# Coffs Harbour Region Ecohealth Project 2014-2015

## Assessment of River and Estuarine Condition

**Final Technical Report**

**April 2016**

**Darren Ryder, Sarah Mika, Ben Vincent, Adrienne Burns and John Schmidt**

COFFS HARBOUR CITY COUNCIL

NSW GOVERNMENT Office of Environment & Heritage

une University of New England

Aquatic Ecology and Restoration RESEARCH GROUP

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Cover Photo: Arrawarra Creek (B. Vincent, 2015).

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David Greenhalgh: Solitary Islands Marine Park (SIMP)

Ana Baker, Max Richardson: University of New England

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# Glossary of General Terms

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|---|---|
| Algal biomass | The mass of algae in a water body at a given time. |
| Aquatic macroinvertebrates | Larger aquatic invertebrates, functionally defined as those retained on a 500µm sieve. Their body length usually exceeds 1mm. |
| Bank slumping | The mass movement of bank material after failure. |
| Chlorophyll *a* | A green pigment found in plants that allows them to photosynthesise. Chlorophyll *a* measurements are an indicator of the amount of phytoplankton and algae in a water body. |
| Dissolved oxygen (DO) | The concentration of gaseous oxygen ($O_2$) dissolved in an aqueous solution. |
| Geomorphic condition | An assessment of bank condition (e.g. slope, bank slumping, exposed tree roots and undercutting), bed condition (active erosion and smothering of the bed substrate by high loads of fine sediment) and trampling by stock. |
| Ecohealth indicators | A selection of measurements that indicate if there are stresses to the aquatic ecosystem as a whole. Indicators include water quality (dissolved oxygen, salinity, acidity, turbidity, nutrients), riparian condition (vegetation composition, occurrence of riparian weeds, riparian habitat), geomorphic condition and composition of aquatic macroinvertebrate communities. |
| Oxides of nitrogen (NOx) | Compounds of nitrogen and oxygen, primarily NO, $NO_2$, $N_2O$ and $N_2O_5$. |
| pH | The dissolved hydrogen ion concentration. Acidic solutions have a pH < 7, basic solutions have a pH > 7. |
| Riparian condition | The health of a riparian zone, based on an assessment of the occurrence of weeds, structure of riparian vegetation, habitat (e.g. logs) and management regime. |
| Riparian zone | The area of land adjoining rivers and streams that has a direct influence on the water and aquatic ecosystems within those rivers and streams. It includes stream banks and a strip of land of variable width along the banks. |
| SIGNAL2 | SIGNAL stands for "Stream Invertebrate Grade Number – Average Level". SIGNAL2 is a scoring system for Australian macroinvertebrates based on their sensitivity to pollution. |
| Soluble reactive phosphorus (SRP) | The concentration of inorganic ions of phosphorus (predominately $HPO_4^{2-}$ and $PO_4^{3-}$) in water. These ions are available to be used by aquatic biota. |
| Total nitrogen (TN) | The concentration of nitrogen in the water, both in organic and inorganic forms. |
| Total phosphorus (TP) | The concentration of phosphorus in natural or anthropogenic substances that contain, or decompose to produce phosphate ions. |
| Total suspended solids (TSS) | All particles suspended in water that do not pass through a 1.2µm filter. |
| Turbidity | The cloudy appearance of water due to suspended material. |

## Glossary of Soil Terms

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|---|---|
| A horizon | The top soil layer containing the greatest concentration of organic material. Consists mainly of clay minerals and quartz with an absence of soluble minterals. |
| Anthroposol | Soils arising from human activities where soil horizons are profoundly modified, truncated or buried; the creation of new soil parent materials by mechanical means. |
| B horizon | The second soil layer comprising an illuvial concentration of silicate clay, iron, aluminium, humus, carbonates, gypsum or silica alone or in combination. |
| Dermosol | Soils having structured subsurface horizons with a lack of textural contrast between A and B horizons. |
| Ferrosol | Soils with subsurface horizons that are high in free iron oxide and that lack textural contrast between surface and subsurface horizons. Formed from basic or ultrabasic igneous rocks or alluvium derived from these. |
| Hydrosol | Soils other than organosols, podosols or vertosols in which the greater part of the soil profile is saturated for at least 2-3 months in most years. |
| Kandosol | Soils that lack strong textural contrast, have massive or weakly structured B horizons, have a maximum clay content exceeding 15% in the B2 horizon, and do not have a calcareous A horizon. |
| Kurosol | Soils with strong textural contrast between A horizons and strongly acid B horizons. |
| Podosol | Soils with B horizons dominated by the accumulation of organic matter, aluminium and/or iron. |
| Rudosol | Typically young soils with neglibile pedologic organization. These soils vary widely in texture and depth with many stratified and some highly saline. |
| Tenosol | Soils that have weak pedologic organization apart from the A horizon. These soils are diverse but includes soils having a peaty horizon or overlying a calcrete pan or hard, unweathered rock. |
| Vertosol | Clay soils (clay texture greater than 35%) with shrink-swell properties that exhibit strong cracking when dry and at depth, have slickensides and/or lenticular structure aggregates. |

# Glossary of Vegetation Terms

| | |
|---|---|
| Canopy | Growth form: the tallest growing layer of vegetation in a plant community. |
| Connectivity | The degree of continuous uninterrupted vegetation: is used as a measure of riparian condition. |
| EEC | Endangered Ecological Community, as determined by State and Federal Government. |
| Fire regime | Refers to the pattern, frequency and intensity of fire. |
| Forb/herb | A small non-woody flowering plant found in the understory. |
| Fringing vegetation | The terrestrial riparian vegetation directly adjacent to a water body/channel, specifically graminoides. |
| Graminoid | Growth form: a collective term for all monocotyledons - grasses, sedges and rushes. |
| Intact remnant | An area of native vegetation that has had little-to-no disturbance or alterations. Remnant conditions can vary from being intact to disturbed. |
| Leaf litter | The collective term for fallen leaves on the ground. |
| Macrophyte | Plant species found growing in water or wetland, which may be submergent, emergent or floating. |
| Midstorey | Growth form: those plants found growing to a height of greater than c.1.5 metres and less than 5 metres. |
| Proximity | How close the patch of vegetation under assessment is to a good condition, large remnant stand of native vegetation. |
| Riparian condition | The health of a riparian zone, based on an assessment of the occurrence of weeds, structure of riparian vegetation habitat (e.g. logs) and management regime. |
| Riparian zone | The area of land adjoining rivers and streams that has a direct influence on the water and aquatic ecosystems within those rivers and streams. It includes stream banks and a strip of land of variable width along the banks. |
| Phase-out strategy | Strategically staggered removal of a weed species (e.g. Camphor Laurel). Such removal allows time for native plantings to replace weed species, while simultaneously maintaining bank stability and wildlife habitat. |
| Species of Interest (SOI) | Refers to both exotic weeds (noxious and environmental), and native species that are rare, uncommon or are an indicator of condition in a vegetation system. |
| Weed control | Where environmental and noxious weed species are reduced or removed through chemical, mechanical, or physical means. |
| Weed monitoring | Where weed species are repeatedly surveyed for their range expansion and potential spread. |
| Understorey | Growth form: those plants found growing to a height of less than c.1.5 metres. |
| Vegetation | All flowering and non-flowering land and water plants. |

# 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 Local Councils who are required to monitor natural resource condition, and water quality and quantity in these systems. Thirty-one study sites were selected across the Coffs coastal catchment; 11 freshwater sites and 20 estuarine sites. These sites were sampled 8 times from September 2014 to December 2015 to contribute to the assessment of the ecological condition of the catchment.

The 14 Coffs coastal catchments were divided into 9 hydrologic units for reporting: Corindi River, Saltwater Creek and Pipeclay Lake; Arrawarra Creek; Darkum Creek; Woolgoolga Creek; Willis Creek and Hearnes Lake; Moonee Creek; Coffs Creek; Boambee and Newports Creeks; and Bonville and Pine Creeks. 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, geomorphic condition and macroinvertebrate assemblages as indicators of aquatic ecosystem health, 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 region.

**Report Card**

The Overall Grade for the Coffs coastal catchment was C-, ranging from an F in Willis Creek, to a C in the Corindi River and Arrawarra, Boambee and Bonville Creeks. Four of the 14 river systems recorded a score of D+ or less. With the exception of aquatic macroinvertebrates that were very poor across the catchment, scores were relatively consistent among indicators within each system, highlighting that issues with water quality, biota and physical condition are affecting the short and long-term condition of the streams.

***Geomorphic Condition***

Geomorphic condition ranged from good to poor throughout the freshwater and estuarine reaches of the Coffs coastal catchment. The subcatchment-scale assessment of stream condition aligned with the site-scale geomorphic assessments, identifying the upper freshwater reaches as predominantly in good or moderate condition, particularly those in conservation reserves. Estuarine reaches were mostly in moderate to poor condition. Geomorphic condition typically declined with riparian condition, highlighting the established importance of maintaining healthy native vegetation to promote bank stability, and that similar stressors (e.g. stock or human trampling) negatively impact both aspects of aquatic ecosystem health.

### *Riparian Condition*

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. Riparian condition was assessed for freshwater reaches and found to be moderate throughout all of the Coffs coastal subcatchments, with only one (Coffs Creek) of the 14 river systems recording a score of D or lower. Saltwater and Moonee Creeks and Hearnes Lake had good riparian condition and Arrawarra Creek had excellent riparian condition.

The main stressors to riparian condition were the dominance of invasive weeds, vegetation clearing causing reduced riparian continuity and isolation from large patches of remnant vegetation, and access by livestock. The most common dominant weed species were Paspalum (*Paspalum dilatatum*), Lantana (*Lantana camara*), Blue Billy Goat Weed (*Ageratum houstonianum*), Crofton Weed (*Ageratina adenophora*) and Senna (*Senna pendula* var. *glabrata*). The influence of clearing and physical stressors (trampling and grazing) have reduced the recruitment of native vegetation in the riparian zone at several sites.

Strongly linked to riparian condition, the active restoration of native riparian vegetation as a long term action for improving geomorphic condition and aquatic macroinvertebrate habitat should be a priority in the Coffs coastal subcatchments.

### *Mangrove, seagrass and saltmarsh cover*

From 1985 to 2011, total mangrove cover and saltmarsh cover increased across the Coffs Harbour estuaries, by 2% and 30%, respectively. The largest increases in mangrove cover occurred in the Corindi River/Saltwater Creek estuary, followed by Moonee estuary. The largest increases in saltmarsh cover occurred in the Corindi River/Saltwater Creek estuary, followed by Boambee/Newports Creek estuary. Mangrove cover decreased in Darkum Creek estuary and saltmarsh decreased in Moonee estuary.

Total seagrass cover decreased by 62% over the same period, and this decrease occurred over all 5 of its recorded sites. The largest decreases in seagrass cover occurred in the Bonville/Pine Creek estuary, Corindi River/Saltwater Creek estuary and Boambee/Newports Creek estuary. Anthropogenic factors that can lead to seagrass decline include global warming and sea-level rise, high turbidity, elevated nutrient levels, stormwater discharge, heavy metal and toxin pollution, substrate loss through erosion, siltation, mining and dredging, coastal development, boat moorings and propeller damage, and competition from introduced species. Management priorities should include long-term monitoring of cover change and addressing the causes of seagrass decline.

### *Water Quality*

Water quality was fair across the Coffs coastal catchments, with an overall grade of C. Water quality declined from 2011 to 2015 in the Corindi River, and Saltwater, Coffs, Newports and Pine Creeks. Water quality improved from 2011 to 2015 in Hearnes Lake, and Darkum, Boambee and Bonville Creeks.

The poorest water quality was recorded at tidal limits, highlighting their role as depositional environments for both freshwater and estuarine contaminants, and the importance of this zone as a focal point for future monitoring programs. Despite lower total nutrient concentrations in 2015 than 2011, very low stream discharge likely resulted in poor hydrological flushing of estuaries and high internal recycling of nutrients, leading to higher algal productivity in 2015 than 2011. Monitoring of bioavailable nutrients, such as Soluble Reactive Phosphorus (the form directly used by aquatic algae and plants), would help identify links between water quality and the biological responses to poor water quality.

No low pH events (<4) were recorded during this study as baseflow rather than flood conditions were sampled. The lowest pH in the study (4.28) was recorded at the tidal limit in Bonville Creek (BONV3) in August 2015. However, pH commonly fell below the trigger threshold in estuary sites.

### *Aquatic Macroinvertebrates*

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. Family level taxonomic richness ranged from 8 in Newports Creek to 35 in Bonville Creek. Similarly, the abundance of individuals ranged from a very low 21 individuals in Newports Creek to 610 in Woolgoolga Creek. Macroinvertebrate community condition improved from 2011 to 2015 in the Bonville/Pine Creeks and Coffs Creeks, but declined in all other subcatchments. The largest declines in condition were observed in the Corindi River, Moonee Creek and Arrawarra Creek.

Macroinvertebrate condition was very low throughout the Coffs coastal catchments. This reflects poor water quality and habitat conditions. The potential for localized increases in macroinvertebrate condition (e.g. Bonville Creek) suggest efforts to improve macroinvertebrate condition should target water quality (nutrients and turbidity) and habitat restoration (e.g. riparian fencing and native revegetation, increases in woody and organic debris). Riparian revegetation with native species will improve the availability of food and promote bank stability, reducing the localized inputs of fine sediments that smother benthic habitat.

### *Fish*

Freshwater fish community condition was assessed in the Corindi River and Woolgoolga, Coffs, Boambee and Bonville Creeks. Overall, fish community condition in the Coffs coastal catchments was good, with Bonville Creek having the best fish community condition. Fish community condition was fair in the Corindi River, and Woolgoolga and Coffs Creeks.

**Recommendations**

- Review Council's listing of noxious weeds and consider including Camphor Laurel (*Cinnamomum camphora*), Senna (*Senna pendular* var. *glabrata*), Singapore Daisy (*Sphagneticola trilobata*), Castor Oil Plant (*Ricinus communis*), Crofton Weed (*Ageratina adenophora*), Morning Glory (*Ipomoea indica*) and Mickey Mouse Plant (*Ochna serrulata*).
- Site-level recommendations to improve riparian condition are given in Part 4. Strategies include monitoring and removal of weeds, riparian fencing and native revegetation.
- Monitor seagrass cover in Coffs estuaries, particularly Bonville/Pine Creek estuary, Corindi River/Saltwater Creek estuary and Boambee/Newports Creek estuary, and investigate causes of seagrass decline in these three estuaries.
- Investigate ASS in the Corindi/Saltwater estuary to identify acid inputs to the estuary.
- Investigate sources of TN at SALT3, PIPE1, ARRA1, DARK1, WOOL1, WOOL3, WILL1, HEAR1, HEAR4, MOON1, MOON3, BOAM3 and BOAM4.
- Investigate point- and diffuse-sources of TP at WILL1, COFFS1, COFFS3 and COFFS4.
- Investigate the role of bioavailable nutrients particularly SRP in promoting high algal productivity at NEW2, NEW3, BONV3 and PINE2.
- Investigate point- and diffuse-sources of faecal coliforms at PIPE1, ARRA1, DARK1, WILL1, HEAR1 and COFFS1.

**Partnerships**

This project was a successful partnership among Coffs Harbour City Council, NSW Office of Environmental and Heritage, SIMP and the University of New England. The inclusion of staff from Councils and Agencies increased the number of sites that could be sampled as part of the program. Continued partnerships are essential, and ensuring training for staff involved will maintain quality data and ensure project outcomes are maximized.

# 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 Local Land Services (LLS), 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 of estuarine or freshwater ecological condition in NSW. 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 region to supplement the MER monitoring and is aligned with the objectives of regional Coastal Zone Management Plans.

### 1.2 Scope

Estuarine 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, and degraded through habitat destruction and changes in biodiversity. 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 Local Land Services and local councils who are required to monitor and report on natural resource condition and water quality and quantity in these systems.

This project uses the Ecohealth framework that integrates 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 State of Catchments (SoC) reports, EHMP Healthy Waterways program; proposed estuary report cards from the NLWRA (through WA Department 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 Ecohealth Waterways Monitoring Program outlines a framework for the development of a catchment-based aquatic health monitoring program for rivers and estuaries with the aim of providing consistency in monitoring and reporting, and establishes the partnerships required for local and regional dissemination of outcomes. This project brings together major stakeholders in the management of coastal catchments in Northern NSW including state agencies (OEH, DPI, SIMP), local councils and university researchers (UNE) to develop, refine, report and promote a standardised river and estuary health assessment tool.

This report provides the second baseline dataset for water quality, freshwater macroinvertebrates, and freshwater riparian and geomorphic condition in the catchments of the Coffs Harbour region. This framework provides an effective reporting mechanism to communicate water quality and resource condition to the general public, stakeholders and managers through simple report cards. This technical report also compares this second baseline dataset to the first baseline dataset captured in 2011, to assess changes in ecological and physical condition over time. Additionally, this program provides specific monitoring and management plans for the study area using the generic framework that outlines a standardised (and tested) set of partnership, monitoring, data management and reporting protocols implemented in coastal catchments throughout the Northern Rivers region.

## 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, macroinvertebrate assemblages, condition of riparian and aquatic vegetation, and geomorphic condition as indicators of ecosystem health in streams of the Coffs Harbour region;
2. Assess the temporal change in aquatic ecosystem health in catchments in the Coffs Harbour region from the 2011 Ecohealth progam to this 2015 Ecohealth program;
3. Inform management priorities and actions for the catchments in the Coffs Harbour region; and
4. 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 Harbour region as context of the need for river and estuarine monitoring, and to provide the background to the study design and site selection processes:

2.1 **Study Area** 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 the detailed description of the study design and protocols for site selection.

2.3 **Study Sites** provides locations and the sampling regime for the 31 study sites.

2.4 **Sampling Methods and Indicators** includes the range of water quality conditions measured, analysis of aquatic macroinvertebrate communities in freshwater sites, geomorphic measures of channel and bank characteristics, riparian condition, and local management issues.

Part 3 of the report details the water chemistry and biophysical data collected from September 2014 to December 2015. Results for water chemistry, macroinvertebrates, riparian and geomorphic condition are reported for each of the nine major hydrological units (that is, Bonville and Pine Creeks, Boambee and Newports Creeks, Coffs Creek, Moonee Creek, Willis Creek and Hearnes Lake, Woolgoolga Creek, Darkum Creek, Arrawarra Creek, and Corindi River, Saltwater Creek and Pipeclay Lake (Figure 2.1). Water chemistry variables assessed include nutrients (nitrogen and phosphorus), chlorophyll *a* and suspended solids, as well as water column profiles for pH, salinity and dissolved oxygen. Exceedances of NSW MER or ANZECC guideline thresholds are identified.

Macroinvertebrate assemblages collected from freshwater sites in autumn 2015 and spring 2015 were used to assess long-term condition of in-channel habitats and health indicators using diversity, SIGNAL2 scores and percent EPT. The riparian condition assessment of freshwater sites includes habitat, native species presence, percentage cover, woody and non-woody debris, management issues, as well as identification of local-scale disturbances to riparian zones. The geomorphic condition assessment of freshwater sites includes site-scale bank and bed condition, and management issues, as well as a subcatchment scale assessment of geomorphic condition. Condition scores are calculated for water chemistry, aquatic macroinvertebrate community assemblages (freshwater sites only), riparian condition and geomorphic condition. These form the basis of the report cards and are collated for the entire Coffs Harbour region, Subcatchments and Sites.

The catchment, subcatchments and sites are organised accordingly:

3.1 Coffs coastal catchments
3.2 Corindi River, Saltwater Creek and Pipeclay Lake
3.3 Arrawarra Creek
3.4 Darkum Creek
3.5 Woolgoolga Creek
3.6 Willis Creek and Hearnes Lake
3.7 Moonee Creek
3.8 Coffs Creek,
3.9 Boambee/Newports Creeks, and
3.10 Bonville/Pine Creeks.

Part 4 of the report details the temporal change observed from the first Ecohealth Round (measured 2011) and this second Ecohealth Round (2014-2015), across all Ecohealth Indices for all of the sites comprising the 2014-2015 Ecohealth project. Part 4 also provides management recommendations for the future management of the instream and riparian condition in rivers and estuaries of the 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 1,173 $km^2$ with approximately 70 kilometres of coastline extending from Pine Creek at Bundagen in the south to Station Creek in the north. The close proximity of the Great Dividing Range to the coast results in a small coastal plain 0-50m elevation above sea level (27% of Coffs LGA, OEH 2012a) comprising 16 major coastal creeks (Figure 2.1). Other landscapes of the Coffs Harbour LGA comprise midland hills 50-250m above sea level (41% of LGA area) and escarpment ranges >250m above sea level (32% of LGA area, OEH 2012a). These escarpment ranges predominantly drain northwards to the Clarence catchment via the Bobo River, Little Nymboida River, Bucca Creek and Orara River.

The geology of the coastal catchments of the Coffs Harbour region are stable weathered Permian and Late Carboniferous metasediments that include the Bellingen Slates, Coramba Beds, Brooklana Beds and Moonbil Siltstones that are dominated by siliceous mudstones, slates, greywackes and siltstones (Figure 2.2). 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. These metasediments are overlain by Triassic and Jurassic sedimentary rocks formed in the Clarence-Moreton Basin that include the Kangaroo Creek Sandstones, Corindi Conglomerates and Walloon Coal Measures (Figure 2.2). There are small areas of volcanic or plutonic intrusions of monzogranite at Diggers Point and Look-at-me-now Headland. The coast and floodplain areas were formed by deposits of unconsolidated sediments in the Pleistocene and Holocene (Figure 2.2).

Soil formation is a combination of the parent lithology's resistance to weathering, mineral composition and chemistry, as well as slope, aspect and moisture. The Permian and Carboniferous metasediments were derived from old marine and riverine sediments. These form fine-grained quartz Kurosols and Kandosols (37 and 47% of the LGA, respectively) ranging from deep red earths on sheltered slopes with high soil moisture, to shallow yellow earths on exposed, drier slopes (Figure 2.3). The coastal plain comprises predominantly unconsolidated alluvial soils along the major non-tidal drainage network, with Holocene estuarine sands, muds and clays in the tidally influenced reaches.

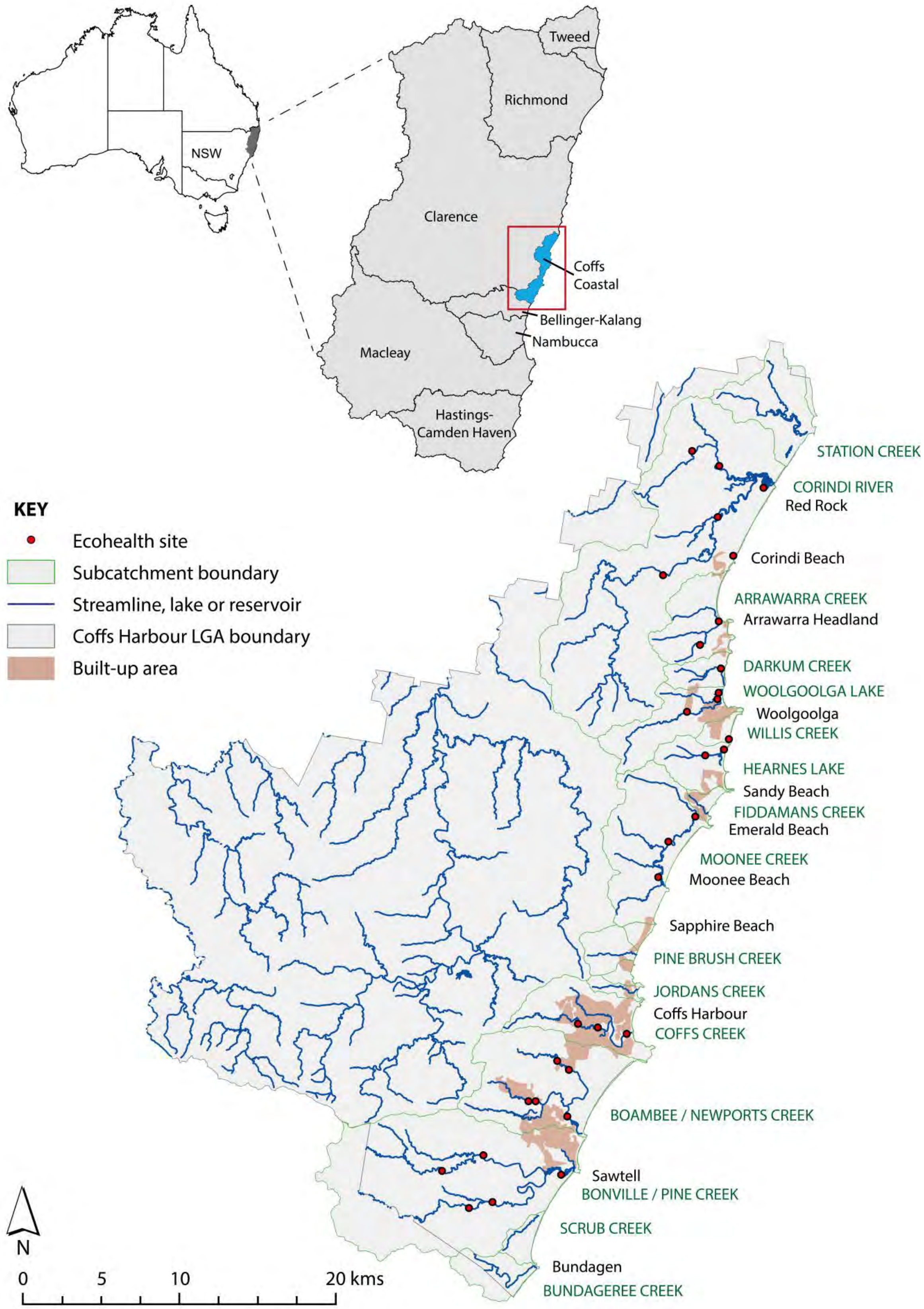



***Figure 0.1*** *The location of Coffs Harbour in the Northern Rivers of NSW showing the region's subcatchments (green lines), location of Ecohealth sites (red circles) and the Coffs Harbour LGA boundary.*

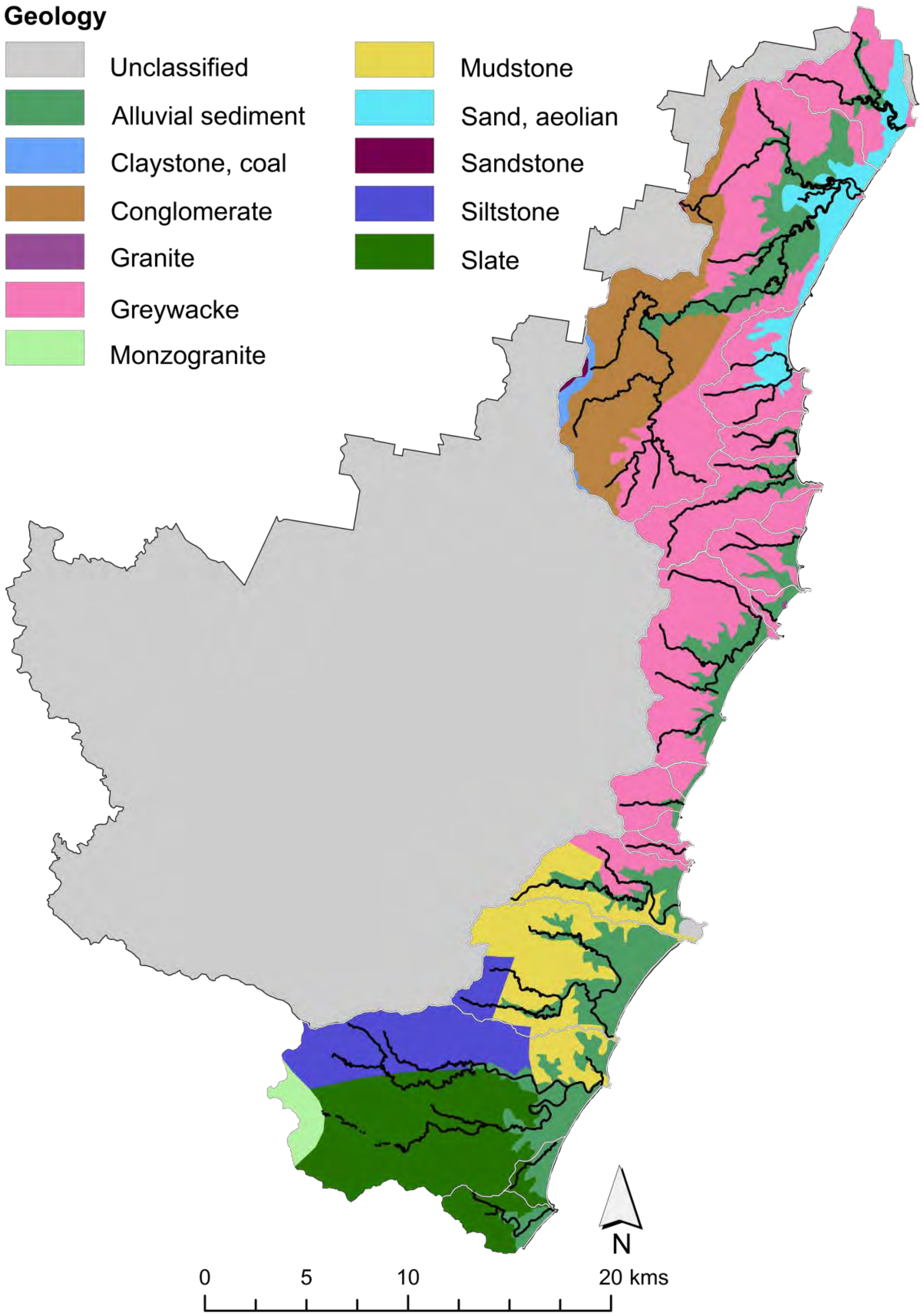



***Figure 2.2*** *Geology of catchments in the Coffs Harbour region.*

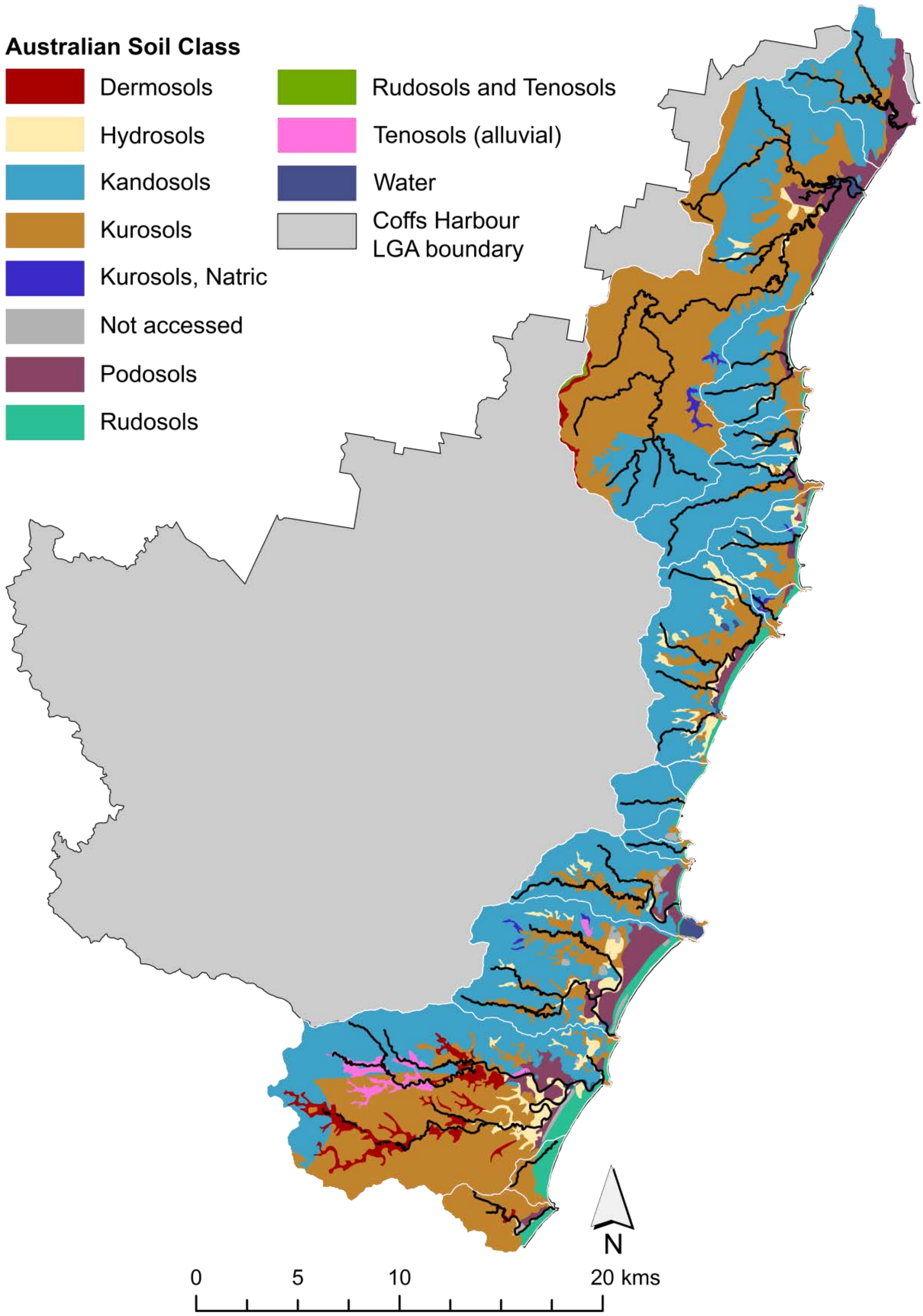



***Figure 2.3** Soils of the Coffs Harbour region.*

Coffs Harbour experiences a humid, sup-tropical climate characterized by warm to hot summers and mild winters. Mean annual temperatures range from maximums of 18.8°C in July to 27.0°C in February and minimums of 7.6°C in July to 19.5°C in February (BOM 2016). The 2015 study period was warmer than the long-term average with consistently higher monthly minimums and maximums (Figure 2.4). Coffs Harbour receives a high average annual rainfall of 1702mm, with most rain falling in late summer to early autumn (BOM 2016). Winter rainfall is typically much less, with dry spells common from April to October (Figure 2.5). Above-average rainfall (annual total of 2242mm) occurred over the 2015 study period, with large monthly totals in January, February and May 2015 (Figure 2.5). Above-average rainfall also occurred during the 2011 study period, which had an annual total of 2294mm.

The escarpment ranges strongly influence rainfall, with high intensity storms and higher rainfall occurring over the coastal plain. Thus, the coastal creeks experience regular flooding due to high intensity rainfall hitting small, relatively steep catchments. Unfortunately, discharge in the coastal creek systems is poorly gauged, with the only gauges in the Coffs Harbour LGA for water level in estuaries. The Orara River at Orange Grove (NOW gauge 204068) is the closest gauge on an unregulated coastal system and here provides indicative discharge of coastal streams in Coffs Harbour LGA (Figure 2.6). Although discharge rates differ, the relative changes in magnitudes of discharge will be indicative of coastal streams for the Coffs Harbour LGA. Long-term average monthly discharge in the Orara River peaks in late summer to early autumn (Figure 2.6). During the 2015 study period, peak monthly discharge occurred in February, March and June, demonstrating a consistent temporal lag from high rainfall events (Figures 2.5, 2.6). Outside of these large rainfall events, baseflows were below the long-term average (Figure 2.6). Although the total annual rainfall was similarly above-average in 2011 and 2015, it was more evenly distributed through the study period. Hence, spring streamflow was above average in 2011 but significantly below average in 2015. This impacted the macroinvertebrate community condition in spring 2015 across the Coffs coastal catchments.

Because of the short, steep catchments and high intensity rainfall events in the region, Coffs Habour LGA experienced significant flood events in 1917, 1938, 1950, 1963, 1974, 1977, 1989, 1991 and 2009. The record maximum flood level in Coffs Habour Creek was 5.4m in 1996 and 5.1m in 2009, with both of these events triggering significant flash flooding. Major wildfires occurred in the Coffs Harbour LGA in 1977, 1990 and 1994. The largest wildfires occurred in the conglomerate and sandstone escarpment ranges in the north and steep gorges in the north-west. However, there have been several wildfires in the coastal Moonee Beach Nature Reserve, and Bongil Bongil and Yuraygir National Parks.

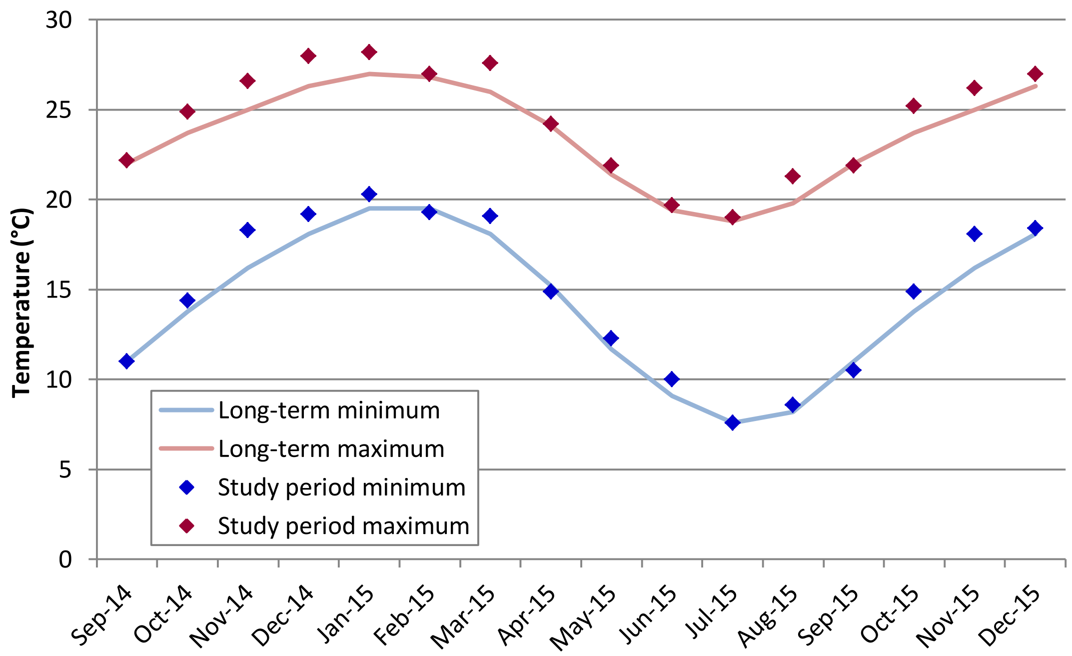



***Figure 2.4*** *Average monthly maximum and minimum temperatures over the study period in comparison to long-term average monthly maximum and minimum temperatures at Coffs Harbour (BOM gauges 059151 for study period and 059040 for long-term averages).*

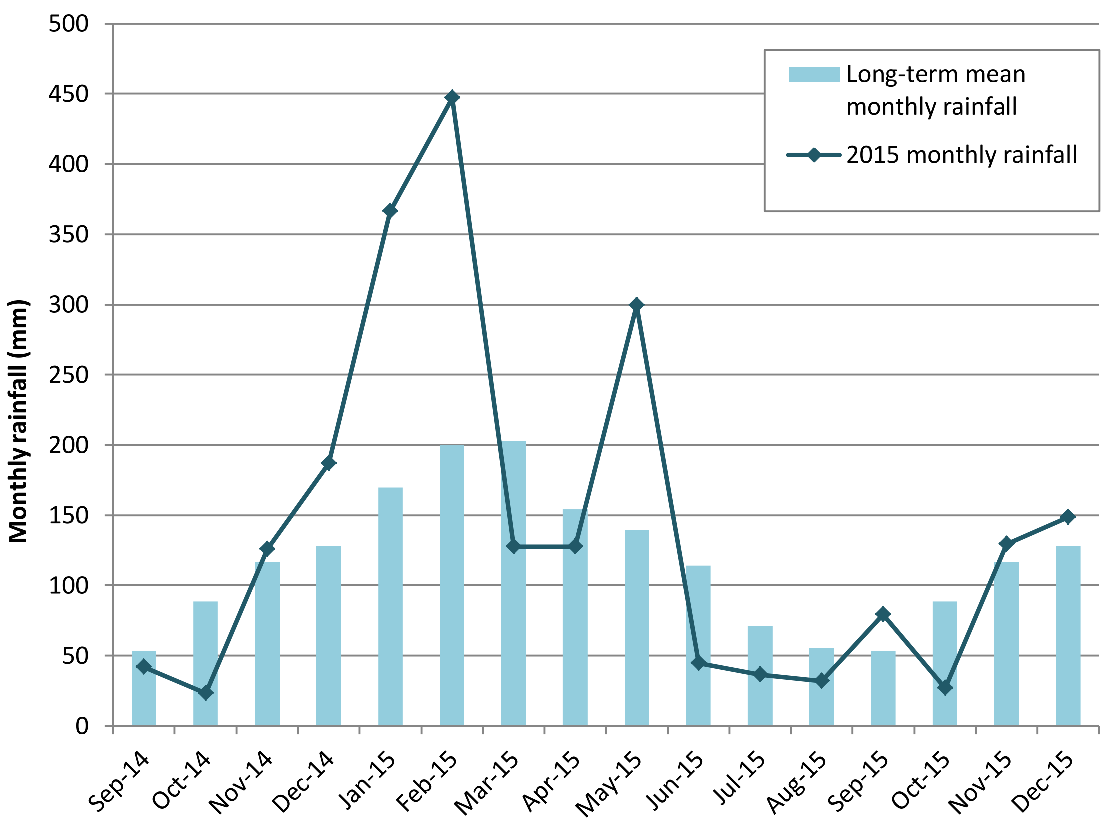



***Figure 2.5*** *Monthly rainfall over the study period in comparison to the long-term average monthly rainfall at Coffs Harbour (BOM gauges 059151 for study period and 059040 for long-term averages).*

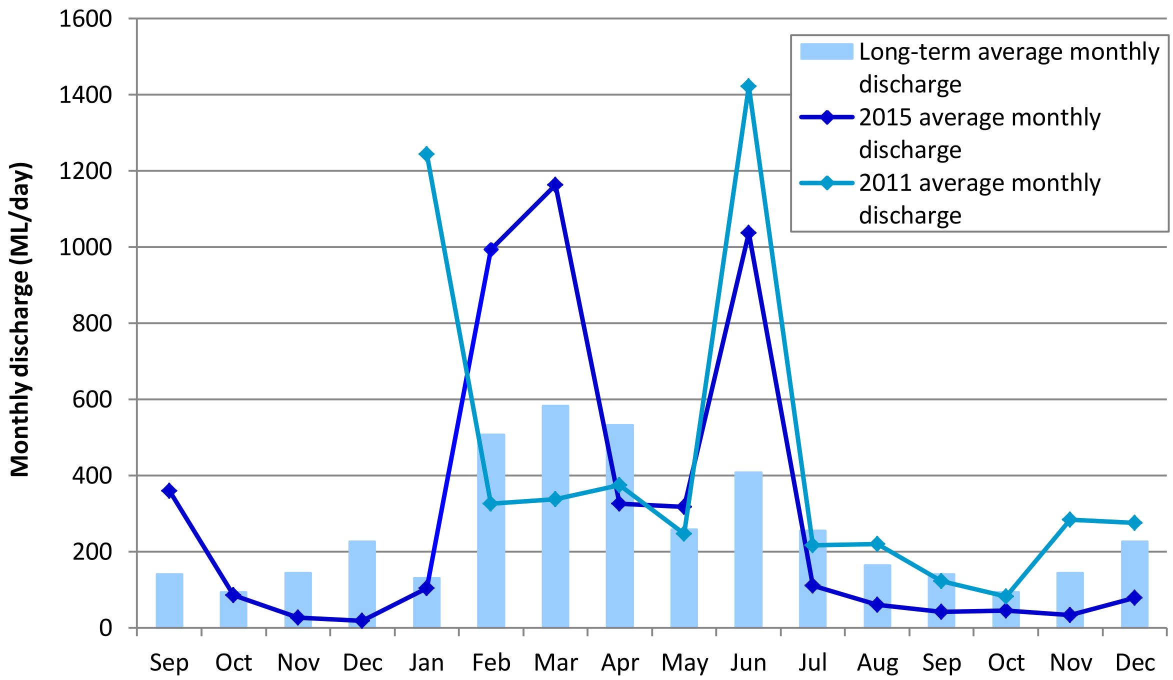



***Figure 2.6*** *Average monthly discharge over the 2015 study period (September 2014 to December 2015) and 2011 study period (January to December 2011) in comparison to the long-term average monthly discharge of the Orara River at Orange Grove (NOW gauge 204068).*

The dominant landuse in the Coffs Harbour LGA is conservation area (39% of LGA) which encompasses national parks, private conservation agreements and the Solitary Islands Marine Park (48km$^2$ in total) as well as state forest (134km$^2$). The second dominant landuse is tree and shrub cover (21% of LGA), which is primarily native forest (82km$^2$) not under conservation protection (Figure 2.7). Most of this vegetated area exists on the escarpment ranges and to a lesser degree, the midland hills. These areas are mostly rural and support grazing (16% of LGA), forestry and isolated areas of horticulture (bananas and blueberries).

Urban areas comprise 12% of the Coffs LGA (58km$^2$, Figure 2.7); these are centred on the coastal plain which supports most of the human population (72,000 in the Coffs Harbour LGA, ABS 2014 census). Besides Coffs Harbour, other towns in the LGA include Woolgoolga, Urunga and Sawtell. The gross regional product of Coffs Harbour is estimated at $4.0 billion (2013/2014 data, CHCC 2014). Tourism is an important part of the regional economy, with the total number of tourist visits increasing by 0.3% annually, to a total of 1,597,000 visits in 2014.

Coffs Harbour LGA sources its domestic water from the Orara River and Nymboida River. There are two water storage dams: Karangi Dam is 15km west of Coffs Harbour CBD and holds 5,600ML and Shannon Creek Dam is west of the village of Coutts Crossing and holds 30,000ML. Karangi Dam receives water from the Orara River, Nymboida River or Shannon Creek dam via an underground pipeline. Shannon Creek dam receives water from the Nymboida River and supplies water to Coffs

Harbour City Council and Clarence Valley Council areas. There is one active point-source discharger in the Coffs coastal catchments. This is the Pet Porpoise Pool on Coffs Creek with a miscellaneous license to discharge to waters at any time. There are also small sewage treatment works at Woolgoolga, Coffs Harbour and Sawtell that do not discharge to waterways.

Partly confined valley settings (PCVS) account for 45% of the total stream length in the Coffs coastal catchments, followed by laterally unconfined valley setting – continuous channel (LUV CC, 27%), confined valley setting (CVS, 21%), and swampy meadow group (SMG, 6%). Approximately 1% of the catchment's stream channels are classified as highly modified urban streams or water storages (Figure 2.8). Of the total stream length (317 km), 29% are considered to be in good geomorphic condition, 61% in moderate geomorphic condition and 10% in poor geomorphic condition (NC LLS 2014). The stream channels in good condition are dominated by headwaters (28%) and gravel-bed channels with floodplain pockets (17%), while the stream channels in poor condition predominantly comprise planform controlled, meandering fine-grained channels (50%) and planform controlled, low sinuosity, fine-grained channels (15%). The majority of the upper reaches of the Coffs coastal coastal catchments are headwaters and gravel-bed channels with floodplain pockets, while the lower reaches and estuary comprise laterally unconfined, meandering, fine-grained channels (Figure 2.8).

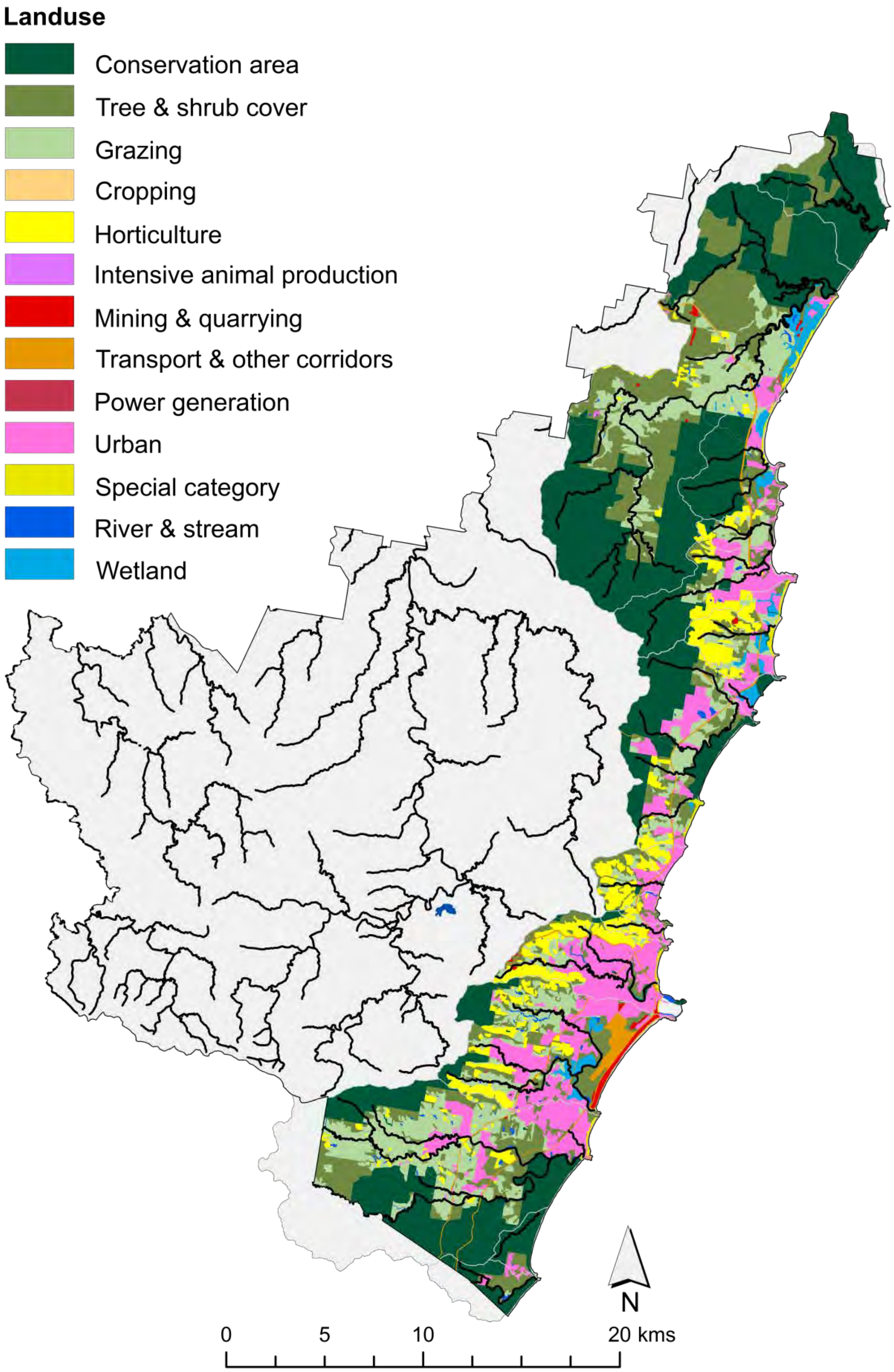



***Figure 2.7*** *Landuse of the Coffs Harbour region.*

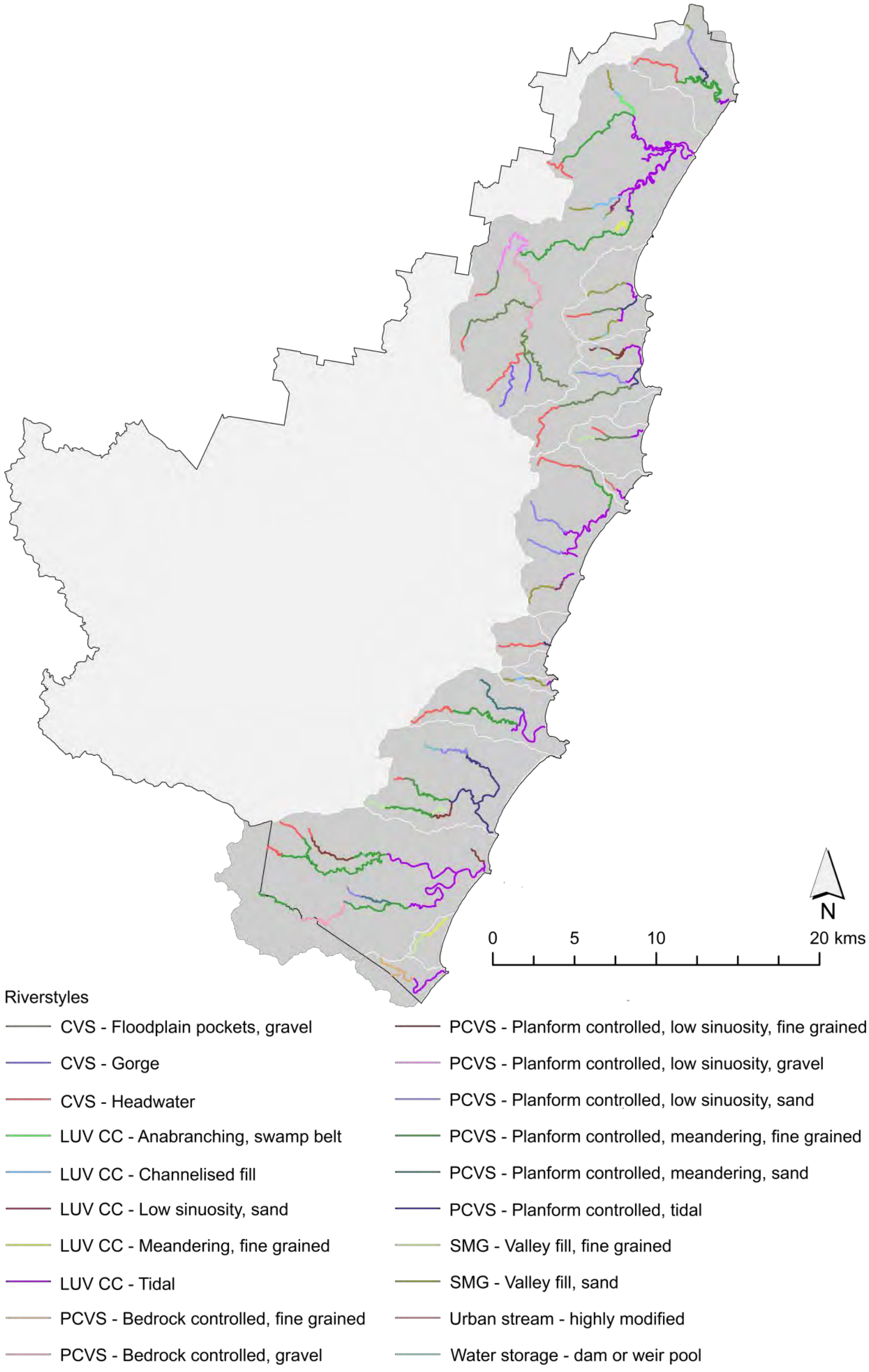



***Figure 2.8*** *River Styles in catchments of the Coffs Harbour region.*

## 2.2 Study design

The design of the Ecohealth freshwater/estuarine monitoring program for catchments in the Coffs Harbour region was based on Ecohealth standard methods (Ryder et al. 2016). The number and location of sample sites were designed to assess spatial and temporal variability of catchments in the Coffs Harbour region with statistical robustness.

Locations of 11 freshwater monitoring sites were selected to:

- Assess end of system inputs from tributaries; and
- Compare River Styles, Condition and Recovery Potential, and elevation within and across subcatchments.

Locations of the 20 estuarine monitoring sites were selected to:

- Identify longitudinal change and potential point source (tributary) issues within the main stem of each river system and end of system flows;
- Compare River Styles, Condition and Recovery Potential within and across subcatchments; and
- Locate ecological changes at the point of the tidal limit.

The design of the Ecohealth program in the Coffs Harbour region required prioritization of sites to optimise available resources.

### *2.2.1 Sampling Schedule*

Water chemistry was sampled 8 times, freshwater macroinvertebrates were sampled bi-annually in autumn and spring 2015, and riparian condition and geomorphic condition were assessed once in October 2015 (Table 2.1).

Sampling events typically comprised 4 days within a month. Multiple freshwater and estuarine sites were sampled on each sampling day to ensure consistency in freshwater discharge and tidal regime. Estuarine sites were consistently sampled on an incoming high tide to maximize boat access to all sites. OEH supplied the boat and skipper as in-kind support to the project. All freshwater sites were sampled via road access. Water quality was sampled by staff from CHCC, SIMP and OEH who were trained in Ecohealth sampling procedures, while aquatic macroinvertebrates, riparian condition and geomorphic condition were assessed by staff from UNE.

***Table 2.1*** *Sampling regime for field collection of water chemistry and biota.*

| Sampling event | Month | Variables at freshwater sites | Variables at estuary sites |
|---|---|---|---|
| 1 | September 2014 | Water quality | Water quality |
| 2 | November 2014 | Water quality | Water quality |
| 3 | March 2015 | Water quality | Water quality |
| 4 | April 2015 | Water quality, aquatic macroinvertebrates | Water quality |
| 5 | July 2015 | Water quality | Water quality |
| 6 | August 2015 | Water quality | Water quality |
| 7 | October 2015 | Water quality, aquatic macroinvertebrates, riparian condition, geomorphic condition | Water quality |
| 8 | December 2015 | Water quality | Water quality |

## 2.3 Study sites

Thirty one sites were sampled within the Coffs Harbour LGA with 11 freshwater sites and 20 estuarine sites spread across 10 creek catchments (Table 2.2). Sites were distributed as follows from north to south: Corindi River (2 estuarine, 1 freshwater), Saltwater Creek (1 estuarine, 1 freshwater), Pipeclay Lake (1 estuarine), Arrawarra Creek (1 estuarine, 1 freshwater), Darkum Creek (1 estuarine), Woolgoolga Creek (2 estuarine, 1 freshwater), Willis Creek (1 estuarine), Hearnes Lake (1 estuarine, 1 freshwater), Moonee Creek (2 estuarine, 1 freshwater), Coffs Creek (2 estuarine, 1 freshwater), Boambee/Newports Creeks (3 estuarine, 2 freshwater) and Bonville/Pine Creeks (3 estuarine, 2 freshwater).

Sites (names and locations) are consistent with the 2011 Coffs Ecohealth project.Any differences are clearly stated in the relevant site descriptions (i.e. sites are new to the 2015 Coffs Ecohealth project or site locations were adjusted to 2015 conditions).

***Table 2.2*** *Location of field sample sites in the Coffs Harbour LGA.*

| Name | Site Code | Easting (m E) | Northing (m S) | Elevation (m) | Salinity Zone |
|---|---|---|---|---|---|
| Corindi River | CORI1 | 521831 | 6683164 | 1 | Marine |
| | CORI3 | 518901 | 6681300 | 12 | Tidal limit |
| | CORI4 | 515408 | 6677577 | 24 | Freshwater |
| Saltwater Creek | SALT2 | 518995 | 6684560 | 10 | Tidal limit |
| | SALT3 | 517268 | 6685511 | 20 | Freshwater |
| Pipeclay Lake | PIPE1 | 519900 | 6678825 | 2 | Lagoon |
| Arrawarra Creek | ARRA1 | 518966 | 6674631 | 2 | Lagoon |
| | ARRA4 | 517767 | 6673123 | 17 | Freshwater |
| Darkum Creek | DARK1 | 519103 | 6671619 | 11 | Lagoon |
| Woolgoolga Creek | WOOL1 | 518958 | 6670065 | 2 | Lagoon |
| | WOOL3 | 518886 | 6669663 | 3 | Tidal limit |
| | WOOL4 | 516934 | 6668853 | 20 | Freshwater |
| Willis Creek | WILL1 | 519611 | 6667105 | 2 | Marine |
| Hearnes Lake | HEAR1 | 519304 | 6666448 | 4 | Lagoon |
| | HEAR4 | 518105 | 6666069 | 16 | Freshwater |
| Moonee Creek | MOON1 | 515103 | 6658283 | 1 | Marine |
| | MOON3 | 515747 | 6660553 | 12 | Tidal limit |
| | MOON4 | 517470 | 6662155 | 13 | Freshwater |
| Coffs Creek | COFFS1 | 521831 | 6648273 | 2 | Marine |
| | COFFS3 | 511238 | 6648680 | 11 | Tidal limit |
| | COFFS4 | 509966 | 6648913 | 12 | Freshwater |
| Boambee Creek | BOAM1 | 509287 | 6642989 | 2 | Marine |
| | BOAM3 | 507259 | 6643963 | 12 | Tidal limit |
| | BOAM4 | 506799 | 6643962 | 12 | Freshwater |
| Newports Creek | NEW2 | 509391 | 6645972 | 8 | Tidal limit |
| | NEW3 | 508642 | 6646544 | 11 | Freshwater |
| Bonville Creek | BONV1 | 508894 | 6639266 | 0 | Marine |
| | BONV3 | 503922 | 6640515 | 9 | Tidal limit |
| | BONV4 | 501275 | 6639506 | 24 | Freshwater |
| Pine Creek | PINE2 | 505279 | 6637530 | 15 | Tidal limit |
| | PINE3 | 502993 | 6637137 | 17 | Freshwater |

## 2.4 Sampling methods and indicators

The indicators chosen focus on the condition of the system to best identify the stressors and pressures that cause change in ecological condition. The selection of indices (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 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 2.3). 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 2.3*** *Water chemistry indicators measured at all sites.*

| In situ measurements | Water quality samples sent for laboratory analysis |
|---|---|
| Water depth | Total nutrients (nitrogen and phosphorus) |
| pH | Dissolved nutrients (nitrate-nitrite, and phosphate) |
| Temperature | Chlorophyll *a* |
| Salinity/Conductivity | Total Suspended Solids (TSS) |
| Dissolved oxygen | |
| Turbidity | |

### *Field and laboratory methods*

At each sampling site, *in situ* water quality measurements were measured with the use of a Hydrolab Quanta, Troll 9500 water quality multi-probe (pH, conductivity, dissolved oxygen (DO), temperature and 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 1m 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 1m 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 the sample was taken at least 1.5m from the edge of the boat or riverbank. Samples were transferred to acid-washed and rinsed (thrice rinsed with sample water) PET containers. Duplicate samples for each parameter were taken from each site. 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 1L bottle of water from 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 analysis.

