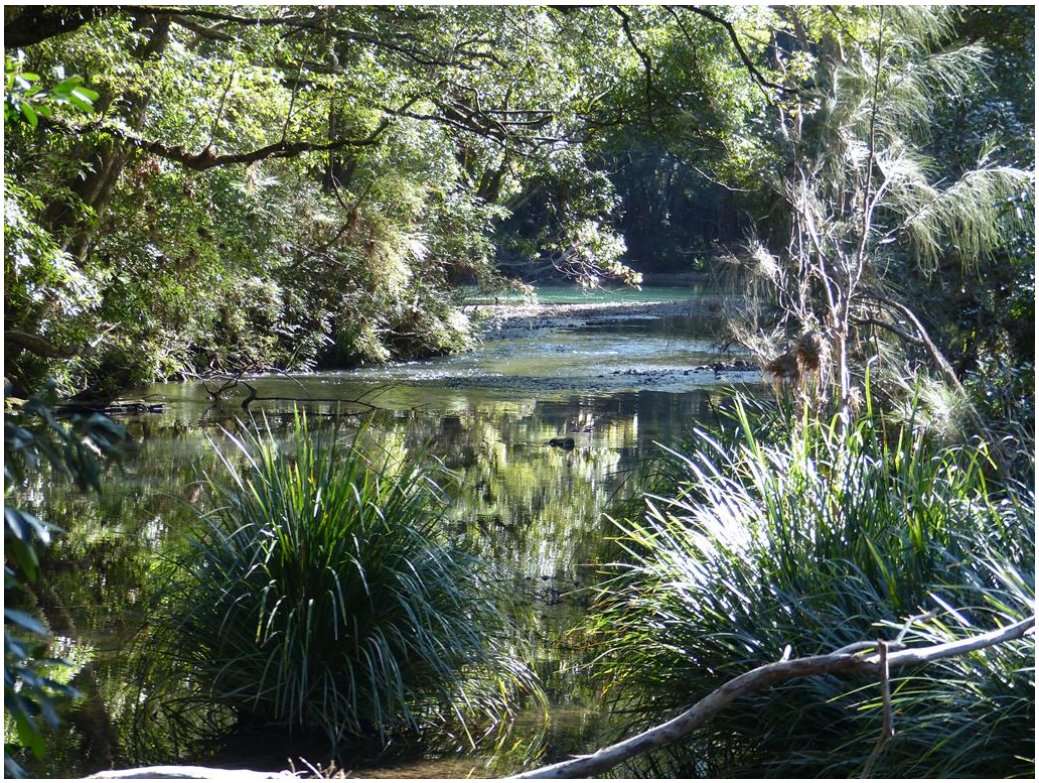
Coffs Harbour Region Ecohealth Project 2019-2022

Assessment of River and Estuarine Condition



Technical Report

March 2023

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University of New England

Aquatic Ecology and Restoration

Coffs Harbour Region Ecohealth Project 2019-2022

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Cover Photo: The upper Orara River (Z. Lewis, 2022).

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Glossary of General Terms

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

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-six study sites were selected across the Coffs coastal catchment; 16 freshwater sites and 20 estuarine sites. These sites were sampled 13 times from July 2019 to August 2022 to contribute to the assessment of the ecological condition of the catchment.

The 16 Coffs coastal catchments were divided into 11 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; Bonville and Pine Creeks; and the Orara River and its tributary Bucca Bucca Creek. 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.

This report should be read in conjunction with the website www.ecohealth.une.edu.au, which outlays changes to the methodology for water quality scoring and grading, and macroinvertebrate community condition scoring and grading. For the most part, assessment of temporal change between the 2015 program and this program (2019-2022), are reported in the website because 2015 grades needed to be recalculated using current formulae in order to accurately assess temporal change in condition. Changes to the scoring and grading algorithms were made to align with NSW DPE Estuary MER protocols.

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. Inform management priorities and actions for the catchments in the Coffs Harbour region; and
3. 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 study design and site selection processes:

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

2.2 **Study Sites** provides locations and the sampling regime for the 36 study sites.

2.3 **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 July 2019 to November 2022. Field data collection was disrupted by bushfires, floods and COVID travel restrictions thoughout the project. 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, and the upper Orara River along with Bucca Bucca Creek. 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 and spring 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. 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
3.11 Orara River and Bucca Bucca Creek.

PART 2

DESIGN AND SITE DESCRIPTIONS

2.1 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 16 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 13 times, freshwater macroinvertebrates were sampled bi-annually in autumn and spring 2019-20 and 2021-22, riparian condition was assessed twice in spring/late summer (2019, 2021), and geomorphic condition were assessed once in 2020.

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. NSW DPE and NSW Solitary Islands Marine Parks supplied the boats and skippers as in-kind support to the project. All freshwater sites were sampled via road access. Water quality, aquatic macroinvertebrates, riparian condition and geomorphic condition were assessed by staff from UNE.

2.3 Study sites

Thirty-six sites were sampled within the Coffs Harbour LGA with 16 freshwater sites and 20 estuarine sites spread across 11 creek catchments (Table 2.1). Sites were distributed as follows from north to south: Corindi River (2 estuarine, 1 freshwater), Saltwater Creek (1 estuarine, 1 freshwater), Dirty Creek (1 freshwate), 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), Bonville/Pine Creeks (3 estuarine, 2 freshwater), Orara River (4 freshwater).

Sites (names and locations) are consistent with the 2015 Coffs Ecohealth project. Any differences are clearly stated in the relevant site descriptions (i.e. sites are new to the 2019-22 Coffs Ecohealth project or site locations were adjusted to 2015 conditions).

Table 2.1 *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
Dirty Creek	DIRT1	516876	6684686	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
Orara River	ORAR5	500750	6666492	73	Freshwater
	ORAR6	501538	6656721	121	Freshwater
	ORAR7	501898	6652308	139	Freshwater
Bucca Bucca Creek	BUCC1	501708	6666627	75	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 2.2 *Water chemistry indicators measured at all sites.*

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

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 *Guideline values for freshwater and estuary ecosystems. Freshwater guidelines are from ANZECC and estuary guidelines are derived by NSW Estuary and Science team.*

Sub-indicator	Variable	Units	Lowland Freshwater	Upper Estuary	Mid Estuary	Lower Estuary	Estuarine Lagoon
Nutrients	TN	µg/L	350	608	380	205	300
Nutrients	TP	µg/L	25	15	18	10.3	13.3
Nutrients	NOx	µg/L	40	46	36.6	5.1	10.3
Nutrients	SRP	µg/L	20	6.4	8	6.5	6.3
PhysChem	DO%_min	%	80	80	80	80	80
PhysChem	DO%_max	%	110	110	110	110	110
PhysChem	pH_min		6.5	7	7	7	7
PhysChem	pH_max		8.5	8.5	8.5	8.5	8.5
PhysChem	EC	µS/cm	2200	n/a	n/a	n/a	n/a
PhysChem	Turbidity	NTU	50	6	2.6	2.8	5.7
Biological	Chl_a	µg/L	3	4.8	4.3	2.3	3.9

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

2.4.6 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 the site scale. 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.

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 10th and/or the 90th 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.

2.5.5 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 July 2019 to August 2022. Results for water quality, macroinvertebrates, riparian condition and geomorphic condition are reported for each subcatchment. *Geomorphic condition* assessed site-scale condition of stream banks and bed at freshwater sites and site-scale condition of streambanks at estuarine sites. *Riparian condition* assessed 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 were 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 each subcatchment:

3.1 Coffs coastal catchments

The overall grade for the Coffs coastal catchments was C+ (Table 3.1). Subcatchment grades ranged from C- in Coffs Creek to B- in the Corindi River, Pipeclay Creek and Woolgoolga Creek (Table 3.1). 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 the freshwater creek to Hearnes Lake, and poor in the Orara River and Moonee Creek.

Table 3.1 *Most recent catchment and subcatchment Ecohealth grades for Coffs coastal catchments (surveyed 2021-22).*

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

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

3.2 Corindi River, Saltwater Creek, Dirty Creek and Pipeclay Lake

3.2.1 Catchment description

The Corindi River catchment is 151km^2 (Table 3.2). 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) that drain to confined discontinuous floodplains. 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. 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.

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. 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. The Corindi River Estuary has a rich cultural history, particularly for the indigenous Gumbaingirr people of the Red Rock/Corindi area (Waterways Authority 2002).

