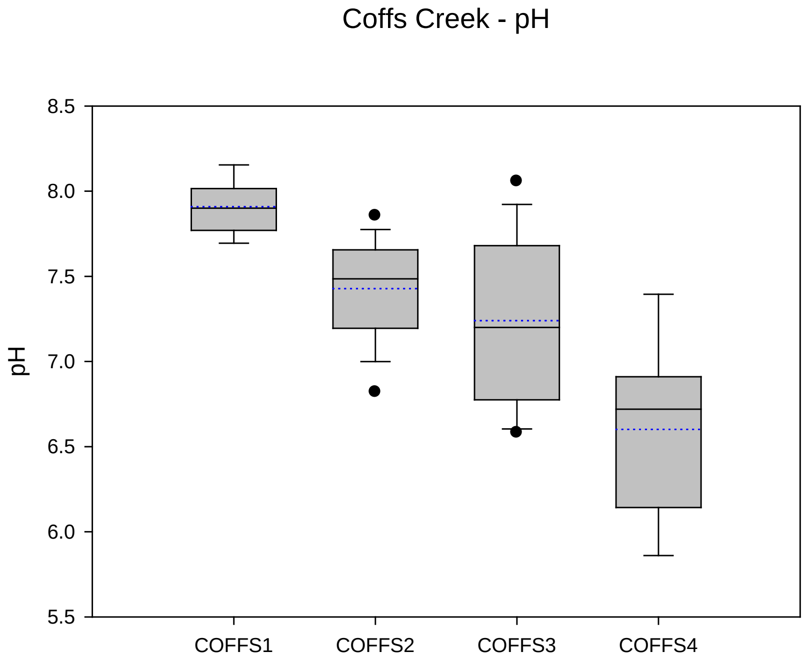

Figure 3.3.8 Mean, median, 25th and 75th percentiles, and range of pH values from Coffs Creek sites, COFFS1 to COFFS4, from January to December 2011.

Table 3.3.6 Proportion of monthly pH values within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0.5-1	1-1.5	>1.5	*n*	Maximum	Minimum
COFFS1	0.00	1.00	0.00	17	7.63	8.17
COFFS2	0.08	0.92	0.00	26	6.75	7.88
COFFS3	0.43	0.62	0.00	21	6.58	8.07
COFFS4	0.33	0.67	0.00	9	5.86	7.40

Faecal coliform

Cell counts of coliforms were below 36cells/100mL primary contact threshold for all but two of the sample periods (Table 3.3.7). Aligning with the 2 months with high rainfall, coliform counts of 560cells/100mL in April and 950cells/100mL in July well exceeded the primary contact trigger value and approached the secondary contact trigger value in July. The maximum value recorded was 110cells/100mL was recorded in May 2011.

Table 3.3.7 Monthly faecal coliform values (fc/mL) from Coffs Creek site, COFFS1. Concentrations more than 1 times the trigger value are highlighted in red.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
COFFS1	15			560	18	22	950	0	8	15	17	36

Water chemistry variables

The range of water temperatures, salinity and measures of Secchi depth from Coffs Creek sites, COFFS1, COFFS2, COFFS3 and COFFS4, are outlined in table 3.3.8. Water temperatures in Coffs Creek reflected seasonal climatic changes with the summer maximum temperatures ranging from 23.35°C to 28.50°C and winter minimum temperatures ranged from 13.67°C to 18.07°C. Conductivity at the most upstream site, COFFS4, had consistently low conductivity with a maximum of 0.17mS/cm recorded throughout the study period. At sites COFFS2 and COFFS3, minimum conductivities were 2.97mS/cm and 0.35mS/cm, respectively, and maximum conductivities were 50.1mS/cm and 46.26mS/cm, respectively. Conductivity ranged from 25.55mS/cm to a maximum of 53.8mS/cm at site COFFS1. Minimum secchi depths across the Coffs Creek sites ranged from 0.2m to 0.4m, while maximum values ranged from 0.3m to 2.0m. Dissolved oxygen concentrations varied substantially over the sampling period, with all sites (except COFFS 1) recorded low concentrations that persisted from COFFS2 to COFFS4. Lower dissolved oxygen values were also generally found at the base of the water column at all sites.

Table 3.3.8 – Summary of range of water chemistry variables including water temperature, conductivity, secchi depth and dissolved oxygen for Coffs Creek sites, COFFS1, COFFS2, COFFS3 and COFFS4.

Site	Water temp (°C)	Conductivity (mS/cm)	Secchi Depth (m)	Dissolved Oxygen %
COFFS1	18.07 - 28.2	25.55 - 53.8	0.4 - 2	76.8 - 104
COFFS2	16.1 - 28.5	2.97 - 50.1	0.35 - 1	41 - 102
COFFS3	15.42 - 27.2	0.35 - 46.26	0.4 - 1.1	34.3 – 103
COFFS4	13.67 - 23.35	0.10 - 0.17	0.2 - 0.3	41.4 – 102.2

3.3.4 Macroinvertebrates

Twelve macroinvertebrate families were recorded from Coffs Creek during the Autumn and Spring sampling in 2011, dominated by Trichoptera (Caddis Flies) and Odonata (Dragon Flies) with 4 families recorded of each (Table 3.3.9; 10). Family level richness was higher in Autumn than Spring, driven by the presence of Odonatans (Table 3.3.9).

Despite family level richness being higher in Autumn than Spring, the abundance of individuals was actually higher in Spring (107) than Autumn (58) responding to increased water temperatures and breeding cues for many aquatic insects. Although there were a number of families represented in each season, abundances in Spring were biased by a few taxa including Chironomidae (45), Hydrophilidae (29) and Leptoceridae (26). Equally, there were a number of taxa that were rare in the catchment, with eight taxa having less than five individuals recorded in both seasons.

Mean SIGNAL2 score for Coffs Creek was 4.5 in Spring with a score range of 2-7, while the mean SIGNAL2 score in Autumn was 5.4, with a score range of 3-8. The two most abundant species were from the Dipteran families, Chironomidae (midge larvae) and Hydrophilidae (scavenger beetles), which have signals scores of 3 and 2. The low mean score and dominance of taxa with low SIGNAL2 scores suggests the water quality and habitat conditions in the freshwater reaches of Newports Creek are in poor condition.

Table 3.3.9 Summary of macroinvertebrate data for Coffs Creek.

	Spring	Autumn
Family Richness	6	9
Total Abundance	107	58
EPT richness	2	3
EPT abundance	27	9
Mean Signal score	4.5	5.4
Signal score range	2-7	3-8

Table 3.3.10 Summary of macroinvertebrate abundance and SIGNAL grade scores for Coffs Creek.

Order	Family	SIGNAL grade	Spring	Autumn
			COFFS4	COFFS4
Trichoptera	IF	8	0	1
Trichoptera	Hydropsychidae	6	1	0
Trichoptera	Ecnomidae	4	0	1
Trichoptera	Leptoceridae	6	26	7
Odonata	IF	3	3	0
Odonata	Corduliidae	5	0	2
Odonata	Protonuridae	4	0	3
Odonata	Diphlebiidae	6	0	1
Coleoptera	Elmidae	7	3	8
Coleoptera	Psephenidae	6	0	2
Coleoptera	Hydrophilidae	2	29	0
Diptera	Chironnomidae	3	45	33

3.3.5 Riparian Condition

The riparian condition score for Coffs Creek COFFS4 was 7.31/10 (Table 3.2.11). Bank Condition recorded the highest score or 4.5/5 with Disturbances also recording a high score with no evidence of clearing. The Vegetation index and Habitat indices had lower individual scores reflecting high weed cover throughout the site.

Table 3.2.11 Site level summary of riparian condition scores for Coffs Creek. Individual scores maximum of 5, total score out of 10.

	VEGETATION	BANK CONDITION	HABITAT	DISTURBANCE	Total/10
COFFS4	3.13	4.5	3.00	4.00	7.31

The vegetation at site COFFS4 was described as a Disturbed Subtropical Rainforest with Camphor Laurel and Brush Box, and was given a vegetation score of 3.13/5 (Table 3.2.11; 13). The mid-storey was dominated by the natives, *Ficus coronate* and *Cordyline stricta*, and the exotic species, *Senna pendula* var. *glabrata, Ligustrum lucidum, and Cinnamomum camphora*. Native species that dominated the understorey included *Lomandra hystrix and Hypolepis glandulifera*, with no native grasses. The were no dominant exotic species in the understorey, with the exotic grass *Paspalum mandiocanum* dominating groundcover.

Site COFFS4 also had a very high bank condition score of 4.50/5, with only bank slopes with a score of 3.00/5, indicating the potential for increased bank erosion at this site (Table 3.2.12). There was no evidence of undercutting, slumping or exposed tree roots all of which indicate current good condition of the banks.

The riparian habitat condition scores were 3.0/5 with no fallen trees and very few remnant logs in the riparian zone. There were many standing dead trees suggesting potential for riparian habitat in the canopy strata. A heavy weed litter layer and poor connectivity and proximity to other vegetation due to the urban setting lowered the Habitat and Disturbance scores.

Table 3.2.12 Site level summary of riparian condition scores for each sub-index for COFFS4. Individual scores maximum of 5.

	BOAM4
Vegetation	
Large trees	2.00
Canopy Cover	4.00
Mid-storey Cover	2.33
Mid-storey Weeds	4.67
Grass Cover	1.00
Grass Weeds	1.00
Understorey Cover	3.00
Understorey Weeds	4.33
Vines	5.00
Vegetation Layers	4.00
Total/5	**3.13**
Bank Condition	
Slope score	3.00
Undercutting	5.00
Exposed Tree Roots	5.00
Slumping	5.00
Total/5	**4.50**
Habitat	
Standing Dead Trees	5.00
Logs	2.00
Fallen Trees	0
Reeds	5.00
Large Trees	4.00
Organic Litter	2.33
Weed Litter	4.67
Proximity to remnant	1.00
Total/5	**3.00**
Disturbance	
Tree Clearing	5.00
Fencing	5.00
Livestock	5.00
Connectivity to vegetation	1.00
Total/5	**4.00**

Table 3.2.13 Dominant riparian vegetation for each strata at sites, COFFS4.

Vegetation Description	COFFS4
Left/Right bank (facing downstream)	
Dominant Large Trees A	Disturbed Subtropical Rainforest with Camphor Laurel, Brush Box
	Cinnamomum camphora
Dominant Large Trees B	*Lophostemon confertus*
Dominant Large Trees C	*Cinnamomum camphora*
Midstorey Cover (native) dominants	*Ficus coronata*
	Cordyline stricta
	Glochidion ferdinandi var. ferdinandi
	Lophostemon confertus
	Sloanea australis
Midstorey Cover (weeds) dominants	*Ligustrum lucidum*
	Senna pendula var. glabrata
	Cinnamomum camphora
Grass Cover (native) dominants	no native grass
Grass Cover (weeds) dominants	*Paspalum mandiocanum*
Understorey Cover (native) dominants	*Blechnum cartilagineum*
	Lomandra hystrix
	Hypolepis glandulifera
	Arachnoides aristata
Understorey Cover (weeds) dominants	
Organic Litter (natives) dominants	*Lophostemon confertus*
Organic Litter (weeds) dominants	*Cinnamomum camphora*
Vines dominants	*Cissus antarctica*
	Morinda jasminoides

3.4 MOONEE CREEK

3.4.1 Catchment description

The Moonee Creek has a catchment area of approximately 42 km^2 with the estuary located approximately 8 km north of Coffs Harbour, entering the ocean immediately north of Green Bluff and adjacent to the village of Moonee Beach. The underlying geology is the Coramba Beds of the Coffs Harbour association metasediments, consisting of siliceous mudstones, siltstones and greywacke. Headwaters are typically steep hills of Suicide soil landscape group with slopes 33-56% grading to low rolling hills of Ulong and Megan soil landscapes with slopes 5-20%. The coastal plain is characterised by the Newports Creek swamp soil landscape. All these soil landscapes have strongly acid soils <5.5pH, low subsoil fertility and commonly exhibit subsoil aluminium toxicity (Milford 1999).

Moonee Creek and its catchment contain a diverse suite of habitat types, including mangroves, seagrasses, saltmarshes, freshwater wetlands and in-tact riparian vegetation (BMT WBM 2008). The Moonee Beach Nature Reserve is located along the coastal sand barrier dunes between the estuary and the ocean. There are extensive wetlands to the south of Green Bluff that are listed at a state level and protected by SEPP-14 legislation (BMT WBM 2008) The relative low levels of development and clearing (particularly in the north and east areas of the catchment) around the foreshores indicates that Moonee Creek should be in a relatively healthy condition compared to many of the more developed catchments. As such it may provide an example of one of the least degraded estuaries in the Coffs Harbour LGA (Fig. 3.4.1).

The permanent ocean entrance and good tidal range within Moonee Creek enables effective flushing of pollutants from the estuary. Tidal motion within Moonee Creek is regulated by the condition of the entrance, which is influenced by heavy scouring following significant floods. Similar to many coastal catchments, water quality is also likely to be impacted by flood events with reduced dissolved oxygen and pH levels recorded, possibly resulting from runoff from well-vegetated protected areas high in organic matter in the Moonee catchment (BMT WBM 2008).

3.4.2 Site descriptions

Four sites were selected for Moonee Creek including a freshwater site (MOON4) located on a major eastern flowing tributary (Tiki Rd), and a site (MOON3) located on a southern flowing tributary and located within the tidal limit zone (Table 3.4.1). The downstream sites, MOON2 and MOON1, are within intermediate salinity and marine salinity zones respectively. Site MOON1, is closest to the mouth of the estuary and has a salinity range of 30+ ppt. This site (MOON1) was the only site on the Creek systems to be sampled for faecal coliforms. All sites were sampled each month from January to December 2011 for water chemistry.

Figure 3.4.1 Dominant land-use and location of sites in Moonee Creek in the Coffs Harbour catchment Source (CHCC).

Table 3.4.1 Location of sampling sites, River Style and Condition in Moonee Creek.

River System – Site Code	Easting	Northing	Zone	Organisation collecting	Samples collected
Moonee Creek 1 (MOON1)	515103 m E	6658283 m S	Marine (30+ppt)	MPA/CHCC	Faecal, Nutrients, TSS & Chl *a*
Moonee Creek 2 (MOON2)	515299 m E	6659441 m S	Intermediate salinity	MPA/CHCC	Nutrients, TSS & Chl *a*
Moonee Creek 3 (MOON3)	515747 m E	6660553 m S	Tidal limit	MPA/CHCC	Nutrients, TSS & Chl *a*
Moonee Creek 4 (MOON4)	517470 m E	6662155 m S	Freshwater	CHCC/UNE	Nutrients, TSS Chl *a*, Macroinverts

Figure 3.4.2 Site MOON4 in Moonee Creek looking downstream from crossing.

Figure 3.4.3 Site 1 in Moonee Creek looking downstream.

3.4.3 Water Chemistry

Chlorophyll *a*

The mean chlorophyll *a* concentrations in Moonee Creek ranged from 1.17µg/L at site MOON1 to 3.05µg/L at site MOON3 (Figure 3.4.4). The minimum concentration at Moonee Creek was 0.90µg/L, and recorded on more than one occasion at each site during 2011. The maximum chlorophyll *a* concentrations were 2µg/L at MOON1 and 6.00 µg/L at MOON2 during Feburary, 8µg/L at MOON3 during July, and 3 µg/L at MOON4 during February and July 2011. All chlorophyll *a* samples collected from sites MOON1 and MOON4 during 2011, had concentrations that fell below the prescribed trigger value, while 28% and 37% of samples from MOON2 and MOON3, respectively, exceeded the trigger value (Table 3.4.2).

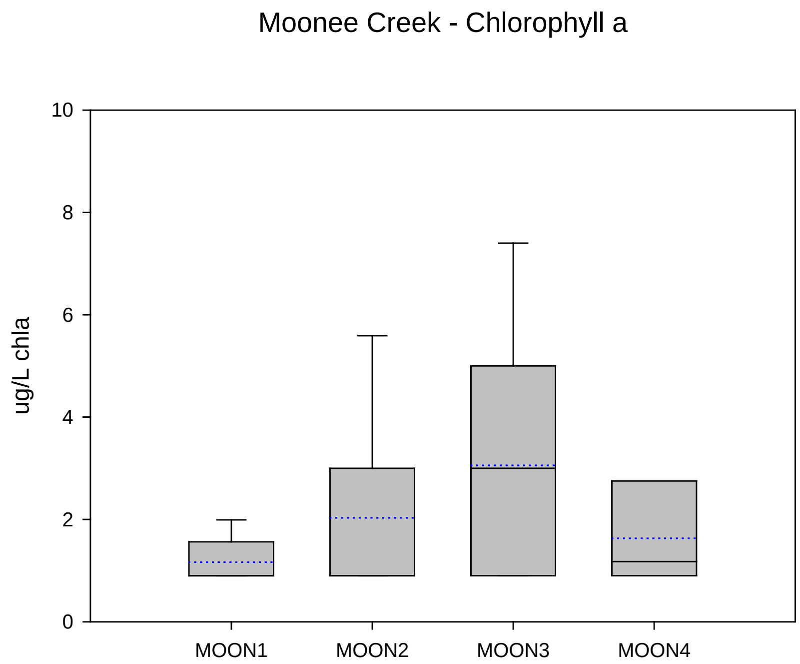

Figure 3.4.4 Mean, median, 25[th] and 75[th] percentiles, and range of chlorophyll *a* concentrations from Moonee Creek sites, MOON1 to MOON4, from January to December 2011.

Table 3.4.2 Proportion of monthly chlorophyll *a* samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
MOON1	0.80	0.20	0.00	0.00	10	2.00	
MOON2	0.45	0.27	0.14	0.14	11	6.00	Feb
MOON3	0.36	0.27	0.10	0.27	11	8.00	Jul
MOON4	0.63	0.37	0.00	0.00	8	3.00	

Total Nitrogen (TN)

The mean TN concentrations in Moonee Creek ranged from 373µg/L at site MOON1 to 513.18µg/L at site MOON3 (Figure 3.4.5). The minimum concentrations ranged from 210µg/L at MOON1 during September to 300µg/L at MOON4 during January 2011. The maximum TN concentrations were 470µg/L at MOON1 during November, 820µg/L at MOON2 and 780µg/L at MOON3 during April, and 920µg/L at MOON4 during December 2011. At sites MOON2 and MOON3, 91% of TN samples collected during 2011 had concentrations that exceeded the prescribed trigger value, whereas at sites MOON1 and MOON4, 80% and 26% of samples, respectively, also exceeded the trigger value (Table 3.4.3).

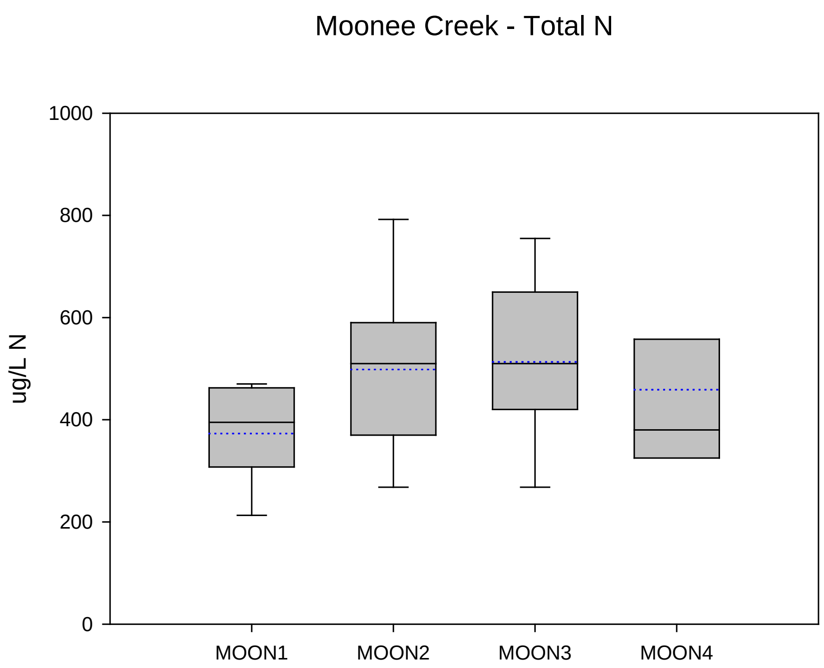

Figure 3.4.5 Mean, median, 25th and 75th percentiles, and range of TN concentrations from Moonee Creek sites, MOON1 to MOON4, from January to December 2011.

Table 3.4.3 Proportion of monthly TN samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
MOON1	0.00	0.20	0.40	0.40	10	470	Nov
MOON2	0.00	0.09	0.36	0.55	11	820	Apr
MOON3	0.00	0.09	0.18	0.73	11	780	Apr
MOON4	0.00	0.74	0.13	0.13	8	920	Dec

Total Phosphorous (TP)

The mean TP concentrations in Moonee Creek ranged from 38.00µg/L at site MOON1 to 49.55µg/L at site MOON3 (Figure 3.4.6). The minimum concentration in Moonee Creek was 30µg/L, and detected on more than one occasion at each site during 2011. The maximum TP concentrations were 110µg/L at MOON1, 100µg/L at MOON2 and 150µg/L at MOON3 all recorded during May, and 80µg/L at MOON4 during December 2011. At sites MOON2 and MOON3, 27% and 36% of TN samples collected during 2011, respectively, had concentrations that exceeded the prescribed trigger value. At sites MOON1 and MOON4, 10% and 13% of samples, respectively, also exceeded the trigger value (Table 3.4.4).

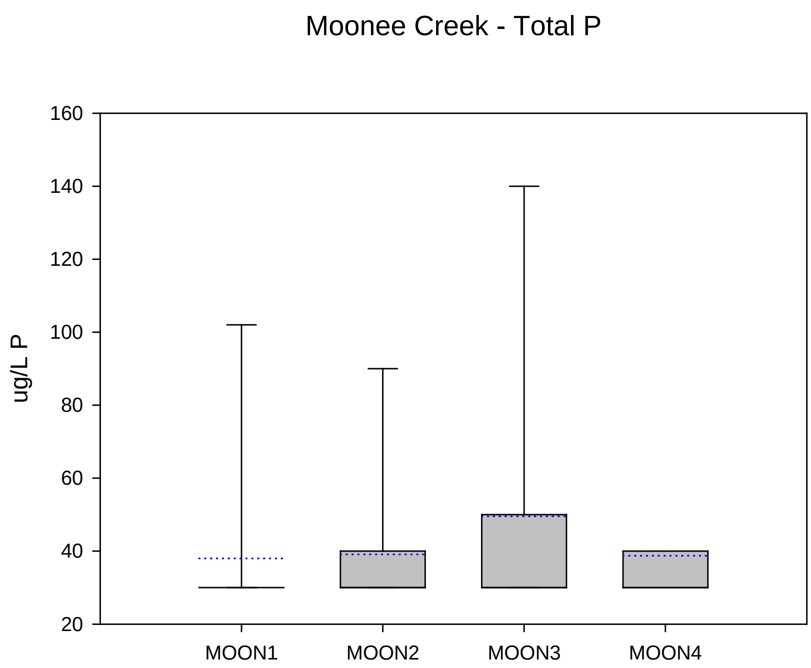

Figure 3.4.6 Mean, median, 25th and 75th percentiles, and range of TP concentrations from Moonee Creek sites, MOON1 to MOON4, from January to December 2011.

Table 3.4.4 Proportion of monthly TN samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
MOON1	0.00	0.90	0.00	0.10	10	110	May
MOON2	0.00	0.73	0.09	0.18	11	100	May
MOON3	0.00	0.64	0.09	0.27	11	150	May
MOON4	0.00	0.88	0.00	0.13	8	80	Dec

Turbidity

The mean turbidity values in Moonee Creek ranged from 5.39NTU at site MOON1 to 12.47NTU at site MOON4 (Figure 3.4.7). The minimum values in Moonee Creek ranged from 0.60NTU at MOON1 during December to 6.30NTU at MOON4 during March 2011. The maximum turbidity values were 15NTU at MOON1 during September, 10.20NTU at MOON2 during December, 15.6NTU at MOON3 during November, and 22NTU at MOON4 during November 2011. All samples collected from MOON4 during 2011 were below the prescribed trigger value for lowland creeks. At sites MOON1, MOON2 and MOON3, 17%, 7% and 28% of samples, respectively, exceeded the prescribed trigger value for estuaries (Table 3.4.5).