*Total Suspended Solids*

Total suspended solids (TSS) is a direct measure of turbidity of the water. In the field, a pre-labelled 1-L bottle of water from 0.2m depth was collected at each site using the hand held sampling device, and the sample placed into a cool, dark esky for transport to the Coffs Harbour Water Laboratory for analysis.

*Inorganic Nutrients*

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 1L 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.

### *2.4.2 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 (ANZECC 1994).

The ANZECC *Australian Water Quality Guidelines for Fresh and Marine Waters* were 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. 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 *a* 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 2.4).

***Table 2.4*** *ANZECC Guidelines (2000) and NSW MER – Minimum and Maximum trigger values for freshwater reaches (above and below 150m elevation) and estuarine systems of southeast Australia. *Revised MER trigger values for reference condition coastal systems were used.*

| Category | pH | DO (%) | EC (µScm) | Turbidity (NTU) | Chla (µgL) | NOx* (µgL) | SRP (µgL) | TN (µgL) | TP (µgL) |
|---|---|---|---|---|---|---|---|---|---|
| Freshwater sites >150m | 6.5 – 7.5 | 80-110 | 30 - 350 | 25 | 4 | 25 | 15 | 250 | 20 |
| Freshwater sites <150m | 6.5 - 8 | 80-110 | 125 - 2200 | 50 | 4 | 40 | 20 | 500 | 50 |
| Estuary sites | 7 - 8.5 | 80-110 | no ANZECC values | 10 | 3.3 | 15 | 5 | 300 | 30 |

### *2.4.3 Freshwater 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 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 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 stands for 'Stream Invertebrate Grade Number – Average Level.' It 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 system uses the EPT index. This index claims that although different insect taxa vary 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.

*Field and laboratory methods*

Macroinvertebrates were sampled bi-annually (autumn and spring 2015) at the freshwater sites to align with the MER protocols. Kick net samples (250µm mesh) that comprised 10 linear meters of combined pool, riffle and edge habitats were taken from each of the 11 freshwater sites on each of the two 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 250µm sieves. All taxa from the 2mm and 1mm sieves were recorded, with material retained on the 250µm sieve sorted for a standardized 30-minute period. Macroinvertebrates were identified to Family/genera level, assigned a SIGNAL2 score for pollution tolerance, and the EPT score calculated. Metrics of abundance, richness, and composition were recorded.

### *2.4.4 Riparian condition*

Riparian zones are broadly defined as the interface between terrestrial and aquatic ecosystems (Gregory et al. 1991), and they are found where any body of water directly influences, or is influenced by adjacent land (Boulton et al. 2014). The riparian land is an intermediary semi-terrestrial zone with boundaries that extend outward from the water's edges to the limits of flooding and upward into the canopy of the riverside vegetation (Naiman et al. 2005). Riparian zones are therefore dynamic environmental transition zones that are 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 ecological functions of a riparian zone can be grouped into four main categories: nutrient flux, geomorphic control, temperature and light regulation, and litter input land (Boulton et al. 2014). Each of the four categories involves different attributes of the riparian zone and may encompass significantly different areas of channel bank. The area within a riparian zone contains valuable water resources, highly fertile soil and supports diverse habitats that contain high levels of biodiversity (Naiman et al. 2005). Riparian zones contribute to numerous ecological functions as well as fulfill many social and economic functions, both directly and indirectly. Given the importance of such systems, riparian health is essential.

#### *Rapid Assessment of Riparian Condition*

The Ecohealth Rapid Assessment of Riparian Condition (ERARC) is a multi-metric index of riparian condition, which has been modified from a combination of the Sub-Tropical Rapid Appraisal for Riparian Condition (STRARC) (Southwell 2011), the adapted Tropical Rapid Appraisal of Riparian Condition (TRARC) (Dixon et al. 2006), and the original Rapid Appraisal for Riparian Condition (RARC) (Jansen et al. 2004). The ERARC is comprised of 29 indicators which are grouped into five sub-indices that when combined with equal weighting, calculate to an overall index of riparian condition. The five sub-indices help to identify the general components that contribute to the condition of a site (Dixon et al. 2006). For the purposes of Ecohealth grading, the ERARC was modified to separate out geomorphic condition from riparian condition. Riparian condition subindices and their indicators are listed below in Table 2.5.

In summary the five riparian condition subindices describe:

1. Overall extent and condition of vegetation, and provision of habitat in the riparian zone (HABITAT).

2. Originality, weediness and overall quality of the riparian vegetation (NATIVE SPECIES).

3. Extent of the riparian vegetation footprint with regards to structural complexity (COVER).

4. Presence of dead and decaying vegetative material and fringing vegetation (DEBRIS).

5. Current and historic human induced influences on the riparian zone (MANAGEMENT).

*HABITAT*

Habitats within riparian zones are an important characteristic of riparian condition. Riparian zones play a crucial role in supporting wildlife by providing services such as nesting and roosting habitats, food and shelter from predators and harsh physical conditions, and migratory transport networks. The quality of such services is dependent upon structural complexity, stand age and vegetation continuity and connectivity to larger intact remnant vegetation stands. The HABITAT subindex assesses riparian condition by considering the extent and quality of vegetation, and provision of habitat within the riparian zone. This is achieved by quantifying riparian vegetation continuity and proximity to larger tracts of forest at a landscape scale, channel: riparian width ratio, structural complexity, and the presence of both large and hollow bearing native trees, otherwise known as 'habitat trees', which are known to provide habitat for approximately 15% of all Australian terrestrial vertebrate fauna at any point in time (Gibbons and Lindenmayer 2002). In addition to onsite surveys, spatial data layers from the SIX Maps Vegetation Map Viewer (OEH 2016) are used to assist with the assessment of the Habitat subindex.

*NATIVE SPECIES*

Invasive exotic plant species have the potential to threaten the ecological integrity and productivity of riparian zone ecosystems, by excluding native species, altering nutrient, light and moisture levels, and can have detrimental effects on natural processes such as terrestrial and aquatic invertebrate food webs. The originality and overall quality of the riparian vegetation is assessed at each structural layer with regards to native plant versus weedy plant species. The layers assessed are canopy, midstory, herbs and forbs, graminoids, and macrophytes or vines, depending on the vegetation community present (closed or open forest systems). The identification of the dominant floristics of each structural layer is a valuable additional measure of stand quality and condition, and allows for the important distinction between native and exotic plant species. In addition to onsite surveys, the Atlas of Living Australia (Atlas of Living Australia [ALA} 2016), is used to assist with the assessment of the Native Species subindex.

*COVER*

The number of naturally occurring vegetation layers and the percentage cover of each of these layers found in a system can be used as an indicator of the overall presence and extent of the riparian vegetation footprint. The contribution that each layer adds to the system is quantified and provides an overall indication of the presence of riparian vegetation, its structural complexity and its resilience to major flood and other disturbance events. Each of the five riparian structural layers, canopy, midstory, herbs and forbs, graminoids, and macrophytes/vines, is assessed for its completeness and contributes to overall riparian condition.

*DEBRIS*

Debris refers to the presence of dead and decaying vegetative material and fringing vegetation in the riparian zone. Debris assists with the regeneration of native woody species with the provision of protected habitats, while leaf litter and woody debris are essential for maintaining nutrient cycles and other aquatic and terrestrial ecological processes including food webs. In addition to providing shelter for smaller invertebrates, organic leaf litter is a source of course particulate organic matter, while woody debris in the form of fallen trees and logs provide instream 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). In addition to the provision of core habitat, debris and fringing vegetation aid river bank stabilisation, and are an important foraging resource for a variety of mammals, birds, reptiles, invertebrates and microorganisms. Debris contributes to riparian condition and is assessed by quantifying woody and non-woody debris - dead standing and fallen trees, logs and branches, and leaf litter from both native and exotic species, along with fringing vegetation.

*MANAGEMENT*

This considers both current and historic anthropogenic influences on the riparian zone. A particularly important indicator of disturbance or the lack thereof is the presence and abundance of large trees, given the history of logging and land clearing within upper catchments. Vegetation clearing and the presence of livestock continue to accelerate the deterioration of riparian condition. The presence of fencing indicates that there has been an attempt made to exclude livestock from the site. The MANAGEMENT indicators assessed that contribute to riparian condition are tree clearing, fencing, animal impact, noxious weeds, exposed roots and woody regeneration. If left unchecked, human-induced impacts may be detrimental to the health and the complexity of the plant and animal species of the riparian zone, and accelerate the deterioration of riparian condition. The extent and success of site-level measures taken to improve the ecological condition and function of the riparian zone are also considered.

### *Riparian field methods*

All 11 freshwater sites in the Coffs Harbour catchments were sampled in October 2015 using the ERARC method developed for the Ecohealth project (Ryder et al. 2016). Data for each of the five sub-indices were collected at the reach (100m) scale adjacent to the freshwater sampling sites (Table 2.5), and via desktop survey using satellite imagery, vegetation datalayers and species record lists (Atlas of Living Australia [ALA] 2016, Office of Environment and Heritage [OEH] 2016).

***Table 2.5*** *Vegetation condition subindices, their indicators and scores.*

| Sub-indices and their indicators | Assessment | Score |
|---|---|---|
| **HABITAT** | | **20** |
| Channel width | Riparian vegetation width ÷ channel width | 4 |
| Proximity | Distance to closest stand of native vegetation | 4 |
| Continuity | Longitudinal continuity of riparian vegetation | 4 |
| Layers | Presence/absence of integral growth forms | 4 |
| Large native trees | Presence/absence of large trees (>30cm dbh) | 2 |
| Hollow-bearing trees | Presence/absence of hollow-bearing trees | 2 |
| **NATIVE SPECIES** | | **20** |
| Native canopy species | Percentage of woody native species >5m tall | 4 |
| Native midstory species | Percentage of woody native species <5m tall | 4 |
| Native herb/forb species | Percentage of non-woody understory plants | 4 |
| Native graminoid species | Percentage of grass & grass-like plants | 4 |
| Native macrophyte species | Percentage of in-stream waterplants | 4 |
| **SPECIES COVER** | | **20** |
| Canopy species | Percentage cover of woody native species >5m tall | 4 |
| Midstory species | Percentage cover of woody native species <5m tall | 4 |
| Herb/forb species | Percentage cover of non-woody understory plants | 4 |
| Graminoid species | Percentage cover of grass & grass-like plants | 4 |
| Macrophyte species | Percentage cover of in-stream waterplants | 4 |
| **DEBRIS** | | **20** |
| Total leaf litter | Percentage cover of total leaf litter | 3 |
| Native leaf litter | Percentage cover of native leaf litter | 3 |
| Dead trees standing | Presence/absence of dead trees standing | 3 |
| Dead trees fallen | Presence/absence of dead trees fallen | 3 |
| Lying logs | Presence/absence of lying logs | 4 |
| Fringing vegetation | Presence/absence of graminoids | 4 |
| **MANAGEMENT** | | **20** |
| Tree clearing | Clearing and age of stand assessment | 4 |
| Fencing | Presence/absence of riparian fencing | 3 |
| Animal impact | Evidence of livestock grazing | 3 |
| Species of interest | Presence of uncommon &/or noxious weed species | 2 |
| Exposed tree roots | Extent of exposed tree roots due to erosion | 4 |
| Native woody regeneration | Presence/absence of native woody species | 2 |
| Weedy woody regeneration | Presence/absence of weedy woody species | 2 |

### *2.4.5 Mangrove, seagrass and saltmarsh cover in estuarine sites*

Riparian and in-stream vegetation in estuaries also perform many functions by providing habitat for a wide range of organisms, preventing erosion of banks from storm surge and tidal action, and acting as a buffer to filter nutrients entering estuaries. In estuaries, mangroves are common in the riparian zone, providing crucial nursery habitat to many aquatic organisms including commercially important fish and prawn species. Seagrasses are also a critical part of estuaries and coastal lagoons. They provide primary production and stability to habitats, and support nurseries and food webs for important species including fish, prawns and invertebrates. One of the most common factors leading to the loss of seagrass is direct human disturbance (hauling nets, boat anchors) or indirect effects from increasing water turbidity and reducing light penetration.

Cover of estuarine macrophytes (mangroves, seagrass and saltmarsh) for 9 of the Coffs estuaries was calculated using the 2011 spatial dataset provided by NSW Department of Industry and Investment – Primary Industries and Energy. The total area of mangrove, seagrass and saltmarsh, and the average patch size of each were calculated for each estuary system. An initial survey of estuarine macrophytes for the same Northern River estuary systems was undertaken in 1985 (Crease et al. 2009). While the two mapping exercises provide a basis for assessing broad change in relation to estuarine macrophyte cover in Northern River estuaries, it is difficult to determine error arising from differences in methodology. Future surveys using the 2011 methods will provide a more accurate assessment of actual temporal change in estuarine macrophyte cover.

### *2.4.6 Geomorphic Condition*

Fluvial geomorphology refers to the sediment dynamics of river systems, from the configuration of entire stream networks within catchments to the organisation of sediment particles within a single feature in a stream reach. These complex sediment erosion and transport processes form the physical template that regulates ecological habitat and processes in rivers. Human disturbances can negatively affect the equilibrium of these sediment erosion and transport processes. For example, catchment and riparian clearing can accelerate erosion and delivery of sediment to the stream channel, where it is stored and transported slowly over many floods. However, while the sediment is stored within the channel, it may negatively impact stream ecology by physically smothering habitat, releasing nutrients and contaminants into the streambed or water column, or damaging stream biota.

The condition of the geomorphic template is assessed once for each site during a low-flow period, usually concurrent with the riparian condition assessment. The assessment considers the condition of stream banks (freshwater and estuary sites), stream bed (freshwater sites), and local management that directly impacts reach-scale geomorphic condition. The assessment is conducted within the River Styles framework that classifies stream reaches according to the shape of the surrounding river valley, the shape and mobility of the channel within the valley and the dominant sediment size of the channel.

### *Geomorphic field methods*

Geomorphic condition was assessed at two spatial scales. Subcatchment scores and grades were calaculated using the entire stream network for each subcatchment using the River Styles 2014 data layer supplied by NC LLS. The proportions of total subcatchment stream length in Good, Moderate and Poor Condition were calculated and weighted (3, 2, and 1 for Good, Moderate and Poor, respectively). These were summed to a total score, divided by 3 and converted to proportions. The standard Ecohealth grading structure was applied to each subcatchment proportions.

Site-level geomorphic condition is assessed by field surveys using the geomorphic indicators in Table 2.6. Field assessments are conducted over a 100-m reach for each site. Both bank and bed condition are assessed at freshwater sites. Both these site-level geomorphic sub-indices comprise several indicators. All indicators are assessed on a scale of 1-5 where 1 is poor and 5 is very good, and indicators are equally weighted when calculating sub-indices.

The representativeness of sites in reporting geomorphic condition is considered at the subcatchment scale and for the site-specific River Style within the subcatchment. In practice, site-level grades are usually consistent with subcatchment grades, but may under-estimate the condition of specific River Styles (e.g. headwaters) due to the logistical constraints of accessing reaches in better condition.

***Table 2.6*** *Geomorphic condition subindices for bank and bed condition.*

| **Geomorphic condition subindices and their indicators** | |
|---|---|
| **BANK CONDITION** | |
| - Exposed tree roots | Evidence of exposed tree roots |
| - Bank slumping | Evidence of bank slumping |
| - Pugging/trampling | Evidence of pugging and trampling |
| - Active erosion | Evidence of active erosion |
| **BED CONDITION** | |
| - Active erosion | Evidence of active erosion |
| - Pugging/trampling | Evidence of pugging and trampling |
| - Smothering fines | Evidence of smothering by fine-grained sediments |

## 2.5 Calculating scores for Ecohealth Indices

### *2.5.1 Water Quality*

A guideline trigger value is formally defined as the value that is commonly used to assess the ecological condition of a waterbody. An exceedance indicates that a variable is outside the expected range. Triggers are likely to be recalculated periodically as additional data from reference systems becomes available. A combination of ANZECC (2000, 2006) and NSW MER developed trigger values were used to explore water quality across sites and sampling occasions (Table 2.4).

Calculating non-compliance is the proportion of time that the measured values of the indicator are outside the adopted trigger values (number of samples non-compliant with trigger value divided by the total number of samples (expressed as a value between 0 and 1, with 0 equal to all values being compliant and 1 equal to all values non-compliant)). The result of this process is a score between 0 and 1 for each individual water quality parameter measured as part of Ecohealth monitoring. These scores are simply averaged to determine an overall score between 0 and 1 for Water Quality.

### *2.5.2 Freshwater macroinvertebrates*

Regional trigger values must be developed from literature and past studies for Family Richness (number of families), Total Abundance, SIGNAL2 Score (pollution tolerance index), and EPT taxa (number of Mayflies, Stoneflies and Caddisflies) for each study. In the absence of these, the default threshold values reported in Chessman (2003) can be used for SIGNAL2. Alternatively, it should be determined if one or more sites sampled during the Ecohealth program in a specific catchment can be used as a ‘reference condition’ for Family Richness and EPT grade. In addition to a trigger value, a Worst Expected Value (WEV) must be calculated for Family Richness, Total Abundance, EPT score and SIGNAL2. The WEV scores are derived from either the $10^{th}$ and/or the $90^{th}$ percentile of data for all relevant available data, and represent a site that is the ‘unhealthiest’. Calculation of a standardized score involves the comparison of each of the four macroinvertebrate indicators against the corresponding guideline value and WEV scenario. The maximum score for each indicator is 25 and indicators are equally weighted when calculating the Macroinvertebrate Condition Index.

### *2.5.3 Riparian Condition*

The assessment of each site affords each indicator an average site score, where a minimum value of 0 represents a poor state and a maximum value represents pristine condition. These scores assessed both in the field and using a desktop data assessment are combined to produce summary scores for each sub-index, and an overall condition index (Table 2.5). Indicators that are assessed at three points along the transect required averaging to give only one number for each indicator, those recorded at the transect level have only one value for each site. The indicators are then grouped into the five subindices and summary scores for each grouping are calculated to produce a condition score out of 20 for each subindex (i.e. Habitat, Native Species, Species Cover, Debris, and Management). These scores are then summed to a total score out of 100, standardised to a score ranging from 0 to 1 through simple division and assigned a final Ecohealth Report Card grade for riparian condition.

### *2.5.4 Mangrove, seagrass and saltmarsh cover in estuaries*

As this is the first time mangrove, seagrass and saltmarsh are reported as part of an Ecohealth assessment of the Coffs coastal subcatchments, they do not contribute to Ecohealth scores. Area and patch size will be calculated during the next Ecohealth round if the surveys are updated, and these temporal changes will be used to assess system change which will contribute to estuarine riparian condition scores.

### *2.5.5 Geomorphic Condition*

Site-level geomorphic condition is assessed by field surveys using the geomorphic indicators in Table 2.6. The assessment of each site affords each indicator a maximum score out of five, where a score of 1 represented the worst possible condition and a score of 5 represents excellent condition. The scores recorded in the field were combined to produce summary scores for both subindices and an overall condition index. The indicators are grouped into the 3 subindices and summary scores for each grouping are calculated through simple averaging to produce a condition score out of 5 for each subindex (i.e. bank condition and bed condition). To calculate the Ecohealth Geomorphic Condition Index, these scores are then summed to a total score out of 10, and through simple division are standardised to a score ranging from 0 to 1.

## 2.6 Spatial Scales

The above process provides the methods for calculating standardized scores for each index used in a particular Ecohealth monitoring program for an individual site. Total scores for a site are simply calculated as an average of the 0 to 1 range of scores across all indices. The scores can then be 'pooled' at spatial scales relevant to reporting requirements such as site, river, sub-catchment, freshwater or estuarine, catchment and region.

## 2.7 Calculating grades

The condition scores were grouped in ranges and given a corresponding grade (see Table 2.7). This scoring and grading system is based on the traditional format of a school report, with primary ratings ranging from a high of 'A', through intermediate ratings of 'B', 'C' and 'D', to the lowest possible score of an F. Secondary grades of + and – are included to provide greater resolution within a grade, and to better help show improvements over time.

***Table 2.7*** *Standardised scores from 0-1 and their corresponding Ecohealth grades.*

| Score | Grade | Condition | |
|---|---|---|---|
| ≥0.95/1 | A | Excellent | Environmental values met (The indicators measured meet all of the benchmark values for almost all of the year) |
| 0.85/1 | B | Good | Most environmental values met (The indicators measured meet all of the benchmark values for most of the year) |
| 0.70/1 | C | Fair | Some of the environmental values met (The indicators measured meet some of the benchmark values for some of the year) |
| 0.55/1 | D | Poor | Few of the environmental values met (The indicators measured meet few of the benchmark values for some of the year) |
| ≤0.45/1 | F | Very Poor | Very few of the environmental values met (The indicators measured meet very few of the benchmark values for almost all of the year) |

## 2.8 Ecohealth report cards

The calculation and reporting of Ecohealth grades involves the synthesis all available indicators each recorded up to 8 times during the program. Scores are calculated for individual sites, but also must fulfill the broader aims of wider-scale reporting at river, subcatchment, catchment and regional scales. To produce an Ecohealth grade, the value for each index – Water Quality, Freshwater Macroinvertebrates, Riparian Condition and Geomorphic Condition– must be transformed into standardized scores that account for differing physical conditions and scales of measurement among indices and prevailing climate conditions. The result is a scoring system from 0 to 100, where 0 represents the most ‘unhealthy’ condition and 100 indicates a ‘healthy’ waterway.

# PART 3

## RESULTS

This section of the report provides detail of the water chemistry and biophysical data collected from September 2014 to December 2015. Results for water chemistry, macroinvertebrates, riparian condition (including estuarine macrophytes were data exist) and geomorphic condition are reported for each subcatchment. *Geomorphic condition* assessed site-scale condition of stream banks and bed at freshwater sites and subcatchment-scale assessment of the stream network. *Riparian condition* assessed freshwater sites and included habitat, native species presence, percentage cover, woody and non-woody debris, management issues, as well as identification of local-scale disturbances to riparian zones. *Water quality* identified trends in nutrients (nitrogen (N) and phosphorus (P)), chlorophyll *a* (chl-*a*), suspended solids (TSS) and coliform values, as well as static variables such as pH, salinity, dissolved oxygen (DO) and temperature measured from water column profiles at each site. Attributes that exceed ANZECC or NSW MER guideline thresholds for aquatic ecosystem health are identified. *Aquatic macroinvertebrate* assemblages collected from freshwater sites in autumn and spring 2015 are used to assess long-term condition of channel habitats and water quality. The taxonomic richness and abundance reported, as well as health indicators using SIGNAL2 scores and EPT richness and abundance. All water chemistry and biophysical data are reported for the Coffs coastal catchments overall and each subcatchment:

3.1 Coffs coastal catchments

3.2 Corindi River, Saltwater Creek and Pipeclay Lake

3.3 Arrawarra Creek

3.4 Darkum Creek

3.5 Woolgoolga Creek

3.6 Willis Creek and Hearnes Lake

3.7 Moonee Creek

3.8 Coffs Creek

3.9 Boambee and Newports Creeks

3.10 Bonville and Pine Creeks

## 3.1 Coffs coastal catchments

The overall grade for the Coffs coastal catchments was C (Table 3.1, Figure 3.1), ranging from an F in Willis Creek to C+ in the Corindi River, and Arrawarra, Boambee and Bonville Creeks (Table 3.1). With the exception of aquatic macroinvertebrate communities, scores were typically consistent among indices, highlighting that biophysical stressors to aquatic ecosystem health are affecting short- and long-term condition of the streams (Figure 3.2). Riparian and geomorphic condition were closely related, reiterating that healthy riparian vegetation is critical to maintaining bank stability, and that riparian and geomorphic condition are similarly impacted by degrading landuse practices. Aquatic macroinvertebrates were found to be in very poor condition in many subcatchments and overall.

Freshwater fish communities were in good condition, receiving an overall grade of B- for the Coffs coastal catchments. Condition ranged from lows of C+ in Corindi River, Woolgoolga Creek and Coffs Creek, to a high of B+ in Bonville Creek (Table 3.1). NATIVENESS was the best performing indicator across all systems, scoring >95, a grade of Excellent, at all sites except in the Corindi River (Appendix B). For Corindi, Coffs, Boambee, and Bonville Creeks, RECRUITMENT was the poorest performing indicator, with scores c.50 (Moderate, Appendix B). EXPECTEDNESS was the poorest indicator (c.41) in Woolgoolga Creek.

***Table 3.1*** *Catchment and subcatchment Ecohealth grades for Coffs coastal catchments. Geomorphic condition was assessed at the subcatchment scale.*

| System | Water quality | Aquatic Macroinvertebrates | Fish | Riparian Condition | Geomorphic Condition | Overall |
|---|---|---|---|---|---|---|
| Coffs Harbour region | C | F | B- | C+ | C+ | C- |
| | | | | | | |
| Corindi | C+ | F | C+ | C | B- | C |
| Saltwater | D+ | F | | B+ | B- | D+ |
| Pipeclay | C- | | | | | C- |
| Arrawarra | C | F | | A- | B- | C |
| Darkum | C- | | | | C | C- |
| Woolgoolga | C | C+ | C+ | C | C+ | C- |
| Hearnes | C | F | | B+ | C | C- |
| Willis | F | | | | | F |
| Moonee | C | F | | B+ | B | C- |
| Coffs | D+ | F | C+ | D | C | D |
| Boambee | C+ | D | B- | C+ | D | C |
| Newports | C- | F | | C- | D | D |
| Bonville | C+ | A- | B+ | C | C | C |
| Pine | C- | D+ | | C+ | C | C- |

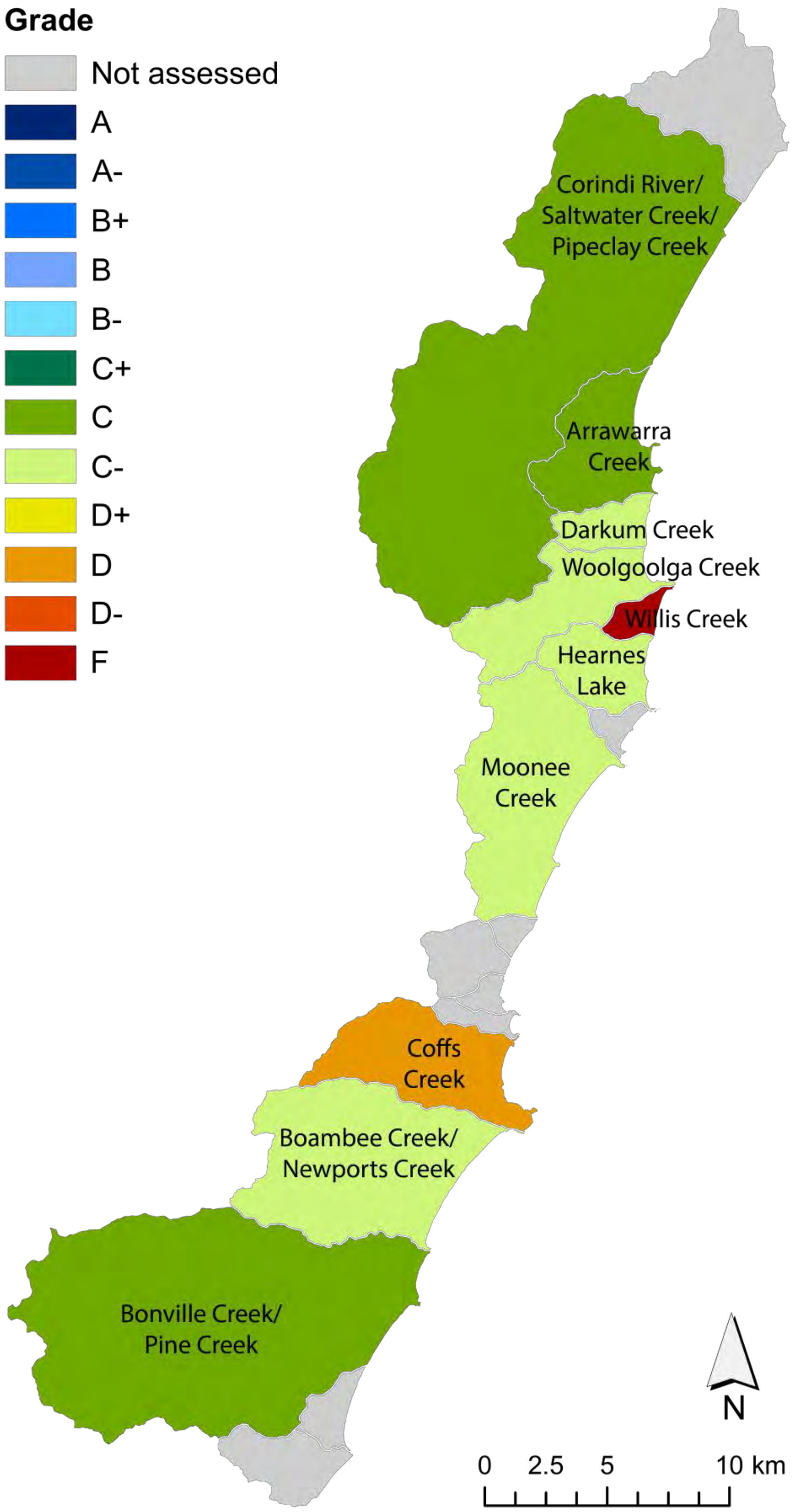
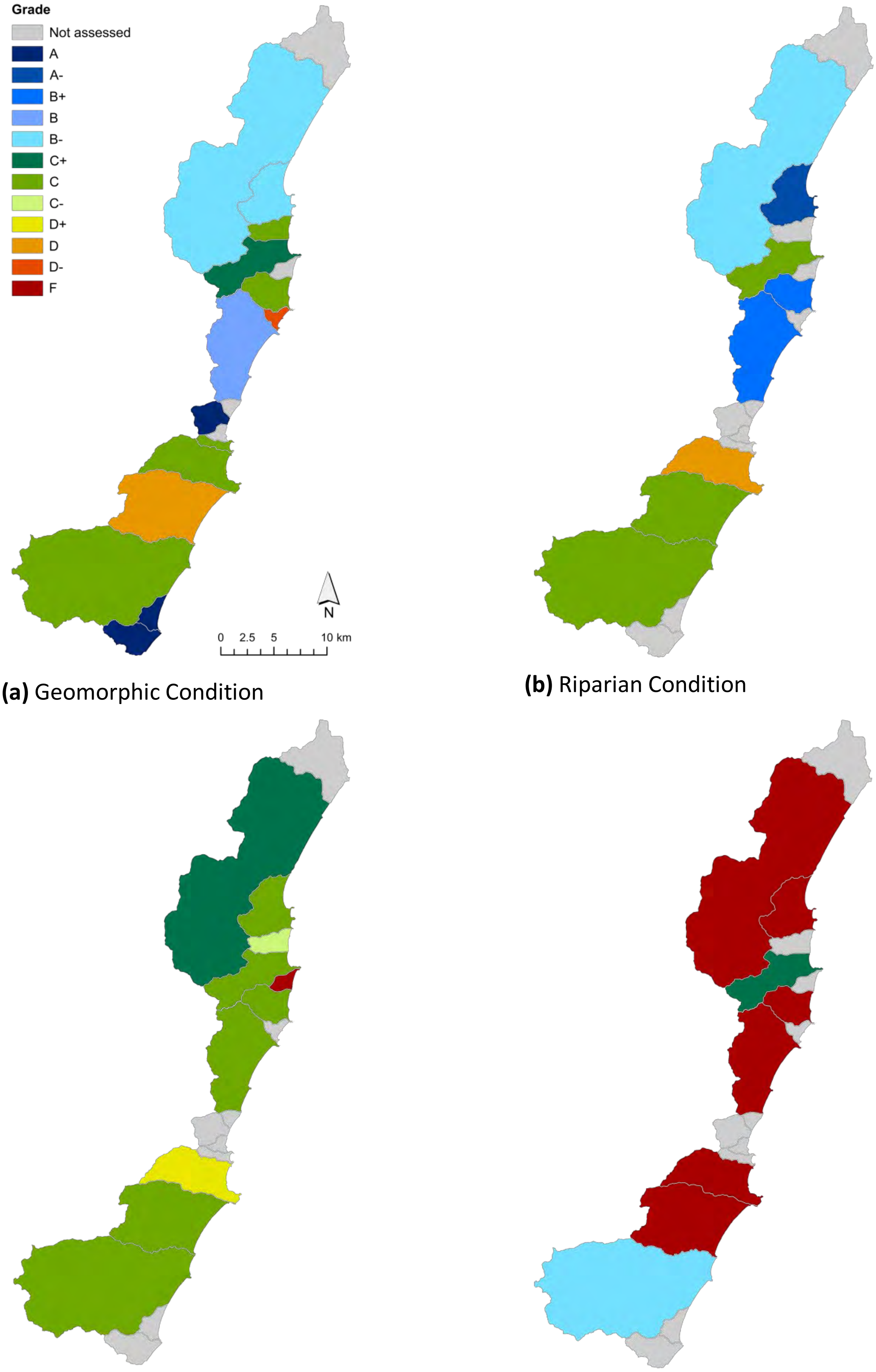



***Figure 3.1*** *Overall Ecohealth grades for Coffs coastal catchments.*




**(a)** Geomorphic Condition

**(b)** Riparian Condition

**(c)** Water Quality

**(d)** Aquatic Macroinvertebrates

***Figure 3.2*** *Subcatchment Ecohealth grades for (a) geomorphic condition, (b) riparian condition, (c) water quality, and (d) aquatic macroinvertebrate communities. Aquatic macroinvertebrate communities were not assessed for estuarine reaches.*

### *3.1.1 Geomorphic condition*

Assessments of stream condition over the Coffs coastal catchments show that most (61%) of the stream network is in moderate condition (Table 3.2). Overall, the Coffs coastal catchments achieved a grade of C+ for subcatchment geomorphic condition. Of the subcatchments monitored during this 2015 Ecohealth program, Arrawarra Creek (44%), Moonee Creek (40%) and Corindi River/Saltwater Creek (36%) contained the highest proportions of channels in good geomorphic condition. These subcatchments also had little to no channels in poor condition. Management priorities in these subcatchments should continue to focus on maintaining the good geomorphic condition of stream channels.

At the other end of the spectrum, Boambee/Newports Creek subcatchment contained no stream channels in good geomorphic condition (Table 3.2), and significant percentages in poor condition (38% and 52%, respectively). Although one quarter of the channels in the Bonville/Pine Creek subcatchment also were in poor condition, its better grade of C was influenced by almost one quarter of its stream network being in good condition. The stream network in the subcatchments of Coffs Creek, Willis Creek/Hearnes Lake and Darkum Creek were predominantly in moderate geomorphic condition.

***Table 3.2*** *Subcatchment scale geomorphic condition calculated over the subcatchments' total stream length using the 2014 River Styles datalayer from NC LLS.*

| Subcatchment | % Good Condition | % Moderate Condition | % Poor Condition | Geomorphic Grade |
|---|---|---|---|---|
| Coffs coastal catchments overall | 29 | 61 | 10 | C+ |
| | | | | |
| Corindi River and Saltwater Creek | 36 | 60 | 5 | B- |
| Arrawarra Creek | 44 | 49 | 7 | B- |
| Darkum Creek | 0 | 96 | 4 | C |
| Woolgoolga Creek | 23 | 74 | 2 | C+ |
| Willis Creek and Hearnes Lake | 0 | 100 | 0 | C |
| Moonee Creek | 40 | 60 | 0 | B |
| Coffs Creek | 0 | 100 | 0 | C |
| Boambee and Newports Creeks | 0 | 62 | 38 | D |
| Bonville and Pine Creeks | 24 | 51 | 25 | C |

Two of the 11 freshwater sites were classified as having a confined valley setting and a continuous gravel-bed channel with discontinuous floodplain pockets. Both these sites (WOOL4 and HEAR4) were in moderate condition (C+, Table 3.3). Seven of the 11 freshwater sites were classified as having a partially confined valley setting with a planform controlled, meandering channel comprising fine-grained banks and bed. Of these, BOAM4 was in the best condition, with a grade of B while COFFS4, BONV4 and PINE3 were all graded C-, the lowest score for this River Style. Bank condition was typically worse than bed condition for these sites (Table 3.3). This is not surprising, but highlights the importance of good riparian management of these streams that have fine-grained banks. The clearing of riparian vegetation both increases the velocity and erosivity of overland runoff to the stream channel and decreases bank strength through the loss of plant roots.

Two sites were sand-bed streams: NEW3 was classified as having a partially confined valley setting with a planform controlled, low sinuosity channel comprising sand banks and bed, while ARRA4 was classified as a swampy meadow with bed and bank sediments comprising sandy valley fill. Both sand streams were assessed as being in moderate geomorphic condition. ARRA4 scored a C+, while NEW3 scored a C- (Table 3.3). ARRA4 had intact native riparian zones in excellent condition, while NEW3 was adjacent to a light industrial estate and had a cleared left bank and stormwater drains impacting the site.

***Table 3.3*** *Site-level geomorphic condition of the freshwater sites assessed in the 2015 Coffs Ecohealth program.*

| Site | Bank Condition Score | Bank Condition Grade | Bed Condition Score | Bed Condition Grade | Overall Site Score | Overall Site grade |
|---|---|---|---|---|---|---|
| [2]CORI4 | 57.8 | D+ | 73.7 | C+ | 66 | C |
| [2]SALT4 | 78.2 | B- | 73.7 | C+ | 76 | B- |
| [4]ARRA4 | 71.4 | C+ | 73.7 | C+ | 73 | C+ |
| [1]WOOL4 | 61.2 | C- | 79.3 | B- | 70 | C+ |
| [1]HEAR4 | 68.0 | C | 73.7 | C+ | 71 | C+ |
| [2]MOON4 | 74.8 | C+ | 85.0 | B | 80 | B- |
| [2]COFFS4 | 61.2 | C- | 68.0 | C | 65 | C- |
| [2]BOAM4 | 81.6 | B | 85.0 | B | 83 | B |
| [3]NEW3 | 68.0 | C | 56.7 | D+ | 62 | C- |
| [2]BONV4 | 57.8 | D+ | 68.0 | C | 63 | C- |
| [2]PINE3 | 61.2 | C- | 68.0 | C | 65 | C- |

[1] *River Style is CVS – floodplain pockets, gravel*
[2] *River Style is PCVS – planform controlled, meandering, fine grained*
[3] *River Style is PCVS – planform controlled, low sinuosity, sand*
[4] *River Style is SMG – valley fill, sand*

### *3.1.2 Riparian condition*

The overall 2015 Ecohealth score for riparian condition at 11 sites across the Coffs coastal catchments was 73.2, or C+.

Sites that scored well (B and above) were generally still 'intact' systems. Riparian vegetation continuity and vegetation:channel width ratio was high in these systems, and sites were connected to large remnant patches of native vegetation. Weeds encountered in these good-condition sites did not dominate their structural layer and were often only present at disturbed edge areas. Large native habitat trees were common, woody and non-woody debris were present, fringing vegetation was abundant, and extent of exposed tree roots were low. At each structural layer, native species presence and cover was representative of the original vegetation community type. Generally, there was adequate riparian fencing, no sign of stock impact and significant native woody regeneration taking place.

Sites that received a fair-to-poor score (C and below) performed poorly in several of these elements of healthy riparian systems. Such sites were often isolated from larger patches of remnant vegetation, had poor riparian vegetation continuity and inadequate riparian vegetation width. Riparian fencing was often lacking and stock impact was common at these sites. Environmental and noxious weeds were generally present in all or several structural layers, often as dominant species, and appeared to be the greatest threat to riparian condition.

Of the 169 dominant riparian vegetation species recorded from the 11 Coffs Ecohealth sites, 47 were recognised as exotic species, while 122 species were native species. When averaged across all sites, for every dominant weed species there were 2.6 native dominant species. When divided into growth forms, dominant weed species were most prevalent in the Herb/forb layer (15 species), followed by shrubs (12 species), Graminoids (10 species), Trees (5 species), Vines (3 species), and lastly Macrophytes (2 species). The most common dominant weed species were Paspalum (*Paspalum dilatatum*) in 10 sites, Lantana (*Lantana camara*) in 9 sites, Blue Billy Goat Weed (*Ageratum houstonianum*) in 7 sites, Crofton Weed (*Ageratina adenophora*) also in 7 sites, and Senna (*Senna pendula* var. *glabrata*) found in 6 of the 11 Ecohealth sites in 2015.

There were weed species encountered that were not listed as being 'noxious' under the Coffs Harbour Local Control Authority (LCA), despite being listed as noxious in other New South Wales LCA's (New South Wales Department of Primary Industries [NSW DPI] 2016). Many of these weeds have the potential to expand in range and out-compete native plant species. At the time of reporting, Coffs Harbour did not list the following weed species, found in our 2015 Ecohealth survey, as noxious: Camphor Laurel (*Cinnamomum camphora*), Senna (*Senna pendula var. glabrata*), Singapore Daisy (*Sphagneticola trilobata*), Castor Oil Plant (*Ricinus communis*), Crofton Weed (*Ageratina adenophora*), Morning Glory (*Ipomoea indica*), and Mickey Mouse Plant (*Ochna serrulata*) (NSW DPI 2016).

### 3.1.3 Mangrove, seagrass and saltmarsh cover

Estuarine macrophytes are essential components of estuarine ecology. They improve water quality, contribute to the food chain, stabilise morphology by binding sediments, and provide both habitat and a nursery ground for fish and other marine species (West and Williams 2008, Crease et al. 2009). As with most ecological systems, estuarine macrophyte boundaries are dynamic in nature and may fluctuate over time due to environmental variability (Clough 1982; Leadbitter et al. 1999; West and Williams 2008). However, direct pressures on these sytems (natural and anthropogenic) may influence community boundaries and can result in both positive and negative temporal change.

While this assessment found temporal differences in estuarine macrophytes, precision is low due to the broad scale used for mapping (Thomas et al. 1999), and we cannot quantify the uncertainty of methodological differences in the collection and processing of the two GIS datasets underlying our assessment (Crease et al. 2009, and NSW Department of Industry and Investment – Primary Industries and Energy 2011). In order to detect and report on real estuarine macrophyte cover change in Coffs Harbour estuaries, it is recommended that future satellite imagery comparisons are made using methodology consistent to that used to capture and process the 2011 GIS data. Despite these differences in data collection and processing, both datasets identified similar estuarine macrophyte cover (e.g. both Hearns and Woolgoolga Lake estuaries), providing a degree of confidence in temporal trends.

In comparison to the 1985 spatial dataset, total estuarine macrophyte cover (i.e. grouped - mangroves, saltmarsh and seagrass) increased in total cover in 2011 (0.372km$^2$) across the Coffs Harbour estuaries (Table 3.4). This increase in total estuarine macrophyte cover can be attributed to an increase in both total mangrove cover (2%, or +0.105km$^2$), and total saltmarsh cover (30%, or +0.411km$^2$). Because there is no estuarine macrophyte cover data for the Coffs Harbour estuaries prior to 1985, it is unknown whether the apparent increase in both mangrove and saltmarsh cover observed in this report is an expansion in estuarine macrophyte range, or if it is simply an indication that both the mangrove and saltmarsh communities are both recovering towards pre-disturbance levels. The third estuarine macrophyte community, seagrass, decreased its total cover across all Coffs Harbour estuaries by 62%, (-0.129km$^2$) from 1985 to 2011 (Table 3.4).

The largest increase in estuarine macrophyte cover was observed in the Corindi River/Saltwater Creek estuary (0.341km$^2$), followed by the Boambee and Newport Creek estuary (0.075km$^2$) (Table 3.4). The largest increase in mangrove cover was observed in the Corindi River/Saltwater Creek estuary (0.042km$^2$), followed by the Moonee Creek estuary (0.021km$^2$). The largest increase in saltmarsh cover was again observed in the Corindi River/Saltwater Creek estuary (0.317km$^2$), followed by the Boambee and Newport Creek estuary (0.076km$^2$). No increases in seagrass cover were observed in any of the 9 Coffs Harbour estuaries.

A decrease in estuarine macrophyte cover was observed for three sites, with the largest decrease observed in the Bonville and Pine Creek estuary (-0.055km$^2$) (Table 3.4). A decrease in mangrove cover was observed in only one site, which was Darkum Creek estuary (-0.003km$^2$). A decrease in saltmarsh cover was observed in two sites, with the largest decrease observed in the Moonee Creek estuary (-0.015km$^2$) (Table 3.4). A decrease in seagrass cover was observed in all 5 sites where seagrass was recorded, with the greatest declines observed in the estuaries of Bonville and Pine Creeks (-0.079km$^2$), Corindi River/Saltwater Creek (-0.019km$^2$), and the Boambee and Newport Creeks (-0.018km$^2$) (Table 3.4).

The significant decrease observed in seagrass cover is concerning. In addition to naturally occurring weather events such as storms, cyclones and floods, anthropogenic factors that can lead to seagrass degradation and decline include global warming and sea-level rise, excessive turbidity, elevated nutrient levels, stormwater discharge, heavy metal and toxin deposition, erosion, increased turbidity and siltation that reduces light intensity, mining and dredging, coastal development, moorings, boat propellers and introduced species (Kirkman 1997, Leadbitter et al. 1999, West and Williams 2008). Management priorities should be focused on long-term monitoring and mapping of seagrass cover change and addressing direct causes of this estuarine macrophyte community decline (West and Williams 2008, Crease et al. 2009).

***Table 3.4*** *Summary of total macrophyte cover differences, and total mangrove, saltmarsh and seagrass site differences between 1985 and 2011.*

| Estuary System | Total Macrophyte Cover Difference 1985 - 2011 (km$^2$) | Total Mangrove Cover Difference 1985 - 2011 (km$^2$) | Total Saltmarsh Cover Difference 1985 - 2011 (km$^2$) | Total Seagrass Cover Difference 1985 - 2011 (km$^2$) |
|---|---|---|---|---|
| *Corindi River/ Saltwater Creek* | 0.341 (26%) | 0.042 (10%)<br>-0.081* (22%) | 0.317 (36%) | -0.019 (77%) |
| *Arrawarra Creek* | 0.008 (29%) | 0.006 (37%) | 0.003 (26%) | - |
| *Darkum Creek* | -0.016 (70%) | -0.003 (34%) | 0 | - |
| *Woolgoolga Lake* | 0.003 (34%) | 0.002 (26%) | 0.001 | - |
| *Hearnes Lake* | 0.003 (5%) | 0.005 (61%) | -0.002 (4%) | - |
| *Moonee Creek* | -0.007 (3%) | 0.021 (20%) | -0.015 11%) | -0.013 42%) |
| *Coffs Creek* | 0.020 (9%) | 0.009 (4%) | 0.012 (85%) | -0.0002 8%) |
| *Boambee / Newport Creeks* | 0.075 (15%) | 0.017 (5%) | 0.076 (72%) | -0.018 (30%) |
| *Bonville / Pine Creeks* | -0.055 (14%) | 0.007 (5%) | 0.018 (10%) | -0.079 (89%) |
| **Totals** | **0.372 (14%)** | **0.105* (8%)** | **0.411 (30%)** | **-0.129 (62%)** |

** Corindi mixed mangrove/saltmarsh layer was removed from the summary table as it was not observed in the 1985 dataset. Instead, we have added the cover data to the mangrove layer for this site, given that mangroves are the dominant overstory/canopy species. This increased mangrove cover for this site and suggested an overall increase in mangrove cover.*

### *3.1.4 Water quality*

Water quality was fair across the Coffs coastal catchments, with an overall grade of C (Table 3.5). The 2015 and 2011 results are similar. Water quality declined in the Corindi River, Saltwater Creek, Coffs Creek, Newports Creek and Pine Creek. Improvements in water quality were observed in Darkum Creek, Hearnes Lake, Boambee Creek and Bonville Creek.

There were several spatial and temporal patterns that were consistent across the Coffs coastal catchments. Firstly, in most cases the poorest water quality occurred at the tidal limit. This is similar to 2011 assessments. Secondly, total nutrient concentrations (N and P) consistently declined across the catchment from 2011 to 2015. Only Willis and Coffs Creeks had TP exceeding trigger thresholds in 2015, and only SALT3, BOAM3 and BOAM4 had higher TN concentrations in 2015 than in 2011. However, in 2015, chl-*a* concentrations in several tidal limits (e.g. Coffs, Boambee, Newports, Bonville and Pine Creeks) increased from 2011, resulting in more frequent and higher magnitude exceedances.

Because stream discharge was below baseflow for 69% of the 2015 monitoring period, catchment inputs of N and P to streams were low. Hence, catchment inputs of nutrients to streams in the Coffs coastal catchment were lower in 2015 than 2011. Nonetheless, poor hydrological flushing of estuaries in 2015 combined with high concentrations of nutrients stored within the waterbodies likely led to nutrient release from stream sediments and high algal productivity (indicated by higher chl-*a* concentrations), particularly at tidal limits. Without data on bioavailable nutrient concentrations, the link between water column nutrients and the biological response of algal blooms is unclear: including monitoring of bioavailable nutrients would improve our understanding of chemical and biological interactions in these systems.

Pipeclay (PIPE1) and Willis Creeks (WILL1) were new sites for the 2015 monitoring program. Both sites exceeded the trigger threshold for TN in all sampling occasions with site maximums significantly higher than the 500µg/L threshold value. Chl-*a* and turbidity also persistently exceeded trigger thresholds. Investigating sources of nutrients, particularly TN, to these estuarine systems will help determine the appropriate management strategies to improve water quality at these sites. Monitoring of these sites should continue into the future.

***Table 3.5*** *Subcatchment grades for water quality assessed in 2011 and 2015.*

| System | 2015 Water Quality grade | 2011 Water Quality grade |
|---|---|---|
| **Coffs Harbour region** | **C** | **C** |
| | | |
| Corindi River | C+ | B- |
| Saltwater Creek | D+ | B |
| Pipeclay Lake | C- | |
| Arrawarra Creek | C | C |
| Darkum Creek | C- | D |
| Woolgoolga Creek | C | C |
| Hearnes Lake | C | D+ |
| Willis Creek | F | |
| Moonee Creek | C | C |
| Coffs Creek | D+ | C- |
| Boambee Creek | C+ | C- |
| Newports Creek | C- | C+ |
| Bonville Creek | C+ | C |
| Pine Creek | C- | C |

### *3.1.5 Aquatic macroinvertebrates*

Aquatic macroinvertebrate community condition was very poor across the Coffs coastal catchments, with an overall macroinvertebrate grade of F (Table 3.6). Of the four macroinvertebrate indicators, family richness (10), and EPT richness and abundance (7) were very poor (<11/25), and total abundance (12) and SIGNAL2 (12) were poor.

Bonville Creek (BONV4) had the best macroinvertebrate community composition in the Coffs coastal catchments, with excellent scores for family richness, and EPT richness and abundance, and very good scores for total abundance and SIGNAL2. Macroinvertebrate community condition improved from 2011 to 2015 in the Bonville/Pine Creeks and Coffs Creek subcatchments, with BONV4 improving from a B to an A-, PINE3 improving from an F to a D+, and COFFS4 improving but remaining an F.

Macroinvertebrate community condition declined from 2011 to 2015 in all other subcatchments. The greatest declines were recorded in Corindi Creek (CORI4, from D+ to an F), Moonee Creek (MOON4, remaining an F), and Arrawarra Creek (ARRA4, from D to an F).

The spatial and temporal patterns in aquatic macroinvertebrate community condition in the Coffs coastal catchments in 2015 suggests that low stream discharge negatively impacts aquatic macroinvertebrate communities through triggering poor water quality (particularly algal blooms and low DO), reducing the availability and quality of aquatic habitat, and reducing food supply. However, improvement in some subcatchments between seasons and overall also indicates that populations of macroinvertebrates indicative of good water quality exist in the Coffs catchment, and these macroinvertebrates colonise sites when good water quality and the availability of appropriate habitats co-occur.

***Table 3.6*** *Summary of aquatic macroinvertebrate indicator scores and the overall macroinvertebrate grade for freshwater sites for 2015. Each indicator has a maximum score of 25.*

| Site | Family Richness | Total Abundance | EPT | SIGNAL2 | Macroinvertebrate Score | Macroinvertebrate Grade |
|---|---|---|---|---|---|---|
| **Catchment Mean** | **10** | **12** | **7** | **12** | **41** | **F** |
| | | | | | | |
| CORI4 | 6 | 6 | 9 | 15 | 36 | F |
| SALT3 | 5 | 8 | 0 | 5 | 18 | F |
| ARRA4 | 12 | 13 | 1 | 9 | 35 | F |
| WOOL4 | 18 | 24 | 18 | 14 | 74 | C+ |
| HEAR4 | 3 | 7 | 1 | 16 | 28 | F |
| MOON4 | 2 | 5 | 0 | 1 | 8 | F |
| COFFS4 | 10 | 15 | 2 | 12 | 39 | F |
| BOAM4 | 13 | 18 | 9 | 13 | 52 | D |
| NEW3 | 1 | 0 | 2 | 11 | 14 | F |
| BONV4 | 24 | 23 | 24 | 23 | 94 | A- |
| PINE3 | 19 | 14 | 13 | 14 | 59 | D+ |

## 3.2 Corindi River, Saltwater Creek and Pipeclay Lake

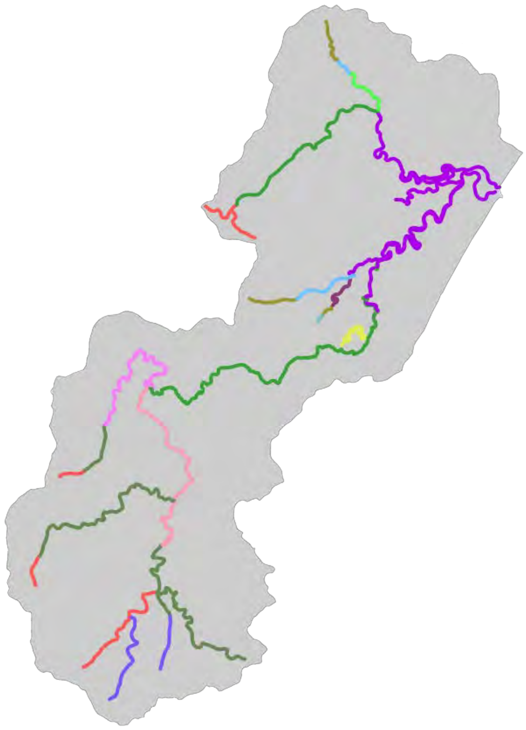
### *3.2.1 Catchment description*

The Corindi River catchment is 151km$^2$ (Table 3.7). The river length is 25km with the tidal limit occurring 12.3km from the river mouth. The headwaters of the Corindi River drain escarpment ranges (>250m elevation) and steep midland hills (50-250m elevation, Figure 3.3a) that drain to confined discontinuous floodplains (Figure 3.3b). The geology of the midland hills landscape is greywacke (Coramba Beds) and conglomerate (Bundamba Group). The greywacke forms kandosols such as red and brown earths in well-drained areas, and yellow and grey earths in poorly drained areas (Figure 3.3d). These soils comprise sandy to loamy A horizons and porous sandy-clay subsoils with low fertility and poor water-holding capacity. The conglomerate forms kurosols with strongly acidic, clay-rich B horizons that have low chemical fertility and poor water-holding capacity. The dominant landuse of the upper reaches of the Corindi River are forestry and conservation areas, including Madmans Creek Forest Reserve, part of the Yuraygir National Park (Figure 3.3c).

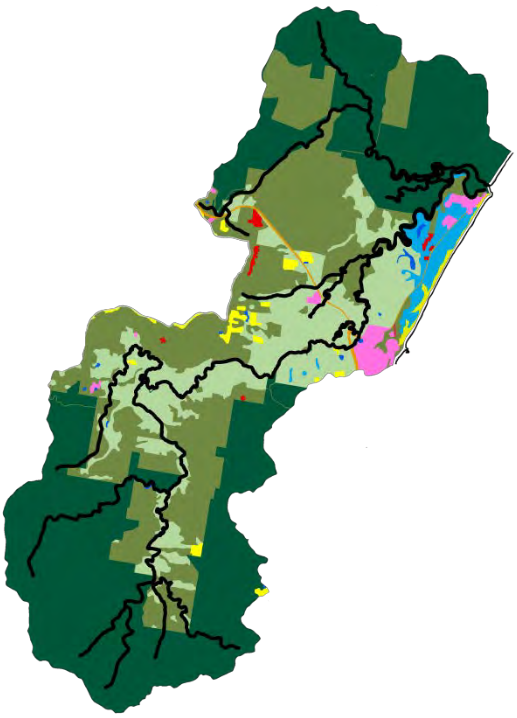
The lower part of Corindi River contains an intermediate valley setting in which there is continuous alluvial floodplain with a stable channel (Waterways Authority 2002). The dominant landuse is grazing, and tree and shrub cover (Figure 3.3c). The coastal plain is underlain by aeolian sand. The aeolian sand forms podosols that are dominated by organic matter, aluminium and/or iron compounds. These podosols are poorly drained and may be waterlogged for much of the time, and have very low chemical fertility and water-holding capacity.

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, and fish kills and flood related water quality issues have been reported (Waterways Authority 2002). Forestry and conservation areas are the dominant landuse with the latter including the Solitary Islands Marine Park (including significant areas of sanctuary zone) (Waterways Authority 2002). There are approximately 2km$^2$ of wetlands adjoining the estuary that includes mangroves, seagrass, and saltmarsh (Figure 3.4). The Corindi River Estuary has a rich cultural history, particularly for the indigenous Gumbaingirr people of the Red Rock/Corindi area (Waterways Authority 2002).

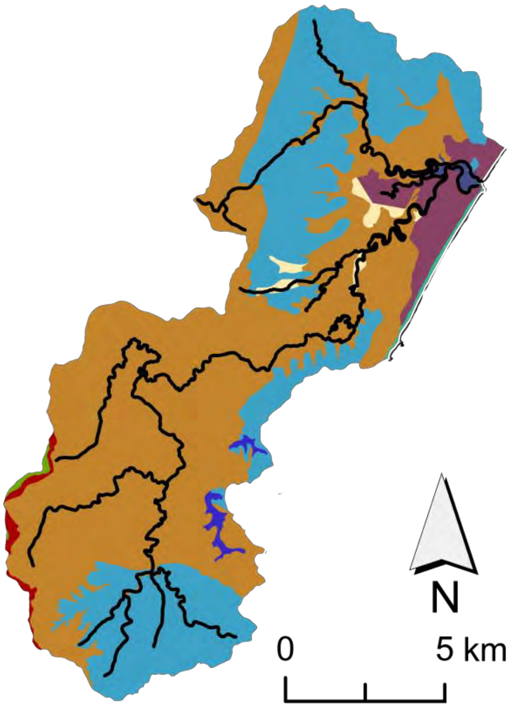

**(a)** Topography and location of Ecohealth sites.



**(b)** River Styles: refer to Figure 2.8 for key.



**(c)** Landuse: refer to Figure 2.7 For key.




**(d)** Soils: refer to Figure 2.3 For key.

***Figure 3.3*** *The Corindi River, Saltwater Creek and Pipeclay Lake subcatchment showing (a) locations of Ecohealth sites and catchment topography (contour lines are 50m intervals), (b) River Styles, (c) landuse, and (d) soils. Data layers from CHCC (site locations), Geoscience Australia (topography), NC LLS (River Styles) and OEH (landuse and soils).*

***Table 3.7*** *Subcatchment description of Corindi River, Saltwater Creek and Pipeclay Lake. Data from NC LLS and OEH.*

| Variable | Subcatchment composition |
|---|---|
| Area ($km^2$) | 151 |
| Geology | 40% Greywacke; 36% Conglomerate; 16% Alluvial Sediment; 7% Aoelian Sand; 2% Claystone/Coal |
| Soils | 58% Kurosols; 33% Kandosols; 4% Podosols, 4% other. |
| River Styles | 30% LUV CC – Tidal; 17% PCVS - Planform controlled, meandering, fine grained; 16% CVS - Floodplain pockets, gravel; 8% CVS Headwater; 7% PCVS - Bedrock controlled, gravel; 5% CVS – Gorge; 11% mixed other. |
| Landuse | 37% State Forest; 25% Native Forest; 16% Grazing; 10% National Park; 2% wetland. |
| Major point source discharge | Nil |
| Tree Cover | 29% |

### *3.2.2 Site descriptions*

Three sites were monitored along the Corindi River (Figure 3.3a): CORI1 (Plate 3.1) is downstream of the confluence of Corindi River and its major tributary of Saltwater Creek. CORI1 is in the lower estuary in the marine-influenced zone with a salinity range of +30ppt. CORI3 is at the tidal limit of Corindi River and CORI4 (Plate 3.2) is a freshwater site in the River Style defined as planform controlled, meandering, fine grained.

Saltwater Creek is the main tributary of the Corindi River. Two sites were sampled: SALT1 is 1.5km upstream of the confluence of Saltwater Creek and the Corindi River, and experiences an intermediate salinity range of 15-30 ppt. All estuary sites in the Corindi River/Saltwater Creek are defined as laterally unconfined continuous tidal channels (Figure 3.3b). SALT3 (Plate 3.3) is the most upstream site and is in a freshwater reach defined as planform controlled, meandering, fine grained.

Pipeclay Lake is a small coastal system east of the southern part of the Corindi River/Saltwater Creek subcatchment (Figure 3.3a). PIPE1 is in the lower estuary and is a new site first sampled in the 2015 sampling period.