Table 3.2 *Subcatchment description of Corindi River, Saltwater Creek, Dirty 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 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. 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 61.2, a grade of C-, for BANK CONDITION and 78.0, a B-, for BED CONDITION. The overall Ecohealth geomorphic condition for CORI4 was 70, a grade of C. While this overall grade is the same as the 2015 survey, bank condition had improved in this later survey.

The River Style at SALT3 and SALT2 is also partially confined valley setting: planform controlled, fine grained. The bed and bank sediments were fine grained, with no cobbles, pebbles or gravel present. At SALT3, 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. Recent flooding had resulted in bank erosion along both banks. SALT3 scored 75.6, a grade of B- for BANK CONDITION and 78.0, a grade of B- for BED CONDITION. The overall Ecohealth geomorphic condition for SALT3 was 77, a grade of B-, which was the same as the 2015 survey. SALT2 had extensive bank erosion caused by recent flooding and scored 57.6, a grade of D+ for BANK CONDITION and 84.0, a grade of B for BED CONDITION. The overall Ecohealth geomorphic condition for SALT2 was 71, a grade of C+.

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. Localised bed erosion is the most significant issue for site-level geomorphic condition at SALT2 and SALT3. Maintaining the riparian vegetation at SALT3 and upstream of the site will continue to

protect bank stability, and help slow runoff, reducing its erosivity. Gravel roads and obvious use for recreational 4wd-driving also impacted the geomorphic condition at SALT2 and SALT3.

3.2.3 Riparian condition

Corindi River

CORI4 Riparian Condition: T1 = 63.5 (C-) T2 = 73.3 (C+). Temporal difference = +9.8

Corindi River 4 was a mildly disturbed freshwater system that supported a Coast and Hinterland Riparian Flooded Gum - Bangalow Wet Forest (CH_WSF01) riparian zone (Table 3.3). The site sat within a corridor approximately 1km wide and 7km long of cleared land surrounded by large stands of intact vegetation. The predominant land use in the surrounding area was grazing and horticulture. Historic disturbances in the form of clearing and logging were evident throughout large sections of the immediate riparian zone where many stumps remain and exotic species occurred in all structural layers except vines. Mixed-age stands of native trees and shrubs were present in less disturbed areas along with representative plant species of the remnant vegetation community throughout all structural layers on site. Note that this site was moved for T2 surveys due to high water levels at the T1 site.

CORI4 scored well for the Habitat and Debris subindices and moderately for the Native Species, Species Cover and Management subindices. Although relatively few, riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: camphor laurel (*Cinnamomum camphora*), lantana (*Lantana camara*), paspalum (*Paspalum dilatatum*) (see dominant species list for full site details). Limited understory cover, particularly native graminoids and limited native woody regeneration also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2
What caused the difference?

- Higher canopy species cover and improvement in canopy health
- Lower weedy woody regeneration
- Reduced animal impacts.

Why?

- Much of the change seen between T1 (September 2019) and T2 (March 2022) is likely attributable to the change of site location.
- Above average rainfall between T1 and T2 would have improved conditions across a broad area and may have contributed to some of the observed improvements.

What else?

- The site surveyed in T2 had fencing on one side and lower animal impacts than noted in T1 site which had no fencing. This highlights the value of riparian fencing for livestock exclusion.

Recommendations

- Install and maintain riparian fencing on both sides of creek to exclude livestock. This will assist with regeneration of native vegetation, improve cover and assist with reducing erosion impacts here and downstream.
- Implement weed control measures.
- Flashy floods which have led to erosion issues lower in this catchment may be a result of historical clearing in this area and higher-up in the catchment. Efforts to stabilise and mitigate further erosion might consider a catchment scale strategic riparian revegetation and widening program to improve cover, reduce runoff and limit high flow peaks.

Table 3.3 *Site-level summary of riparian condition of Corindi River #4, including subindices and indicators.*

Corindi River #4	Survey 1	Survey 2	Change
HABITAT	**16.5**	**16.5**	**0.0**
Channel width	2.0	2.0	**0.0**
Proximity	3.0	3.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	1.5	1.5	**0.0**
Hollow-bearing trees	2.0	2.0	**0.0**
NATIVE SPECIES	**12.0**	**13.5**	**1.5**
Native canopy species	3.0	3.0	**0.0**
Native midstory species	1.5	3.0	**1.5**
Native herb/forb species	3.0	3.0	**0.0**
Native graminoid species	0.5	0.5	**0.0**
Native macrophyte species	4.0	4.0	**0.0**
SPECIES COVER	**11.0**	**14.5**	**3.5**
Canopy species	1.0	3.0	**2.0**
Midstory species	3.0	3.5	**0.5**
Herb/forb species	1.0	2.0	**1.0**
Graminoid species	2.0	2.0	**0.0**
Macrophyte species	4.0	4.0	**0.0**
DEBRIS	**16.0**	**17.0**	**1.0**
Total leaf litter	3.0	2.0	**-1.0**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	1.5	3.0	**1.5**
Dead trees fallen	2.5	2.0	**-0.5**
Lying logs	4.0	4.0	**0.0**
Fringing vegetation	2.0	3.0	**1.0**

MANAGEMENT	**8.0**	**11.8**	**3.8**
Tree clearing	2.0	2.0	**0.0**
Fencing	0.0	1.0	**1.0**
Animal impact	0.0	1.0	**1.0**
Species of interest	1.0	1.8	**0.8**
Exposed tree roots	4.0	3.0	**-1.0**
Native woody regeneration	1.0	1.0	**0.0**
Weedy woody regeneration	0.0	2.0	**2.0**
TOTAL	**63.5**	**73.3**	**9.8**

CORI3 Riparian Condition: T1 = 76.4 (B-) T2 = 78.0 (B-). Temporal difference = +1.6

Corindi River 3 was a mildly disturbed estuarine system that supported a Coast and Escarpment Blackbutt Dry Forest (CH_DOF01) riparian zone (Table 3.4). Immediate site surroundings were predominantly intact vegetation intersected by tracks, with some clearing for rural development and grazing within approximately 1km of the site to the north and south. Historic disturbances in the form of upstream clearing and livestock grazing was evident, and bank erosion was prevalent at the sites and throughout these reaches of the Corindi River. Mixed-age stands of native trees and shrubs were present along with representative plant species of the remnant vegetation community throughout all structural layers. This site was monitored in previous Ecohealth programs. Scores for 2011 (C) and 2015 (C) were unchanged and there was a slight improvement in riparian condition in the current reporting round.

CORI3 scored well for the Habitat and Native Species subindices and moderately for the Species Cover, Debris and Management subindices. Riparian condition was affected by erosion leading to exposed tree roots (>50% exposed). Low overall cover in the understory, reduced canopy health and the presence of the weedy grass species, paspalum (*Paspalum dilatatum*), also contributed to the reduction in riparian grade at this site (see dominant species list for full site details).

Temporal difference in riparian condition between T1 and T2
What caused the difference?

- Increase in native woody regeneration
- Increase in herb/forb species cover
- Decrease in graminoid species overall, and native species in particular
- Slight decrease in canopy species cover, but increase in canopy health
- Slight reduction in debris cover including Lying logs and Fringing vegetation.

Why?

- Higher than average rainfall between T1 and T2 likely improved understory herb and forb presence, canopy health and supported native woody regeneration.

What else?

- There was evidence of significant, widespread bank erosion during both surveys. This may be attributed to both historic clearing at the local level, which has caused instability over time, combined with clearing higher up in the catchment which leads to flashier flood flows.
- T2 survey noted that nearby road access is a potential point of introduction for weeds.
- T1 survey noted evidence of grazing across flats between Salt Creek and CORI3.

Recommendations

- Active bank erosion was present along this riparian section. Efforts to stabilise and mitigate further erosion might consider a catchment scale strategic riparian revegetation and widening program to improve cover, reduce runoff and limit high flow peaks.
- Monitor for weed incursions and manage as necessary. Implementing control measures while weed incursion is low will reduce long-term management efforts and associated costs.