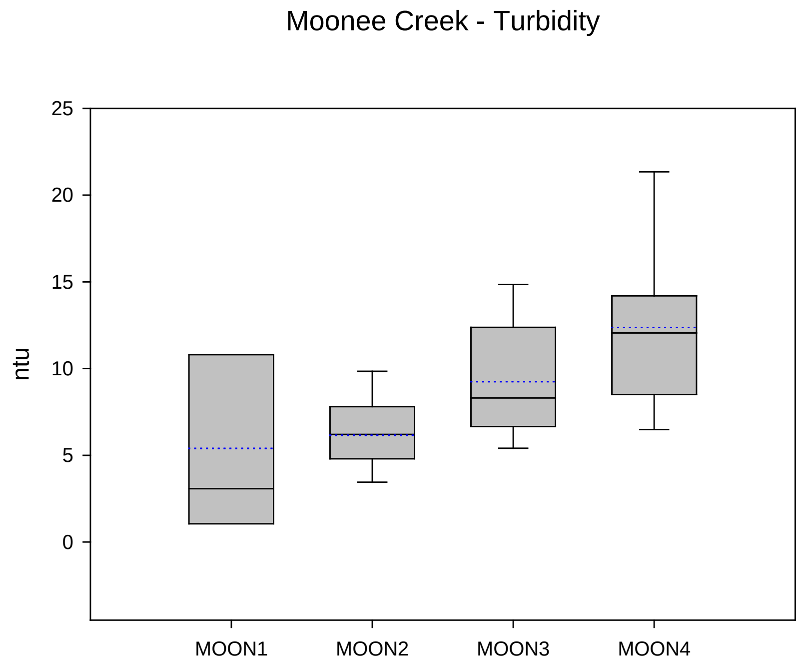

Figure 3.4.7 Mean, median, 25th and 75th percentiles, and range of turbidity values from Moonee Creek sites, MOON1 to MOON4, from January to December 2011.

Table 3.4.5 Proportion of monthly turbidity samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
MOON1	0.67	0.17	0.17	0.00	6	15	Sep (0.1m)
MOON2	0.27	0.67	0.07	0.00	15	10.2	Dec (2m)
MOON3	0.07	0.64	0.21	0.07	14	15.6	Nov (2m)
MOON4	1.00	0.00	0.00	0.00	12	22	

pH

Mean pH values in Moonee Creek ranged from 6.53 at site MOON4 to 8.07 at site MOON1 (Figure 3.4.8). The minimum values in Moonee Creek ranged from 5.76 at MOON4 during July to 7.60 at MOON1 during September 2011. The maximum pH values were 8.25 at MOON1 during August, 8.20 at MOON2 during October, 7.88 at MOON3 during June, and 7.66 at MOON4 during November 2011. All pH samples collected from sites MOON1, MOON2 and MOON3 during 2011 had values within the prescribed trigger value range of 7.0 to 8.5, while 45% of the samples from MOON4 had values that fell below the 6.5 lower limit (Table 3.4.6).

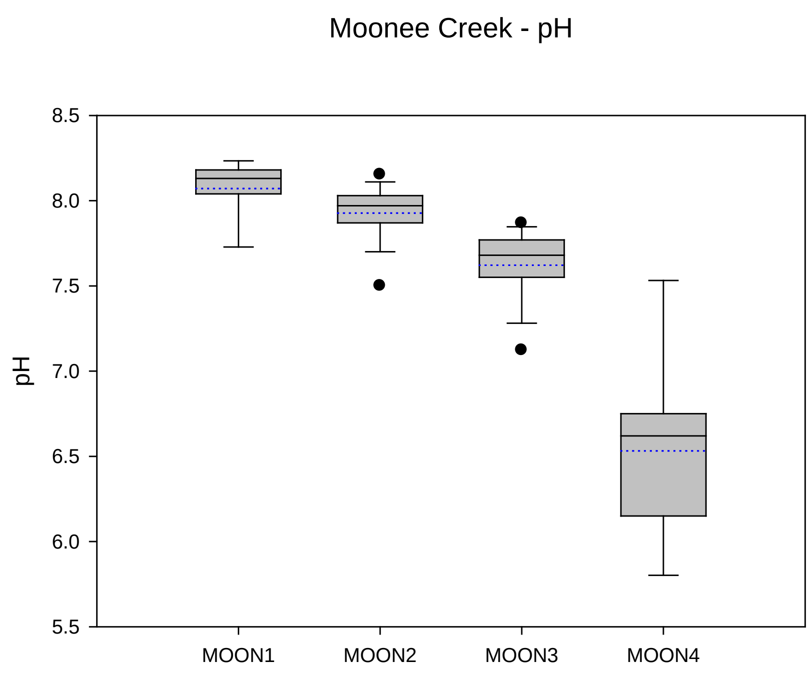

Figure 3.4.8 Mean, median, 25th and 75th percentiles, and range of pH values from Moonee Creek sites, MOON1 to MOON4, from January to December 2011.

Table 3.4.6 Proportion of monthly turbidity samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0.5-1	1-1.5	>1.5	*n*	Minimum	Maximum
MOON1	0.00	1.00	0.00	17	7.6	8.25
MOON2	0.00	1.00	0.00	31	7.32	8.2
MOON3	0.00	1.00	0.00	32	7.07	7.88
MOON4	0.45	0.64	0.00	11	5.76	7.66

Faecal coliform

Feacal coliforms were collected on 8 occasions throughout the year, with only one sampling time (July) exceeding the primary contact trigger value (Table 3.4.7).

Table 3.4.7 Monthly faecal coliform values (fc/mL) from Moonee Creek site, MOON1. Concentrations more than 1 times the trigger value are highlighted in red.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MOON1	0			3	0	33	415	1	0		0	

Water chemistry variables

The range of water temperatures, salinity and measures of Secchi depth from Moonee Creek sites, MOON1 to MOON4, are outlined in table 3.4.8. Water temperatures in Moonee Creek reflected seasonal climatic changes with the summer maximum temperatures ranging from 25.4°C to 29.6°C and winter minimum temperatures ranged from 13.9°C to 17.7°C. Minimum conductivities in Moonee Creek ranged from 0.16mS/cm to 38mS/cm, while maximum conductivities ranged from 0.31mS/cm to 63.2mS/cm. Minimum secchi depths across the sites ranged from 0.2 m to 0.5 m, while maximum values ranged from 1.0 m to more than 1.2 m. Dissolved oxygen concentrations varied substantially over the sampling period, with all sites recorded very low concentrations that generally decreased with distance and lowest concentrations at the tidal limit (MOON3). Lower dissolved oxygen values were also generally found at the base of the water column at all sites.

Table 3.4.8 Summary of range of water chemistry variables including water temperature, conductivity, secchi depth and dissolved oxygen for Moonee Creek sites, MOON1 to MOON4.

Site	Water temp (°C)	Conductivity (mS/cm)	Secchi Depth (m)	Dissolved Oxygen %
MOON1	17.70 - 27.10	38.11 - 60.40	0.5 - >1.2	88 – 107.9
MOON2	16.40 – 29.00	2.54 - 63.20	0.3 - 1.8	58.4 – 105.1
MOON3	16.20 - 29.60	0.38 – 52.00	0.2 - 1.6	25.8 – 80.7
MOON4	13.89 - 25.40	0.16 - 0.31	0.3 – 1.0	46.7 - 104

3.4.4 Macroinvertebrates

Thirteen macroinvertebrate families were recorded from Moonee Creek during the Autumn and Spring sampling in 2011, and consisted of a range of orders including Hemiptera (Water Boatmen), Odonata (Dragon Flies) and Diptera (Flies), which had two families present each (Table 3.4.9; 10). Family level richness was higher in Autumn than Spring, driven by the presence of Trichopterans (Caddis Flies) and Odonatans in Autumn (Table 3.4.9).

The abundance of individuals was also higher in Autumn (73) compared to Spring (17), although these numbers are exceptionally low. Although there were a number of families represented in Autumn, these abundances were biased by the taxa Atyidae (28) and Chrinomidae (45). There were a number of taxa that were rare in the catchment, with nine of the thirteen taxa having less than five individuals recorded in both seasons.

Mean SIGNAL2 score for Moonee Creek was 4.8 in Autumn with a score range of 2-8, while the mean SIGNAL2 score in Spring was 3.9, with a score range of 3-7. The two most abundant species were from the Dipteran families, Chrinomidae (midge larvae) and Atyidae (Freshwater Shrimps), which both have signal scores of 3. The low mean score and dominance of taxa with low SIGNAL2 scores suggests the water quality and habitat conditions in the freshwater reaches of Newports Creek are in poor condition.

Table 3.4.9 Summary of macroinvertebrate data for Moonee Creek.

	Spring	Autumn
Family Richness	7	13
Total Abundance	17	73
EPT richness	0	3
EPT abundance	0	10
Mean Signal score	3.9	4.8
Signal score range	2-7	2-8

Table 3.4.10 Summary of macroinvertebrate abundance and SIGNAL grade scores for Moonee Creek.

Order	Family	SIGNAL grade	Spring	Autumn
			MOON	MOON
Ephemeroptera	Leptophlebiidae	8	0	4
Trichoptera	Calamoceratidae	7	0	1
Trichoptera	Leptoceridae	6	0	5
Odonata	Corduliidae	5	2	2
Odonata	Protonuridae	4	0	3
Coleoptera	Elmidae	7	1	6
Lepidoptera	Pyralidae	3	0	1
Megaloptera	Corydalidae	7	0	1
Hemiptera	Corixidae	2	3	4
Hemiptera	Gerridae	4	1	6
Decapoda	Atyidae	3	8	28
Diptera	IF	3	1	1
Diptera	Chironnomidae	3	1	11

3.5 HEARNES LAKE & CREEK

3.5.1 Catchment description

Hearnes Lake is located approximately 25 km north of Coffs Harbour, and 4 km south of the township of Woolgoolga. Hearnes Creek drains to Hearnes Lake. Hearnes Lake and Double Crossing Creek are underlain by Coramba Beds of the Coffs Harbour association metasediments consisting of siliceous mudstones, siltstones and greywacke. Headwaters are typically steep hills of Suicide soil landscape group with slopes 33-56% grading to low rolling hills of Ulong and Megan soil landscapes with slopes 5-20%. The coastal plain is largely characterised by the Newports Creek swamp soil landscape. The hilly soil landscapes have strongly acid soils <5.5pH, low subsoil fertility and commonly exhibit subsoil aluminium toxicity (Milford 1999).

Hearnes Lake has a typical water surface area of 10 ha, and drains a catchment area of 6.8km^2, primarily through its main tributary, Double Crossing Creek that enters from the north (BMT WBM 2009). The majority of the Hearnes Lake catchment is under private freehold ownership, with an active intensive horticulture industry, limited forestry activity in the very upper catchment and Crown land adjacent to the coastline (Fig. 3.5.1).

Hearnes Lake is a classified as an ICOLL (Intermittently Closed and Open Lake or Lagoon), the result of a large sand bar blocking Double Crossing Creek from the ocean (WBM Oceanics Australia 2006). When the entrance is open, the estuary experiences regular tidal movements. When water levels are sufficiently high in the lake and the estuary opening is closed, localized rainfall may result in the entrance barrier being breached. As Hearnes Lake is frequently blocked from tidal exchange with the ocean it is particularly vulnerable to nutrient and pollutant accumulation. As a result various restrictions have been incorporated in land use zonings in the catchment. When the entrance is closed, catchment runoff dominates that typically has lower pH, lower salinity and higher turbidity (WBM Oceanics Australia 2006). Catchment runoff is also likely to contain higher concentrations of nutrients, making the lake more susceptible to eutrophication and associated algal blooms following rainfall and when the entrance is closed.

Hearnes Lake is known to contain a rich diversity of estuarine habitats, including mangroves, saltmarsh and fringing sedgelands and saltmarsh, and forming part of the Solitary Islands Marine Park (SIMP) (BMT WBM 2009).Considerable areas of natural vegetation have been lost from throughout the catchment, although areas immediately fringing the lake mostly contain native vegetation. Some areas of littoral rainforest can be found around the shoreline, as well as behind the coastal dunes to the immediate north of the lake entrance (BMT WBM 2009).

3.5.2 Site descriptions

Three sites were selected for Hearnes Lake and were in zones considered to be part of the estuarine lagoon (Table 3.5.1; Figures 3.5.2, 3, 4). Site HEAR3 was located in the south of the Lake and HEAR2 was located at the confluence of Hearnes Creek with the Lake. Site HEAR1 was located closest to the mouth of the Lake with Double Crossing Creek. This most downstream site (HEAR1) was the only site in Hearnes Lake that was sampled for faecal coliform. All sites were sampled each month from January to December 2011 for water chemistry.

Figure 3.5.1 Dominant land-use and location of sites in Hearnes Lake and Creek in the Coffs Harbour catchment (Source CHCC).

Table 3.5.1 Location of sampling sites, River Style and Condition in Hearnes Lake and Creek.

River System – Site Code	Easting	Northing	Zone	Organisation collecting	Samples collected
Hearnes Lake 1 (HEAR1)	519304 m E	6666448 m S	Lagoon	OEH	Faecal, Nutrients, TSS & Chl *a*
Hearnes Lake 2 (HEAR2)	518952 m E	6665629 m S	Lagoon	OEH	Nutrients, TSS & Chl *a*
Hearnes Lake 3 (HEAR3)	518719 m E	6666120 m S	Lagoon	OEH	Nutrients, TSS & Chl *a*

Figure 3.5.2 Site HEAR1 in Hearnes Lake/Creek looking downstream.

Figure 3.5.3 Site HEAR2 in Hearnes Lake/Creek near the Pacific Highway overpass.

Figure 3.5.4 Site HEAR3 in Hearnes Lake/Creek.

3.5.3 Water Chemistry

Chlorophyll a

The mean chlorophyll *a* concentrations from Hearnes Lake sites were 4.98µg/L at HEAR1, 6.85µg/L at HEAR2 and 9.28µg/L at HEAR3 (Figure 3.5.5). The minimum concentration across all Hearnes Lake sites was 0.90µg/L, and was detected on more than one occasion at each site. The maximum chlorophyll *a* concentrations were 11µg/L at HEAR1 during January, and 27µg/L HEAR2 and 54µg/L at HEAR3 during September 2011. At sites HEAR1 and HEAR2, 45% and 54% of the samples collected in 2011, respectively, had concentrations that exceeded the prescribed trigger value, while 64% of the samples from HEAR3 also exceeded the trigger value (Table 3.5.2).

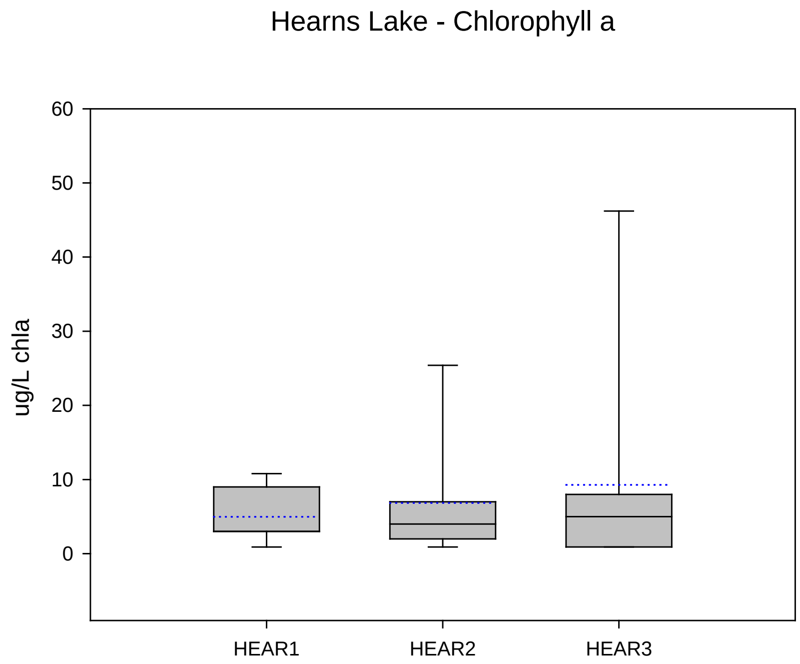

Figure 3.5.5 Mean, median, 25th and 75th percentiles, and range of chlorophyll *a* concentrations from Hearnes Lake sites, HEAR1, HEAR2 and HEAR3, from January to December 2011.

Table 3.5.2 Proportion of monthly chlorophyll *a* samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
HEAR1	0.18	0.37	0.00	0.45	11	11	Jan
HEAR2	0.18	0.28	0.18	0.36	11	27	Sep
HEAR3	0.36	0.00	0.00	0.64	11	54	Sep

Total Nitrogen (TN)

The mean TN concentrations from Hearnes Lake sites were 787.50µg/L at HEAR1, 939.50µg/L at HEAR2 and 638.35µg/L at HEAR3 (Figure 3.5.6). The minimum concentrations across all Hearnes Lake sites were 580µg/L at HEAR1 during December 211, 600µg/L at HEAR2 during November, and 368.5 at HEAR3 during May 2011. The maximum TN concentrations were 1300µg/L at HEAR1 and 1785µg/L HEAR2 during May, and 840µg/L at HEAR3 during February 2011. All TN samples from the three Hearnes Lake sites collected in 2011 had concentrations that exceeded the prescribed trigger (Table 3.5.3).

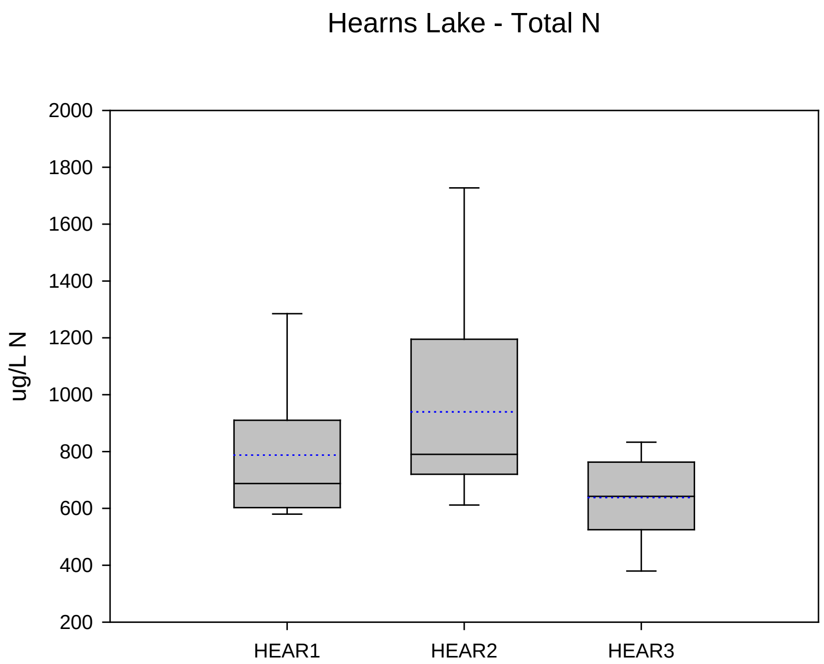

Figure 3.5.6 Mean, median, 25th and 75th percentiles, and range of TN concentrations from Hearnes Lake sites, HEAR1, HEAR2 and HEAR3, from January to December 2011.

Table 3.5.3 Proportion of monthly TN samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
HEAR1	0.00	0.00	0.00	1.00	10	1300	May
HEAR2	0.00	0.00	0.00	1.00	10	1785	May
HEAR3	0.00	0.00	0.00	1.00	10	840	Feb

Total Phosphorous (TP)

The mean TP concentrations from Hearnes Lake sites were 35.0µg/L at HEAR1, 36.5µg/L at HEAR2 and 30.5µg/L at HEAR3 (Figure 3.5.7). The minimum concentration across all Hearnes Lake sites was 30µg/L , and recorded on more than one occasion at each site. The maximum TN concentrations were 70µg/L at HEAR1 and HEAR2, and 35µg/L at HESR3, all recorded during May 2011. At sites HEAR1 and HEAR2, 20% and 30% of the TP samples collected during 2011, respectively, had concentrations that exceeded the prescribed trigger value of 30µg/L, while 10% of the samples from HEAR3 had concentrations that also exceeded this trigger value (Table 3.5.4).

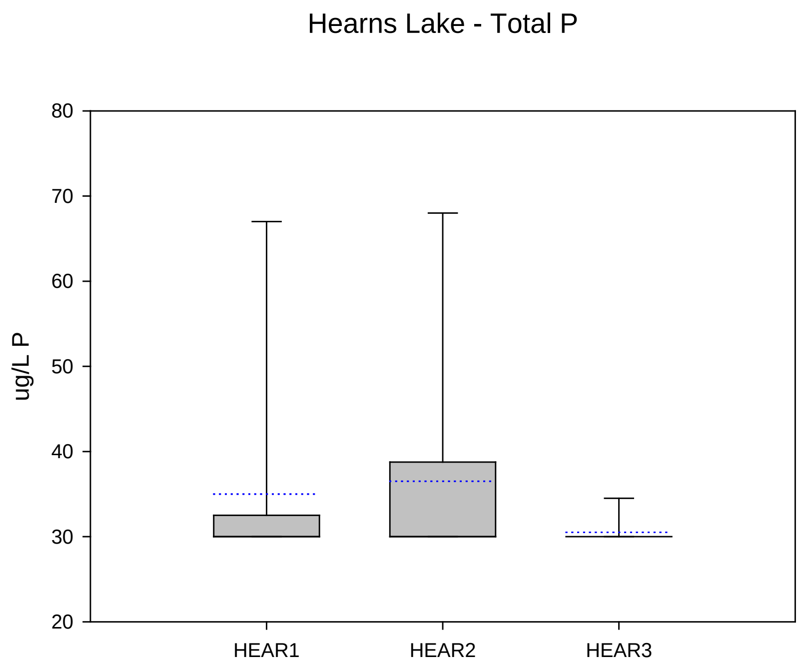

Figure 3.5.7 Mean, median, 25th and 75th percentiles, and range of TP concentrations from Hearnes Lake sites, HEAR1, HEAR2 and HEAR3, from January to December 2011.

Table 3.5.4 Proportion of monthly TP samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
HEAR1	0.00	0.80	0.10	0.10	10	70	May
HEAR2	0.00	0.70	0.10	0.20	10	70	May
HEAR3	0.00	0.90	0.10	0.00	10	35	May

Turbidity

Mean turbidity values from Hearnes Lake sites were 14.04NTU at HEAR1, 27.27NTU at HEAR2 and 17.50NTU at HEAR3 (Figure 3.5.8). The minimum values across all Hearnes Lake sites were 1NTU at HEAR1, 2NTU at HEAR2 and 0NTU at HEAR3, all recorded during August 2011. The maximum turbidity values were 71.5NTU at HEAR1, 100NTU at HEAR2 and 64NTU at HEAR3, all recorded during May 2011. At sites HEAR1 and HEAR3, 32% and 40% of the turbidity samples collected during 2011, respectively, had values that exceeded the prescribed trigger value of 10NTU, while 73% of the samples from HEAR2 had values that also exceeded this trigger value (Table 3.5.5).

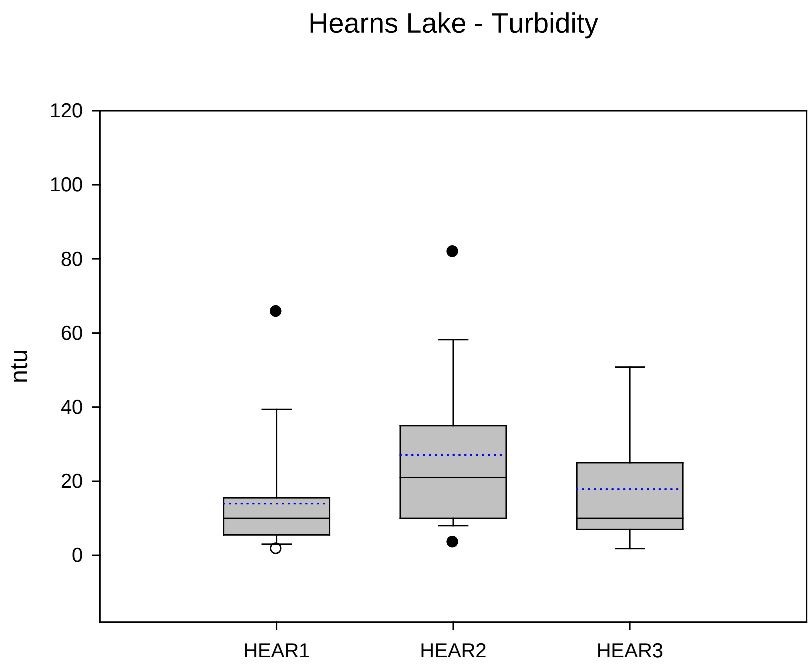

Figure 3.5.8 Mean, median, 25th and 75th percentiles, and range of turbidity values from Hearnes Creek sites, HEAR1, HEAR2 and HEAR3, from January to December 2011.