***Plate 3.1*** *Site CORI1in the lower Corindi River estuary.*

***Plate 3.2*** *Site CORI4 in the freshwater reach of the Corindi River.*

***Plate 3.3*** *Site SALT3 in the freshwater reaches of Saltwater Creek.*

### *3.2.3 Geomorphic condition*

The geomorphic River Style at CORI4 is partially confined valley setting: planform controlled, fine grained. The bed sediments were matrix dominated with more than 60% fine sediment. The banks were well vegetated, but there were areas of concentrated erosion on the right bank (>20m combined length) in the form of undercutting and exposed tree roots (Plate 3.2). The left bank was affected by an area >20m of bank slumping. There was significant large woody debris present in the stream, comprising single large trees and small debris jams. CORI4 scored 57.8, a grade of D+, for BANK CONDITION and 73.7, a C+, for BED CONDITION. The overall Ecohealth geomorphic condition for CORI4 was 66, a grade of C.

The River Style at SALT3 is also partially confined valley setting: planform controlled, fine grained. At the time of sampling, streamflow had contracted to pools with little or no surface connection (Plate 3.3). The bed and bank sediments were fine grained, with no cobbles, pebbles or gravel present. Small areas of erosion were centred on knickpoints in the bed at the upstream end of the small pools, where water 'plunges' from the shallow channels between pools. However, the significant fringing vegetation has reduced bank erosion to very minor undercutting on both banks (<5m combined length). SALT3 scored 78.2, a grade of B- for BANK CONDITION and 73.7, a grade of C+ for BED CONDITION. The overall Ecohealth geomorphic condition for SALT3 was 76, a grade of B-.

In summary, CORI was assessed as being in moderate geomorphic condition, with bank erosion the most significant issue for site-level geomorphic condition. Fencing the riparian zone to exclude stock and allow for regeneration of native revegetation would assist to improve geomorphic condition at this site. SALT3 was assessed as being in good geomorphic condition. Localised bed erosion is the most significant issue for site-level geomorphic condition. Maintaining the riparian vegetation at SALT3 and upstream of the site will continue to protect bank stability, and help slow runoff, reducing its erosivity.

The desktop GIS assessment of subcatchment geomorphic condition found the Corindi River/ Saltwater Creek subcatchment to be in good condition with a grade of B-. Although SALT3 was assessed as average for the subcatchment, CORI4 was assessed to be slightly below the subcatchment average for geomorphic condition.

### *3.2.4 Riparian condition*

#### *Corindi River*

The riparian vegetation community at Corindi River #4 (CORI4, Plate 3.4), can be described as 'Coast and Hinterland Riparian Flooded Gum – Bangalow Wet Forest', CH_WSF01 (Office of Environment and Heritage [OEH] 2012b), or North Coast Wet Sclerophyll Forest (Keith 2004), and received a moderate riparian condition score of 66.5, or C (Table 3.8).

The dominant canopy species were Camphor Laurel (*Cinnamomum camphora*), Flooded Gum (*Eucalyptus grandis*), and Bangalow Palm (*Archontophoenix cunninghamiana*). The midstory was dominated by Lantana (*Lantana camara*), Green Wattle (*Acacia irrorata*), Sandpaper Fig (*Ficus coronata*), Cheese Tree (*Glochidion fernandii*), and Banana Bush (*Tabernaemontana pandacaqui*). The understory was dominated by Lomandra (*Lomandra hystrix*), Creeping Beard Grass (*Oplismenus imbecillis*), Blady Grass (*Imperata cylindrica*), and Paspalum species (*Paspalum dilatatum*, and *P.mandiocanum*). Dominant vine species included Kangaroo Vine (*Cissus antarctica*), Wait-a-while Vine (*Smilax australis*), Common Silkpod (*Parsonsia* sp.) and Wombat Berry (*Eustrephus latifolius*), while the macrophyte layer included Water Ribbons (*Triglochin procera*).

Lantana (*Lantana camara* - class 4) was the only noxious weed species observed. Other weedy species present included, Camphor Laurel (*Cinnamomum camphora*), Wild Tobacco (*Solanum mauritianum*), Arsenic Bush (*Senna septemtrionalis*), Sida (*Sida rhombifolia*), Paspalum species (*Paspalum dilatatum*, and *P.mandiocanum*), Wandering Jew (*Tradescantia fluminensis*), and Bamboo (*Bambusa* sp.).

CORI4 scored 16/20 for HABITAT, with reduced vegetation:channel width ratio and interrupted continuity reducing the score. Proximity to large tracts of remnant native vegetation was good, and large and hollow-bearing trees were present, as were all structural layers. While over 60% NATIVE SPECIES cover was present in each layer, weedy species were also common, bringing this sub-indicator mark to 13.5/20. Canopy and midstory cover was high at CORI4, however while Herb/forb and graminoid cover is generally sparse for this vegetation community (c.5-35%), observed cover for these layers appeared to be lower than average, and SPECIES COVER received 16/20. DEBRIS had relatively good fringing vegetation and leaf litter values, and while there appeared to be adequate standing dead timber, a lack of lying and fallen woody debris brought the mark down to 14/20. Management scored a very low 7/20, with marks deducted for the presence of weeds and weed regeneration, and the absence of riparian fencing leading to an increased frequency of livestock presence.

***Plate 3.4*** *Riparian vegetation at Corindi River #4 was in an average condition. While remnant elements were present in all structural layers, riparian condition could be greatly improved with the strategic phasing out of Camphor Laurel, the removal of other weed species and fencing of the riparian zone.*

***Table 3.8*** *Site-level summary of riprian condition of Corindi River #4, including subindices and indicators.*

| Corindi River #4 | Scores |
|---|---|
| **HABITAT** | **16** |
| Channel width | 2 |
| Proximity | 3 |
| Continuity | 3 |
| Layers | 4 |
| Large native trees | 2 |
| Hollow-bearing trees | 2 |
| **NATIVE SPECIES** | **13.5** |
| Native canopy species | 2.5 |
| Native midstory species | 2.5 |
| Native herb/forb species | 3 |
| Native graminoid species | 2.5 |
| Native macrophyte species | 2 |
| **SPECIES COVER** | **16** |
| Canopy species | 4 |
| Midstory species | 4 |
| Herb/forb species | 3 |
| Graminoid species | 3 |
| Macrophyte species | 3 |
| **DEBRIS** | **14** |
| Total leaf litter | 3 |
| Native leaf litter | 2 |
| Dead trees standing | 2 |
| Dead trees fallen | 1 |
| Lying logs | 3 |
| Fringing vegetation | 3 |
| **MANAGEMENT** | **7** |
| Tree clearing | 3 |
| Fencing | 0 |
| Animal impact | 0 |
| Species of interest | 0 |
| Exposed tree roots | 3 |
| Native woody regeneration | 1 |
| Weedy woody regeneration | 0 |
| **TOTAL** | **66.5** |

*Saltwater Creek*

The riparian vegetation communities at Saltwater Creek #3 (SALT3, Plate 3.5), can be described as a gallery 'Coastal Paperbark – Sedgeland Dominated Forest', CH_FrW04 (Office of Environment and Heritage [OEH] 2012b), or Coastal Freshwater Lagoon (Keith 2004), grading into a second broader community of Blackbutt Dry Sclerophyll Forest 'Coast and Escarpment Blackbutt Dry Forest', CH_DOF01, or Dry Sclerophyll Forests – North Coast Dry Sclerophyll Forest (Keith 2004), and received a high riparian condition score of 89%, or B+ (Table 3.9).

The dominant canopy species were *Melaleuca* species Broad-leaved Paperbark (*M*. *quinquenervia*), and Swamp Paperbark (*M*. *ericifolia*), and *Eucalyptus* species, Blackbutt (*E.pillularis*), Needlebark Stringybark (*E.plachoniana*), and Swamp Mahogany (*E.robusta*). The midstory was dominated by Brisbane Golden Wattle (*Acacia fimbriata*), Tantoon (*Leptospermum polygalifolium* subsp. *cismontanum*) and Large-leaved Hop Bush (*Dodonaea triquetra*). The understory was dominated by fern species, Swamp Water Fern (*Blechnum indicum*), and Pouched Coral fern (*Gleichenia dicarpa*), and grasses, Boardered Panic grass (*Entolasia marginata*), and Creeping Beard Grass (*Oplismenus imbecillis*). Common Silkpod (*Parsonsia* sp.) was the only vine species observed, while the macrophyte layer included Water Ribbons (*Triglochin procera*) and rush species Jointed Twig Rush (*Baumea articulate*), Grey Rush (*Lepironia articulate*), and River Club Rush (*Schoenoplectus validus*).

Noxious weed species present on site included Groundsel Bush (*Baccharis halimifolia* - class 3), Bitou Bush (*Chrysanthemoides monilifera* subsp. *Rotundata* - class 4), and Fireweed (*Senecio madagascariensis* - class 4). Other weedy species present included Slash Pine (*Pinus elliottii*), Crofton Weed (*Ageratina adenophora*), Senna (*Senna pendula* var*. glabrata*), Green-leaved Desmodium (*Desmodium intortum*), and Whiskey Grass (*Andropogon viginicus*). A species of interest on site was the native Large Tongue Orchid (*Cryptostylis subulata*).

SALT3 scored highly for HABITAT 19/20, with the presence of representative structural layers, large and hollow-bearing trees, uninterupted riparian continuity and connectivity to large tracts of remnant native vegetation. Aside from weeds in the midstory layer (10-25%), NATIVE SPECIES also scored highly with 19/20, while SPECIES COVER with 20/20, received maximum values of cover for all structural layers. Despite high levels of total and native leaf litter, fringing vegetation, and good levels of standing dead trees, DEBRIS scored 15/20 due to the lack of large and small lying woody debris. Although SALT3 recorded low levels of exposed tree roots, appropriate fencing and absence of livestock, MANAGEMENT received 16/20, reflecting the presence of both environmental and noxious weeds and weed regeneration, most notably at the site edge.

***Plate 3.5*** *Riparian vegetation at Saltwater Creek #3 was in exceptional condition. Although limited in their presence, several noxious weed species were observed at the northern edge of the site; thus weed control and monitoring would be beneficial to ensure the current exemplary condition was maintained.*

***Table 3.9*** *Site-level summary of riprian condition of Saltwater Creek #3, including subindices and indicators.*

| Saltwater Creek #3 | Scores |
|---|---|
| **HABITAT** | **19** |
| Channel width | 4 |
| Proximity | 4 |
| Continuity | 4 |
| Layers | 4 |
| Large native trees | 2 |
| Hollow-bearing trees | 1 |
| **NATIVE SPECIES** | **19** |
| Native canopy species | 4 |
| Native midstory species | 3 |
| Native herb/forb species | 4 |
| Native graminoid species | 4 |
| Native macrophyte species | 4 |
| **SPECIES COVER** | **20** |
| Canopy species | 4 |
| Midstory species | 4 |
| Herb/forb species | 4 |
| Graminoid species | 4 |
| Macrophyte species | 4 |
| **DEBRIS** | **15** |
| Total leaf litter | 3 |
| Native leaf litter | 3 |
| Dead trees standing | 2 |
| Dead trees fallen | 1 |
| Lying logs | 2 |
| Fringing vegetation | 4 |
| **MANAGEMENT** | **16** |
| Tree clearing | 3 |
| Fencing | 3 |
| Animal impact | 3 |
| Species of interest | 1 |
| Exposed tree roots | 4 |
| Native woody regeneration | 1 |
| Weedy woody regeneration | 1 |
| **TOTAL** | **89** |

### *3.2.5 Mangrove, seagrass and saltmarsh cover*

The Corindi River/Saltwater Creek estuary contained the highest total estuarine macrophyte cover of the 9 Coffs Harbour estuarine systems, which was mainly attributed to saltmarsh cover Figure 3.4). Saltmarsh was the dominant mapped vegetation community in the Corindi River/Saltwater Creek estuarine system covering 0.889km$^2$, followed by mangroves (0.290km$^2$), mixed mangrove/saltmarsh (0.123km$^2$), and seagrass (0.005km$^2$) (Table 3.10). The mixed community of mangrove/saltmarsh recorded in the Corindi River/Saltwater Creek estuary was the only mixed system mapped in all of the Coffs Harbour estuaries. Monitoring priorities in the Corindi River/Saltwater Creek system should focus on both the seagrass layer, which as the minor component of this system exists in just several small patches (averaging 260m$^2$), and the mangrove layer, which recorded the lowest total cover values of all 9 Coffs Harbour estuaries (Table 3.10).

Total estuarine macrophyte cover in the Corindi River/Saltwater Creek estuary increased from 1985 (0.967km$^2$) to 2011 (1.308km$^2$) (Table 3.10). Increases were not consistent among macrophyte types: seagrass cover decreased from 1985 (0.024km$^2$) to 2011 (0.005 km$^2$), while saltmarsh cover increased (0.572 and 0.889km$^2$ in 1985 and 2011, respectively). While mangrove cover decreased from 0.371km$^2$ in 1985 to 0.290km$^2$ in 2011, there was an overall increase in total mangrove cover if the mixed mangrove/saltmarsh cover is added to the mangrove cover for 2011 (Table 3.10).

***Table 3.10*** *Total area covered by mangrove, seagrass or saltmarsh in the Corindi River/Saltwater Creek estuary in 2011 and 1985, and mean patch size of each vegetation community in 2011.*

| **Vegetation community** | **Total area in 1985 (km$^2$)** | **Total area in 2011 (km$^2$)** | **Total area in 2011 (m$^2$)** | **Mean patch size in 2011 (m$^2$)** |
|---|---|---|---|---|
| Mangrove | 0.371 | 0.290 | 290,166 | 303 |
| Mangrove/Saltmarsh | - | 0.123 | 123,032 | 5,592 |
| Saltmarsh | 0.572 | 0.889 | 889,422 | 13,080 |
| Seagrass (*Zostera*) - total | 0.024 | 0.005 | 5,470 | 260 |
| Dense *Zostera* | - | 0.004 | 4,092 | 273 |
| Sparse *Zostera* | - | 0.001 | 1,135 | 567 |
| Estuary total | 0.967 | 1.308 | 1,308,090 | |


***Figure 3.4*** *Mangrove, seagrass and saltmarsh habitats in the Corindi River/Saltwater Creek estuary (NSW Department of Industry and Investment – Primary Industries and Energy 2011).*

### *3.2.6 Water quality*

The subcatchment of the Corindi River, Saltwater Creek and Pipeclay Lake received a score of 69, a grade of C, for water quality. The Corindi River received a score of 74 (C+) for water quality, with the best water quality recorded at the freshwater site CORI4 (B), and the worst water quality recorded at the tidal limit (CORI3, C). Saltwater Creek received a score of 60 (D+) for water quality, with the best water quality recorded at the freshwater site SALT3 (C+), and the worst water quality recorded at the tidal limit (SALT2, D-). Pipeclay Lake received a score of 64 (C-) for water quality based on the single estuarine site PIPE1.

Water temperatures at all sites reflected seasonal climatic changes (Figure 3.5). Table 3.11 outlines the ranges and means of water chemistry variables for the 3 sites on the Corindi River. Summer maximum water temperatures ranged from 23.7°C in the freshwater CORI4, to 26.8°C at the tidal limit (CORI3). Winter minimum water temperatures were also lowest (13.0°C) at the freshwater site CORI4, but were highest in the marine-influenced lower estuary site CORI1 (19.1°C). Similar patterns in water temperatures were observed in Saltwater Creek, where the freshwater site (SALT3) was consistently cooler than the tidal limit (SALT2, Table 3.12). Water temperatures in Pipeclay Lake ranged from a winter minimum of 18.0°C to a summer maximum of 28.9°C (Table 3.12).

Percent saturation of dissolved oxygen (DO%) was higher in estuarine sites than freshwater sites (Figure 3.5). DO% in the Corindi River ranged from 57.6% in CORI4 to 161% in CORI3 (Table 3.11). In the Corindi River estuary (CORI1), DO% exceeded the maximum estuarine trigger threshold of 110% on 3 sampling occasions, with DO% consistently higher at the water's surface (0.1m). At the tidal limit (CORI3), DO% was lower than the minimum estuary trigger threshold (80%) on 2 sampling occasions (March and October 2015). DO% exceeding the maximum estuary trigger threshold was recorded once (May 2015). In the freshwater site CORI4, DO% was lower than the minimum freshwater trigger threshold (80%) on 2 occasions (July and October 2015), and slightly exceeded the maximum freshwater trigger threshold (110%) once (in August 2015, Table 3.13).

DO% in Saltwater Creek ranged from 51.1% in the SALT3 to 171% in SALT2 (Table 3.12). DO% at the tidal limit (SALT2) exceeded the maximum estuarine trigger threshold on all sampling occasions (Table 3.13). DO% at the freshwater SALT3 was lower than the minimum freshwater trigger threshold on 3 occasions (March, July and October 2015), and exceeded the maximum freshwater trigger threshold once (May 2015, Table 3.13). DO% in the estuarine site on Pipeclay Lake (PIPE1) exceeded the maximum estuarine trigger threshold on 2 occasions (March and August 2015, Table 3.13).

pH in the Corindi River ranged from a minimum of 5.9 at CORI3 to a maximum of 9.1 at CORI4 (Figure 3.5). pH at CORI1 was lower than the minimum estuary trigger threshold of 7pH on 4 sampling occasions (Table 3.13). pH was consistently lowest at the surface (0.1m), but low pH extended through the water column on 3 occasions. pH was lower than the minimum estuary trigger threshold at the tidal limit (CORI3) on all sampling occasions (Figure 3.5, Table 3.12). pH at CORI4 exceeded the maximum lowland freshwater trigger threshold of 8.5 on 2 occasions (May and July 2015, Table 3.13).

pH in Saltwater Creek ranged from a minimum of 5.3 at SALT2 to a maximum of 9.0 at SALT3 (Table 3.12). SALT2 had consistently low pH (Figure 3.5) and was lower than the minimum estuary trigger threshold at all depths on all sampling occasions (Table 3.13). pH at SALT3 exceeded the maximum freshwater trigger threshold (8.5) on 3 sampling occasions (March, July and August 2015, Table 3.13). pH in Pipeclay Lake ranged from 6.2 to 7.5 (Table 3.12). pH of PIPE was lower than the minimum estuarine trigger threshold (7) on 3 sampling occasions (December 2014, and August and October 2015, Table 3.13).

Turbidity ranged from 0-29.5NTU in the Corindi River, 0.9-25.0NTU in Saltwater Creek and 0.9-13.1NTU in Pipeclay Lake (Tables 3.11, 3.12). The sites at tidal limits (CORI3 and SALT2) and PIPE1 exceeded the estuarine trigger threshold (10NTU): CORI3 in March and August 2015, SALT2 in March 2015, and PIPE1 in August 2015 (Table 3.13).

Water column chlorophyll *a* (chl-*a*) in the Corindi River ranged from 1-3µg/L (Table 3.11), with no sites exceeding trigger thresholds. Chl-*a* in Saltwater Creek ranged from 3-46µg/L (Table 3.12). The estuarine trigger threshold was exceeded on 3 sampling occasions at SALT2 (December 2014, and March and May 2015). The freshwater trigger threshold (4µg/L) was exceeded twice at SALT3 (December 2014 and August 2015). Chl-*a* in Pipeclay Lake ranged from 2-6µg/L (Table 3.12) and exceeded the estuarine trigger threshold once in March 2015 (Table 3.13).

Concentrations of total nitrogen in the water column (TN) of Corindi River ranged from 0.2-0.4mg/L (Figure 3.5). The estuarine trigger threshold (0.3mg/L) was exceeded twice at CORI1 (May and July 2015), and 3 times at CORI3 (December 2014, and July and September 2015, Table 3.13). Concentrations of TN in Saltwater Creek ranged from 0.2-0.7mg/L (Table 3.12), with both sites exceeding ANZECC guideline thresholds for healthy aquatic ecosystems (Table 3.13). SALT2 exceeded the estuarine trigger threshold on the first 6 sampling occasions (December 2014 to July 2015). SALT3 exceeded the freshwater trigger threshold (0.5mg/L) 4 times (March, May, August and December 2015, Table 3.13). TN in Pipeclay Lake ranged from 0.4-0.8mg/L, exceeding the estuarine trigger threshold on all 6 sampling occasions (Table 3.13). Concentrations of total phosphorus in the water columns (TP) of the Corindi River, Saltwater Creek and Pipeclay Lake were generally below the detection limit of 0.03mg/L (Tables 3.11, 3.12); when detected, concentrations were below the guideline thresholds (Table 3.13).

Faecal coliforms were collected from CORI1 and PIPE1 seven times through the sampling period. CORI1 never exceeded the estuarine trigger threshold for primary contact (150fc/100mL), recording a maximum of 8fc/100mL in September 2014, and 2fc/100mL in December 2014, March 2015 and July 2015 (Table 3.11). Coliforms were recorded on every sampling occasion at PIPE1, with its maximum of 750fc/100mL (August 2015) exceeding the estuarine trigger threshold for primary contact, followed by 108fc/100mL in December 2014 (Table 3.12). On the other sampling occasions, counts were ≤40fc/100mL.

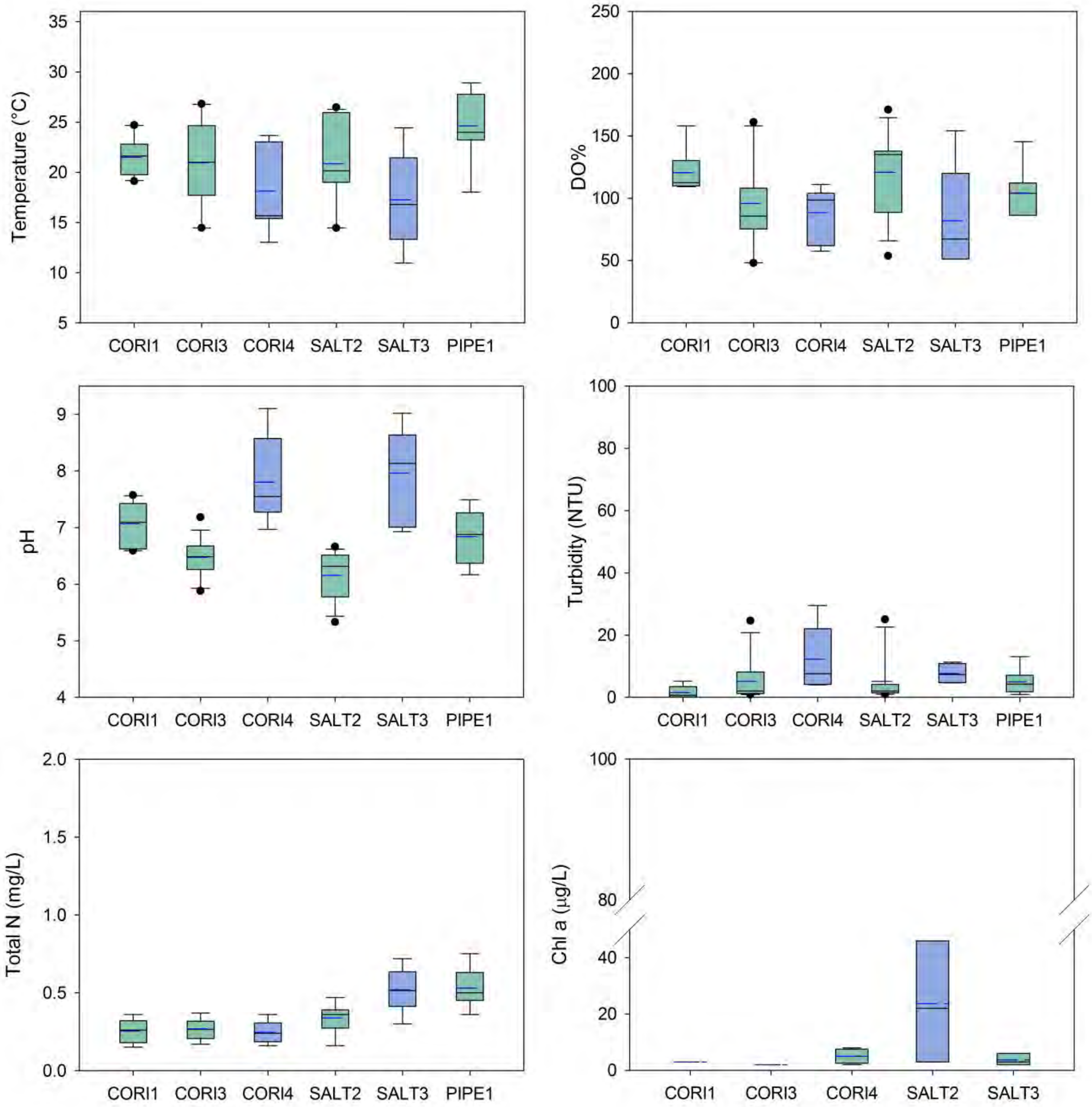



***Figure 3.5*** *Mean (blue line), median (black line), 25th and 75th percentiles, and range of water quality variables in the Corindi River, Saltwater Creek and Pipeclay Lake subcatchment over 2015. Outliers are represented by black dots. Green and blue boxes represent estuary and freshwater sites, respectively.*

***Table 3.11*** *Minimums, maximums and means of measured water quality variables for the three sites on Corindi River.*

| | CORI1 | | | CORI3 | | | CORI4 | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean |
| Temperature | 19.1 | 24.7 | 21.4 | 14.5 | 26.8 | 20.9 | 13.0 | 23.7 | 18.1 |
| pH | 6.6 | 7.6 | 7.0 | 5.9 | 7.2 | 6.5 | 7.0 | 9.1 | 7.8 |
| EC | 47.2 | 56.6 | 51.5 | 6.3 | 50.2 | 28.1 | 0.1 | 0.2 | 0.2 |
| Salinity (PPT) | 35.0 | 43.0 | 36.8 | 3.2 | 35.4 | 18.3 | 0.0 | 0.0 | 0.0 |
| DO (mg/L) | 7.3 | 16.5 | 10.7 | 5.5 | 14.7 | 8.9 | 5.4 | 16.7 | 10.7 |
| DO % | 109.3 | 158.0 | 119.7 | 70.5 | 161.0 | 102.7 | 57.6 | 111.0 | 88.5 |
| Turbidity | 0.0 | 5.2 | 1.6 | 0.8 | 24.6 | 5.2 | 4.0 | 29.5 | 12.3 |
| Max Depth | 0.8 | 2.1 | 1.7 | 1.2 | 2.3 | 1.7 | 0.3 | 1.0 | 0.7 |
| Chla (µg/L) | <1.0 | <1.0 | <1.0 | <1.0 | 3.0 | <1.0 | <1.0 | 2.0 | <1.0 |
| TSS (mg/L) | 5.0 | 15.0 | 10.8 | 4.0 | 15.0 | 9.9 | 3.0 | 5.0 | 3.8 |
| TN (mg/L) | 0.2 | 0.4 | 0.3 | 0.2 | 0.4 | 0.3 | 0.2 | 0.4 | 0.2 |
| TP (mg/L) | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 |
| Coliforms (cells/100mL) | 0 | 8 | 2 | | | | | | |

***Table 3.12*** *Minimums, maximums and means of measured water quality variables for the two sites on Saltwater Creek and the one site on Pipeclay Lake.*

| | SALT2 | | | SALT3 | | | PIPE1 | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean |
| Temperature | 14.4 | 26.5 | 21.0 | 11.0 | 24.4 | 17.3 | 18.0 | 28.9 | 24.6 |
| pH | 5.3 | 6.7 | 6.1 | 6.9 | 9.0 | 8.0 | 6.2 | 7.5 | 6.8 |
| EC | 24.0 | 56.3 | 38.6 | 0.1 | 0.3 | 0.2 | 3.1 | 51.0 | 30.0 |
| Salinity (PPT) | 14.6 | 42.6 | 25.8 | 0.1 | 0.1 | 0.1 | 3.3 | 35.8 | 22.0 |
| DO (mg/L) | 6.1 | 14.2 | 9.5 | 4.8 | 15.7 | 8.4 | 6.1 | 13.8 | 8.5 |
| DO % | 84.1 | 171.0 | 124.6 | 51.1 | 154.2 | 82.0 | 86.3 | 145.4 | 104.3 |
| Turbidity | 0.9 | 25.0 | 5.9 | 4.6 | 11.3 | 7.7 | 0.9 | 13.1 | 5.0 |
| Max Depth | 1.2 | 3.4 | 1.6 | 0.3 | 0.5 | 0.3 | 0.8 | 1.2 | 1.0 |
| Chla (µg/L) | 4.0 | 8.0 | 6.0 | 3.0 | 46.0 | 23.7 | 2.0 | 6.0 | 3.7 |
| TSS (mg/L) | 0.5 | 16.0 | 8.2 | 2.0 | 28.0 | 9.4 | 4.0 | 13.0 | 9.0 |
| TN (mg/L) | 0.2 | 0.5 | 0.3 | 0.3 | 0.7 | 0.5 | 0.4 | 0.8 | 0.5 |
| TP (mg/L) | <0.03 | <0.03 | <0.03 | <0.03 | 0.05 | 0.04 | <0.03 | <0.03 | <0.03 |
| Coliforms (cells/100mL) | | | | | | | 15 | 750 | 161 |

***Table 3.13*** *Exceedances[1] observed in the Corindi River for pH, conductivity (EC), percent saturated dissolved oxygen (DO), turbidity, chlorophyll a (Chl-a), total nitrogen (TN) and total phosphorus (TP), and the site-level WQ grades.*

| Site | pH | EC | DO % | Turbidity | Chl-a | TN | TP | WQ Grade |
|---|---|---|---|---|---|---|---|---|
| CORI1 | 7(58%) 7,0 | NA | 6(75%) 0,1 | 0 | 0 | 2(33%) | 0 | C+ |
| CORI3 | 15(94%) 15,0 | NA | 7(50%) 3,4 | 2(17%) | 0 | 3(38%) | 0 | C |
| CORI4 | 3(33%) 0,3 | 0 | 3(50%) 1,2 | 0 | 0 | 0 | 0 | B |
| SALT2 | 13(100%) 13,0 | NA | 9(75%) 0,9 | 2(18%) | 3(38%) | 6(75%) | 0 | D- |
| SALT3 | 3(50%) 0,3 | 1(14%)1,0 | 4(80%) 3,1 | 0 | 2(25%) | 4(50%) | 0 | C+ |
| PIPE1 | 5(56%) 5,0 | NA | 2(29%) 0,2 | 1(14%) | 1(17%) | 6(100%) | 0 | C- |

*[1] Numbers in black represent the total number and percent of exceedances. Numbers in blue and red represent the numbers of measurements lower than the minimum threshold and higher than the maximum threshold, respectively. The number of exceedances includes all depths sampled so may be greater than the number of times sampled. Turbidity, chlorophyll a, and total nutrients only have maximum trigger thresholds.*

### *3.2.7 Aquatic macroinvertebrates*

*Corindi River*

Corindi River #4 (CORI4) recorded 18 and 14 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.14). In autumn, abundance was dominated by Atyidae (Freshwater Shrimp, 56 individuals) and richness was dominated by Coleoptera (Aquatic Beetles) and Ephemeroptera (Mayflies) with 3 families each. In contrast, the dominant family in spring for both taxonomic richness and abundance was Ephemeroptera (Mayflies, 83 individuals across 5 genera). Family richness was higher in autumn than spring but was not driven by the presence of any particular order. Abundance was greater in spring (170) than autumn (121) driven by Leptophlebiidae Mayflies (45) and Chironomidae Midge Larvae (28). There were a number of rare taxa at the site, with 13 and 7 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for Corindi River were consistent between autumn (4.2) and spring (4.5). The increase in SIGNAL2 range in spring was due to 1 individual Crustacean (Koonungidae) which is a detritivore able to withstand the drying of streams by burrowing into bed sediments (SIGNAL2 of 1).

Corindi River #4 (CORI4) received an overall Ecohealth score of 36, a grade of F, for aquatic macroinvertebrate community condition. Although the macroinvertebrate indicators of mean EPT richness and abundance (9) and mean SIGNAL2 (15) were above average for the Coffs coastal catchments (7 and 12, respectively, Table 3.6), family richness (6) and total abundance (6) were both below average for the Coffs coastal catchments (10 and 12, respectively). The macroinvertebrate indicators suggest the water quality and habitat conditions in the freshwater reaches of the Corindi River are in very poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

***Table 3.14*** *Summary of aquatic macroinvertebrate data for Corindi River #4 (CORI4).*

| CORI4 | | | | |
|---|---|---|---|---|
| **Macroinvertebrate indicator** | **Autumn 2015** | **Spring 2015** | **Autumn 2011** | **Spring 2011** |
| Family richness | 18 | 14 | 13 | 16 |
| Total abundance | 121 | 170 | 96 | 125 |
| EPT richness | 5 | 6 | 5 | 6 |
| EPT abundance | 22 | 90 | 17 | 51 |
| Mean SIGNAL2 score | 4.2 | 4.5 | 4.8 | 4.4 |
| SIGNAL2 score range | 2 - 8 | 1 - 8 | 2 - 8 | 2 - 8 |
| Ecohealth score (grade) | **36 (F)** | | **56 (D+)** | |

### *Saltwater Creek*

Aquatic macroinvertebrate community condition in Saltwater Creek #3 (SALT3) was poorer than in CORI4 (Table 3.15). Family richness was similar between the sites, with 17 and 13 families in SALT3 in autumn and spring, respectively (Table 3.15). Total abundance was greater in autumn than spring with the former dominated by 4 taxa: Hydraenidae (Aquatic Beetles with 70 individuals), Atyidae (Freshwater Shrimp with 28 individuals), Chironomidae (Midge Larvae with 40 invidiuals) and Ostrocoda (Seed Shrimp with 67 individuals). Abundance was dominated by 2 taxa in spring: Hydrophilidae (Aquatic Beetles with 34 individuals) and Atyidae (Freshwater Shrimp with 83 individuals). More rare taxa (fewer than 5 individuals) were present in autumn (11) than spring (9).

Mean SIGNAL2 scores improved from 2.3 in autumn to 3.3 in spring; this was driven primarily by the absence of Chironomidae (Midge Larvae) with their SIGNAL2 of 3 as they are able to withstand poor water quality and habitat condition. EPT richness and abundance were both very low at SALT3 in autumn, with only 2 Ephemeropteran individuals; there were no EPT individuals at SALT3 in spring. This contributed significantly to the poor score for the Ecohealth macroinvertebrate index for this site.

Saltwater Creek #3 (SALT3) received an overall Ecohealth score of 18, a grade of F, for aquatic macroinvertebrate community condition. All four macroinvertebrate indicators were below average for the Coffs coastal catchments in 2015 with mean EPT richness and abundance (0) the worst indicator (catchment average 7, Table 3.6). The macroinvertebrate indicators suggest the water quality and habitat conditions in the freshwater reaches of Saltwater Creek are in very poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

***Table 3.15*** *Summary of aquatic macroinvertebrate data for Saltwater Creek #3 in 2011 and 2015.*

| SALT3 | | | | |
|---|---|---|---|---|
| **Macroinvertebrate indicator** | **Autumn 2015** | **Spring 2015** | **Autumn 2011** | **Spring 2011** |
| Family richness | 17 | 13 | 7 | 13 |
| Total abundance | 232 | 145 | 32 | 84 |
| EPT richness | 2 | 0 | 1 | 4 |
| EPT abundance | 2 | 0 | 3 | 7 |
| Mean SIGNAL2 score | 2.3 | 3.3 | 3.4 | 4.4 |
| SIGNAL2 score range | 2 - 8 | 1 - 9 | 2 - 6 | 2 - 9 |
| Ecohealth score (grade) | **18 (F)** | | **56 (D+)** | |

## 3.3 Arrawarra Creek

### *3.3.1 Catchment description*

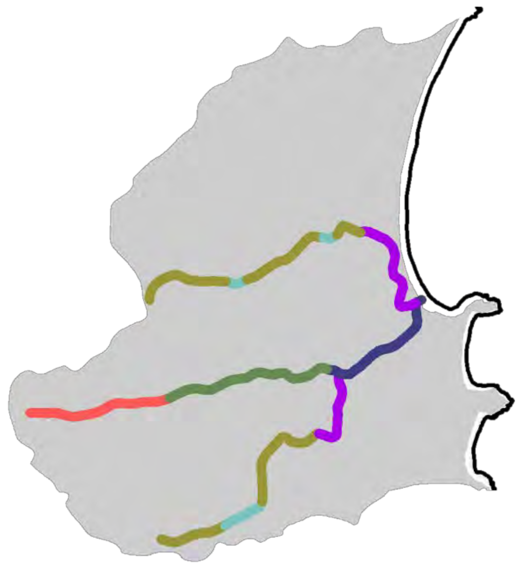
Arrawarra Creek is a small estuarine water body (30% of the stream network is tidal). The subcatchment is approximately 30km north of Coffs Harbour and drains a catchment area of approximately 20km$^2$ (Table 3.16). Very little of the subcatchment comprises midland hills (Figure 3.6a); only 13% of the stream network comprises headwaters and 15% drains to confined discontinuous floodplains (Figure 3.6b, Table 3.16). The catchment is underlain by Coramba Beds of the Coffs Harbour association metasediments consisting of siliceous mudstones, siltstones and greywacke (72%, Table 3.16), with aeolian sand underlying the coastal areas. Kandosols (typically yellow and grey earths) overlie the greywacke and are the dominant soil type (65% of catchment area). These soil landscapes have strongly acid soils <5.5pH, low subsoil fertility and commonly exhibit subsoil aluminium toxicity (Milford 1999). The dominant landuse of the upper and mid reaches of Arrawarra Creek is state forest (61%) and native forest (11%) (Figure 3.6c, Table 3.16).

Most of the subcatchment is coastal plain. The estuarine reaches of Arrawarra Creek are underlain by kurosols (26% of subcatchment area) with strongly acidic, clay-rich B horizons that have low chemical fertility and poor water-holding capacity (Figure 3.6d). The dominant landuses of the coastal plain are tree and shrub cover, urban residential (10%), transport corridor (3%), rural residential (3%) and wetlands (6%, Table 3.16).

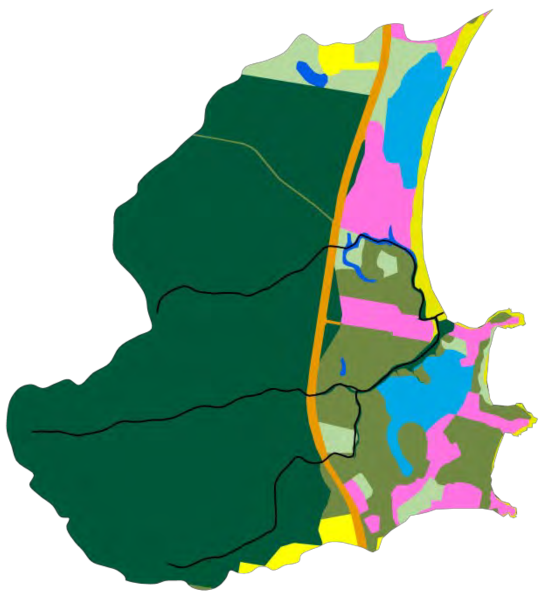
The estuary contains several cultural heritage sites that are highly valued by the local indigenous community, including middens and open campsites. While the creek is open to the sea most of the time, it occasionally closes due to natural accretion of the entrance sand berm (Umwelt 2001). Breakout events 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 (Umwelt 2011), 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).

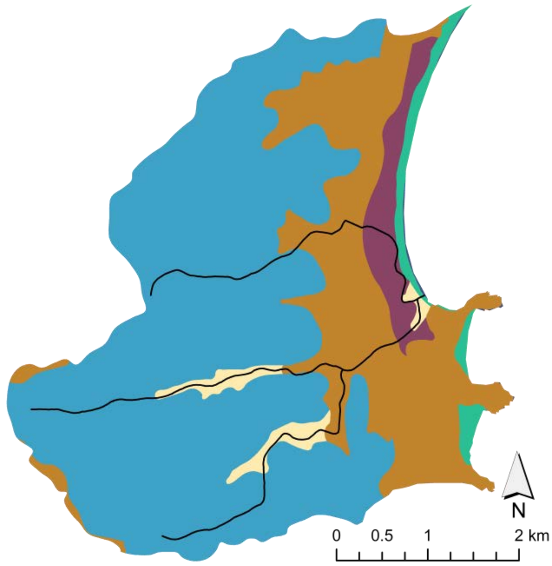

**(a)** Topography and location of Ecohealth sites.



**(b)** River Styles: refer to Figure 2.8 for key.



**(c)** Landuse: refer to Figure 2.7 For key.




**(d)** Soils: refer to Figure 2.3 For key.

***Figure 3.6*** *The Arrawarra Creek subcatchment showing (a) locations of Ecohealth sites and catchment topography, (b) River Styles, (c) landuse, and (d) soils. Data layers from CHCC (site locations), ESRI (topography), NC LLS (River Styles) and OEH (landuse and soils).*

***Table 3.16*** *Subcatchment description of Arrawarra Creek. Data from NC LLS and OEH.*

| Variable | Subcatchment composition |
|---|---|
| Area ($km^2$) | 20 |
| Geology | 72% Greywacke; 27% Aoelian Sand |
| Soils | 65% Kandosols; 26% Kurosols; 4% Podosols, 5% other |
| River Styles | 35% SMG - Valley fill, sand; 18% LUV CC – Tidal; 15% CVS - Floodplain pockets, gravel; 13% CVS – Headwater; 12% PCVS - Planform controlled, tidal; 7% Water storage - dam or weir pool. |
| Landuse | 61% State Forest; 11% Native Forest; 10% Urban; 6% Wetland; 3% Rural Residential; 3% Transport; 5% Other; 1% Beach. |
| Major point source discharge | Nil |
| Tree Cover | 12% |

### *3.3.2 Site descriptions*

Two sites were monitored for the Arrawarra Creek subcatchment. Site ARRA1 is the most downstream site located in the tidal lagoon (Plate 3.6). The channel in this reach is defined as planform controlled tidal. The freshwater site ARRA4 is upstream of the tidal limit; it is also close to the Pacific Highway (Plate 3.7). The reach surrounding ARRA4 is defined as swampy meadow, valley fill, sand.

***Plate 3.6*** *Site ARRA1 in the lagoon at the mouth of Arrawarra Creek.*

***Plate 3.7*** *Site ARRA4 in the freshwater reaches of Arrawarra Creek.*

### *3.3.3 Geomorphic condition*

The River Style at ARRA4 is swampy meadow group: valley fill, sand. The bed and bank sediments were fine grained sediments with cobbles, pebbles and gravel absent. Streamflow was below baseflow levels at the time of assessment and the stream consisted of a series of very small disconnected pools. The banks were well vegetated and bank erosion was localized to bed knickpoints at the upstream of pools where water ‘plunges’ into pools when they are connected by surface flow. There was moderate undercutting (5-10m combined length) along both banks. Localised areas of scour around trees exposed small areas of roots. There was no evidence of stock damage to the bank or bed. ARRA4 scored 71.4, a grade of C+ for BANK CONDITION and 73.7, a grade of C+ for BED CONDITION. The overall Ecohealth geomorphic condition for ARRA4 was 73, a grade of C+.

In summary, ARRA4 was assessed as being in good geomorphic condition. Localised erosion at knickpoints in the stream bed is the most significant issue for site-level geomorphic condition, similar to SALT3. Maintaining the riparian vegetation at ARRA4 and upstream of the site will continue to protect bank stability, and help slow runoff, reducing its erosivity. The desktop GIS assessment of subcatchment geomorphic condition found the Arrawarrwa Creek subcatchment to be in good condition with a grade of B-. This means that the site level assessment for ARRA4 was slightly below the average subcatchment geomorphic condition for Arrawarra Creek.

### *3.3.4 Riparian condition*

The riparian vegetation community at Arrawarra Creek #4 (ARRA4, Plate 3.8) can be described as Paper Bark Freshwater Swamp grading into Dry Sclerophyll Eucalypt Forest with Wet Sclerophyll elements; similar to the described communities ‘Lowlands Swamp Box – Paperbark – Red Gum Dry Forest’, CH_DOF06 (OEH 2012b), or Coastal Freshwater Lagoon (Keith 2004), grading into ‘Coast And Escarpment Blackbutt Dry Forest’, CH_DOF01 (OEH, 2012b), or North Coast Dry Sclerophyll Forest (Keith 2004), with riparian condition scoring a very high with 90.5%, or A- (Table 3.17).

The dominant canopy species were Broad-leaved Paperbark (*Melaleuca quinquenervia*), Brush Box (*Lophostemon confertus*), Turpentine (*Syncarpia glomulifera*), and *Eucalyptus* species, Tallowood (*E.microcorys*), and Blackbutt (*E.pilularis*). The midstory was dominated by Forest Oak (*Allocasuarina torulosa*), Brush Cherry (*Syzygium australe*), Swamp Paperbark (*Melaleuca ericifolia*), and Rough Tree Fern (*Cyathea australis*). The understory was dominated by Lomandra species (*L.hystrix* and *L.longifolia*), Common Bracken (*Pteridium esculentum*), Swamp Water Fern (*Blechnum indicum*), Black Bog Rush (*Schoenus melanostachys*), Variable Sword-sedge (*Lepidosperma laterale*), and Tall Spikerush (*Eleocharis sphacelata*). Dominant vine species included Wait-a-while Vine (*Smilax australis*), Common Silkpod (*Parsonsia* sp.) and Climbing Lily (*Geitonoplesium cymosum*), while the macrophyte layer included Common Reed (*Pragmites australis*) and Water Ribbons (*Triglochin procera*).

Lantana (*Lantana camara* - class 4) was the only noxious weed species observed on-site. Other weedy species present included Prairie Grass (*Bromus catharticus*), Rhodes Grass (*Chloris gayana*) and Paspalum (*Paspalum dilatatum*), Blue Billy Goat Weed (*Ageratum houstonianum*) and Green-leaved Desmodium (*Desmodium intortum*).

Riparian Condition scored highly at ARRA4 for good connectivity and proximity to large tracts of remnant native vegetation, structural complexity, high species cover at all structural levels including fringing vegetation, low weed density and good levels of woody and non-woody debris (HABITAT 18/20, NATIVE SPECIES 20/20, SPECIES COVER 19.5/20, and DEBRIS 18/20). The site was reduced due to a lack of standing and lying woody debris and hollow bearing trees, and a small but significant cleared break in riparian continuity. MANAGEMENT scored 15/20, with a reduction for the presence of weeds and weed regeneration (both noxious and environmental), a small section of recent tree clearing for powerlines, and an unfenced riparian zone, despite there being no evidence of animal impact.

***Plate 3.8*** *Riparian vegetation at Arrawarra Creek #3 was in exceptional condition. Although limited in their presence, weed control and monitoring would be beneficial to ensure the current exemplary condition was maintained.*

***Table 3.17*** *Site-level summary of riprian condition of Arrawarra Creek #3, including subindices and indicators.*

| Arrawarra Creek #3 | Scores |
|---|---|
| **HABITAT** | **18** |
| Channel width | 4 |
| Proximity | 4 |
| Continuity | 3.5 |
| Layers | 4 |
| Large native trees | 1.5 |
| Hollow-bearing trees | 1 |
| **NATIVE SPECIES** | **20** |
| Native canopy species | 4 |
| Native midstory species | 4 |
| Native herb/forb species | 4 |
| Native graminoid species | 4 |
| Native macrophyte species | 4 |
| **SPECIES COVER** | **19.5** |
| Canopy species | 3.5 |
| Midstory species | 4 |
| Herb/forb species | 4 |
| Graminoid species | 4 |
| Macrophyte species | 4 |
| **DEBRIS** | **18** |
| Total leaf litter | 3 |
| Native leaf litter | 3 |
| Dead trees standing | 2 |
| Dead trees fallen | 2 |
| Lying logs | 4 |
| Fringing vegetation | 4 |
| **MANAGEMENT** | **15** |
| Tree clearing | 3 |
| Fencing | 2 |
| Animal impact | 2 |
| Species of interest | 1 |
| Exposed tree roots | 4 |
| Native woody regeneration | 2 |
| Weedy woody regeneration | 1 |
| **TOTAL** | **90.5** |

### 3.3.5 Mangrove, seagrass and saltmarsh cover

Of the 9 Coffs Harbour estuarine systems, Arrawarra Creek estuary recorded the third lowest cover for total estuarine macrophytes (Figure 3.7). Mangroves were the dominant vegetation community in the Arrawarra Creek estuarine system covering 0.016km$^2$, and were closely followed by seagrass (0.014km$^2$).

Total estuarine macrophyte cover in the Arrawarra Creek estuary increased from 1985 (0.021km$^2$) to 2011 (0.029km$^2$) (Table 3.18). This is due to increases in both mangrove cover and saltmarsh cover from 1985 to 2011 (Table 3.18). Despite being present in the 1985 estuarine macrophyte survey, no seagrass community was recorded here in 2011. Therefore, a management priority for estuarine macrophytes in the Arrawarra estuary is for further research to determine where seagrass has been lost from the estuary and to identify contributing factors. Future investment may include re-establishing seagrass in this estuary once the underlying causes of seagrass loss are better understood and mitigated.

***Table 3.18*** *Total area covered by mangrove, seagrass or saltmarsh in the Arrawarra Creek estuary in 2011 and 1985, and mean patch size of each vegetation community in 2011.*

| Vegetation community | Total area in 1985 (km$^2$) | Total area in 2011 (km$^2$) | Total area in 2011 (m$^2$) | Mean patch size in 2011 (m$^2$) |
|---|---|---|---|---|
| Mangrove | 0.010 | 0.016 | 16,046 | 102 |
| Saltmarsh | 0.010 | 0.013 | 13,503 | 964 |
| Seagrass (*Zostera*) - total | 0.001 | 0 | 0 | 0 |
| Dense *Zostera* | - | - | - | - |
| Sparse *Zostera* | - | - | - | - |
| Estuary total | 0.021 | 0.029 | 29,549 | |


***Figure 3.7*** *Mangrove, seagrass and saltmarsh habitats in the Arrawarra Creek estuary (NSW Department of Industry and Investment – Primary Industries and Energy 2011).*

### 3.3.6 Water quality

Arrawarra Creek received a score of 69, a grade of C, for water quality, with the estuary site ARRA1 (C+) recording better water quality than the freshwater site ARRA4 (C). Water temperatures reflected seasonal climatic changes, ranging from winter minimums of 15.9°C at ARRA4, to summer maximums of 29.3°C at ARRA1 (Figure 3.8, Table 3.19). DO% ranged from 34-140.9% (Table 3.19). DO% at ARRA1 exceeded the maximum estuarine trigger threshold twice (May and August 2015). DO% at ARRA4 was lower than the minimum freshwater trigger threshold on all but 1 sampling occasion: in December 2014, it exceeded the maximum freshwater trigger threshold (Table 3.20). pH ranged from 5.9-8.6 (Table 3.19). At ARRA1, pH was below the minimum estuarine trigger threshold on 5 of 6 sampling occasions (March – October 2015), while at ARRA4, pH exceeded the maximum freshwater trigger threshold on 5 occasions (Table 3.20), only falling within the guidelines for healthy aquatic ecosystems in March 2015. Turbidity ranged from 0.5-20.1NTU and did not exceed guideline thresholds.

Chl-*a* ranged from 2-10µg/L (Table 3.19), and remained below the guideline threshold in the estuary (ARRA1). At ARRA4, chl-*a* exceeded the freshwater trigger threshold once in October 2015 (Table 3.20). TN ranged from 0.2-0.53mg/L, and only exceeded the trigger threshold once in the estuary (ARRA1), in July 2015. TP remained at or below the detection limit of 0.03mg/L for the duration of sampling (Table 3.19).

Faecal coliforms were collected from ARRA1 8 times through the sampling period. No coliforms were recorded in September 2014. On 3 occasions, coliform counts exceeded the estuarine trigger threshold for primary contact. The maximum count was >1000fc/100mL in October 2015, followed by 420fc/100mL in July 2015 and 165fc/100mL in August 2015.

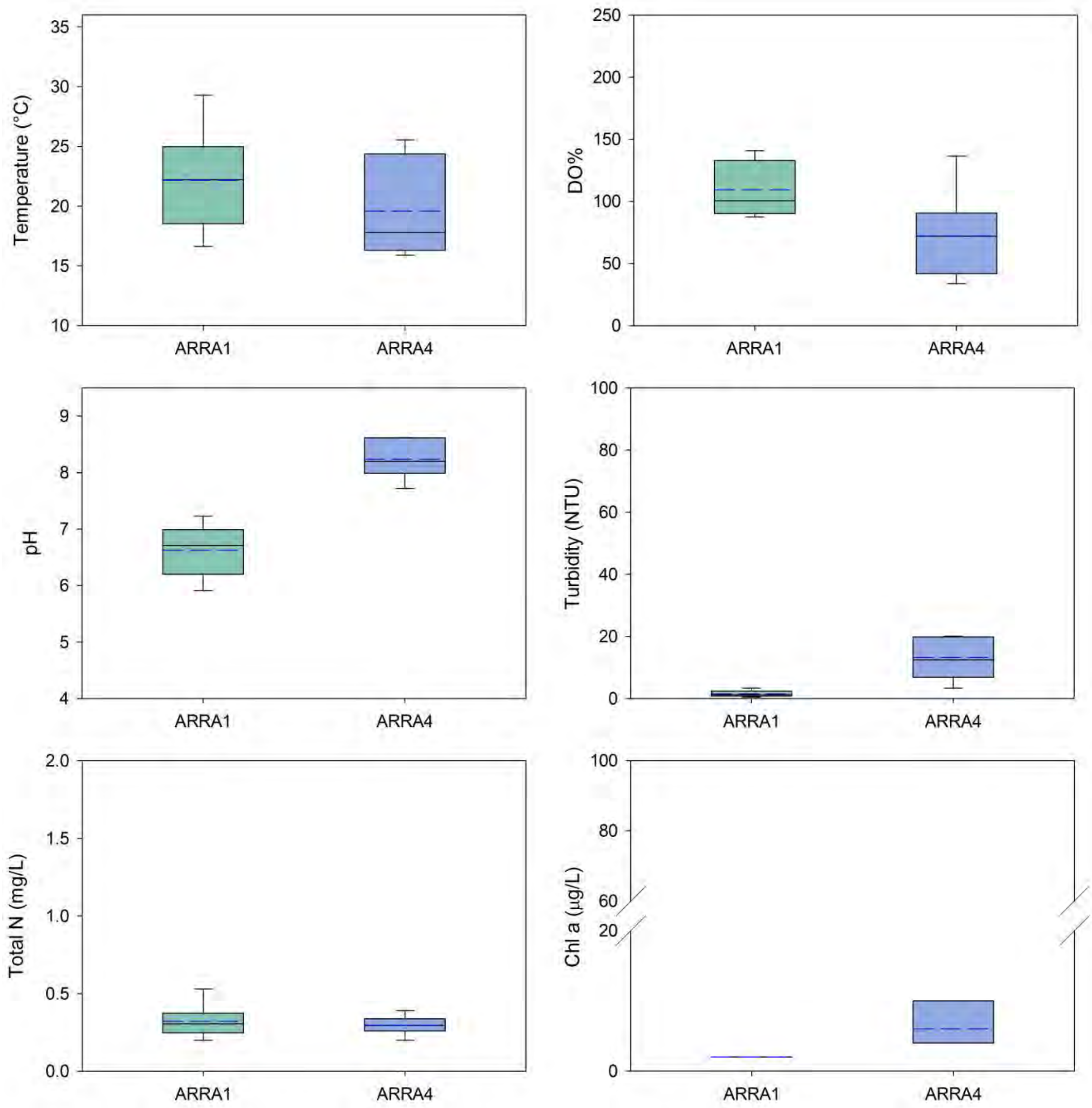



***Figure 3.8** Mean (blue line), median (black line), 25th and 75th percentiles, and range of water quality variables in the Arrawarra Creek subcatchment over 2015. Outliers are represented by black dots. Green and blue boxes represent estuary and freshwater sites, respectively.*

***Table 3.19*** *Minimums, maximums and means of measured water quality variables for the two sites on Arrawarra Creek.*

| | ARRA1 | | | ARRA4 | | |
|---|---|---|---|---|---|---|
| **Variable** | **Min** | **Max** | **Mean** | **Min** | **Max** | **Mean** |
| **Temperature** | 16.6 | 29.3 | 22.1 | 15.9 | 25.6 | 19.6 |
| **pH** | 5.9 | 7.23 | 6.6 | 7.72 | 8.6 | 8.2 |
| **EC** | 33.3 | 58.6 | 47.6 | 0.3321 | 0.4314 | 0.38 |
| **Salinity (PPT)** | 25.8 | 43.5 | 34.0 | 0.16 | 0.24 | 0.21 |
| **DO (mg/L)** | 5.4 | 11.8 | 8.6 | 3.4 | 11.4 | 6.5 |
| **DO %** | 87.4 | 140.9 | 109.4 | 34 | 136.6 | 72.4 |
| **Turbidity** | 0.5 | 3.4 | 1.5 | 3.4 | 20.1 | 13.2 |
| **Max Depth** | 0.2 | 0.4 | 0.2 | 0.2 | 0.3 | 0.3 |
| **Chla (µg/L)** | 2 | 2 | 2.0 | 4 | 10 | 6.0 |
| **TSS (mg/L)** | 6 | 31 | 14.5 | 4 | 21 | 11.3 |
| **TN (mg/L)** | 0.2 | 0.53 | 0.32 | 0.2 | 0.4 | 0.3 |
| **TP (mg/L)** | <0.03 | <0.03 | <0.03 | <0.03 | 0.03 | <0.03 |
| **Coliforms** | 0 | >1000 | 209 | | | |

***Table 3.20*** *Exceedances[1] observed in Arrawarra Creek for pH, conductivity (EC), percent saturated dissolved oxygen (DO), turbidity, chlorophyll a (Chl-a), total nitrogen (TN) and total phosphorus (TP), and the site-level WQ grades.*

| Site | pH | EC | DO % | Turbidity | Chl-a | TN | TP | WQ grade |
|---|---|---|---|---|---|---|---|---|
| ARRA1 | 5(83%) 5,0 | NA | 2(40%) 0,2 | 0 | 0 | 4(50%) | 0 | C+ |
| ARRA4 | 5(83%) 0,5 | 0 | 6(100%) 5,1 | 0 | 1(13%) | 0 | 0 | C |

*[1] Numbers in black represent the total number and percent of exceedances. Numbers in blue and red represent the numbers of measurements lower than the minimum threshold and higher than the maximum threshold, respectively. The number of exceedances includes all depths sampled so may be greater than the number of times sampled. Turbidity, chlorophyll a, and total nutrients only have maximum trigger thresholds.*

### *3.3.7 Aquatic macroinvertebrates*

Family richness and total abundance were higher in autumn than spring in Arrawarra Creek #4 (ARRA4 Table 3.21). There were 24 families in autumn and these were dominated by Coleoptera (Aquatic Beetles with 5 families), Gastropoda (Aquatic Snails with 3 families), and Hemiptera (True Bugs with 3 families). Abundance was dominated by Atyidae (Freshwater Shrimp with 129 individuals). EPTs were a small component of the macroinvertebrate community with 2 Ephemeropteran (Mayfly) families represented by only 7 individuals.

Spring abundance was also dominated by Atyidae with Freshwater Shrimps (163) comprising almost 75% of the total individuals counted. Hemipterans (4 families) dominated the family richness in spring, but only comprised 9 individuals. EPTs were represented by 1 Mayfly individual (Table 3.21). Although there were lower family and EPT richness in spring, the mean SIGNAL2 score was higher at 3.8, driven primarily by the absence of Coleoptera and Gastropoda with their relatively low SIGNAL2 scores.

Arrawarra Creek #4 (ARRA4) received an overall Ecohealth score of 35, a grade of F for aquatic macroinvertebrate community condition. Total family richness and abundance were above average for Coffs coastal subcatchments (Table 3.6), with the poor grade driven primarily by the absence of EPTs. The macroinvertebrate indicators suggest the water quality and habitat conditions in the freshwater reaches of Arrawarra Creek are in very poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores. However, the loss of biota with high SIGNAL2 scores between autumn and spring 2015 is worth noting, as this may indicate declining water quality, or the quality or availability of habitat at ARRA4.

***Table 3.21*** *Summary of aquatic macroinvertebrate data for Arrawarra Creek #4 (ARRA4) in 2011 and 2015.*

| ARRA4 | | | | |
|---|---|---|---|---|
| **Macroinvertebrate indicator** | **Autumn 2015** | **Spring 2015** | **Autumn 2011** | **Spring 2011** |
| Family richness | 24 | 19 | 8 | 13 |
| Total abundance | 321 | 219 | 90 | 108 |
| EPT richness | 2 | 1 | 1 | 7 |
| EPT abundance | 7 | 1 | 1 | 33 |
| Mean SIGNAL2 score | 3.0 | 3.8 | 4.75 | 4.77 |
| SIGNAL2 score range | 1 - 8 | 1 - 6 | 2 - 8 | 2 - 8 |
| Ecohealth score (grade) | **36 (F)** | | **53 (D)** | |

## 3.4 Darkum Creek

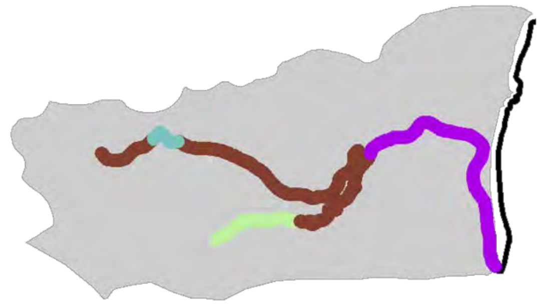
### *3.4.1 Catchment description*

Darkum Creek is an Intermittently Closed and Open Lake or Lagoon (ICOLL) and is part of the Solitary Islands Marine Park; the eastern fringe of the estuary catchment is located in the Coffs Coast Regional Park. The catchment area of Darkum Creek is $7km^2$ (Table 3.22), with a small area of lower midland hills (Figure 3.9a). Darkum Creek catchment is underlain by Coramba Beds of the Coffs Harbour association metasediments consisting of siliceous mudstones, siltstones and greywacke (89% of subcatchment area, Table 3.22). The hilly soil landscapes units comprise kandosols (Figure 3.9d) that are strongly acid <5.5pH, have low chemical fertility and often, aluminium toxicity (Milford 1999).