Table 3.4 *Site-level summary of riparian condition of Corindi River #3, including subindices and indicators.*

Corindi River #3	Survey 1	Survey 2	Change
HABITAT	**20.0**	**20.0**	**0.0**
Channel width	4.0	4.0	**0.0**
Proximity	4.0	4.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	2.0	2.0	**0.0**
NATIVE SPECIES	**20.0**	**19.0**	**-1.0**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	4.0	4.0	**0.0**
Native herb/forb species	4.0	4.0	**0.0**
Native graminoid species	4.0	3.0	**-1.0**
Native macrophyte species	4.0	4.0	**0.0**
SPECIES COVER	**12.0**	**12.0**	**0.0**
Canopy species	2.5	2.0	**-0.5**
Midstory species	3.0	3.0	**0.0**
Herb/forb species	1.0	2.0	**1.0**
Graminoid species	2.5	2.0	**-0.5**
Macrophyte species	3.0	3.0	**0.0**

DEBRIS	**14.5**	**13.8**	**-0.7**
Total leaf litter	3.0	3.0	**0.0**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	3.0	3.0	**0.0**
Dead trees fallen	1.0	1.0	**0.0**
Lying logs	2.0	1.8	**-0.2**
Fringing vegetation	2.5	2.0	**-0.5**
MANAGEMENT	**9.9**	**13.2**	**3.3**
Tree clearing	2.0	2.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	0.9	1.2	**0.3**
Exposed tree roots	0.0	0.0	**0.0**
Native woody regeneration	1.0	2.0	**1.0**
Weedy woody regeneration	0.0	2.0	**2.0**
TOTAL	**76.4**	**78.0**	**1.6**

CORI1 Riparian Condition: T1 = 68.8 (C) T2 = 68.1 (C). Temporal difference = -0.7

Corindi River 1 was a moderately disturbed estuarine system that supported a Swamp Oak Forested Wetland (CH_FrW10) riparian zone (Table 3.5). Immediate site surroundings were predominantly intact vegetation except for the township of Red Rock approximately 150m to the south. Disturbances resulting from historic clearing and recreational activities were evident in the observed bank erosion throughout the site. Mixed-age stands of native trees and shrubs were present in undisturbed areas along with representative plant species of the remnant vegetation community throughout all structural layers on site, although diversity is naturally low in this community type.

CORI1 scored well for the Habitat Native Species subindices, moderately for the Species Cover and Management subindices and poorly for the Debris subindex. Riparian condition was affected by a general lack of large native trees and hollow bearing trees, poor canopy health, limited large woody debris and by the presence of the weed species, senna (*Senna pendula*) (see dominant species list for full site details).

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Substantial increase in native woody regeneration
- Marginal increase in large woody debris cover (Lying logs)
- Reduction in canopy species cover, herb/forb species cover and total leaf litter

Why?

- Flood flows occurring between T1 (September 2019) and T2 (March 2022) surveys may have deposited some logs at the site.
- The reduction in canopy health was likely a combination of long-term drought and potential changes in salinity gradients.

- Native woody regeneration may indicate recovery of *Melaleuca* spp.

What else?

- Both surveys noted active bank erosion (slumping) at this site from a possible combination of boat wash and large floods/higher tides.
- Foot traffic off walking tracks can increase erosion potential over time.
- Both surveys noted dieback and extremely poor health in *Melaleuca* spp. (see note above re possible drought and salinity impacts).
- High algal biomass was observed during the 2021-22 survey period. Nutrient concentrations were measured as moderate during the same period.

Recommendations

- Rock fillets along selected reaches may help to stabilise bank erosion, recolonise mangroves and stabilise sediments in selected sections.
- Active bank erosion was present along this riparian section and may be a result from historical clearing higher in the catchment, localised site disturbances, and heavy rainfall events and subsequent flashy flows experienced between T1 and T2. Efforts to stabilise and mitigate further erosion might consider a catchment scale strategic riparian revegetation and widening program to improve cover, reduce runoff and limit high flow peaks.
- Consider installing observation platforms and guard rails on walking tracks to limit erosion.
- Monitor algal biomass to assess longevity of high algal production. Further investigation into nutrient and algae dynamics may help determine management actions to reduce algal biomass.

Table 3.5 *Site-level summary of riparian condition of Corindi River #1, including subindices and indicators.*

Corindi River #1	Survey 1	Survey 2	Change
HABITAT	**15.5**	**15.5**	**0.0**
Channel width	4.0	4.0	**0.0**
Proximity	4.0	4.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	3.0	3.0	**0.0**
Large native trees	0.5	0.5	**0.0**
Hollow-bearing trees	0.0	0.0	**0.0**
NATIVE SPECIES	**20.0**	**20.0**	**0.0**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	4.0	4.0	**0.0**
Native herb/forb species	4.0	4.0	**0.0**
Native graminoid species	4.0	4.0	**0.0**
Native macrophyte species	4.0	4.0	**0.0**
SPECIES COVER	**12.0**	**10.5**	**-1.5**
Canopy species	2.0	1.0	**-1.0**
Midstory species	1.0	1.0	**0.0**

Herb/forb species	1.0	0.5	**-0.5**
Graminoid species	4.0	4.0	**0.0**
Macrophyte species	4.0	4.0	**0.0**
DEBRIS	**9.5**	**8.3**	**-1.2**
Total leaf litter	3.0	1.3	**-1.7**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	0.0	0.0	**0.0**
Dead trees fallen	0.0	0.0	**0.0**
Lying logs	0.5	1.0	**0.5**
Fringing vegetation	3.0	3.0	**0.0**
MANAGEMENT	**11.8**	**13.8**	**2.0**
Tree clearing	2.0	2.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	0.8	0.8	**0.0**
Exposed tree roots	3.0	3.0	**0.0**
Native woody regeneration	0.0	2.0	**2.0**
Weedy woody regeneration	0.0	0.0	**0.0**
TOTAL	**68.8**	**68.1**	**-0.7**

Saltwater Creek

SALT3 Riparian Condition: T1 = 79.2 (B-) T2 = N/A. Temporal difference = N/A

Saltwater Creek 3 was a mildly disturbed freshwater system that supported a narrow band of Coastal Paperbark - Sedgeland Dominated Forest (CH_FrW04) grading into a Coastal Swamp Mahogany Forest (CH_FrW02) riparian zone (Table 3.6). Immediate site surroundings were predominantly intact vegetation in the form of Yuraygir National Park, which was minimally intersected by tracks and powerlines, and Barcongere State Forest to the north. Historic disturbance from forestry was evident in some areas of the riparian zone with the presence pine tree seedlings and a moderate proportion of regrowth in native trees. Mixed-age stands of native trees were present along with representative plant species of the remnant vegetation communities throughout all structural layers on site. SALT3 was monitored in previous Ecohealth programs (see reports for 2011 and 2015) and scores remain essentially unchanged.

SALT3 scored well for the Habitat, Native Species and Management subindices and moderately for the Species Cover and Debris subindices. Riparian condition was affected by the presence and regeneration of a single weed species, pine (*Pinus* spp.), which was present throughout the midstory and understory (see dominant species list for full site details). A lower than expected cover score for

herb/forb species and a lack of standing dead trees also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2
SALT3 was only visited in T1 (September 2019) so temporal comparison is not applicable.

What else?

- This site lay near the border with Barcongere State Forest where there were active pine plantations. This is a likely source of woody weed introduction and monitoring and control of pine is required.
- 4wd tracks in the vicinity are potential points of weed species introduction.

Recommendations

- Low disturbance removal of large pines i.e. cut and paint poisoning and immediate removal of emergent seedlings.
- Monitor site for new weed incursion.

Table 3.6 *Site-level summary of riparian condition of Saltwater Creek #3, including subindices and indicators.*

Saltwater Creek #3	Survey 1		
HABITAT	**18.0**		
Channel width	4.0		
Proximity	4.0		
Continuity	4.0		
Layers	4.0		
Large native trees	2.0		
Hollow-bearing trees	0.0		
NATIVE SPECIES	**18.0**		
Native canopy species	3.0		
Native midstory species	3.0		
Native herb/forb species	4.0		
Native graminoid species	4.0		
Native macrophyte species	4.0		
SPECIES COVER	**13.0**		
Canopy species	3.0		
Midstory species	3.0		
Herb/forb species	1.0		
Graminoid species	4.0		
Macrophyte species	2.0		
DEBRIS	**14.0**		
Total leaf litter	3.0		

Native leaf litter	3.0		
Dead trees standing	0.0		
Dead trees fallen	1.0		
Lying logs	3.0		
Fringing vegetation	4.0		
MANAGEMENT	**16.2**		
Tree clearing	2.0		
Fencing	3.0		
Animal impact	3.0		
Species of interest	1.2		
Exposed tree roots	4.0		
Native woody regeneration	2.0		
Weedy woody regeneration	1.0		
TOTAL	**79.2**		

SALT2 Riparian Condition: T1 = 79.6 (B-) T2 = 81.3 (B). Temporal difference = +1.7

Saltwater Creek 2 was a mild-to low disturbance estuarine system that supported an Estuarine Mangrove Forest (CH_SW01), grading into a Swamp Oak Forested Wetland (CH_FrW10) and Coast and Escarpment Blackbutt Dry Forest (CH_DOF01) riparian zone (Table 3.7). Immediate site surroundings were predominantly intact vegetation in the form of Yuraygir National Park, which was minimally intersected by tracks and powerlines. Historic disturbance from forestry was evident in some areas of the riparian zone with the presence of regrowth and pine tree seedlings. Mixed-age stands of native trees were present along with representative plant species of the remnant vegetation communities throughout all structural layers on site.