Table 3.5.5 Proportion of monthly turbidity samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
HEAR1	0.24	0.44	0.08	0.24	25	71.5	May (1m)
HEAR2	0.06	0.21	0.03	0.70	33	100.0	May (1m)
HEAR3	0.30	0.30	0.10	0.30	15	64.0	May (1m)

pH

Mean pH values from Hearnes Lake sites were 8.03 at HEAR1, and 7.71 at HEAR2 and HEAR3 (Figure 3.5.9). The minimum values across all Hearnes Lake sites were 6.94 at HEAR1 in October 2011, 6.80 at HEAR2 in December 2011, and 6.75 at HEAR3 during May 2011. The maximum pH values were 8.92 at HEAR1 and 8.98 at HEAR2 during September 2011, and 8.42 at HESR3 during March 2011. At sites HEAR1 and HEAR3, 15% of the pH samples collected during 2011 had values that exceeded the prescribed trigger value range, while less than 5% of the samples from all Hearnes Lake sites had values that fell below the 6.5 lower limit (Table 3.5.6).

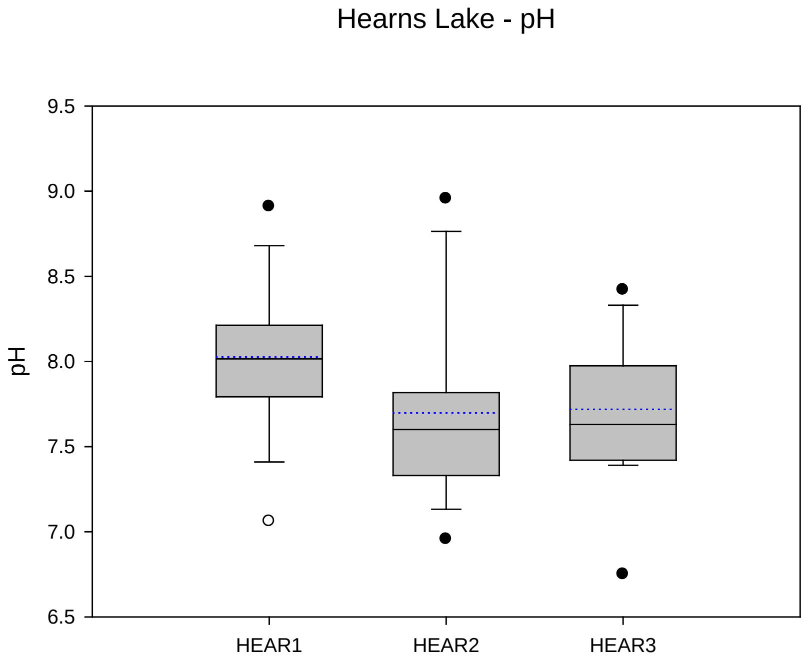

Figure 3.5.9 Mean, median, 25th and 75th percentiles, and range of pH values from Hearnes Creek sites, HEAR1, HEAR2 and HEAR3, from January to December 2011.

Table 3.5.6 Proportion of monthly turbidity samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0.5-1	1-1.5	>1.5	*n*	Minimum	Maximum
HEAR1	0.03	0.81	0.15	30	6.94	8.92
HEAR2	0.05	0.80	0.15	41	6.8	8.98
HEAR3	0.05	0.95	0.00	19	6.75	8.42

Faecal coliform

Feacal coliforms were collected on 7 occasions throughout the year, with none of the sampling periods recording values above the primary contact trigger value (Table 3.5.7).

Table 3.5.7 Monthly faecal coliform values (fc/mL) from Hearnes Creek. Concentrations more than 1 times the trigger value are highlighted in red.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
HEAR1	2						24	0	80	0	6	113

Water chemistry variables

The range of water temperatures, salinity and measures of Secchi depth from Hearnes Lake sites, HEAR1, HEAR2, and HEAR3, are outlined in Table 3.5.8. Water temperatures in Hearnes Lake reflected seasonal climatic changes with the summer maximum temperatures ranging from 26.9°C to 30.3°C and winter minimum temperatures ranged from 14.9°C to 15.3°C. Minimum conductivities in Hearnes Lake ranged from 1.5 mS/cm to 5 mS/cm, while maximum conductivities ranged from 31.8 mS/cm to 44.3 mS/cm. Minimum secchi depths across the sites ranged from 0.22 m to 0.3 m and maximum depths ranged from 1.1 m to 1.5 m. Dissolved oxygen concentrations varied substantially over the sampling period, with all sites recorded very low concentrations with the lowest values at the tidal limit (HEAR2), dropping to an extremely low 0.68mg/L. Lower dissolved oxygen values were also generally found at the base of the water column at all sites.

Table 3.5.8 Summary of range of water chemistry variables including water temperature, conductivity, secchi depth and dissolved oxygen for Hearnes Lake sites, HEAR1, HEAR2 and HEAR3.

Site	Water temp (°C)	Conductivity (mS/cm)	Secchi Depth (m)	Dissolved Oxygen mg/L
HEAR1	15.3 - 29.1	5 - 43.5	0.3 - 1.4	4.6 – 11.17
HEAR2	14.9 - 30.3	2.34 - 44.3	0.3 - 1.5	0.68 – 12.89
HEAR3	15.2 - 26.9	1.5 - 31.8	0.22 - 1.1	6.08 – 11.46

3.6 WOOLGOOLGA CREEK

3.6.1 Catchment description

Woolgoolga Lake is an Intermittently Closed and Open Lakes and Lagoon (ICOLL) with areas of high conservation, recreational and aesthetic value. The estuary is part of the Solitary Islands Marine Park and zoned as a Habitat Protection Zone up to the tidal limit of the tributary creeks (Geolink 2011a). A portion of the vegetated area adjoining the northern shore of the lake is located in the Coffs Coast Regional Park. Woolgoolga Lake catchment is underlain by Coramba Beds of the Coffs Harbour association metasediments consisting of siliceous mudstones, siltstones and greywacke. Headwaters are typically steep hills of Suicide soil landscape group with slopes 33-56% grading to low rolling hills of Megan soil landscapes with slopes 5-20%, with level to gently undulating floodplain. These soil landscapes have strongly acid soils <5.5pH, low subsoil fertility and commonly exhibit subsoil aluminium toxicity (Milford 1999).

The main creeks flowing to the estuary are Woolgoolga Creek and Poundyard Creek. Other tributaries include South Woolgoolga Creek, Cemetery Creek and High School Creek. The estuary catchment area to the tidal limit is 343 ha, and the water body area is 37.6 ha at mean high tide. The total catchment covers an area of 31km^2, with State Forest areas encompassing a large proportion of the upper catchment (Geolink 2011a). Banana plantations and blueberry farms cover a significant proportion of the upper slopes in the mid-catchment (Fig. 3.6.1). A key focus of recreational activity occurs at the public picnic area adjacent to the Woolgoolga Lakeside Holiday Park near the estuary entrance.

Opening of the entrance has been initiated by Council in the past as a flood control measure, opening when the lakes water level reaches 1.8 m AHD (Geolink 2011a). When open, water levels in the lake vary with the full tidal cycle. However, when closed water levels in the lake can be approximately 0.25 to 0.5m higher than when the entrance is open. The maximum water level in the lake is typically in the range of 1.1 to 1.5 m AHD immediately prior to the entrance opening naturally (Geolink 2011a).

3.6.2 Site description

Four sites were selected for Woolgoolga Creek and represent a headwater site (WOOL4) located in a freshwater zone and considered to be in a River Style defined as Fine-Grained Meandering (Table 3.6.1; Figures 3.6.2, 3, 4, 5). The next most upstream site is WOOL3 and located within the tidal limit zone, while the most downstream sites, WOOL2 and WOOL1, are located within the lagoon. Site WOOL1 is located closest to the estuary mouth and was the only site on the Creek to be sampled for faecal coliforms. All sites were sampled each month from January to December 2011 for water chemistry.

Figure 3.6.1 Dominant land-use and location of sites in Woolgoolga Creek in the Coffs Harbour catchment (Source CHCC).

Table 3.6.1 Location of sampling sites, River Style and Condition in Woolgoolga Creek.

River System – Site Code	Easting	Northing	Zone	Organisation collecting	Samples collected
Wooloolga Creek 1 (WOOL1)	518958 m E	6670065 m S	Lagoon	OEH	Faecal, Nutrients, TSS & Chl *a*
Woolgoolga Creek 2 (WOOL2)	518467 m E	6669139 m S	Lagoon	OEH	Nutrients, TSS & Chl *a*
Woolgoolga Creek 3 (WOOL3)	518886 m E	6669663 m S	Tidal limit	OEH	Nutrients, TSS & Chl *a*
Woolgoolga Creek 4 (WOOL4)	516934 m E	6668853 m S	Freshwater	CHCC/UNE	Nutrients, TSS Chl *a*, Macroinverts

Figure 3.6.2 Site WOOL1 in Woolgoolga Creek.

Figure 3.6.3 Site WOOL2 in Woolgoolga Creek.

Figure 3.6.4 Site WOOL3 in Woolgoolga Creek.

Figure 3.6.5 Site WOOL4 in Woolgoolga Creek looking downstream.

3.6.3 Water Chemistry

Chlorophyll *a*

The mean chlorophyll *a* concentrations in Woolgoolga Creek ranged from 1.77µg/L at WOOL4 to 4.37µg/L at WOOL3 (Figure 3.6.6). The minimum concentrations across all sites were 0.90µg/L, and were recorded on more than one occasion at each site during 2011. The maximum chlorophyll *a* concentration at each site was 5µg/L at WOOL1 during May, 16µg/L at WOOL2 during February, 12µg/L at WOOL3 during March, and 4µg/L at WOOL4 during May 2011. All chlorophyll *a* samples collected from WOOL4 during 2011, had concentrations that fell below the prescribed trigger value. At site WOOL3, 55% of the samples had concentrations that exceeded the trigger value, while 18% and 10% of samples from WOOL1 and WOOL2, respectively, had concentrations that also exceeded the trigger value (Table 3.6.2).

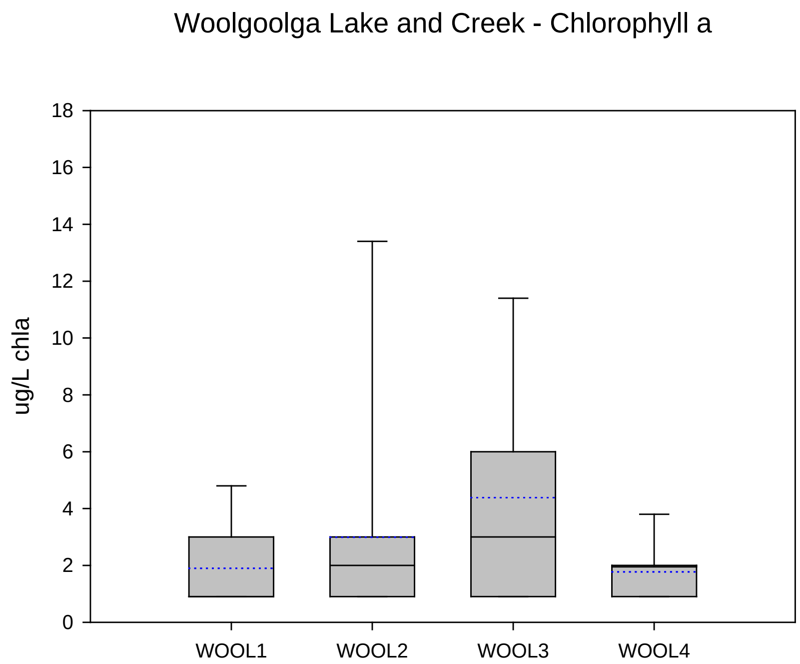

Figure 3.6.6 Mean, median, 25th and 75th percentiles, and range of chlorophyll *a* concentrations from Woolgoolga Lake and Creek sites, WOOL1 to WOOL4, from January to December 2011.

Table 3.6.2 Proportion of monthly chlorophyll *a* samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
WOOL1	0.64	0.18	0.18	0.00	11	5.00	May
WOOL2	0.45	0.45	0.00	0.10	11	16.00	Feb
WOOL3	0.27	0.18	0.10	0.45	11	12.00	Mar
WOOL4	0.82	0.18	0.00	0.00	11	4.00	

Total Nitrogen (TN)

The mean TN concentrations in Woolgoolga Creek ranged from 271.36µg/L at WOOL4 to 426.11µg/L at WOOL3 (Figure 3.6.7). The minimum concentration across all sites ranged from 90µg/L at WOOL1 during August to 270µg/L at WOOL2 during September 2011. The maximum TN concentration at each site was 595µg/L at WOOL1, 645µg/L at WOOL2 and 630µg/L at WOOL3 all recorded during May 2011, whereas the maximum at WOOL4 was 670µg/L during July 2011. Between 80% and 90% of the TN samples collected from WOOL1, WOOL2 and WOOL3 during 2011, had concentrations that exceeded the prescribed trigger value of 300µg/L, while only 18% of the samples collected from WOOL4 exceeded the trigger value (Table 3.6.3).

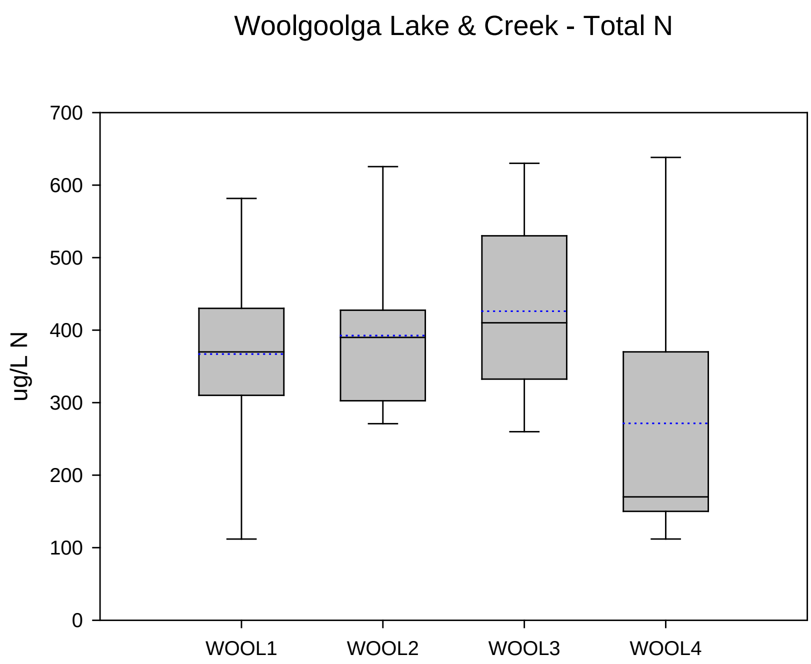

Figure 3.6.7 Mean, median, 25th and 75th percentiles, and range of TN concentrations from Woolgoolga Lake and Creek sites, WOOL1 to WOOL4, from January to December 2011.

Table 3.6.3 Proportion of monthly TN samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
WOOL1	0.10	0.00	0.70	0.20	10	595.00	May
WOOL2	0.00	0.20	0.70	0.10	10	645.00	May
WOOL3	0.00	0.11	0.56	0.33	9	630.00	May
WOOL4	0.55	0.27	0.18	0.00	11	670.00	Jul

Total Phosphorous (TP)

The mean TP concentrations in Woolgoolga Creek ranged from 33.5µg/L at WOOL1 to 38.5µg/L at WOOL2 (Figure 3.6.8). The minimum concentration across all sites was 30µg/L, and recorded on several occasions at each site during 2011. The maximum TP concentration at each site was 65µg/L at WOOL1 and WOOL3, and 80µg/L at WOOL2 all recorded during May, whereas the maximum at WOOL4 was 70µg/L during December 2011. At site WOOL2 and WOOL3, 20% and 40% of TP samples collected during 2011, respectively, had concentrations that exceeded the prescribed trigger value of 30 µg/L, while only 10% of the samples collected from WOOL1 and WOOL4 exceeded the trigger value (Table 3.6.4).

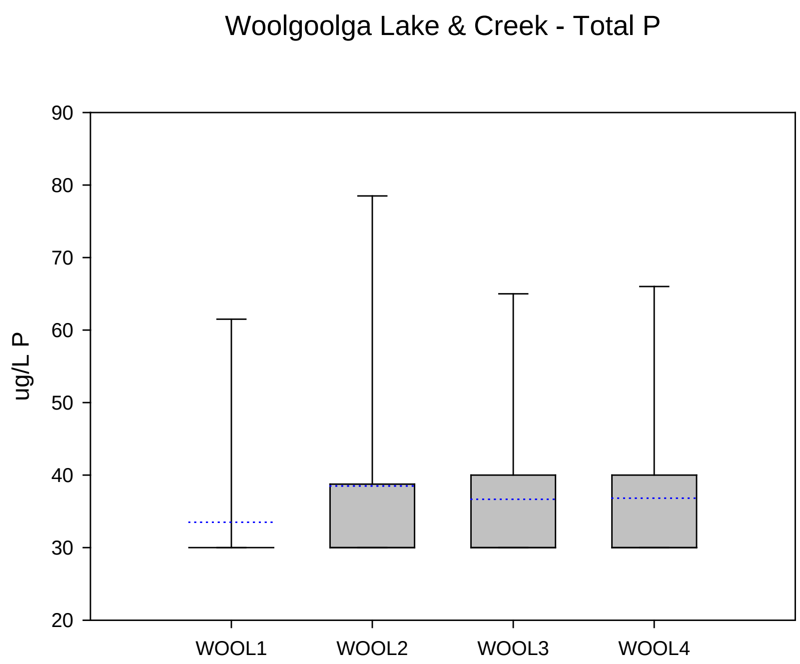

Figure 3.6.8 Mean, median, 25th and 75th percentiles, and range of TP concentrations from Woolgoolga Lake and Creek sites, WOOL1 to WOOL4, from January to December 2011.

Table 3.6.4 Proportion of monthly TP samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
WOOL1	0.00	0.90	0.00	0.10	10	65.00	May
WOOL2	0.00	0.80	0.00	0.20	10	80.00	May
WOOL3	0.00	0.56	0.33	0.11	9	65.00	May
WOOL4	0.00	0.90	0.10	0.00	11	70.00	Dec

Turbidity

The mean turbidity values in Woolgoolga Creek ranged from 5.9NTU at WOOL4 to 16NTU at WOOL3 (Figure 3.6.9). The minimum values ranged from 0NTU at WOOL1 and WOOL2 during August to 1NTU at WOOL3 also during August 2011. The maximum turbidity value at each site was 47NTU at WOOL1, 40.5NTU at WOOL2 and 60NTU at WOOL3, all recorded during May, whereas the maximum at WOOL4 was 14NTU and recorded during July 2011. All of the turbidity samples collected from WOOL4 during 2011 had values that fell below the prescribed trigger value of 50NTU for lowland streams. At sites WOOL2 and WOOL3, 54% and 40% of turbidity samples collected during 2011, respectively, had values that exceeded the prescribed trigger value of 10NTU, while only 25% of the samples collected from WOOL1 exceeded the trigger value (Table 3.6.5).

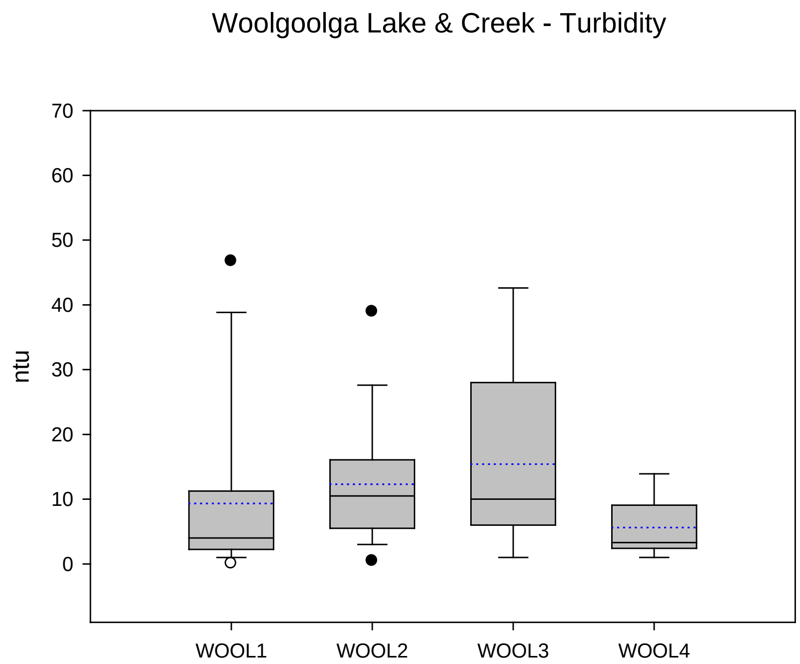

Table 3.6.2 Mean, median, 25th and 75th percentiles, and range of turbidity values from Woolgoolga Lake and Creek sites, WOOL1 to WOOL4, from January to December 2011.

Table 3.6.5 Proportion of monthly turbidity samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
WOOL1	0.60	0.15	0.15	0.10	20	47.00	May (0.3m)
WOOL2	0.23	0.23	0.18	0.36	22	40.50	May (0.1m)
WOOL3	0.20	0.40	0.07	0.33	15	60.00	May (0.3m)
WOOL4	1.00	0.00	0.00	0.00	14	14.00	

pH

The mean pH values in Woolgoolga Creek ranged from 6.29 at WOOL4 to 8.25 at WOOL1 (Figure 3.6.10). The minimum values ranged from 5.41 at WOOL4 during July 2011 to 7.65 at WOOL2 during October 2011. The maximum pH value at each site was 8.86 at WOOL1 and 8.98 at WOOL2 during July 2011, 8.16 at WOOL3 during May 2011, and 7.71 at WOOL4 during December 2011. At sites WOOL1 and WOOL2, 21% and 6% of the pH samples collected during 2011, respectively had values that exceeded the prescribed trigger value range. Less than 5% of samples from sites WOOL1, WOOL2 and WOOL3 had values that fell below the lower limit (Table 3.6.6).

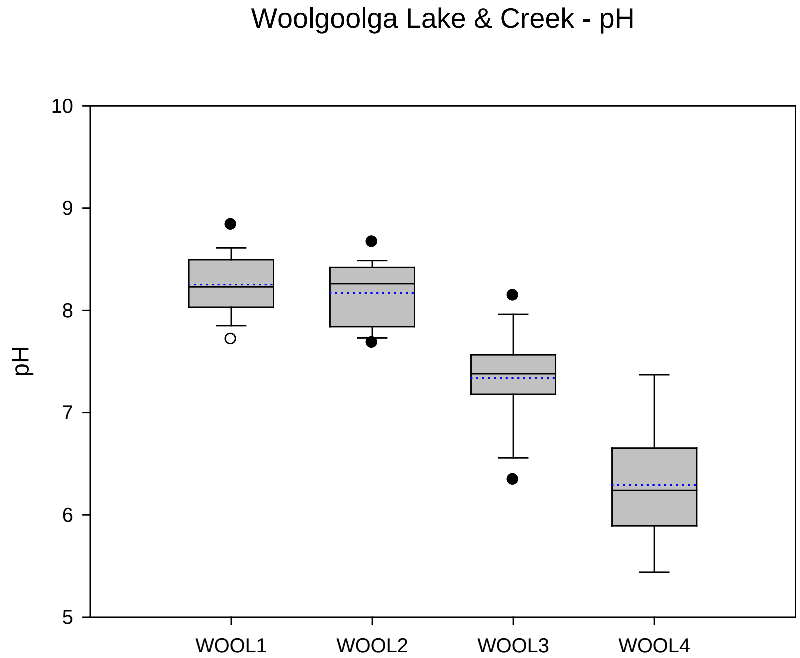

Figure 3.6.10 Mean, median, 25th and 75th percentiles, and range of pH values from Woolgoolga Lake and Creek sites, WOOL1 to WOOL4, from January to December 2011.