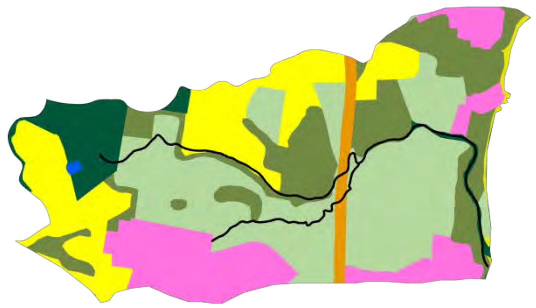
The catchment area of Darkum Creek comprises state forest, banana plantations and blueberry farms in the upper limits of the catchment, and large areas of cleared agricultural land in the mid-catchment (Figure 3.9c, Table 3.22). The Woolgoolga Golf Course adjoins a large section of Darkum Creek and comprises a large portion of the estuary catchment. The Safety Beach residential area is situated in the southern section of the estuary catchment (Fig. 3.9c).

The ocean entrance to Darkum Creek is generally closed 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.

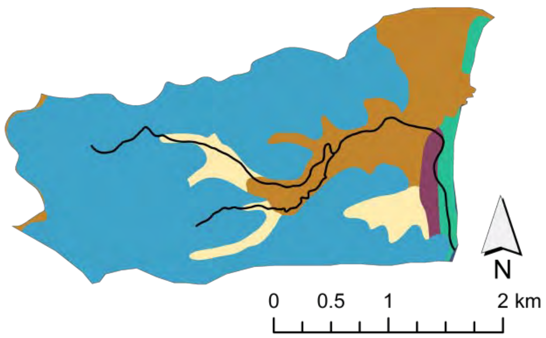

**(a)** Topography and location of Ecohealth sites.



**(b)** River Styles: refer to Figure 2.8 for key.



**(c)** Landuse: refer to Figure 2.7 For key.




**(d)** Soils: refer to Figure 2.3 For key.

***Figure 3.9*** *The Darkum Creek subcatchment showing (a) locations of Ecohealth sites and catchment topography, (b) River Styles, (c) landuse, and (d) soils. Data layers from CHCC (site locations), ESRI (topography), NC LLS (River Styles) and OEH (landuse and soils).*

***Table 3.22*** *Subcatchment description of Darkum Creek. Data from NC LLS and OEH.*

| Variable | Subcatchment composition |
|---|---|
| Area ($km^2$) | 7 |
| Geology | 89% Greywacke; 11% Alluvial Sediment |
| Soils | 69% Kandosols; 19% Kurosols; 7% Hydrosols, 5% other |
| River Styles | 52% PCVS - Planform controlled, low sinuosity, fine grained; 32% LUV CC – Tidal; 12% SMG - Valley fill, fine grained; 4% Water storage - dam or weir pool. |
| Landuse | 34% Grazing; 20% Residual Native Cover; 20% Horticulture; 10% Rural Residential; 6% Plantation; 6% Urban; 2% Transport |
| Major point source discharge | Nil |
| Tree Cover | 26% |

### 3.4.2 Site description

One site was located on Darkum Creek in the lagoon adjacent to Darkum Road (Figure 3.9a). This site represents the water quality at the end of the freshwater creek system that exchanges with the estuary (when open). The reach surrounding the site is defined as laterally unconfined continuous tidal channel (Figure 3.9b).

### 3.4.3 Geomorphic condition

Site-level geomorphic condition was not assessed for Darkum Creek. The desktop GIS-based assessment of the stream network across the whole subcatchment scored Darkum Creek a C, as 96% of streams were assessed to be in moderate condition.

### 3.4.4 Mangrove, seagrass and saltmarsh cover

Of the 9 Coffs Harbour estuarine systems, Darkum Creek estuary recorded the lowest cover for total estuarine macrophytes (Figure 3.10). Two estuarine vegetation communities were present in the Darkum Creek estuarine system: mangroves were the dominant vegetation community covering 0.007km$^2$, with saltmarsh covering less than 0.001km$^2$. Saltmarsh was not present in the 1985 estuarine macrophyte survey of Darkum Creek, indicating an expansion in range for saltmarsh. Despite being present in the 1985 estuarine macrophyte survey, no seagrass community was recorded in Darkum estuary in 2011. Therefore, a management priority for estuarine macrophytes in the Darkum estuary is for further research to determine where seagrass has been lost from the estuary and to identify contributing factors. Future investment may include re-establishing seagrass in this estuary once the underlying causes for seagrass loss are better understood.

Total estuarine macrophyte cover in the Darkum Creek estuary has decreased from 1985 (0.023km$^2$) to 2011 (0.007km$^2$) (Table 3.23). Both mangrove cover and seagrass cover have decreased from 1985 to 2011 (Table 3.23).


***Figure 3.10*** *Mangrove, seagrass and saltmarsh habitats in the Darkum Creek estuary (NSW Department of Industry and Investment – Primary Industries and Energy 2011).*

***Table 3.23*** *Total area covered by mangrove, seagrass or saltmarsh in the Darkum Creek estuary in 2011 and 1985, and mean patch size of each vegetation community in 2011.*

| Vegetation community | Total area in 1985 ($km^2$) | Total area in 2011 ($km^2$) | Total area in 2011 ($m^2$) | Mean patch size in 2011 ($m^2$) |
|---|---|---|---|---|
| Mangrove | 0.010 | 0.007 | 6,631 | 109 |
| Saltmarsh | 0 | <0.001 | 334 | 167 |
| Seagrass (*Zostera*) - total | 0.013 | 0 | 0 | 0 |
| Dense *Zostera* | - | - | - | - |
| Sparse *Zostera* | - | - | - | - |
| Estuary total | 0.023 | 0.007 | 6,965 | |

### *3.4.5 Water quality*

Darkum Creek received a score of 61, a grade of C-, for water quality. Water temperatures reflected seasonal climatic changes, ranging from a winter minimum of 18.3°C to a summer maximum of 35.1°C (Figure 3.11, Table 3.24). DO% ranged from 54.1-163.0% (Table 3.24). DO% fell below the minimum estuarine trigger threshold in July 2015, and exceeded the maximum estuarine trigger threshold in December 2014 and May 2015 (Table 3.25). pH ranged from 6.0-7.2, remaining below the minimum estuarine trigger threshold from May – November 2015 (Table 3.25). Turbidity ranged from 1.7-9.5 and remained below the guideline threshold for the duration of sampling (Table 3.24).

Chl-*a* ranged from 3.0-4.0µg/L (Table 3.24) and exceeded the estuarine trigger threshold once in March 2015 (Table 3.25). TN ranged from 0.32-0.75mg/L, exceeding the estuarine trigger threshold of 0.3mg/L on all sampling occasions (Table 3.25). In contrast, TP remained at or below the guideline threshold for the duration of sampling.

Faecal coliforms were collected from DARK1 6 times through the sampling period. Coliform counts exceeded the estuarine trigger threshold for primary contact on 3 occasions. The maximum count exceeded the upper detection limit of 1000fc/100mL and was recorded in July and August 2015, followed by 320fc/100mL in November 2015.

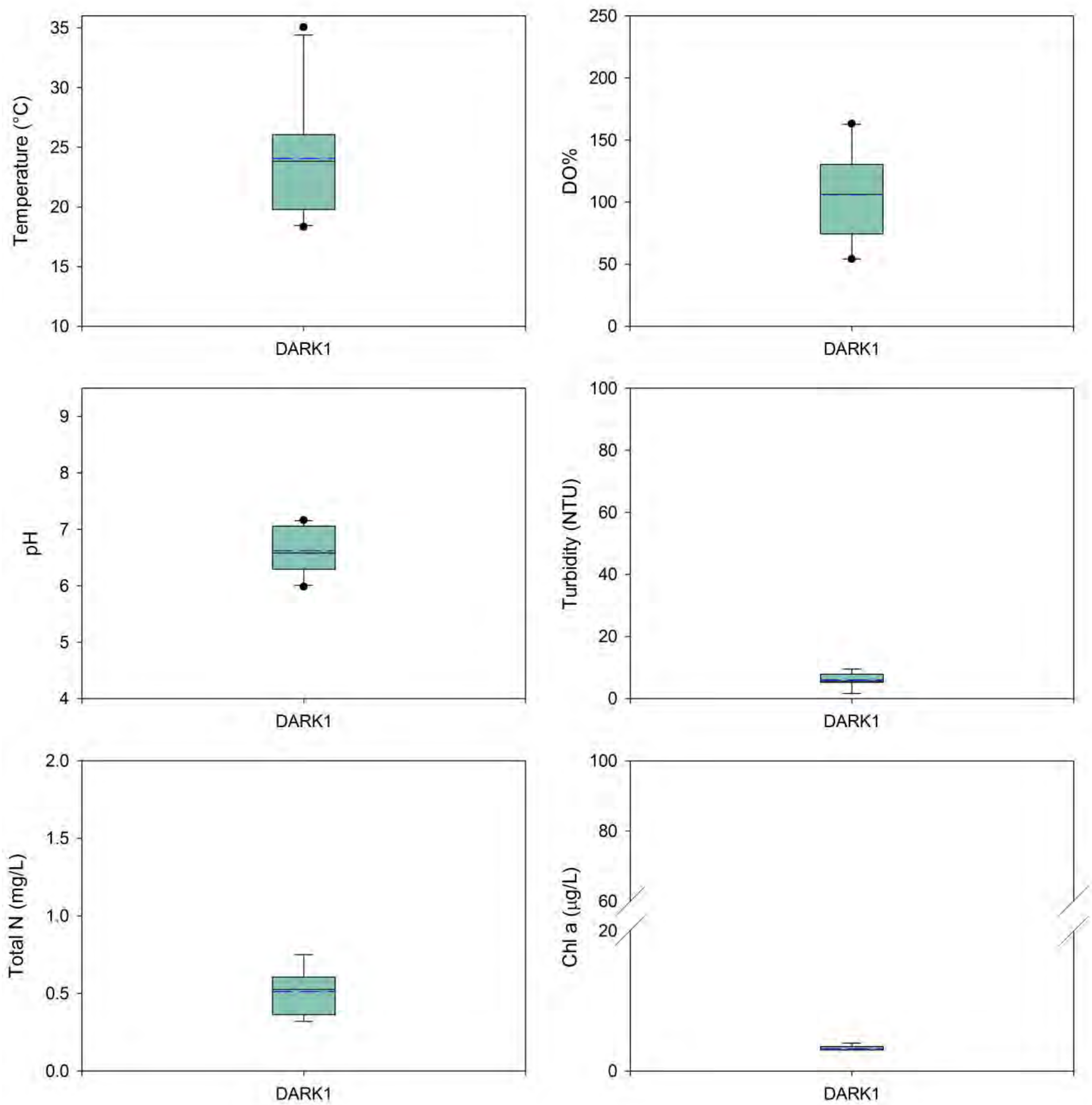



***Figure 3.11*** *Mean (blue line), median (black line), 25th and 75th percentiles, and range of water quality variables in the Darkum Creek subcatchment over 2015. Outliers are represented by black dots. Green boxes represent an estuary sites.*

***Table 3.24*** *Minimums, maximums and means of measured water quality variables for the one site on Darkum Creek.*

| | DARK1 | | |
|---|---|---|---|
| **Variable** | **Min** | **Max** | **Mean** |
| **Temperature** | 18.3 | 35.1 | 24.1 |
| **pH** | 6.0 | 7.2 | 6.6 |
| **EC** | 7.5 | 52.0 | 28.1 |
| **Salinity (PPT)** | 5.6 | 36.5 | 18.1 |
| **DO (mg/L)** | 4.6 | 11.0 | 7.9 |
| **DO %** | 54.1 | 163.0 | 106.0 |
| **Turbidity** | 1.7 | 9.5 | 6.0 |
| **Max Depth** | 0.3 | 1.2 | 0.7 |
| **Chla (µg/L)** | 3.0 | 4.0 | 3.2 |
| **TSS (mg/L)** | 4.0 | 20.0 | 8.8 |
| **TN (mg/L)** | 0.23 | 0.75 | 0.5 |
| **TP (mg/L)** | <0.03 | 0.03 | <0.03 |
| **Coliforms (cells/100mL)** | 10 | >1000 | 574 |

***Table 3.25*** *Exceedances[1] observed in Darkum Creek for pH, conductivity (EC), percent saturated dissolved oxygen (DO), turbidity, chlorophyll a (Chl-a), total nitrogen (TN) and total phosphorus (TP), and the site-level WQ grade.*

| **Site** | **pH** | **EC** | **DO %** | **Turbidity** | **Chl-a** | **TN** | **TP** | **WQ grade** |
|---|---|---|---|---|---|---|---|---|
| DARK1 | 7(70%) 7,0 | NA | 5(50%) 2,3 | 0 | 1(13%) | 8(100%) | 0 | C- |

*[1] Numbers in black represent the total number and percent of exceedances. Numbers in blue and red represent the numbers of measurements lower than the minimum threshold and higher than the maximum threshold, respectively. The number of exceedances includes all depths sampled so may be greater than the number of times sampled. Turbidity, chlorophyll a, and total nutrients only have maximum trigger thresholds.*

## 3.5 Woolgoolga Creek

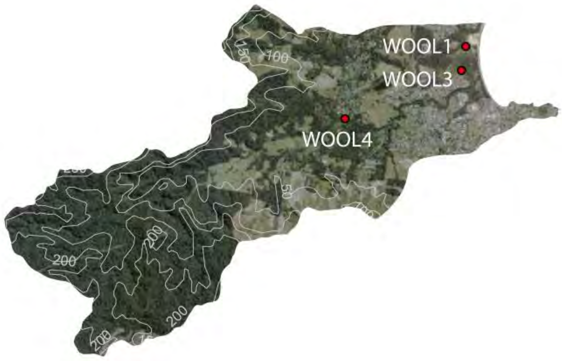
### *3.5.1 Catchment description*

Woolgoolga Lake is an Intermittently Closed and Open Lake or Lagoon (ICOLL) with areas of high conservation, recreational and aesthetic values. 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. Headwaters lie in steep midland hills (33-56% slope) with small areas of escarpment ranges at the subcatchment divide (Figure 3.12a), and drain to confined discontinuous floodplains (Figure 3.12b). 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 343ha, and the water body area is 37.6ha at mean high tide. The total subcatchment area is 22km$^2$ (Table 3.26).

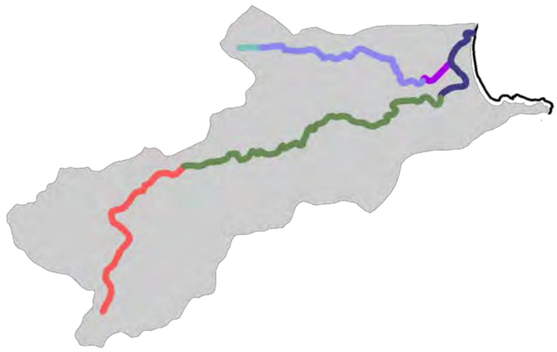
Woolgoolga Creek catchment is underlain by Coramba Beds of the Coffs Harbour association metasediments consisting of siliceous mudstones, siltstones and greywacke (87% of subcatchment area, Table 3.26). These metasediments form kandosols (85%, Figure 3.12d), that are strongly acid <5.5pH, have low chemical fertility and often, aluminium toxicity (Milford 1999). The coastal plain comprises predominantly unconsolidated alluvial soils along the major non-tidal drainage network (13% of subcatchment area), with Holocene estuarine sands, muds and clays in the tidally influenced reaches (Figure 3.12d).

The upper subcatchment is dominated by forestry (46% of subcatchment area). Intensive horticulture (22% of area) comprising banana plantations and blueberry orchards are a significant landuse in the upper slopes of the midcatchment (Figure 3.12c). Urban development (8%) is concentrated on the lower estuary (Figure 3.12c). A key focus of recreational activity occurs at the public picnic area adjacent to the Woolgoolga Lakeside Holiday Park near the estuary entrance.

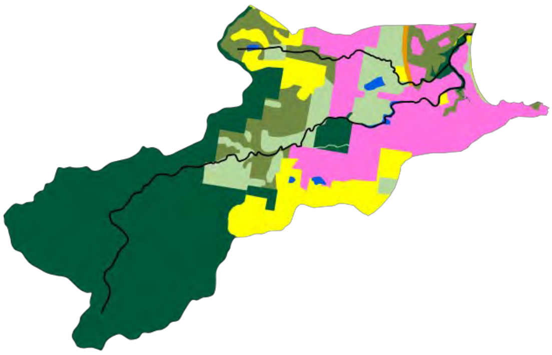
Opening of the entrance has been initiated by Council in the past as a flood control measure, opening when the lake’s water level reaches 1.8m AHD (Geolink 2011a). When open, water levels in the lake vary with the full tidal cycle. However, when closed, water levels in the lake can be approximately 0.25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



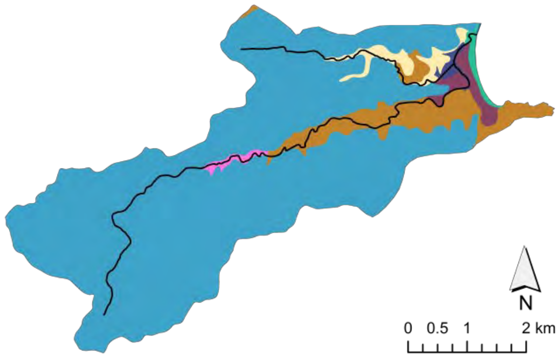

**(a)** Topography and location of Ecohealth sites.



**(b)** River Styles: refer to Figure 2.8 for key.



**(c)** Landuse: refer to Figure 2.7 For key.




**(d)** Soils: refer to Figure 2.3 For key.

***Figure 3.12*** *The Woolgoolga Creek subcatchment showing (a) locations of Ecohealth sites and catchment topography, (b) River Styles, (c) landuse, and (d) soils. Data layers from CHCC (site locations), ESRI (topography), NC LLS (River Styles) and OEH (landuse and soils).*

***Table 3.26*** *Subcatchment description of Woolgoolga Creek. Data from NC LLS and OEH.*

| Variable | Subcatchment composition |
|---|---|
| Area ($km^2$) | 22 |
| Geology | 87% Greywacke; 13% Alluvial Sediment |
| Soils | 85% Kandosols; 9% Kurosols; 7% other |
| River Styles | 37% CVS - Floodplain pockets, gravel; 23% CVS – Headwater; 22% PCVS - Planform controlled, low sinuosity, sand; 11% PCVS - Planform controlled, tidal; 4% LUV CC – Tidal; 2% Water storage - dam or weir pool. |
| Landuse | 46% Forestry; 26% Rural Residential; 22% Horticulture; 10% Residual native cover; 10% Grazing; 8% Urban, 2% Services |
| Major point source discharge | Nil |
| Tree Cover | 60% |

### *3.5.2 Site descriptions*

Three sites were monitored in Woolgoolga Creek subcatchment in 2015 (Figure 3.12a). WOOL1 was located in the lagoon close to the estuary mouth in a reach defined as planform controlled, tidal (Plate 3.9). WOOL3 was located at the tidal limit, also in a reach defined as planform controlled, tidal (Plate 3.10). WOOL4 was the most upstream site, located in the freshwater zone in a reach defined as confined valley with floodplain pockets, gravel (Plate 3.11).

***Plate 3.9*** *The site WOOL1 was located in the lagoon, close to the estuary mouth.*

***Plate 3.10*** *The site WOOL3 was located at the tidal limit in Woolgoolga Lake.*

***Plate 3.11*** *The site WOOL4 was located in the freshwater reach of Woolgoolga Creek.*

### *3.5.3 Geomorphic condition*

The River Style at WOOL4 is confined valley setting: floodplain pockets, gravel. Small attached gravel bars formed 10% of the total stream area over the 100m survey reach and were colonized by grasses and herbs. Bed sediments comprised well-rounded pebbles in a matrix with 32-60% fine sediment. Undercutting was moderate, comprising 5-10m combined length on each bank. There were few exposed tree roots on either bank and little slumping on the right bank (<5m combined length). Larger areas of bank slumping (10-20m combined length) were observed on the left bank. The left bank was unfenced and there was evidence of recent stock access. Small areas of rock revetment occurred around the bridge at the downstream end of the site. WOOL4 scored 61.2, a grade of C- for BANK CONDITION and 79.3, a grade of B- for BED CONDITION. The overall geomorphic condition for WOOL4 was 70, a grade of C+.

In summary, WOOL4 was assessed as being in moderate geomorphic condition. Fencing the riparian zone to remove stock access and revegetating the streambanks with native vegetation are two management strategies that would improve the geomorphic condition of WOOL4. The desktop GIS assessment of subcatchment geomorphic condition found the Woolgoolga Creek subcatchment to be in moderate condition with a grade of C+. The site-level grade for WOOL4 is representative of the average subcatchment condition.

### *3.5.4 Riparian condition*

The riparian vegetation community at Woolgoolga Creek #4 (WOOL4, Plate 3.12), can be described as 'Coast and Hinterland Riparian Flooded Gum – Bangalow Wet Forest', CH_WSF01 (OEH 2012b), or North Coast Wet Sclerophyll Forest (Keith 2004), with riparian condition scoring 65.7%, or C (Table 3.27).

The dominant canopy species were *Eucalyptus* species, Flooded Gum (*E.grandis*), Tallowwood (*E.microcorys*), and Blackbutt (*E.pilularis*). The midstory was dominated by Red Cedar (*Toona ciliata*), Sandpaper Fig (*Ficus coronata*), Bleeding Heart (*Homolanthus populifolius*), Forest Oak (*Allocasuarina torulosa*), Sweet Pittosporum (*Pittosporum undulatum*) and Lantana (*Lantana camara*).The understory was dominated by Lomandra (*Lomandra hystrix*), Soft Water Fern (*Blechnum cartilagineum*), and Paspalum (*Paspalum dilatatum*), and Buffalo Grass (*Stenotaphrum secundatum*). Dominant vine species included Kangaroo Vine (*Cissus Antarctica*) and Wait-a-while Vine (*Smilax australis*), while the macrophyte layer included Spotted Knotweed (*Persicaria strigosa*) and Water Primrose (*Ludwigia peploides*).

Lantana (*Lantana camara* - class 4) was the only noxious weed species observed on-site. Other weedy species present included Wild Tobacco (*Solanum mauritianum*), Senna (*Senna pendula* var. glabrata), Crofton Weed (*Ageratina adenophora*), Blue Billy Goat Weed (*Ageratum houstonianum*), Scarlet Sage (*Salvia coccinea*), and grasses Paspalum (*Paspalum dilatatum*), Prairie Grass (*Bromus catharticus*), Molasses Grass (*Melinis minutiflora*), and Buffalo Grass (*Stenotaphrum secundatum*).

WOOL4 scored 14.7/20 for HABITAT, losing marks for reduced riparian vegetation width, interrupted riparian vegetation continuity and patchy connectivity to larger tracts of remnant native vegetation (Plate 3.12). Full marks were given for the presence of representative structural layers and large mature and hollow-bearing trees. NATIVE SPECIES scored 13/20, and while no weeds were recorded in the canopy at site-level, weeds were present in the midstory at 40% relative cover, and in the understory Herb/Forb and Graminoid layers at 50% relative cover. SPECIES COVER scored 14.5/20 with reduced scores for large gaps in the canopy and midstory riparian vegetation layers. Understory layers herb/forb and graminoids recorded high cover values, while macrophyte cover was moderate. DEBRIS received 15/20 with a high abundance of lying woody and non-woody debris and good fringing vegetation. Marks were reduced for weedy leaf litter and a lack of standing dead trees. Cleared sections of riparian vegetation, the presence of noxious weeds and woody weed regeneration, and a lack of fencing and evident animal impact, saw the MANAGEMENT subindex score a low 8.5/20. The presence of woody native species regeneration and low levels of exposed tree roots gained marks for this subindex.

***Plate 3.12*** *Riparian vegetation at Woolgoolga Creek #4 was in average condition. While remnant sections of the site were representative of the original vegetation community, noxious and environmental weeds, and cleared and unfenced sections of riparian vegetation reduced the final score.*

***Table 3.27*** *Site-level summary of riprian condition of Woolgoolga Creek #4, including subindices and indicators.*

| Woolgoolga Creek #4 | Scores |
|---|---|
| **HABITAT** | **14.7** |
| Channel width | 2.7 |
| Proximity | 2 |
| Continuity | 2 |
| Layers | 4 |
| Large native trees | 2 |
| Hollow-bearing trees | 2 |
| **NATIVE SPECIES** | **13** |
| Native canopy species | 4 |
| Native midstory species | 2 |
| Native herb/forb species | 1.5 |
| Native graminoid species | 1.5 |
| Native macrophyte species | 4 |
| **SPECIES COVER** | **14.5** |
| Canopy species | 2.5 |
| Midstory species | 2 |
| Herb/forb species | 4 |
| Graminoid species | 4 |
| Macrophyte species | 2 |
| **DEBRIS** | **15** |
| Total leaf litter | 3 |
| Native leaf litter | 2 |
| Dead trees standing | 1 |
| Dead trees fallen | 2 |
| Lying logs | 4 |
| Fringing vegetation | 3 |
| **MANAGEMENT** | **8.5** |
| Tree clearing | 2.5 |
| Fencing | 1 |
| Animal impact | 0 |
| Species of interest | 1 |
| Exposed tree roots | 3 |
| Native woody regeneration | 1 |
| Weedy woody regeneration | 0 |
| **TOTAL** | **65.7** |

### *3.5.5 Mangrove, seagrass and saltmarsh cover*

Of the 9 Coffs Harbour estuarine systems, Woolgoolga Lake estuary recorded the second lowest total cover of estuarine macrophytes (Figure 3.13). Similar to the Darkum Creek estuary, there were two estuarine vegetation communities present in 2011 in the Woolgoolga Lake estuary: mangroves were the dominant vegetation community covering 0.008km$^2$, with saltmarsh covering approximately 0.001km$^2$. Again, this is despite saltmarsh being absent from the 1985 estuarine macrophyte survey (Table 3.28).

Total estuarine macrophyte cover in the Woolgoolga Lake estuary increased from 1985 (0.006km$^2$) to 2011 (0.009km$^2$) (Table 3.28). Only mangroves (0.006km$^2$) were present in 1985, and their cover increased in 2011 (0.008km$^2$) (Table 3.28). Monitoring priorities in the Woolgoolga Lake estuarine system should focus on maintaining the saltmarsh habitat, which is a small component of the estuarine macrophytes that exists as several small patches (Table 3.28).

***Table 3.28*** *Total area covered by mangrove, seagrass or saltmarsh in the Woolgoolga Lake estuary in 2011 and 1985, and mean patch size of each vegetation community in 2011.*

| Vegetation community | Total area in 1985 (km$^2$) | Total area in 2011 (km$^2$) | Total area in 2011 (m$^2$) | Mean patch size in 2011 (m$^2$) |
|---|---|---|---|---|
| Mangrove | 0.006 | 0.008 | 8,091 | 124 |
| Saltmarsh | 0 | 0.001 | 1,091 | 364 |
| Seagrass (*Zostera*) - total | 0 | 0 | 0 | 0 |
| Dense *Zostera* | - | - | - | - |
| Sparse *Zostera* | - | - | - | - |
| Estuary total | 0.006 | 0.009 | 9,182 | |


***Figure 3.13*** *Mangrove, seagrass and saltmarsh habitats in the Woolgoolga Lake estuary (NSW Department of Industry and Investment – Primary Industries and Energy 2011).*

### *3.5.6 Water quality*

Woolgoolga Creek received a score of 69, a grade of C, for water quality. Water quality deteriorated longitudinally downstream from a B+ in the freshwater site WOOL4, to a D+ in the lower estuary WOOL1. Water temperatures at all sites reflected seasonal climatic changes (Figure 3.14), and ranged from a winter minimum of 15.1°C at WOOL4 to a summer maximum of 30.7°C at WOOL3 (Table 3.29). DO% ranged from 56.5%, observed at both WOOL3 and WOOL4, to 123% at WOOL1 (Table 3.29). DO% at WOOL1 fell below the minimum estuarine trigger threshold once in July 2015, and exceeded the maximum estuarine trigger threshold once in November 2015 (Table 3.30). DO% at WOOL3 also fell below the minimum estuarine trigger threshold in July 2015, and exceeded the maximum estuarine trigger threshold once in March 2015 (Table 3.30). DO% at WOOL4 fell below the minimum freshwater trigger threshold twice (July and November 2015), and exceeded the maximum freshwater trigger threshold twice (December 2014 and March 2015, Table 3.30).

pH in Woolgoolga Creek ranged from a minimum of 5.9 at WOOL3 to a maximum of 8.8 at WOOL4 (Figure 3.14). pH at WOOL1 was lower than the minimum estuarine trigger threshold on 5 sampling occasions (from March – November 2015, Table 3.30). pH at WOOL3 was consistently lower than the minimum estuarine trigger threshold, only recording >7pH once, in May 2015 (Table 3.30). pH was more alkaline at WOOL4, exceeding the maximum freshwater trigger threshold once (May 2015, Table 3.30).

Turbidity ranged from 1.3 – 15.2NTU in Woolgoolga Creek (Figure 3.14), but guideline thresholds were only exceeded once. This was at WOOL1 in July 2015 (Table 3.30). Chl-*a* ranged from 2.0-9.0µg/L in Woolgoolga Creek (Figure 3.14). Guideline thresholds were only exceeded in estuarine sites: once at WOOL1 (August 2015) and once at WOOL3 (November 2015, Table 3.30). TN ranged from 0.1-0.6mg/L (Table 3.29), and also only exceeded guideline thresholds at estuarine sites (Figure 3.29). However, exceedances were persistent, with TN concentrations at WOOL1 only observed twice below the estuarine trigger threshold (September 2014 and May 2015, Table 3.30). TN at WOOL3 also consistently exceeded the estuarine trigger threshold (December 2014, and July, August, November and December 2015, Table 3.30). TP remained below detection limits at all times in Woolgoolga Creek.

Faecal coliforms were collected from WOOL1 on 8 occasions and ranged from a minimum of 23fc/100mL (May 2015) to a maximum that exceeded the detection limit of >1000fc/100mL (July 2015, Table 3.29). Numbers of faecal coliforms consistently exceeded the trigger threshold for primary contact (September and December 2014, and March, July and December 2015).

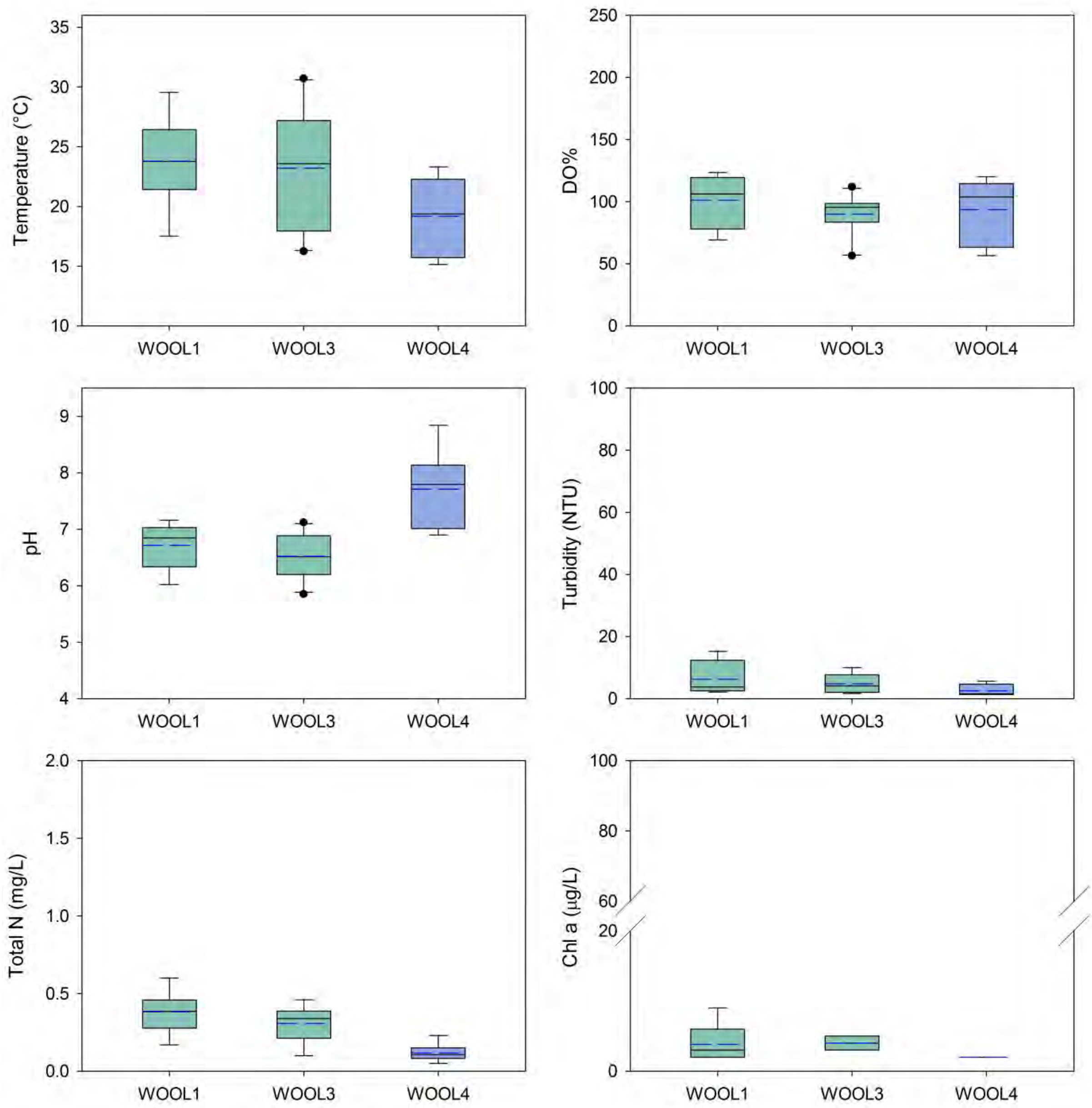



***Figure 3.14*** *Mean (blue line), median (black line), 25th and 75th percentiles, and range of water quality variables in the Woolgoolga Creek subcatchment over 2015. Outliers are represented by black dots. Green and blue boxes represent estuary and freshwater sites, respectively.*

***Table 3.29*** *Minimums, maximums and means of measured water quality variables for the three sites on Woolgoolga Creek.*

| | WOOL1 | | | WOOL3 | | | WOOL4 | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **Min** | **Max** | **Mean** | **Min** | **Max** | **Mean** | **Min** | **Max** | **Mean** |
| **Temperature** | 17.5 | 29.6 | 23.8 | 16.2 | 30.7 | 23.2 | 15.1 | 23.3 | 19.2 |
| **pH** | 6.0 | 7.2 | 6.7 | 5.9 | 7.1 | 6.5 | 6.9 | 8.8 | 7.7 |
| **EC** | 32.7 | 53.9 | 41.3 | 2.4 | 51.6 | 37.6 | 0.2 | 0.4 | 0.3 |
| **Salinity (PPT)** | 19.7 | 38.1 | 28.2 | 5.0 | 34.7 | 25.7 | 0.1 | 0.1 | 0.1 |
| **DO (mg/L)** | 5.7 | 13.0 | 8.9 | 4.7 | 9.0 | 6.6 | 5.1 | 10.4 | 8.6 |
| **DO %** | 69.2 | 123.4 | 101.3 | 56.5 | 111.8 | 90.0 | 56.5 | 120.1 | 93.8 |
| **Turbidity** | 2.1 | 15.2 | 6.3 | 1.7 | 10.0 | 4.8 | 1.3 | 5.6 | 2.5 |
| **Max Depth** | 0.2 | 0.9 | 0.4 | 0.5 | 1.0 | 0.8 | 0.3 | 0.4 | 0.4 |
| **Chla (µg/L)** | 2.0 | 9.0 | 3.8 | 3.0 | 5.0 | 4.0 | 2.0 | 2.0 | 2.0 |
| **TSS (mg/L)** | 2.0 | 16.0 | 9.9 | 2.0 | 11.0 | 5.6 | 3.0 | 7.0 | 3.9 |
| **TN (mg/L)** | 0.2 | 0.6 | 0.4 | 0.1 | 0.5 | 0.3 | 0.1 | 0.2 | 0.1 |
| **TP (mg/L)** | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 |
| **Coliforms (cells/100mL)** | 23 | >1000 | 313 | | | | | | |

***Table 3.30*** *Exceedances[1] observed in Woolgoolga Creek for pH, conductivity (EC), percent saturated dissolved oxygen (DO), turbidity, chlorophyll a (Chl-a), total nitrogen (TN) and total phosphorus (TP), and the site-level WQ grades.*

| Site | pH | EC | DO % | Turbidity | Chl-a | TN | TP | WQ grade |
|---|---|---|---|---|---|---|---|---|
| WOOL1 | 5(83%) 5,0 | NA | 2(50%) 1,1 | 1(25%) | 1(13%) | 6(75%) | 0 | D+ |
| WOOL3 | 9(90%) 9,0 | NA | 3(30%) 2,1 | 0 | 1(13%) | 5(63%) | 0 | C- |
| WOOL4 | 1(17%) 0,1 | 0 | 4(67%) 2,2 | 0 | 0 | 0 | 0 | B+ |

*[1] Numbers in black represent the total number and percent of exceedances. Numbers in blue and red represent the numbers of measurements lower than the minimum threshold and higher than the maximum threshold, respectively. The number of exceedances includes all depths sampled so may be greater than the number of times sampled. Turbidity, chlorophyll a, and total nutrients only have maximum trigger thresholds.*

### *3.5.7 Aquatic macroinvertebrates*

Woolgoolga Creek #4 (WOOL4) was relatively diverse with 22 and 32 families recorded in autumn and spring, respectively (Table 3.31). In autumn, Trichoptera (Caddisflies) were the most diverse order, contributing 5 families, followed by Ephemeroptera (Mayflies) with 4 families. In spring, both Trichoptera and Ephemeroptera contributed 5 families. There were a number of rare taxa with 12 and 18 families represented by fewer than 5 individuals in autumn and spring, respectively. Abundances were much greater in autumn with 610 individuals: the most in any sample across all sites in the Coffs coastal catchments in 2015. These high abundances were driven by Simuliidae (Black Fly Larvae with 223 individuals), Chironomidae (Midge Larvae with 125 individuals) and Hydropsychidae (Net-spinning Caddisflies with 91 individuals).

Woolgoolga Creek #4 (WOOL4) received an overall Ecohealth score of 74, a grade of C+, for aquatic macroinvertebrate community condition. All macroinvertebrate condition indicators were above the averages for Coffs coastal catchments, particularly total abundance, family richness and EPT richness (Table 3.6). However, SIGNAL2 scores were lower than expected, primarily due to the abundance of Chironomidae that tolerate poor water quality (SIGNAL2 of 3).

***Table 3.31** Summary of aquatic macroinvertebrate data for Woolgoolga Creek #4 (WOOL4).*

| WOOL4 | | | | |
|---|---|---|---|---|
| **Macroinvertebrate indicator** | **Autumn 2015** | **Spring 2015** | **Autumn 2011** | **Spring 2011** |
| Family richness | 22 | 32 | 20 | 14 |
| Total abundance | 610 | 332 | 132 | 133 |
| EPT richness | 9 | 10 | 9 | 9 |
| EPT abundance | 140 | 125 | 77 | 85 |
| Mean SIGNAL2 score | 4.6 | 3.8 | 5.7 | 5.5 |
| SIGNAL2 score range | 2 - 8 | 1 - 8 | 3 - 8 | 2 - 9 |
| Ecohealth score (grade) | **74 (C+)** | | **83 (B)** | |

## 3.6 Willis Creek and Hearnes Lake

### *3.6.1 Catchment descriptions*

Hearnes Lake is located approximately 25km north of Coffs Harbour, and 4km south of the township of Woolgoolga. Hearnes Creek drains to Hearnes Lake. Hearnes Lake has a typical water surface area of 10ha 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 total subcatchment area is 12km$^2$ (Table 3.32). Willis Creek is a small coastal stream to the north of Hearnes Lake (Figure 3.15a); it drains a subcatchment area of 3km$^2$ (Table 3.33).

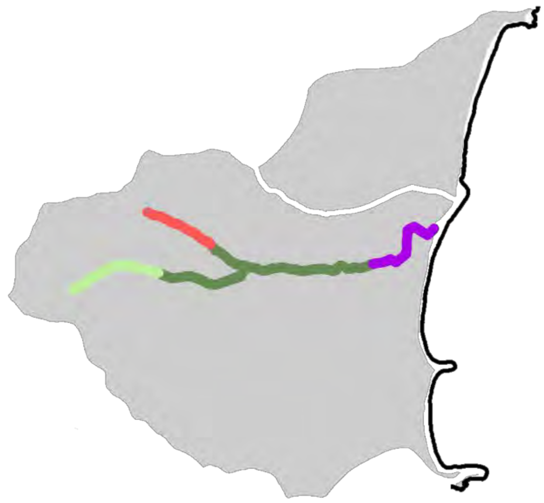
Headwaters of both creek systems are on steep midland hills with slopes 33-56% (Figure 3.15a, Milford 1999), draining to confined discontinuous floodplains (Figure 3.15b). The majority of both subcatchments are underlain by Coramba Beds of the Coffs Harbour association metasediments consisting of siliceous mudstones, siltstones and greywacke (Tables 3.32, 3.33). The soils are dominated by kandosols (Figure 3.15d) that are strongly acid <5.5pH, have low chemical fertility and often, aluminium toxicity (Milford 1999).

The majority of the Hearnes Lake subcatchment is under private freehold ownership, with an active intensive horticulture industry (38% of subcatchment area), limited forestry activity in the very upper catchment (2% of area), and Crown land adjacent to the coastline (Figure 3.15c). Urban residential comprises 16% and 6% of the Willis Creek and Hearnes Lake subcatchments, respectively.

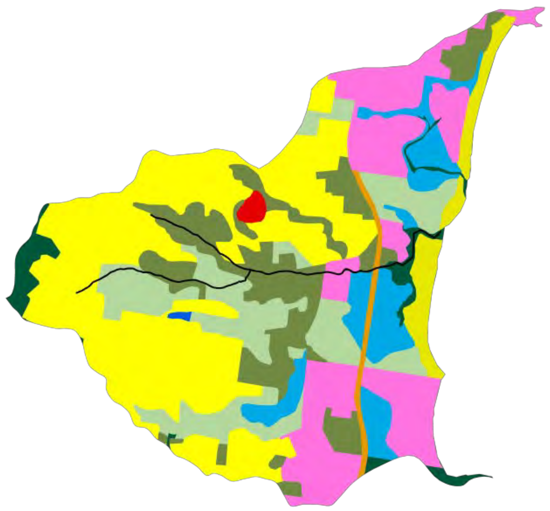
Hearnes Lake is classified as an ICOLL (Intermittently Closed and Open Lake or Lagoon), the result of a large sand bar blocking Double Crossing Creek from the ocean (WBM Oceanics Australia 2006). When the entrance is open, the estuary experiences regular tidal movements. When water levels are sufficiently 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 landuse zonings in the subcatchment. When the entrance is closed, inflows are dominated by catchment runoff 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 forms 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).

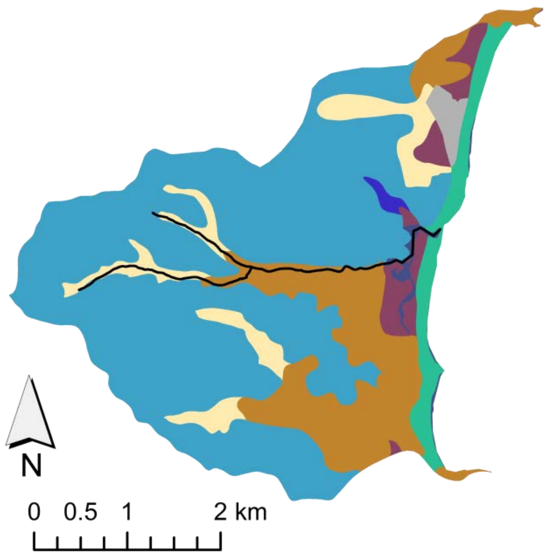

**(a)** Topography and location of Ecohealth sites.



**(b)** River Styles: refer to Figure 2.8 for key.



**(c)** Landuse: refer to Figure 2.7 For key.




**(d)** Soils: refer to Figure 2.3 For key.

***Figure 3.15*** *The Willis Creek and Hearnes Lake subcatchments showing (a) locations of Ecohealth sites and catchment topography, (b) River Styles, (c) landuse, and (d) soils. Data layers from CHCC (site locations), ESRI (topography), NC LLS (River Styles) and OEH (landuse and soils).*

***Table 3.32*** *Subcatchment description of Hearnes Lake. Data from NC LLS and OEH.*

| Variable | Subcatchment composition |
|---|---|
| Area (km$^2$) | 12 |
| Geology | 79% Greywacke; 21% Alluvial Sediment |
| Soils | 66% Kandosols; 20% Kurosols; 6% Hydrosols; 7% other; 1% water |
| River Styles | 52% CVS - Floodplain pockets, gravel; 17% LUV CC – Tidal; 17% SMG - Valley fill, fine grained; 14% CVS - Headwater |
| Landuse | 38% Horticulture; 17% Grazing; 15% Residual Native Cover; 7% Wetland; 6% Urban; 5% Rural Residential; 3% Landscape; 3% Services; 2% National Park; 2% Forestry; 1% Transport |
| Major point source discharge | Nil |
| Tree Cover | 40% |

***Table 3.33*** *Subcatchment description of Willis Creek. Data from NC LLS and OEH.*

| Variable | Subcatchment composition |
|---|---|
| Area (km$^2$) | 3 |
| Geology | 99% Greywacke |
| Soils | 51% Kandosols; 14% Hydrosols; 11% Kurosols; 9% Rudosols; 8% Podosols; 6% not accessed; 1% other. |
| River Styles | Not mapped |
| Landuse | 40% Horticulture; 18% Services; 16% Rural Residential; 16% Urban; 12% Wetland; 7% Waste; 1% National park, 1% Transport |
| Major point source discharge | Nil |
| Tree Cover | 19% |

### *3.6.2 Site descriptions*

Two sites were located in Hearnes Lake in 2015 (Figure 3.15a). Site HEAR1 was located in the estuarine lagoon close to the mouth of the lake with Double Crossing Creek (Plate 3.13). Site HEAR4 was a new site established in 2015. HEAR4 was the most upstream site, located in a freshwater inflow in a reach defined as a confined valley with floodplain pockets, gravel (Plate 3.14).

WILL1 was a new site established in 2015 at the mouth of Willis Creek. Details of the location of WILL1 (and all sites) are given in Table 2.2.

***Plate 3.13*** *Site HEAR1 is located in an estuarine lagoon near its mouth.*

***Plate 3.14*** *Site HEAR4 is located in the freshwater input to Hearnes Lake.*

### 3.6.3 Geomorphic condition

Site-level geomorphic condition was not assessed separately for Willis Creek. The desktop GIS-based assessment of the stream network across Willis Creek and Hearnes Lake scored the subcatchment as C, as 100% of streams were assessed as in moderate condition.

The River Style at HEAR4 is a confined valley setting: floodplain pockets, gravel, similar to WOOL4. However, HEAR4 is a smaller system than WOOL4 and lacks the morphological complexity of attached gravel bars. At the time of sampling, earthworks were underway for a new housing estate adjacent to the site, creating a significant area of bare ground. Cobbles and pebbles were not observed in the banks or bed of the site, with the streambed classified as relatively uncompacted fine sediment (matrix dominated with >60% fine sediments). Obvious active erosion was limited to slumping with 10-20m combined length observed on each bank. HEAR4 scored 68, a grade of C for BANK CONDITION and 73.7, a grade of C+ for BED CONDITION. The overall Ecohealth geomorphic condition for HEAR4 was 71, a C+.

In summary, HEAR4 was assessed as being in moderate geomorphic condition, with bank erosion the most significant issue for site-level geomorphic condition. Fencing the riparian zone to allow for regeneration of native revegetation would assist to improve geomorphic condition at this site. The desktop GIS assessment of subcatchment geomorphic condition found that 100% of streams in the Willis Creek/Hearnes Lake subcatchment were in moderate condition, with an overall grade of C. The site level score for HEAR4 was assessed as being in slightly better geomorphic condition than the subcatchment average.

### 3.6.4 Riparian condition

#### *Hearnes Lake*

The riparian vegetation community at Hearns Lake #4 (HEAR4, Plate 3.15), can be described as 'Coast and Hinterland Riparian Flooded Gum – Bangalow Wet Forest', CH_WSF01 (OEH 2012b), or North Coast Wet Sclerophyll Forest (Keith 2004), and received a high riparian condition score of 86.5% or B+ (Table 3.34).

The dominant canopy species were the eucalypts, Flooded Gum (*Eucalyptus grandis*), Tallowwood (*E.microcorys*), and Blackbutt (*E.pilularis*), and Brush Box (*Losphostemon confertus*). The midstory was dominated by Narrow-leaved Palm Lily (*Cordyline stricta*), Lantana (*Lantana camara*), Bangalow Palm (*Archontophoenix cunninghamiana*), Sandpaper Fig (*Ficus coronata*), Rough-Tree Fern (*Cyathea australis*), and Banana Bush (*Tabernaemontana pandacaqui*). The understory was dominated by Lomandra (*Lomandra hystrix*), Creeping Beard Grass (*Oplismenus imbecillis*), and the fern species, Black Stem Maidenhair (*Adiantum formosum*), and Gristle Fern (*Blechnum cartilagineum*). Dominant vine species included Wait-a-while Vine (*Smilax australis*), Common Silkpod (*Parsonsia* sp.) and

White Passionfruit (*Passiflora subpeltata*). Most macrophytes were shaded out in this system, however Soft Twig Rush (*Baumea rubiginosa*) was present.

Lantana (*Lantana camara* - class 4) was the only noxious weed species observed on-site. Other weedy species present included Crofton Weed (*Ageratina adenophora*), Senna (*Senna pendula* var. *glabrata*), and Paspalum (*Paspalum dilatatum*).

HEAR4 scored 20/20 for HABITAT, with full marks given for vegetation:channel width ratio, proximity to larger tracts of remnant native vegetation, large and hollow-bearing trees, and the presence of all structural layers. Despite the canopy and herbs/forbs layers containing <10% weeds, NATIVE SPECIES received a score of 15/20 due to weedy species in the vine/liane, midstory and graminoid layers. SPECIES COVER received 19/20 and was very high in all structural layers. DEBRIS too received high marks with 18.5/20 being for good levels of woody and non-woody debris and fringing vegetation. An on-site score of 14/20 was given for MANAGEMENT, with scores reduced for the lack of fencing, and presence of both noxious weeds and woody weed regeneration.

***Plate 3.15** Riparian vegetation at Hearnes Lake #4 was in very good condition, with riparian species representative of the original remnant vegetation community. Lantana remains an issue in the midstorey; riparian condition would improve with the removal of Lantana.*

***Table 3.34*** *Site-level summary of riprian condition of Hearnes Lake #4, including subindices and indicators.*

| Hearnes Lake #4 | Scores |
|---|---|
| **HABITAT** | **20** |
| Channel width | 4 |
| Proximity | 4 |
| Continuity | 4 |
| Layers | 4 |
| Large native trees | 2 |
| Hollow-bearing trees | 2 |
| **NATIVE SPECIES** | **15** |
| Native canopy species | 4 |
| Native midstory species | 2 |
| Native herb/forb species | 4 |
| Native graminoid species | 3 |
| Native macrophyte species | 2 |
| **SPECIES COVER** | **19** |
| Canopy species | 4 |
| Midstory species | 4 |
| Herb/forb species | 4 |
| Graminoid species | 3 |
| Macrophyte species | 4 |
| **DEBRIS** | **18.5** |
| Total leaf litter | 3 |
| Native leaf litter | 2.5 |
| Dead trees standing | 2 |
| Dead trees fallen | 3 |
| Lying logs | 4 |
| Fringing vegetation | 4 |
| **MANAGEMENT** | **14** |
| Tree clearing | 3 |
| Fencing | 1 |
| Animal impact | 2 |
| Species of interest | 1 |
| Exposed tree roots | 4 |
| Native woody regeneration | 2 |
| Weedy woody regeneration | 1 |
| **TOTAL** | **86.5** |

### *3.6.5 Mangrove, seagrass and saltmarsh cover*

Mangrove, seagrass and saltmarsh communities were not mapped in the Willis Creek estuary, so no assessment can be made for this catchment.

Of the 9 Coffs Harbour estuarine systems, Hearns Lake estuary recorded the fourth lowest total for total estuarine macrophytes (Figure 3.16). Unlike the Darkum Creek and Woolgoolga Lake estuaries, of the two estuarine vegetation communities present in the Hearns Lake system, saltmarsh was the dominant vegetation community, covering 0.043km$^2$, with mangroves covering approximately 0.008km$^2$ (Table 3.35). Priorities in the Hearns Lake estuarine system should focus on maintaining the current cover of both the saltmarsh and mangrove vegetation communities.

Total estuarine macrophyte cover in the Hearns Lake estuary increased slightly from 1985 (0.048km$^2$) to 2011 (0.051km$^2$) (Table 3.35). This has been driven by mangroves, which increased from 0.003m$^2$ in 1985 to 0.008m$^2$ in 2011 (Table 3.35). In contrast, saltmarsh cover decreased from 0.045km$^2$ in 1985 to 0.008m$^2$ in 2011.

***Table 3.35*** *Total area covered by mangrove, seagrass or saltmarsh in the Hearnes Lake estuary in 2011 and 1985, and mean patch size of each vegetation community in 2011.*

| Vegetation community | Total area in 1985 (km$^2$) | Total area in 2011 (km$^2$) | Total area in 2011 (m$^2$) | Mean patch size in 2011 (m$^2$) |
|---|---|---|---|---|
| Mangrove | 0.003 | 0.008 | 7,640 | 121 |
| Saltmarsh | 0.045 | 0.043 | 43,122 | 4,312 |
| Seagrass (*Zostera*) - total | 0 | 0 | 0 | 0 |
| Dense *Zostera* | - | - | - | - |
| Sparse *Zostera* | - | - | - | - |
| Estuary total | 0.048 | 0.051 | 50,761 | - |

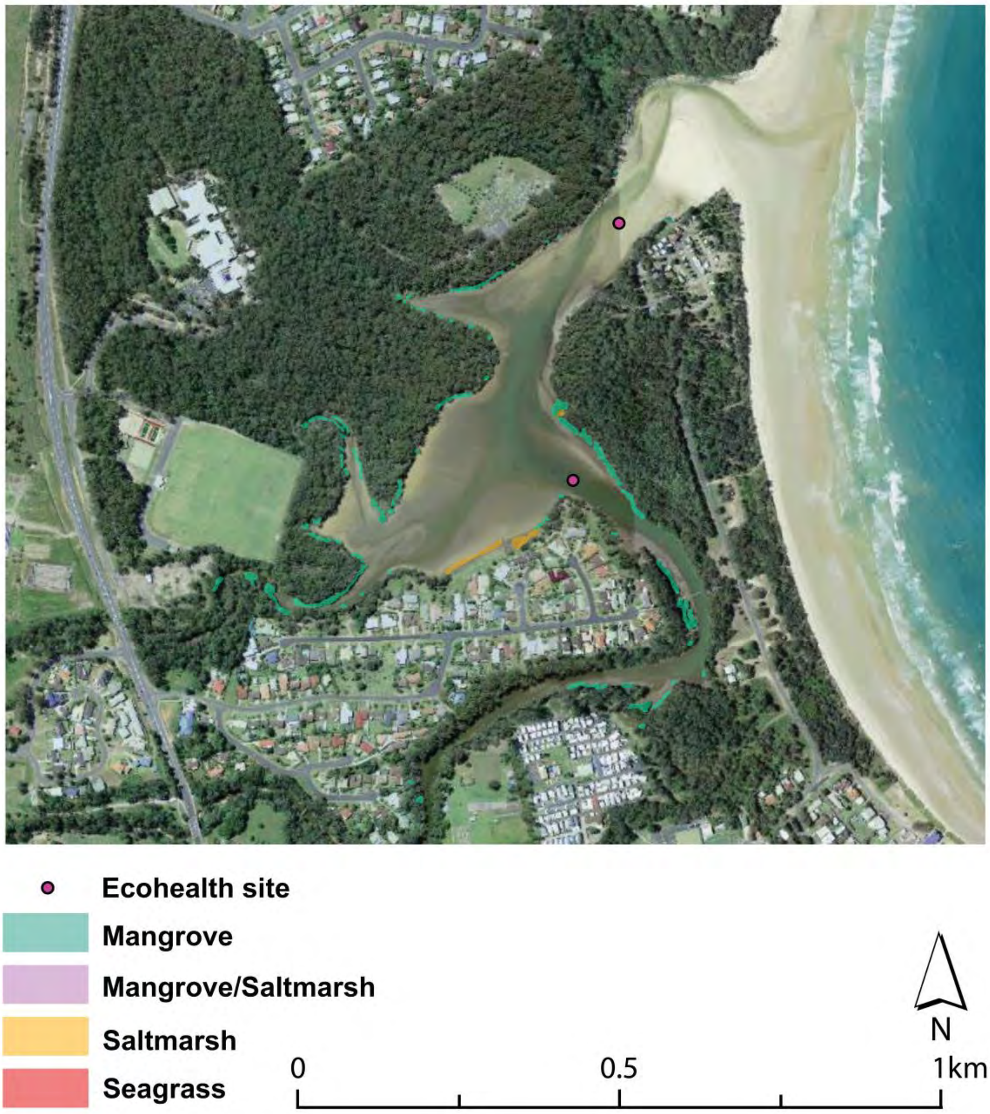



***Figure 3.16*** *Mangrove, seagrass and saltmarsh habitats in the Hearnes Lake estuary (NSW Department of Industry and Investment – Primary Industries and Energy 2011).*

### *3.6.6 Water quality*

Willis Creek subcatchment received a score of 32, a grade of F, for water quality, based on the data from a single estuarine site, WILL1. Hearnes Lake subcatchment received a score of 70, a grade of C, for water quality. The water quality was better at the freshwater site HEAR4 (78, B-) than the estuarine site HEAR1 (61, C-). Table 3.36 outlines the ranges and means of water chemistry variables for the single site on Willis Creek and the two sites on Hearnes Lake.

Water temperatures reflected seasonal climatic changes (Figure 3.17). Temperatures in Willis Creek ranged from a winter minimum of 16.5°C to a summer maximum of 30.2°C (Table 3.36). In Hearnes Lake, temperatures ranged from a winter minimum of 14.3°C at HEAR4, to a summer maximum of 30.1°C at HEAR1 (Table 3.36). Temperatures were consistently higher in the estuarine lagoon (HEAR1) than the freshwater inflow (HEAR4). DO% in Willis Creek ranged from 73.6% to 155% (Table 3.36). DO% fell below the minimum estuarine trigger threshold on two occasions (March and July 2015). DO% exceeding the maximum estuarine trigger threshold was recorded on the other 4 sampling occasions (Table 3.37). In Hearnes Lake, DO% in the lagoon (HEAR1) exceeded the maximum estuarine trigger threshold on 4 sampling occasions (December 2014, and May, August and November 2015, Table 3.37). DO% in the freshwater inflow (HEAR4) fell below the the minimum freshwater trigger threshold once, in July 2015 (Table 3.37).

pH in Willis Creek ranged from 7.1 to 8.6 (Table 3.36), exceeding the maximum estuarine trigger threshold once, in November 2015 (Table 3.37). pH in Hearnes Lake ranged from 7.0 to 8.8 (Table 3.36). pH at HEAR1 fell below the minimum estuarine trigger threshold once (July 2015). HEAR4 had higher pH, exceeding the maximum freshwater trigger threshold on 3 occasions (May, August and November 2015). Turbidity ranged from 1.5 – 95.8NTU in Willis Creek and 2.0 – 64.0 in Hearnes Lake (Table 3.36). Turbidity remained within guideline thresholds in Hearnes Lake but exceeded the estuarine trigger threshold 3 times (March, July and August 2015). The March 2015 exceedance was 9x the trigger threshold.

Chl-*a* ranged from 3.0 – 16.0µg/L in Willis Creek and 2.0 – 11.0µg/L in Hearnes Lake (Table 3.36). Both estuarine sites consistently exceeded the estuarine trigger threshold: WILL1 on 5 occasions and HEAR1 on 4 occasions (Table 3.37). TN ranged from 0.5 – 1.0mg/L in Willis Creek, exceeding the estuarine trigger threshold on all sampling occasions (Table 3.37). TN ranged from 0.2 – 0.6mg/L in Hearnes Lake. Concentrations at HEAR1 and HEAR4 exceeded guideline thresholds on all sampling occasions (Table 3.37). In particular, TN twice the freshwater trigger threshold was recorded in August 2015 (1.19mg/L), and 3x the freshwater trigger threshold on 3 occasions: September 2014 (1.74mg/L), May 2015 (1.49mg/L) and July 2015 (1.55mg/L, Figure 3.17). TP was below detection limits on all sampling occasions at HEAR1 and HEAR3 (Table 3.35). TP was only detected once at WILL1 (July 2015) and exceeded the estuarine trigger threshold on that occasion (Table 3.37).

Faecal coliforms were collected from WILL1 and HEAR1 8 times through the sampling period. Coliform counts at WILL1 ranged from 24 – 910fc/100mL, with the maximum observed in July 2015 (Table 3.36). Coliform counts at HEAR1 ranged from 30 – 186fc/100mL, with the maximum observed in November 2015, followed by 175fc/100mL in September 2014.