SALT2 scored well for Habitat, Native Species, Debris and Management subindices and moderately for the Species Cover subindex. Riparian condition was affected by the presence and regeneration of a single weed species, pine (*Pinus* spp.), which was present throughout the midstory and understory (see dominant species list for full site details). Lower than expected cover scores in canopy and herb/forb species contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Slight increase in herb/forb and graminoid species cover
- Increase in debris cover (Dead trees standing and Lying logs)
- Increase in native woody regeneration
- Decrease in overall leaf litter cover
- Increase in weedy woody regeneration.

Why?

- Higher than average rainfall and favourable growth conditions experienced between T1 (September 2019) and T2 (March 2022) likely supported an increase in native and exotic woody regeneration and expansion of herb/forb and graminoid species cover.

- Flood flows may have removed leaf litter which has yet to re-establish, but delivered large woody debris to the site (Lying logs).

What else?

- This site lay within 1km of Barcongere State Forest where there were active pine plantations, and the upper catchment ran through the plantation. This is a likely source of woody weed introduction and monitoring and control of pine is required.

Recommendations

- Low disturbance removal of large pines (i.e. cut/stump painting) and immediate removal of emergent seedlings.
- Monitor site for new weed incursion.

Table 3.7 *Site-level summary of riparian condition of Saltwater Creek #2, including subindices and indicators.*

Saltwater Creek #2	Survey 1	Survey 2	Change
HABITAT	**19.5**	**19.5**	**0.0**
Channel width	4.0	4.0	**0.0**
Proximity	4.0	4.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	1.5	1.5	**0.0**
Hollow-bearing trees	2.0	2.0	**0.0**
NATIVE SPECIES	**20.0**	**20.0**	**0.0**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	4.0	4.0	**0.0**
Native herb/forb species	4.0	4.0	**0.0**
Native graminoid species	4.0	4.0	**0.0**
Native macrophyte species	4.0	4.0	**0.0**
SPECIES COVER	**10.0**	**10.8**	**0.8**
Canopy species	1.0	1.0	**0.0**
Midstory species	2.0	2.0	**0.0**
Herb/forb species	1.0	1.3	**0.3**
Graminoid species	2.5	3.0	**0.5**
Macrophyte species	3.5	3.5	**0.0**
DEBRIS	**14.0**	**15.0**	**1.0**
Total leaf litter	3.0	2.0	**-1.0**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	2.0	3.0	**1.0**
Dead trees fallen	2.0	2.0	**0.0**
Lying logs	1.0	2.0	**1.0**

Fringing vegetation	3.0	3.0	**0.0**
MANAGEMENT	**16.1**	**16.0**	**-0.1**
Tree clearing	3.0	3.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	0.6	1.5	**0.9**
Exposed tree roots	3.5	3.5	**0.0**
Native woody regeneration	1.0	2.0	**1.0**
Weedy woody regeneration	2.0	0.0	**-2.0**
TOTAL	**79.6**	**81.3**	**1.7**

Dirty Creek

DIRT1 Riparian Condition: T1 = 86.1 (B+) T2 = 86.4 (B+). Temporal difference = +0.3

Dirty Creek 1 was a low disturbance freshwater system that supported a Coastal Paperbark - Sedgeland Dominated Forest (CH_FrW04) riparian zone (see dominant species list for full site details; Table 3.8). Immediate site surroundings were predominantly intact vegetation which was partially intersected by roads. Former pine and other tree plantation plots lay approximately 500m north of the site, in Barcongere State Forest. Historic disturbances in some sections of the immediate riparian zone were evident in the lower than expected number of mature trees. Mixed-age stands of native trees and shrubs were present in throughout the site along with representative plant species of the remnant vegetation community throughout all structural layers on site.

DIRT1 scored well for the Habitat, Native Species, Species Cover and Management subindices and moderately for the Debris subindex. Riparian condition was slightly reduced due to lower canopy and herb/forb species cover and moderate levels of large woody debris cover than would be expected in a low disturbance system. Overall, this site was in excellent condition and no weed incursion was noted in either survey.

Temporal difference in riparian condition between T1 and T2
What caused the difference?

- Increase in Hollow-bearing tree score
- Marginal improvement in canopy health
- Reduction in herb/forb species cover and total leaf litter.

Why?

- The increase in Hollow-bearing trees was likely due to observer bias. That is, they were there previously but not seen.
- Higher than average rainfall and flood flows between T1 (September 2019) and T2 (March 2022) likely removed leaf litter which has not yet re-established.
- Higher rainfall would also have contributed to improved canopy health and the growth of graminoids which may have come at the expense of some herb/forb species.

What else?

- This site had high structural and taxonomic diversity.

- T2 survey noted evidence of large-scale frog breeding in creek.
- Dissolved oxygen was frequently low, below the 80% saturation minimum trigger threshold and often below 2mg O_2/L which is hypoxic and impacts aquatic fauna. This occurred during both low flow and baseflows.

Recommendations

- Maintain current practices for riparian condition.
- Investigate cause of low oxygenation of water.

Table 3.8 *Site-level summary of riparian condition of Dirty Creek #1, including subindices and indicators.*

Dirty Creek #1	Survey 1	Survey 2	Change
HABITAT	**18.0**	**20.0**	**2.0**
Channel width	4.0	4.0	**0.0**
Proximity	4.0	4.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	0.0	2.0	**2.0**
NATIVE SPECIES	**20.0**	**20.0**	**0.0**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	4.0	4.0	**0.0**
Native herb/forb species	4.0	4.0	**0.0**
Native graminoid species	4.0	4.0	**0.0**
Native macrophyte species	4.0	4.0	**0.0**
SPECIES COVER	**16.0**	**15.0**	**-1.0**
Canopy species	2.0	2.0	**0.0**
Midstory species	3.0	3.0	**0.0**
Herb/forb species	3.0	2.0	**-1.0**
Graminoid species	4.0	4.0	**0.0**
Macrophyte species	4.0	4.0	**0.0**
DEBRIS	**15.0**	**14.0**	**-1.0**
Total leaf litter	3.0	2.0	**-1.0**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	2.0	2.0	**0.0**
Dead trees fallen	1.0	1.0	**0.0**
Lying logs	2.0	2.0	**0.0**
Fringing vegetation	4.0	4.0	**0.0**
MANAGEMENT	**17.1**	**17.4**	**0.3**

Tree clearing	3.0	3.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	1.1	1.4	**0.3**
Exposed tree roots	4.0	4.0	**0.0**
Native woody regeneration	1.0	1.0	**0.0**
Weedy woody regeneration	2.0	2.0	**0.0**
TOTAL	**86.1**	**86.4**	**0.3**

Pipeclay Creek

PIPE1 Riparian Condition: T1 = 66.0 (C) T2 = 72.5 (C+). Temporal difference = +6.5

Pipeclay Creek 1 was a moderately disturbed Intermittently Closed and Open Lagoon (ICOL) system that supported an Estuarine Paperbark - Twig Rush Forest (CH_FrW11) grading into a Coast Banksia Shrubland on Holocene Dunes (CH_H01) riparian zone (Table 3.9). Immediate site surroundings were predominantly intact vegetation which was partially intersected by trails, roads and a powerline easement, with areas of urban and rural development including housing and recreation to the southwest and west. Disturbances were evident in the form of historic clearing, recent burning and the incursion of weeds throughout the mid- and understory of this riparian zone. Mixed-age stands of native trees and shrubs were present along with representative plant species of the remnant vegetation communities throughout all structural layers on site.