Table 3.6.6 Proportion of monthly pH samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0.5-1	1-1.5	>1.5	*n*	Minimum	Maximum
WOOL1	0.03	0.83	0.13	30	6.94	8.92
WOOL2	0.05	0.80	0.15	41	6.8	8.98
WOOL3	0.05	0.95	0.00	19	6.75	8.42
WOOL4	0.07	0.29	0.00	14	5,41	7.71

Faecal coliform

Feacal coliforms were collected on 8 occasions throughout the year, with only one sampling time (June) exceeding the primary and secondary contact trigger value with a very high level of 2860fc/100mL (Table 3.6.7).

Table 3.6.7 Monthly faecal coliform values (fc/mL) from Woolgoolga sites. Concentrations more than 1 times the trigger value are highlighted in red.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WOOL1	20					2860	4	0	62	0	6	140

Water chemistry variables

The range of water temperatures, salinity and measures of Secchi depth from Woolgoolga Creek sites, WOOL1 to WOOL4, are outlined in Table 3.6.8. Water temperatures in Woolgoolga Creek reflected seasonal climatic changes with the summer maximum temperatures ranging from 22.46°C to 29.50°C and winter minimum temperatures ranged from 14.0°C to 16.5°C. Minimum conductivities in Woolgoolga Creek ranged from 0.16mS/cm to 18.0mS/cm, while maximum conductivities ranged from 0.34mS/cm to 52.90mS/cm. Minimum secchi depths across the sites ranged from 0.2m to 0.3m, while maximum values ranged from 1.0m to more than 1.5m. Dissolved oxygen concentrations varied substantially over the sampling period, with all sites recorded low concentrations that were lowest around the tidal limit (WOOL2 and WOOL3). Lower dissolved oxygen values were also generally found at the base of the water column and in warmer months at all sites.

Table 3.6.8 Summary of range of water chemistry variables including water temperature, conductivity, secchi depth and dissolved oxygen for Woolgoolga Creek sites, WOOL1 to WOOL4.

Site	Water temp (°C)	Conductivity (mS/cm)	Secchi Depth (m)	Dissolved Oxygen mg/L
WOOL1	14.00 - 26.50	5.73 - 52.30	0.3 - >1.5	5.2 – 10.5
WOOL2	16.50 - 29.50	18.00 - 52.90	0.3 - 1.5	1.95 – 9.76
WOOL3	13.80 – 28.20	0.32 – 45.10	0.2 – 0.7	3.35 – 10.28
WOOL4	14.11 - 22.46	0.16 - 0.34	0.2 – 1.0	5.14 – 10.4

3.6.4 Macroinvertebrates

Twenty-five macroinvertebrate families were recorded from Woolgoolga Creek during the Autumn and Spring sampling in 2011, dominated by Trichoptera (Caddis Flies) with 7 families, and Coleoptera (Aquatic Beetles) with 6 families recorded for each (Table 3.6.10). Family level richness was higher in Autumn than Spring, owing to the presence of families in several orders including Diptera, Coleoptera and Megaloptera (Alderflies) (Table 3.6.9).

The abundance of individuals was similar between Autumn (132) and Spring (133). Although there were a number of families represented in Autumn compared to Spring, these abundances were biased by the taxa Calamoceratidae Caddis Flies (40) and Chrinomidae Midge larvae (19). In Spring when only 14 families were present, the abundances were biased by Leptophlebiidae Caddis Flies (42), as well as Chrinomidae (38) and Calamoceratidae (22), which was similar to the Autumn abundances. There were a number of taxa that were rare in the catchment, with fourteen of the twenty-five taxa having less than five individuals recorded in both seasons.

Mean SIGNAL2 score for Coffs Creek was 5.7 in Autumn with a score range of 3-8, while the mean SIGNAL2 score in Spring was 5.5, with a score range of 2-9. Two of the most abundant species were from the families Leptophlebiidae and Calamoceratidae, which have signal scores of 8 and 7, respectively, which suggests that the water quality and habitat condition in the freshwater reaches are in excellent condition.

Table 3.6.9 Summary of macroinvertebrate data for Woolgoolga Creek.

	Spring	Autumn
Family Richness	14	20
Total Abundance	133	132
EPT richness	9	9
EPT abundance	85	77
Mean Signal score	5.5	5.7
Signal score range	2-9	3-8

Table 3.6.10 Summary of macroinvertebrate abundance and SIGNAL grade scores for Woolgoolga Creek site, WOOL4.

Order	Family	SIGNAL grade	Spring	Autumn
			WOOL4	WOOL4
Ephemeroptera	Amelitopsidae	7	1	0
Ephemeroptera	Leptophlebiidae	8	42	8
Ephemeroptera	Baetidae	5	4	1
Ephemeroptera	Caenidae	4	1	0
Plecoptera	Gripopterygidae	8	0	6
Trichoptera	IF	8	2	2
Trichoptera	Calamoceratidae	7	22	40
Trichoptera	Glossomatidae	9	2	0
Trichoptera	Hydropsychidae	6	0	8
Trichoptera	Philopotamidae	8	0	1
Trichoptera	Ecnomidae	4	7	3
Trichoptera	Leptoceridae	6	4	8
Odonata	Gomphidae	5	0	3
Odonata	Corduliidae	5	2	1
Coleoptera	Elmidae	7	2	11
Coleoptera	Psephenidae	6	0	2
Coleoptera	Dytiscidae	2	2	0
Coleoptera	Gyrinidae	4	0	1
Coleoptera	Hydrophilidae	2	4	0
Coleoptera	Scirtidae	6	0	1
Megaloptera	Corydalidae	7	0	8
Decapoda	Atyidae	3	0	7
Diptera	IF	3	0	1
Diptera	Tipulidae	5	0	1
Diptera	Chironnomidae	3	38	19

3.6.5 Riparian condition

The overall riparian condition score for Woolgoolga Creek was 6.96/10 (Table 3.6.11). The lowest score across the four different indices was 2.87/5 for the vegetation index, while the highest score was 4.00/5 for the site-based disturbance index.

Table 3.6.11 Site level summary of riparian condition scores for Woolgoolga Creek. Individual scores maximum of 5, total score out of 10.

	VEGETATION	BANK CONDITION	HABITAT	DISTURBANCE	Total/10
Mean	2.87	3.67	3.38	4.00	**6.96**

The vegetation at WOOL4 was described as Tallowood Gallery Forest with a rainforest mid-storey (Table 3.6.12; 13). Native species including *Jagera pseudorhus*, *Melia azedarach*, *Hibiscus heterophyllus*, *Neolitsea dealbata*, *Baloghia inophylla* and *Glochidion ferdinandi* var. *ferdinandi* were present in the mid-storey of WOOL4. The only exotic species present were *Lantana camara* in the mid-storey, and *Hedychium gardnerianum* and the grasses, *Paspalum mandiocanum* and *Melinis minutiflora,* in the understorey. The native species in the understorey included *Lomandra hystrix*, *Adiantum formosum*, and the grass, *Ottochloa gracillima*. There were also a number of native vines including *Stephania japonica*, *Cissus Antarctica* and *Geitonoplesium cymosum*, present in the mid-storey and tree canopy of WOOL4.

Site WOOL4 had a bank condition score of 3.67/5. Although there was strong evidence of exposed tree roots along the bank indicating active erosion, site WOOL4 had reduced bank undercutting and slumping.

The score for riparian habitat at WOOL4 was 3.38/5. There were a large number of standing dead tree and reed habitats, however, there was a limited number of fallen logs, fallen trees and standing large trees that could be used as habitats within the site. WOOL4 was also located adjacent to the habitat Protection areas which meant that it was in close proximity to patches of remnant native vegetation.

There was no evidence of tree removal or livestock movement within the riparian zone of WOOL4, which attributed to the high score of 4.00/5 for site-based disturbances. However, there were a number of fences within nearby cleared land that may be used to limit stock access to the creek. Site WOOL4 also had good connectivity with other patch of remnant vegetation.

Table 3.6.12 Site level summary of riparian condition scores for each sub-index for Woolgoolga Creek site, WOOL4. Individual scores maximum of 5.

	WOOL4
Vegetation	
Large trees	1.33
Canopy Cover	4.67
Mid-storey Cover	2.33
Mid-storey Weeds	4.67
Grass Cover	3.00
Grass Weeds	2.33
Understorey Cover	3.00
Understorey Weeds	1.67
Vines	2.33
Vegetation Layers	3.33
Total/5	**2.87**
Bank Condition	
Slope score	n/a
Undercutting	4.00
Exposed Tree Roots	2.00
Slumping	5.00
Total/5	**3.67**
Habitat	
Standing Dead Trees	5.00
Logs	2.00
Fallen Trees	0.00
Reeds	5.00
Large Trees	2.00
Organic Litter	3.00
Weed Litter	5.00
Proximity to remnant	5.00
Total/5	**3.38**
Disturbance	
Tree Clearing	5.00
Fencing	1.00
Livestock	5.00
Connectivity to vegetation	5.00
Total/5	**4.00**

Table 3.6.13 Dominant riparian vegetation for each strata at Woolgoolga Creek site, WOOL4.

Vegetation Description	WOOL4
Left/Right bank (facing downstream)	L
Dominant Large Trees A	Tallowwood Gallery Forest with rainforest mid-storey
	Eucalyptus microcorys
Dominant Large Trees B	*Eucalyptus microcorys*
Dominant Large Trees C	*Eucalyptus microcorys*
Dominant Mid-storey Cover (native)	*Jagera pseudorhus*
	Melia azedarach
	Hibiscus heterophyllus
	Neolitsea dealbata
	Baloghia inophylla
	Glochidion ferdinandi var. *ferdinandi*
Dominant Mid-storey Cover (weeds)	*Lantana camara*
Dominant Grass Cover (native)	*Ottochloa gracillima*
Dominant Grass Cover (weeds)	*Paspalum mandiocanum*
	Melinis minutiflora
Dominant Understorey Cover (native)	*Lomandra hystrix*
	Adiantum formosum
Dominant Understorey Cover (weeds)	*Lantana camara*
	Hedychium gardnerianum
Dominant Organic Litter (natives)	various Rainforest sp.
Dominant Organic Litter (weeds)	*Lantana camara*
Dominant Vines	*Stephania japonica*
	Cissus antarctica
	Geitonoplesium cymosum

3.7 DARKUM CREEK

3.7.1 Catchment description

Darkum Creek is an Intermittently Closed and Open Lakes and Lagoon (ICOLL) and is part of the Solitary Islands Marine Park and the eastern fringe of the estuary catchment is located in the Coffs Coast Regional Park. The catchment area of Darkum Creek comprises State Forest, banana plantations and blueberry farms in the upper limits of the catchment, and large areas of cleared agricultural land in the mid-catchment (Geolink 2011b). The Woolgoolga Golf Course adjoins a large section of Darkum Creek and comprises a large portion of the estuary catchment. The Safety Beach residential area is situated in the southern section of the estuary catchment (Fig. 3.7.1).

Darkum Creek catchment is underlain by Coramba Beds of the Coffs Harbour association metasediments consisting of siliceous mudstones, siltstones and greywacke. Headwaters are typically steep hills of Suicide soil landscape group with slopes 33-56% grading to low rolling hills of Megan and Ulong soil landscapes with slopes 5-20%, with level to gently undulating coastal floodplain soil landscapes. The hilly soil landscapes units have strongly acid soils <5.5pH, low subsoil fertility and commonly exhibit subsoil aluminium toxicity (Milford 1999).

The entrance to Darkum Creek is generally closed entrance and no artificial opening of the Darkum Creek entrance has been recorded (Geolink 2011b). The entrance area of Darkum Creek offers little structured aquatic habitat and is predominantly unconsolidated sand. The position of the channel and banks is dynamic in this part of the creek and as a result, vegetation is largely absent from these features for most of the time. The central channel of Darkum Creek is a long section of relatively homogenous aquatic habitat availability with the most diverse and abundant benthic macroinvertebrate fauna. Riparian vegetation through the study area is generally in good to very good condition. Mangroves are widely dispersed with evidence of consistent recruitment, with the riparian corridor is largely intact (Geolink 2011).

3.7.2 Site description

One site was located on Darkum Creek in the lagoon adjacent to Darkum Road and representing the water quality at the end of the creek system that exchanges with the estuary (when open) (Table 3.7.1).

Table 3.7.1 Location of sampling sites, River Style and Condition in Darkum Creek.

River System – Site Code	Easting	Northing	Zone	Organisation collecting	Samples collected
Darkum Creek 1 (DARK1)	519103 m E	6671619 m S	Lagoon	CHCC	Faecal, Nutrients, TSS & Chl a

Figure 3.7.1 Dominant land-use and location of sites in Darkum Creek in the Coffs Harbour catchment (Source CHCC).

3.7.3 Water Chemistry

Chlorophyll *a*

Mean chlorophyll *a* concentration was DARK1 of 5.62µg/L and ranged from 0.9µg/L during June, October and December to a maximum of 22µg/L in January 2011 (Fig. 3.7.2). Approximately 41% of chlorophyll *a* samples collected from Darkum Creek throughout 2011 had concentrations that exceeded the prescribed trigger value (Table 3.7.2).

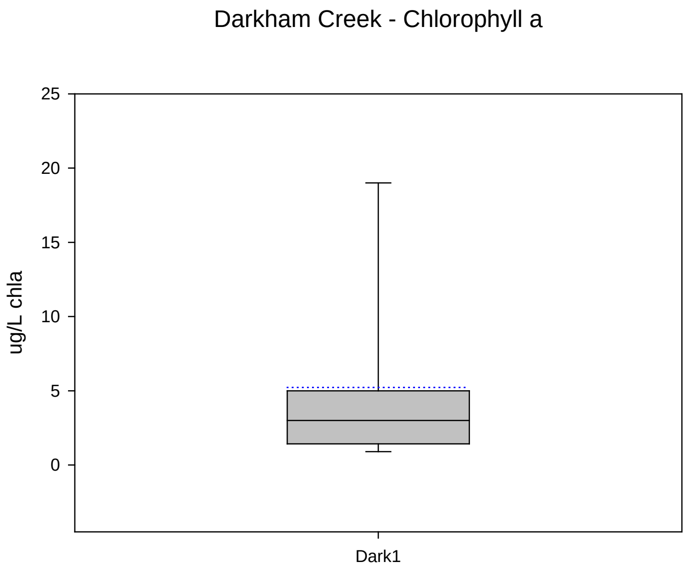

Figure 3.7.2 Mean, median, 25th and 75th percentiles, and range of chlorophyll *a* concentrations from Darkum Creek from January to December 2011.

Table 3.7.2 Proportion of monthly chlorophyll *a* samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
DARK1	0.25	0.33	0.08	0.33	12	22.00	Jan

Total Nitrogen (TN)

There was a mean TN concentration in DARK1 of 634.55µg/L and ranged from 420µg/L in September to a maximum of 810µg/L in March 2011 (Fig. 3.7.3). All TN samples collected from Darkum Creek throughout 2011 had concentrations that exceeded the prescribed trigger value of 300µg/L (Table 3.7.3).

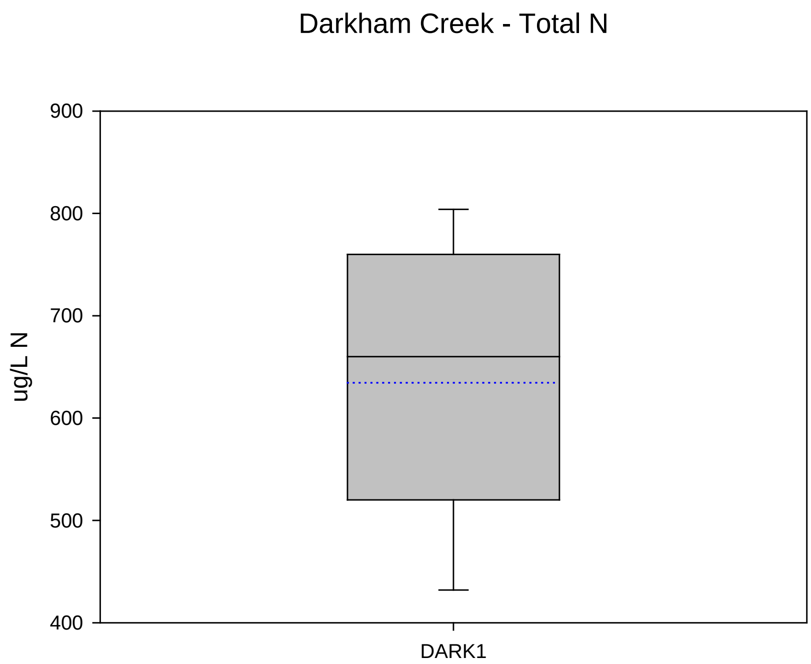

Figure 3.7.3 Mean, median, 25th and 75th percentiles, and range of TN concentrations from Darkum Creek from January to December 2011.

Table 3.7.3 Proportion of monthly TN samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
DARK1	0.00	0.00	0.09	0.91	11	810.00	Mar

Total Phosphorous (TP)

There was a mean TP concentration in DARK1 of 32.2µg/L and ranged from 30µg/L during ten of the 12 sampling occasions to a maximum of 45µg/L in November 2011 (Fig. 3.7.4). As a consequence, approximately 18% of the TP samples collected from Darkum Creek throughout 2011 had concentrations that exceeded the prescribed trigger value (Table 3.7.4).

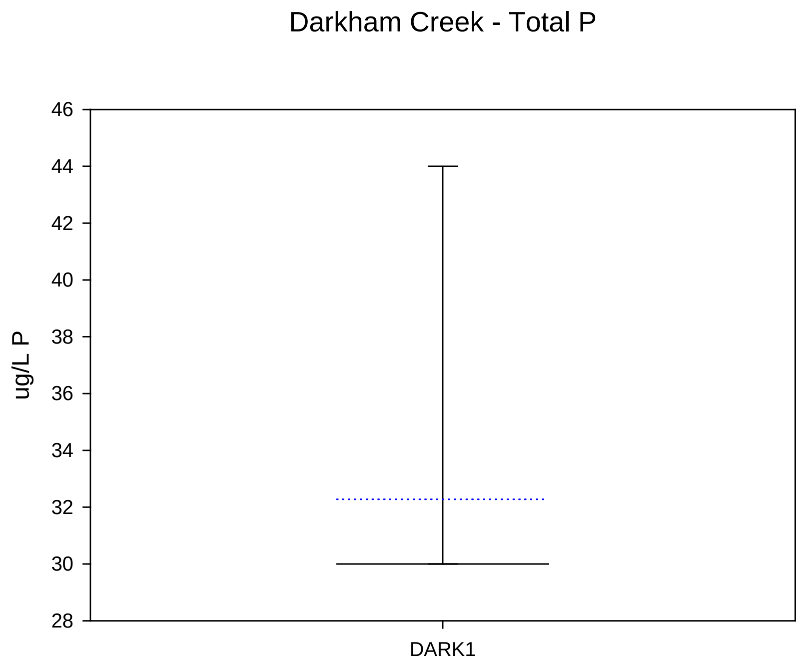

Figure 3.7.4 Mean, median, 25th and 75th percentiles, and range of TP concentrations from Darkum Creek from January to December 2011.

Table 3.7.4 Proportion of monthly TP samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
DARK1	0.00	0.82	0.18	0.00	11	45.00	Nov

Turbidity

The mean turbidity value in DARK1 was 19.48NTU and ranged from 2.9NTU during May to a maximum of 49.6NTU during March 2011 (Fig. 3.7.5). Approximately 80% of turbidity samples collected from Darkum Creek throughout 2011 had values that exceeded the prescribed trigger value (Table 3.7.5).

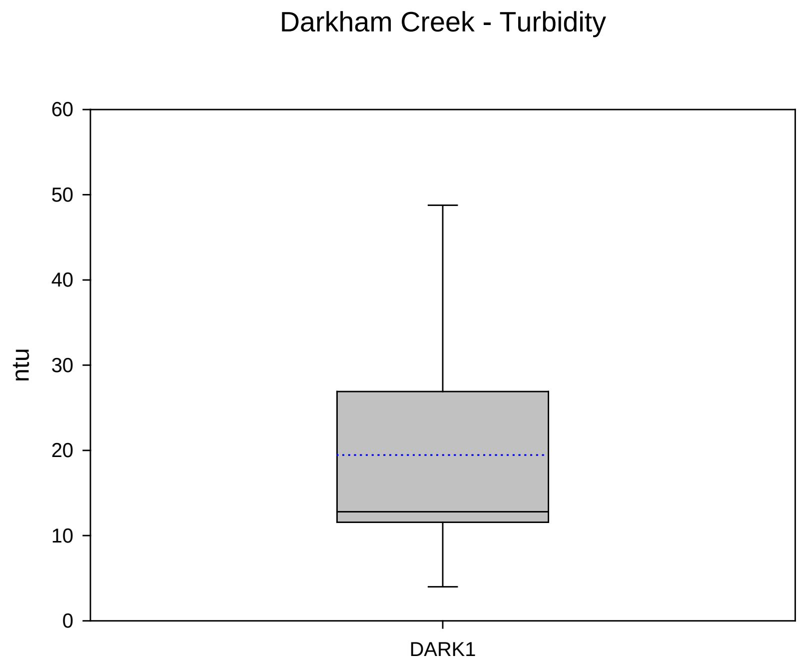

Figure 3.7.5 Mean, median, 25th and 75th percentiles, and range of turbidity values from Darkum Creek from January to December 2011.

Table 3.7.5 Proportion of monthly turbidity samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
DARK1	0.13	0.07	0.33	0.47	15	49.6	May (0.9m)

pH

The mean pH value in DARK1 was 7.25 and ranged from 6.91 during November 2011 to a maximum of 7.59 during January 2011 (Fig. 3.7.6). Approximately 13% of pH samples collected from Darkum Creek throughout 2011 had values that fell below the prescribed trigger value range of 7.00 to 8.50 (Table 3.7.6).

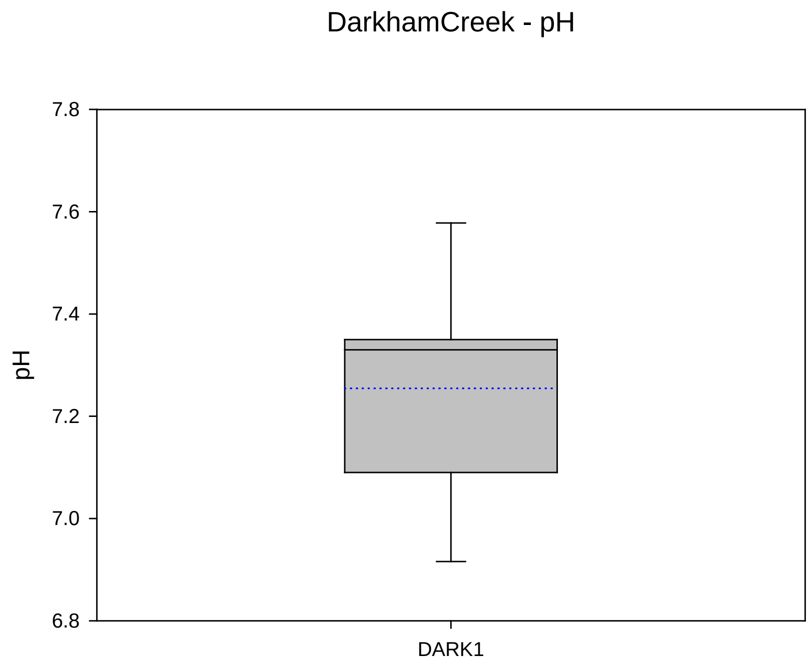

Figure 3.7.6 Mean, median, 25th and 75th percentiles, and range of pH values from Darkum Creek from January to December 2011.

Table 3.7.6 Proportion of monthly pH samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0.5-1	1-1.5	>1.5	*n*	Minimum	Maximum
DARK1	0.13	0.87	0.00	15	6.91	7.59

Faecal coliform

Feacal coliforms were collected on 9 occasions throughout the year, with only one sampling time (May) exceeding the primary trigger value with a level of 162fc/100mL (Table 3.7.7).