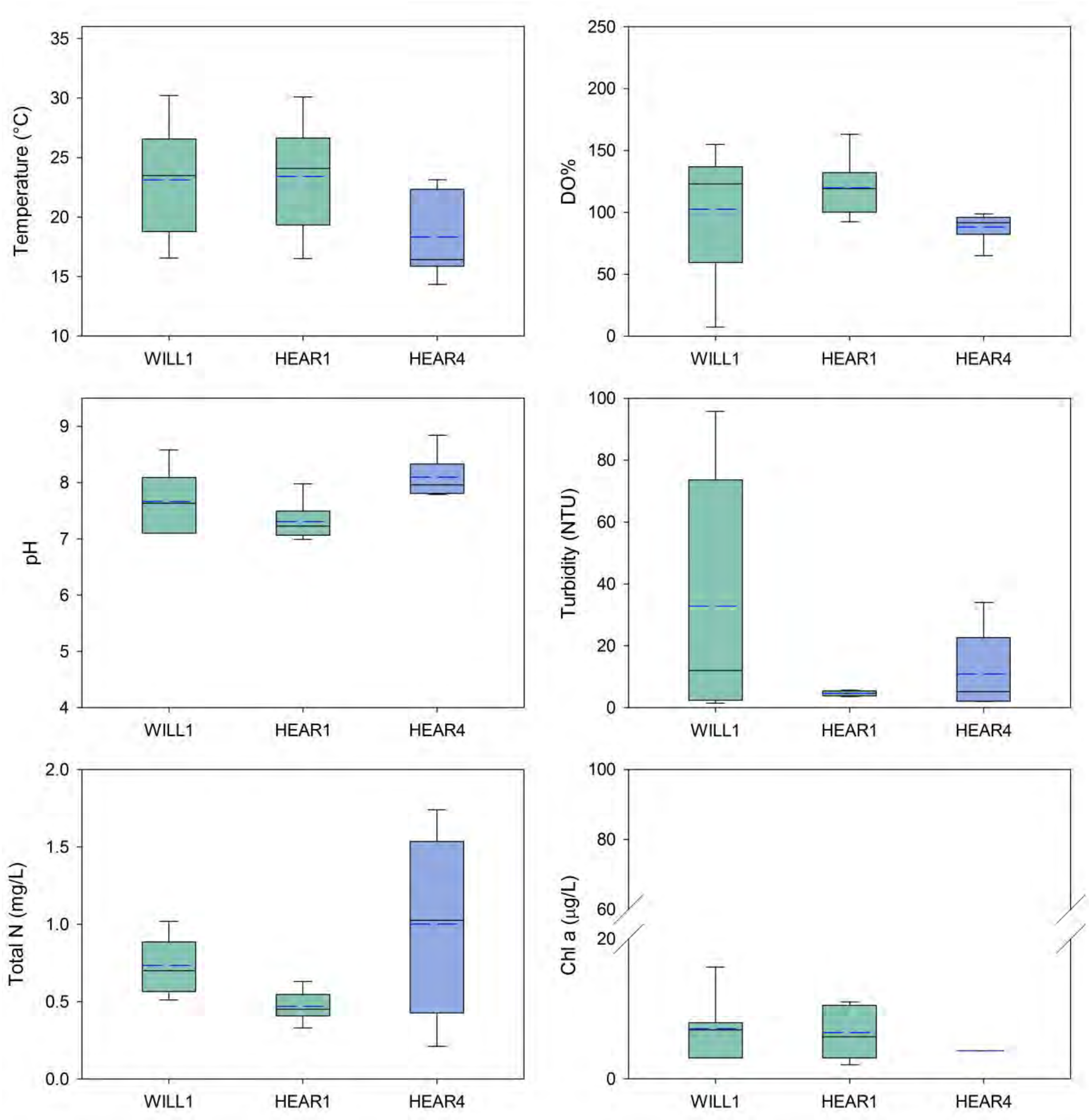



***Figure 3.17*** *Mean (blue line), median (black line), 25th and 75th percentiles, and range of water quality variables in the Willis Creek and Hearnes Lake subcatchment over 2015. Outliers are represented by black dots. Green and blue boxes represent estuary and freshwater sites, respectively.*

***Table 3.36*** *Minimums, maximums and means of measured water quality variables for the one site on Willis Creek and two sites on Hearnes Lake.*

| | WILL1 | | | HEAR1 | | | HEAR4 | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **Min** | **Max** | **Mean** | **Min** | **Max** | **Mean** | **Min** | **Max** | **Mean** |
| **Temperature** | 16.5 | 30.2 | 23.1 | 16.5 | 30.1 | 23.4 | 14.3 | 23.1 | 18.3 |
| **pH** | 7.1 | 8.6 | 7.7 | 7.0 | 8.0 | 7.3 | 7.8 | 8.8 | 8.1 |
| **EC** | 3.2 | 30.1 | 12.7 | 11.0 | 43.9 | 21.2 | 0.0 | 0.4 | 0.3 |
| **Salinity (PPT)** | 2.2 | 20.6 | 7.5 | 7.1 | 30.6 | 13.8 | 0.2 | 0.2 | 0.2 |
| **DO (mg/L)** | 7.4 | 12.0 | 10.1 | 7.8 | 11.7 | 9.4 | 6.7 | 9.6 | 8.1 |
| **DO %** | 73.6 | 155.0 | 113.7 | 92.6 | 163.0 | 119.8 | 65.0 | 98.7 | 88.1 |
| **Turbidity** | 1.5 | 95.8 | 32.8 | 3.6 | 5.7 | 4.7 | 2.0 | 34.0 | 10.9 |
| **Max Depth** | 0.3 | 0.5 | 0.4 | 0.3 | 0.6 | 0.4 | 0.4 | 0.6 | 0.5 |
| **Chla (µg/L)** | 3.0 | 16.0 | 7.1 | 2.0 | 11.0 | 6.6 | 4.0 | 4.0 | 4.0 |
| **TSS (mg/L)** | 3.0 | 24.0 | 11.4 | 4.0 | 50.0 | 18.4 | 2.0 | 11.0 | 6.3 |
| **TN (mg/L)** | 0.5 | 1.0 | 0.7 | 0.3 | 0.6 | 0.5 | 0.2 | 1.7 | 1.0 |
| **TP (mg/L)** | <0.03 | 0.04 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 |
| **Coliforms (cells/100mL)** | 24 | 910 | 234 | 30 | 186 | 101 | | | |

***Table 3.37*** *Exceedances[1] observed in Willis Creek and Hearnes Lake for pH, conductivity (EC), percent saturated dissolved oxygen (DO), turbidity, chlorophyll a (Chl-a), total nitrogen (TN) and total phosphorus (TP), and the site-level WQ grades.*

| Site | pH | EC | DO % | Turbidity | Chl-a | TN | TP | WQ grade |
|---|---|---|---|---|---|---|---|---|
| WILL1 | 1(17%) 0,1 | NA | 6(100%) 2,4 | 3(60%) | 5(63%) | 8(100%) | 2(67%) | F |
| HEAR1 | 1(17%) 1,0 | NA | 4(67%) 0,4 | 0 | 4(50%) | 8(100%) | 0 | C- |
| HEAR4 | 3(43%) 0,3 | 1(14%) 1,0 | 1(14%) 1,0 | 0 | 0 | 6(75%) | 0 | B- |

*[1] Numbers in black represent the total number and percent of exceedances. Numbers in blue and red represent the numbers of measurements lower than the minimum threshold and higher than the maximum threshold, respectively. The number of exceedances includes all depths sampled so may be greater than the number of times sampled. Turbidity, chlorophyll a, and total nutrients only have maximum trigger thresholds.*

### *3.6.7 Aquatic macroinvertebrates*

Water quality was the only indicator sampled at Willis Creek #1, and Hearnes Lake #4 (HEAR4) is a new site for the Coffs Ecohealth program so was not sampled in 2011. Family richness at HEAR4 was below the mean richness for Coffs coastal catchments in 2015 (Table 3.6). There were 13 and 14 families recorded in autumn and spring, respectively (Table 3.38). In autumn, Coleoptera (Aquatic Beetles) was the most diverse with 3 families comprising 114 individuals, while in spring, Diptera (Midges, Mosquitos and Gnats) was the most diverse with 5 families (75 individuals, Table 3.38). There were a number of rare taxa with 6 and 8 families comprising fewer than 5 individuals in autumn and spring, respectively.

Total abundance of macroinvertebrates at HEAR4 was below the mean for Coffs coastal catchments in 2015 (Table 3.6). Abundance was greater in autumn than spring (Table 3.38). EPT richness at HEAR4 was very low: in autumn there was 1 Trichopteran (Hydropsychid Caddisfly with a SIGNAL2 of 6) and in spring there were 2 Ephemeroptera (Caenid and Leptophlebid Mayflies). SIGNAL2 scores at HEAR4 were well above the mean for Coffs coastal catchments (Table 3.6). This was primarily due to the high mean SIGNAL2 score in autumn (5.8) driven by 2 taxa: Elmid Beetles (70 individuals with SIGNAL2 of 7) and Hydropsychid Caddisflies (26 individuals with SIGNAL2 of 6).

Hearnes Lake #4 (HEAR4) received an overall Ecohealth score of 28, a grade of F for aquatic macroinvertebrate community condition. The relatively low mean scores and dominance of taxa with low SIGNAL2 scores suggests the water quality and habitat conditions in the freshwater reaches of Hearnes Lake are in very poor condition.

***Table 3.38*** *Summary of aquatic macroinvertebrate data for Hearnes Lake #4 (HEAR4).*

| HEAR4 | | | | |
|---|---|---|---|---|
| **Macroinvertebrate indicator** | **Autumn 2015** | **Spring 2015** | **Autumn 2011** | **Spring 2011** |
| Family richness | 13 | 14 | | |
| Total abundance | 187 | 153 | | |
| EPT richness | 1 | 2 | | |
| EPT abundance | 26 | 7 | | |
| Mean SIGNAL2 score | 5.8 | 3.4 | | |
| SIGNAL2 score range | 3 - 7 | 1 - 8 | | |
| Ecohealth score (grade) | **28 (F)** | | | |

## 3.7 Moonee Creek

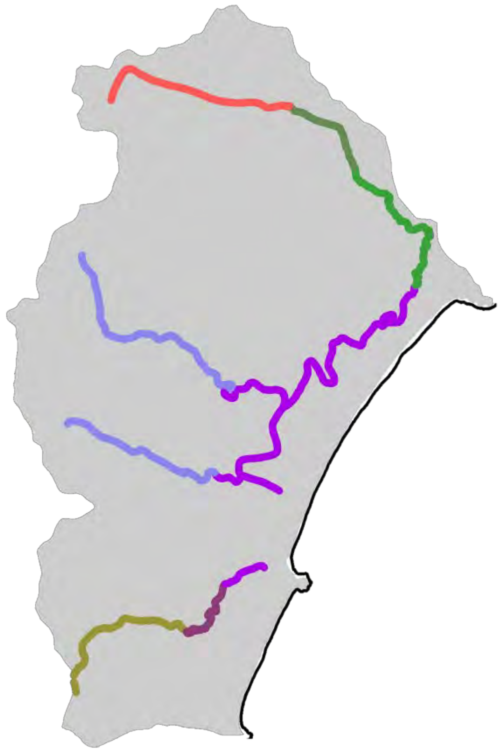
### *3.7.1 Catchment description*

Moonee Creek has a catchment area of approximately $42km^2$ (Table 3.39), with the estuary located approximately 8km north of Coffs Harbour, entering the ocean immediately north of Green Bluff and adjacent to the village of Moonee Beach. Headwaters lie in steep midland hills (33-56% slope) with small areas of escarpment ranges at the subcatchment divide (Figure 3.18a), and drain to confined discontinuous floodplains (Figure 3.18b). The underlying geology is the Coramba Beds of the Coffs Harbour association metasediments, consisting of siliceous mudstones, siltstones and greywacke (76%, Table 3.39). These metasediments form kandosols (60%, Figure 3.18d), that are strongly acid <5.5pH, have low chemical fertility and often, aluminium toxicity Milford 1999). The coastal plain comprises predominantly unconsolidated alluvial soils along the major non-tidal drainage network (24% of subcatchment area), with Holocene estuarine sands, muds and clays in the tidally influenced reaches (Figure 3.18d).

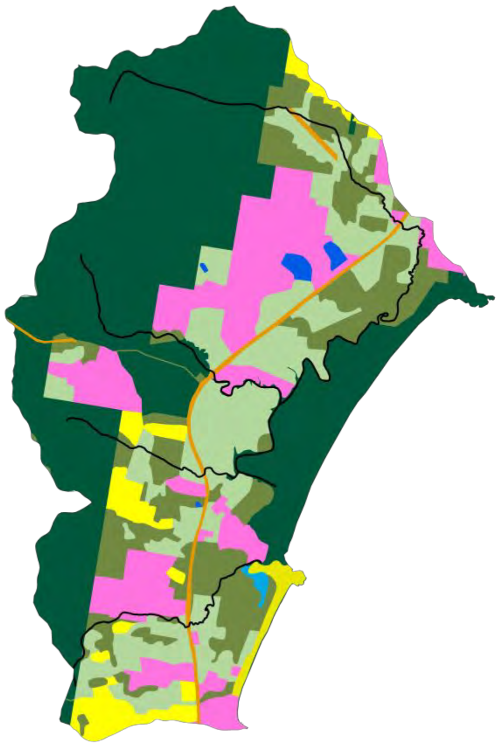
Moonee Creek and its subcatchment contain a diverse suite of habitat types, including mangroves, seagrasses, saltmarshes, freshwater wetlands and intact riparian vegetation (BMT WBM 2008). The Moonee Beach Nature Reserve is located along the coastal sand barrier dunes between the estuary and the ocean. 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 relatively low levels of development and clearing (particularly in the north and east areas of the catchment) (Table 3.39) indicates that Moonee Creek should be in a relatively healthy condition compared with 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. 3.18c).

The permanent ocean entrance and good tidal range within Moonee Creek enables effective flushing of any 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).

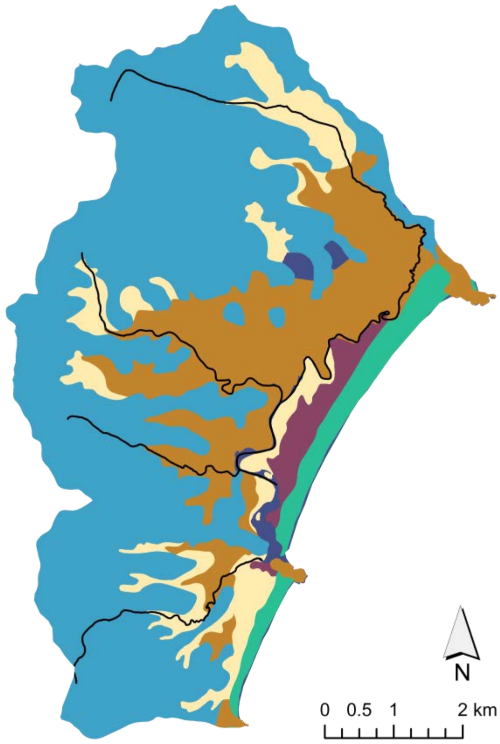

**(a)** Topography and location of Ecohealth sites.



**(b)** River Styles: refer to Figure 2.8 for key.



**(c)** Landuse: refer to Figure 2.7 For key.




**(d)** Soils: refer to Figure 2.3 For key.

***Figure 3.18*** *The Moonee Creek subcatchment showing (a) locations of Ecohealth sites and catchment topography, (b) River Styles, (c) landuse, and (d) soils. Data layers from CHCC (site locations), ESRI (topography), NC LLS (River Styles) and OEH (landuse and soils).*

***Table 3.39*** *Subcatchment description of Moonee Creek. Data from NC LLS and OEH.*

| Variable | Subcatchment composition |
|---|---|
| Area ($km^2$) | 42 |
| Geology | 76% Greywacke; 24% Alluvial Sediment |
| Soils | 60% Kandosols; 21% Kurosols; 10% Hydrosols; 7% other; 2% water |
| River Styles | 34% LUV CC – Tidal; 24% PCVS - Planform controlled, low sinuosity, sand; 12% CVS – Headwater; 11% PCVS - Planform controlled, meandering, fine grained; 9% SMG - Valley fill, sand; 6% CVS - Floodplain pockets, gravel; 5% LUV CC - Low sinuosity, sand. |
| Landuse | 37% Forestry; 18% Grazing; 13% Rural Residential; 12% Residual Native Cover; 8% National Park; 4% Horticulture; 2% Urban Residential, 1% Dams/Reservoirs; 1% Landscape; 1% Transport |
| Major point source discharge | Nil |
| Tree Cover | 41% |

### *3.7.2 Site descriptions*

Three sites on Moonee Creek were sampled in 2015 (Figure 3.18). Site MOON1 (Plate 3.16) was in the lower estuary in the marine-influence salinity zone (+30ppt). Site MOON3 was located at the tidal limit in a reach defined as laterally unconfined and tidal (Plate 3.17). Site MOON4 was located on a freshwater reach of a major eastern flowing tributary of Moonee Creek (Plate 3.18). The surrounding reach was defined as planform controlled, meandering, fine grained.

***Plate 3.16*** *The site MOON1 looking downstream towards the mouth of the Moonee Creek estuary.*

***Plate 3.17*** *The site MOON4 in the freshwater reach of Moonee Creek.*

### *3.7.3 Geomorphic condition*

The River Style at MOON4 is partially confined valley setting: planform controlled, meandering, fine grained (Figure 3.18b). At the time of assessment, stream discharge was below baseflow and the channel had contracted to pools connected by very little or no surface flow. Bed and bank sediments were fine grained, with no cobbles, pebbles or gravels present. There was no indication of active erosion at the site. MOON4 scored 74.8, a grade of C+, for BANK CONDITION and 85, a grade of (B) for BED CONDITION. The overall Ecohealth geomorphic condition for MOON4 was 80, a grade of B-.

In summary, MOON4 was assessed as being in good geomorphic condition. Revegetation of the right bank with native vegetation has improved bank stability at this site. The desktop GIS assessment of subcatchment geomorphic condition found the Moonee Creek subcatchment to be in good condition with a grade of B. The site level score for MOON4 is slightly below the subcatchment average for geomorphic condition.

### *3.7.4 Riparian condition*

The riparian vegetation community at Moonee Creek #4 (MOON4, Plate 3.18), can be described as 'Coastal Paperbark – Swamp Oak Floodplain Forest', CH_FrW01 (OEH 2012b), grading into 'Coastal Swamp Mahogany Forest', CH_FrW02 (OEH 2012b), both recognised as Forested Wetlands – Coastal Swamp Forests, (Keith 2004), and was adjacent to 'Coast and Escarpment Blackbutt Dry Forest', CH_DOF01 (OEH 2012b), or Dry Sclerophyll Forests – North Coast Dry Sclerophyll Forest (Keith 2004). The site received a high riparian condition score of 88.5% or B+ (Table 3.40).

The dominant canopy species were the Paperbarks*;* Broad-leaved Paperbark (*M. quinquenervia*) and Willow Bottlebrush (*Callistemon salignus*), and eucalypts; Swamp Mahogany (*Eucalyptus robusta*), Tallowwood (*E.microcorys*), Blackbutt (*E.pilularis*), Apple Gum (*Angophora costata*), and Turpentine (*Syncarpia glomulifera* subsp. *glomulifera*). The midstory was dominated by Narrow-leaved Palm Lily (*Cordyline stricta*), Lantana (*Lantana camara*), Large-leaf Hop Bush (*Dodonaea triquetra*), Blueberry Ash (*Elaeocarpus reticulatus*) and Forest Oak (*Allocasuarina torulosa*), while the understory was dominated by Tall Saw Sedge (*Ghania clarkei*), *Lomandra* species (*L.longifolia* and *L.hystrix*), Blue Flax-lily (*Dianella caerula*), Creeping Beard Grass (*Oplismenus imbecillis*), and Common Bracken (*Pteridium esculentum*). Dominant vine species included Wait-a-while Vine (*Smilax australis*), Common Silkpod (*Parsonsia* sp.) and Climbing Guinea (*Hibbertia scandens*), while macrophytes present included Water Ribbons (*Triglochin procera*), Swamp Lily (*Ottelia ovalifolia*), and Water Snowflake (*Nymphoides indica*).

Lantana (*Lantana camara* - class 4) was the only noxious weed species observed on-site. The only other weedy species present was Paspalum (*Paspalum dilatatum*).

MOON4 scored 17.5/20 for HABITAT, with full marks given for large and hollow-bearing trees, and the presence of all structural layers. Scores were reduced due to vegetation:channel width ratio and proximity to larger tracts of intact remnant native vegetation; satellite imagery revealved surrounding vegetation to be moderately disturbed. The NATIVE SPECIES subindex received a high score of 18.5/20, only losing marks due to a weed encroachment in the midstory. SPECIES COVER received 19.5/20 and was very high in all structural layers despite the graminoid layer being patchy in parts. DEBRIS received 18/20 with high levels of woody and non-woody debris and fringing vegetation and MANAGEMENT scored 14.5/20, with marks being lost for a lack of fencing, stand age and the presence of both noxious weeds and woody weed regeneration.

***Plate 3.18*** *Riparian vegetation at Moonee Creek #4 was in very good condition. Weed removal and monitoring would be beneficial to ensure that the current riparian conditions were maintained.*

***Table 3.40*** *Site-level summary of riprian condition of Moonee Creek #4, including subindices and indicators.*

| Moonee Creek #4 | Scores |
|---|---|
| **HABITAT** | **17.5** |
| Channel width | 3 |
| Proximity | 2.5 |
| Continuity | 4 |
| Layers | 4 |
| Large native trees | 2 |
| Hollow-bearing trees | 2 |
| **NATIVE SPECIES** | **19.5** |
| Native canopy species | 4 |
| Native midstory species | 3.5 |
| Native herb/forb species | 4 |
| Native graminoid species | 4 |
| Native macrophyte species | 4 |
| **SPECIES COVER** | **19** |
| Canopy species | 4 |
| Midstory species | 4 |
| Herb/forb species | 4 |
| Graminoid species | 3 |
| Macrophyte species | 4 |
| **DEBRIS** | **18** |
| Total leaf litter | 3 |
| Native leaf litter | 3 |
| Dead trees standing | 2 |
| Dead trees fallen | 3 |
| Lying logs | 4 |
| Fringing vegetation | 3 |
| **MANAGEMENT** | **15** |
| Tree clearing | 2.5 |
| Fencing | 2 |
| Animal impact | 2 |
| Species of interest | 1 |
| Exposed tree roots | 4 |
| Native woody regeneration | 2 |
| Weedy woody regeneration | 1 |
| **TOTAL** | **88.5** |

### *3.7.5 Mangrove, seagrass and saltmarsh cover*

The Moonee Creek estuary contained the fourth highest total estuarine macrophyte cover of the 9 Coffs Harbour estuarine systems (Figure 3.19), attributed to the two dominant vegetation communities, saltmarsh (0.117km$^2$), and mangroves (0.106km$^2$) (Table 3.41). The Moonee Creek estuary also recorded the second highest cover of seagrass in the Coffs Harbour estuaries (0.019km$^2$) (Table 3.41).

Total estuarine macrophyte cover in the Moonee Creek estuary decreased from 1985 (0.249km$^2$) to 2011 (0.242km$^2$) (Table 3.41). This is due to losses in both saltmarsh and seagrass cover (Table 3.41). In contrast, mangrove cover increased from 0.085km$^2$ in 1985 to 0.106km$^2$ in 2011.

***Table 3.41*** *Total area covered by mangrove, seagrass or saltmarsh in the Moonee Creek estuary in 2011 and 1985, and mean patch size of each vegetation community in 2011.*

| Vegetation community | Total area in 1985 (km$^2$) | Total area in 2011 (km$^2$) | Total area in 2011 (m$^2$) | Mean patch size in 2011 (m$^2$) |
|---|---|---|---|---|
| Mangrove | 0.085 | 0.106 | 106,259 | 389 |
| Saltmarsh | 0.132 | 0.117 | 117,206 | 4,508 |
| Seagrass (*Zostera*) - total | 0.032 | 0.019 | 18,696 | 1661 |
| Dense *Zostera* | - | 0.018 | 18,304 | 162 |
| Sparse *Zostera* | - | 0 | 0 | 0 |
| Estuary total | 0.249 | 0.242 | 242,161 | |


***Figure 3.19*** *Mangrove, seagrass and saltmarsh habitats in the Moonee Creek estuary (NSW Department of Industry and Investment – Primary Industries and Energy 2011).*

### *3.7.6 Water quality*

Moonee Creek received a score of 68, a grade of C, for water quality. The freshwater site MOON4 recorded the best water quality in the subcatchment, with a score of 75 (B-). The lower estuary (MOON1) received a score of 70 (C), with the tidal limit (MOON3) recording the worst water quality in the subcatchment (58, D+).

Water temperatures reflected seasonal climatic changes, but the freshwater site was the most variable (Figure 3.20), ranging from a winter minimum of 11.3°C to a summer maximum of 30.1°C (Table 3.42). DO% was lowest in the freshwater site MOON4 (Figure 3.20), ranging from 85.9 – 113.4% (Table 3.42). DO% did not fall below the minimum guideline thresholds in Moonee Creek. DO% at MOON1 exceeded the maximum estuarine trigger threshold on all 7 sampling occasions (Table 3.43). DO% at MOON3 exceeded the maximum estuarine trigger threshold on 6 sampling occasions with the only observations within the guideline in August and November 2015 (Table 3.43). DO% at MOON4 exceeded the maximum freshwater trigger threshold on 3 occasions (September 2014, and May and August 2015); however, exceedances were very low (≤4%, Table 3.43).

pH ranged from 5.9 – 7.5 in Moonee estuary. pH was below the minimum estuarine trigger threshold at MOON1 on 3 occasions (July, August and November 2015, Table 3.43). MOON3 also consistently recorded pH below the minimum estuarine trigger threshold (Table 3.43): pH only fell within the guideline threshold in December 2014. pH only fell below the minimum freshwater trigger threshold at MOON4 on one occasion, in August 2015. pH exceeded the maximum freshwater trigger threshold twice (March and May 2015, Table 3.43).

Chl-*a* ranged from 1.0 – 6.0µg/L in the Moonee estuary (Table 3.42), with greater variability in the lower estuary (Figure 3.20). At MOON1, chl-*a* exceeded the estuarine trigger threshold once, in December 2014 (Table 3.43). Chl-*a* ranged from 2.0 – 16.0µg/L in MOON4, exceeding the freshwater trigger threshold twice (December 2014 and 2015, Table 3.43). TN ranged from 0.2 – 0.6mg/L in the estuary. At MOON1, TN exceeded the estuarine trigger threshold twice (July and December 2015, Table 3.43). At MOON3, TN exceeded the estuarine trigger threshold on 6 occasions, only falling within the guideline threshold in September 2014 and July 2015 (Table 3.43). TN only exceeded the freshwater trigger threshold once at MOON4, in December 2015 (Table 3.43). TP remained below detection limits at all times in Moonee Creek (Table 3.42).

Faecal coliforms were collected from MOON1 8 times through the sampling period. No coliforms were observed in May 2015. Coliform counts exceeded the estuarine trigger threshold for primary contact once in November 2015 (156fc/100mL).

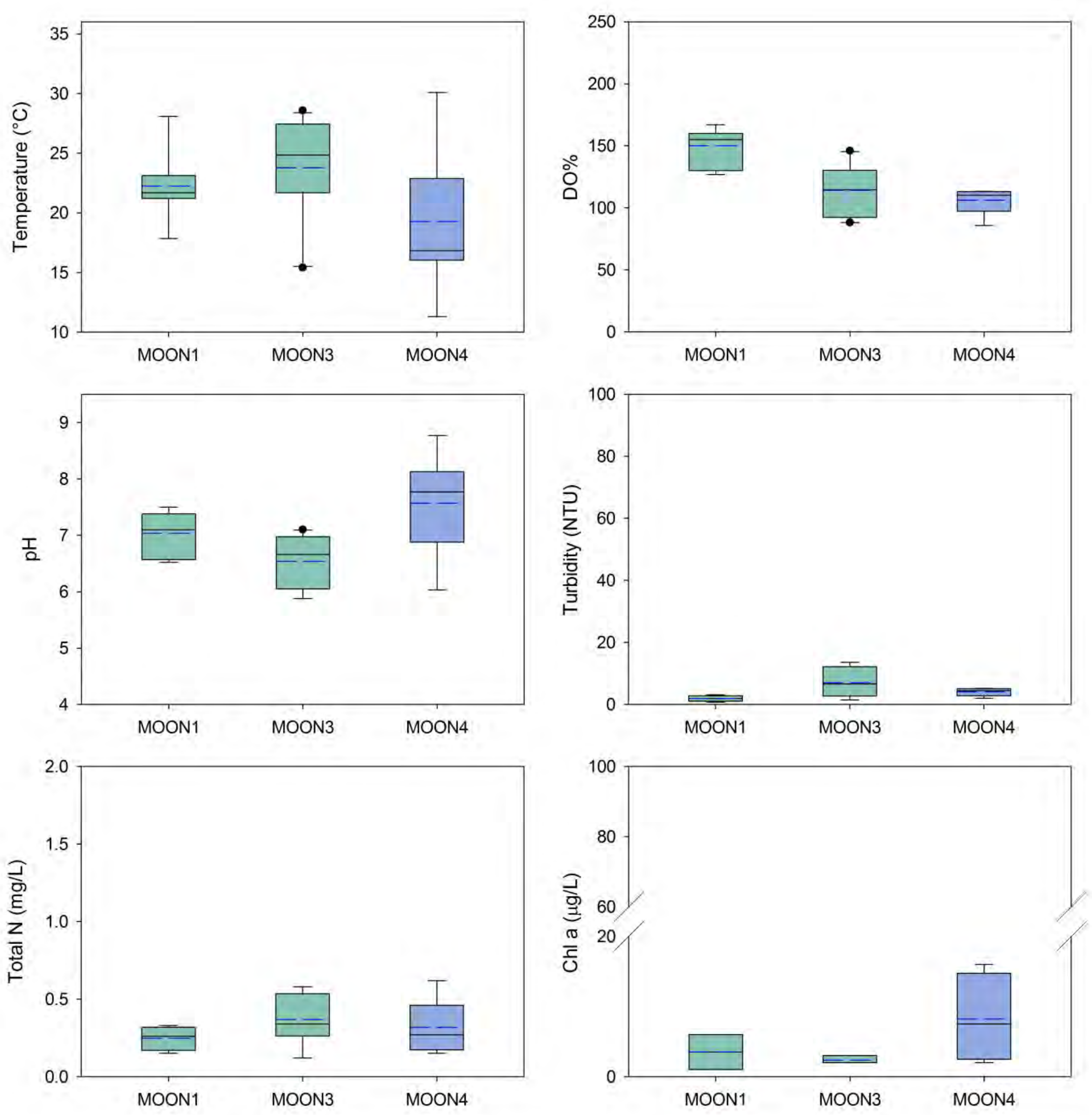



***Figure 3.20*** *Mean (blue line), median (black line), 25th and 75th percentiles, and range of water quality variables in the Moonee Creek subcatchment over 2015. Outliers are represented by black dots. Green and blue boxes represent estuary and freshwater sites, respectively.*

***Table 3.42** Minimums, maximums and means of measured water quality variables for the three sites on Moonee Creek.*

| | MOON1 | | | MOON3 | | | MOON4 | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **Min** | **Max** | **Mean** | **Min** | **Max** | **Mean** | **Min** | **Max** | **Mean** |
| **Temperature** | 17.8 | 28.1 | 22.3 | 15.4 | 28.6 | 23.8 | 11.3 | 30.1 | 19.3 |
| **pH** | 6.5 | 7.5 | 7.0 | 5.9 | 7.1 | 6.5 | 6.0 | 8.8 | 7.6 |
| **EC** | 45.5 | 54.6 | 51.0 | 36.6 | 56.8 | 46.4 | 0.2 | 1.2 | 0.4 |
| **Salinity (PPT)** | 35.0 | 38.1 | 36.7 | 25.7 | 38.8 | 32.0 | 0.1 | 29.3 | 9.9 |
| **DO (mg/L)** | 8.2 | 13.1 | 10.7 | 5.7 | 11.2 | 8.4 | 7.3 | 11.1 | 9.9 |
| **DO %** | 127.0 | 167.0 | 150.1 | 88.1 | 146.0 | 114.3 | 85.9 | 113.4 | 106.3 |
| **Turbidity** | 0.8 | 3.1 | 2.0 | 1.5 | 13.6 | 7.1 | 2.0 | 5.2 | 4.1 |
| **Max Depth** | 0.2 | 0.4 | 0.3 | 0.7 | 1.2 | 1.1 | 0.1 | 0.2 | 0.2 |
| **Chla (µg/L)** | 1.0 | 6.0 | 3.5 | 2.0 | 3.0 | 2.3 | 2.0 | 16.0 | 8.3 |
| **TSS (mg/L)** | 6.0 | 21.0 | 12.0 | 3.0 | 46.0 | 21.5 | 2.0 | 26.0 | 7.9 |
| **TN (mg/L)** | 0.2 | 0.3 | 0.2 | 0.1 | 0.6 | 0.4 | 0.2 | 0.6 | 0.3 |
| **TP (mg/L)** | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 |
| **Coliforms (cells/100mL)** | 0 | 156 | 41 | | | | | | |

***Table 3.43** Exceedances[1] observed in Moonee Creek for pH, conductivity (EC), percent saturated dissolved oxygen (DO), turbidity, chlorophyll a (Chl-a), total nitrogen (TN) and total phosphorus (TP), and the site-level WQ grades.*

| Site | pH | EC | DO % | Turbidity | Chl-a | TN | TP | WQ grade |
|---|---|---|---|---|---|---|---|---|
| MOON1 | 3(43%) 3,0 | NA | 7(100%) 0,7 | 0 | 1(13%) | 2(25%) | 0 | C |
| MOON3 | 10(83%) 10,0 | NA | 6(60%) 0,6 | 2(25%) | 0 | 6(83%) | 0 | D+ |
| MOON4 | 3(43%) 1,2 | 0 | 3(60%) 0,3 | 0 | 2(25%) | 1(13%) | 0 | B- |

*[1] Numbers in black represent the total number and percent of exceedances. Numbers in blue and red represent the numbers of measurements lower than the minimum threshold and higher than the maximum threshold, respectively. The number of exceedances includes all depths sampled so may be greater than the number of times sampled. Turbidity, chlorophyll a, and total nutrients only have maximum trigger thresholds.*

### 3.7.7 Aquatic macroinvertebrates

Family richness was lower in autumn than spring in Moonee Creek #4, with 10 and 15 families recorded respectively (Table 3.44). In autumn, Coleoptera (Aquatic Beetles) were the most diverse, with 4 families (but only 12 individuals). In spring, MOON4 contained 4 families of Aquatic Beetles (9 individuals), and 4 families of Diptera (4 individuals). There were 5 and 11 rare taxa in autumn and spring, respectively, that each comprised fewer than 5 individuals.

Total abundance in autumn was dominated by Chironomids (Midge Larvae, 71 individuals) and Notonectidae (Backswimmers, 44 individuals). In spring, the freshwater pulmonate snail *Austropeplea* dominated total abundance with 68 individuals, followed by Atyidae (Freshwater Shrimp) with 20 individuals.

No EPTs were recorded at MOON4 in 2015 (Table 3.44). This contributed to low SIGNAL2 scores of 2.4 and 1.9 in autumn and spring, respectively. This suggests poor water quality at this site.

Moonee Creek #4 (MOON4) received an overall Ecohealth score of 8, a grade of F for aquatic macroinvertebrate community condition. All four macroinvertebrate indicators for MOON4 were significantly below the mean for Coffs coastal subcatchments in 2015 (Table 3.6). The very low score for this site reflects an absence of EPTs and low SIGNAL2 scores of the macroinvertebrates recorded. The low mean scores and dominance of taxa with low SIGNAL2 scores suggests the water quality and habitat conditions in the freshwater reaches of Moonee Creek are in very poor condition.

***Table 3.44*** *Summary of aquatic macroinvertebrate data for Moonee Creek #4 (MOON4).*

| MOON4 | | | | |
|---|---|---|---|---|
| **Macroinvertebrate indicator** | **Autumn 2015** | **Spring 2015** | **Autumn 2011** | **Spring 2011** |
| Family richness | 10 | 15 | 13 | 7 |
| Total abundance | 140 | 129 | 73 | 17 |
| EPT richness | 0 | 0 | 3 | 0 |
| EPT abundance | 0 | 0 | 10 | 0 |
| Mean SIGNAL2 score | 2.4 | 1.9 | 4.8 | 3.9 |
| SIGNAL2 score range | 1 - 6 | 1 - 6 | 2 - 8 | 2 - 7 |
| Ecohealth score (grade) | **8 (F)** | | **26 (F)** | |

## 3.8 Coffs Creek

### *3.8.1 Catchment description*

Coffs Creek is a relatively small, but highly populated catchment extending through the main town of Coffs Harbour. The creek is approximately 12km long, and has a catchment area (excluding its northern tributaries) of 27km$^2$ (Table 3.45). Headwaters are in steep midland hills (33-56% slopes), and drain confined valleys lacking floodplains (Figure 3.21a, Table 3.45). These midland hills are underlain by the Coramba Beds (in the north) and Brooklana Beds (middle and south), both of the Coffs Harbour association consisting of slates, siliceuos mudstone (43%), lamainated greywackes (26%), siltstone, minor cherts and jasper. These metasediments form strongly acid stony kandosols (Figure 3.21d). 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 dominant landuse in the upper catchment is intensive horticulture (23% of subcatchment area), with small areas of residual native cover (12%) and grazing (10%, Table 3.45). The coastal floodplain is highly urbanized (28% of subcatchment area).

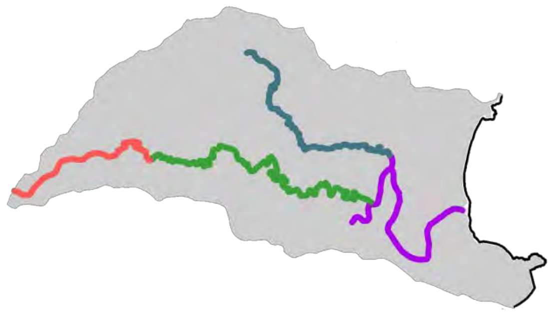
Coffs Creek was once pivotal in the transport of logged cedar to the Coffs Harbour Jetty for export and is now utilised for recreational pastimes such as fishing and kayaking (Bewsher Consulting 2005). For these reasons and its proximity to urban areas, the condition of the creek ecosystem comes under 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 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).

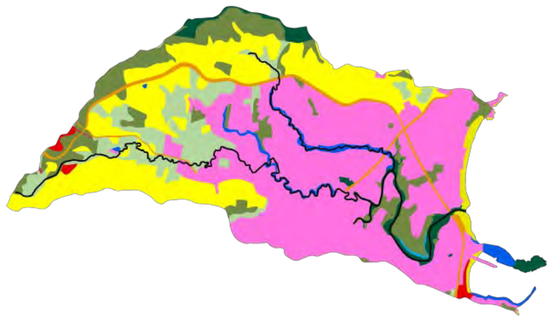
The Coffs Creek Coastal Zone Management Plan (CHCC 2012) identified a number of major issues in the catchment including:

- 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.

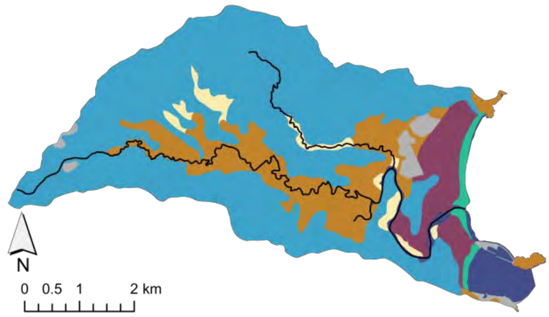

**(a)** Topography and location of Ecohealth sites.



**(b)** River Styles: refer to Figure 2.8 for key.



**(c)** Landuse: refer to Figure 2.7 For key.




**(d)** Soils: refer to Figure 2.3 For key.

***Figure 3.21*** *The Coffs Creek subcatchment showing (a) locations of Ecohealth sites and catchment topography, (b) River Styles, (c) landuse, and (d) soils. Data layers from CHCC (site locations), ESRI (topography), NC LLS (River Styles) and OEH (landuse and soils).*

***Table 3.45*** *Subcatchment description of Coffs Creek. Data from NC LLS and OEH.*

| Variable | Subcatchment composition |
|---|---|
| Area ($km^2$) | 27 |
| Geology | 43% Mudstone; 28% Alluvial Sediment; 26% Greywacke; 4% Water |
| Soils | 64% Kandosols; 17% Kurosols; 7%Podosols; 6% other; 5% water |
| River Styles | 35% PCVS - Planform controlled, meandering, fine grained; 26% LUV CC – Tidal; 23% PCVS - Planform controlled, meandering, sand; 17% CVS – Headwater. |
| Landuse | 28% Urban; 23% Horticulture;15% Services; 12% Residual Native Cover; 10% Grazing; 4% Transport; 1% Forestry |
| Major point source discharge | Nil |
| Tree Cover | 23% |

### *3.8.2 Site descriptions*

Three sites were monitored in Coffs Creek subcatchment in 2015 (Figure 3.21a). The site COFFS1 was the most downstream site and was located in the lower estuary of Coffs Creek in the marine zone (salinity of +30ppt, Plate 3.19). The site COFFS2 was located in the mid estuary, in an intermediate salinity zone of 15-30ppt. The site COFFS4 was located in the freshwater zone of Coffs Creek in a channel defined as planformed controlled, meandering, fine grained (Plate 3.20).

***Plate 3.19*** *The site COFFS1 was located in the lower Coffs Creek estuary.*

***Plate 3.20*** *The site COFFS4 was located in the freshwater reaches of Coffs Creek.*

### *3.8.3 Geomorphic condition*

The River Style at COFFS4 is partially confined valley setting: planform controlled, meandering, fine grained (Figure 3.21b). Bank and bed sediments were fine grained with cobbles, pebbles and gravel absent. Evidence of active bank erosion included 10-20m combined length of undercutting along each bank and 5-10m combined length of slumping along each bank. Undercutting was concentrated around the bridge at the downstream end of the site. There were significant amounts of large woody debris in the low-flow channel. COFFS4 scored 61.2, a grade of C- for BANK CONDITION and 68, a grade of C for BED CONDITION. The overall Ecohealth geomorphic condition for COFFS4 was 65, a grade of C-.

In summary, COFFS4 was assessed as being in moderate geomorphic condition. The banks are well vegetated, but fine-grained and prone to erosion. The existing bank undercutting is likely due to changes in runoff associated with the impervious surfaces of urban development and bridge scour. The desktop GIS assessment of subcatchment geomorphic condition found 100% of the stream nework in the Coffs Creek subcatchment to be in moderate condition. The site level score for COFFS4 is slightly below the subcatchment average for geomorphic condition.

### *3.8.4 Riparian condition*

The riparian vegetation community at Coffs Creek #4 (COFFS4, Plate 3.21) would have originally been described as 'Coast and Hinterland Riparian Flooded Gum – Bangalow Wet Forest', CH_WSF01 (OEH 2012b), or North Coast Wet Sclerophyll Forest (Keith 2004), and received a very poor riparian condition score of 50% or D (Table 3.46).

The dominant canopy species were Camphor Laurel (*Cinnamomum camphora*), Flooded Gum (*Eucalyptus grandis*), Mulberry (*Morus alba*), and Brush Box (*Losphostemon confertus*). The midstory was dominated by Small-leaved Privet (*Ligustrum sinense*), Bangalow Palm (*Archontophoenix cunninghamiana*), Sweet Pittosporum (*Pittosporum undulatum*), Sandpaper Fig (*Ficus coronata*), and Narrow-leaved Palm Lily (*Cordyline stricta*). The understory was dominated by Fishbone Fern (*Nephrolepis cordifolia*), Green-leaved Desmodium (*Desmodium intortum*), Crofton Weed (*Ageratina adenophora*), Blue Billy Goat Weed (*Ageratum houstonianum*), and Paspalum species (*P.dilatatum* and *P.mandiocanum*). Despite canopy light gaps, no macrophyte species were present, and the dominant vine species on-site were Baloon Vine (*Cardiospermum grandiflorum*), and Wait-a-while Vine (*Smilax australis*).

Lantana (*Lantana camara*) and Small-leaved Privet (*Ligustrum sinense*) (both class 4), were the only noxious weed species observed on-site. Other weedy species present included Camphor Laurel (*Cinnamomum camphora*), Mulberry (*Morus alba*), Jacaranda (*Jacaranda mimosifolia*), Ladies Teardrop (*Malvaviscus arboreus*), Wild Tobacco (*Solanum mauritianum*), Mickey Mouse Plant (*Ochna serrulata*) Crofton Weed (*Ageratina adenophora*), Elephants Ears (*Colocasia esculenta*), Japanese Sunflower (*Tithonia diversifolia*), Blue Billy Goat Weed (*Ageratum houstonianum*), Green-leaved Desmodium (*Desmodium intortum*), Baloon Vine (*Cardiospermum grandiflorum*), Wandering Jew (*Tradescantia fluminensis*), Prarie Grass (*Bromus catharticus*) and Paspalum species (*P.dilatatum* and *P.mandiocanum*).

COFFS4 scored 12.5/20 for HABITAT, and lost marks for all indices except for the presence of all structural layers. Channel:vegetation width, proximity to larger tracts of remnant native vegetation, and large mature and hollow-bearing tree indicators each received half marks, while riparian vegetation continuity was significantly affected by several large interruptions. NATIVE SPECIES scored very poorly, with 4.5/20. While native species were present on-site, weedy species outweighed native species at each structural layer; canopy and midstory ~55%, herb/forbs and graminoids >70%, with no macrophyte species being recorded (perhaps shaded out by the Camphor Laurel canopy). SPECIES COVER scored 14/20 with reduced marks for gaps in canopy cover, a reduced graminoid cover (despite being corrected for naturally low cover values), and the absence of macrophytes. DEBRIS received a low 9/20. Although the site had a good presence of total leaf litter and moderate quantities of lying timber, marks were lost for reduced native leaf litter (the majority of litter being from both Narrow-leaved Privet and Camphor Laurel), large woody debris - standing and fallen, and a low presence of on-site fringing vegetation. While low levels of exposed tree roots gained marks, on-site vegetation stand history, cleared sections of riparian vegetation, the presence of noxious weeds, woody weed regeneration, and an absence of woody native regeneration resulted in a low subindex score for MANAGEMENT, 10/20.

***Plate 3.21*** *Riparian vegetation at Coffs Creek #4 was in very poor condition. While native species representative of the original vegetation community were present, they were outweighed at most structural levels by both noxious and environmental weed species. The strategic phasing out of Camphor Laurel, removal and monitoring of other weed species in addition to native plantings would improve riparian condition at this site.*

***Table 3.46*** *Site-level summary of riprian condition of Coffs Creek #4, including subindices and indicators.*

| Coffs Creek #4 | Scores |
|---|---|
| **HABITAT** | **12.5** |
| Channel width | 2 |
| Proximity | 2 |
| Continuity | 1.5 |
| Layers | 4 |
| Large native trees | 2 |
| Hollow-bearing trees | 1 |
| **NATIVE SPECIES** | **4.5** |
| Native canopy species | 1.5 |
| Native midstory species | 2 |
| Native herb/forb species | 0.5 |
| Native graminoid species | 0.5 |
| Native macrophyte species | 0 |
| **SPECIES COVER** | **14** |
| Canopy species | 3 |
| Midstory species | 4 |
| Herb/forb species | 4 |
| Graminoid species | 3 |
| Macrophyte species | 0 |
| **DEBRIS** | **9** |
| Total leaf litter | 3 |
| Native leaf litter | 2 |
| Dead trees standing | 1 |
| Dead trees fallen | 0 |
| Lying logs | 2 |
| Fringing vegetation | 1 |
| **MANAGEMENT** | **10** |
| Tree clearing | 1 |
| Fencing | 2 |
| Animal impact | 2 |
| Species of interest | 1 |
| Exposed tree roots | 3 |
| Native woody regeneration | 0 |
| Weedy woody regeneration | 0 |
| **TOTAL** | **50** |

### *3.8.5 Mangrove, seagrass and saltmarsh cover*

The Coffs Creek estuary contained the fifth highest total estuarine macrophyte cover of the 9 Coffs Harbour estuarine systems (Figure 3.22). Mangroves were the dominant vegetation community (0.201km$^2$), with the Coffs Creek estuary containing the second highest cover of mangroves in the Coffs Harbour region. Saltmarsh was also present (0.014km$^2$), as was seagrass, albeit at low cover values (0.002km$^2$) (Table 3.47). Coffs Creek recorded the lowest seagrass cover of the 5 Coffs Harbour estuary systems that contained seagrass, with a mean patch size of 56m$^2$ (Table 3.47). Management priorities in this system should focus on maintaining the current seagrass and estuarine macrophyte cover.

Total estuarine macrophyte cover in the Coffs Creek estuary increased from 1985 (0.196km$^2$) to 2011 (0.216km$^2$) (Table 3.47). While seagrass cover was similar between 1985 and 2011 (0.002km$^2$), mangrove and saltmarsh cover increased from 1985 (0.192km$^2$ and 0.002 km$^2$, respectively) to 2011 (0.201km$^2$ and 0.014 km$^2$, respectively) (Table 3.47).

***Table 3.47*** *Total area covered by mangrove, seagrass or saltmarsh in the Coffs Creek estuary in 2011 and 1985, and mean patch size of each vegetation community in 2011.*

| Vegetation community | Total area in 1985 (km$^2$) | Total area in 2011 (km$^2$) | Total area in 2011 (m$^2$) | Mean patch size in 2011 (m$^2$) |
|---|---|---|---|---|
| Mangrove | 0.192 | 0.201 | 200,667 | 1,544 |
| Saltmarsh | 0.002 | 0.014 | 13,607 | 1,134 |
| Seagrass (*Zostera*) - total | 0.002 | 0.002 | 1,855 | 56 |
| Dense *Zostera* | - | <0.001 | 67 | 67 |
| Sparse *Zostera* | - | 0.002 | 1,788 | 56 |
| Estuary total | 0.196 | 0.216 | 216,129 | |

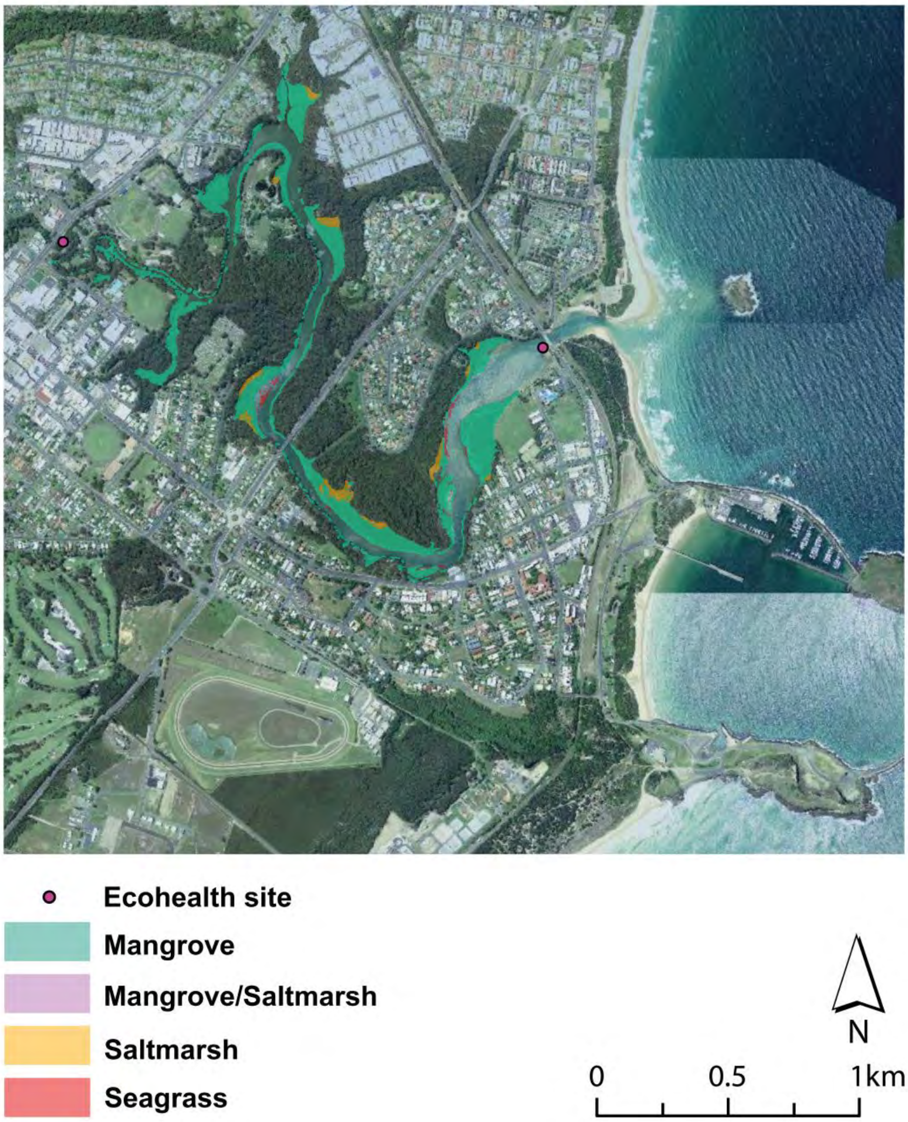



***Figure 3.22*** *Mangrove, seagrass and saltmarsh habitats in the Coffs Creek estuary (NSW Department of Industry and Investment – Primary Industries and Energy 2011).*

### *3.8.6 Water quality*

Coffs Creek received a score of 56, a grade of D+, for water quality, with the tidal limit (COFFS3) recording the poorest water quality (42, F) of the 3 sites. Both the lower estuary (COFFS1, 63) and the freshwater zone (COFFS4, 64) scored a C- for water quality.

Water temperatures reflected seasonal climatic fluctuations, ranging from winter minimums of 13.5°C in the estuary and 11.5°C in the freshwater zone, to summer maximums of 27.6°C in the estuary and 23.1°C in the freshwater site (Figure 3.23, Table 3.48). DO% ranged from 82.1-162% in the estuary, and was much lower at the freshwater site, with a range of 54.1-138.2°C (Table 3.48). DO% exceeded the maximum estuarine trigger threshold at COFFS1 on 6 occasions (Table 3.49), falling within guideline thresholds only twice (September 2014 and March 2015). DO% exceeded the maximum estuarine trigger threshold at COFFS3 twice, in May and July 2015 (Table 3.49). DO% varied in COFFS4, falling below the minimum freshwater trigger threshold once (November 2015), and exceeding the maximum freshwater trigger threshold twice (September 2014 and May 2015, Table 3.49).

pH ranged from 6.1 – 7.7 in the Coffs estuary and was consistently below the minimum estuarine trigger thresholds. At COFFS1, pH fell below the minimum estuarine trigger threshold on 3 occasions (March, May and July 2015, Table 3.49). At COFFS3, pH fell below the minimum estuarine trigger threshold on 4 occasions (September and December 2014, and July and August 2015). pH ranged from 6.2 – 9.0 in the freshwater zone (Table 3.48). At COFFS 4, pH fell below the minimum freshwater trigger threshold once (December 2014), and exceeded the maximum freshwater trigger threshold 4 times (September 2014, and March, May and July 2015, Table 3.49). Turbidity ranged from 1.2 – 28.9NTU in Coffs Creek. COFFS 3, the tidal limit, was the only site that exceeded the guideline threshold (December 2014, and August and November 2015).

Chl-*a* ranged from 2.0 – 97.0µg/L in the Coffs estuary (Table 3.48). Chl-*a* exceeded the estuarine trigger threshold at COFFS1 on 3 times (March, May and November 2015, Table 3.49), and COFFS3 on 4 times (December 2014, and August, November and December 2015, Table 3.49). The highest exceedances at COFFS3 occurred in December 2014 (97µg/L) and August 2015 (29µg/L). Chl-*a* ranged from 2.0 – 15.0 in the freshwater site COFFS4 (Table 3.48). Chl-*a* at COFFS4 exceeded the freshwater trigger threshold twice (September and December 2014, Table 3.49).

TN ranged from 0.2 – 1.5mg/L in the Coffs estuary. TN at COFFS1 exceeded the estuarine trigger threshold twice (March and May 2015, Table 3.49). At COFFS3, TN exceeded the estuarine trigger threshold on all but one occasion, falling within the guideline threshold in November 2015 (Table 3.49). The largest exceedance was 3x the guideline threshold (1.54mg/L in December 2014). At COFFS4, TN exceeded the freshwater trigger threshold on 4 occasions (September 2014, and March, May and August 2015, Table 3.49). The highest concentrations of TP were found at the tidal limit (COFFS3) at more than 4x the estuarine trigger threshold of 0.03mg/L (Table 3.48). TP at COFFS1 exceeded the estuarine trigger threshold twice (March and November 2015, Table 3.49). TP consistently exceeded the estuarine trigger threshold at COFFS3, recording exceedances on 5 occasions (September and December 2014, and August and November 2015). There was only 1 exceedance for TP at COFFS4 and this was in December 2015; however, it was twice the freshwater trigger threshold (Tables 3.48, 3.49).

Faecal coliforms were collected from COFFS1 8 times through the sampling period. The maximum count was greater than the detection limit of 1000fc/100mL and was observed in November 2015 (Table 3.48). Coliform counts also exceeded the estuarine trigger threshold for primary contact in March 2015 (300fc/100mL) and August 2015 (172fc/100mL).

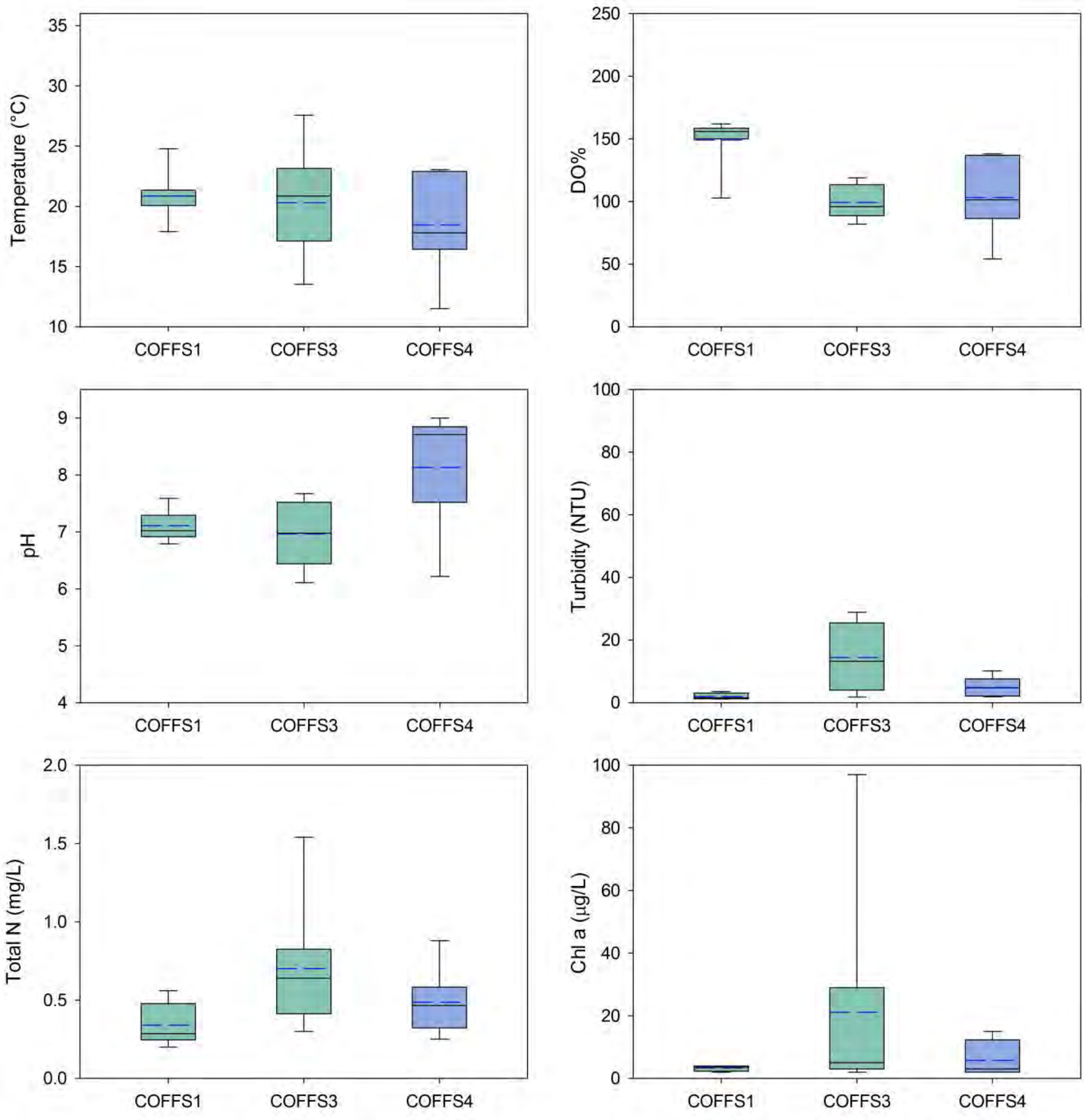



***Figure 3.23*** *Mean (blue line), median (black line), 25th and 75th percentiles, and range of water quality variables in the Coffs Creek subcatchment over 2015. Outliers are represented by black dots. Green and blue boxes represent estuary and freshwater sites, respectively.*

***Table 3.48*** *Minimums, maximums and means of measured water quality variables for the three sites on Coffs Creek.*

| | COFFS1 | | | COFFS3 | | | COFFS4 | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **Min** | **Max** | **Mean** | **Min** | **Max** | **Mean** | **Min** | **Max** | **Mean** |
| **Temperature** | 17.9 | 24.8 | 20.9 | 13.5 | 27.6 | 20.3 | 11.5 | 23.1 | 18.5 |
| **pH** | 6.8 | 7.6 | 7.1 | 6.1 | 7.7 | 7.0 | 6.2 | 9.0 | 8.1 |
| **EC** | 34.9 | 52.2 | 43.7 | 3.0 | 13.4 | 8.3 | 0.1 | 0.2 | 0.2 |
| **Salinity (PPT)** | 23.0 | 37.5 | 30.8 | 1.7 | 7.5 | 4.3 | 0.1 | 0.1 | 0.1 |
| **DO (mg/L)** | 7.5 | 12.1 | 11.1 | 7.2 | 23.4 | 11.0 | 4.8 | 13.4 | 9.8 |
| **DO %** | 102.9 | 162.0 | 149.0 | 82.1 | 119.0 | 99.3 | 54.1 | 138.2 | 103.1 |
| **Turbidity** | 1.2 | 3.6 | 2.0 | 1.8 | 28.9 | 14.4 | 1.9 | 10.1 | 4.8 |
| **Max Depth** | 0.5 | 1.1 | 0.8 | 0.5 | 0.8 | 0.6 | 0.2 | 0.3 | 0.2 |
| **Chla (µg/L)** | 2.0 | 4.0 | 3.3 | 2.0 | 97.0 | 21.1 | 2.0 | 15.0 | 5.8 |
| **TSS (mg/L)** | 5.0 | 27.0 | 13.0 | 4.0 | 24.0 | 12.8 | 2.0 | 14.0 | 5.5 |
| **TN (mg/L)** | 0.2 | 0.6 | 0.3 | 0.3 | 1.5 | 0.7 | 0.3 | 0.9 | 0.5 |
| **TP (mg/L)** | <0.03 | 0.08 | <0.03 | <0.03 | 0.15 | 0.07 | <0.03 | 0.06 | 0.04 |
| **Coliforms (cells/100mL)** | 21 | >1000 | 127 | | | | | | |

***Table 3.49*** *Exceedances[1] observed in Coffs Creek for pH, conductivity (EC), percent saturated dissolved oxygen (DO), turbidity, chlorophyll a (Chl-a), total nitrogen (TN) and total phosphorus (TP), and the site-level WQ grades.*

| Site | pH | EC | DO % | Turbidity | Chl-a | TN | TP | WQ grade |
|---|---|---|---|---|---|---|---|---|
| COFFS1 | 3(43%) 3,0 | NA | 6(86%) 0,6 | 0 | 3(30%) | 2(33%) | 2(33%) | C- |
| COFFS3 | 4(47%) 4,0 | NA | 2(33%) 0,2 | 3(60%) | 4(50%) | 7(88%) | 5(63%) | F |
| COFFS4 | 5(71%) 1,4 | 0 | 3(43%) 1,2 | 0 | 2(25%) | 4(50%) | 1(13%) | C- |

*[1] Numbers in black represent the total number and percent of exceedances. Numbers in blue and red represent the numbers of measurements lower than the minimum threshold and higher than the maximum threshold, respectively. The number of exceedances includes all depths sampled so may be greater than the number of times sampled. Turbidity, chlorophyll a, and total nutrients only have maximum trigger thresholds.*

### *3.8.7 Aquatic macroinvertebrates*

Coffs Creek #4 (COFFS4) recorded 22 and 18 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.50). In autumn, richness was dominated by Elmid Beetles with 3 families (35 individuals), while in spring, richness was dominated by Diptera (Midges, Mosquitos and Gnats) with 5 families (139 individuals), followed by Odonata (Dragonflies) with 3 families (4 individuals). Total abundance was also higher in autumn (384 individuals) than spring (209 individuals, Table 3.50). In autumn, 2 taxa accounted for 66% of the total abundance: Chironomidae (Midge Larvae) with 127 individuals and Hydropsychid Caddisflies with 125 individuals. Chironomid Midge Larvae comprised 61% of the total abundance in spring (127 individuals). There were a number of rare taxa with 13 and 14 families in autumn and spring, respectively, each comprising fewer than 5 individuals.