PIPE1 scored well for the Habitat and Native Species subindices, moderately for the Species Cover and Management subindices and poorly for the Debris subindex. Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: lantana (*Lantana camara*), bitou bush (*Chrysanthemoides monilifera* subsp. *rotundata*), groundsel bush (*Baccharis halimifolia*), paspalum (*Paspalum dilatatum*) and coastal morning glory (*Ipomoea cairica*) (see dominant species list for full site details). Low levels of cover in the mid and understories and low debris cover also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2
What caused the difference?

- Significant increase in overall cover, particularly canopy, midstory, and macrophyte species
- Significant increase in native species occurrence, particularly graminoids, macrophytes and midstory species
- Reduction in weedy woody regeneration
- Slight reduction in canopy health and increased exposure of tree roots.

Why?

- T1 (September 2019) survey noted recent fire at the site. Improvements in cover scores and native species occurrence in T2 (March 2022) reflect healthy recovery of this system. post-fire aided by above average rainfall and favourable growth conditions between T1 and T2.

What else?

- Mature bitou bush and groundsel bush at this site were killed by fire; however, fire has stimulated seed germination and there were concerns that it would flourish at this site post fire. While emergence and regrowth was lower than expected in T2, control and monitoring of new seedlings is recommended.
- Algal biomass was high during the 2019-20 survey period. This was likely due to resuspension of nutrients contained within the sediments of Pipeclay Creek during the low flows, as nutrient concentrations were measured as moderate during the same period.

Recommendations

- Removing and controlling woody weeds, particularly lantana, bitou bush and groundsel bush, will reduce competition in the long-term and encourage natural regeneration of native shrubs and improve ground cover. This site should be monitored for new occurrences and expansion.

Table 3.9 *Site-level summary of riparian condition of Pipeclay Creek #1, including subindices and indicators.*

Pipeclay Creek #1	Survey 1	Survey 2	Change
HABITAT	**18.0**	**18.0**	**0.0**
Channel width	4.0	4.0	**0.0**
Proximity	4.0	4.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	1.0	1.0	**0.0**
Hollow-bearing trees	1.0	1.0	**0.0**
NATIVE SPECIES	**13.5**	**16.5**	**3.0**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	2.0	2.5	**0.5**
Native herb/forb species	4.0	3.5	**-0.5**
Native graminoid species	1.5	3.5	**2.0**
Native macrophyte species	2.0	3.0	**1.0**
SPECIES COVER	**7.5**	**11.5**	**4.0**
Canopy species	1.5	2.5	**1.0**
Midstory species	1.0	2.0	**1.0**
Herb/forb species	2.0	2.0	**0.0**
Graminoid species	2.0	2.0	**0.0**
Macrophyte species	1.0	3.0	**2.0**
DEBRIS	**12.0**	**12.0**	**0.0**
Total leaf litter	1.0	1.0	**0.0**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	3.0	3.0	**0.0**

Dead trees fallen	1.0	1.0	**0.0**
Lying logs	1.0	1.0	**0.0**
Fringing vegetation	3.0	3.0	**0.0**
MANAGEMENT	**14.0**	**13.5**	**-0.5**
Tree clearing	2.0	2.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	1.0	0.5	**-0.5**
Exposed tree roots	3.0	2.0	**-1.0**
Native woody regeneration	2.0	2.0	**0.0**
Weedy woody regeneration	0.0	1.0	**1.0**
TOTAL	**65.0**	**71.5**	**6.5**

3.2.4 Water quality

Survey Period 1

In Survey Period 1 (2019 – 2020), the subcatchment of the Corindi River, Saltwater Creek, Dirty Creek and Pipeclay Lake received a score of 73, a grade of C. Within the Corindi River, upper estuary sites CORI3 (84) and low land freshwater site CORI4 (77) recorded better water quality with a grade of B compared to lower estuary site CORI1 (72) with a water quality grade of C. At Saltwater Creek, estuary site SALT2 (79, B) received better water quality than the freshwater site SALT3 (65, C). Pipeclay Lake received a 63 (C) score for water quality based on the single estuarine site PIPE1. Dirty Creek received a 70 (C) score for water quality based on the single freshwater site DIRT1 (Table 3.10).

Water temperatures at all sites reflected seasonal climatic changes. Table 3.11 outlines the ranges and means of water chemistry variables for the sites on the Corindi River, Saltwater Creek, Dirty Creek and Pipeclay Lake. Summer maximum water temperatures ranged from 27.6°C at the tidal limit (CORI3) to 24.3°C at the freshwater CORI4. Winter minimum water temperatures were also the lowest (11.8°C) at the freshwater CORI4. Similar patterns in water temperatures were observed in Saltwater Creek, where the freshwater site (SALT3) was consistently cooler than the tidal limit (SALT2, Table 3.11). Water temperatures in Pipeclay Lake ranged from a winter minimum of 20.2°C to a summer maximum of 30.5°C (Table 3.11). Water temperatures in Dirty Creek ranged from a winter minimum of 8.1°C to a summer maximum of 24.5°C (Table 3.11).

Percent dissolved oxygen saturation (DO%) was higher in estuarine than in freshwater sites. DO% in the Corindi River ranged from 2.4% in CORI4 to 122.3% in CORI1 (Table 3.11). In the Corindi River estuary (CORI1), DO% exceeded the maximum estuarine guideline value of 110% on 5 sampling occasions. This exceedance was likely wave-driven reaeration rather than an association with an algal bloom, given chl-a concentration was within guidelines on 7 of 8 sampling occasions. At the

tidal limit (CORI3), DO% was lower than the minimum estuary guideline value (80%) on 3 sampling occasions (December 2019, January 2020 and November 2020). In the freshwater site CORI4, DO% was lower than the minimum freshwater guideline value (80%) on 3 occasions (September 2019, December 2019 and January 2020), with concentration dropping below 2mg/L in December 2019.

DO% in Saltwater Creek ranged from 7.6% in the SALT3 to 90.4% in SALT2 (Table 3.11). DO% at the freshwater SALT3 was lower than the minimum freshwater guideline value on all sampling occasions, with concentration falling below 2mg/L on 4 occasions. DO% at the tidal limit (SALT2) was lower than the minimum freshwater guideline value on 5 of 8 sampling occasions. DO% in the estuarine site on Pipeclay Lake (PIPE1) exceeded the maximum estuarine guideline value on 4 occasions (July 2019, December 2019, January 2020 and November 2020). This exceedance was likely associated with an algal bloom, given that chl-a concentrations were above guidelines on the first 3 of these sampling occasions. DO% dropped below the guideline in March 2020 (73.6%) in PIPE1. DO% in Dirty Creek (DIRT1) were recorded below the minimum guideline on all occasions, with DO concentration falling below 2mg/L in January 2020 and November 2020.

pH in the Corindi River ranged from a minimum of 6.5 at CORI3 to a maximum of 10.3 at CORI1 (Table 3.11). pH at CORI1 and CORI3 exceeded the maximum estuary guideline value of 8.5pH in September 2019. pH was lower than the minimum estuary guideline value at the tidal limit (CORI3) on March 2020. pH in Saltwater Creek ranged from a minimum of 6 at SALT3 to a maximum of 9.6 at SALT2 (Table 3.11). SALT2 had lower than the minimum estuary guideline value in March 2020. pH dropped below the guideline in 2 of 7 sampling occasions in SALT3. pH at SALT2 (9.6) exceeded the maximum freshwater guideline value (8.5) on September 2019. pH in Pipeclay Lake ranged from 6.1 to 10 (Table 3.11). pH of PIPE was lower than the minimum estuarine guideline value (7) on March 2020 but higher than the guideline value in 3 of 6 sampling occasions. pH in Dirty creek ranged from 6 to 8.5 (Table 3.11). pH of DIRT was lower than the freshwater guideline (6.5) on 3 of 8 sampling occasions.

Turbidity ranged from 0.2 – 43NTU in the Corindi River, 0.8 – 47.5NTU in Saltwater Creek, 1.7 – 252.6NTU in Dirty Creek and 0.2 – 9.1 NTU in Pipeclay Lake (Table 3.11). The sites at tidal limits CORI3 and SALT2 exceeded the estuarine guideline value(6NTU) in March 2020. Turbidity was recorded 5 times higher than the guideline value at DIRT1 in July 2019 (Table 3.11).