Table 3.7.7 Monthly faecal coliform values (fc/mL) from Darkum Creek. Concentrations more than 1 times the trigger value are highlighted in red.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
DARK1	5			0	162	130	72		58	71	22	42

Water chemistry variables

Table 3.7.8 outlines the range of water temperatures, conductivity and measures of secchi depth from Darkum Creek site, DARK1. Water temperatures reflected seasonal climatic changes with summer maxima of 33.37°C and winter minima of 18.11°C. Conductivity at DARK1 ranged from 2.10mS/cm to a maximum of 45.76mS/cm. Secchi depth values were consistently low throughout the study with a maximum of 2.0m. Dissolved oxygen concentrations varied from 4.4 to 104% over the sampling periods, representing a very large range of biophysical and chemical conditions.

Table 3.7.8 Summary of range of water chemistry variables including water temperature, conductivity, secchi depth and dissolved oxygen for Darkum Creek.

	Water temp (°C)	Conductivity (mS/cm)	Secchi Depth (m)	Dissolved Oxygen %
DARK1	18.11 - 33.37	2.10 - 45.76	0.2 – 1.0	4.4 - 104

3.8 ARRAWARRA CREEK

3.8.1 Catchment description

Arrawarra Creek is a small estuarine water body situated approximately 30 km north of Coffs Harbour draining a catchment area of approximately 20 km^2 (Figure 3.8.1). While the creek is open to the sea most of the time, it occasionally closes due to natural accretion of the entrance sand berm (Umwelt 2001). The catchment is underlain by Coramba Beds of the Coffs Harbour association metasediments consisting of siliceous mudstones, siltstones and greywacke. Headwaters are typically steep hills of Suicide soil landscape group with slopes 33-56% grading to low rolling hills of Megan soil landscapes with slopes 5-20%, with level to gently undulating floodplains. These soil landscapes have strongly acid soils <5.5pH, low subsoil fertility and commonly exhibit subsoil aluminium toxicity (Milford 1999).

The estuary catchment has several cultural heritage sites that are highly valued by the local indigenous community, which include middens and open campsites. Breakout events of the closed creek can cause erosion of a large midden located adjacent to the estuary entrance (Umwelt 2001). The creek is lined with mangroves and *Casuarina* with marine influence of sea grasses supporting high levels of fish diversity. Fish kills have been reported in the estuary resulting from decay processes reducing oxygen levels in the estuary when large amounts of kelp are deposited from storm events (Umwelt 2001).

Over the past 50 years residential and tourist areas have been established adjacent to the lower estuary, potentially effecting both hydrology and water quality of the creek. An interim entrance management strategy (Interim Management Strategy Arrawarra Creek 2010), recommends that artificial opening of the mouth be carried out when there are clear risks to ecological and human health. Artificial opening of the mouth should not significantly affect the ecology of the creek which currently has predominantly year round marine conditions (Umwelt 2001).

Figure 3.8.1 Dominant land-use and location of sites in Arrawarra Creek in the Coffs Harbour catchment (Source CHCC).

3.8.2 Site descriptions

Three sites were selected for Arrawarra Creek and represent a headwater site (ARR3) located above the tidal limit zone and close to the Pacific Highway (Table 3.8.1). The downstream sites on Arrawarra Creek are ARR2, which is an area of intermediate salinity, and ARR1, which is located in the lagoon. Site ARR1, the most downstream site, was the only site on Arrawarra Creek that was sampled for faecal coliform. All sites on Arrawarra Creek were sampled each month from January to December 2011 for nutrients, TSS and chlorophyll *a* concentrations.

Table 3.8.1 Location of sampling sites, River Style and Condition in Arrawarra Creek.

River System – Site Code	Easting	Northing	Zone	Organisation collecting	Samples collected
Arrawarra Creek 1 (ARR1)	518966 m E	6674631 m S	Lagoon	OEH	Faecal, Nutrients, TSS & Chl *a*
Arrawarra Creek 2 (ARR2)	518390 m E	6674042 m S	Intermediate salinity	OEH	Nutrients, TSS & Chl *a*
Arrawarra Creek 3 (ARR3)	518143 m E	6673631 m S	Tidal limit	OEH	Nutrients, TSS & Chl *a*

Figure 3.8.2 Site ARR1 in Arrawarra Creek.

Figure 3.8.3 Site ARR2 in Arrawarra Creek.

Figure 3.8.4 Site ARR3 in Arrawarra Creek looking downstream from crossing

3.8.3 Water Chemistry

Chlorophyll *a*

The mean chlorophyll *a* concentrations in Arrawarra Creek were 2.80µg/L at ARR1, 2.83µg/L at ARR2 and 2.61µg/L at ARR3 (Figure 3.8.5). The minimum concentration across all Arrawarra Creek sites was 0.99µg/L, and was detected on more than one occasion at each site. The maximum concentrations at each site were 5µg/L at ARR1 during February and September, 6µg/L at ARRA2 during January, and 5µg/L at ARR3 in October 2011. All chlorophyll *a* samples collected from ARRA3 during 2011 had concentrations that fell below the prescribed trigger value, while 44% of samples from ARR1 and ARR2 exceeded the prescribed trigger value for estuaries (Table 3.8.2).

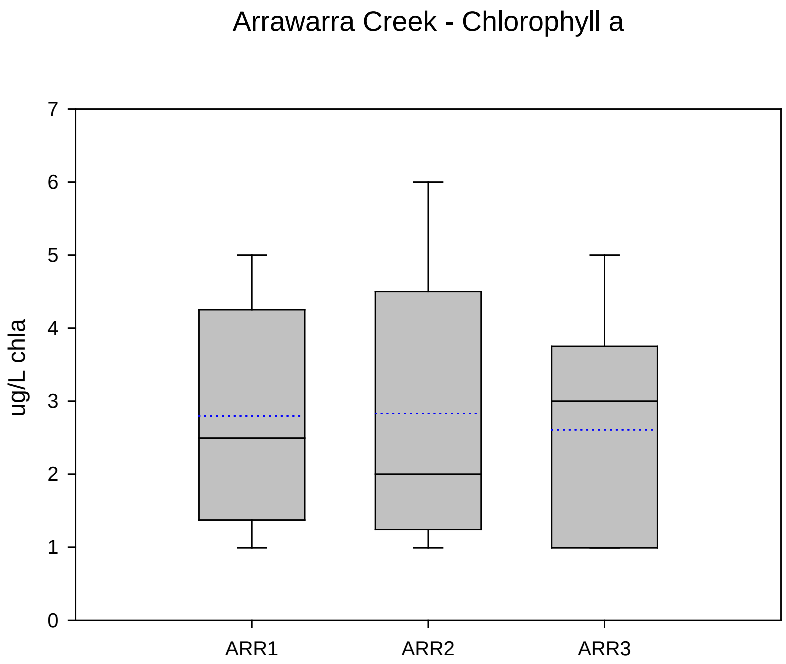

Figure 3.8.5 Mean, median, 25th and 75th percentiles, and range of chlorophyll *a* concentrations from Arrawarra Creek sites, ARR1, ARR2 and ARR3, from January to December 2011.

Table 3.8.2 Proportion of monthly chlorophyll *a* samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
ARR1	0.44	0.22	0.44	0.00	10	6	Feb/Sep
ARR2	0.33	0.33	0.44	0.00	9	5	Jan
ARR3	0.44	0.56	0.00	0.00	9	5	

Total Nitrogen (TN)

The mean TN concentrations in Arrawarra Creek were 434.0µg/L at ARR1, 475.5µg/L at ARR2 and 486µg/L at ARR3 (Figure 3.8.6). The minimum concentrations were 290µg/L at ARR1 and ARR3, recorded during August and July, respectively, and 370µg/L at ARR2 during both July and August 2011 sampling periods. The maximum concentrations at each site were 690µg/L at ARR1, 645µg/L at ARR2 and 580µg/L at ARR3 all during December 2011. All TN samples collected from ARR2 during 2011 had concentrations that exceeded the prescribed trigger value, while 90% of samples from ARR1 and ARR3 also exceeded the prescribed trigger value (Table 3.8.3).

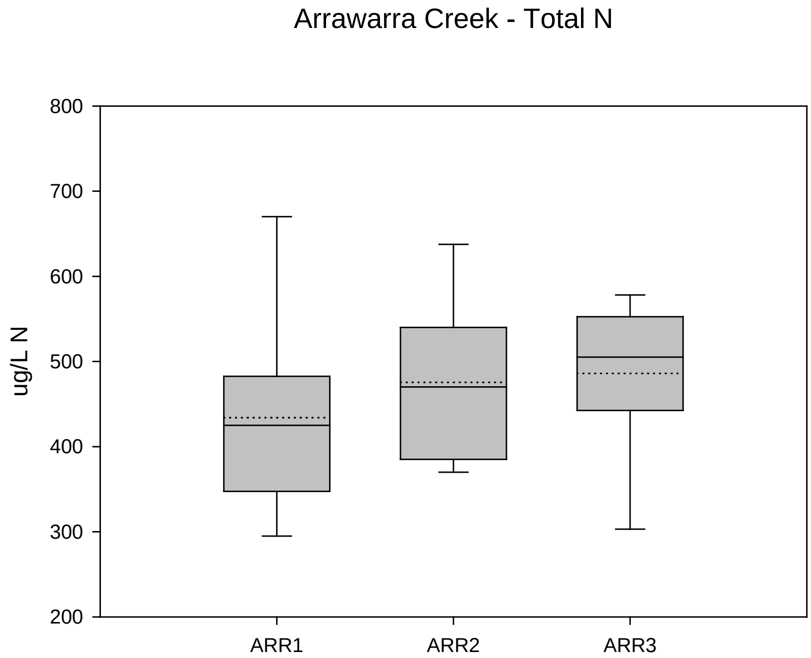

Figure 3.8.6 Mean, median, 25th and 75th percentiles, and range of TN concentrations from Arrawarra Creek sites, ARR1, ARR2 and ARR3, from January to December 2011.

Table 3.8.3 Proportion of monthly TN samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
ARR1	0.00	0.10	0.60	0.30	10	690	Dec
ARR2	0.00	0.00	0.40	0.60	10	645	Dec
ARR3	0.00	0.10	0.20	0.70	10	580	Dec

Total Phosphorous (TP)

The mean TP concentrations in Arrawarra Creek were 35µg/L at ARR1, 37µg/L at ARR2 and 33µg/L at ARR3 (Figure 3.8.7). The minimum concentration across all Arrawarra Creek sites was 30µg/L and was detected on more than one occasion at each site. The maximum concentrations at each site were 65µg/L at ARR1, 70µg/L at ARR2, and 60µg/L at ARR3 during May 2011. At sites ARR1 and ARR2, 30% of samples collected during 2011 had concentrations that exceeded the prescribed trigger value, while 10% of samples collected from ARR3 also had concentrations that exceeded this value (Table 3.8.4).

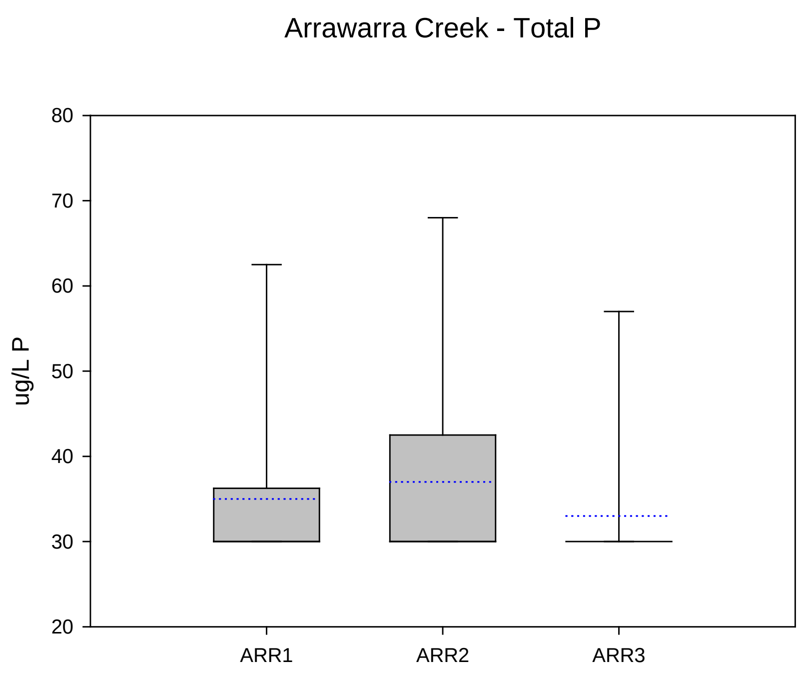

Figure 3.8.7 Mean, median, 25th and 75th percentiles, and range of TP concentrations from Arrawarra Creek sites, ARR1, ARR2 and ARR3, from January to December 2011.

Table 3.8.4 Proportion of monthly TP samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
ARR1	0.00	0.70	0.20	0.10	10	65	May
ARR2	0.00	0.70	0.10	0.20	10	70	May
ARR3	0.00	0.90	0.10	0.00	10	60	May

Turbidity

The mean turbidity values in Arrawarra Creek were 7.05NTU at ARR1, 16.58NTU at ARR2 and 15.63NTU at ARR3 (Figure 3.8.8). The minimum values recorded were 2NTU at ARR1 during July and October, 7.5NTU at ARR2 during December, and 8NTU at ARR3 during July 2011. The maximum values at each site were 18NTU at ARR1 and 40NTU at ARR2 during May, and 29NTU at ARR3 during December 2011. At sites ARR1 and ARR2, 10% and 60% of turbidity samples collected during 2011, respectively, had values that exceeded the prescribed trigger value, while all of the samples collected from ARR3 had values that fell below the prescribed trigger value for lowland streams (Table 3.8.5).

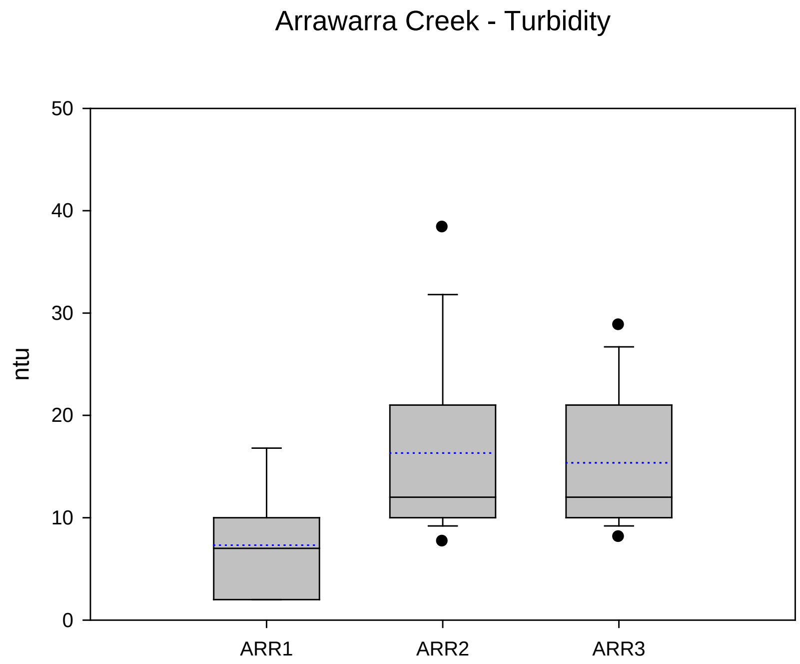

Figure 3.8.8 Mean, median, 25th and 75th percentiles, and range of turbidity values from Arrawarra Creek sites, ARR1, ARR2 and ARR3, from January to December 2011.

Table 3.8.5 Proportion of monthly turbidity samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
ARR1	0.45	0.45	0.10	0.00	11	18.5	May (0.1m)
ARR2	0.00	0.40	0.20	0.40	25	40	May (0.9m)
ARR3	0.86	0.14	0.00	0.00	21	29	

pH

The mean pH values in Arrawarra Creek were 8.22 at ARR1, 8.11 at ARR2 and 7.93 at ARR3 (Figure 3.8.9). The minimum values recorded were 7.35 at ARR1 during June 2011, and 6.92 at ARR2 and 6.90 at ARR3 during February 2011. The maximum values at each site were 8.88 at ARR1, 8.97 at ARR2 and 8.77 at ARR3 all recorded during July 2011. At sites ARR1 and ARR3, 17% and 24% respectively of pH samples collected during 2011, had values that exceeded the trigger value range. At site ARR2, 10% of samples collected had values that fell exceeded the 8.0 upper limit and 3% of samples that fell below the 6.5 lower limit (Table3.8.6).

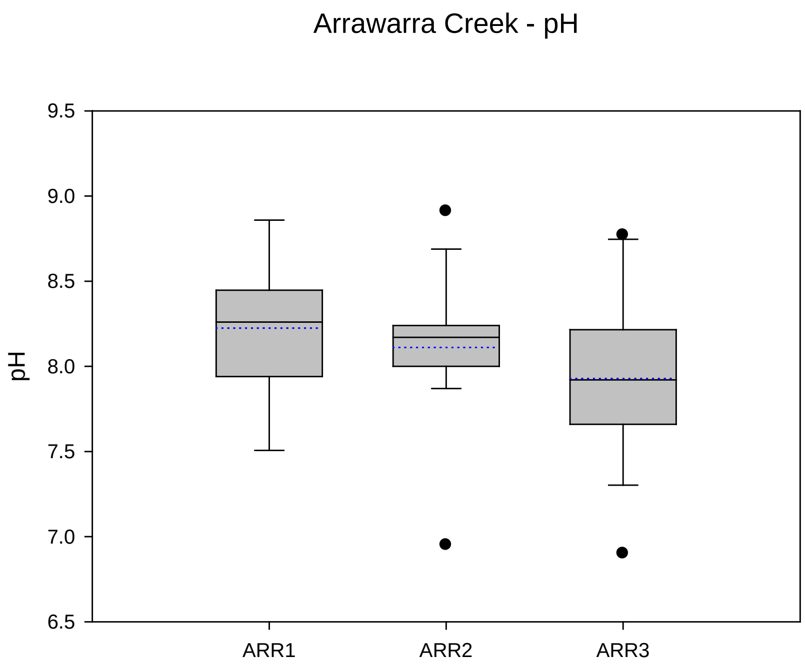

Figure 3.8.9 Mean, median, 25th and 75th percentiles, and range of pH values from Arrawarra Creek sites, ARR1, ARR2 and ARR3, from January to December 2011.

Table 3.8.6 Proportion of monthly pH values within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0.5-1	1-1.5	>1.5	*n*	Maximum	Minimum
ARR1	0.00	0.83	0.17	12	7.35	8.88
ARR2	0.03	0.87	0.10	31	6.92	8.91
ARR3	0.00	0.76	0.24	25	6.9	8.77

Faecal coliform

Feacal coliforms were collected on 8 occasions throughout the year, with only one sampling time (July) exceeding the trigger value for primary contact with a very high concentration of 3000fc/100mL (Table 3.8.7).

Table 3.8.7 – Monthly faecal coliform values (fc/100mL) from Arrawarra Creek site, ARR1. Concentrations more than 1 times the trigger value are highlighted in red.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ARR1	4					3000	6	0	0	10	15	100

Water chemistry variables

The range of water temperatures, salinity and measures of Secchi depth from Arrawarra Creek sites, ARR1, ARR2 and ARR3, are outlined in Table 3.8.8. Water temperatures in Arrawarra Creek reflected seasonal climatic changes with the summer maximum temperatures ranging from 29.0°C to 31.3°C and winter minimum temperatures ranged from 15.7°C to 18.8°C. Minimum conductivities in Arrawarra Creek ranged from 5.2mS/cm to 15.5mS/cm, while maximum conductivities ranged from 50.7mS/cm to 52.8mS/cm. Minimum secchi depths across the sites ranged from 0.1 m to 0.5 m, while maximum values ranged from 0.5 m to 1.4 m. Dissolved oxygen concentrations varied substantially over the sampling period, with all sites recorded low concentrations that were progressively lower with distance upstream. Lower dissolved oxygen values were also generally found at the base of the water column and in warmer months at all sites.

Table 3.8.8 – Summary of range of water chemistry variables including water temperature, conductivity, secchi depth and dissolved oxygen for Arrawarra Creek sites, ARR1, ARR2 and ARR3.

Site	Water temp (°C)	Conductivity (mS/cm)	Salinity (ppt)	Secchi Depth (m)	Dissolved Oxygen mg/L
ARR1	18.8 - 31.3	15.5 - 51.8	0.9 - 3.41	0.1 - 0.5	5.45 – 10.83
ARR2	16.6 - 28.5	8.5 - 52.8	1 - 3.49	0.4 - 1.4	3.52 – 10.66
ARR3	15.7 - 29.0	5.2 - 50.7	1.12 - 3.33	0.5 - 0.7	2.45 – 9.7

3.8.4 Macroinvertebrates

Eighteen macroinvertebrate families were recorded from Arrawarra Creek during the Autumn and Spring sampling in 2011, dominated by Trichoptera (Caddis Flies) with 3 families, and Ephemeroptera (Mayflies) and Coleoptera (Aquatic Beetles) with 3 families recorded each (Table 3.8.9; 10). Family level richness was higher in Spring than Autumn, driven by the presence of Ephemeropterans (Mayflies) and Trichopterans (Caddis Flies) in spring when these insect larvae and nymphs breed (Table 3.8.9). The EPT index identifies approximately 40% of the families and 36% of the individuals recorded are from these families that require good habitat and water quality condition.

The abundance of individuals were higher in Spring (108) than Autumn (90) responding to increased water temperatures and breeding cues for many aquatic insects. Although there were a number of families represented in each season, abundances in Spring were biased by a few taxa including Chrinomidae Midge Larvae (45), Atayidae Freshwater Shrimp (18) and Calamoceratidae Caddis Flies (17). In Autumn, the abundance of individuals was also biased by taxa including Dipteran IF (37), Gerridae Water Striders (25) and Diphlebiidae Damselflies (14). Equally, there were a number of taxa that were rare in the catchment, with ten taxa having less than five individuals recorded in both seasons.

Mean SIGNAL2 score for Arrawarra Creek was 4.77 in Spring with very little difference between seasons in the mean scores or the range of scores recorded. The two most abundant species were from the Dipteran families that have signal scores of 3, suggesting the water quality and habitat conditions at the freshwater site was in poor condition.

Table 3.8.9 Summary of macroinvertebrate data for Arrawarra Creek.

	Spring	Autumn
Family Richness	13	8
Total Abundance	108	90
EPT richness	7	1
EPT abundance	33	1
Mean Signal score	4.77	4.75
Signal score range	2-8	2-8

Table 3.8.10 Summary of macroinvertebrate abundance and SIGNAL grade scores for Arrawarra Creek site.

Order	Family	SIGNAL grade	Spring	Autumn
			ARR1	ARR1
Ephemeroptera	Leptophlebiidae	8	7	1
Ephemeroptera	Baetidae	5	2	0
Ephemeroptera	Caenidae	4	1	0
Trichoptera	IF	8	1	0
Trichoptera	Calamoceratidae	7	17	0
Trichoptera	Ecnomidae	4	2	0
Trichoptera	Leptoceridae	6	3	0
Odonata	Protonuridae	4	0	1
Odonata	Diphlebiidae	6	0	14
Coleoptera	Elmidae	7	3	0
Coleoptera	Psephenidae	6	0	2
Coleoptera	Dytiscidae	2	6	0
Lepidoptera	Pyralidae	3	0	2
Hemiptera	Corixidae	2	2	0
Hemiptera	Gerridae	4	0	25
Decapoda	Atyidae	3	18	0
Diptera	IF	3	1	37
Diptera	Chironnomidae	3	45	0

3.8.5 Riparian condition

The overall riparian condition score for Arrawarra Creek was 8.71/10 (Table 3.8.11). The scores for the individual indices ranged from 3.70/5 for the vegetation index and 5.00/5 for the site-based disturbance index. The bank condition score of 4.75/5 also contributed to the high overall riparian condition score.

Table 3.8.11 Site level summary of riparian condition scores for Arrawarra Creek site, ARRA4. Individual scores maximum of 5, total score out of 10.

	VEGETATION	BANK CONDITION	HABITAT	DISTURBANCE	Total/10
Mean	3.70	4.75	3.96	5.00	**8.71**

The vegetation at ARRA4 was described as a Blackbutt and Brush Cherry Forest (Table 3.8.12; 13). The dominant native species found in the mid-storey included *Ficus coronata*, *Backhousia myrtifolia* and *Cordyline stricta*, while *Lantana camara* was the only exotic species found in the mid-storey. The native vegetation found within the understorey of ARRA4 included *Cordyline stricta*, *Lomandra hystrix*, *Arachnoides aristata*, and the native grass, *Ottochloa gracillima*. There was a limited amount of exotic vegetation in the understory of ARRA4 with the grass, *Paspalum dilatatum*, being the only exotic species present. Several native vines were present at ARRA4 and included *Geitonoplesium cymosum*, *Parsonsia straminea* and *Aphanopetalum resinosum*.