EPT richness was low in both sampling periods, with the same 2 Trichopteran (Caddisfly) genera (*Cheumatopsyche* and *Triplectides*) present in both seasons (Table 3.50). However, abundances of both were much higher in autumn (125 and 33) than spring (2 and 5, respectively). The mean SIGNAL2 score of COFFS4 was higher in autumn than spring (4.6 and 3.2, respectively). The higher score in autumn was driven by Elmid Beetles (SIGNAL2 of 7) and the Trichoptera (both with SIGNAL2 of 6).

Coffs Creek #4 (COFFS4) received an overall Ecohealth score of 39, a grade of F for aquatic macroinvertebrate community condition. Although the macroinvertebrate indicators of family richness and total abundance were above the means for Coffs coastal catchments in 2015, the indicators for SIGNAL2 and particularly EPT were below the catchment means (Table 3.6). The low mean scores and dominance of taxa with low SIGNAL2 scores suggests the water quality and habitat conditions in the freshwater reaches of Coffs Creek are in very poor condition.

***Table 3.50*** *Summary of aquatic macroinvertebrate data for Coffs Creek #4 (COFFS4).*

| COFFS4 | | | | |
|---|---|---|---|---|
| **Macroinvertebrate indicator** | **Autumn 2015** | **Spring 2015** | **Autumn 2011** | **Spring 2011** |
| Family richness | 22 | 18 | 9 | 6 |
| Total abundance | 384 | 209 | 58 | 107 |
| EPT richness | 2 | 2 | 3 | 2 |
| EPT abundance | 158 | 7 | 9 | 27 |
| Mean SIGNAL2 score | 4.6 | 3.2 | 5.4 | 4.5 |
| SIGNAL2 score range | 1 - 7 | 2 - 7 | 3 - 8 | 2 - 7 |
| Ecohealth score (grade) | **39 (F)** | | **33 (F)** | |

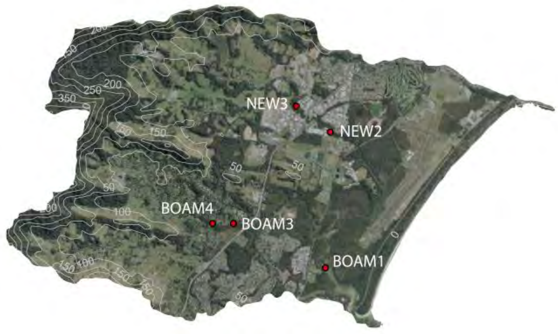
## 3.9 Boambee/Newports Creeks

### *3.9.1 Catchment description*

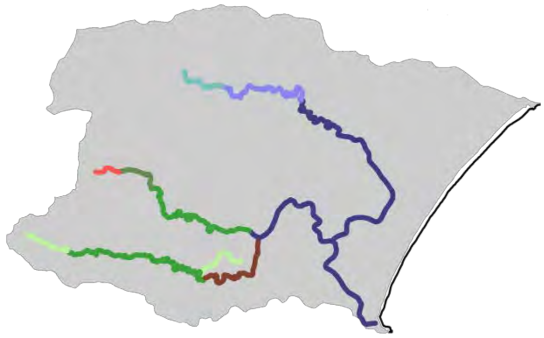
The Boambee-Newports Estuary is located between the city of Coffs Harbour (to the north) and the town of Sawtell (to the south). The estuary has an approximately rectangular-shaped catchment area of approximately 51km$^2$, extending approximately 8km from the coast with a coastal floodplain of approximately 3km wide (Table 3.51). Headwaters lie in steep midland hills (33-56% slope) with small areas of escarpment ranges at the subcatchment divide (Figure 3.24a), and drain confined valleys lacking floodplains (Figure 3.24b). The midland hills are underlain by metasediments of the Coffs Harbour association (Brooklana Beds consisting of silicious mudstones and siltstones typically highly fractured, cleaved and deformed) that form strongly acid stony kandosols (57% of subcatchment area, Figure 3.24d) with strong subsoil acidity and low chemical fertility (Milford 1999).

The drainage network consists of two main tributaries: the largest is Newports Creek in the north; followed by Boambee Creek that drains the mid-catchment (Figure 3.24). The Boambee/Newports Estuary is permanently open to the ocean and the entrance is naturally trained by Boambee Headland (GHD 2012). 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).

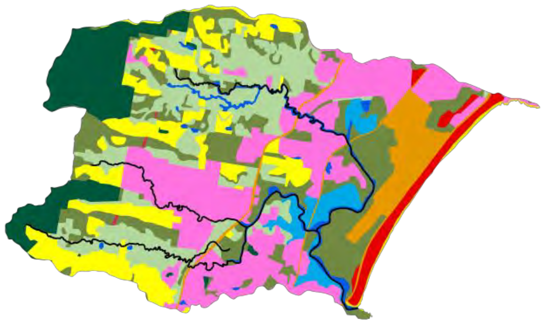
Much of the catchment is affected by urbanisation (24% subcatchment area, Figure 3.24c). Large industrial areas (10% area) in the mid-catchment include a sewage treatment plant (1% area) and the Coffs Harbour regional airport (6% area, Table 3.51). Significant land use changes are expected to continue within the catchment with residential, rural and industrial development.



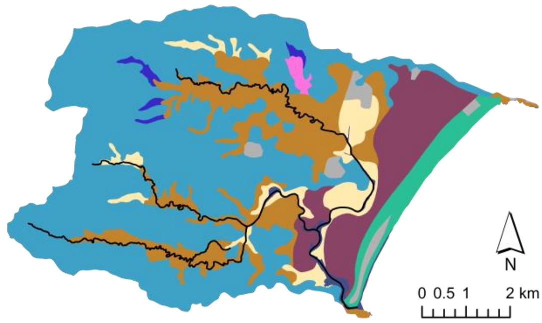

**(a)** Topography and location of Ecohealth sites.



**(b)** River Styles: refer to Figure 2.8 for key.



**(c)** Landuse: refer to Figure 2.7 For key.




**(d)** Soils: refer to Figure 2.3 For key.

***Figure 3.24*** *The Boambee/Newports Creeks subcatchment showing (a) locations of Ecohealth sites and catchment topography, (b) River Styles, (c) landuse, and (d) soils. Data layers from CHCC (site locations), ESRI (topography), NC LLS (River Styles) and OEH (landuse and soils).*

***Table 3.51*** *Subcatchment description of Boambee/Newports Creeks. Data from NC LLS and OEH.*

| Variable | Subcatchment composition |
|---|---|
| Area (km$^2$) | 51 |
| Geology | 54% Mudstone; 28% Siltstone; 11% Alluvial Sediment; 6% Mudstone; 6% Monzogranite |
| Soils | 57% Kandosols; 18% Kurosols; 11% Podosols; 6% Hydrosols; 8% other; 2% water |
| River Styles | 38% PCVS - Planform controlled, tidal; 27% PCVS - Planform controlled, meandering, fine grained; 10% PCVS - Planform controlled, low sinuosity, sand; 8% PCVS - Planform controlled, low sinuosity, fine grained; 7% SMG - Valley fill, fine grained; 9% mixed other. |
| Landuse | 20% Residual Native Cover; 18% Grazing; 14% Horticulture; 10% Forestry; 10% Services; 7% Rural residential, 7% Urban; 6% Transport; 2% River; 1% Waste |
| Major point source discharge | Nil |
| Tree Cover | 23% |

### 3.9.2 Site descriptions

Three sites were sampled on Boambee Creek in 2015 (Figure 3.24a). The site BOAM1 was located in the lower estuary downstream of the confluence of Boambee and Newports Creeks and is considered to be in the marine zone (salinity +30ppt, Plate 3.22). The site BOAM3 was located at the tidal limit of Boambee Creek in a reach defined as planform controlled, meandering, fine grained. The most upstream site, BOAM4 was in the freshwater reach of Boambee Creek (Plate 3.23). The reach at BOAM4 is also defined as planform controlled, meandering, fine grained.

Two sites were sampled on Newports Creek in 2015. Site NEW2 was at the tidal limit of Newports Creek and is defined as planform controlled, tidal. Site NEW3 is the most upstream site on Newports Creek, located in the freshwater reach (Plate 3.24). The channel at NEW3 is defined as planform controlled, low sinuousity, sand.

***Plate 3.22*** *The site BOAM1 looking upstream at the mouth of Boambee Creek.*

***Plate 3.23*** *The site BOAM4 in the freshwater reach of Boambee Creek.*

***Plate 3.24*** *The site NEW3 in the freshwater reach of Newports Creek.*

### 3.9.3 Geomorphic condition

The River Style at BOAM4 is partially confined valley setting: planform controlled, meandering, fine grained (Figure 3.24b). Bedrock outcropping formed a significant component of both banks (40%) in the survey site and formed a small section of rapid (average rapid length was 2m with 0.3m fall). The streambed was stable with no evidence of active erosion. BOAM4 scored 81.6, a grade of B for BANK CONDITION and 85, a grade of B, for BED CONDITION. The overall Ecohealth geomorphic condition for BOAM4 was 83, a grade of B.

The River Style at NEW3 is partially confined valley setting: planform controlled, low sinuosity, sand. Bed and bank sediments were silty sands. The survey site was adjacent to a light industrial area and was impacted by a stormwater drain and cleared left bank. Instream large woody debris was restricted to small debris jams in the low flow channel. The geomorphic complexity of the streambed was low, with the channel comprising a shallow run. Active erosion was minimal and confined to undercut banks with a combined length of 5-10m on each side of the channel. NEW3 scored 68, a grade of C, for BANK CONDITION and 56.7, a grade of D+ for BED CONDITION. The overall Ecohealth geomorphic condition for NEW3 was 62, a grade of C-.

In summary, BOAM4 was assessed as being in good geomorphic condition. Management strategies should continue to maintain well-vegetated streambanks to maintain the good geomorphic condition of this reach. NEW3 was assessed as being in moderate geomorphic condition. Management strategies should focus on native revegetation of the left bank. The desktop GIS assessment of subcatchment geomorphic condition in this subcatchment combined the stream networks of Boambee Creek and Newports Creek to calculate a subcatchment geomorphic grade of D, indicating poor geomorphic condition. Both sites assessed in the 2015 Ecohealth program were found to be in above average condition for the subcatchment.

### 3.9.4 Riparian condition

#### *Boambee Creek*

The riparian vegetation community at Boambee Creek #4 (BOAM4, Plate 3.25), can be described as 'Coast and Hinterland Riparian Flooded Gum – Bangalow Wet Forest', CH_WSF01 (OEH 2012b), or North Coast Wet Sclerophyll Forest (Keith 2004), and received a riparian condition score of 70.7% or C+ (Table 3.52).

The dominant canopy species on-site were Flooded Gum (*Eucalyptus grandis*), Tallowwood (*E.microcorys*), Watergum (*Tristaniopsis laurina*), Brush Box (*Losphostemon confertus*), and Camphor Laurel (*Cinnamomum camphora*). The midstory was dominated by Sweet Pittosporum (*Pittosporum undulatum*), Sandpaper Fig (*Ficus coronata*), Black Wattle (*Callicoma serratifolia*), and Narrow-leaved Palm Lily (*Cordyline stricta*). The understory was dominated by Native Wandering Jew (*Commelina* *cyanea*), Prickly Rasp Fern (*Doodia aspera*), Singapore Daisy (*Sphagneticola trilobata*), Lomandra species (*L.hystrix*, and *L.longifolia*), Harsh Ground Fern (*Hypolepis muelleri*), Common Rush (*Juncus usitatus*), and Crofton Weed (*Ageratina adenophora*). Spotted Knotweed (*Persicaria strigosa*) was the only Macrophyte species present on-site, while dominant vine species included Climbing Guinea (*Hibbertia scandens*), Common Silkpod (*Parsonsia* sp.), and Water Vine (*Cissus hypoglauca*).

Two noxious weed species were observed on-site; Lantana (*Lantana camara* - class 4), and Cockspur Coraltree (*Erythrina crista-galli* – class 3). Many other weedy species were also present on-site, with densities of most species increasing with proximity to the disturbed area surrounding the bridge. These included Camphor Laurel (*Cinnamomum camphora*), Ladies Teardrop (*Malvaviscus arboreus*), Coral Berry (*Ardisia crenata*), Senna species (*S. pendula* var. *glabrata* and *S. septemtrionalis*), Crofton Weed (*Ageratina adenophora*), Blue Billy Goat Weed (*Ageratum houstonianum*), Coblers Pegs (*Bidens pilosa*), Black Nightshade (*Solanum nigrum*), Singapore Daisy (*Sphagneticola trilobata*), Wandering Jew (*Tradescantia fluminensis*), Taro (*Colocasia esculenta*), Tous-les-mois-Arrowroot (*Canna indica*), Green-leaved Desmodium (*Desmodium intortum*), and several grass species, including Paspalum (*Paspalum dilatatum*), Purple Pigeon Grasses (*Setaria sphacelata*), Bamboo (*Bambusa sp.*) and Whisky Grass (*Andropogon virginicus*).

BOAM4 scored 15.7/20 for HABITAT, and received full marks for the indicators large mature native trees, hollow-bearing trees and for the presence of all four structural layers. Riparian vegetation continuity scored well as did vegetation:channel width ratio. However, grades were reduced due to limited proximity to large undisturbed tracts of remnant vegetation. NATIVE SPECIES scored 10/20, and had their greatest presence in the canopy layer (c.85%). Midstory, herb/forb and graminoid layers all scored half marks with weedy species reducing native species presence (~55-75%). The low score for macrophyte species arose from only a single species being recorded. SPECIES COVER scored 16/20, which can be attributed to maximum cover values in all structural layers except for macrophytes. DEBRIS received a score of 14.5/20. Maximum values were reported for total leaf litter, while the indicators for fringing vegetation, native leaf litter, large woody debris in the form of standing and lying dead trees all received higher grades. MANAGEMENT received 13.5/20, with maximum indicator values reached for very low values of exposed roots of fringing woody vegetation, for native woody regeneration, and for animal impact. Despite the site having no animal impact, satellite imagery revealed it as a potential threat and thus the fencing indicator was left unadjusted and recieved a low score. The tree clearing indicators received fair scores due to the ratio of mature trees:regrowth:cleared, while weeds continued to reduce the site score with the presence of both noxious weed species and woody weed regeneration.

***Plate 3.25** Riparian vegetation at Boambee Creek #4 was in fair condition. Remnant elements were present in all structural layers. However, riparian condition could be improved greatly with the strategic phasing out of Camphor Laurel, and the removal and monitoring of other weed species. Native plantings would improve riparian condition at this site, particularly in cleared weedy sections.*

***Table 3.52*** *Site-level summary of riprian condition of Boambee Creek #4, including subindices and indicators.*

| Boambee Creek #4 | Scores |
|---|---|
| **HABITAT** | **15.7** |
| Channel width | 3.7 |
| Proximity | 1 |
| Continuity | 3 |
| Layers | 4 |
| Large native trees | 2 |
| Hollow-bearing trees | 2 |
| **NATIVE SPECIES** | **10** |
| Native canopy species | 3 |
| Native midstory species | 2 |
| Native herb/forb species | 2 |
| Native graminoid species | 2 |
| Native macrophyte species | 1 |
| **SPECIES COVER** | **17** |
| Canopy species | 4 |
| Midstory species | 4 |
| Herb/forb species | 4 |
| Graminoid species | 4 |
| Macrophyte species | 1 |
| **DEBRIS** | **14.5** |
| Total leaf litter | 3 |
| Native leaf litter | 2.5 |
| Dead trees standing | 2 |
| Dead trees fallen | 2 |
| Lying logs | 2 |
| Fringing vegetation | 3 |
| **MANAGEMENT** | **13.5** |
| Tree clearing | 2.5 |
| Fencing | 1 |
| Animal impact | 3 |
| Species of interest | 1 |
| Exposed tree roots | 4 |
| Native woody regeneration | 2 |
| Weedy woody regeneration | 0 |
| **TOTAL** | **70.7** |

*Newports Creek*

The riparian vegetation community at Newports Creek #3 (NEW3, Plate 3.26), can be described as 'Coast and Hinterland Riparian Flooded Gum – Bangalow Wet Forest', CH_WSF01 (OEH 2012b), or North Coast Wet Sclerophyll Forest (Keith 2004). NEW3 received a riparian condition score of 61% or C- (Table 3.53).

The dominant canopy species on-site were Camphor Laurel (*Cinnamomum camphora*), Flooded Gum (*Eucalyptus grandis*), Watergum (*Tristaniopsis laurina*), and Brush Box (*Losphostemon confertus*). The midstory was dominated by both Large- and Small-leaved Privet (*Ligustrum lucidum* and *L.sinense*), Lantana (*Lantana camara*), Sandpaper Fig (*Ficus coronata*), Cheese Tree (*Glochidion ferdinandi*), and Senna (*Senna pendula* var. *glabrata*). The understory was dominated by Native Wandering Jew (*Commelina cyanea*), Blue Billy Goat Weed (*Ageratum houstonianum*), Stinking Pennywort (*Hydrocotyle laxiflora*), Lomandra (*Lomandra hystrix*) and Paspalum (*Paspalum dilatatum*). Water Pepper (*Persicaria hydropiper*) and Small Pondweed (*Potamogeton ochtandrus*), were the macrophyte species present, while dominant vine species included Morning Glory (*Ipomoea indica*), Common Silkpod (*Parsonsia* sp.) and Kangaroo Vine (*Cissus antarctica*).

Three noxious weed species were observed on-site; Lantana (*Lantana camara*), and both Privet species, Large- and Small-leaved (*Ligustrum lucidum* and *L.sinense*) (all class 4 noxious weeds). Other weedy species present included Camphor Laurel (*Cinnamomum camphora*), Senna (*Senna pendula* var. *glabrata*), Coblers Pegs (*Bidens pilosa*), Blue Billy Goat Weed (*Ageratum houstonianum*), Umbrella Sedge (*Cyperus eragrostis*), and several grass species including Paspalum (*Paspalum dilatatum*), Prarie (*Bromus catcharticus*) and Purple Pigeon Grasses (*Setaria sphacelata*).

NEW3 scored 13/20 for HABITAT, with reduced scores for all indices except for the presence of large mature native trees and all structural layers. Riparian vegetation continuity scored well and hollow-bearing trees received half marks. A lack of depth in channel:vegetation width along with limited proximity to large undisturbed tracts of remnant vegetation reduced the site grades for this subindex. NATIVE SPECIES scored very poorly, 8/20. Native species had their greatest presence in the canopy and herb/forb layers (c.65%). Of the three species of macrophytes, one was a weed, while in the midstory and graminoid structural layers, weed species were prevelant (~60% and 50%). SPECIES COVER scored well with 17/20. This was attributed to maximum cover values in the Graminoid and herb/forb layers, while canopy, midstory and macrophytes all performed well with high cover percentages. DEBRIS received a score of 13/20. Maximum values were reported for lying logs, while total leaf litter and fringing vegetation scored well. However, at the site level, large woody debris in the form of standing and lying dead trees were lacking and the leaf litter present contained a high proportion of weedy species. MANAGEMENT received 10/20, with no maximum indicator values recorded, although fencing and animal impact were adjusted at the site level. Grades were reduced by the presence of noxious weeds, moderate levels of exposed tree roots, low levels of native woody regeneration and high levels of weedy woody regeneration, and site history in the form of vegetation stand age and disturbance.

***Plate 3.26*** *Riparian vegetation at Newports Creek #3 was in fair condition. While native species representative of the original vegetation community were present, they were outweighed at most structural levels by both noxious and environmental weed species. The strategic phasing out of Camphor Laurel, removal and monitoring of other weed species in addition to native plantings would improve riparian condition at this site.*

***Table 3.53*** *Site-level summary of riprian condition of Newports Creek #3, including subindices and indicators.*

| Newports Creek #3 | Scores |
|---|---|
| **HABITAT** | **13** |
| Channel width | 2 |
| Proximity | 1 |
| Continuity | 3 |
| Layers | 4 |
| Large native trees | 2 |
| Hollow-bearing trees | 1 |
| **NATIVE SPECIES** | **8** |
| Native canopy species | 2 |
| Native midstory species | 1.5 |
| Native herb/forb species | 2 |
| Native graminoid species | 1.5 |
| Native macrophyte species | 1 |
| **SPECIES COVER** | **17** |
| Canopy species | 3 |
| Midstory species | 3 |
| Herb/forb species | 4 |
| Graminoid species | 4 |
| Macrophyte species | 3 |
| **DEBRIS** | **13** |
| Total leaf litter | 3 |
| Native leaf litter | 2 |
| Dead trees standing | 0 |
| Dead trees fallen | 1 |
| Lying logs | 4 |
| Fringing vegetation | 3 |
| **MANAGEMENT** | **10** |
| Tree clearing | 2 |
| Fencing | 2 |
| Animal impact | 2 |
| Species of interest | 1 |
| Exposed tree roots | 2 |
| Native woody regeneration | 1 |
| Weedy woody regeneration | 0 |
| **TOTAL** | **61** |

### *3.9.5 Mangrove, seagrass and saltmarsh cover*

The Boambee/Newports Creek estuary contained the second highest total estuarine macrophyte cover of the 9 Coffs Harbour estuarine systems (Figure 3.25). The dominant vegetation community was mangroves (0.348km$^2$) with the Boambee/Newports Creek estuary containing the highest cover of this community in the Coffs Harbour estuaries. Saltmarsh was present as a co-dominant community (0.105km$^2$). While seagrass was also present in the estuary at lower cover (0.042km$^2$), the Boambee/Newports Creek estuary represented the largest seagrass cover of all the 9 Coffs Harbour estuarine systems (Table 3.54). Thus, management priorities in this system should focus on maintaining the current estuarine macrophyte cover.

Total estuarine macrophyte cover in the Boambee/Newports Creek estuary increased from 0.420km$^2$ in 1985 to 0.496km$^2$ in 2011 (Table 3.54). This was driven by increases in mangroves and particularly saltmarsh (0.029 and 0.105km$^2$ in 1985 and 2011, respectively). In contrast, seagrass cover decreased from 0.060km$^2$ in 1985 to 0.042km$^2$ in 2011 (Table 3.54).

***Table 3.54*** *Total area covered by mangrove, seagrass or saltmarsh in the Boambee/Newports Creeks estuary in 2011 and 1985, and mean patch size of each vegetation community in 2011.*

| Vegetation community | Total area in 1985 (km$^2$) | Total area in 2011 (km$^2$) | Total area in 2011 (m$^2$) | Mean patch size in 2011 (m$^2$) |
|---|---|---|---|---|
| Mangrove | 0.331 | 0.348 | 348,389 | 1,044 |
| Mangrove/Saltmarsh | - | 0 | 0 | 0 |
| Saltmarsh | 0.029 | 0.105 | 104,980 | 4,772 |
| Seagrass (*Zostera*) - total | 0.060 | 0.042 | 42,132 | 726 |
| Dense *Zostera* | - | 0.042 | 42,132 | 726 |
| Sparse *Zostera* | - | 0 | 0 | 0 |
| Estuary total | 0.420 | 0.496 | 495,664 | |

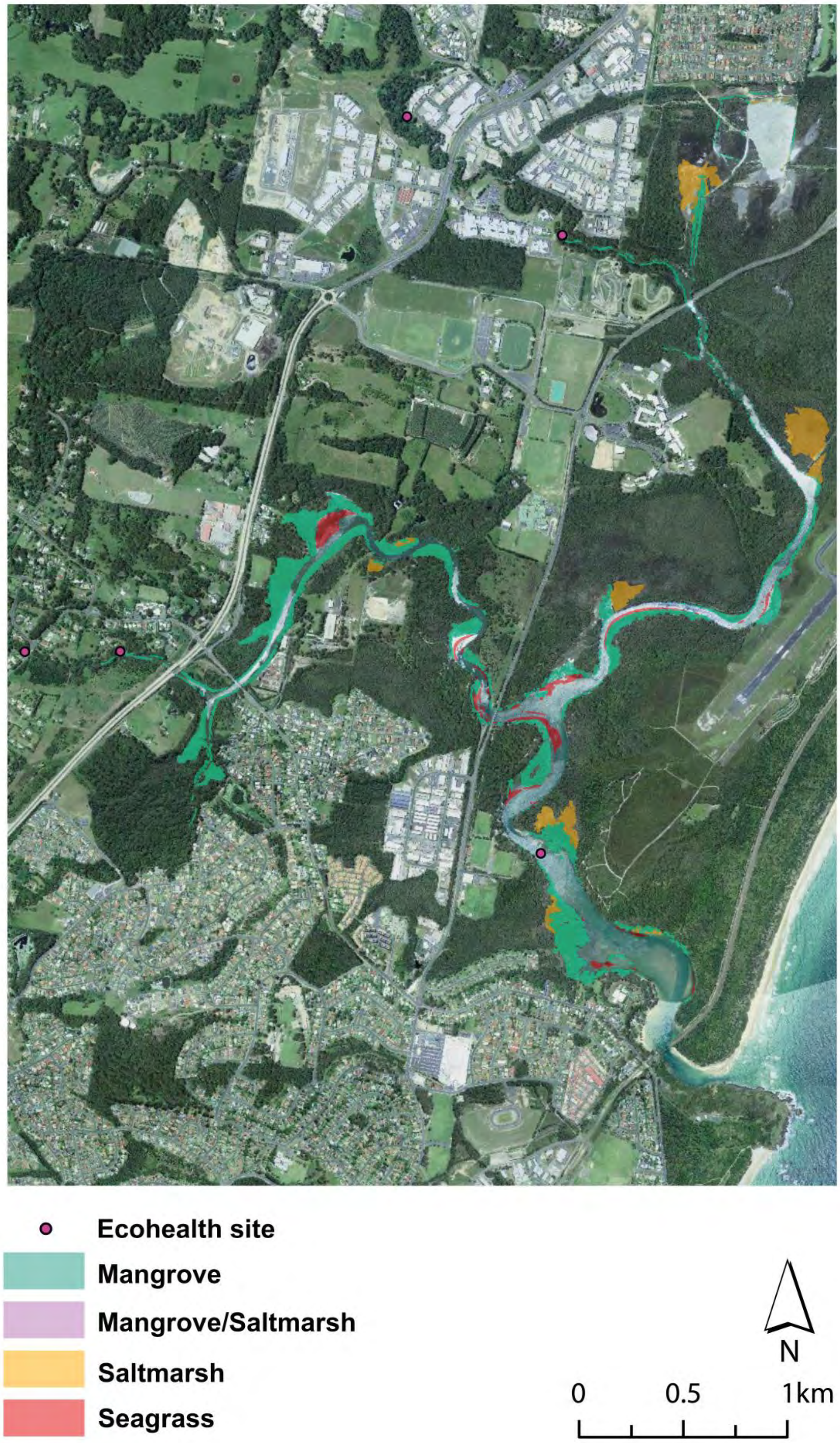



***Figure 3.25*** *Mangrove, seagrass and saltmarsh habitats in the Boambee/Newports Creeks estuary (NSW Department of Industry and Investment – Primary Industries and Energy 2011).*

### *3.9.6 Water quality*

The subcatchment of Boambee and Newports Creeks received a score of 68, a grade of C, for water quality. Boambe Creek received a score of 71 (C+) for water quality, with the best water quality recorded at the freshwater site BOAM4 (B), and the poorest water quality recorded at the tidal limit (BOAM3, D). Newports Creek received a score of 64 (C-) for water quality, with the freshwater site NEW3 (B) having better water quality than the tidal limit (NEW2, D-).

Water temperatures at all sites reflected seasonal climatic fluctuations (Figure 3.26). Water temperature ranged from a winter minimum of 15.3°C at BOAM4 to a summer maximum of 27°C at BOAM3 (Table 3.55). A similar pattern was observed in Newports Creek, with winter minimum water temperatures lowest at the freshwater site (14.6°C at NEW3) and summer maximum temperatures highest at the tidal limit (27.3°C at NEW2, Table 3.56).

DO% in Boambee Creek ranged from 58.0% in BOAM4 to 170% at BOAM 1 (Table 3.55). At BOAM1, DO% consistently exceeded the estuarine maximum trigger threshold (9 exceedances), only falling within guideline thresholds in July 2015 (Table 3.57). At BOAM3, DO% exceeded the maximum estuarine trigger threshold once (May 2015), and fell below the minimum estuarine trigger threshold on 3 occasions (July, August and December 2015, Table 3.57). At BOAM4, DO% exceeded the maximum freshwater trigger threshold 4 times (September and December 2014, and May and July 2015), and fell below the minimum freshwater trigger threshold once (October 2015) with a very low 58% satuaration (Table 3.57).

DO% in Newports Creek ranged from 42% at NEW3 to 143.3%, also at NEW3 (Table 3.56). DO% at NEW2 fell below the minimum estuarine trigger threshold twice (April and August 2015) and exceeded the maximum estuarine trigger threshold on 3 other occasions (March, July and October 2015, Table 3.57). DO% at NEW3 fell below the freshwater trigger threshold on 3 occasions (March, October and December 2015), and exceeded the maximum freshwater trigger threshold twice (May and July 2015, Table 3.57).

pH in Boambee Creek ranged from 6.5 – 7.6 (Table 3.55). At BOAM1, pH was below the minimum estuarine trigger threshold on 3 occasions (May, August and December 2015, Table 3.57). Similarly, BOAM3 consistently recorded pH below the minimum estuarine trigger thresholds (5 occasions, Table 3.57). pH at BOAM4 remained within freshwater guideline thresholds for the duration of the project (Table 3.57). pH ranged from 5.4 to 8.6 in Newports Creek (Table 3.56), and remained below the minimum estuarine trigger threshold at NEW2 on all sampling occasions (Table 3.57). At NEW3, pH exceeded the maximum freshwater trigger threshold once (May 2015, Table 3.57).

Turbidity ranged from 0.3 – 18.0NTU in Boambee Creek (Table 3.55) and remained below the guideline threshold in the lower estuary (BOAM1) and freshwater site (BOAM4). The tidal limit (BOAM3) exceeded the estuarine trigger threshold once, in December 2015 (Table 3.57). In Newports Creek, turbidity ranged from 1.7 – 13.8NTU (Table 3.56). Turbidity at the tidal limit (NEW2) exceeded the estuarine trigger threshold on 3 occasions (November 2014, and October and December 2015, Table 3.57).

Chl-*a* ranged from 2.0 to 15.0µg/L in Boambee Creek (Table 3.55), and remained below the guideline threshold in the lower estuary (BOAM1) and freshwater site (BOAM4). Chl-*a* at BOAM3 exceeded the estuarine trigger threshold on 4 occasions (November 2014, and March, August and October 2015, Table 3.57). The highest exceedance of 15µg/L (March 2015) was almost 3x the estuarine trigger threshold. Chl-*a* ranged from 3.0 – 14.0µg/L in Newports Creek (Table 3.56). At NEW2, chl-*a* exceeded the estuarine trigger threshold on 4 occasions (March, April, July and October 2015, Table 3.57). The highest exceedance (14µg/L) in March 2015 was 3x the estuarine trigger threshold. At NEW3, chl-*a* exceeded the freshwater trigger threshold twice (December 2014 and August 2015); the exceedance in December was 3x the freshwater trigger threshold (Table 3.57).

TN ranged from 0.2-0.7mg/L in Boambee Creek (Table 3.55). Concentrations in the lower estuary (BOAM1) remained within the guideline threshold, but exceeded the estuarine trigger threshold at the tidal limit (BOAM3) on all sampling occasions (Table 3.57). At BOAM4, TN exceeded the freshwater trigger threshold on 3 occasions (May, July and August, 2015, Table 3.57). TN ranged from 0.3-0.5mg/L in Newports Creek (Table 3.56). TN consistently exceeded estuarine trigger thresholds at NEW2, falling below the threshold only once (August 2015, Table 3.57). In contrast, the only time TN exceeded the freshwater trigger threshold at NEW3 was in December 2014 (Table 3.57). TP was consistently below detection limits in Boambee and Newports Creeks. Maximums of 0.5mg/L were observed in the freshwater BOAM4 and NEW3, but these were within the freshwater trigger threshold (Table 3.57).

Faecal coliforms were collected from BOAM1 8 times through the sampling period. The estuarine trigger threshold for primary contact (150fc/100mL) was never exceeded with the maximum coliform count of 40fc/100mL recorded in December 2015 (Table 3.55).

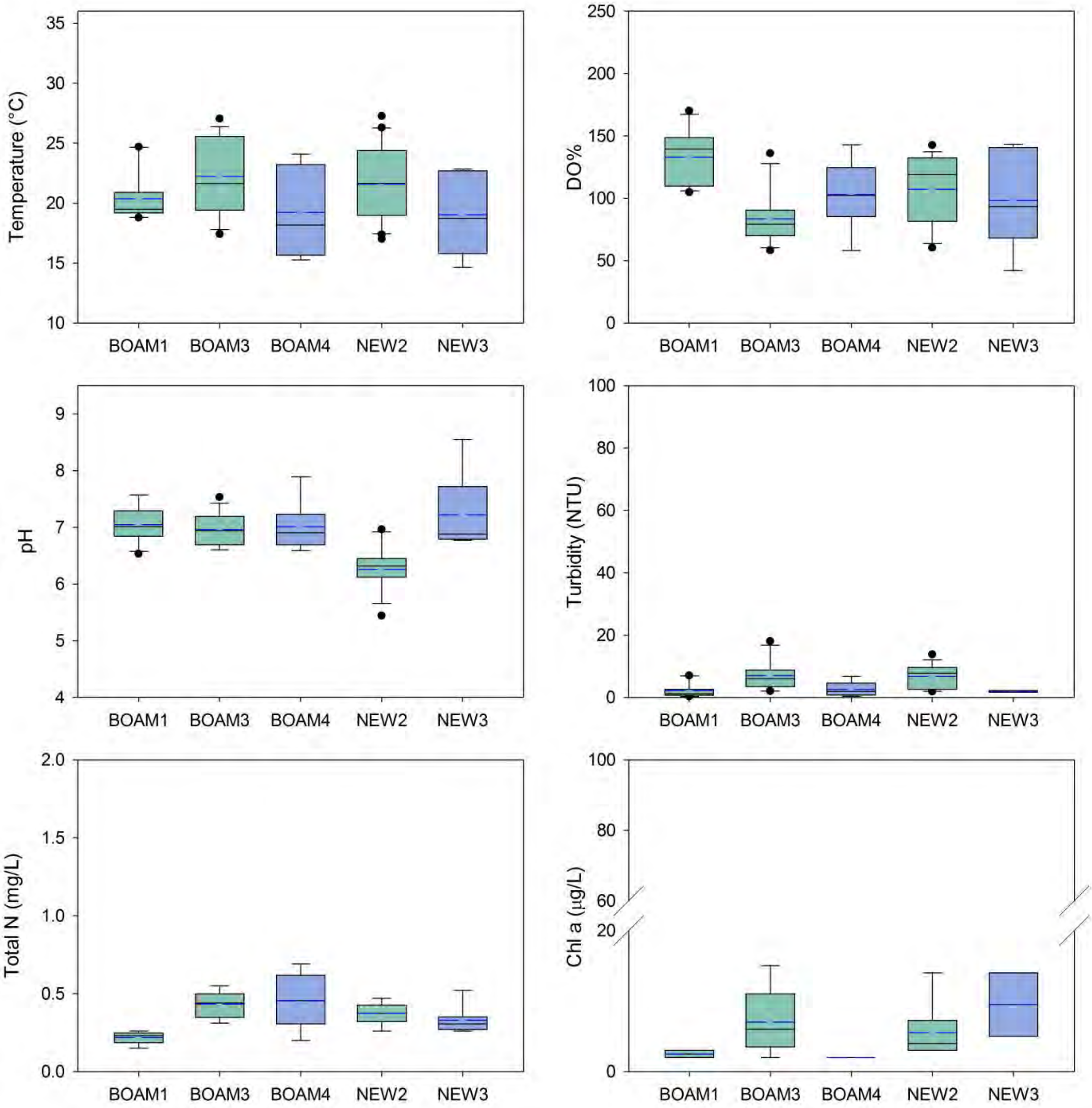



***Figure 3.26*** *Mean (blue line), median (black line), 25th and 75th percentiles, and range of water quality variables in the Boambee and Newports Creeks subcatchment over 2015. Outliers are represented by black dots. Green and blue boxes represent estuary and freshwater sites, respectively.*

***Table 3.55*** *Minimums, maximums and means of measured water quality variables for the three sites on Boambee Creek.*

| | BOAM1 | | | BOAM3 | | | BOAM4 | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **Min** | **Max** | **Mean** | **Min** | **Max** | **Mean** | **Min** | **Max** | **Mean** |
| **Temperature** | 18.8 | 24.7 | 20.3 | 17.4 | 27.0 | 22.2 | 15.3 | 24.1 | 19.2 |
| **pH** | 6.5 | 7.6 | 7.0 | 6.6 | 7.5 | 7.0 | 6.6 | 7.9 | 7.0 |
| **EC** | 19.1 | 55.7 | 45.7 | 0.0 | 48.6 | 27.1 | 0.1 | 5.9 | 1.0 |
| **Salinity (PPT)** | 30.4 | 43.1 | 36.9 | 6.8 | 38.4 | 26.1 | 0.1 | 0.1 | 0.1 |
| **DO (mg/L)** | 7.6 | 15.2 | 10.7 | 4.4 | 18.1 | 8.1 | 5.4 | 14.3 | 9.5 |
| **DO %** | 104.8 | 170.0 | 132.1 | 58.3 | 136.0 | 83.5 | 58.0 | 142.9 | 102.9 |
| **Turbidity** | 0.3 | 7.0 | 2.3 | 2.0 | 18.0 | 7.0 | 0.4 | 6.8 | 2.6 |
| **Max Depth** | 1.0 | 2.0 | 1.5 | 1.1 | 1.8 | 1.3 | 0.2 | 0.3 | 0.3 |
| **Chla (µg/L)** | 2.0 | 3.0 | 2.5 | 2.0 | 15.0 | 7.0 | 2.0 | 2.0 | 2.0 |
| **TSS (mg/L)** | 2.0 | 25.0 | 12.0 | 3.0 | 22.0 | 8.9 | 2.0 | 6.0 | 4.2 |
| **TN (mg/L)** | 0.2 | 0.3 | 0.2 | 0.3 | 0.6 | 0.4 | 0.2 | 0.7 | 0.5 |
| **TP (mg/L)** | <0.03 | <0.03 | <0.03 | <0.03 | 0.03 | <0.03 | <0.03 | 0.05 | <0.03 |
| **Coliforms (cells/100mL)** | 4 | 40 | 18 | | | | | | |

***Table 3.56*** *Minimums, maximums and means of measured water quality variables for the two sites on Newports Creek.*

| | NEW2 | | | NEW3 | | |
|---|---|---|---|---|---|---|
| **Variable** | **Min** | **Max** | **Mean** | **Min** | **Max** | **Mean** |
| **Temperature** | 17.0 | 27.3 | 21.6 | 14.6 | 22.8 | 19.0 |
| **pH** | 5.4 | 7.0 | 6.3 | 6.8 | 8.6 | 7.2 |
| **EC** | 11.5 | 52.4 | 32.5 | 0.1 | 0.2 | 0.1 |
| **Salinity (PPT)** | 11.3 | 38.1 | 26.8 | 0.1 | 0.1 | 0.1 |
| **DO (mg/L)** | 4.6 | 14.3 | 8.9 | 3.9 | 14.5 | 9.8 |
| **DO %** | 60.3 | 142.6 | 107.2 | 42.0 | 143.3 | 98.2 |
| **Turbidity** | 1.9 | 13.8 | 6.8 | 1.7 | 2.2 | 1.9 |
| **Max Depth** | 1.1 | 2.7 | 2.0 | 0.1 | 0.8 | 0.4 |
| **Chla (µg/L)** | 3.0 | 14.0 | 5.5 | 5.0 | 14.0 | 9.5 |
| **TSS (mg/L)** | 2.0 | 21.0 | 9.3 | 2.0 | 11.0 | 4.9 |
| **TN (mg/L)** | 0.3 | 0.5 | 0.4 | 0.3 | 0.5 | 0.3 |
| **TP (mg/L)** | <0.03 | <0.03 | <0.03 | <0.03 | 0.05 | <0.03 |
| **Coliforms (cells/100mL)** | | | | | | |

***Table 3.57*** *Exceedances[1] observed in Boambee and Newports Creeks for pH, conductivity (EC), percent saturated dissolved oxygen (DO), turbidity, chlorophyll a (Chl-a), total nitrogen (TN) and total phosphorus (TP), and the site-level WQ grades.*

| Site | pH | EC | DO % | Turbidity | Chl-a | TN | TP | WQ grade |
|---|---|---|---|---|---|---|---|---|
| BOAM1 | 6(40%) 6,0 | NA | 9(82%) 0,9 | 0 | 0 | 0 | 0 | B |
| BOAM3 | 9(60%) 9,0 | NA | 7(64%) 6,1 | 2(18%) | 4(50%) | 8(100%) | 0 | D |
| BOAM4 | 0 | 2(25%) 1,1 | 5(63%)1,4 | 0 | 0 | 3(38%) | 0 | B |
| NEW2 | 20(100%) 20,0 | NA | 12(75%) 3,9 | 3(17%) | 4(50%) | 7(88%) | 0 | D- |
| NEW3 | 1(14%) 0,1 | 1(14%) 1,0 | 5(75%) 3,2 | 0 | 2(25%) | 1(13%) | 0 | B |

*[1] Numbers in black represent the total number and percent of exceedances. Numbers in blue and red represent the numbers of measurements lower than the minimum threshold and higher than the maximum threshold, respectively. The number of exceedances includes all depths sampled so may be greater than the number of times sampled. Turbidity, chlorophyll a, and total nutrients only have maximum trigger thresholds.*

### *3.9.7 Aquatic macroinvertebrates*

#### *Boambee Creek*

Boambee Creek #4 (BOAM4) recorded 24 and 20 families during the 2015 autumn and spring, respectively (Table 3.58). In autumn, Coleoptera (Aquatic Beetles) were the most diverse group with 5 families (93 individuals), followed by Trichoptera (Caddisflies) with 3 families (20 individuals). In spring, Trichoptera was the most diverse group with 5 families (16 individuals). Total abundances at BOAM4 were also high relative to the Coffs coastal catchments, with over 300 individuals recorded in both sampling periods (Table 3.58). In autumn, Atyidae (Freshwater Shrimp) were the most abundant taxa (110 individuals), followed by Elmid Beetles (87 individuals). Abundances were spread more evenly across several taxa in spring: there were 105 Freshwater Snails, 89 Water Slaters (Sphaeromatidae) and 68 Freshwater Shrimps. There were 12 rare taxa at the site (recording fewer than 5 individuals) in autumn and spring.

EPT richness and abundance were also above the catchment average (Table 3.58). BOAM4 was one of the 2 sites that recorded all three EPT Orders. In autumn, there were 6 Baetid Mayflies (Ephemeroptera, SIGNAL2 of 5), 4 Gripopterygid Stoneflies (Plecoptera, SIGNAL2 of 8) and 20 Caddisflies (Trichoptera, SIGNAL2 of 4-7). In spring, BOAM4 had 1 Leptophlebid Mayfly (SIGNAL2 of 8) and 16 Caddisflies (SIGNAL2 of 4-8).

The mean SIGNAL2 score for BOAM4 was 4.6 in autumn, dropping to 3.5 in spring 2015 (Table 3.58). The primary cause for the decrease in SIGNAL2 score between autumn and spring was the high number of Water Slaters (SIGNAL2 of 1) recorded in spring.

Boambee Creek #4 (BOAM4) received an overall Ecohealth score of 52, a grade of D, for aquatic macroinvertebrate communities. This suggests the water quality and habitat conditions in the freshwater reaches of Boambee Creek are in poor condition. All four macroinvertebrate indicators were slightly above the means calculated for the Coffs coastal catchments in 2015 (Table 3.6).

***Table 3.58*** *Summary of aquatic macroinvertebrate data for Boambee Creek #4 (BOAM4).*

| BOAM4 | | | | |
|---|---|---|---|---|
| **Macroinvertebrate indicator** | **Autumn 2015** | **Spring 2015** | **Autumn 2011** | **Spring 2011** |
| Family richness | 24 | 20 | 19 | 10 |
| Total abundance | 322 | 379 | 120 | 77 |
| EPT richness | 5 | 6 | 6 | 6 |
| EPT abundance | 30 | 17 | 15 | 15 |
| Mean SIGNAL2 score | 4.6 | 3.5 | 4.8 | 4.6 |
| SIGNAL2 score range | 1 - 8 | 1 - 8 | 2 - 8 | 2 - 8 |
| Ecohealth score (grade) | **52 (D)** | | **60(C-)** | |

*Newports Creek*

Newports Creek #3 (NEW3) recorded relatively low family richness with 15 and 8 families during the 2015 autumn and spring, respectively (Table 3.59). No one group dominated family richness: the most diverse Order was Coleoptera (Aquatic Beetles) with 3 families. Total abundances were also relatively low, with Baetid Mayflies (16) and Freshwater Shrimps (12) the dominant families in autumn, and Chironomidae Midge Larvae (11) the dominant family in spring. There were several rare taxa with 10 and 6 families comprising fewer than 5 individuals in autumn and spring, respectively.

EPT richness was low with 2 Ephemeropteran families recorded in both sampling periods (Table 3.59). The greater abundance recorded in autumn was dominated by Baetid Mayflies (16). Mean SIGNAL2 scores were consistent between seasons with scores of 3.8 and 3.7 in autumn and spring, respectively. However, this was despite different ranges in SIGNAL2 scores. In autumn, SIGNAL2 ranged from 1 – 6, while in spring SIGNAL2 ranged from 3 – 8.

Newports Creek #3 (NEW3) received an overall Ecohealth score of 14, a grade of F, for aquatic macroinvertebrate communities. This suggests the water quality and habitat conditions in the freshwater reaches of Newports Creek are in very poor condition. Three of the four macroinvertebrate indicators were substantially below the means calculated for the Coffs coastal catchments in 2015: family richness, EPT richness and abundance, and total abundance (Table 3.6).

***Table 3.59*** *Summary of aquatic macroinvertebrate data for Newports Creek #3 (NEW3).*

| NEW3 | | | | |
|---|---|---|---|---|
| **Macroinvertebrate indicator** | **Autumn 2015** | **Spring 2015** | **Autumn 2011** | **Spring 2011** |
| Family richness | 15 | 8 | 7 | 5 |
| Total abundance | 69 | 21 | 41 | 42 |
| EPT richness | 2 | 2 | 2 | 1 |
| EPT abundance | 17 | 2 | 10 | 1 |
| Mean SIGNAL2 score | 3.8 | 3.7 | 4.0 | 4.6 |
| SIGNAL2 score range | 1 - 6 | 3 - 8 | 2 - 7 | 2 - 7 |
| Ecohealth score (grade) | **14 (F)** | | **21 (F)** | |

## 3.10 Bonville/Pine Creeks

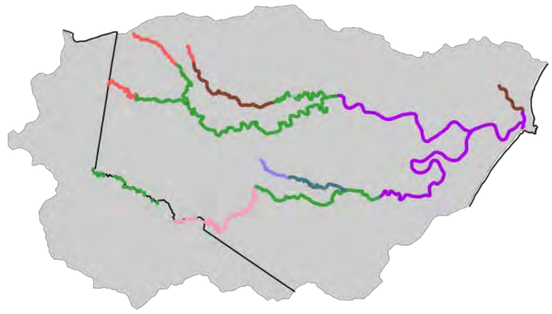
### *3.10.1 Catchment description*

The Bonville-Pine Creek estuary is situated south of Sawtell, approximately 9km south of Coffs Harbour. The estuary drains a catchment area approximately 115km$^2$ (Table 3.60), extending more than 15km inland from the coast. The headwaters of Bonville and Pine Creeks are in escarpment ranges, rising to Tuckers Nob with an elevation of 920m above sea level (Figure 3.27a). These escarpment ranges form extremely steep terrain with slopes exceeding 30%, and headwaters drain confined valleys lacking floodplains (Figure 3.27b). The ranges give way to steep midland hills (Figure 3.27a), with upper reaches draining confined valleys with significant bedrock outcropping (Table 3.60). In the north, the ranges and midland hills are underlain by Moombil Siltstone (11% subcatchment area) of the Coffs Harbour association metasediments, consisting of siliceous mudstones, siltstones and greywacke. In the south, Glenifer Monzogranite forms the escarpment ranges, with the midland hills and mid coastal plain underlain by the Nambucca Beds metasediments dominated by slates (49% of subcatchment area). The metasediments form strongly acidic soils with moderately low to low chemical fertility (Milford 1999). Dermosols occur along the upper and mid reaches of Boambee and Pine Creeks and are characterized by deep, well-drained acidic soils (Figure 3.27d). The coastal plain is predominantly alluvial sediments (35%, Table 3.60).

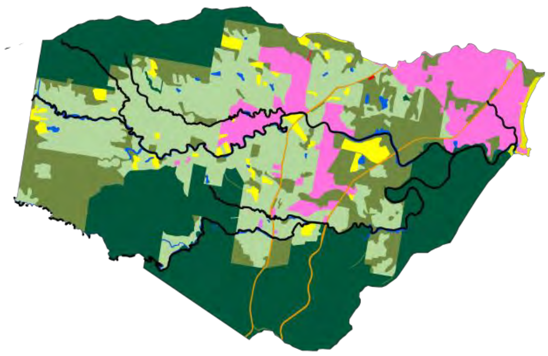
The northern section of the upper reaches of Bonville Creek lie within Tuckers Nob State Forest (Figure 3.27c). Bonville Creek flows southeasterly through predominantly grazed agricultural land. Pine Creek also drains the lower slopes of the Tuckers Nob State Forest, then meanders through pine plantations 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 estuary opens to the ocean to the south of Sawtell Headland. The entrance is shallow and untrained but generally remains open. Most of the lower reaches of the estuary are within Bongil Bongil National Park, which has an area of 978ha, and extends to the south of the estuary and along the coastal fringe (Patterson-Britton 2003).

Urban development (9% area) is concentrated on the township of Sawtell, and extends 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 potentially threatens 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 landuse has seen an increase in clearing and conversion of the land for grazing and modified hydrology through floodplain drainage (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.

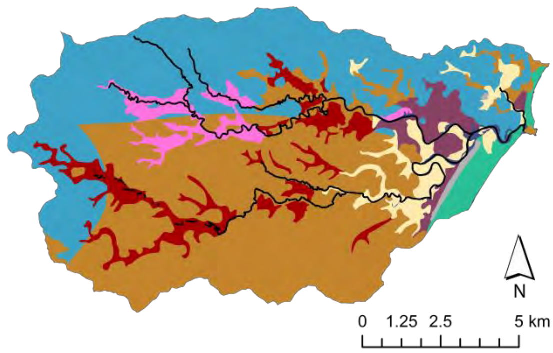

**(a)** Topography and location of Ecohealth sites.



**(b)** River Styles: refer to Figure 2.8 for key.



**(c)** Landuse: refer to Figure 2.7 For key.




**(d)** Soils: refer to Figure 2.3 For key.

***Figure 3.27*** *The Bonville/Pine Creeks subcatchment showing (a) locations of Ecohealth sites and catchment topography, (b) River Styles, (c) landuse, and (d) soils. Data layers from CHCC (site locations), ESRI (topography), NC LLS (River Styles) and OEH (landuse and soils).*

***Table 3.60*** *Subcatchment description of Bonville/Pine Creeks. Data from NC LLS and OEH.*

| Variable | Subcatchment composition |
|---|---|
| Area (km$^2$) | 115 |
| Geology | 49% Slate; 35% Alluvial Sediment; 11% Siltstone |
| Soils | 43% Kurosols; 34% Kandosols; 7% Dermosols; 5% Hydrosols; 9% other; 1% water |
| River Styles | 40% PCVS - Planform controlled, meandering, fine grained; 29% LUV CC – Tidal; 9% PCVS - Planform controlled, low sinuosity, fine grained; 8% PCVS - Bedrock controlled, gravel; 7% CVS – Headwater; 6% mixed other. |
| Landuse | 33% Forestry; 27% Grazing; 15% Residual Native Cover; 7% National Park; 5% Urban; 4% Rural Residential; 4% Services; 2% River; 2% Horticulture; 1% Transport |
| Major point source discharge | Nil |
| Tree Cover | 35% |

### *3.10.2 Site descriptions*

Three sites on Bonville Creek were sampled in 2015 (Figure 3.27a). The most downstream site was BONV1 in the lower estuary downstream of the confluence with Pine Creek (Plate 3.27). The site was in the marine influence zone (salinity +30ppt) and the channel is defined as laterally unconfined tidal. The site BONV3 is at the tidal limit in Bonville Creek and the surrounding channel is defined as laterally unconfined tidal. The most upstream site, BONV4 (Plate 3.28), was located in the freshwater reaches of Bonville Creek, and the channel was defined as planform controlled, meandering, fine grained.

Two sites were monitored on Pine Creek in 2015. The most downstream site was PINE2, located at the tidal limit in Pine Creek. The channel is defined as planform controlled, meandering, fine grained. The most upstream site on Pine Creek was PINE3, located on the freshwater reaches (Plate 3.29). The channel surrounding PINE3 is also defined as planform controlled, meandering, fine grained.

***Plate 3.27*** *The site BONV1 was near the mouth of the Bonville Creek estuary.*

***Plate 3.28*** *The site BONV4 was in the freshwater reaches of Bonville Creek.*

***Plate 3.29*** *The site PINE3 was in the tidal limit of Pine Creek.*

### *3.10.3 Geomorphic condition*

The River Style at BONV4 is classified as partially confined valley setting: planform controlled, meandering, fine grained (Figure 3.27b). However, bed sediments at the site comprised sub-angular gravelly pebbles in a framework dilated matrix (containing 32-60% fine sediments, i.e. sands and silts). Several small attached gravel bars comprised approximately 10% of the channel width. Some of these gravel bars were well vegetated with gramminoids and herbs, while most were unvegetated. Large woody debris primarily consisted of single large trees partially submerged in the low flow channel. There was significant active erosion of both banks at BONV4, associated with severe undercutting on the left bank (20-100m combined length) on the outside of a bend at the downstream end of the site (Plate 3.28). Undercutting on the right bank (also severe at 20-100m combined length) was associated with bridge scour at the upstream end of the reach. There was no evidence of stock access on the left bank, but the right bank was unfenced and showed recent signs of stock impacts. BONV4 scored 57.8, a grade of D+, for BANK CONDITION and 68, a grade of C, for BED CONDITION. The overall Ecohealth geomorphic condition for BONV4 was 63, a grade of C-.

The River Style at PINE3 is defined as partially confined valley setting: planform controlled, meandering, fine grained. The bed and bank sediments were fine grained, with no cobbles, pebbles or gravel present. There was moderate active erosion at this site: bank undercutting was moderate (5-10m combined length) on each bank and was associated with bridge scour. Bank slumping was also moderate on both banks with 5-10m combined length of slumping on each bank. At the downstream end of the survey reach, the site was unfenced and there was severe pugging/trampling by stock. PINE3 scored 61.2, a grade of C- for BANK CONDITION and 68, a grade of C for BED CONDITION. The overall Ecohealth geomorphic condition for PINE3 was 65, a grade of C-.

In summary, BONV4 was assessed as being in moderate geomorphic condition, with bank erosion the most significant issue for site-level geomorphic condition. Fencing the riparian zone on the right bank to exclude stock and revegetating the streambanks with native vegetation would assist to improve geomorphic condition at this site. The left bank is well vegetated and erosion of outside bends is a natural process in the evolution of planform controlled streams. However, this site of active erosion will contribute fine-grained sediments that may smother downstream aquatic habitat.

PINE3 was also assessed as being in moderate geomorphic condition, with bank erosion the most significant issue for site-level geomorphic condition. Fencing the riparian zone at the upstream half of the study reach would reduce stock access and trampling of banks. Revegetating these banks with native vegetation will also significantly improve the geomorphic condition of this site. The desktop GIS assessment of subcatchment geomorphic condition found the Bonville/Pine Creeks subcatchment to be in moderate condition with a grade of C. Site level assessments of both BONV4 and PINE3 were assessed as being slightly below the subcatchment average for geomorphic condition.

### *3.10.4 Riparian condition*

*Bonville Creek*

The riparian vegetation community at Bonville Creek #4 (BONV4, Plate 3.30), can be described as 'Coast and Hinterland Riparian Flooded Gum – Bangalow Wet Forest', CH_WSF01 (OEH 2012b), or North Coast Wet Sclerophyll Forest (Keith 2004), and received a riparian condition score of 66.2% or C (Table 3.61).

The dominant canopy species on-site were Flooded Gum (*Eucalyptus grandis*), Bangalow palm (*Archontophoenix cunninghamiana*), Watergum (*Tristaniopsis laurina*), Coachwood (*Ceratopetalum apetalum*), and Brush Box (*Losphostemon confertus*). The midstory was dominated by Black Wattle (*Callicoma serratifolia*), Elderberry (*Cuttsia viburnea*), Sandpaper Fig (*Ficus coronata*), Narrow-leaved Palm Lily (*Cordyline stricta*), Lantana (*Lantana camara*) and Large-leaved Privet (*Ligustrum lucidum*). The understory was dominated by Lomandra (*Lomandra longifolia*), Blue Billy Goat Weed (*Ageratum houstonianum*), Crofton Weed (*Ageratina adenophora*), Five-finger Maidenhair (*Adiantum hispidulum*), Common Rush (*Juncus usitatus*), Creeping Beard Grass (*Oplismenus imbecillis*) and Paspalum (*Paspalum dilatatum*). The three macrophyte species present were Spotted Knotweed (*Persicaria strigosa*), Jointed Twig Rush (*Baumea articulate*), and Swamp Club Rush (*Isolepis inundata*). Common Silkpod (*Parsonsia* sp.), and Kangaroo Vine (*Cissus antarctica*) were the only vine species recorded on-site.

Three noxious weed species were observed on-site: Lantana (*Lantana camara* - class 4), Large-leaved Privet (*Ligustrum lucidum* – class 4), and Fireweed (*Senecio madagascariensis* - class 4). Other weedy species present on-site included Mickey Mouse Plant (*Ochna serrulata*), Crofton Weed (*Ageratina adenophora*), False Papyrus (*Cyperus involucratus*), Blue Billy Goat Weed (*Ageratum houstonianum*), Cobblers Pegs (*Bidens pilosa*) and the grass, Paspalum (*Paspalum dilatatum*).