Water column chlorophyll *a* (chl-*a*) in the Corindi River ranged from 0.3 – 14.4µg/L (Table 3.11), with CORI1 (4.8µg/L) exceeding the lower estuarine guideline (2.3µg/L) in March 2020, and CORI3 (4.9µg/L) exceeding the upper estuarine guideline (3µg/L) in August 2020. CORI4 (14.4µg/L) exceeded the freshwater guideline (3µg/L) more than 4 times, correlating with high TN, TP and NOx exceedance in December 2019. Chl-*a* in Saltwater Creek ranged from 0.3 – 282.7µg/L (Table 3.11). The estuarine guideline value was exceeded on 3 sampling occasions at SALT2 (December 2019, January, and November 2020). The freshwater guideline value (3µg/L) was exceeded in 7 of 8 sampling occasions in SALT3, recording up to 282.7µg/L in December 2019. The exceedance of chl-a could result from algal bloom due to high levels of nutrients as average TN, TP, and NOx exceeded the guideline at SALT3. In Pipeclay Lake, chl-a ranged from 1.7 – 13.5µg/L (Table 3.11) and exceeded the estuarine guideline value 4 of 8 sampling occasions, which could be associated with high nutrient availability in the water (Table 3.11). Chl-a in Dirty Creek ranged from 2 – 74.6µg/L, with 7 of 8

readings exceeding the freshwater guideline of 3µg/L correlating with high nutrient availability in the site.

Total nitrogen concentrations in the water column (TN) of Corindi River ranged from 30.3 – 945µg/L (Table 3.11). The lower estuarine guideline (205µg/L) was exceeded 5 of 8 sampling occasions at CORI1, and the freshwater guideline (350µg/L) was exceeded 5 of 8 sampling occasions at CORI4. Concentrations of TN in Saltwater Creek ranged from 149 – 1761µg/L (Table 3.11). The upper estuary site SALT2 had TN within the guideline, but values exceeded the freshwater guideline (350µg/L) in 6 of 8 sampling occasions. TN concentration at Dirty Creek exceeded the freshwater guideline on every sampling occasion, with a maximum recorded value (1293µg/L) 4 times above the guideline value. Except in August 2019, all the TN values exceeded the estuarine lagoon guideline of 300µg/L at PIPE1, with the maximum recorded 2.6 times above the guideline value.

Concentrations of total phosphorus in the water column (TP) of Corindi River ranged from 6 – 200µg/L (Table 3.11). The lower estuarine guideline (10.3µg/L) was exceeded at CORI1 in every sampling period. Upper estuary site CORI3 exceeded the upper estuarine TP guideline in 5 of 8 sampling occasions. CORI4 exceeded the freshwater guideline of 25µg/L in 4 of 8 sampling occasions. The maximum value (200µg/L) of TP in Corindi River was recorded at CORI4 in December 2019. Concentrations of TP in Saltwater Creek ranged from 10 – 177.3µg/L (Table 3.11). The upper estuary site SALT2 had TP above the guideline in 4 of 8 sampling occasions, whereas freshwater site SALT3 exceeded the freshwater guideline (25µg/L) in 6 of 8 sampling occasions. Maximum TP in Saltwater Creek was recorded at SALT2, which was 11.8 times higher than the upper estuarine guideline. TP concentration at Dirty Creek exceeded the freshwater guideline in 5 of 7 sampling occasions with a maximum recorded (121µg/L) 4.8 times above the guideline value. All the TP values exceeded the estuarine lagoon guideline of 13.3µg/L at PIPE1, with the maximum value recorded 15.5 times above the guideline value.

Concentrations of NOx in the water column of Corindi River ranged from 3 – 646µg/L (Table 3.11). The lower estuarine guideline (5.1µg/L) was exceeded at CORI1 on every sampling occasion except November 2020. CORI3 exceeded the upper estuarine NOx guideline in 3 of 8 sampling occasions. CORI4 exceeded the freshwater guideline of 40µg/L in 6 of 8 sampling occasions. The maximum value (646µg/L) of NOx in Corindi River was recorded at CORI4 in December 2019. Concentrations of NOx in Saltwater Creek ranged from 3 – 246µg/L (Table 3.11). The upper estuary site SALT2 had NOx above the guideline in 6 of 8 sampling occasions, whereas freshwater site SALT3 exceeded the freshwater guideline (40µg/L) in half of the sampling occasions. Maximum NOx in Saltwater Creek was recorded at SALT3, which was 6 times higher than the guideline. NOx concentration at Dirty Creek exceeded the freshwater guideline in 4 of 7 sampling occasions, with the maximum recorded value (239µg/L) being 6 times above the freshwater guideline value. NOx values exceeded the estuarine lagoon guideline of 10.3µg/L at PIPE1 in 6 of 8 sampling occasions, with the maximum value recorded 29.4 times above the guideline value.

Concentrations of SRP in the water column of Corindi River ranged from 1 – 15µg/L (Table 3.11). The lower estuarine guideline (6.5µg/L) was exceeded at CORI1 on every sampling occasion except November 2020. Concentrations of SRP in Saltwater Creek ranged from 2 – 22µg/L (Table 3.11). The upper estuary site SALT2 had SRP above the guideline in 4 of 8 sampling occasions, whereas

freshwater site SALT3 exceeded the freshwater guideline (20µg/L) in March and May 2020. SRP concentration at Dirty Creek ranged between 4.3 – 16µg/L with no values exceeding the guideline value. SRP values exceeded the estuarine lagoon guideline of 6.3µg/L at PIPE1 in 3 of 8 sampling occasions with the maximum value of 22µg/L.

Survey Period 2

Water quality in the subcatchment of the Corindi River, Saltwater Creek, Dirty Creek and Pipeclay Lake in Survey Period 2 (2021 – 2022) was better than in Survey Period 1 (2019 – 2020), with the catchment receiving a score of 78, a grade of B. Within the Corindi River, upper estuary sites CORI3 (85) and freshwater site CORI4 (85) recorded better water quality with a grade of B compared to lower estuary site CORI1 (65) with a water quality grade of C. At Saltwater Creek, estuary site SALT2 (82, B) received better water quality than the freshwater site SALT3 (73, C). Compared to Survey Period 1, water quality improved in Pipeclay Lake and Dirty Creek. Pipeclay Lake received a 78 (B) score for water quality based on the single estuarine site PIPE1 in Survey Period 2. Dirty Creek received a 78 (B) score for water quality based on the single freshwater site DIRT1 (Table 3.10).

Water temperatures at all sites reflected seasonal climatic changes. Table 3.11 outlines the ranges and means of water chemistry variables for the sites on the Corindi River, Saltwater Creek, Dirty Creek and Pipeclay Lake. Summer maximum water temperatures ranged from 23.3°C at the tidal limit (CORI3) to 21.5°C at the freshwater CORI4. Winter minimum water temperatures were also the lowest (13.4°C) at the freshwater CORI4. Similar patterns in water temperatures were observed in Saltwater Creek, where the freshwater site (SALT3) was consistently cooler than the tidal limit (SALT2, Table 3.11). Water temperatures in Pipeclay Lake ranged from a winter minimum of 19.4°C to a summer maximum of 25.1°C (Table 3.11). Water temperatures in Dirty Creek ranged from a winter minimum of 11.6°C to a summer maximum of 21.1°C (Table 3.11).

Percent saturation of dissolved oxygen (DO%) was higher in estuarine site CORI1 than other two sites at Corindi River. DO% in the Corindi River ranged from 40.2% in CORI3 to 139.3% in CORI1 (Table 3.11). In the Corindi River estuary (CORI1), DO% exceeded the maximum estuarine guideline value of 110% on 2 of 5 sampling occasions but dropped below the guideline in June 2022 with a DO concentration of 3.9mg/L. At the tidal limit (CORI3), DO% was lower than the minimum estuary guideline value (80%) in June 2022, with a DO concentration of 3.8mg/L. In the freshwater site CORI4, DO% was lower than the minimum freshwater guideline value (80%) in February 2022.