There was little evidence of bank undercutting, exposed tree roots or bank slumping at site ARRA4. Similarly, the slope score for the site was 5.00/5, which further reduces the potential for bank erosion at this site.

Site ARRA4 had a high number of standing dead tree, standing large tree and reed habitats present. Several fallen log habitats were also present within the site and added to the overall score of 3.96/5 for habitat condition. The location of the site meant that it was in close proximity to patches of remnant native vegetation.

There was little evidence of any site-based disturbances at ARRA4, with a perfect score of 5.00/5 recorded at this site. This meant that there was no tree removal in the riparian zone, evidence of fencing or livestock movement in the main channel and riparian zone, as well as having good connectivity with outside patches of remnant vegetation.

Table 3.8.12 Site level summary of riparian condition scores for each sub-index for Arrawarra Creek site, ARR4. Individual scores maximum of 5.

	ARR4
Vegetation	
Large trees	1.00
Canopy Cover	2.33
Mid-storey Cover	3.67
Mid-storey Weeds	5.00
Grass Cover	1.67
Grass Weeds	5.00
Understorey Cover	4.33
Understorey Weeds	5.00
Vines	5.00
Vegetation Layers	4.00
Total/5	**3.70**
Bank Condition	
Slope score	5.00
Undercutting	4.00
Exposed Tree Roots	5.00
Slumping	5.00
Total/5	**4.75**
Habitat	
Standing Dead Trees	5.00
Logs	3.00
Fallen Trees	0.00
Reeds	5.00
Large Trees	4.00
Organic Litter	4.67
Weed Litter	5.00
Proximity to remnant	5.00
Total/5	**3.96**
Disturbance	
Tree Clearing	5.00
Fencing	5.00
Livestock	5.00
Connectivity to vegetation	5.00
Total/5	**5.00**

Table 3.8.13 Dominant riparian vegetation for each strata at sites Arrawarra Creek site, ARR4.

Vegetation Description	ARR4
Left/Right bank (facing downstream)	R
Dominant Large Trees A	no large trees
Dominant Large Trees B	*Eucalyptus pilularis*
Dominant Large Trees C	*Syzygium australe*
Dominant Mid-storey Cover (native)	*Ficus coronata*
	Backhousia myrtifolia
	Cordyline stricta
Dominant Mid-storey Cover (weeds)	*Lantana camara*
Dominant Grass Cover (native)	*Ottochloa gracillima*
Dominant Grass Cover (weeds)	*Paspalum dilatatum*
Dominant Understorey Cover (native)	*Cordyline stricta*
	Lomandra hystrix
	Syzygium australe
	Arachnoides aristata
Dominant Understorey Cover (weeds)	*Lantana camara*
Dominant Organic Litter (natives)	various Rf
Dominant Organic Litter (weeds)	no weedy litter
Dominant Vines	*Geitonoplesium cymosum*
	Parsonsia straminea
	Aphanopetalum resinosum

3.9 CORINDI & SALTWATER CREEKS

3.9.1 Catchment description

The Corindi River system has a riverine form with a catchment area of 148 km^2, extending approximately 25 km from the coast (including a distance of 12.3 km from the entrance to the tidal limit). The catchment includes Madmans Creek Forest Reserve, part of the Yuraygir National Park, and the Solitary Islands Marine Park (including significant areas of sanctuary zone) (Waterways Authority 2002). There are approximately 2 km^2 of wetlands adjoining the estuary that includes mangroves, seagrass, and saltmarsh (Fig. 3.9.1). The lower and upper reaches of Saltwater Creek have forestry as the dominant land use. The Corindi River Estuary has a rich cultural history, particularly for the indigenous Gumbaingirr people of the Red Rock/Corindi area (Waterways Authority 2002).

These coastal headwaters comprise steep catchments which drain to confined discontinuous floodplain. The lower part of Corindi River contains an intermediate valley setting in which there is continuous floodplain with a stable channel (Waterways Authority 2002). The water levels in the estuary are predominantly driven by tidal forces, and fluvial flows in the estuary are only significant during major flood events. The water quality is generally good but some Acid Sulfate Soils have been exposed in the subcatchment, as well as some reported fish kills and flood related water quality issues (Waterways Authority 2002).

Figure 3.9.1 Dominant land-use and location of sites on Corindi River and Saltwater Creek in the Coffs Harbour catchment (Source CHCC).

3.9.2 Site description

Four sites were selected along Corindi River and three sites along the major tributary of Saltwater Creek (Table 3.9.1, Figures 3.9.2, 3, 4, 5). The most upstream sites are represented by COR4 in Corindi River and SALT3 in Saltwater Creek, which are both within freshwater zones and in a River Style defined as Fine-grained Meandering. The next most upstream sites, COR3 and SALT2, are both within the tidal limit zone, while sites COR2 and SALT1 are within zones of intermediate salinity. Site SALT1 is the most downstream site on Saltwater Creek and is located approximately 1.5km upstream of the confluence of Saltwater Creek and Corindi River. Site COR1 is located after the confluence and is considered to be in a marine zone with a salinity range of 30+ ppt. Site COR1, was the only site on Corindi River and Saltwater Creek that was sampled for faecal coliform. All sites were sampled each month from January to December 2011 for water chemistry.

Table 3.9.1 Location of sampling sites, River Style and Condition in Corindi River and Saltwater Creek.

River System – Site Code	Easting	Northing	Zone	Organisation collecting	Samples collected
Corindi River 1 (COR1)	521831 m E	6683164 m S	Marine (30+ppt)	OEH	Faecal, Nutrients, TSS & Chl *a*
Corindi River 2 (COR2)	520253 m E	6682367 m S	Intermediate salinity	OEH	Nutrients, TSS & Chl *a*
Corindi River 3 (COR3)	518901 m E	6681300 m S	Tidal limit	OEH	Nutrients, TSS & Chl *a*
Corindi River 4 (COR4)	515408 m E	6677577 m S	Freshwater	OEH/UNE	Nutrients, TSS Chl *a*, Macroinverts
Saltwater Creek 1 (SALT1)	520028 m E	6683643 m S	Intermediate salinity	OEH	Nutrients, TSS & Chl *a*
Saltwater Creek 2 (SALT2)	518995 m E	6684560 m S	Tidal limit	OEH	Nutrients, TSS & Chl *a*
Saltwater Creek 3 (SALT3)	517268 m E	6685511 m S	Freshwater	OEH/UNE	Nutrients, TSS Chl *a*, Macroinverts

Figure 3.9.2 Site COR1 in Corindi River.

Figure 3.9.3 Site COR4 in Corindi River.

Figure 3.9.4 Site SALT3 near road crossing in Saltwater Creek.

Figure 3.9.5 Riparian vegetation at site SALT3 in Saltwater Creek.

3.9.3 Water Chemistry

Chlorophyll *a*

The mean chlorophyll *a* concentration in Corindi River ranged from 1.29µg/L at site COR4 to 3.33µg/L at site COR3 (Fig. 3.9.5). At the Saltwater Creek sites, the mean chlorophyll *a* concentrations ranged from 2µg/L at SALT1 and SALT3 to 3µg/L at SALT2. The minimum chlorophyll *a* concentration across all Corindi River and Saltwater Creek sites was 0.99 µg/L, and was detected during more than one sampling occasion at each site. The maximum chlorophyll *a* concentrations in Corindi River were 3µg/L at COR1 during March and September, 5µg/L at COR2 during December, 16µg/L at COR3 during May, and 3µg/L at COR4 during March and December 2011. The maximum concentrations at Saltwater Creek were 4µg/L at SALT1 and SALT3 during January, and 8µg/L at SALT2 also during January 2011. All of the chlorophyll *a* samples from sites COR1, COR2, COR4 and SALT3, had concentrations that fell below the prescribed trigger value. At site SALT2, 56% of chlorophyll *a* samples had concentrations that exceeded the trigger value. At sites COR3 and SALT1, 13% and 11% of samples, respectively, had concentrations that also exceeded the trigger value (Table 3.9.2).

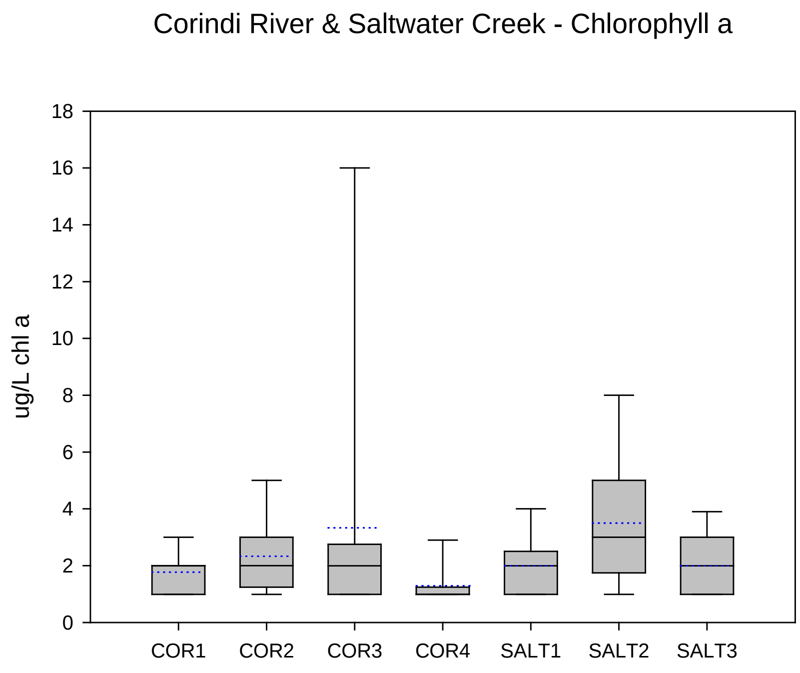

Figure 3.9.5 Mean, median, 25th and 75th percentiles, and range of chlorophyll *a* concentrations from Corindi River and Saltwater Creek sites, COR1 to COR4, SALT1, SALT2 and SALT3, from January to December 2011.

Table 3.9.2 Proportion of monthly chlorophyll *a* samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
COR1	0.33	0.67	0.00	0.00	9	3.00	
COR2	0.44	0.56	0.00	0.00	9	5.00	Dec
COR3	0.47	0.40	0.00	0.13	9	16.00	May
SALT1	0.33	0.56	0.11	0.00	9	4.00	Jan
SALT2	0.22	0.22	0.34	0.22	9	8.00	Jan
COR4	0.90	0.10	0.00	0.00	10	3.00	
SALT3	0.70	0.30	0.00	0.00	10	4.00	

Total Nitrogen (TN)

The mean TN concentration in Corindi River ranged from 324.09µg/L at site COR1 to 674.55µg/L at site COR3 (Fig. 3.9.6). At the Saltwater Creek sites, the mean TN concentrations ranged from 356.36µg/L at SALT1 to 502.73µg/L at SALT3. The minimum TN concentration in Corindi River ranged from 180µg/L at COR1 to 330µg/L at COR2 during June 2011. The maximum concentrations in Corindi River were 445µg/L at COR1 during November, 1100µg/L at COR2 during August, 590µg/L at COR3 during March, and 910µg/L at COR4 during December 2011. The minimum TN concentration in Saltwater Creek ranged from 190µg/L at SALT1 during August to 310µg/L at SALT3 during June 2011. The maximum concentrations at Saltwater Creek were 490µg/L at SALT1 during March, 595µg/L at SALT2 during November, and 700µg/L at SALT3 during July 2011. All of the TN samples collected from COR2 during 2011 had concentrations that exceeded the prescribed trigger value. At sites SALT1 and SALT2, 82% of samples had concentrations that exceeded the trigger value, while 64% of samples from COR3 had concentrations that exceeded the trigger value. Between 45% and 55% of the TN samples collected from COR1, COR4 and SALT3 during 2011, also had concentrations that exceeded the trigger value (Table 3.9.3).

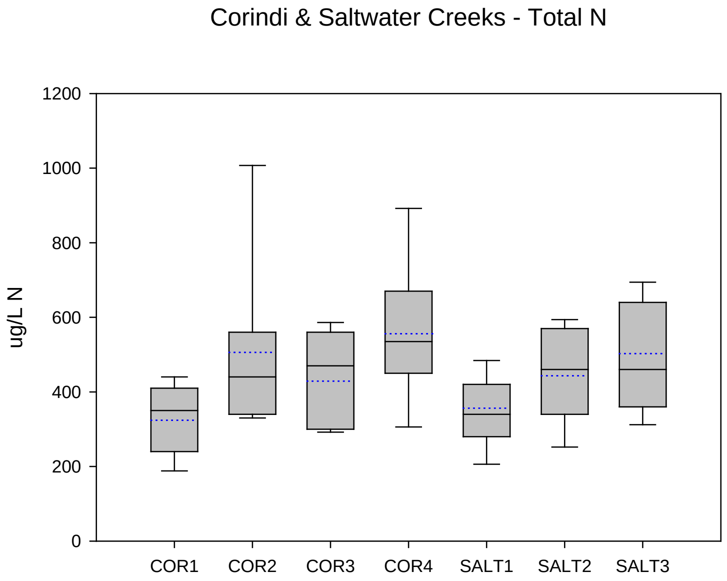

Figure 3.9.6 Mean, median, 25th and 75th percentiles, and range of TN concentrations from Corindi River and Saltwater Creek sites, COR1 to COR4, SALT1, SALT2 and SALT3, from January to December 2011.

Table 3.9.3 Proportion of monthly TN samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
COR1	0.00	0.45	0.55	0.00	11	445	Nov
COR2	0.00	0.00	0.64	0.36	11	1100	Aug
COR3	0.00	0.36	0.09	0.55	10	590	Mar
SALT1	0.00	0.18	0.55	0.27	11	490	Mar
SALT2	0.00	0.18	0.18	0.64	11	595	Nov
COR4	0.00	0.50	0.40	0.10	10	910	Dec
SALT3	0.00	0.55	0.45	0.00	11	700	Jul

Total Phosphorous (TP)

The mean TP concentration in Corindi River ranged from 30µg/L at site COR2 to 52µg/L at site COR4 (Fig. 3.9.7). At the Saltwater Creek sites, the mean TP concentrations ranged from 30µg/L at SALT1 to 33.91 µg/L at SALT3. The minimum TP concentration in Corindi River and Saltwater Creek was 30µg/L, and detected on more than one occasion at each site during 2011. The maximum concentrations in Corindi River were 35µg/L at COR1 during November, 30µg/L at COR2, 50µg/L at COR3 and 120µg/L at COR4 during December 2011. The maximum concentrations at Saltwater Creek were 30µg/L at SALT1, 50µg/L at SALT2 during May, and 60µg/L at SALT3 during December 2011. All of the TP samples collected from COR2 and SALT1 during 2011 had concentrations that fell below the prescribed trigger value. At sites COR3 and COR4, 30% of samples had concentrations that exceeded the trigger value, while 9% of samples from COR1, SALT2 and SALT3 had concentrations that exceeded the trigger value (Table 3.9.4).

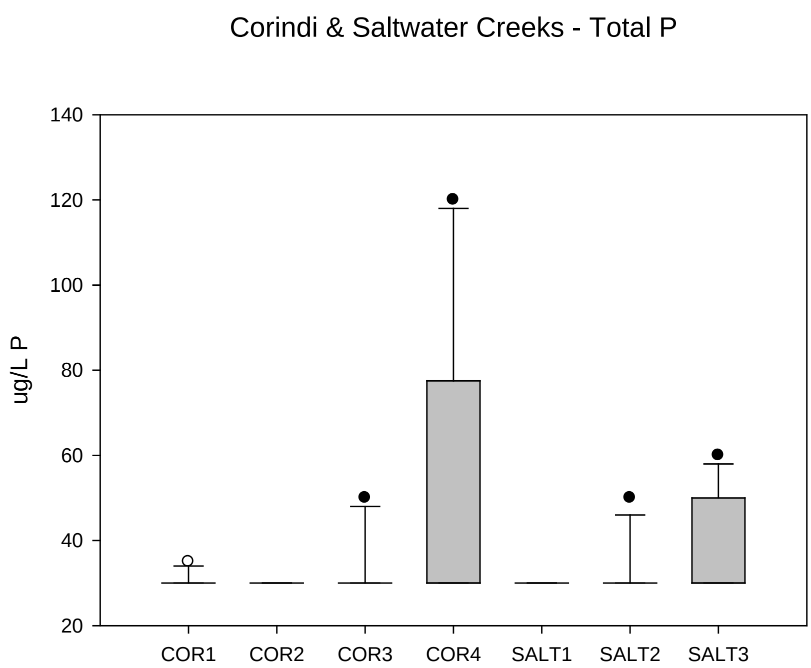

Figure 3.9.7 Mean, median, 25th and 75th percentiles, and range of TP concentrations from Corindi River and Saltwater Creek sites, COR1 to COR4, SALT1, SALT2 and SALT3, from January to December 2011.

Table 3.9.4 Proportion of monthly TP samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
COR1	0.00	0.91	0.09	0.00	11	35	Nov
COR2	0.00	1.00	0.00	0.00	11	30	
COR3	0.00	0.70	0.16	0.14	11	50	Dec
SALT1	0.00	1.00	0.00	0.00	11	30	
SALT2	0.00	0.91	0.00	0.09	11	50	May
COR4	0.00	0.70	0.20	0.10	10	120	Dec
SALT3	0.00	0.91	0.09	0.00	11	60	Dec

Turbidity

The mean turbidity values in Corindi River ranged from 1.09NTU at site COR1 to 22.26NTU at site COR4 (Fig. 3.9.8). At the Saltwater Creek sites, the mean turbidity values ranged from 3.18NTU at SALT1 to 19.01NTU at SALT3. The minimum values in Corindi River ranged from 0.10NTU at COR1 during September to 8.7NTU at COR4 during April 2011. The maximum values in Corindi River were 3.2NTU at COR1 during July, 10.50nTU at COR2 and 57.9NTU at COR3 during December, and 58.3NTU at COR4 during June. The minimum turbidity values in Saltwater Creek ranged from 0.8nTU at SALT1 during August to 7.6NTU at SALT3 during June 2011. The maximum values at Saltwater Creek were 9.1NTU at SALT1 and SALT2 during August and November, respectively, and 33.9ntu at SALT3 during May. All of the turbidity samples collected from COR1, COR4 and all Saltwater Creeks sites during 2011 had values that fell below the prescribed trigger value. At sites COR2 and COR3, 5% and 47% of samples, respectively, had values that exceeded the trigger value (Table 3.9.5).

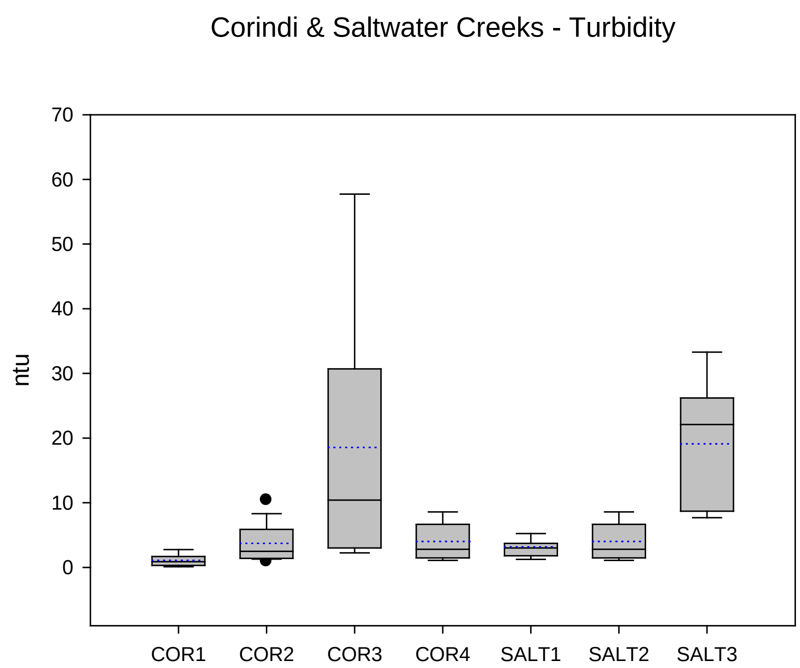

Figure 3.9.8 Mean, median, 25th and 75th percentiles, and range of turbidity values from Corindi River and Saltwater Creek sites, COR1 to COR4, SALT1, SALT2 and SALT3, from January to December 2011.

Table 3.9.5 Proportion of monthly turbidity samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0-0.5	0.5-1	1-1.5	>1.5	*n*	Maximum	Month
COR1	1.00	0.00	0.00	0.00	13	3.2	
COR2	0.62	0.33	0.05	0.00	21	10.5	Dec (0.1m)
COR3	0.46	0.07	0.07	0.40	15	57.9	Dec (0.2/2m)
SALT1	0.94	0.06	0.00	0.00	18	9.1	
SALT2	0.64	0.36	0.00	0.00	14	9	
COR4	0.65	0.35	0.00	0.00	17	58.3	
SALT3	0.82	0.18	0.00	0.00	11	33.9	

pH

The mean pH values in Corindi River ranged from 6.43 at site COR4 to 8.09 at site COR1 (Fig. 3.9.9). At the Saltwater Creek sites, the mean pH values ranged from 5.87 at SALT3 to 7.95 at SALT1. The minimum values in Corindi River ranged from 5.45 at COR4 during July 2011 to 7.26 at COR1 during November 2011. The maximum values in Corindi River were 8.50 at COR1 during October 2011, 8.07 at COR2 during March 2011, 8.47 at COR3 during August 2011, and 6.96 at COR4 during December 2011. The minimum pH values in Saltwater Creek ranged from 5.17 at SALT3 during July 2011 to 7.11 at SALT1 during July 2011. The maximum values at Saltwater Creek were 8.81 at SALT1 during October 2011, 8.00 at SALT2 during October 2011, and 6.62 at SALT3 during December 2011. All of the pH samples collected from COR1 and SALT2 had values that fell within the prescribed trigger value range. Less than 3% of samples from SALT1 had values that exceeded the upper limit, while 2% and 16% of samples from COR2 and COR3, respectively, fell below the lower limit. At sites COR4 and SALT3, 47% and 91% of samples, respectively, had values that fell below the lower limit (Table 3.9.6).

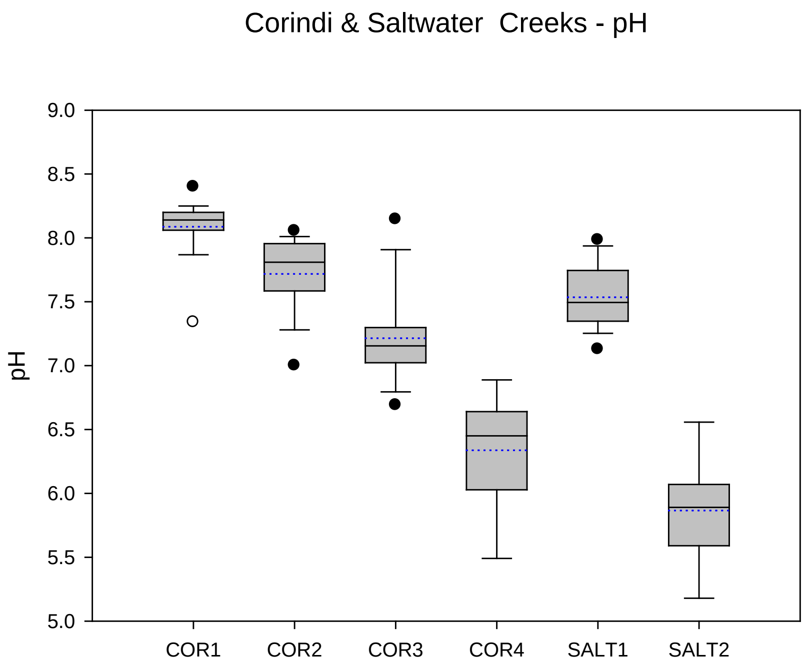

Figure 3.9.9 Mean, median, 25th and 75th percentiles, and range of pH values from Corindi River and Saltwater Creek sites, COR1 to COR4, SALT1, SALT2 and SALT3, from January to December 2011.