BONV4 scored 15.7/20 for HABITAT, receiving full marks for the indicators large mature native trees, hollow-bearing trees and for the presence of all four structural layers. Riparian vegetation continuity scored well as did depth ratio of channel:vegetation width. Marks were lost for poor proximity to large undisturbed tracts of remnant vegetation. NATIVE SPECIES scored 13.5/20, with the canopy layer scoring maximum points. Graminoides and macrophytes scored highly with proportion of native species (c.85%), the midstory scored moderately (c.75%), and the herb/forb layer poorly (<30%). SPECIES COVER scored fairly with 15/20, with maximum cover values in the midstory, graminoids and herb/forb structural layers. Canopy scored half marks while macrophyte cover was low. DEBRIS received a score of 13/20 with total leaf litter the only indicator receiving full marks. Native leaf litter, dead trees standing and fringing vegetation all performed well, while there appeared to be a lack of small and large woody debris in the form of lying logs and fallen dead trees. MANAGEMENT received 9/20, with native woody regeneration the only indicator receiving full marks. The tree clearing indicator received fair scores due to the on-site ratio of mature trees:regrowth:cleared. Weedy woody regeneration was present, with moderate rates of root exposure of woody vegetation on-site. The absence of fencing, visible animal impact and the presence of noxious weeds negatively impacted on riparian condition.

***Plate 3.30*** *Riparian vegetation at Bonville Creek #4 was in fair condition. While remnant elements representative of the original vegetation community were present in all structural layers, noxious and environmental weeds in addition to unfenced sections of riparian vegetation reduced the final score.*

***Table 3.61*** *Site-level summary of riprian condition of Bonville Creek #4, including subindices and indicators.*

| Bonville Creek #4 | Scores |
|---|---|
| **HABITAT** | **15.7** |
| Channel width | 2.7 |
| Proximity | 2 |
| Continuity | 3 |
| Layers | 4 |
| Large native trees | 2 |
| Hollow-bearing trees | 2 |
| **NATIVE SPECIES** | **13.5** |
| Native canopy species | 4 |
| Native midstory species | 2.5 |
| Native herb/forb species | 1 |
| Native graminoid species | 3 |
| Native macrophyte species | 3 |
| **SPECIES COVER** | **15** |
| Canopy species | 2 |
| Midstory species | 4 |
| Herb/forb species | 4 |
| Graminoid species | 4 |
| Macrophyte species | 1 |
| **DEBRIS** | **13** |
| Total leaf litter | 3 |
| Native leaf litter | 2 |
| Dead trees standing | 2 |
| Dead trees fallen | 1 |
| Lying logs | 2 |
| Fringing vegetation | 3 |
| **MANAGEMENT** | **9** |
| Tree clearing | 3 |
| Fencing | 0 |
| Animal impact | 0 |
| Species of interest | 1 |
| Exposed tree roots | 2 |
| Native woody regeneration | 2 |
| Weedy woody regeneration | 1 |
| **TOTAL** | **66.2** |

### *Pine Creek*

The riparian vegetation community at Pine Creek #3 (PINE3, Plate 3.31), can be described as 'Coast and Hinterland Riparian Flooded Gum – Bangalow Wet Forest', CH_WSF01 (OEH 2012b) or North Coast Wet Sclerophyll Forest, (Keith 2004), and received a riparian condition score of 70.7% or C+ (Table 3.62).

The dominant canopy species on-site were Flooded Gum (*Eucalyptus grandis*), Broad-leaved Paperbark (*Melaleuca quinquenervia*), Watergum (*Tristaniopsis laurina*), Red Bloodwood (*Corymbia gummifera*), Swamp Oak (*Casuarina glauca*) and Brush Box (*Losphostemon confertus*). The midstory was dominated by Black Wattle (*Callicoma serratifolia*), Green Wattle (*Acacia irrorata*), Cheese Tree (*Glochidion ferdinandi*), Sandpaper Fig (*Ficus coronata*), Willow Bottlebrush (*Callistemon salignus*) and Lantana (*Lantana camara*). The understory was dominated by Blue Billy Goat Weed (*Ageratum houstonianum*), Purple Pigeon Grass (*Setaria sphacelata*), Paspalum (*Paspalum dilatatum*), Tassel Sedge (*Carex fascicularis*) and Lomandra species (*L.hystrix*, and *L.longifolia*). Macrophyte diversity at this site was very high, with the dominant species being Spotted Knotweed (*Persicaria strigosa*), Water Snowflake (*Nymphoides indica*) and Water ribbons (*Triglochin procera*). The two vine species recorded on-site were Common Silkpod (*Parsonsia* sp.) and Native raspberry (*Rubus parvifolius*).

Two noxious weed species were observed on-site: Lantana (*Lantana camara* - class 4) and Cabomba (*Cabomba caroliniana* – class 5). Other weedy species present on-site included Senna (*S. septemtrionalis*), Crofton Weed (*Ageratina adenophora*), Blue Billy Goat Weed (*Ageratum houstonianum*), Wandering Jew (*Tradescantia fluminensis*), Sidratusa (*Sida rhombifolia*), Green-leaved Desmodium (*Desmodium intortum*), and the grass species Paspalum (*Paspalum dilatatum*), Purple Pigeon Grasses (*Setaria sphacelata*) and Whisky Grass (*Andropogon virginicus*).

PINE3 scored 15.7/20 for HABITAT, receiving full marks for the indicator large mature native trees, hollow-bearing trees and the presence of all structural layers. Riparian vegetation continuity scored well as did proximity to large undisturbed tracts of remnant vegetation. A lack of depth in channel:vegetation width ratio reduced the score. NATIVE SPECIES scored 13.5/20, with the macrophyte layer (>90% native species) recording the greatest species richness in the Coffs coastal Ecohealth sites for 2015. The canopy layer had a high proportion of native species (~85%), followed by the midstory (~75%), with the herb/forb, and graminoid layers scoring half marks (~55-75%). Aside from the break in riparian continuity associated with highway bridges and adjacent riparian clearing, SPECIES COVER scored well with 18/20, with maximum cover values in all structural layers except for canopy and midstory. DEBRIS received a score of 10/20 with good quantities of total leaf litter, native leaf litter, and fringing vegetation. A lack of small and large woody debris (lying logs, standing and lying dead trees) negatively impacted on this subindex. MANAGEMENT received 13.5/20, with maximum indicator values reached for very low values of exposed roots of fringing woody vegetation, and for the presence of native woody regeneration. The tree clearing indicator received reduced scores due to the ratio of mature trees:regrowth:cleared. Fencing was partially present on-site, however, animal impact was also evident on one side of the creek, and subsequently reduced the indicator score. The presence of noxious weeds and weedy woody regeneration also negatively impacted the site score.

***Plate 3.31*** *Riparian vegetation at Pine Creek #3 was in fair condition. Remnant elements were present in all structural layers. However, riparian condition could be improved greatly with the removal and monitoring of Lantana and Cabomba weed species. Additional native plantings in combination with complete riparian fencing would continue to improve riparian condition at this site.*

***Table 3.62*** *Site-level summary of riprian condition of Pine Creek #3, including subindices and indicators.*

| **Pine Creek #3** | **Scores** |
|---|---|
| **HABITAT** | **15.7** |
| Channel width | 1.7 |
| Proximity | 3 |
| Continuity | 3 |
| Layers | 4 |
| Large native trees | 2 |
| Hollow-bearing trees | 2 |
| **NATIVE SPECIES** | **13.5** |
| Native canopy species | 3 |
| Native midstory species | 2.5 |
| Native herb/forb species | 2 |
| Native graminoid species | 2 |
| Native macrophyte species | 4 |
| **SPECIES COVER** | **18** |
| Canopy species | 3 |
| Midstory species | 3 |
| Herb/forb species | 4 |
| Graminoid species | 4 |
| Macrophyte species | 4 |
| **DEBRIS** | **10** |
| Total leaf litter | 2 |
| Native leaf litter | 2 |
| Dead trees standing | 0 |
| Dead trees fallen | 1 |
| Lying logs | 2 |
| Fringing vegetation | 3 |
| **MANAGEMENT** | **13.5** |
| Tree clearing | 2.5 |
| Fencing | 2 |
| Animal impact | 1 |
| Species of interest | 1 |
| Exposed tree roots | 4 |
| Native woody regeneration | 2 |
| Weedy woody regeneration | 1 |
| **TOTAL** | **70.7** |

### *3.10.5 Mangrove, seagrass and saltmarsh cover*

The Bonville/Pine Creek estuary contained the third highest total estuarine macrophyte cover of the 9 Coffs Harbour estuarine systems (Figure 3.28). The dominant vegetation community was saltmarsh (0.177km$^2$) with the Boambee/Newport Creek estuary containing the second highest cover of this community in the Coffs Harbour region estuaries. Mangroves were co-dominants (0.144km$^2$), and seagrass was present at lower cover values (0.042km$^2$) (Table 3.63). In addition to maintaining current mangrove and saltmarsh cover, management priorities in the Bonville/Pine Creek system should focus on monitoring the seagrass layer, which as the minor component of this system, exists in just several small patches (averaging 170m$^2$), (Table 3.63).

Total estuarine macrophyte cover in the Bonville/Pine Creek estuary decreased from 1985 (0.385km$^2$) to 2011 (0.330km$^2$) (Table 3.63). This is primarily due to a substantial decrease in seagrass cover from 0.089km$^2$ in 1985 to 0.010km$^2$ in 2011. In contrast, both mangrove and saltmarsh cover have increased since 1985 (Table 3.63).

***Table 3.63*** *Total area covered by mangrove, seagrass or saltmarsh in the Bonville/Pine Creeks estuary in 2011 and 1985, and mean patch size of each vegetation community in 2011.*

| Vegetation community | Total area in 1985 (km$^2$) | Total area in 2011 (km$^2$) | Total area in 2011 (m$^2$) | Mean patch size in 2011 (m$^2$) |
|---|---|---|---|---|
| Mangrove | 0.137 | 0.144 | 143,870 | 475 |
| Saltmarsh | 0.159 | 0.177 | 176,574 | 4,528 |
| Seagrass (*Zostera*) - total | 0.089 | 0.010 | 9,862 | 170 |
| Dense *Zostera* | - | 0.003 | 3,436 | 127 |
| Sparse *Zostera* | - | 0.006 | 6,349 | 227 |
| Estuary total | 0.385 | 0.330 | 330,306 | |

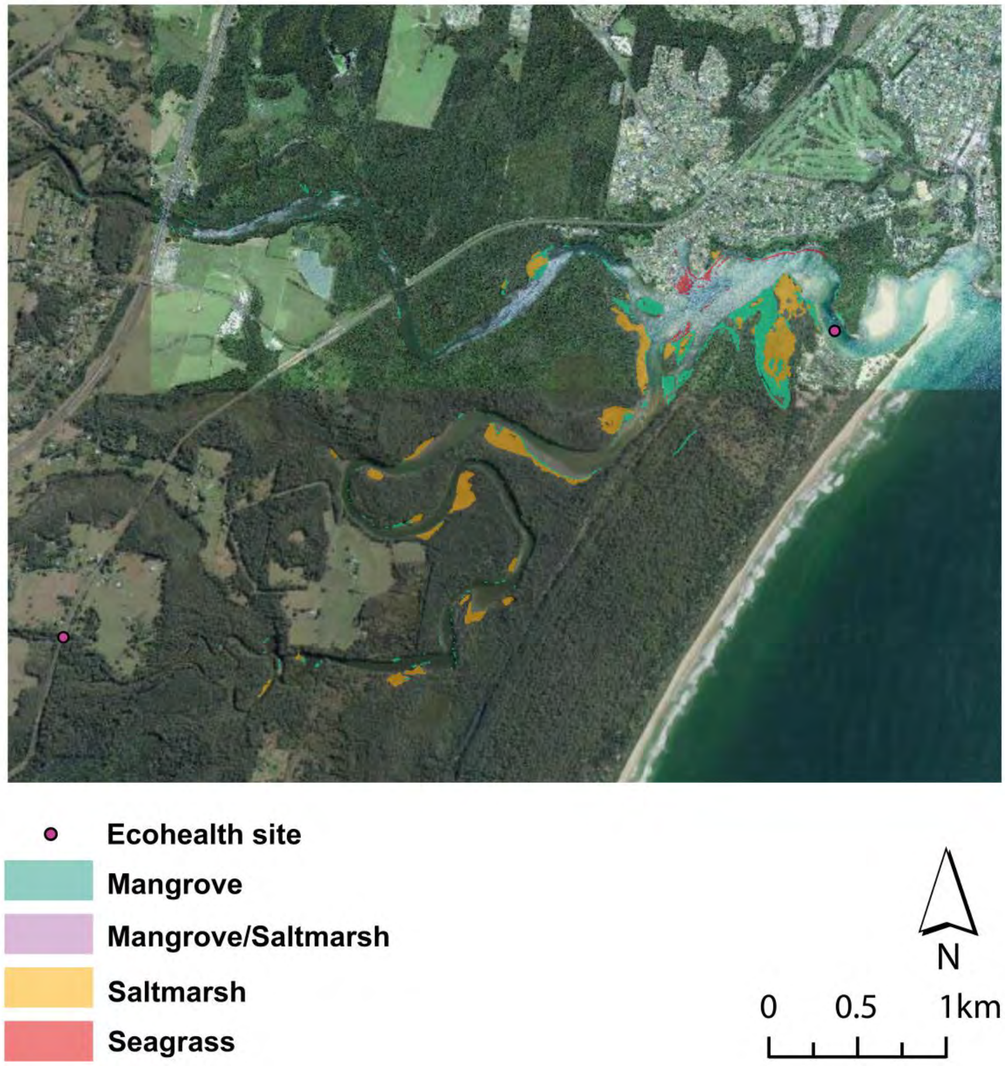



***Figure 3.28*** *Mangrove, seagrass and saltmarsh habitats in the Bonville/Pine Creeks estuary (NSW Department of Industry and Investment – Primary Industries and Energy 2011).*

### *3.10.6 Water quality*

The subcatchment of Bonville and Pine Creeks received as score of 68, a grade of C, for water quality. Bonville Creek received a score of 73 (C+) for water quality, with the best water quality recorded at the lower estuary (BONV1, B+), and the poorest water quality recorded at the tidal limit (BONV3, D+). Pine Creek received a score of 64 (C-) for water quality, with water quality in the freshwater site (PINE3, C+) better than at the tidal limit (PINE2, D+).

Water temperatures were highest at the tidal limit in both creeks (Figure 3.29). In Bonville Creek, water temperatures ranged from winter minimums of 16.2°C at BONV3 and BONV4, to a summer maximum of 31.4°C at BONV3 (Table 3.64). In Pine Creek, water temperatures ranged from a winter minimum of 14.6°C at PINE3 to a summer maximum of 31.1°C at PINE2 (Table 3.65). DO% in Bonville Creek ranged from a very low 4.6% in BONV3 to 216.3% in BONV1 (Table 3.64). DO% at BONV1 exceeded the maximum estuarine trigger threshold on all but 1 sampling occasion (July 2015, Table 3.64). The very high maximum and mean DO% at BONV1 combined with chl-*a* concentrations below detection limits, suggests that wave action may be a regulating factor of DO% in this estuary. DO% at BONV3 was below the minimum estuary trigger threshold on 4 occasions (March, August, October and December 2015, Table 3.66). In March 2015, DO% was very low, from 6.4% at the surface to 4.6% at 2m depth. DO% at BONV3 also exceeded the maximum estuarine trigger threshold twice (November 2014 and April 2015. DO% in Pine Creek ranged from 53.2% to 186.3%, both in PINE2 (Table 3.65). DO% at PINE2 exceeded the maximum estuarine trigger threshold twice (November 2014 and April 2015) and fell below the minimum estuarine trigger threshold on 4 occasions (March, July, August and December 2015, Table 3.66). DO% at PINE3 exceeded the maximum freshwater trigger threshold 3 times (September 2014, and March and May 2015), and fell below the minimum freshwater trigger threshold twice (October and December 2015, Table 3.66).

pH in Bonville Creek ranged from 4.3 to 8.5, both at BONV3, and consistently fell below the estuarine guideline threshold. pH at BONV1 was below the minimum estuarine trigger threshold on 3 occasions (September 2014, and August and October 2015, Table 3.66). pH at BONV3 was below the minimum estuarine trigger threshold on most sampling occasions (Table 3.66). In contrast, pH at BONV4 only exceeded the maximum freshwater trigger threshold once, in July 2015 (Table 3.66). pH ranged 6.1 – 8.8 in Pine Creek (Table 3.65). pH consistently fell below the minimum estuarine trigger threshold at PINE2, on 6 of the 8 sampling occasions (Table 3.66). In contrast, pH at the freshwater PINE3 exceeded the maximum freshwater trigger threshold once (July 2015), and recorded below the minimum freshwater trigger threshold twice (December 2014 and March 2015, Table 3.66).

Turbidity ranged from 0.4 – 75.1NTU in Bonville Creek, and 0.5-8.3NTU in Pine Creek (Tables 3.64, 3.65). Only BONV3 exceeded the guideline threshold, doing so twice (November 2014 and March 2015). The exceedances in March 2015 were more than 7x the estuarine trigger threshold (Table 3.66).

Chl-*a* ranged 0 - 18µg/L in Bonville Creek (Table 3.64). Chl-*a* only exceeded the estuarine trigger threshold in Bonville Creek, and this occurred at the tidal limit (BONV3) twice (November 2014 and October 2015, Table 3.66). The exceedance in November 2014 was more than 5x the estuarine trigger threshold. Chl-*a* ranged 2.0 – 5.0µg/L in Pine Creek (Table 3.65), and also only exceeded the guideline threshold at the tidal limit (PINE2). Chl-*a* at PINE2 exceeded the estuarine trigger threshold once, in November 2014 (Table 3.66).

TN ranged from 0.1 – 0.4mg/L in Bonville Creek, only exceeding the estuarine trigger threshold twice at BONV3 (November 2014 and October 2015 (Table 3.66). TN ranged from 0.2 – 0.4mg/L in Pine Creek, and also only recorded exceedances at the tidal limit. TN exceeded the estuarine trigger threshold at PINE3 on 4 occasions (November 2014, and March, October and December 2015, Table 3.66). TP was below detection limits on all but one sampling period for both Bonville and Pine Creeks, and did not exceed guideline thresholds (Tables 3.64, 3.65).

Faecal coliforms were collected from BONV1 eight times through the sampling period, and never exceeded the estuarine trigger threshold for primary contact (150fc/100mL). BONV1 recorded a maximum of 60fc/100mL in July 2015 (Table 3.64).

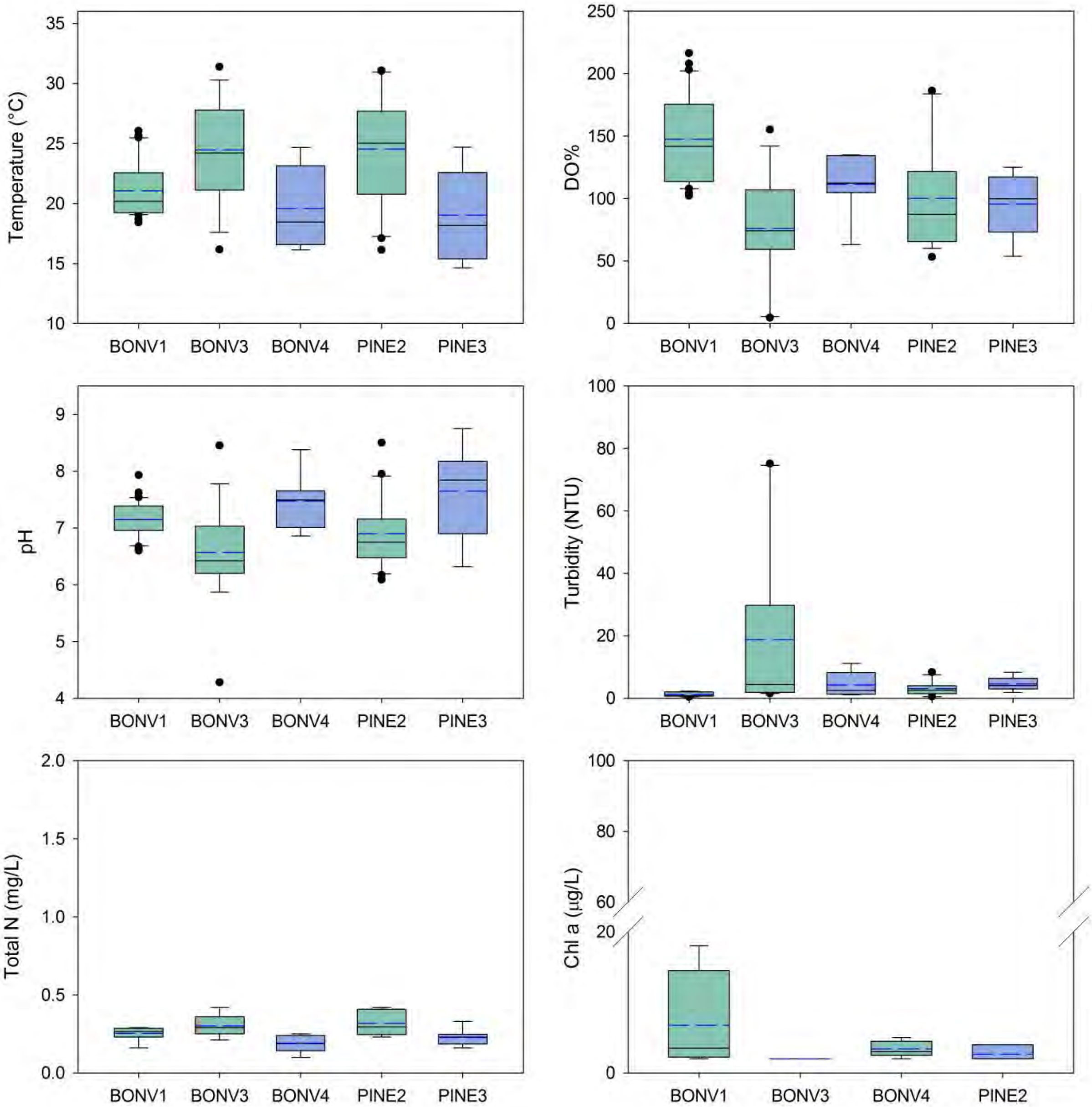



***Figure 3.29*** *Mean (blue line), median (black line), 25th and 75th percentiles, and range of water quality variables in the Bonville and Pine Creeks subcatchment over 2015. Outliers are represented by black dots. Green and blue boxes represent estuary and freshwater sites, respectively.*

***Table 3.64*** *Minimums, maximums and means of measured water quality variables for the three sites on Bonville Creek.*

| | BONV1 | | | BONV3 | | | BONV4 | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **Min** | **Max** | **Mean** | **Min** | **Max** | **Mean** | **Min** | **Max** | **Mean** |
| **Temperature** | 18.4 | 26.0 | 21.1 | 16.2 | 31.4 | 24.5 | 16.2 | 24.7 | 19.6 |
| **pH** | 6.6 | 7.6 | 8.1 | 4.3 | 8.5 | 6.6 | 6.9 | 8.4 | 7.5 |
| **EC** | 17.0 | 52.5 | 43.0 | 0.1 | 58.7 | 30.8 | 0.0 | 2.6 | 0.4 |
| **Salinity (PPT)** | 22.5 | 43.0 | 36.2 | 0.1 | 38.9 | 18.4 | 0.1 | 0.1 | 0.1 |
| **DO (mg/L)** | 7.4 | 19.2 | 11.3 | 0.5 | 20.7 | 7.7 | 5.8 | 13.2 | 10.4 |
| **DO %** | 102.2 | 216.3 | 147.5 | 4.6 | 155.2 | 76.1 | 63.0 | 135.0 | 111.6 |
| **Turbidity** | 0.4 | 2.3 | 1.2 | 1.5 | 75.1 | 18.8 | 1.2 | 11.2 | 4.3 |
| **Max Depth** | 2.2 | 5.0 | 3.7 | 1.0 | 2.4 | 1.6 | 0.2 | 0.5 | 0.3 |
| **Chla (µg/L)** | 0.0 | 0.0 | 0.0 | 2.0 | 18.0 | 6.8 | 2.0 | 2.0 | 2.0 |
| **TSS (mg/L)** | 6.0 | 23.0 | 12.3 | 2.0 | 12.0 | 5.4 | 2.0 | 4.0 | 3.2 |
| **TN (mg/L)** | 0.2 | 0.3 | 0.3 | 0.2 | 0.4 | 0.3 | 0.1 | 0.3 | 0.2 |
| **TP (mg/L)** | <0.03 | <0.03 | <0.03 | <0.03 | 0.03 | <0.03 | <0.03 | <0.03 | <0.03 |
| **Coliforms (cells/100mL)** | 0 | 60 | 17 | | | | | | |

***Table 3.65*** *Minimums, maximums and means of measured water quality variables for the two sites on Pine Creek.*

| | PINE2 | | | PINE3 | | |
|---|---|---|---|---|---|---|
| **Variable** | **Min** | **Max** | **Mean** | **Min** | **Max** | **Mean** |
| **Temperature** | 16.1 | 31.1 | 24.5 | 14.6 | 24.7 | 19.0 |
| **pH** | 6.1 | 8.5 | 6.9 | 6.3 | 8.8 | 7.7 |
| **EC** | 1.7 | 57.5 | 35.0 | 0.1 | 4.5 | 0.6 |
| **Salinity (PPT)** | 25.8 | 38.5 | 23.7 | 0.1 | 0.1 | 0.1 |
| **DO (mg/L)** | 3.9 | 12.4 | 7.5 | 5.0 | 12.6 | 9.2 |
| **DO %** | 53.2 | 186.3 | 100.3 | 53.7 | 125.0 | 95.8 |
| **Turbidity** | 0.5 | 8.3 | 3.1 | 1.9 | 8.3 | 4.6 |
| **Max Depth** | 1.2 | 2.4 | 1.6 | 0.3 | 0.5 | 0.4 |
| **Chla (µg/L)** | 2.0 | 5.0 | 3.4 | 2.0 | 4.0 | 2.7 |
| **TSS (mg/L)** | 2.0 | 9.0 | 4.9 | 2.0 | 9.0 | 5.0 |
| **TN (mg/L)** | 0.2 | 0.4 | 0.3 | 0.2 | 0.3 | 0.2 |
| **TP (mg/L)** | <0.03 | <0.03 | <0.03 | <0.03 | 0.03 | <0.03 |
| **Coliforms (cells/100mL)** | | | | | | |

***Table 3.66** Exceedances[1] observed in Bonville and Pine Creeks for pH, conductivity (EC), percent saturated dissolved oxygen (DO), turbidity, chlorophyll a (Chl-a), total nitrogen (TN) and total phosphorus (TP), and the site-level WQ grades.*

| Site | pH | EC | DO % | Turbidity | Chl-a | TN | TP | WQ grade |
|---|---|---|---|---|---|---|---|---|
| BONV1 | 10(30%) 10,0 | NA | 11(37%) 0,11 | 0 | 0 | 0 | 0 | B+ |
| BONV3 | 13(72%) 13,0 | NA | 13(73%) 10,3 | 4(29%) | 2(50%) | 2(25%) | 0 | D+ |
| BONV4 | 1 (13%) 0,1 | 8(100%) 7,1 | 6(86%) 1,5 | | 0 | 0 | 0 | C+ |
| PINE2 | 13(65%) 13,0 | NA | 10(63%) 6,4 | 0 | 2(40%) | 4(50%) | 0 | D+ |
| PINE3 | 3(38%) 2,1 | 8(100%) 7,1 | 5(71%) 2,3 | 0 | 0 | 0 | 0 | C+ |

*[1] Numbers in black represent the total number and percent of exceedances. Numbers in blue and red represent the numbers of measurements lower than the minimum threshold and higher than the maximum threshold, respectively. The number of exceedances includes all depths sampled so may be greater than the number of times sampled. Turbidity, chlorophyll a, and total nutrients only have maximum trigger thresholds.*

### *3.10.7 Aquatic macroinvertebrates*

*Bonville Creek*

Bonville Creek #4 (BONV4) recorded very high richness with 30 and 35 families recorded in autumn and spring, respectively (Table 3.67). In autumn, Trichoptera (Caddisflies) dominated family richness with 8 families (73 individuals), followed by Coleoptera (Aquatic Beetles) with 6 families (107 individuals) and Diptera (Midge Larvae) with 4 families (65 individuals). In spring, Trichoptera (77 individuals) and Coleoptera (51 individuals) co-dominated richness with 8 families each. Total abundances were also high with over 400 individuals recorded in each season (Table 3.67). Abundances were evenly distributed across several genera in autumn, but not in spring where almost one quarter of the individuals were Leptophlebid Mayflies. Rare taxa (comprising fewer than 5 individuals) formed a significant component of the community with 12 and 20 families in autumn and spring, respectively.

EPT richness and abundance were high at BONV4 (Table 3.67). About 40% of the recorded families and 47% of abundance were EPTs, spread across all 3 Orders. Mean SIGNAL2 scores were consistently high between seasons at 5.6 and 5.7 in autumn and spring, respectively. The community included Glossomatidae and Calocidae Caddisflies that require very good water quality and good habitat (SIGNAL2 of 9).

Bonville Creek #4 (BONV4) recorded the best aquatic macroinvertebrate community condition of the Coffs coastal catchments, receiving an overall Ecohealth score of 94, a grade of A-. All four macroinvertebrate indicators were significantly above the average for Coffs coastal catchments in

2015 (Table 3.6). This suggests the water quality and habitat conditions in the freshwater reaches of Bonville Creek are in excellent condition.

***Table 3.67*** *Summary of aquatic macroinvertebrate data for Bonville Creek #4 (BONV4).*

| BONV4 | | | | |
|---|---|---|---|---|
| **Macroinvertebrate indicator** | **Autumn 2015** | **Spring 2015** | **Autumn 2011** | **Spring 2011** |
| Family richness | 30 | 35 | 24 | 22 |
| Total abundance | 413 | 479 | 220 | 148 |
| EPT richness | 12 | 13 | 10 | 10 |
| EPT abundance | 158 | 225 | 88 | 76 |
| Mean SIGNAL2 score | 5.6 | 5.7 | 5.6 | 5.3 |
| SIGNAL2 score range | 2 - 9 | 2 - 9 | 2 - 9 | 2 - 8 |
| Ecohealth score (grade) | **94 (A-)** | | **83 (B)** | |

### *Pine Creek*

Pine Creek #3 (PINE3) recorded high richness with 26 and 29 families in autumn and spring, respectively (Table 3.68). In autumn, Coleoptera (Aquatic Beetles) dominated richness with 6 families (35 individuals), followed by Ephemeroptera (Mayflies) with 4 families (114 individuals). Aquatic Beetles also dominated family richness in spring, with 8 families (22 individuals), followed by Trichoptera (Caddisflies) with 4 families (6 individuals). Total abundances were also relatively high, with 345 and 223 individuals recorded in autumn and spring, respectively (Table 3.68). Abundances were evenly spread across several genera, with Atyidae (Freshwater Shrimp) and Chironomidae (Midge Larvae) the most numerous in autumn and spring. Rare taxa (comprising fewer than 5 individuals) formed a significant component of the community with 16 and 21 families in autumn and spring, respectively.

EPT richness and abundances were also high, especially autumn abundances where 117 individuals were Ephemeroptera (Mayflies). EPTs in both seasons comprised Ephemeroptera and Trichoptera (Table 3.68). Mean SIGNAL2 scores were above the average for Coffs coastal catchments, particularly in autumn at 4.8.

Pine Creek #3 (PINE3) received a score of 59, a grade of D+, for aquatic macroinvertebrate community condition. This suggests the water quality and habitat conditions in the freshwater reaches of Pine Creek are in poor condition. Nonetheless, all four macroinvertebrate indicators were above the average for Coffs coastal catchments (Table 3.6).

***Table 3.68*** *Summary of aquatic macroinvertebrate data for Pine Creek #3 (PINE3).*

| PINE3 | | | | |
|---|---|---|---|---|
| **Macroinvertebrate indicator** | **Autumn 2015** | **Spring 2015** | **Autumn 2011** | **Spring 2011** |
| Family richness | 26 | 29 | 9 | 10 |
| Total abundance | 345 | 223 | 79 | 64 |
| EPT richness | 7 | 7 | 5 | 5 |
| EPT abundance | 121 | 25 | 12 | 17 |
| Mean SIGNAL2 score | 4.8 | 3.6 | 5.4 | 5.1 |
| SIGNAL2 score range | 2 - 8 | 2 - 8 | 3 - 8 | 2 - 8 |
| Ecohealth score (grade) | **59 (D+)** | | **42 (F)** | |

# PART 4

# SUMMARY AND RECOMMENDATIONS

## 4.1 Background

The development of a standardised framework for collecting, analyzing and presenting riverine, coastal and estuarine assessments of ecological condition has been identified as a key need for coastal Councils and State natural resource management agencies, who are required to monitor natural resource condition, and water quality and quantity in these systems. This project was conducted over a 16-month period from September 2014 to December 2015 in the Coffs Harbour Region covering the subcatchments of the Corindi River, Saltwater Creek and Pipeclay Lake, Arrawarra Creek, Darkum Creek, Woolgoolga Creek, Willis Creek and Hearnes Lake, Moonee Creek, Coffs Creek, Boambee and Newports Creeks, and Bonville and Pine Creeks. This project aimed to contribute to the assessment of the ecological condition of these subcatchments by:

- Assessing the health of coastal catchments using standardised indicators and reporting for estuaries and freshwater river reaches using hydrology, water quality, riparian vegetation, geomorphic condition, aquatic macroinvertebrate communities and fish as indicators of aquatic ecosystem health,
- Reporting the temporal change in the condition of these indicators from the 2011 Ecohealth assessment to this 2015 assessment, and
- Contributing scientific information to the development of report cards for communicating the health of the estuarine and freshwater systems of the Coffs Harbour region.

This section provides a summary for each of the study subcatchments, identifying major issues with geomorphic condition, riparian condition, water quality and aquatic macroinvertebrate communities, and the potential drivers of change in these systems. The temporal change (2011 to 2015) in indicators is provided here, as well as management priorities.

## 4.2 Subcatchment summaries

### *4.2.1 Corindi River, Saltwater Creek and Pipeclay Lake*

*Corindi River*

The Corindi River received an overall Ecohealth score of 68, a grade of C. The Corindi estuary (70, C), comprising the lower estuary (CORI1: 72, C+) and the tidal limit (CORI3: 67, C), was in better overall condition than the freshwater reach (CORI4: 65, C-). The assessment of estuary condition consisted only of the water quality indicator, whereas the assessment of the freshwater reach comprised geomorphic condition, riparian condition, water quality, aquatic macroinvertebrate community composition and fish community composition. Fish condition was assessed at 3 freshwater locations (Appendix B) and considered to be fair (71, C+).

The Corindi River received a score of 74 (C+) for water quality, with the best water quality recorded at the freshwater site CORI4 (84, B) and the poorest water quality recorded at the tidal limit (CORI3: 67, C). At the subcatchment scale, this was a decline from 2011 when the Corindi River received a B-. The poorest water quality for the subcatchment was observed at the tidal limit in both assessments.

Some water quality indicators improved from 2011 to 2015. In 2015, concentrations of TN exceeded trigger thresholds in the estuary (CORI1, CORI3), but not the freshwater site (CORI4), whereas all 3 sites had exceedances in 2011. Furthermore, both the percent exceedance and magnitude of exceedance were lower in 2015. At CORI1, TN exceeded the trigger threshold in 33% of samples (compared to 55% in 2011), and the maximum concentration was 360µg/L compared to 445µg/L in 2011. At CORI3, TN exceeded the trigger threshold in 33% of samples compared with 64% in 2011, with a 2015 maximum concentration of 370µg/L compared with 590µg/L in 2011. TP did not exceed trigger thresholds at any site in 2015, in contrast to 2011 when exceedances were observed at CORI1 and CORI4. Concentrations of chl-*a* did not exceed trigger thresholds at any site in 2015, in contrast to 2011 when chl-*a* at CORI4 exceeded the trigger threshold in 13% of samples, with a maximum concentration of 16µg/L. Low turbidity and chl-*a* concentrations indicated that there were limited consequences to algal productivity from elevated TN in the estuary. Faecal coliforms at CORI1 did not exceed the trigger threshold for primary contact, similar to 2011 observations.

The overall decline in water quality scores for the Corindi River subcatchment was due to widespread and consistent exceedances for pH and DO%. In the Corindi River estuary, pH was below the minimum trigger threshold for 58% of samples at CORI1 and 94% of samples at CORI3. Minimum pH was 6.6 at CORI1 and 5.9 at CORI3. Given that exposed acid sulphate soils (ASS) are known to be an issue in the subcatchment, Council should investigate this issue further to determine the magnitude and spatial extent of ASS leaching.

DO% consistently exceeded maximum trigger thresholds at estuary sites. The low turbidity and chl-*a* concentrations observed at these sites suggests that high saturated DO may be due to wave action and not nuisance algal blooms. In this instance, a regional refinement of the estuarine DO% trigger thresholds may improve the accuracy of aquatic ecosystem health assessments. Notwithstanding this, DO% fell below the minimum trigger thresholds at both CORI3 and CORI4, and had the potential to impact aquatic biota (macroinvertebrates and fish) and facilitate sediment nutrient regeneration processes.

CORI4 received a score of 66 (C) for geomorphic condition. The banks were well vegetated, but the right bank comprised areas of concentrated erosion while the left bank was affected by bank slumping. Strategic riparian fencing could increase native vegetation and reduce stock impacts; both would assist in reducing bank erosion.

CORI4 was assessed as a moderately disturbed system of mature and regrowth forest with the surrounding rural landuse predominantly being used for grazing, agriculture and horticulture. Riparian Condition at CORI4 scored positively with representative elements of the remnant vegetation community present in all structural layers. Weedy species negatively impacted the overall grade with riparian condition improved through both weed control and livestock exclusion via fencing. In addition, strategic riparian fencing could be used to assist native species regeneration and increase riparian vegetation width and continuity in this system.

In 2011, riparian condition at CORI4 scored 67.1 (C) compared with a score of 65.5 (C) in 2015 representing very little change (1.6%) in the four years between Ecohealth surveys. The factors negatively affecting riparian condition score in 2011 were reduced native species presence at each structural level, i.e. weed invasion, large fallen woody debris and riparian continuity. In 2015, weed presence was still the most significant issue. Large fallen woody debris is still lacking in these freshwater reaches; however, the continuity of riparian vegetation appears to have improved.

CORI4 received a score of 36 (F), for aquatic macroinvertebrate community condition. This was the poorest performing indicator in the subcatchment, and was slightly lower than the 2011 grade. Family richness and abundance were similar or slightly better in 2015, but mean site SIGNAL2 scores were lower in 2015. The macroinvertebrate indicators suggest the water quality and habitat conditions in the freshwater reaches of the Corindi River are in very poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

*Management Priority – CORI1 and CORI3*

- Investigate WQ issues: low pH in the estuary may be caused by ASS

*Management Priorities – CORI4*

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species
- Phase out Camphor: promotion of native canopy species and Camphor removal over time
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation and reduce streambank erosion

*Saltwater Creek*

Saltwater Creek received an overall Ecohealth score of 56, a grade of D+. Similar to the Corindi River, the Saltwater Creek tidal limit (SALT2: 49, D-) had poorer overall condition than the freshwater reach (SALT3: 63, C-). The assessment of the tidal limit consisted only of the water quality indicator, whereas the assessment of the freshwater reach comprised geomorphic condition, riparian condition, water quality and aquatic macroinvertebrate community composition.

Saltwater Creek received a score of 60 (D+) for water quality, with the water quality recorded at the freshwater site SALT3 (71, C+) significantly better than at the tidal limit SALT2 (49, D-). At the subcatchment scale, this was a substantial decline from 2011 when Saltwater Creek received a B. This may be partially due to the absence of the lower estuary site (SALT1) in the 2015 assessment, as water quality was good in the lower Saltwater Creek estuary in 2011.

Even though the tidal limit (SALT2) had poor water quality, some indicators improved from 2011 to 2015. In 2015, concentrations of TN exceeded the trigger threshold in 75% of samples compared with 82% in 2011. Furthermore, the maximum TN concentration in 2015 was 470µg/L compared with 595µg/L in 2011. Concentrations of TP did not exceed the trigger threshold in 2015, in contrast to the 9% exceedance in 2011. Exceedances of chl-*a* decreased from 56% in 2011 to 38% in 2015, although maximum concentrations remained at 8µg/L. The overall decline in water quality score for SALT2 from 2011 to 2015 was due to increases in exceedances for pH, DO% and turbidity. pH was below the minimum trigger threshold for 100% of samples in 2015, with a site minimum pH of 5.33. DO% exceeded the maximum trigger threshold in 75% of samples with a site maximum of 171%. Turbidity exceeded the trigger threshold in 18% of samples with a site maximum of 25NTU.

SALT3 was the only site in the Corindi River/Saltwater Creek subcatchment to have higher concentrations of TN in 2015 than 2011. TN concentrations exceeded the trigger threshold in 50% of samples with a site maximum of 720µg/L in 2015, compared with 45% exceedances and a site maximum of 700µg/L in 2011. In contrast, TP did not exceed the trigger threshold in 2015, compared with 9% exceedance in 2011. Chl-*a* concentrations in SALT3 may have been responding to increased TN, with chl-*a* exceeding trigger thresholds in 25% of samples with a site maximum of 46µg/L in 2015 (compared with no exceedances and a site maximum <4µg/L in 2011). pH and DO% were also worse in 2015 than 2011: pH exceeded maximum trigger thresholds in 50% of samples with a site maximum of 9.02 in 2015, and DO% exceeded both the minimum (60%, minimum of 51.1%) and maximum (20%, maximum of 154.2%) trigger thresholds in 2015.

SALT3 received a score of 76 (B-) for geomorphic condition. Both bank and bed erosion were very minor at this site and maintenance of the riparian vegetation will keep this site in good geomorphic condition.

SALT3 was assessed as a low disturbance system of mature and regrowth forest with the immediate surrounding landuse a predominantly high disturbance system utilised for forestry, beyond which is National Park. Overall, the riparian vegetation at SALT3 scored highly and was found to be in very good representative condition. The reduced quantity of both habitat trees and lying woody debris is a likely reflection of historic selective logging practices and bushfire events. With mature trees in this system, these indicators are expected to improve over time. Noxious weed encroachment appears to be the most pertinent issue and is a likely reflection of the site's landuse history and proximity to the neighbouring forestry plantation where weed presence and spread are often accelerated by increased light gaps and soil disturbance from forestery operations. Indeed, most of the weed species encountered were located at the northern edge of the site adjacent to disturbed land. It was observed en-route to the site that riparian conditions deteriorated rapidly 100m north of the site due to weed invasion and landclearing for forestry.

In 2015, the riparian assessment was of a similarly representative section of riparian vegetation 1km downstream of the 2011 site that was inaccessibile due to locked forestry gates. In 2011, SALT3 received a riparian condition score of 78.2% (B-), while in 2015 the new SALT3 received a riparian condition score of 87% (B+). The difference in scores (8.8% or two grades) can be explained by a combination of factors such as differences in canopy and grass cover suggesting that the 2011 site was a more 'open' sclerophyll forest than its 2015 counterpart, despite the similarity in vegetation types. The high standing woody debris scores and evidence of tree removal suggests a higher level of disturbance in the 2011 SALT3 than the 2015 site and partially explains the difference in riparian condition scores. The 2011 site recorded only one weed species while several weed species, including three noxious species, were noted in the 2015 sampling. Hence, while riparian condition in Saltwater Creek has received high scores in both 2011 and 2015, weed encroachment remains the dominant management issue at a site level.

SALT3 received an overall Ecohealth score of 18 (F) for aquatic macroinvertebrate community condition. All four macroinvertebrate indicators were below average for the Coffs coastal catchments in 2015 with mean EPT richness and abundance the worst indicator. The macroinvertebrate indicators suggest the water quality and habitat conditions in the freshwater reaches of Saltwater Creek are in very poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

Aquatic macroinvertebrate community condition was lower in 2015 than 2011. Although family richness and abundance were greater in 2015 than 2011, EPT richness and abundance were lower and SIGNAL2 scores declined significantly. This may have been partly due to sampling when stream discharge was below baseflow conditions in spring 2015 when the stream at SALT3 had contracted to disconnected pools.

*Management Priority – SALT2*

- Investigate WQ issues: low pH in the estuary may be caused by ASS

*Priorities – SALT3*

- Investigate sources of TN
- Maintain riparian vegetation to keep the site in good geomorphic condition
- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species

*Pipeclay Lake*

Pipeclay Lake received an overall Ecohealth score of 64, a gradeof C-, based on the water quality assessment at one site PIPE1, which was established in this 2015 Ecohealth monitoring program. Concentrations of TN exceeded the trigger threshold in 100% of samples, with a site maximum of 800µg/L. In contrast, TP did not exceed the trigger threshold in 2015. Chl-*a* concentrations exceeded the trigger threshold in 17% of samples, with a site maximum of 6.0µg/L and turbidity exceeded the trigger threshold in 14% of samples with a site maximum of 13.1NTU. pH fell below the minimum trigger threshold in 56% of samples, with a site minimum of 6.17. DO% exceeded the maximum trigger threshold in 29% of samples with a site maximum of 145.4%. This maximum coincided with the site maximum of chl-*a*, suggesting high DO% may have been due to an algal bloom, rather than wave action.

Faecal coliforms at PIPE1 exceeded the trigger threshold for primary contact once in August 2015 (site maximum of 750fc/100mL).

*Management Priorities – PIPE1*

- Investigate sources of TN
- Investigate sources of faecal coliforms

### 4.2.2 Arrawarra Creek

Arrawarra Creek received an overall Ecohealth score of 69, a grade of C. The estuary (ARRA1) was assessed to be in better condition overall than the freshwater reach (ARRA4). However, the assessment of estuary condition consisted only of the water quality indicator, whereas the assessment of the freshwater reach comprised geomorphic condition, riparian condition, water quality and aquatic macroinvertebrate community composition.

Arrawarra Creek received a score of 69 (C) for water quality, with better water quality recorded in the estuary (ARRA1: 71, C+) than the freshwater site (ARRA4: 67, C). At the subcatchment scale, this is the same as the 2011 assessment.

Some water quality indicators improved from 2011 to 2015, particularly in the estuary. In 2015, concentrations of TN at ARRA1 exceeded the trigger threshold in 50% of samples with a site maximum of 530µg/L. This was an improvement from 2011, where TN exceeded the trigger threshold in 90% of samples with a site maximum of 690µg/L. At the freshwater site ARRA4, TN concentrations also improved, with no exceedances recorded in 2015 compared with 90% of samples in 2011 (2011 site maximum of 580µg/L). TP concentrations did not exceed trigger thresholds at either site in Arrawarra Creek in 2015. This was an improvement from 2011, where TP exceeded the trigger thresholds in 30% (site maximum of 65µg/L) and 10% (site maximum of 60µg/L) of samples at ARRA1 and ARRA4, respectively.

Chl-*a* concentrations and turbidity did not exceed the trigger thresholds at ARRA1 in 2015. This was an improvement from 2011, where chl-*a* exceeded the trigger threshold in 44% of samples (site maximum of 6µg/L) and turbidity in 10% of samples (site maximum of 18.5NTU). In contrast, chl-*a* at ARRA4 exceeded the trigger threshold in 13% of samples (site maximum of 10µg/L). This is a decline from 2011, when chl-*a* did not exceed the trigger threshold at ARRA4.

As with other sites, persistent exceedances of pH and DO% reduced water quality scores in Arrawarra Creek. pH at ARRA1 fell below the minimum trigger threshold in 83% of samples (site minimum of 5.91). At ARRA4, pH also exceeded trigger thresholds in 83% of samples, but here it was the maximum threshold (site maximum of 8.62). DO% exceeded the maximum trigger threshold in 40% of samples at ARRA1 (site maximum of 140.9%). However, this did not coincide with high chl-*a* concentrations or turbidity, suggesting the exceedances may have been caused by wave action rather than algal blooms. DO% at ARRA4 fell below the minimum trigger threshold in 83% of samples with a site minimum of 34% DO. This equaled a DO concentration of 3.43mg/L and had the potential to impact aquatic biota (macroinvertebrates and fish) and facilitate sediment nutrient regeneration processes.

Faecal coliform counts exceeded the estuarine trigger threshold for primary contact on 3 occasions at ARRA1. The site maximum was >1000fc/100mL in October 2015, followed by 420fc/100mL in July 2015 and 165fc/100mL in August 2015.

ARRA4 received a score of 73 (C+) for geomorphic condition. Localised erosion at knickpoints in the stream bed is the most significant issue for site-level geomorphic condition. Maintaining the riparian vegetation at ARRA4 and upstream of the site will continue to protect bank stability, and help slow runoff, reducing its erosivity.

ARRA4 is a low disturbance system of mature/oldgrowth forest, with the surrounding rural landuse being predominantly used for forestry, grazing and horticulture. Riparian Condition at ARRA4 scored exceptionally well with representative elements of the remnant vegetation community present in all structural layers. Although weeds were present in very low densities at the site-level, it would be beneficial to monitor and employ weed control as necessary, in order to ensure the current riparian condition was maintained.

In 2015, riparian condition at ARRA4 scored 90.5 (A-), an improvement from the 2011 assessment (87.1, B+). The factors most affecting riparian condition scores in 2011 were the presence of the noxious weed Lantana, at the midstory level, and the lack of large and hollow bearing native trees. In 2015, weed presence is still the most significant issue, with Lantana still present and additional weedy grass species detected on the southern edge of ARRA4.

ARRA4 received an overall Ecohealth score of 35 (F) for aquatic macroinvertebrate community condition. Total family richness and abundance were above average for Coffs coastal subcatchments, with the poor grade driven primarily by the absence of EPTs. The macroinvertebrate indicators suggest the water quality and habitat conditions in the freshwater reaches of Arrawarra Creek are in very poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

Aquatic macroinvertebrate community condition at ARRA4 was poorer in 2015 than 2011. Total family richness and abundance were significantly higher, but EPT richness and abundance and SIGNAL2 scores were much lower in 2015. No Trichoptera (Caddisflies) were recorded in 2015; these generally have high SIGNAL2 scores as they require good water quality. Likewise, no Odonata (Dragonflies) were recorded from ARRA4 in 2015. The low stream discharge in spring meant that pools had very low water velocity with warm, shallow water connecting pools.

*Management Priorities – ARRA1*

- Investigate sources of TN
- Investigate sources of faecal coliforms

*Management Priorities – ARRA4*

- Maintain riparian vegetation on streambanks to maintain bank stability
- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species

### *4.2.3 Darkum Creek*

Darkum Creek received an overall Ecohealth score of 61, a gradeof C-, based on the water quality assessment at one site, DARK1. This is an improvement from the 2011 assessment where DARK1 received a grade of D for water quality.

Although TN concentrations at DARK1 exceeded the trigger threshold in 100% of samples in 2015, similar to the 2011 assessment, the site maximum was lower in 2015: 750µg/L compared with 810µg/L in 2011. TP concentrations did not exceed the trigger threshold in 2015 (site maximum of 30µg/L), compared with 18% of samples in 2011 (and a site maximum of 45µg/L). Chl-*a* concentrations also improved in 2015, exceeding the trigger threshold in 13% of samples (site maximum of 4µg/L), compared with 41% of samples and a site maximum of 12µg/L in 2011. Turbidity also improved significantly, not exceeding the trigger threshold in 2015, compared with 80% exceedance in 2011 with the 2011 site maximum almost 5x the 2015 site maximum (9.5NTU).

Similar to other sites, pH and DO% reduced the scores for water quality. pH fell below the minimum trigger threshold in 70% of samples with a site minimum of 5.98. DO% fell below the minimum trigger threshold in 20% of samples with a site minimum of 54.1%. DO% also exceeded the maximum trigger threshold in 30% of samples with a site maximum of 163%. However, exceedances of DO% did not coincide with high concentrations of chl-*a*, indicating that algal blooms were not responsible for these high DO% observations.

Faecal coliform counts exceeded the estuarine trigger threshold for primary contact on 3 occasions. The maximum count exceeded the upper detection limit of 1000fc/100mL and was recorded in July and August 2015, followed by 320fc/100mL in November 2015.

*Management Priorities – DARK1*

- Investigate sources of TN
- Investigate sources of faecal coliforms

### *4.2.4 Woolgoolga Creek*

Woolgoolga Creek received an overall Ecohealth score of 64, a grade of C-. Woolgoolga estuary (60, C-) comprising the lower estuary (WOOL1: 59, D+) and the tidal limit (WOOL3: 61, C-) were in poorer overall condition than the freshwater reach (WOOL4: 73, C+). The assessment of estuary condition consisted only of the water qualiy indicator, wheras the assessment of the freshwater site comprised geomorphic condition, riparian condition, water quality, aquatic macroinvertebrate community composition and fish community composition. Fish condition was assessed at 3 freshwater locations (Appendix B) and considered to be fair (70, C+).

Woolgoolga Creek received a score of 69 (C) for water quality, with the best water quality recorded at the freshwater site WOOL4 (86, B+) and the poorest water quality recorded in the lower esuary (WOOL1: 59, D+). At the subcatchment scale, Woolgoolga Creek received the same grade for water quality in 2015 as in 2011.

Although WOOL1 received the poorest water quality score (D+), several indicators improved from 2011 to 2015. TN concentrations exceeded the trigger threshold in 75% of samples in 2015, compared with 90% of samples in 2011. The 2015 site maximum was 600µg/L, compared with 595µg/L in 2011. Similar to TN, chl-*a* concentrations had fewer exceedances in 2015 (13% compared with 18%) but a higher site maximum (9µg/L compared with 5µg/L). TP remained below the trigger threshold in 2015, an improvement from 2011 (10% of samples, site maximum of 65µg/L). Turbidity exceeded the trigger threshold in 25% of samples in 2015; the same as in 2011. However, the site maximum in 2015 was 15.2NTU compared with the 2011 site maximum of 47NTU. pH fell below the minimum trigger threshold in 83% of samples, with a site minimum of 6.02. DO% was below the minimum trigger threshold in 25% of observations (site minimum of 69.2%) and above the maximum trigger threshold in 25% of observations (site maximum of 123.4%).

Nutrient concentrations were also better at WOOL3 in 2015 than 2011. TN exceeded the trigger threshold in 63% of samples with a site maximum of 500µg/L, compared with 89% and 630µg/L in 2011. TP remained below the trigger threshold in 2011 (compared with 44% in 2011). Chl-*a* concentrations in 2015 exceeded the trigger threshold in 13% of samples compared with 55% in 2015, with the 2015 site maximum (5µg/L) lower than the 2011 site maximum (12µg/L). Turbidity remained below the trigger threshold in 2015 (compared with 40% exceedance and a 2011 site maximum 6x the 2015 maximum of 10NTU). In contrast, pH persistently fell below the minimum trigger threshold in 2015 (90% of observations), with a site minimum of 5.85. DO% was below the minimum trigger threshold in 20% of observations in 2015 (site minimum of 56.5%), and above the maximum trigger threshold in 10% of observations (site maximum of 111.8%).

Water quality at WOOL4 was very similar in 2015 to 2011: chl-*a* and turbidity remained below trigger thresholds in both sampling periods. 2015 TN concentrations remained below the trigger threshold, compared with 18% exceedance in 2011: the site maximum was significantly better in 2015 (200µg/L) than 2011 (670µg/L). TP concentrations in 2015 remained below the trigger threshold compared with 10% exceedance in 2011 and the 2015 site maximum (<30µg/L) was less than half of the 2011 site maximum (70µg/L). DO% fell below the minimum trigger threshold in 23% of observations in 2015 (site minimum of 56.6%) and exceeded the maximum trigger threshold in 23% of observations (site maximum of 120.1%).

WOOL4 received a score of 70 (C+) for geomorphic condition. Both banks had moderate bank erosion, with undercutting, exposed tree roots and slumping present on both banks. The left bank was unfenced and there was evidence of recent stock access. Fencing the riparian zone to remove stock access and revegetating the streambanks with native vegetation are two management strategies that would improve the geomorphic condition of WOOL4.

WOOL4 is a moderate-to-high disturbance system of mature and regrowth forest, with the surrounding rural landuse being predominantly used for forestry, grazing and horticulture. Although representative elements of the remnant vegetation community were present at each structural layer, riparian condition at WOOL4 received a moderate score, and was reduced by the presence of weedy species, and cleared unfenced riparian sections. Riparian condition could be markedly improved through weed control and livestock exclusion via fencing measures. In addition, strategic riparian fencing could be used to assist native species regeneration, increase vegetation width, riparian vegetation continuity, and proximity to larger intact remnant stands of native vegetation.

There was very little change (3.9%) in riparian condition between 2011 (69.6, C) and 2011 (65.7, C). The slight decrease in site score is attributed to both an increase in midstory weeds and visible signs of livestock presence in the riparian zone.

WOOL4 received an overall Ecohealth score of 74 (C+), for aquatic macroinvertebrate community condition. There was a slight decline in the condition of aquatic macroinvertebrate communities in WOOL4 between 2011 and 2015. Although total family richness, total abundance and EPT abundance were higher in 2015, mean SIGNAL2 scores were substantially lower. This was due to high abundances of families with low SIGNAL2 scores in 2015 (e.g. Notonectidae – Backswimmers with SIGNAL2 of 1) and low abundances or absences of families with high SIGNAL2 scores (e.g. the Trichopterans Glossomatidae (SIGNAL2 of 9), Philopotamidae (SIGNAL2 of 8) and Calamoceratidae (SIGNAL2 of 7)).

*Management Priorities – WOOL1 and WOOL3*

- Investigate sources of TN to Woolgoolga estuary
- Investigate sources of acidity to Woolgoolga estuary

*Management Priorities – WOOL4*

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species
- Riparian fencing: to reduce livestock impact, encourage native regeneration and improve geomorphic condition of the streambanks

### *4.2.5 Willis Creek and Hearnes Lake*

*Willis Creek*

Willis Creek received an overall Ecohealth score of 32, a grade of F. This assessment was based solely on water quality at one site, WILL1. This site was established in the 2015 Ecohealth monitoring program so this is the initial baseline assessment.

TN concentrations exceeded the trigger threshold on all sampling occasions with a site maximum of 1020µg/L (3.4x the trigger threshold). TP concentrations exceeded the trigger threshold in 67% of samples with a site maximum of 40µg/L). These high nutrient concentrations may be impacting aquatic ecosystem health in the estuary: chl-*a* concentrations exceeded the trigger threshold in 63% of samples (with a site maximum of 16µg/L, nearly 5x the trigger threshold) and turbidity exceeded the trigger threshold in 60% of samples (with a site maximum of 95.8NTU). DO% fell below the minimum trigger threshold in 33% of samples (site minimum of 73.6%), and exceeded the maximum trigger threshold in 67% of samples (site maximum of 155%). High DO% did not conincide with high chl-*a*, suggesting wave action may have been contributing to high DO%.

Faecal coliform counts at WILL1 ranged from 24 – 910fc/100mL, with the maximum observed in July 2015, followed by 510fc/100mL in December 2015.

*Management Priorities – WILL1*

- Investigate sources of TN including from historic inputs of sewerage effluent and sediment from development activities
- Investigate sources of TP including from historic inputs of sewerage effluent and sediment from development activities
- Investigate sources of faecal coliforms

### *Hearnes Lake*

Hearnes Lake received an overall Ecohealth score of 63, a grade of C-. The estuarine lagoon (HEAR1: 61, C-) was in poorer condition than its freshwater tributary (HEAR4: 66, C). The assessment of estuary condition consisted only of the water quality indicator, whereas the assessment of the freshwater site comprised geomorphic condition, riparian condition, water quality and aquatic macroinvertebrate community composition.

Hearnes Lake received a score of 70 (C) for water quality, with the best water quality recorded at the freshwater site HEAR4 (78, B-). At the subcatchment scale, this is an improvement from 2011 when Hearnes Lake received a D+.

Concentrations of TN at HEAR1 exceeded trigger thresholds in 100% of samples in 2015, consistent with 2011 results. However, the 2015 site maximum (630µg/L) was significantly lower than the 2011 site maximum (1300µg/L). At HEAR4, TN concentrations in 2015 exceeded the trigger threshold in 75% of samples with a site maximum of 1740µg/L. This is almost 3.5x the trigger threshold. In contrast to 2011, TP concentrations at both sites remained below trigger thresholds in 2015; an improvement from 2011. Chl-*a* concentrations at HEAR1 exceeded the trigger threshold in 50% of samples compared with 45% in 2011, and site maximums were the same for 2011 and 2015 at 11µg/L. Turbidity at both sites remained below trigger thresholds in 2015, an improvement from 2011. pH at HEAR1 fell below the minimum trigger threshold in 17% of samples, but the site minimum of 6.99 was very close to the threshold value of 7.0. In contrast, pH at HEAR4 exceeded the maximum trigger threshold in 43% of samples, with a site maximum of 8.84. DO% exceeded the maximum trigger threshold in 67% of samples at HEAR1, with a site maximum of 163%. This site maximum did not coincide with an exceedance in chl-*a* concentration, indicating that physical factors such as wave action may have been responsible for the high DO% at HEAR1.

Faecal coliform counts at HEAR1 ranged from 30 – 186fc/100mL, exceeding the trigger threshold for primary contact. The site maximum was observed in November 2015, followed by 175fc/100mL in September 2014. Coliform counts were higher in 2015 than 2011, when there were no exceedances.

HEAR4 received a score of 71 (C+) for geomorphic condition. Bank erosion on both banks was the most significant issue for site-level geomorphic condition. Fencing the riparian zone to exclude stock and allow for regeneration of native revegetation would improve geomorphic condition at this site.

HEAR4 is a low to moderately disturbed system of mature native forest surrounded by residential and commercial dwellings, agriculture, horticulture and grazing. Riparian Condition at HEAR4 scored highly with good representative elements of the remnant vegetation community present in all structural layers. While satellite imagery revealed close proximity to neighboring farmland, there was no obvious sign of animal impact at the site. Weed species were not only present on the disturbed forest edges, but also in the core of the riparian stand. The midstory was the weediest structural layer (with Lantana), negatively impacting the overall grade of the site. Riparian condition could be markedly improved with the removal/management of this species.

In 2011, the Ecohealth survey of riparian condition was not assessed at any of the Hearns Lake sites. Due to the proximity of ongoing roadworks for the Pacific Highway upgrade, and the consequent site specific riparian disturbance encountered, it was decided that the riparian condition for the 2015 assessment would be done upstream from HEAR3 at the nearby HEAR4. Thus, the 2015 survey of HEAR4 riparian condition of 86.5 (B+) is the initial baseline assessment.