DO% in Saltwater Creek ranged from 29.9% in the SALT3 to 102.3% in SALT2 (Table 3.11). DO% at the tidal limit (SALT2) dropped below the minimum estuarine guideline value on 3 of 5 sampling occasions. DO% at the freshwater SALT3 was lower than the minimum freshwater guideline value on 2 of 3 sampling occasions, but concentrations were above 2mg/L. DO% in the estuarine site on Pipeclay Lake (PIPE1) exceeded the maximum estuarine guideline value on May 2021 (139.8%), likely due to wave-driven reaeration rather than an association with an algal bloom, given chl-a concentration was within guidelines. DO saturation dropped below the guideline in May 2022 (37%, 2.7 mg/L). Like Survey Period 1, DO% in the Dirty Creek (DIRT1) were recorded below the minimum guideline on all occasions, with DO concentration below 2mg/L in February 2022.

pH in the Corindi River ranged from a minimum of 6.6 at CORI4 to a maximum of 9.2 at CORI4 (Table 3.11). pH at CORI4 (9.2) was higher than the maximum estuary guideline value of 8.5pH on May 2022. pH was lower than the minimum estuary guideline value at the tidal limit (CORI3, 6.8) on February 2022. pH in Saltwater Creek ranged from a minimum of 6 at SALT3 to a maximum of 7.4 at SALT2 (Table 3.11). SALT2 had lower than the minimum estuary guideline value in May 2022. pH was recorded in only 3 trips, and the value dropped below the guideline in June 2022 in SALT3 (6). pH in Pipeclay Lake ranged from 6.9 to 8 (Table 3.11). pH of PIPE (6.9) was slightly lower than the minimum estuarine guideline value (7) on May 2022. pH in Dirty creek ranged from 5.9 to 7.9 (Table 3.11). pH of DIRT was lower than the freshwater guideline (6.5) on 2 of 5 sampling occasions.

Turbidity ranged from 0.1 – 28.8NTU in the Corindi River, 0.5 – 22.6NTU in Saltwater Creek, 11.2 – 26.2NTU in Dirty Creek and 0.3 – 2.4NTU in Pipeclay Lake (Table 3.11). The site at tidal limits CORI3 exceeded the estuarine guideline value(6NTU) in May 2021, February 2022 and May 2022. Another tidal limit SALT2 also exceeded the guideline in May 2022.

Water column chlorophyll *a* (chl-*a*) in the Corindi River ranged from 0.2 – 33.3µg/L (Table 3.11), with the maximum recorded in CORI1 exceeding the lower estuarine guideline (2.3µg/L) in February 2022 which might be due to warm temperature and light levels in summer. Chl-a at Saltwater Creek ranged from 0.5 – 9.7µg/L (Table 3.11), with the maximum value recorded at SALT3 in May 2021 being 3 times higher than the freshwater guideline value. In Pipeclay Lake, chl-a ranged from 0.6 – 4µg/L (Table 3.11). Chl-a in Dirty Creek ranged from 0.1 – 4.8µg/L.

Total nitrogen concentrations in the water column (TN) of Corindi River ranged from 62 – 852.3µg/L (Table 3.11). The lower estuarine guideline (205µg/L) was exceeded 2 of 5 sampling occasions at CORI1, the upper estuarine guideline (608µg/L) was exceeded 3 of 5 sampling occasions at CORI3, and the freshwater guideline (350µg/L) was exceeded 2 of 5 sampling occasions at CORI4. Concentrations of TN in Saltwater Creek ranged from 60 – 925.7µg/L (Table 3.11). The upper estuary site SALT2 had TN within the guideline as in Sampling Period 1, but values exceeded the freshwater guideline (350µg/L) in June 2022. TN concentration at Dirty Creek exceeded the freshwater guideline in 4 of 5 sampling occasions, with the maximum recorded value (633.3µg/L) being 1.8 times above the guideline value. The TN values exceeded the estuarine lagoon guideline of 300µg/L at PIPE1 in May 2022 (665µg/L) and June 2022 (1128.7µg/L).

Concentrations of total phosphorus in the water column (TP) of Corindi River ranged from 15 – 845.3µg/L (Table 3.11). The guideline for TP was exceeded at the river in all sampling occasions except once at CORI4 in August 2022. The maximum value (845.3µg/L) of TP in Corindi River was recorded at CORI4 in May 2021. Concentrations of TP in Saltwater Creek ranged from 13 – 1746.7µg/L (Table 3.11). The upper estuary site SALT2 had TP above the guideline in 4 of 5 sampling occasions, whereas freshwater site SALT3 exceeded the freshwater guideline (25µg/L) in June 2022. Maximum TP in Saltwater Creek was recorded at SALT2, which was more than 100-fold the upper estuarine guideline value. TP concentration at Dirty Creek exceeded the freshwater guideline in every sampling trip as in Sampling Period 1, with the maximum recorded value (551µg/L) being 22 times above the guideline value. All the TP values exceeded the estuarine lagoon guideline of 13.3µg/L at PIPE1, similar to Sampling Period 1, with the maximum value recorded 26.6 times above the guideline value.

NOx in the water column of Corindi River ranged from 3 – 65µg/L (Table 3.11). The lower estuarine guideline (5.1µg/L) was exceeded at CORI1 in 4 of 5 sampling occasions but never exceeded 9.3µg/L. CORI4 exceeded the freshwater guideline of 40µg/L in August 2022 only. Concentrations of NOx in Saltwater Creek ranged from 1.7 – 25.3µg/L (Table 3.11), with all the values lying under the guideline value. NOx concentration at Dirty Creek exceeded the freshwater guideline in August 2022 with a recorded value of 48µg/L, just exceeding the guideline value (40µg/L). The estuarine lagoon PIPE1 has NOx within the range of 5.7 – 26.3 guideline, with 4 of 5 readings above the estuarine guideline of 10.3µg/L.

There was a substantial drop in SRP level in river water in the subcatchment of Corindi River, Saltwater Creek, Dirty Creek and Pipeclay Lake compared to Survey Period 1. SRP in the water column of Corindi River ranged from 1 – 8.7µg/L (Table 3.11). The lower estuarine guideline (6.5µg/L) was slightly exceeded at CORI1 in 3 of 5 sampling occasions. Concentrations of SRP in Saltwater Creek ranged from 2 – 5µg/L, Dirty Creek ranged between 1.7 – 5.3µg/L and Pipeclay Lake at PIPE1 ranged between 2 – 3µg/L (Table 3.11) with no values exceeding the guideline value.

Table 3.10. *Water quality grades for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Corindi River subcatchment.*

	CORI1		CORI3		CORI4		DIRT1	
	2019-2020	2021-2022	2019-2020	2021-2022	2019-2020	2021-2022	2019-2020	2021-2022
WQ Grade	72	65	84	85	77	85	70	78
Phys-Chem	23	25	22	23	23	25	19	21
Nutrients	21	22	30	29	26	27	26	28
Chl-a	28	18	32	33	28	33	25	29
	PIPE1		SALT2		SALT3			
	2019-2020	2021-2022	2019-2020	2021-2022	2019-2020	2021-2022		
WQ Grade	63	78	79	82	65	73		
Phys-Chem	24	24	24	25	19	21		
Nutrients	20	25	25	26	22	27		
Chl-a	19	29	30	31	24	25		

Table 3.11. *Minimum and maximum (and mean) values of water quality variables for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Corindi River subcatchment.*

	CORI1						CORI3					
	Survey Period 1			Survey Period 2			Survey Period 1			Survey Period 2		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temp (°C)	18.9	23.2	21.5	18	22.5	20.8	14.1	27.6	21	14.5	23.3	18.2
pH	7.9	10.3	8.4	8	8.5	8.2	6.5	10.1	7.6	6.8	7.3	7.1
Cond (µS/cm)	35190.7	74349	56451.2	26916.7	55553.3	48149.2	3703.3	65046.7	37617	245.3	21004.3	12118.1
Salinity (PPT)	22.2	62.3	39.2	24.5	36.9	33.2	2	44.1	24.5	0.1	12.6	7.1
DO (mg/L)	7.1	8.8	8.1	3.9	10.1	7.7	4.1	8.1	6.1	3.8	9.2	7