Table 3.9.6 Proportion of monthly pH samples within trigger value ranges. Proportion of concentrations more than 1 times the trigger value are highlighted in red.

Exceedence of trigger value	0.5-1	1-1.5	>1.5	*n*	Minimum	Maximum
COR1	0.00	1.00	0.00	27	7.26	8.5
COR2	0.02	0.98	0.00	49	6.81	8.07
COR3	0.16	0.84	0.00	32	6.6	8.47
SALT1	0.00	0.97	0.03	38	7.11	8.81
SALT2	0.00	1.00	0.00	30	7.04	8
COR4	0.47	0.53	0.00	17	5.45	6.96
SALT3	0.91	0.09	0.00	11	5.17	6.62

Faecal coliform

Feacal coliforms were collected on 7 occasions throughout the year, with 6 sampling periods recording a value of 0, with the maximum of 2 fc/mL recorded in April (table 3.9.7).

Table 3.9.7 – Monthly faecal coliform values (fc/mL) from Corindi River site, COR1. Concentrations more than 1 times the trigger value are highlighted in red.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
COR1				2	0	0	0		0		0	0

Water chemistry variables

Table 3.2.8 outlines the range of water temperatures, salinity and measures of Secchi depth from Corindi River and Saltwater Creek sites, COR1 to COR4, SALT1, SALT2 and SALT3. Water temperatures in all sites reflected seasonal climatic changes. In Corindi River, the summer maximum temperatures ranged from 23.65°C to 28.30°C and winter minimum temperatures ranged from 13.00°C to 17.20°C. In Saltwater Creek, the summer maximum temperatures ranged from 24.80°C to 30.10°C and winter minimum temperatures ranged from 12.51°C to 16.30°C. Conductivity at the most upstream sites COR4 and SALT3 had consistently low conductivity with a maximum of 0.25mS/cm recorded throughout the study period. At sites COR2, COR3, SALT1 and SALT2, minimum conductivities ranged from 0.53mS/cm to 29.73mS/cm and maximum conductivities ranged from 43.05mS/cm to 55.9mS/cm. Conductivity ranged from 46.8mS/cm to a maximum of 62.6mS/cm at site COR1. Minimum secchi depths across the Corindi River sites ranged from 0.2m to 1.1m, while maximum values ranged from 0.5m to more than 2.5m. Minimum secchi depths in Saltwater Creek sites ranged from 0.2m to 1.45m, while maximum values ranged from 0.5m to more than 3.0m. Dissolved oxygen concentrations varied substantially over the sampling period, with all sites recording low concentrations that were lowest around the tidal limit (COR3) in the Corindi River and lowest at the most upstream site (SALT3) in Saltwater Creek. Lower dissolved oxygen values were also generally found at the base of the water column and in warmer months at all sites.

Table 3.9.8 Summary of range of water chemistry variables including water temperature, conductivity, secchi depth and dissolved oxygen for Corindi River and Saltwater Creek sites, COR1 to COR4, SALT1 to SALT3.

Site	Water temp (°C)	Conductivity (mS/cm)	Secchi Depth (m)	Dissolved Oxygen %
COR1	17.2 - 25.5	46.8 - 62.6	1.1 - >2.5	90.3 – 108.5
COR2	16.1 - 28.3	17.61 - 51.8	0.7 - 2.5	56.9 – 91.1
COR3	14.5 - 27.1	0.53 - 43.05	0.4 - 2	35.8 – 84.2
COR4	13.0 - 23.65	0.126 - 0.19	0.2 - 0.5	46.3 – 106.8
SAL1	16.3 - 29.5	29.73 - 55.9	1.45 - >3	67.7 - 100
SAL2	15.7 - 30.1	21.91 - 50.5	0.5 - 2.5	53.1 – 87.1
SAL3	12.51 - 24.8	0.13 - 0.25	0.2 - 0.5	20.7 – 107.9

3.9.4 Macroinvertebrates

Corindi River

Twenty-four macroinvertebrate families were recorded from Corindi River during the Autumn and Spring sampling in 2011, dominated by Odonata (Dragon Flies) and Coleoptera (Aquatic Beetles) with 5 families recorded each (Table 3.9.9, 10). Family level richness was higher in Spring than Autumn, but was not driven by the presence of any particular order (Table 3.9.9). The EPT index identifies approximately 40% of the families and 36% of the individuals recorded are from these families that require good habitat and water quality condition.

The abundance of individuals was also higher in Spring (150) compared to Autumn (96). There were a number of families that contributed to the larger abundances in Spring including Chrinomidae Midge Larvae (23), Elmidae Riffle Beetles (21), Caenidae mayflies (19) and Leptophlebiidae Mayflies (13). In Autumn, the abundance of individuals was biased by the presence of Diptera IF (29), Odonata IF (10) and Tipulidae Crane Flies (10). There were a number of taxa that were rare in the catchment, with thirteen taxa having less than five individuals recorded in both seasons.

Mean SIGNAL2 score for Corindi River was 4.4 in Spring and 4.8 in Autumn with no difference between the range of scores recorded. The two most abundant species were from Dipteran families that both have signal scores of 3, suggesting the water quality and habitat condition were generally poor at this freshwater site.

Table 3.9.9 Summary of macroinvertebrate data for Corindi River.

	Spring	Autumn
Family Richness	16	13
Total Abundance	125	96
EPT richness	6	5
EPT abundance	51	17
Mean Signal score	4.4	4.8
Signal score range	2-8	2-8

Table 3.9.10 Summary of macroinvertebrate abundance and SIGNAL grade scores for Corindi River.

Order	Family	SIGNAL grade	Spring	Autumn
			COR4	COR4
Ephemeroptera	Leptophlebiidae	8	13	3
Ephemeroptera	Baetidae	5	3	2
Ephemeroptera	Caenidae	4	19	0
Trichoptera	Calamoceratidae	7	8	1
Trichoptera	Ecnomidae	4	3	0
Trichoptera	Hydrobiosidae	8	0	1
Trichoptera	Leptoceridae	6	5	0
Odonata	IF	3	0	10
Odonata	Gomphidae	5	1	0
Odonata	Corduliidae	5	1	1
Odonata	Protonuridae	4	10	0
Odonata	Diphlebiidae	6	0	6
Coleoptera	Elmidae	7	21	0
Coleoptera	Psephenidae	6	0	1
Coleoptera	Dytiscidae	2	1	0
Coleoptera	Gyrinidae	4	0	1
Coleoptera	Hydrophilidae	2	3	0
Lepidoptera	Pyralidae	3	1	0
Hemiptera	Corixidae	2	1	0
Hemiptera	Gerridae	4	0	1
Decapoda	Atyidae	3	12	0
Diptera	IF	3	0	29
Diptera	Tipulidae	5	0	10
Diptera	Chironnomidae	3	23	0

Saltwater Creek

Seventeen macroinvertebrate families were recorded from Saltwater Creek during the Autumn and Spring sampling in 2011, dominated by Odonata (Dragon Flies) with 4 families, and Coleoptera (Aquatic Beetles) with 3 families recorded (Table 3.9.11, 12). Family level richness was higher in Spring than Autumn, driven by the presence of Ephemeroptera (Mayflies) and Trichoptera (Caddis Flies) (Table 3.9.11). The EPT index identifies approximately 40% of the families and 36% of the individuals recorded are from these families that require good habitat and water quality condition.

The abundance of individuals was also considerably higher in Spring (84) compared to Autumn (32). The larger abundances in Spring was due to an increase in individuals from the Atyidae Freshwater Shrimp family (59). In Autumn, the abundance of individuals was biased by the presence of Diptera IF (12) and Diphlebiidae Water Striders (7). There was a large number of taxa that were considered to be rare in the catchment, with thirteen of the seventeen taxa having less than five individuals recorded in both seasons.

Mean SIGNAL2 score for Saltwater Creek was 4.4 in Spring and 3.4 in Autumn with a slightly lower range of scores recorded during Autumn compared to Spring. The two most abundant species were from Dipteran and Atyidae families, suggesting the water quality and habitat condition were generally poor at this freshwater site.

Table 3.9.11 Summary of macroinvertebrate data for Saltwater Creek.

	Spring	Autumn
Family Richness	13	7
Total Abundance	84	32
EPT richness	4	1
EPT abundance	7	3
Mean Signal score	4.4	3.4
Signal score range	2-9	2-6

Table 3.9.12 Summary of macroinvertebrate abundance and SIGNAL grade scores for Saltwater Creek.

Order	Family	SIGNAL grade	Spring	Autumn
			SALT3	SALT3
Ephemeroptera	Baetidae	5	2	0
Ephemeroptera	Caenidae	4	1	0
Trichoptera	Ecnomidae	4	1	0
Trichoptera	Leptoceridae	6	3	0
Odonata	IF	3	0	3
Odonata	Ashnidae	5	1	2
Odonata	Protonuridae	4	4	0
Odonata	Diphlebiidae	6	0	7
Coleoptera	Elmidae	7	1	0
Coleoptera	Dytiscidae	2	1	0
Coleoptera	Gyrinidae	4	0	4
Megaloptera	Corydalidae	7	0	2
Neuroptera	Neurorthidae	9	1	0
Hemiptera	Corixidae	2	1	0
Decapoda	Atyidae	3	59	0
Diptera	IF	3	3	12
Diptera	Chironnomidae	3	6	0

3.9.5 Riparian condition

The riparian condition scores for the Saltwater and Corindi Creek sites, SALT3 and COR4, were 7.82/10 and 6.71/10, respectively (Table 3.9.13). The Saltwater Creek site had higher individual scores for the bank condition and site-based disturbance indices, compared to the Corindi Creek site. In contrast, both sites had similar riparian habitat scores of 3.67/5, and the Corindi Creek site had a higher vegetation index score.

Table 3.9.13 Site level summary of riparian condition scores for Saltwater and Corindi Creek sites, SALT3 and COR4. Individual scores maximum of 5, total score out of 10.

	VEGETATION	BANK CONDITION	HABITAT	DISTURBANCE	Total/10
SALT3	3.30	4.00	3.67	4.67	7.82
COR4	3.57	2.50	3.67	3.67	6.71
Mean	**3.43**	**3.25**	**3.67**	**4.17**	**7.26**

Vegetation at SALT3 was described as Blackbutt and Sydney Red Gum Forest, and had a score of 3.30/5 (Table 3.9.13; 14). The weed-free mid-storey consisted of the native species *Melaleuca quinquenervia*, *Acacia fimbriata* and *Elaeocarpus reticulates*. The dominant native species present within the understorey of SALT3 included *Lomandra hystrix*, *Acacia floribunda*, *Gahnia sieberiana*, *Baumea juncea*, *Arachnoides aristata*, and the grass, *Entolasia marginate*. Only a single exotic species was found in the understorey, which was the grass, *Paspalum mandiocanum*. In contrast the vegetation at COR4 was described as a Camphor Laurel and Flooded Gum forest, and had a slightly higher score of 3.57/5. The mid-storey had several native species including *Pittosporum undulatum*, *Glochidion ferdinandi var. ferdinandi*, *Trema tomentose* and *Rhodamnia rubescens*. The exotic species, *Lantana camara*, was also present in the mid-storey. Several exotic species were also present in the understorey and included *Tradescantia fluminensis*, *Bidens pilosa*, *Ambrosia artemisifolia*, *Conyza bonariensis*, and the grasses, *Paspalum mandiocanum* and *Paspalum dilatatum*. Native species in the understorey of COR4 consisted of *Carex inversa*, *Cissus Antarctica*, and the grasses, *Imperata cylindrical*, *Ottochloa gracillima*, and *Microlaena stipoides*. Site COR4 also had several vines present in the mid-storey and tree canopy, including the natives *Stephania japonica*, *Smilax australis*, *Trophis scandens*, and the exotic, *Araujia hortorum*.

The bank slope scores at SALT3 and COR4 were 1.00/5 and 3.00/5, respectively, indicating the increased potential for bank erosion, particularly at site SALT3. However, there was little evidence of bank undercutting, exposed tree roots and bank slumping at the Saltwater Creek site. Site COR4 had a higher level of bank undercutting and there were also several areas of exposed tree roots and evidence of bank slumping compared to SALT3.

Both SALT3 and COR4 sites had a large number of standing dead tree, fallen log and reed habitats present within the riparian zones. There were also several standing large tree habitats present in both sites. The location of sites SALT3 and COR4 meant that both sites were in close proximity to patches of remnant native vegetation.

There was a small amount of tree removal from the riparian zones of the SALT3 and COR4 sites. There did not appear to be any evidence of fences or livestock movement within the main channel or riparian zones of both sites. In contrast, there was good connectivity to remnant vegetation at site SALT4, while the location of COR4 meant that this connectivity was limited at this site.

Table 3.9.14 Site level summary of riparian condition scores for each sub-index for Saltwater and Corindi Creek sites, SALT3 and COR4. Individual scores maximum of 5.

	SALT3	COR4
Vegetation		
Large trees	2.00	2.00
Canopy Cover	1.67	4.00
Mid-storey Cover	4.33	3.67
Mid-storey Weeds	5.00	3.67
Grass Cover	1.00	2.00
Grass Weeds	5.00	4.33
Understorey Cover	5.00	3.67
Understorey Weeds	5.00	3.33
Vines	1.00	5.00
Vegetation Layers	3.00	4.00
Total/5	**3.30**	**3.57**
Bank Condition		
Slope score	1.00	3.00
Undercutting	5.00	1.00
Exposed Tree Roots	5.00	3.00
Slumping	5.00	3.00
Total/5	**4.00**	**2.50**
Habitat		
Standing Dead Trees	5.00	5.00
Logs	4.00	4.00
Fallen Trees	0.00	0.00
Reeds	5.00	5.00
Large Trees	2.00	3.00
Organic Litter	3.33	4.33
Weed Litter	5.00	3.00
Proximity to remnant	5.00	5.00
Total/5	**3.67**	**3.67**
Disturbance		
Tree Clearing	3.67	3.67
Fencing	5.00	5.00
Livestock	5.00	5.00
Connectivity to vegetation	5.00	1.00
Total/5	**4.67**	**3.67**

Table 3.9.15 Dominant riparian vegetation for each strata at sites, SALT3 and COR4.

Vegetation Description	SALT3	COR4
Left/Right bank (facing downstream)	L	R
Dominant Large Trees A	*Eucalyptus pilularis*	*Cinnamomum camphora*
Dominant Large Trees B	*Angophora costata*	*Eucalyptus grandis*
		Cinnamomum camphora
Dominant Large Trees C	*Angophora costata*	*Eucalyptus grandis*
	Eucalyptus pilularis	*Cinnamomum camphora*
Dominant Mid-storey Cover (native)	*Melaleuca quinquenervia*	*Pittosporum undulatum*
	Acacia fimbriata	*Glochidion ferdinandi var. ferdinandi*
	Elaeocarpus reticulatus	*Trema tomentosa*
		Rhodamnia rubescens
Dominant Mid-storey Cover (weeds)	no weeds	*Lantana camara*
Grass Cover (native)	*Entolasia marginata*	*Imperata cylindrica*
		Ottochloa gracillima
		Microlaena stipoides
Grass Cover (weeds)	*Paspalum mandiocanum*	*Paspalum mandiocanum*
		Paspalum dilatatum
Dominant Understorey Cover (native)	*Lomandra hystrix*	*Pittosporum undulatum*
	Acacia floribunda	*Carex inversa*
	Gahnia sieberiana	*Cissus antarctica*
	Baumea juncea	
Dominant Understorey Cover (weeds)	no weeds	*Cinnamomum camphora*
		Tradescantia fluminensis
		Lantana camara
		Bidens pilosa
Dominant Organic Litter (natives)	*Melaleuca quinquenervia*	
	Angophora costat	
	Syncarpia glomulifera	
Dominant Organic Litter (weeds)	no weedy litter	*Cinnamomum camphora*
Dominant Vines	no vines	*Stephania japonica*
		Smilax australis
		Trophis scandens

Part 4 - Catchment Summaries

4.1. Introduction

The development of a standardised means of collecting, analysing and presenting riverine, coastal and estuarine assessments of ecological condition has been identified as a key need for coastal Catchment Management Authorities and Local Councils who are required to monitor natural resource condition, and water quality and quantity in these systems. This project was conducted over a 12 month period in 2011 in the Coffs Harbour Region covering Bonville/Pine Creeks, Boambee/Newports Creeks, Coffs Creek, Moonee Creek, Hearnes Lake, Darkum Creek, Woolgoolga Lake, and Corindi/Saltwater Creeks to contribute to the assessment of the ecological condition of the catchment. The project aimed to

- Assess the health of coastal catchments using standardised indicators and reporting for estuaries, and freshwater river reaches using hydrology, water quality, riparian vegetation and habitat quality, and macroinvertebrates assemblages as indicators of ecosystem health in streams of the Coffs Harbour region, and

- Contribute scientific information to the development of a report card system for communicating the health of the estuarine and freshwater systems in the Coffs Harbour City Council region.

This section will provide a summary for each of the study catchments, identifying major issues with water quality, macroinvertebrate communities and riparian condition, and the potential drivers of change in these systems.

4.2 Bonville and Pine Creeks

Concentrations of TN and TP consistently exceeded trigger values, with TN in estuarine reaches exceeding trigger values between 72 and 100% of sample events (Table 4.1). The high concentrations of nutrients did not result in persistently high chlorophyll a concentrations, with the trigger value of 3.3µg/L exceeded between 18 and 36% of sampling events in estuarine reaches. The high chlorophyll a concentrations were generally recorded after rainfall and high flow events and coincided with high turbidity values that may have limited the growth of phytoplankton during these periods. Concentrations of faecal coliforms did not exceed the trigger value for primary contact despite the urban populations surrounding the lower reaches of both systems. Saturation of dissolved oxygen frequently fell below the trigger value of 80% in all sites except BONV1 where tidal exchange most influenced dissolved oxygen. Values for dissolved oxygen at remaining sites ranged from 9 to 55.4%, generally recorded at the base of the water column during times of low flow rather than following rainfall events. These low values were persistent and sufficient to affect aquatic processes and biota, possibly driven by high benthic loads of organic matter increasing respiration.

The high taxa richness and abundance of macroinvertebrates at the freshwater reach of Bonville Creek relative to Pine Creek was not reflected in the mean SIGNAL scores with both recording similar values of 5.4 and 5.2 respectively. This was due to an abundance of pollution tolerant taxa such as Chironomidae (midge) larvae at BONV4 and an abundance of taxa with very few individuals. Nonetheless, both sites had abundant taxa from a range of SIGNAL scores from 2-9 indicating the system has a diversity of habitats, food resources and water quality to sustain diverse populations. The Riparian condition scores reflected the positive macroinvertebrate outcome with an overall mean of 6.87/10 for the system, with very good Habitat, Bank Condition and Disturbance scores. The Vegetation score was lowest in these sites with introduced *Lantana camara* and *Paspalum* grasses dominating sites.

4.3 Boambee and Newports Creeks

Concentrations of TN and TP consistently exceeded trigger values, with TN all sites exceeding trigger values between 72 and 100%, and TP between 10 and 45% of sample events (Table 4.2). The highest concentrations of nutrients and resultant concentrations of chlorophyll a that exceeded the trigger values were evident in reaches proximal to the tidal limit and most pronounced during higher temperature and low flow conditions. Up to 54% of sample events also had turbidity values exceeding the trigger value, generally occurring following high rainfall events and coinciding with high nutrient concentrations suggesting the excess N and P are a result of catchment run-off. Surprisingly, concentrations of faecal coliforms did not exceed the trigger value for primary contact despite the urban populations surrounding the lower reaches of both systems. Saturation of dissolved oxygen frequently fell below the trigger value of 80% in all sites. Minimum values for dissolved oxygen ranged from 5 to 74%, generally recorded at the base of the water column during times of low flow. These low values were persistent and sufficient to affect aquatic processes and biota, and may be a result of high nutrient suspended sediment being deposited following high flow events.

These two creek systems followed the same pattern as Bonville and Pine Creeks, with the larger Boambee Creek having substantially higher taxa richness and abundance of macroinvertebrates compared to Newports Creek. Similarly, both sites recorded mean SIGNAL scores of 4.6 and 4.3 respectively. This was due to an abundance of pollution tolerant taxa such as Chironomidae (midge) larvae and Elmidae (Beetles) at BOAM4, and Atayidae (freshwater shrimps) at NEW3. Nonetheless, both sites had abundant taxa from a range of SIGNAL scores from 2-8 indicating the system has a diversity of habitats, food resources and water quality to sustain diverse populations. However, the persistent low dissolved oxygen saturations from these sites have potential to influence the distribution of less-mobile macroinvertebrates. The Riparian condition scores reflected this outcome with an overall mean of 6.84/10 for the system, with average scores for all four indices. The dominance of introduced Camphor Laurel trees in the canopy, *Lantana camara* understory influences both the condition of the riparian zone, but also the organic matter sources driving aquatic food webs in these reaches.

Table 4.1 Summary table for percent exceedence of trigger values and maximum value for chlorophyll a, TN, TP, Turbidity, and faecal coliforms. Macroinvertebrate family richness, abundance and mean SIGNAL score, and mean riparian condition score are provided for freshwater sites in Boambee and Pine Creeks.

	Chla %	Max µg/L	TN %	Max µg/L	TP %	Max µg/L	Turbidity %	Max NTU	Faecal Coli %	Max Fc/100ml	Macroinvertebrates			Riparian Score
											Richness	Abundance	SIGNAL2	
BONV1	**20**	13	**100**	880	**10**	100			0	148				
BONV2	**20**	11	**90**	640	**40**	100	**4**	13.4						
BONV3	**18**	10	**73**	660	**36**	90								
PINE1			**100**	510	**18**	110	**2**	16.8						
PINE2	**36**	17	**82**	610	**45**	110	**11**	25.6						
BONV4			**9**	530	**27**	100					28	368	5.4	7.24
PINE3			**11**	780	**10**	80					12	143	5.2	6.50

Table 4.2 Summary table for percent exceedence of trigger values and maximum value for chlorophyll a, TN, TP, Turbidity, and faecal coliforms. Macroinvertebrate family richness, abundance and mean SIGNAL score, and mean riparian condition score are provided for freshwater sites in Bonville and Newports Creeks.

	Chla %	Max µg/L	TN %	Max µg/L	TP %	Max µg/L	Turbidity %	Max NTU	Faecal Coli %	Max Fc/100ml	Macroinvertebrates			Riparian Score
											Richness	Abundance	SIGNAL2	
BOAM1	**8**	5	**73**	640	**18**	145			0	110				
BOAM2	**25**	10	**100**	810	**18**	100	**33**	20						
BOAM3	**41**	9	**100**	103	**45**	110	**8**	21.8						
NEW1	**25**	8	**100**	850	**36**	100	**54**	25.2						
NEW2	**16**	5	**99**	760	**36**	110	**26**	19						
BOAM4			**91**	106	**18**	70	**7**	42.9			22	197	4.6	6.42
NEW3	**8**	6	**70**	750	**10**	80					10	83	4.3	7.26

4.4 Coffs Creek

Concentrations of TN and TP consistently exceeded trigger values, with TN all sites exceeding trigger values between 72 and 100%, and TP between 10 and 64% of sample events (Table 4.3). The highest concentration of both nutrients was evident in reaches proximal to the tidal limit with TN and TP concentrations over two times the trigger values for estuarine systems. The upper estuarine reaches of COFFS2 and COFFS3 were also impacted by chlorophyll a concentrations exceeding trigger values 55% and 46% of sample events respectively, with maximum values over eight times the trigger value. Turbidity values also frequently exceeded the trigger value in estuarine reaches, but at a different time of year to the high nutrient concentrations. Concentrations of faecal coliforms ranged from 0fc/100mL during low flows up to 950 fc/100mL during rainfall events, exceeding the primary and secondary contact thresholds on two occasions. Saturation of dissolved oxygen frequently fell below the trigger value of 80% in all sites. Minimum values for dissolved oxygen ranged from 34 to 76%, generally recorded at the base of the water column during times of low flow. These low values were persistent and sufficient to affect aquatic processes and biota.