HEAR4 received an overall Ecohealth score of 28 (F) for aquatic macroinvertebrate community condition. The relatively low mean scores and dominance of taxa with low SIGNAL2 scores suggests the water quality and habitat conditions in the freshwater reaches of Hearnes Lake are in very poor condition. As 2011 was the first time a freshwater site was included in the Hearnes Lake subcatchment monitoring, no temporal comparison was possible.

*Management Priorities – HEAR1*

- Investigate sources of TN
- Investigate sources of faecal coliforms

*Management Priorities – HEAR4*

- Investigate sources of TN
- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species
- Riparian fencing: to reduce livestock impact, encourage native regeneration and promote bank stability

### *4.2.6 Moonee Creek*

Moonee Creek received an overall Ecohealth score of 64, a grade of C-. Although the estuary overall (64, C-) was similar to the freshwater site (MOON4: 63, C-), the lower estuary (MOON1: 70, C) was in much better condition than the tidal limit (MOON3: 58, D+). The assessment of estuary condition consisted only of the water quality indicator, whereas the assessment of the freshwater reach comprised geomorphic condition, riparian condition, water quality and aquatic macroinvertebrate community composition.

Moonee Creek received a score of 68 (C) for water quality, with the best water quality recorded at the freshwater site MOON4 (75, B-) and the poorest water quality recorded at the tidal limit (MOON3: 58, D+). The assessment of fair water quality for the subcatchment was the same as in 2011.

Concentrations of TN and TP were lower across Moonee Creek in 2015 compared with 2011. TN at MOON1 exceeded the trigger threshold in 25% of samples with a site maximum of 330µg/L. This is an improvement from 2011, when TN exceeded the trigger threshold in 80% of samples and had a site maximum of 470µg/L. A similar pattern was seen at MOON4, where TN exceeded the trigger threshold in 13% of samples (compared with 26% in 2011) and had a site maximum of 620µg/L (compared with 920µg/L in 2011). Although TN persistently exceeded the trigger threshold at MOON3, there were improvements in both the exceedance (83% in 2015 and 91% in 2011) and site maximum (580µg/L in 2015 and 780µg/L in 2011). TP had improved significantly in the estuary (no exceedances at MOON1 or MOON3) and 2015 site maximums were less than a third of the 2011 site maximums (110 and 150µg/L for MOON1 and MOON3, respectively). TP also decreased at the freshwater site MOON4 with no exceedances observed in 2015 (compared with 10% of samples in 2011).

In contrast, chl-*a* concentrations were worse in 2015 than 2011. At MOON1, chl-*a* exceeded the trigger threshold in 13% of samples with a site maximum of 6µg/L, almost double the 2011 site maximum. At MOON4, chl-*a* exceeded the trigger threshold in 25% of samples with a site maximum of 16µg/L in 2015, almost 5x the 2011 site maximum that remained below the trigger threshold. In contrast to MOON1 and MOON4, chl-*a* at MOON3 remained below the trigger threshold, improving from 2011 where 37% of samples exceeded the trigger threshold.

As with other sites, persistent exceedances of pH and DO% reduced water quality scores in Moonee Creek. pH fell below the minimum trigger threshold in 43% of samples at MOON1 and 83% of samples at MOON3. Site minimums were 6.52 and 5.88 for MOON1 and MOON3, respectively. DO% exceeded the maximum trigger threshold in all samples at MOON1 (site maximum of 167%) and 60% of samples at MOON3 (site maximum of 146%). However, although this did coincide with high chl-*a* at MOON1, it didn't coincide with high chl-*a* at MOON3. Turbidity improved at MOON1, remaining below the trigger threshold for the duration of sampling, and was similar between 2015 and 2011 at MOON3 (25% of samples exceeded the trigger threshold with a site maximum of 13.6NTU).

Faecal coliform counts exceeded the estuarine trigger threshold for primary contact once in November 2015 (with a site maximum of 156fc/100mL). This is an improvement from 2011, where exceedances were equally infrequent but the site maximum was 415fc/100mL.

MOON4 received a score of 80 (B-) for geomorphic condition. There was no indication of active erosion at the site and revegetation of the right bank with native vegetation has improved bank stability.

MOON4 was assessed as a low to moderately disturbed system of regrowth and mature native forest surrounded by residential and urban landuses, agriculture, forestry, and transport networks. Riparian Condition at MOON4 scored highly with representative elements of the remnant vegetation community present in all structural layers. While riparian vegetation width was very good on one bank, clearing due to the recent highway upgrade could be susceptible to weed invasion and should be monitored accordingly. Lantana was the only weed of concern at the site and negatively impacted the overall grade of the site as did the presence of woody weed recruitment and significant distance to larger tracts of intact remnant vegetation. The 2011 survey of riparian condition did not assess any of the Moonee Creek sites. Thus, the 2015 survey of MOON4 riparian condition of 88.5 (B+) was an initial Ecohealth baseline assessment.

MOON4 received a score of 8 (F) for aquatic macroinvertebrate community condition. All four macroinvertebrate indicators for MOON4 were significantly below the mean for Coffs coastal subcatchments in 2015. The low mean scores and dominance of taxa with low SIGNAL2 scores suggests the water quality and habitat conditions in the freshwater reaches of Moonee Creek are in very poor condition.

There was a significant decline in aquatic macroinvertebrate community condition between 2011 and 2015 at MOON4. Although family richness and total abundances were higher in 2015, no EPTs were recorded in 2015. SIGNAL2 scores significantly declined from 2011, primarily driven by the loss of EPTs. Low SIGNAL2 scores in 2015 were a combination of the absence of taxa with high SIGNAL2 scores (Leptophlebidae Mayflies (SIGNAL2 of 8) and Elmid Beetles (SIGNAL2 of 7)), as well as the introduction of taxa with very low SIGNAL2 scores such as Backwimmers (Notonectidae) and Freshwater Snails (Lymnaeidae; both with SIGNAL2 of 1).

*Management Priorities – MOON1 and MOON3*

- Continue to manage sources of TN to the estuary

*Management Priorities – MOON4*

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species
- Investigate causes of the decline in the aquatic macroinvertebrate community

### 4.2.7 Coffs Creek

Coffs Creek received an overall Ecohealth score of 54, a grade of D. The Coffs estuary (52, D), comprising the lower estuary (COFFS1: 63, C-) and the tidal limit (COFFS3: 42, F), was in slightly poorer condition than the freshwater reach (COFFS4: 58, D+). The assessment of estuary condition consisted only of the water quality indicator, whereas the assessment of the freshwater reach comprised geomorphic condition, riparian condition, water quality, aquatic macroinvertebrate community composition and fish community composition. Fish condition was assessed at 3 freshwater locations (Appendix B) and considered to be fair (72, C+).

Coffs Creek received a score of 56 (D+) for water quality, with the best water quality recorded at the freshwater site (COFFS4: 64, C-) and the poorest water quality recorded at the tidal limit (COFFS3: 42, F). At the subcatchment scale, this was a slight decline from 2011, when Coffs Creek received a C-.

TN concentrations improved from 2011 to 2015. In 2015, concentrations of TN at COFFS1 exceeded the trigger threshold in 33% of samples and had a site maximum of 560µg/L, compared with 72% of samples in 2011 and a 2011 site maximum of 860µg/L. Similarly at COFFS4, TN exceeded trigger thresholds in 50% of samples in 2015, with a site maximum of 880µg/L, compared with 90% of samples in 2011 and a 2011 site maximum of 1270µg/L. However, although the exceedances at COFFS3 decreased from 100% in 2011 to 83% in 2015, the site maximum increased from 1190µg/L in 2011 to 1540µg/L in 2015. This latter site maximum is more than 5x the trigger threshold.

There were more exceedances in TP concentrations at COFFS1 in 2015 than 2011 (33% of samples compared with 18% of samples), but the 2015 site maximum was significantly lower (80µg/L compared with 110µg/L). This was still 2.7x the trigger threshold. Although the TP exceedances were comparable at COFFS3 in 2015 and 2011 (63% compared with 64%, respectively), the 2015 site maximum was greater at 150µg/L (compared with 120µg/L). This was similar at COFFS4, where TP exceedances increased from 10% in 2011 to 13% in 2015, with the 2015 site maximum (60µg/L) greater than the 2011 site maximum (55µg/L).

Chl-*a* concentrations were significantly higher in 2015 than 2011. In 2015 at COFFS1, chl-*a* exceeded the trigger threshold in 30% of samples with a site maximum of 4µg/L. In contrast, chl-*a* remained below the trigger threshold at COFFS1 in 2011. In 2015 at COFFS3, chl-*a* exceeded the trigger threshold in 50% of samples with a site maximum of 97µg/L. This maximum is more than 29x the trigger threshold and coincided with extremely high DO (23.4mg/L) and high turbidity (22NTU), indicating the existence of a nuisance algal bloom at this time. In contrast, chl-*a* at COFFS3 in 2011 exceeded the trigger threshold in 46% of samples with a much lower site maximum of 28µg/L. In 2015 at COFFS4, chl-*a* exceeded the trigger threshold in 25% of samples with a site maximum of 15µg/L; in 2011, chl-*a* at COFFS4 remained below the trigger threshold for the duration of sampling.

pH persistently fell below the minimum trigger threshold in the Coffs estuary. At COFFS1, minimum exceedances occurred in 43% of observations, with a site minimum of 6.79. At COFFS3, minimum exceedances occurred in 47% of observations, with a site minimum of 6.11. In contrast, pH at COFFS4 exceeded the minimum trigger threshold in 14% of samples (site minimum of 6.22) and the maximum trigger threshold in 57% of samples (site maximum of 9.0). In the estuary, DO% exceeded the maximum trigger threshold in 86% of observations at COFFS1 (site maximum of 162%) and 33% of observations at COFFS3 (site maximum of 119%). Some of these exceedances coincided with high chl-*a* and high turbidity, indicating the presence of algal blooms.

Faecal coliform counts exceeded the estuarine trigger threshold for primary contact three times at COFFS1. The site maximum was greater than the detection limit of 1000fc/100mL (November 2015) and greater than the 2011 site maximum of 950fc/100mL. Coliform counts also exceeded the trigger threshold in March 2015 (300fc/100mL) and August 2015 (172fc/100mL).

COFFS4 received a score of 65 (C-) for geomorphic condition. Bank erosion consisted of undercutting and slumping along both banks. Although the banks were well vegetated, they comprise fine-grained sediment and were prone to erosion.

COFFS4 was a very highly disturbed system of mixed regrowth and mature native forest surrounded by transport networks, urban and residential and recreational landuses. Riparian Condition at COFFS4 scored poorly with weedy species outweighing representative native species of the original vegetation community at each structural layer. Noxious and environmental weeds were abundant and heavily impacted the final site score. Despite visible attempts to remove Lantana, riparian vegetation condition could be markedly improved through continual strategic weed removal and control of weedy woody species. Native plantings along Coffs Creek will assist in site regeneration of native species, improved riparian continuity and could also be used to phase out and replace dominant canopy weed species such as Camphor Laurel. Implementation of large woody debris back into this system could reduce the exposure of plant roots and stablise river banks in the long term, promote niche habitats for native woody regeneration, provide habitat for native animal species, and as midstream snags, have the potential to slow down the erosive forces of unresisted water flows.

In 2011, the Ecohealth survey of riparian condition at COFFS4 assessed a comparatively intact strip of riparian vegetation, upstream of the bridge on Robin Street. While this assessment accurately graded the on-site remnant strip 73.2 (C+), it did not take into account the weedy species surrounding the bridge and adjacent cleared areas to the south of the site. Subsequently in the 2015 Ecohealth survey, it was decided to include the more representative vegetation surrounding the bridge on Robin Street in order to make a holistic assessment of both the remnant strip of vegetation in addition to its weedy surrounds. For the 2015 assessment, COFFS4 received a very poor riparian condition score of 50 (D). Because of the adjustment to the site location, no temporal comparison was made for this site.

COFFS4 received a score of 39 (F) for aquatic macroinvertebrate community condition. Although the macroinvertebrate indicators of family richness and total abundance were above the means for Coffs coastal catchments in 2015, the indicators for SIGNAL2 and particularly EPT were below the catchment means. The low mean scores and dominance of taxa with low SIGNAL2 scores suggests the water quality and habitat conditions in the freshwater reaches of Coffs Creek are in very poor condition.

Overall, macroinvertebrate community condition in COFFS4 improved slightly between 2011 AND 2015. Family richness and total abundance in 2015 were more than 3 times that in 2011. Although EPT richness declined in 2015, the abundance of EPT taxa increased. However, SIGNAL2 scores declined from 2011, primarily driven by the dominance of taxa with relatively low SIGNAL2 scores such as Glossiphoniidae (Leeches, SIGNAL2 of 1) and Chironomid Midge Larve (SIGNAL2 of 3) in autumn, and Hydrophilid Beetles (SIGNAL2 of 2) and Chironomid Midge Larve (SIGNAL2 of 3) in spring.

*Management Priorities – COFFS1 and COFFS3*

- Investigate TP sources to the estuary
- Investigate sources of faecal coliforms to the estuary

*Management Priorities – COFFS4*

- Investigate TP sources
- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species
- Phase out of Camphor: promotion of native canopy species and Camphor removal over time
- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian continuity and connectivity to larger tracts of remnant vegetation

### *4.2.8 Boambee/Newports Creeks*

*Boambee Creek*

Boambee Creek received an overall Ecohealth score of 68, a grade of C. The Boambee Creek estuary (66, C) comprised the lower estuary (BOAM1: 80, B) and the tidal limit (BOAM3: 51, D). The assessment of estuary condition consisted only of the water quality indicator, wheras the assessment of the freshwater reach (BOAM4: 73, C+) comprised geomorphic condition, riparian condition, water quality, aquatic macroinvertebrate community composition and fish community composition. Fish condition as assessed at 3 freshwater locations (Appendix B) and considered to be fair (C+).

Boambee Creek received a score of 71 (C+) for water quality, with the best water quality recorded at the freshwater site BOAM4 (82, B), closely followed by the lower estuary (BOAM1: 80, B). The water quality at the tidal limit was significantly worse (BOAM3: 51, D). At a subcatchment scale, this is an improvement from 2011 when Boambee Creek received a C-.

Some water quality indicators improved from 2011 to 2015. In 2015, concentrations of TN at BOAM1 remained below the trigger threshold for the duration of sampling (site maximum of 290µg/L), in contrast to 2011 that had exceedances in 73% of samples with a site maximum of 640µg/L. In contrast, at BOAM4, TN concentrations in 2015 had fewer exceedances (38% compared with 91% in 2011) but had a higher site maximum (250µg/L compared with 106µg/L in 2011). Similarly, although TN exceededances at BOAM3 were the same in 2015 and 2011 (100% of samples), the 2015 site maximum of 290µg/L was almost 3x the 2011 site maximum of 103µg/L.

TP remained below the trigger threshold in 2015 at all sites in Boambee Creek. This is a significant improvement from 2011 when maximum TP concentrations in all three sites were more than twice the trigger threshold. Chl-*a* concentrations in the lower estuary (BOAM1) remained below the trigger threshold in 2015, an improvement from 2011 when there was a brief exceedance (8% of samples with a site maximum of 8µg/L – twice the trigger threshold). Similarly, chl-*a* at BOAM4 remained below the trigger threshold, consistent with 2011 results. However, chl-*a* concentrations did increase at the tidal limit (BOAM3), with 50% of samples exceeding the trigger threshold (and a site maximum of 15µg/L, more than 4x the trigger threshold). This is a significant increase from 2011 (43% exceedances and a site maximum of 9µg/L). Generally, turbidity improved in Boambee Creek, with the only exceedances observed at BOAM3 (18% of samples and a site maximum of 18NTU).

DO% exceeded the maximum trigger threshold in 82% of observations at BOAM1 (site maximum of 170%). This was not associated with high chl-*a* or turbidity observations, indicating that high DO% was due to physical factors such as wave action, rather than biological factors such as an algal bloom. DO% fell below the minimum trigger threshold in 54% of samples at BOAM3 with a site minimum of 58.3%. pH was persistently lower than the minimum trigger threshold in Boambee estuary, with 40% and 60% of samples were below the minimum trigger threshold at BOAM1 (site minimum of 6.53) and BOAM3 (site minimum of 6.6), respectively. Faecal coliform counts at BOAM1 did not exceed the trigger threshold for primary contact during 2015, similar to 2011 observations. The site maximum was 40fc/100mL recorded in December 2015.

BOAM4 received a score of 83 (B) for geomorphic condition. The streambed was stable with no evidence of active erosion and management strategies should continue to maintain well-vegetated streambanks to maintain the good geomorphic condition of this reach.

BOAM4 was a moderately disturbed system of regrowth and mature remnant native forest, surrounded by transport networks, and both urban and rural landuses. Riparian Condition at BOAM4 scored fairly with representative elements of the remnant vegetation community present in all structural layers. Camphor Laurel, Lantana, and Coraltree are just some of the weeds of concern that were present on-site and negatively impacted on the overall riparian condition of BOAM4. Weed species at this site should be monitored for their spread downstream into higher quality remnant vegetation. Riparian condition could be markedly improved through weed removal and control of weedy woody species, while native plantings along Boambee Creek will assist in regeneration of native species. If strategically implemented, such plantings could improve both riparian vegetation continuity, and connectivity to surrounding remnant patches of native vegetation, e.g. along the creek towards the vegetation stand at Boambee East.

In 2011, BOAM4 scored 57.4 for riparian condition. Upon revision of the original site selection using recent satellite imagery (ADS40), it was decided to move the 2015 Ecohealth riparian assessment to an adjacent site downstream, deemed to be more representative of the broader surrounding vegetation community. The result was an improved and more representative score of 70.7 (C+), as it took into account both weedy species in the disturbed area, along with the remnant vegetation of the Flooded gum – Bangalow palm community. It should be noted that the site score would not have improved if the same site from the 2011 Ecohealth round had been resampled, due to a dominance of weed species in the disturbed area surrounding the bridge.

BOAM4 received a score of 52 (D), for aquatic macroinvertebrate communities. All four macroinvertebrate indicators were slightly above the means calculated for the Coffs coastal catchments in 2015 and BOAM4 was one of the 2 sites that recorded all three EPT Orders. There was a slight decline in the condition of aquatic macroinvertebrate communities in BOAM4 between 2011 and 2015. Although family richness, total abundance and EPT abundance were higher in 2015, mean SIGNAL2 scores were lower, particularly between the spring assessments. This is driven by higher abundances of biota with low SIGNAL2 scores (e.g. Water Slaters), rather than a loss of biota with high SIGNAL2 scores.

*Management Priorities – BOAM1 and BOAM3*

- Investigate sources of TN to BOAM3

*Management Priorities – BOAM4*

- Investigate sources of TN
- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species
- Phase out of Camphor: promotion of native canopy species and Camphor removal over time
- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian continuity and connectivity to larger tracts of remnant vegetation

*Newports Creek*

Newports Creek received an overall Ecohealth score of 50, a grade of D. The estuary (NEW2: 45, D-) was in poorer condition overall than the freshwater reach (NEW3: 55, D+). The assessment of estuary condition consisted only of the water quality indicator, wheras the assessment of the freshwater reach comprised geomorphic condition, riparian condition, water quality and aquatic macroinvertebrate community composition.

Newports Creek received a score of 64 (C-) for water quality, with the water quality at the freshwater site (NEW3: 83, B) much better than in the estuary (NEW2: 45, D-). At the subcatchment scale, this was a decline from 2011 when Newports Creek received a C+.

Although there was an overall decline in water quality across Newports Creek, concentrations of TN and TP were lower in 2015 than 2011. In 2015, TN concentrations at NEW2 exceeded the trigger threshold in 88% of samples with a site maximum of 470μg/L, and concentrations at NEW3 exceeded trigger thresholds in 13% of samples with a site maximum of 520μg/L. This is an improvement from 2011, where 99% and 70% of samples exceeded trigger thresholds at NEW2 and NEW3, with site maximums of 760μg/L and 750μg/L, respectively. Similar to Boambee Creek, TP concentrations in 2015 remained below trigger thresholds in NEW2 and NEW3. This meant that site maximums in 2015 were less than half those of 2011.

Surprisingly, despite the decreases in nutrients, chl-*a* concentrations were significantly worse in 2015 than 2011. In 2015, chl-*a* at NEW2 exceeded the trigger threshold in 50% of samples with a site maximum of 14μg/L (compared with 16% of samples and a site maximum of 5μg/L in 2011). 2015 chl-*a* concentrations at NEW3 exceeded the trigger threshold in 25% of samples also with a site maximum of 14μg/L (compared with 8% of samples and a site maximum of 6μg/L in 2011). Given the decreases in total nutrient concentrations and the increases in chl-*a* concentrations in Newports Creek, it is worth investigating the concentrations of bioavailable nutrients at these sites to identify whether these are driving increases in algal productivity in Newports Creek.

DO% exceeded the maximum trigger threshold in 56% of samples at NEW2, with a site maximum of 142.6%. However, these exceedances did not coincide with high chl-*a* concentrations, suggesting physical drivers such as wave action. While DO% was very variable at NEW3, exceeding both the maximum and minimum trigger thresholds, the site minimum of 42% had a concentration of 3.93mg/L and had the potential to impact aquatic biota (macroinvertebrates and fish) and facilitate sediment nutrient regeneration processes. NEW2 persistently had lower pH than the minimum trigger threshold (100% of samples, with a site minimum of 5.44).

NEW3 received a score of 62 (C-) for geomorphic condition. The survey site was adjacent to a light industrial area and was impacted by a stormwater drain and cleared left bank. Hence, geomorphic complexity of the streambed was low, with the channel comprising a shallow run. Bank erosion was minimal and confined to undercutting of both banks. Management strategies to improve the geomorphic condition of NEW3 should focus on native revegetation of the left bank.

NEW3 was a moderate to highly disturbed system of regrowth and mature remnant native forest surrounded by transport networks, urban and other commercial landuses. Riparian Condition at

NEW3 scored moderately with representative elements of the remnant vegetation community present in all structural layers. Camphor Laurel, Lantana, and Privet species were weeds of concern and negatively impacted the overall site grade. Riparian condition could be markedly improved through weed removal and control of woody weed species, while native plantings along Newports Creek will assist in site regeneration of native species, and if strategically implemented, could improve riparian vegetation continuity and connectivity to surrounding remnant patches of native vegetation, e.g. east towards Coffs Harbour Airport or west towards Boambee State Forest.

Similarly to COFFS4, the 2011 survey of riparian condition at NEW3 assessed a comparatively intact strip of riparian vegetation. While this assessment graded the on-site remnant strip 72.6 (C+), it did not take into account the adjacent partially cleared, weedy riparian zone upstream. Following a desktop satellite imagery review of Newports Creek, it was decided to move the 2015 Ecohealth site upstream to make a holistic assessment of both the remnant strip of vegetation and its partially cleared weedy surrounds. Hence, no temporal comparison can be made for this site at this time.

NEW3 received a score of 14 (F), for aquatic macroinvertebrate communities, indicating the water quality and habitat conditions in the freshwater reaches of Newports Creek are in very poor condition. Three of the four macroinvertebrate indicators were substantially below the means calculated for the Coffs coastal catchments in 2015: family richness, EPT richness and abundance, and total abundance. There was a slight decline in the condition of aquatic macroinvertebrate communities in NEW3 between 2011 and 2015. Although family richness was greater, total abundances were less consistent between seasons in 2015. Abundances of EPTs increased slightly in 2015. The most significant decrease was in mean SIGNAL2 scores, which dropped from a site mean of 4.35 in 2011 to 3.75 in 2015.

*Management Priorities – NEW2*

- Investigate whether bioavailable nutrients are driving chl-a

*Management Priorities – NEW3*

- Investigate whether bioavailable nutrients are driving chl-a
- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species
- Phase out of Camphor: promotion of native canopy species and Camphor removal over time
- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian continuity and connectivity to larger tracts of remnant vegetation

### *4.2.9 Bonville/Pine Creeks*

*Bonville Creek*

Bonville Creek received an overall Ecohealth score of 75, a grade of C+. The Bonville estuary (74, C+) comprised the lower estuary (BONV1: 89, B+) and the tidal limit (BONV3: 58, D+). The freshwater reach was assessed by a single site BONV4 (76, B-). The assessment of estuary condition consisted only of the water quality indicator, whereas the assessment of the freshwater reach comprised geomorphic condition, riparian condition, water quality, aquatic macroinvertebrate community composition and fish community composition. Fish condition was assessed at 3 freshwater locations (Appendix B) and considered to be good (86, B+).

Bonville Creek received a score of 73 (C+) for water quality, with the best water quality recorded in the lower estuary (BONV1: 89, B+), followed by the freshwater reach (BONV4: 72, C+). The poorest water quality was recorded at the tidal limit (BONV3: 58, D+). At the subcatchment scale, this is an improvement from 2011 when Bonville Creek received a C.

Total nutrient concentrations improved from 2011 to 2015 at all sites on Bonville Creek. In contrast to 2011, TN at BONV1 and BONV4 remained below the trigger thresholds in 2015. At BONV3, TN exceeded the trigger threshold in 25% of samples in 2015 with a site maximum of 420µg/L, compared with 73% of samples and a site maximum of 660µg/L in 2011. TP concentrations remained below trigger thresholds at all sites on Bonville Creek in 2015. This is in contrast to 2011, where exceedances occurred at all 3 sites and site maximums were double the trigger threshold in the estuary and 3x the trigger threshold in the freshwater reach. Chl-*a* concentrations remained below the trigger thresholds at BONV1 and BONV4 in 2015, but exceeded the trigger threshold in 50% of samples at BONV3 (site maximum of 18µg/L). Turbidity also increased at the tidal limit in 2015, with 29% of samples exceeding the trigger threshold and a site maximum of 75.1NTU, more than 7x the trigger threshold.

While DO% exceeded the maximum trigger threshold in 37% of samples at BONV1 in 2015 (site maximum of 216.3%), this did not coincide with any exceedances in chl-*a* or turbidity, indicating that high DO% at BONV1 was driven by physical factors such as wave action, rather than biological factors such as high algal productivity. In contrast, DO% fell below the minimum trigger threshold in 67% of observations at BONV3. The site minimum was 4.6% and this equated to 0.46mg/L, a very low concentration potentially impacting aquatic biota (macroinvertebrates and fish) and facilitating sediment nutrient regeneration processes.

pH was persistently below the minimum trigger threshold in the estuary, with 30% and 72% of observations at BONV1 (site minimum of 6.6) and BONV3 (site minimum of 4.28), respectively. The very low pH observed at BONV3 warrents further investigation into sources of acidity to the upper estuary.

Faecal coliform counts at BONV1 did not exceed the trigger threshold for primary contact during 2015, similar to 2011 observations. The site maximum was 60fc/100mL recorded in July 2015.

BONV4 received a score of 63 (C-) for geomorphic condition. There was significant active erosion of both banks, predominantly severe undercutting associated with being the outside of a bend on the left bank and bridge scour on the right bank. The right bank was unfenced and showed recent signs of stock access.

BONV4 was a moderately disturbed system of regrowth, mature remnant native forest, and cleared land, surrounded by transport networks, grazing, state forest and other rural landuses including horticulture. Riparian Condition at BONV4 was fair with representative elements of the remnant vegetation community present in all structural layers. The impact of livestock brought about by a lack of riparian fencing, in addition to noxious weed presence and regeneration appear to be having the greatest on-site impacts on riparian condition. Weed removal and management, and riparian fencing could allow for natural regeneration of native species and markedly improve on-site riparian condition.

In 2011, riparian condition at BONV4 scored 65 (C). The 2015 assessment of the same site gave riparian condition a score of 66.2 (C). Hence, very little change (1.2%) was detected in the four years between Ecohealth surveys. The slight increase in site score can likely be attributed to both an increase in midstory and herb/forb cover.

BONV4 recorded the best aquatic macroinvertebrate community condition of the Coffs coastal catchments, receiving a score of 94 (A-). All four macroinvertebrate indicators were significantly above the average for Coffs coastal catchments in 2015. Macroinvertebrate community composition in BONV4 improved from a B in 2011 to an A- in 2015. These improvements were due to increased family richness, total abundance and particularly EPT richness and abundance. Mean SIGNAL2 scores and the range of SIGNAL2 scores were also similar between 2011 and 2015. The aquatic macroinvertebrate community at BONV4 is in excellent condition: removal of stock through fencing the riparian zone would promote bank stability and reduce the sediment input and loss of good quality aquatic habitat commonly associated with bank erosion.

*Management Priorities – BONV1 and BONV3*

- Investigate sources of acidity to the estuary (particularly BONV3)
- Investigate whether bioavailable nutrients are driving chl-a in BONV3

*Management Priorities – BONV4*

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species
- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian continuity and connectivity to larger tracts of remnant vegetation
- Riparian fencing: to reduce livestock impact, encourage native regeneration, promote bank stability and protect the excellent condition of the aquatic macroinvertebrate community

*Pine Creek*

Pine Creek received an overall Ecohealth score of 62, a grade of C-. Pine Creek estuary was assessed by a single site PINE2 (57, D+), as was the freshwater reach (PINE3: 66, C). The assessment of estuary condition consisted only of the water quality indicator, whereas the assessment of the freshwater reach comprised geomorphic condition, riparian condition, water quality and aquatic macroinvertebrate community composition.

Pine Creek received a score of 64 (C-) for water quality, with better water quality in the freshwater reach (PINE3: 70, C+) than the upper estuary (PINE2: 57, D+). At the subcatchment scale, this is slight decline from 2011 when Pine Creek received a C. The poorest water quality for the subcatchment was observed at the tidal limit in both assessments.

Like Bonville Creek, total nutrient concentrations improved across both sites in Pine Creek from 2011 to 2015. TN concentrations remained below trigger thresholds at PINE3 in 2015, in comparison with 11% of samples exceeding the trigger threshold in 2011 (site maximum of 780µg/L). TN at PINE2 exceeded the trigger threshold in 50% of samples in 2015, with a site maximum of 420µg/L. This is an improvement from 2011, where 82% of samples exceeded the trigger threshold (site maximum of 610µg/L). Also similar to Bonville Creek, TP concentrations in Pine Creek remained below the trigger thresholds in 2015, a significant decrease from 2011 when TP was more than twice the trigger thresholds.

Chl-*a* concentrations only exceeded the trigger threshold at the tidal limit (PINE2) in 2015, a pattern that is consistent across Boambee and Bonville Creeks. In 2015, chl-*a* exceeded the trigger threshold in 40% of samples at PINE2 with a site maximum of 5µg/L. This is a significant decrease from 2011, when 36% of samples exceeded the trigger threshold and the site maximum was 17µg/L (more than 5x the trigger threshold).

DO% was variable across Pine Creek, exceeding the minimum and maximum trigger thresholds at both sites. At PINE2, the site minimum was 53.2% and site maximum was 186.3% and this coincided with the maximum chl-*a* concentration. However, the chl-*a* maximum of 5µg/L does not suggest high algal productivity, indicating that physical factors are primarily responsible for high DO%. At PINE3, the site minimum was 53.7% and site maximum was 125%. pH persistently fell below the minimum trigger threshold at PINE2, with 65% of observations below the trigger threshold and a site minimum of 6.09.

PINE3 received a score of 65 (C-) for geomorphic condition. There was moderate active erosion at this site with bank undercutting associated with bridge scour and bank slumping on both banks. The uptream part of the site was unfenced and there was severe pugging/trampling by stock. Fencing the riparian zone at the upstream half of the study reach would reduce stock access and trampling of banks and revegetating these banks with native vegetation would also improve the geomorphic condition of this site.

PINE3 was a moderately disturbed system of regrowth, mature remnant native forest and cleared land. The surrounding landuses are transport networks, forestry, and cattle grazing. Riparian Condition at PINE3 scored moderately with representative elements of the remnant vegetation community present in all structural layers. Lantana and the macrophyte Cabomba are just some of the weeds of concern that were present on-site and negatively impacted the overall riparian condition of PINE3. Riparian condition could be markedly improved by addressing weed species at this site, through phasing out techniques, removal and or monitoring for their spread downstream into higher quality patches of remnant vegetation. Additional plantings to those already present on-site could extend into the cleared sections of the riparian zone to assist with native species regeneration. If strategically implemented, such plantings could also improve the overall depth of riparian vegetation. The introduction of large woody debris and adequate fencing would also significantly improve riparian condition.

In 2011, riparian condition at PINE3 received a score of 72.4 (C+). The 2015 assessment of the same site gave riparian condition a score of 70.7 (C+), suggesting very little change (1.7%) occurred in the four years between Ecohealth surveys. The slight decrease in site score can be attributed to both an increase in midstory weeds and exotic species leaf litter.

PINE3 received a score of 59 (D+), for aquatic macroinvertebrate community condition. This suggests the water quality and habitat conditions in the freshwater reaches of Pine Creek are in poor condition. Nonetheless, all four macroinvertebrate indicators were above the average for Coffs coastal catchments. Significantly, the condition of aquatic macroinvertebrate communities in PINE3 improved between 2011 and 2015. Family richness in 2015 was almost 3x that in 2011. Abundances in 2015 were more than 3x those of 2011. EPT richness and abundances were also greater and this persisted across both sampling seasons. Mean SIGNAL2 scores declined due to the community consisting of a greater number of low-scoring biota.

*Management Priorities – PINE2*

- Investigate sources of acidity
- Investigate whether bioavailable nutrients are driving chl-a

*Management Priorities – PINE3*

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species
- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian continuity and connectivity to larger tracts of remnant vegetation
- Riparian fencing: to reduce livestock impact, encourage native regeneration and improve bank stability

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***APPENDIX A*** *Dominant plant species recorded at the 11 Ecohealth sites assessed in the 2015 survey. Rows in red indicate exotic species.*

| Growth Form | N/E | Family | Genus | Species | Common Name | Saltwater Ck #3 | Corindi #4 | Arrawarra #4 | Woolgoolga #4 | Hearns Lake #4 | Moonee #4 | Coffs #4 | Newport #3 | Boambee #4 | Pine #3 | Bonville #4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Macrophytes | N | Cyperaceae | Baumea | articulata | Jointed Twig-rush | Y | | | | | | | | | | Y |
| Macrophytes | N | Cyperaceae | Baumea | rubiginosa | Soft Twig-rush | | | Y | | Y | | | | | | |
| Macrophytes | E | Cabombaceae | Cabomba | caroliniana | Cabomba | | | | | | | | | | Y | |
| Macrophytes | N | Cyperaceae | Carex | appressa | Tall Sedge | | | Y | | | | | | | | |
| Macrophytes | E | Cyperaceae | Cyperus | eragrostis | Umbrella Sedge | | | | | | | | Y | | | |
| Macrophytes | N | Elatinaceae | Elatine | gratioloides | Waterwort | | | | Y | | | | | | Y | |
| Macrophytes | N | Cyperaceae | Eleocharis | sphacelata | Tall Spikerush | | | Y | Y | | Y | | | | Y | |
| Macrophytes | N | Cyperaceae | Isolepis | inundata | A Club Sedge | | | | Y | | | | | | | Y |
| Macrophytes | N | Cyperaceae | Lepironia | articulata | Grey Rush | Y | | | | | | | | | | |
| Macrophytes | N | Onagraceae | Ludwigia | peploides | Water Primrose | | | | Y | | | | | | | |
| Macrophytes | N | Menyanthaceae | Nymphoides | indica | Water Snowflake | | | | | | Y | | | | Y | |
| Macrophytes | N | Hydrocharitaceae | Ottelia | ovalifolia | Swamp Lily | | Y | Y | | | Y | | | | Y | |
| Macrophytes | N | Polygonaceae | Persicaria | decipiens | Slender Knotweed | Y | | | | | | | | | | |
| Macrophytes | N | Polygonaceae | Persicaria | strigosa | Spotted Knotweed | | | | Y | | | | | | Y | Y |
| Macrophytes | N | Polygonaceae | Persicaria | hydropiper | Knotweed | | Y | | | | | | Y | Y | | |
| Macrophytes | N | Philydraceae | Philydrum | lanuginosum | Woolly Frogmouth | Y | | Y | | | | | | | | |
| Macrophytes | N | Poaceae | Phragmites | australis | Common Reed | Y | | Y | | | | | | | | |
| Macrophytes | N | Potamogetonaceae | Potamogeton | ochreatus | Blunt Pondweed | | | | | | | | | | Y | |
| Macrophytes | N | Potamogetonaceae | Potamogeton | ochtandrus | Small Pondweed | | | | | | | | Y | | | |
| Macrophytes | N | Cyperaceae | Schoenoplectiella | mucronatus | Triangular Club-rush | | | | | | | | | | Y | |
| Macrophytes | N | Cyperaceae | Schoenoplectus | validus | River Club-rush | Y | | | Y | | | | | | | |
| Macrophytes | N | Juncaginaceae | Triglochin | procera/microtuberosum | Water Ribbons | Y | Y | Y | | | Y | | | | Y | |
| Macrophytes | | | Lily | sp. | Unknown | Y | | | | | | | | | | |
| Graminoides | E | Poaceae | Andropogon | viginicus | Whisky Grass | Y | | | | | | | | Y | Y | |
| Graminoides | E | Poaceae | Bambusa | sp. | Bamboo | | Y | | | | | | | Y | | |
| Graminoides | E | Poaceae | Bromus | catharticus | Prairie Grass | | | Y | Y | | | Y | Y | | | |
| Graminoides | N | Cyperaceae | Carex | fascicularis | Tassel Sedge | | | | | | | | | | Y | |
| Graminoides | E | Poaceae | Chloris | gayana | Rhodes Grass | | | Y | | | | | | | | |
| Graminoides | N | Poaceae | Cynodon | dactylon | Couch | | | | Y | | | | | | | |
| Graminoides | E | Cyperaceae | Cyperus | involucratus | False Papyrus | | | | | | | | | | | Y |
| Graminoides | N | Poaceae | Echinopogon | ovatus | Forest Hedgehog Grass | | | | | | Y | | | | | |
| Graminoides | N | Poaceae | Entolasia | marginata | Boardered Panic | Y | | | | | | | | | | |
| Graminoides | N | Cyperaceae | Ghania | clarkei | Tall Saw-sedge | Y | | Y | | | Y | | | Y | | |
| Graminoides | N | Poaceae | Imperata | cylindrica | Blady Grass | | Y | | | | | | | Y | Y | |
| Graminoides | N | Juncaceae | Juncus | usitatus | Common Rush | | Y | Y | Y | | | | | Y | Y | Y |
| Graminoides | N | Cyperaceae | Lepidosperma | laterale | Variable Sword-sedge | | | Y | | | | | | | | |
| Graminoides | N | Lomandraceae | Lomandra | longifolia | Spiny-headed Mat-rush | | | Y | | | Y | | | Y | Y | Y |
| Graminoides | N | Lomandraceae | Lomandra | hystrix | Soft Lomandra | | Y | Y | Y | Y | Y | | Y | Y | Y | |
| Graminoides | E | Poaceae | Melinis | minutoflora | Molasses Grass | | | | Y | | | | | | | |
| Graminoides | N | Poaceae | Oplismenus | imbecillis | Creeping Beard Grass | Y | Y | Y | Y | Y | Y | | Y | Y | | Y |
| Graminoides | E | Poaceae | Paspalum | mandiocanum | Broadleaf Paspalum | | Y | | | | | Y | | | | |
| Graminoides | E | Poaceae | Paspalum | dilatatum | Paspalum | | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Graminoides | N | Poaceae | Paspalum | distichum | Water Couch | | | | | | | | | Y | | |
| Graminoides | E | Poaceae | Setaria | sphacelata | Pigeon Grass | | | | | | | | Y | Y | Y | |
| Graminoides | N | Restionaceae | Sporadanthus | interruptus | | Y | | | | | | | | | | |
| Graminoides | E | Poaceae | Stenotaphrum | secundatum | Buffalo Grass | | | | Y | | | | | | | |
| Graminoides | N | Poaceae | Themeda | australis | Kangaroo Grass | | | Y | | Y | Y | | | | | |
| Herbs/Forbs | N | Pteridaceae | Adiantum | aethiopicum | Common Maidenhair | | | Y | | | | | | | | |
| Herbs/Forbs | N | Pteridaceae | Adiantum | hispidulum | Five-finger Maidenhair | | | | | | | | | | | Y |
| Herbs/Forbs | N | Pteridaceae | Adiantum | formosum | Black-stem Maidenhair | | | | | Y | | | | | | |
| Herbs/Forbs | E | Asteracea | Agerating | adenophora | Crofton Weed | Y | | | Y | Y | | Y | | Y | Y | Y |
| Herbs/Forbs | E | Asteracea | Ageratum | houstonianum | Blue Billy Goat Weed | | | Y | Y | | | Y | Y | Y | Y | Y |
| Herbs/Forbs | E | Asteracea | Bidens | pilosa | Coblers Pegs | | | | | | | Y | Y | Y | | Y |
| Herbs/Forbs | N | Blechnaceae | Blechnum | indicum | Swamp Water Fern | Y | | Y | | | | | | | | |
| Herbs/Forbs | N | Blechnaceae | Blechnum | cartilagineum | Soft Water Fern | | | | Y | Y | | | | Y | Y | |
| Herbs/Forbs | N | Dicksoniaceae | Calochlaena | dubia | Rainbow Fern | | | | | | Y | | | | | |
| Herbs/Forbs | E | Cannaceae | Canna | indica | Tous-les-mois-Arrowroot | | | | | | | | | Y | | |
| Herbs/Forbs | E | Araceae | Colocasia | esculenta | Elephants Ear | | | | | | | Y | | Y | | |
| Herbs/Forbs | N | Commelinaceae | Commelina | cyanea | Native Wandering Jew | | | | Y | | | | Y | Y | | Y |
| Herbs/Forbs | N | Orchidaceae | Cryptostylis | subulata | Large Tongue Orchid | Y | | | | | | | | | | |
| Herbs/Forbs | N | Goodeniaceae | Dampiera | sylvestris | Blue Beauty-bush | | | Y | | | | | | | | |
| Herbs/Forbs | E | Fabaceae | Desmodium | intortum | Green-leaved Desmodium | Y | | Y | | | | Y | | Y | Y | |
| Herbs/Forbs | N | Phormaceae | Dianella | caerulea | Blue Flax-lily | | | Y | | | Y | | | | | |
| Herbs/Forbs | N | Blechnaceae | Doodia | aspera | Prickly Rasp fern | | | | | | | | | Y | | |
| Herbs/Forbs | N | Gleicheniaceae | Gleichenia | dicarpa | Coral Fern | Y | | Y | | | | | | | Y | |
| Herbs/Forbs | N | Goodeniaceae | Goodenia | stelligera | Spiked Goodenia | Y | | | | | | | | | | |
| Herbs/Forbs | N | Apiaceae | Hydrocotyle | laxiflora | Stinking Pennywort | | | | | | | | Y | Y | | |
| Herbs/Forbs | N | Dennstaedtiaceae | Hypolepis | muelleri | Harsh Ground Fern | | | | | | | Y | | Y | Y | |
| Herbs/Forbs | N | Lomariopsidaceae | Nephrolepis | cordifolia | Fishbone Fern | | | | | | | Y | | Y | | |
| Herbs/Forbs | N | Dennstaedtiaceae | Pteridium | esculentum | Common Bracken | | | Y | | | Y | Y | | | | |
| Herbs/Forbs | E | Polygonaceae | Rumex | crispus | Curled Dock | | | | Y | | | | | | | |
| Herbs/Forbs | E | Alismataceae | Sagittaria | sp. | Sagittaria | | | | | | | | | | Y | |
| Herbs/Forbs | E | Lamiaceae | Salvia | coccinea | Scarlet Sage | | | | Y | | | | | | | |
| Herbs/Forbs | E | Asteracea | Senecio | madagascariensis | Fireweed | | | | | | | | | | | Y |
| Herbs/Forbs | E | Lamiaceae | Sida | rhombifolia | Sidratusa | | Y | | | | | | | | Y | |
| Herbs/Forbs | E | Solanaceae | Solanum | nigrum | Black-berry Nightshade | | | | | | | | | Y | | |
| Herbs/Forbs | E | Asteracea | Sphagneticola | trilobata | Singapore Daisy | | | | | | | | | Y | | |
| Herbs/Forbs | N | Gleicheniaceae | Sticherus | flabellatus | Umbrella Fern | | | | | | | | | | | Y |
| Herbs/Forbs | E | Asteracea | Tithonia | diversifolia | Japanese Sunflower | | | | | | | Y | | | | |
| Herbs/Forbs | E | Commelinaceae | Tradescantia | fluminensis | Wandering Jew | | Y | | Y | | | Y | | Y | Y | |
| Herbs/Forbs | N | Violaceae | Viola | banksii | Wild Violet | Y | Y | | | | | | | | Y | |

| Growth Form | N/E | Family | Genus | Species | Common Name | Saltwater Ck #3 | Corindi #4 | Arrawarra #4 | Woolgoolga #4 | Hearns Lake #4 | Moonee #4 | Coffs #4 | Newport #3 | Boambee #4 | Pine #3 | Bonville #4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Shrubs | N | *Fabaceae* | *Acacia* | *irrorata* | Green Wattle | | Y | | | | | | | | Y | |
| Shrubs | N | *Mimosoideae* | *Acacia* | *fimbriata* | Brisbane Golden Wattle | Y | | Y | | | | | | | | |
| Shrubs | N | *Zingiberaceae* | *Alpinia* | *caerulea* | Native Ginger | | | | | Y | | | | | | |
| Shrubs | E | *Myrsinaceae* | *Ardisia* | *crenata* | Coral Berry | | | | | | | | | Y | | |
| Shrubs | E | *Asteracea* | *Baccharis* | *halimifolia* | Groundsel Bush | Y | | | | | | | | | | |
| Shrubs | N | *Proteacea* | *Banksia* | *sp.* | aemula? | Y | | | | | | | | | | |
| Shrubs | N | *Proteacea* | *Banksia* | *oblongifolia* | Dwarf Banksia | | | | | | Y | | | | | |
| Shrubs | N | *Proteacea* | *Banksia* | *spinulosa* | Candlestick Banksia | | | Y | | | | | | | | |
| Shrubs | N | *Cunoniaceae* | *Callicoma* | *serratifolia* | Black Wattle | | | | | | | | | Y | Y | Y |
| Shrubs | N | *Myrtaceae* | *Callistemon* | *salignus* | Willow Bottlebrush | | | | | | Y | | | | Y | |
| Shrubs | E | *Asteracea* | *Chrysanthemoides* | *Monilifera subsp. Rotundata* | Bitou Bush | Y | | | | | | | | | | |
| Shrubs | N | *Asteliaceae* | *Cordyline* | *stricta* | Narrow-leaved Palm Lily | | | | | Y | Y | Y | | Y | | Y |
| Shrubs | N | *Rousseaceae* | *Cuttsia* | *virburnea* | Elderberry | | | | | | | | | | | Y |
| Shrubs | N | *Cyatheaceae* | *Cyathea* | *australis* | Rough Tree-Fern | | | Y | | Y | | | | | | |
| Shrubs | N | *Sapindaceae* | *Dodonaea* | *triquetra* | Large-leaf Hop-Bush | Y | | | | | Y | | | | | |
| Shrubs | N | *Elaeocarpaceae* | *Elaeocarpus* | *reticulatus* | Blueberry Ash | | | | | | Y | | | | | |
| Shrubs | N | *Moraceae* | *Ficus* | *coronata* | Sandpaper Fig | | Y | | Y | Y | | Y | Y | Y | Y | Y |
| Trees | N | *Phyllanthaceae* | *Glochidion* | *ferdinandi* | Cheese Tree | | | | | | | Y | Y | | Y | |
| Shrubs | N | *Euphorbiaceae* | *Homalanthus* | *populifolius* | Bleeding Heart | | | | Y | | | | | | | |
| Shrubs | E | *Verbenaceae* | *Lantana* | *camara* | Lantana | | Y | Y | Y | Y | Y | | Y | Y | Y | Y |
| Shrubs | N | *Myrtaceae* | *Leptospermum* | *polygalifolium subsp. cismontanum* | | Y | | | | | | | | | | |
| Shrubs | E | *Oleaceae* | *Ligustrum* | *sinense* | Small-leaved Privet | | | | | | | Y | Y | | | |
| Shrubs | E | *Oleaceae* | *Ligustrum* | *lucidum* | Large-leaved Privet | | | | | | | | Y | | | Y |
| Shrubs | N | *Arecaceae* | *Linospadix* | *monostachyos* | Walking Stick Palm | | Y | | | | | | | | | |
| Shrubs | E | *Malvaceae* | *Malvaviscus* | *arboreus* | Ladies Teardrop | | | | | | | Y | | Y | | |
| Shrubs | N | *Myrtaceae* | *Melaleuca* | *ericifolia* | Swamp Paperbark | Y | | Y | | | | | | | | |
| Shrubs | E | *Musaceae* | *Musa* | *sp.* | Banana | | | | | Y | | | | | | |
| Shrubs | N | *Oleaceae* | *Notelaea* | *longifolia* | Large Mock Olive | | | | | | Y | | | | | |
| Shrubs | N | *Oleaceae* | *Notelaea* | *venosa* | Large-leaved Mock Olive | | | Y | | | | | | | | |
| Shrubs | E | *Ochnaceae* | *Ochna* | *serrulata* | Mickey Mouse Plant | | | | | | | Y | | | | Y |
| Shrubs | N | *Pittosporaceae* | *Pittosporum* | *multiflorum* | Orange Thorn | | Y | | | | | | | | | |
| Shrubs | N | *Pittosporaceae* | *Pittosporum* | *undulatum* | Sweet Pittosporum | | | | Y | | | Y | | Y | | |
| Trees | N | *Myrtaceae* | *Rhodamnia* | *rubescens* | Scrub Turpentine | | Y | | | | | | | | | |
| Shrubs | E | *Caesalpinioideae* | *Senna* | *septemtrionalis* | Arsenic Bush | | Y | | | | | | | Y | Y | |
| Shrubs | E | *Caesalpinioideae* | *Senna* | *pendula var. glabrata* | Senna | Y | | Y | Y | Y | | | Y | Y | | |
| Shrubs | E | *Solanaceae* | *Solanum* | *mauritianum* | Wild Tobacco | | Y | | Y | | | Y | | | | |
| Shrubs | N | *Apocynaceae* | *Tabernaemontana* | *pandacaqui* | Banana Bush | | Y | | | Y | | | | | | |
| Shrubs | N | *Xanthorrhoeaceae* | *Xanthorrhoea* | *macronema* | Bottle Brush Grass Tree | | | | | | Y | | | | | |
| Trees | N | *Euphorbiaceae* | *Alchornea* | *ilicifolia* | Native Holly | | | | | Y | | | | | | |
| Trees | N | *Casuarinaceae* | *Allocasuarina* | *littoralis* | Black Oak | | | Y | | | | | | | | |
| Trees | N | *Casuarinaceae* | *Allocasuarina* | *torulosa* | Forest Oak | Y | | | Y | | Y | | | | | |
| Trees | N | *Myrtaceae* | *Angophora* | *costata* | Apple Gum | | | | | | Y | | | | | |
| Trees | N | *Araucariaceae* | *Araucaria* | *cunninghamii* | Hoop Pine | | | | | | | Y | | | | |
| Trees | N | *Arecaceae* | *Archontophoenix* | *cunninghamiana* | Bangalow Palm | | Y | | | Y | | Y | | | | Y |
| Trees | N | *Myrtaceae* | *Backhousia* | *myrtifolia* | Ironwood | | Y | | | | | | | | | |
| Trees | N | *Casuarinaceae* | *Casuarina* | *glauca* | Swamp Oak | Y | | | | | Y | | | | Y | |
| Trees | N | *Cunoniaceae* | *Cerratopetalum* | *apetalum* | Coachwood | | | | | | | | | | | Y |
| Trees | E | *Lauraceae* | *Cinnamomum* | *camphora* | Camphor Laurel | | Y | | | | | Y | Y | Y | | |
| Trees | N | *Myrtaceae* | *Corymbia* | *gummifera* | Red Bloodwood | | | | | | | | | | Y | |
| Trees | N | *Sapindaceae* | *Cupaniopsis* | *anacardioides* | Tuckeroo | | | | | Y | | Y | Y | | | |
| Trees | E | *Fabaceae* | *Erythrina* | *crista-galli* | Cockspur Coraltree | | | | | | | | | Y | | |
| Trees | N | *Myrtaceae* | *Eucalyptus* | *planchoniana* | Bastard Tallowood | Y | | | | | | | | | | |
| Trees | N | *Myrtaceae* | *Eucalyptus* | *robusta* | Swamp Mahogany | Y | | | | | Y | | | | | |
| Trees | N | *Myrtaceae* | *Eucalyptus* | *microcorys* | Tallowwood | | | Y | Y | Y | Y | | | Y | | |
| Trees | N | *Myrtaceae* | *Eucalyptus* | *pilularis* | Blackbutt | Y | | Y | Y | Y | Y | | | | | |
| Trees | N | *Myrtaceae* | *Eucalyptus* | *grandis* | Flooded Gum | | Y | | Y | Y | | Y | Y | Y | Y | Y |
| Trees | N | *Moraceae* | *Ficus* | *macrophylla* | Morton Bay Fig | | | | | Y | | | | | | |
| Trees | N | *Moraceae* | *Ficus* | *sp.* | Watkinsiana? | | | | | | | Y | | | | |
| Trees | N | *Proteacea* | *Grevillea* | *robusta* | Silky Oak | | | | | | | | | Y | | |
| Trees | E | *Bignoniaceae* | *Jacaranda* | *mimosifolia* | Jacaranda | | | | | | | Y | | | | |
| Trees | N | *Sapindaceae* | *Jagera* | *pseudorhus* | Foam Bark Tree | | | | | | | | | Y | | |
| Trees | N | *Myrtaceae* | *Lophostemon* | *confertus* | Brush Box | Y | Y | Y | Y | Y | | Y | Y | Y | Y | Y |
| Trees | N | *Myrtaceae* | *Melaleuca* | *quinquenervia* | Broad-leaved Paperbark | Y | | Y | | | Y | | | | Y | |
| Trees | N | *Rutaceae* | *Melicope* | *sp.* | Elleryana/Micrococca | | | | | | Y | | | Y | | |
| Trees | N | *Sapindaceae* | *Mischocarpus* | *pyriformis* | Yellow Pear-Fruit | | Y | | | | | | | | | |
| Trees | E | *Moraceae* | *Morus* | *alba* | Mulberry | | | | | | | Y | | | | |
| Trees | E | *Pinaceae* | *Pinus* | *elliottii* | Slash Pine | Y | | | | | | | | | | |
| Trees | N | *Araliaceae* | *Schefflera* | *actinophylla* | Australian Umbrella Tree | | | | | | | Y | | | | |
| Trees | N | *Cunoniaceae* | *Schizomeria* | *ovata* | Crabapple | | Y | | | | | | | | | |
| Trees | N | *Myrtaceae* | *Syncarpia* | *glomulifera subsp. glomulifera* | Turpentine | Y | Y | Y | | | Y | | | | | |
| Trees | N | *Meliaceae* | *Synoum* | *glandulosum* | Scentless Rosewood | | | | | | Y | | | | | |
| Trees | N | *Myrtaceae* | *Syzygium* | *oleosum* | Blue Lilly Pilly | | | | | | Y | | | | | |
| Trees | N | *Myrtaceae* | *Syzygium* | *australe* | Brush Cherry | | | Y | Y | | | Y? | | Y | | |
| Trees | N | *Myrtaceae* | *Syzygium* | *sp.* | | | | | | | | | | Y | Y | Y |
| Trees | N | *Meliaceae* | *Toona* | *australis* | Red Cedar | | | | Y | Y | | | | | | |
| Trees | N | *Myrtaceae* | *Tristaniopsis* | *laurina* | Watergum | | Y | | | | | Y | Y | Y | Y | Y |
| Vines | E | *Sapindaceae* | *Cardiospermum* | *grandiflorum* | Baloon Vine | | | | | | | Y | | | | |
| Vines | N | *Vitaceae* | *Cissus* | *hypoglauca* | Water Vine | | | | | | | | | Y | | |
| Vines | N | *Vitaceae* | *Cissus* | *antarctica* | Kangaroo Vine | | Y | | Y | | | | Y | | | Y |
| Vines | N | *Luzuriageae* | *Eustrephus* | *latifolius* | Wombat Berry | | Y | Y | | | | | | | | |
| Vines | N | *Luzuriageae* | *Geitonoplesium* | *cymosum* | Climbing Lily | | ? | Y | | | | | | | | |
| Vines | N | *Dilleniaceae* | *Hibbertia* | *scandens* | Climbing Guinea Flower | | | | | | Y | | | Y | | |
| Vines | E | *Convolvulaceae* | *Ipomoea* | *indica* | Morning Glory | | | | | | | | Y | | | |
| Vines | N | *Apocynaceae* | *Parsonsia* | *straminea* | Silkpod | Y | Y | Y | | Y | Y | | Y | Y | Y | Y |
| Vines | E | *Passifloraceae* | *Passiflora* | *subpeltata* | White Passionfruit | | | | | Y | | | | | | |
| Vines | N | *Rosaceae* | *Rubus* | *parvifolius* | Native Raspberry | | | | | | | | | | Y | |
| Vines | N | *Smilaceae* | *Smilax* | *latifolia/australis* | Lawyer Vine | | Y | Y | Y | Y | Y | Y | | Y | | |
| Vines | N | *Menispermaceae* | *Stephania* | *japonica* | Snake Vine | | Y | | | Y | | | | | | |

***APPENDIX B** Recruitment, Nativeness, Expectedness and ndxFS (overall) Indicator values for fish at sites sampled in Boambee Creek, Bonville Creek, Coffs Creek, Corindi Creek and Woolgoolga Creek as part of the Coffs Harbour Ecohealth Program, 2015 (Fisheries NSW, NSW Department of Primary Industries, 2016). Dark blue indicates high values, green moderate values and yellow low values. NB# Averages are raw numbers only and are not corrected for stream length.*

| | | | | Health Metrics | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Site name** | **Waterway** | **Latitude** | **Longitude** | **Recruitment** | | **Nativeness** | | **Expectedness** | | **ndxFS** | |
| Boambee - Downstream | Boambee Creek | -30.338 | 153.0705 | 46.9 | Moderate | 100 | Excellent | 59 | Moderate | 55.2 | Moderate |
| Boambee - Upstream | Boambee Creek | -30.3349 | 153.0576 | 46.9 | Moderate | 99.7 | Excellent | 48 | Moderate | 47.7 | Moderate |
| Boambee walk track | Boambee Creek | -30.1954 | 153.0307 | 57.1 | Moderate | 100 | Excellent | 69.3 | Good | 72.9 | Good |
| Average (±S.E.) | | | | 50.3 (3.4) | Moderate | 99.9 (0.1) | Excellent | 58.8 (6.15) | Moderate | 58.6 (7.47) | |
| | | | | | | | | | | | |
| Bonville 3 | Bonville Creek | -30.3763 | 153.013 | 46.9 | Moderate | 100 | Excellent | 82.1 | Excellent | 73 | Good |
| Bonville Junction | Bonville Creek | -30.3682 | 153.0331 | 46.9 | Moderate | 100 | Excellent | 67.5 | Good | 61.8 | Good |
| Bonville Spring | Bonville Creek | -30.3643 | 153.0214 | 57.1 | Moderate | 99.9 | Excellent | 64.3 | Good | 67.9 | Good |
| **Average (±S.E.)** | | | | 50.3 (3.4) | Moderate | 99.9 (0.03) | Excellent | 71.3 (5.48) | Good | 67.6 (3.24) | Good |
| | | | | | | | | | | | |
| Coffs Bannana Farm | Coffs Creek | -30.1716 | 153.0458 | 46.9 | Moderate | 94 | Excellent | 45.7 | Moderate | 45.9 | Moderate |
| Coffs Big Trees | Coffs Creek | -30.293 | 153.1024 | 46.9 | Moderate | 94.4 | Excellent | 45.7 | Moderate | 45.9 | Moderate |
| McCanns Bridge | Coffs Creek | -30.2883 | 153.0973 | 46.9 | Moderate | 100 | Excellent | 54.4 | Moderate | 51.4 | Moderate |
| **Average (±S.E.)** | | | | 46.9 | Moderate | 96.1 (1.94) | Excellent | 48.6 (2.9) | Moderate | 47.7 (1.83) | Moderate |
| | | | | | | | | | | | |
| Corindi Highway | Corindi Creek | -30.0128 | 153.1121 | 46.9 | Moderate | 100 | Excellent | 59 | Moderate | 55.2 | Moderate |
| Corindi Log Bridge | Corindi Creek | -30.0917 | 153.1245 | 57.1 | Moderate | 45.8 | Moderate | 43.1 | Moderate | 37.8 | Poor |
| Corindi Boyles | Corindi Creek | -30.021 | 153.0713 | 57.1 | Moderate | 100 | Excellent | 75.3 | Good | 78.6 | Good |
| **Average (±S.E.)** | | | | 53.7 (5.89) | Moderate | 81.9 (18.07) | Excellent | 59.1 (9.3) | Moderate | 57.2 (11.82) | Moderate |
| | | | | | | | | | | | |
| Jagera | Woolgoolga Creek | -30.114 | 153.1825 | 46.9 | Moderate | 100 | Excellent | 71.4 | Good | 65.2 | Good |
| Woopi Bridge | Woolgoolga Creek | -30.1181 | 153.164 | 46.9 | Moderate | 99.8 | Excellent | 51 | Moderate | 49.5 | Moderate |
| Woopi three-ways | Woolgoolga Creek | -30.073 | 153.0804 | 81 | Excellent | 100 | Excellent | 0 | Very poor | 39.1 | Poor |
| **Average (±S.E.)** | | | | 58.3 (11.37) | Moderate | 99.9 (0.06) | Excellent | 40.8 (21.23) | Moderate | 51.3 (7.59) | Moderate |

***APPENDIX C** Ecohealth data sheets.*

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 (page 2)**

| | |
|---|---|
| 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

| |
|---|
| |