Coffs Creek had the lowest taxa richness of macroinvertebrates of all catchments with just 12 families recorded. A mean SIGNAL score of 4.9 for the freshwater site is biased by 8 of the 12 taxa having fewer than 3 individuals. The numerically dominant taxa were Chironomidae (midges) with a SIGNAL score of 3, suggesting the system has a limited range of habitats and food resources and reflect the poor water quality in these reaches. The Riparian condition scores did not reflect the poor result for macroinvertebrates with an overall mean of 7.31/10 for the system, with good scores for Bank Condition and Disturbance indices. The dominance of introduced Camphor Laurel trees in the canopy and understory as regrowth, *Ligustrum lucidum* understory and *Paspalum* grasses resulted in a poor score for vegetation and habitat.

4.5 Moonee Creek

Concentrations of TN and TP consistently exceeded trigger values, with TN and TP at all estuary sites exceeding trigger values between 80 and 91% of sample events irrespective of high or low flow conditions (Table 4.4). The freshwater reach had the highest recorded concentration of almost 2 times the trigger value, but was during December with high temperatures and low water levels suggesting localized release of nutrients from sediments. In all sample times except following high rainfall in July, concentrations of faecal coliforms were below the trigger value for primary contact. Saturation of dissolved oxygen frequently fell below the trigger value of 80% in all sites except for MOON1 that was well-flushed from tidal exchange. Minimum values for dissolved oxygen ranged from 26% at MOON3 reflecting poor water quality at the tidal limit, and were generally recorded from the base of the water column profile.

Moonee Creek had the second lowest taxa richness of macroinvertebrates with only 13 families recorded. A mean SIGNAL score of 4.3 is biased by 10 of the 13 taxa having fewer than 5 individuals. The numerically dominant taxa were Chironomidae (midges) and Atyidae (freshwater shrimp) accounted for 90% of the abundance and have a SIGNAL score 3, suggesting the system has poor water quality and habitat availability.

Table 4.3 Summary table for percent exceedence of trigger values and maximum value for chlorophyll a, TN, TP, Turbidity, and faecal coliforms. Macroinvertebrate family richness, abundance and mean SIGNAL score, and mean riparian condition score for the freshwater site in Coffs Creek.

	Chla %	*Max µg/L*	***TN %***	*Max µg/L*	**TP %**	*Max µg/L*	**Turbidity %**	*Max NTU*	***Faecal Coli %***	*Max Fc/100ml*	***Macroinvertebrates***			***Riparian Score***
											Richness	*Abundance*	*SIGNAL2*	
COFFS1			**72**	*860*	**18**	*330*	**33**	*10.1*	**17**	*950*				
COFFS2	**55**	*26*	**100**	*1200*	**21**	*110*	**25**	*25*						
COFFS3	**46**	*28*	**100**	*1190*	**64**	*120*	**25**	*15*						
COFFS4			**90**	*1270*	**10**	*55*					*12*	*165*	*4.9*	*7.31*

Table 4.4 Summary table for percent exceedence of trigger values and maximum value for chlorophyll a, TN, TP, Turbidity, and faecal coliforms. Macroinvertebrate family richness, abundance and mean SIGNAL score for the freshwater site in Moonee Creek.

	Chla %	*Max µg/L*	***TN %***	*Max µg/L*	**TP %**	*Max µg/L*	**Turbidity %**	*Max NTU*	***Faecal Coli %***	*Max Fc/100ml*	***Macroinvertebrates***		
											Richness	*Abundance*	*SIGNAL2*
MOON1			**80**	*470*	**80**	*110*	**17**	*15*	**8**	*415*			
MOON2	**28**	*6*	**89**	*820*	**89**	*100*	**7**	*10.2*					
MOON3	**37**	*8*	**91**	*780*	**91**	*150*	**28**	*15.6*					
MOON4			**26**	*920*	**26**	*80*					*13*	*90*	*4.3*

Table 4.5 Summary table for percent exceedence of trigger values and maximum value for chlorophyll a, TN, TP, Turbidity, and faecal coliforms in Hearnes Lake.

	Chla %	*Max µg/L*	***TN %***	*Max µg/L*	**TP %**	*Max µg/L*	**Turbidity %**	*Max NTU*	***Faecal Coli %***	*Max Fc/100ml*
HEAR1	**45**	*11*	**100**	*1300*	**30**	*70*	**32**	71.5		*113*
HEAR2	**54**	*27*	**100**	*1785*	**30**	*70*	**73**	100		
HEAR3	**64**	*54*	**100**	*840*	**10**	*35*	**40**	64		

4.6 Hearnes Lake

Concentrations of TN exceeded trigger values for estuary systems 100% of sampling events, with the highest recorded value of 1785µg/L nearly 6 times the trigger value (Table 4.5). Concentrations of TP exceeded trigger values on 10 to 30% of sampling occasions aligning with the sample times that TN concentrations were also high during high temperature and low flow conditions. Turbidity values in Hearnes Lake were consistently higher than in the other coastal systems in this study, exceeding the trigger value by a factor of 7 between 32 and 73% of sample events. Highest turbidities were in the months following high rainfall. High concentrations of TN and TP, and high turbidity led to the chlorophyll a trigger value exceeded between 45 to 64% of sample events across all sites, the highest of any system in the study area. Maximum concentrations of faecal coliforms of 113 fc/100mL during rainfall events did not exceed the primary contact thresholds. Dissolved oxygen at this site was not measured as saturation and comparisons with trigger values cannot be made. There was evidence for dissolved oxygen concentrations as low as 0.68mg/L, concentrations that will severely impact aquatic biota and facilitate nutrient regeneration processes.

4.7 Woolgoolga Creek

Concentrations of TN consistently exceeded trigger values, with concentrations at all estuarine sites exceeding trigger values between 50 and 90% of sample events (Table 4.6). The highest concentration of both nutrients was evident in reaches proximal to the tidal limit with TN and TP concentrations over two times the trigger values for estuarine systems. The upper estuarine reach of WOOL3 was also impacted by chlorophyll a concentrations exceeding trigger values 55% of sample events, with maximum values over five times the trigger value. Turbidity values also frequently exceeded the trigger value in estuarine reaches associated with high rainfall events. Interestingly, the freshwater reach WOOL4 did not exceed the trigger value for turbidity during the same period. Concentrations of faecal coliforms were generally low except for high rainfall periods, peaking at a very high 2860 0fc/100mL in June. Dissolved oxygen at this site was not measured as saturation and comparisons with trigger values cannot be made. There was evidence for dissolved oxygen concentrations persistently low at all sites with minimum concentrations ranging from 1.95mg/L to 5.2mg/L recorded at the bottom of the water column. These concentrations have the potential to impact aquatic biota and facilitate nutrient regeneration processes.

Woolgoolga Creek had the second highest taxa richness of macroinvertebrates with 25 families recorded, and the highest mean SIGNAL score of 5.6 of all catchments in the study. The two most numerically dominant taxa were two families of caddis flies with SIGNAL scores of 8 and 7, suggesting the system has a diversity of habitats and food resources for macroinvertebrates. In particular, both taxa of caddis flies dominating this site require organic matter (leaves, sticks) from native plants to construct cases, providing an important link to the condition of the riparian zone. The Riparian condition at WOOL4 scored a mean of 6.96/10 for the system, with good scores for Bank Condition and Disturbance indices. The riparian zone was described as a Tallowood gallery forest with a diversity of native mid- and understory species, as well as introduced species such as *Ligustrum lucidum* understory and *Paspalum* grasses.

Table 4.6 Summary table for percent exceedence of trigger values and maximum value for chlorophyll a, TN, TP, Turbidity, and faecal coliforms, Macroinvertebrate family richness, abundance and mean SIGNAL score, and mean riparian condition score for freshwater sites in Woolgoolga Creek.

	Chla %	Max µg/L	TN %	Max µg/L	TP %	Max µg/L	Turbidity %	Max NTU	Faecal Coli %	Max Fc/100ml	Macroinvertebrates Richness	Macroinvertebrates Abundance	Macroinvertebrates SIGNAL2	Riparian Score
WOOL1	**18**	*5*	**90**	*595*	**10**	*65*	**25**	*47*	**8**	*2860*				
WOOL2	**10**	*16*	**50**	*645*	**20**	*80*	**54**	*40*						
WOOL3	**55**	*12*	**89**	*630*	**44**	*65*	**40**	*60*						
WOOL4			**18**	*670*	**10**	*7*					*25*	*265*	*5.6*	*6.96*

Table 4.7 Summary table for percent exceedence of trigger values and maximum value for chlorophyll a, TN, TP, Turbidity, and faecal coliforms for Darkum Creek.

	Chla %	Max µg/L	TN %	Max µg/L	TP %	Max µg/L	Turbidity %	Max NTU	Faecal Coli %	Max Fc/100ml
DARK1	**41**	*12*	**100**	*810*	**18**	*45*	**80**	*49.6*	**8**	*162*

Table 4.8 Summary table for percent exceedence of trigger values and maximum value for chlorophyll a, TN, TP, Turbidity, and faecal coliforms, Macroinvertebrate family richness, abundance and mean SIGNAL score, and mean riparian condition score for freshwater sites in Arrawarra Creek.

	Chla %	Max µg/L	TN %	Max µg/L	TP %	Max µg/L	Turbidity %	Max NTU	Faecal Coli %	Max Fc/100ml	Macroinvertebrates Richness	Macroinvertebrates Abundance	Macroinvertebrates SIGNAL2	Riparian Score
ARR1	**44**	*6*	**90**	*690*	**30**	*65*	**10**	18.5	**8**	*3000*				
ARR2	**44**	*5*	**90**	*645*	**30**	*70*	**50**	40						
ARR3			**90**	*580*	**10**	*60*					*18*	*198*	*4.7*	*8.7*

4.6 Darkum Creek

Concentrations of TN exceeded trigger values for estuary systems 100% of sampling events, with the highest recorded value of 810µg/L nearly 3 times the trigger value (Table 4.7). Turbidity and chlorophyll a concentrations exceeded trigger values 80% and 41% of sample events respectively. Combined, these values indicate persistent poor water quality in Darkum Creek associated with both high flow and low flow conditions. Similarly, low level concentrations of faecal coliforms were persistent throughout the study period (mean 65 fc/100mL) with a peak of 162 fc/100mL in May. Saturation of dissolved oxygen frequently fell below the trigger value of 80%, with a minimum value of just 4.4% recorded, providing evidence for concentrations that will severely impact aquatic biota and facilitate nutrient regeneration processes.

4.8 Arrawarra Creek

Concentrations of TN consistently exceeded trigger values, with concentrations at all sites exceeding trigger values 90% of sample events (Table 4.8), with concentrations consistently 2 times the trigger value. Both estuary reaches also has chlorophyll a concentrations that exceeded the trigger value 44% of sample events, however the maximum concentration of 6 µg/L is less than 2 times the trigger value. The upper estuarine reach of Arrawarra Creek was also impacted by chlorophyll a concentrations exceeding trigger values 55% of sample events, with maximum values over five times the trigger value. Turbidity values at the tidal limit frequently exceeded the trigger value and were not linked to high flow conditions. Concentrations of faecal coliforms were generally low except for June when coliform counts peaked at a very high 3000 0fc/100mL. Dissolved oxygen at this site was not measured as saturation and comparisons with trigger values cannot be made. There was evidence for dissolved oxygen concentrations persistently low at upstream sites with minimum concentrations of 2.45mg/L recorded at the bottom of the water column at ARR3. These concentrations have the potential to impact aquatic biota and facilitate aquatic processes.

Eighteen taxa of macroinvertebrates were recorded from Arrawarra Creek with a mean SIGNAL score of 4.7. The two most numerically dominant taxa were two families of Dipterans (fly larvae) with SIGNAL scores of 3, reinforcing the poor water quality and habitat availability. The Riparian condition at ARR4 8.7/10 was the highest of all the catchments in the study. Excellent scores for Bank Condition and Disturbance indices contributed to the high score. The riparian zone at this site had no overstory and a mid- and understory dominated by a diversity of native species.

4.9 Corindi River and Saltwater Creek

All sites on Corindi and Saltwater Creeks had concentrations of TN that exceeded trigger values, with concentrations at all sites exceeding trigger values between 45 and 100% of sample events (Table 4.9). Unlike other coastal systems, both Corindi and Saltwater had TN and TP concentrations in excess of the trigger values. However, low turbidity and chlorophyll a concentrations at these freshwater sites indicate there were limited consequences to algal productivity from elevated nutrient concentrations. Similar to other coastal systems, the poorest water quality was recorded at the tidal limit, including dissolved oxygen concentrations as low as 20%. Concentrations of faecal coliforms were consistently below the trigger value.

Table 4.9 Summary table for percent exceedence of trigger values and maximum value for chlorophyll a, TN, TP, Turbidity, and faecal coliforms. Macroinvertebrate family richness, abundance and mean SIGNAL score, and mean riparian condition score for freshwater sites in Corindi and Saltwater Creeks.

	Chla %	*Max µg/L*	*TN %*	*Max µg/L*	TP %	*Max µg/L*	Turbidity %	*Max NTU*	*Faecal Coli %*	*Max Fc/100ml*	*Macroinvertebrates*			*Riparian Score*
											Richness	*Abundance*	*SIGNAL2*	
COR1			**55**	*445*	**9**	*35*				*2*				
COR2			**100**	*1100*			**5**	*10.5*						
COR3	**13**	*16*	**64**	*590*	**30**	*50*	**47**	*57.9*						
SALT1	**11**	*4*	**82**	*490*										
SALT2	**56**	*8*	**82**	*595*	**9**	*50*								
COR4			**60**	*910*	**30**	*120*					*24*	*246*	*4.6*	*7.82*
SALT3			**45**	*700*	**9**	*60*					*17*	*116*	*3.9*	*6.71*

The high taxa richness and abundance of macroinvertebrates at the freshwater reach of Corindi relative to Saltwater Creek was similar to the pattern found in Bonville/Pine and Boambee/Newports systems. The high taxa richness was not reflected in the mean SIGNAL scores with both recording low values of 4.6 for Corindi and the lowest score in the study of 3.9 in Saltwater Creek. The numerically dominant taxa in both systems were Chironomidae (midges) and Atyidae (freshwater shrimp) accounting for 90% of the abundance and have a SIGNAL score 3, suggesting the system has poor water quality and habitat availability. The Riparian condition scores did not reflect the poor macroinvertebrate outcome with an overall mean of 7.82/10 for Saltwater and 6.71 for Corindi Creek. The freshwater site at Corindi was dominated by the invasive Camphor Laurel with a *Lantana camara* mid-storey, whereas Saltwater was dominated by natives such as Angophora and native grasses.

Part 5 – Summary and Recommendations

Water chemistry was sampled monthly from 40 sites (10 freshwater, 30 estuarine) from 12 river systems in the Coffs Harbour LGA during 2011. The study was undertaken in a period with above average annual rainfall, with 7 months exceeding long-term monthly averages. Two events exceeding 400mm occurred during the study period and had a clear influence on many of the water quality variables. Trigger values from the ANZECC and NSW MER guidelines were used to interpret water quality data.

Main findings

- Concentrations of Total Nitrogen exceeded the guideline value at some point in all river systems, with the majority of systems exceeding the value more than 50% of the time. Systems with reduced flushing such as Darkum Creek and Hearnes Lake exceeded guideline values on all sampling events, whereas larger systems with increased tidal exchange such as Coffs Creek often exceeded guideline values during high flow events. Elevated Nitrogen concentrations did not consistently result in increased primary production, requiring an investigation to determine if increased nitrogen leads to a decline in ecosystem health or if systems have adapted to increased Nitrogen loads.
- The number of times Total Phosphorus concentrations exceeded guideline values was less than 50% at all sites. The exception was Moonee Creek, where all estuary sites exceeded the guideline value on at least 80% of the sampling events. Investigations into point and diffuse sources of Phosphorus in this catchment are required to minimize impact on ecosystem health of elevated Phosphorus levels.
- Increased chlorophyll *a* concentrations were not directly linked to elevated Total Nitrogen concentrations. In cases where guideline values for chlorophyll *a* were exceeded, both Total Nitrogen and Total Phosphorus concentrations were elevated, suggesting algal productivity in the study estuaries are limited by the concentration of phosphorus. As a consequence, both Darkum Creek and Hearnes Lake had concentrations above the guideline value over 40% of the sampling events. Investigations into nutrient concentrations, loads and hydrology (residence time and flushing) are required to determine the ecosystem responses to increased nutrients and chlorophyll concentrations.
- Low dissolved oxygen concentrations were evident at the majority of the sites, generally during periods of low flow conditions and warmer temperatures. Saturation levels were consistently below the guideline value at all sites throughout the study period, and below 10% at Darkum Creek and Hearnes Lake. Dissolved oxygen levels this low can lead to stress on biota and reduced environments in the water column promoting nutrient release.
- Faecal coliforms were clearly linked to high flow events, and therefore are a consequence of localized runoff. Coffs Creek, Moonee Creek and Darkum Creek all recorded concentrations above the primary contact threshold, and Woolgoolga Creek and Arrawarra Creek recorded concentrations almost double the secondary contact threshold.
- The poorest water quality was recorded from the sites closest to the tidal limit, highlighting their role as a depositional environment for both freshwater and estuarine contaminants, highlighting the importance of this zone being a focal point for future monitoring programs.

- Water quality issues were recorded in both high and low flow conditions, identifying the importance for sampling these coastal systems during both types of hydrologic conditions.

Aquatic macroinvertebrates are non-vertebrate aquatic animals that are visible to the naked eye and which live at least part of their life within a body of freshwater. Because many macroinvertebrates live in a river reach for an extended period of time they can integrate the impacts on the ecosystem over an extended period of time, rather than just at the time of sampling. Macroinvertebrates were collected from 10 freshwater sites in 10 stream systems in Spring and Autumn 2011.

- Family level taxonomic richness ranged from 28 in Bonville Creek to just 12 in Coffs Creek. Similarly, the abundance of individuals ranged from 368 in Bonville Creek to 83 in Newports Creek when both sample periods were combined. The low richness and abundance of macroinvertebrates in the majority of systems suggests these sites have a level of degradation.
- SIGNAL scores ranged from a maximum of 5.6 in Woolgoolga Creek to 3.9 in Saltwater Creek. These scores are particularly low and indicate long-term degradation of water quality and instream habitat.
- The numerical dominance of macroinvertebrate individuals from pollution tolerant and generalist feeding families such as Chironomidae (midge larve) and Atyidae (freshwater shrimps) highlights that these systems are dominated by taxa resilient to long-term disturbances and poor water quality. The exception was Woolgoolga Creek that was dominated by pollution sensitive Caddis Fly larvae with high SIGNAL scores.
- There was a consistent trend among systems with a main stem and tributary of substantially higher richness, abundance and SIGNAL scores in the main stem relative to the smaller tributary. This was evident in Bonville/Pine, Boambee/Newports and Corindi/Saltwater systems.

The riparian land is an intermediary semi-terrestrial zone with boundaries that extend outward from the waters edges to the limits of flooding and upward into the canopy of the riverside vegetation. The area within a riparian zone contains valuable water resources, highly fertile soil and supports high levels of biodiversity as well as many social and economic functions. An assessment of the riparian condition was undertaken from the 10 freshwater sites in 2011.

- Riparian condition scores ranged from a maximum of 8.7/10 in Arrawarra Creek to 6.5/10 in Pine Creek.
- A number of sites such as Corindi, Coffs and Pine Creeks were dominated by the invasive Camphor Laurel as the overstory. The majority of sites had *Lantana camara* as a dominant plant in the mid- and understory layers.
- Exceptions were Saltwater creek dominated by natives such as *Angophora* and native grasses, Arrawarra Creek dominated by native *Ficus* and *Syzygium* mid-story, and Woolgoolga Creek with an overstory dominated by a Tallowood gallery forest with a diversity of native mid- and understory species.
- The majority of sites recorded excellent scores for the Bank Condition index, highlighting the current role of both native and exotic riparian species in minimizing erosion despite the number of large rainfall events during the study.

Management Priorities and Recommendations

Future Monitoring

Analyses of spatial and temporal sampling procedures provide guidance for the optimization of future monitoring in the Coffs LGA. Major outcomes from these analyses are:

- Maintaining a minimum of one freshwater and 2 estuary sites (1 at tidal limit and 1 at estuary mouth) of each of the major subcatchments is recommended. The intention of multiple sites within each river systems is to detect longitudinal trends in water quality and biotic variables.
- Retaining the suite of water quality variables and sampling procedures (water column profiles in sites >1m depth) is recommended as all variables positively contributed to the understanding of issues at each site and development of site-based scores for the report card.
- Season affected the taxonomic composition and abundance of macroinvertebrates in freshwater reaches. Future macroinvertebrate sampling should include autumn and spring, but should consider further research into the link between geomorphic characteristics, condition and hydrology as many of the freshwater sites have degraded physical condition and reduced flow (many sites cease-to-flow) during dry climate periods.
- The riparian condition index contributes to the management priorities by identifying biological (weeds) and biophysical (bank erosion) drivers and should be retained for freshwater reaches as an annual survey. The inclusion of an on-ground riparian assessment for estuarine reaches that includes measures of invasive species and bank condition is recommended to align the data from the riparian assessments in both freshwater and estuary reaches.
- The La Nína conditions experienced in the region during 2011 have influenced the water quality and ecological condition recorded in this study. Ecohealth sampling one out of every four years for the CHCC reporting for SoE/SoC may not reflect the long-term condition of the sites as much as the influence of short-term climate conditions of La Nína and El Níno cycles. It is recommended to consider target sampling to specific flow conditions (>80th percentile) in defined time periods (seasonal) over a multi-year timeframe. This will facilitate the capture of data from all sites under similar flow conditions and replicated temporal periods (seasons) within the four year reporting period (e.g., 1 sample/season, 4 seasons/year, for 3 years = 12 sample times). This recommendation removes the sampling of flood periods from the Ecohealth program. Impact of floods on ecological condition and flood-recovery would require a separate sampling program.

Recommendations

- Investigate ecosystem responses to consistently elevated organic and inorganic nitrogen concentrations in creek and lake systems of the Coffs LGA to determine if increased nitrogen leads to a decline is ecosystem health.
- Investigate the drivers of elevated TN, Chlorophyll *a* concentrations and low DO concentrations in Darkum Creek, Hearnes Lake and Woolgoolga Creek catchments.
- Examine potential point- or diffuse-source catchment contributions of TP to Moonee Creek.

- Investigate point- and diffuse-source of elevated faecal contamination and links to stream hydrology, and remediation options for Woolgoolga, Arrawarra, Coffs, Moonee and Darkum Creeks where elevated concentrations were recorded following rainfall events.
- Future monitoring and assessment to acknowledge the importance of sampling freshwater and tidal reaches under a range of flow conditions.
- Review restoration priorities of stream corridors to include systems impacted by weed species such as Camphor Laurel (particularly in Coffs Creek) and Lantana (in Bonville, Boambee and Corindi systems) and at high-risk of bank erosion (identified in freshwater reaches of Woolgoolga and Corindi systems).

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APPENDIX 1 – Water quality field data sheet

Date:________________________________

Site Name:___________________________ Site ID:________________________

Location: Easting_________________ Northing____________ Datum _________

Decimal degrees - Lat _________ Long____________Elevation _______

Field Personnel ____

Start Time (24 hr) _______________________ End time (24hr) ________________

High Tide Time/Height ____________________ Low Tide Time/Height ____________

Equipment: (Make/Model)___________________ Serial/ID number________________

Calibrated by: _________________________ Calibration Log Complete? Y N

Air Temp ________________________

Weather Conditions

Water Surface: ☐ flat ☐ choppy ☐ rough

Wind: ☐ nil ☐ light ☐ moderate

Rainfall: ☐ nil ☐ light ☐ moderate ☐ heavy in last ☐ 24 hours ☐ 2-5 days

Sky: ☐ sunny ☐ overcast

Depth (m)	Temp (C)	pH	Cond (mS/cm)	Salinity (ppt)	DO (mg/L)	DO (% sat)	Turb (NTU)
0.1							
1.0							

Ecohealth Water Quality Data Sheet

Secchi Depth (m)	
Maximum depth (m)	
Water Velocity ($m.sec^{-1}$) – *freshwater sites only*	

Bacterial sample – *At mouth of estuary only*	Yes	No	Sample ID:	
Duplicate TN/TP sample	Yes	No	Sample ID:	
Duplicate SRP/NOx sample	Yes	No	Sample ID:	
Chl a volume filtered (mL)			Sample ID:	
TSS volume filtered (mL)			Sample ID:	

Samples Forwarded to (Lab Name): ____

Chain of custody form completed: Y N

Comments