DO %	101.5	122.3	113.6	53.5	139.3	104.5	55.3	89.4	77.3	40.2	103.2	77.5
Turbidity (NTU)	0.3	2.6	0.9	0.1	3	1.4	0.2	23.2	5.2	1.9	28.8	13.2
TSS (mg/L)	4.1	24.4	18.2	10.4	29.3	17.1	9.7	19.4	13.8	10.8	21.5	14.8
Chl-a (µg/L)	0.6	4.8	2.1	0.5	33.3	7.4	0.8	4.9	2.2	0.3	2.6	1.4
TN (µg/L)	114	710	389.2	62	852.3	342.3	30.3	519	285.8	92	440.3	254
TP (µg/L)	11	71.3	23.8	21.3	120.3	81.4	6	22	11.8	37.7	131.3	87.8
NOx (µg/L)	3	277	108.1	3	9.3	6.6	10.3	192	65.2	12.7	33.7	20.9
SRP (µg/L)	2	14	6.9	2	8.7	5.7	1	6	3.3	1.7	5.7	3.1
	CORI4						DIRT1					
	Survey Period 1			Survey Period 2			Survey Period 1			Survey Period 2		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temp (°C)	11.8	24.3	17.9	13.4	21.5	16.8	8.1	24.5	16.7	11.6	21.1	15.6
pH	6.8	8.5	7.5	6.6	9.2	7.5	6	8.5	6.9	5.9	7.9	6.8
Cond (µS/cm)	128	51721	6635	131	148.3	140.7	120	280	173.6	125.7	165.7	140.1
Salinity (PPT)	0.1	34.1	4.3	0.1	2.1	0.5	0.1	0.1	0.1	0.1	0.1	0.1
DO (mg/L)	0.2	9.5	5.3	6.4	11	8.8	0.8	6	2.9	1.2	6.4	3.4
DO %	2.4	92.3	56.4	72.6	111.5	89.6	8.7	50.6	29.2	13.2	64.8	34.2
Turbidity (NTU)	1.1	43	13.4	12	28.6	16.8	1.7	252.6	46.4	11.2	26.2	17.6
TSS (mg/L)	1.8	95.5	18.2	5.1	131.9	34.9	2.2	95.5	25.2	2.8	178.4	43.1
Chl-a (µg/L)	0.3	14.4	4.1	0.2	0.5	0.3	2	74.6	16.8	0.1	4.8	1.6
TN (µg/L)	218	945	479.8	185	839.7	384.9	451	1293	793.5	245.3	633.3	412.6
TP (µg/L)	20	200	66.3	15.3	845.3	254.7	17	183.7	62.3	47	551.7	207.5
NOx (µg/L)	9.7	646	185.8	7.7	65	33.9	2.3	239	75.9	3	48	15.9
SRP (µg/L)	2	15	6.8	1	3.7	2.4	4.3	16	7.9	1.7	5.3	3
	PIPE1						SALT2					
	Survey Period 1			Survey Period 2			Survey Period 1			Survey Period 2		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temp (°C)	20.2	30.5	24.7	19.4	25.1	21.8	13.6	27.7	20.7	14.9	25.4	19.2
pH	6.1	10	8.2	6.9	8	7.4	6.4	9.6	7.5	6.5	7.4	7
Cond (µS/cm)	685	45771.7	22866.9	8874	45588.3	28922.9	8318.3	74637	45238.7	7936	36087.7	28403.9

Salinity (PPT)	0.3	29.7	14.2	9.2	29.6	19.1	4.6	51.7	29.9	4.4	22.8	17.7
DO (mg/L)	6.3	17.8	10.2	2.7	10.5	7.6	4.6	7.1	5.9	3.4	8.4	5.8
DO %	73.6	237.8	133.5	37	139.8	95.1	67.4	90.4	77.3	38.6	102.3	69.6
Turbidity (NTU)	0.2	9.1	3.5	0.3	2.4	1.3	0.8	18.1	4	0.5	22.6	5.9
TSS (mg/L)	3.7	19.2	10.3	7.3	19.6	12.7	11	29.1	20.4	11.7	28.3	19.9
Chl-a (µg/L)	1.7	13.5	6.5	0.6	4	2	0.3	10.2	4	1	4.1	2.4
TN (µg/L)	126	930	627.3	269	1128.7	574.3	149	483	340.7	60.7	517.7	281.8
TP (µg/L)	15	207.7	58.3	32.3	354	109.4	10	177.3	39.8	13	1746.7	403.3
NOx (µg/L)	2	303	125.6	5.7	26.3	18.2	3	246	103.3	1.7	15.3	7.7
SRP (µg/L)	1	12	6.1	2	3	2.3	2	15	6.6	2	5	3.5

	SALT3					
	Survey Period 1			Survey Period 2		
	Min	Max	Min	Max	Min	Max
Temp (°C)	9.5	25	17.5	11.7	17.3	13.9
pH	6	8.4	7	6	6.8	6.4
Cond (µS/cm)	166	715	367.9	109.3	12641.7	4291.4
Salinity (PPT)	0.1	0.4	0.2	0.1	7.3	2.5
DO (mg/L)	0.7	5.1	2.5	3.2	8.7	5.5
DO %	7.6	59.1	26.1	29.9	95	55.7
Turbidity (NTU)	1	47.5	24.4	10.7	18.3	14.5
TSS (mg/L)	1.5	26.5	14.4	8.5	33.2	18.8
Chl-a (µg/L)	0.7	282.7	40.3	0.5	9.7	3.6
TN (µg/L)	224	1761	796	272	925.7	597.1
TP (µg/L)	18	141	53.2	14.3	95.7	41.8
NOx (µg/L)	3	246	81.3	3	25.3	16.8
SRP (µg/L)	3	22	10.3	2.7	3.3	3

3.2.5 Aquatic macroinvertebrates

Corindi River

The macroinvertebrate community at the freshwater section of Corindi River received an overall grade of B- for condition in 2019-20 (Table 3.12), an improvement from very poor (F) in 2015. Indicators varied from D to A+. Total Abundance was poor at 9/20 (D). Richness scored 16/20 (B+) and only some EPT taxa were collected giving this indicator a poor rating (10/20, D). Nativeness was very good (20/20), with no exotic taxa collected. The Site Mean SIGNAL was 4.5 with the waterbug community comprising low-scoring, pollution-tolerant taxa (SIGNAL2 score of Good, 17/20). However, there were some high-scoring pollution-sensitive mayfly and caddisfly taxa present at this site.

The macroinvertebrate community at CORI4 received an overall grade of D for condition in 2020-21 (Table 3.12), a decrease in condition (score B-, good), in 2019-20. Indicators varied from F to A+. The Abundance criteria was very poor at 5/20 (F). Richness scored 8/20 (D-) and only a few EPT taxa were collected giving this indicator a very poor rating (3/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The SIGNAL2 scored was 11/20 with the waterbug community comprising mostly low-scoring, pollution-tolerant taxa. However, there were several high-scoring pollution-sensitive mayflies present at this site.

Table 3.12 *Summary of aquatic macroinvertebrate data for Corindi River #4 (CORI4). Indicators are out of 20.*

CORI4				
	Survey Period 1		Survey Period 2	
Macroinvertebrate indicator	**Score**	**Grade**	**Score**	**Grade**
Family richness	9	D	5	F
Total abundance	16	B+	8	D-
EPT	10	D	3	F
Nativeness	20	A+	20	A+
Mean SIGNAL2 score	17	B+	11	C-
Ecohealth score	**72**	**B-**	**48**	**D**

Saltwater Creek

The macroinvertebrate community at Saltwater Creek received an overall grade of D- for condition in 2019-20 (Table 3.13), an improvement from the score of F in 2015. Indicators varied from F to A+. Total Abundance was very poor at 2/20 (F). Richness scored 8/20 (D-) and only two EPT taxa were collected giving this indicator a very poor rating (1/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The Site Mean SIGNAL was 3.7 with the waterbug community comprising mostly low-scoring, pollution-tolerant taxa (SIGNAL2 score of Fair, 14/20). However, there were a two high-scoring pollution-sensitive Leptophlebiidae mayflies and Trichopteran caddisflies present at this site.

The macroinvertebrate community at SALT3 received an overall grade of F for condition in 2020-21 (Table 3.13) a decrease in condition from the overall score of D, poor, in 2019-20. Indicators varied from F to A+. The Abundance criteria was very poor at 2/20 (F). Richness scored 1/20 (F) and no EPT taxa were collected giving this indicator a very poor rating (0/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The SIGNAL2 scored was 11/20 with the waterbug community comprising of low-scoring, pollution-tolerant taxa, as well as several high-scoring pollution-sensitive mayflies and caddiflies present at this site.

Table 3.13 *Summary of aquatic macroinvertebrate data for Saltwater Creek #3. Indicators are out of 20.*

SALT3				
	Survey Period 1		Survey Period 2	
Macroinvertebrate indicator	**Score**	**Grade**	**Score**	**Grade**
Family richness	2	F	2	F
Total abundance	8	D-	1	F
EPT	1	F	0	F
Nativeness	20	A+	20	A+
Mean SIGNAL2 score	14	C+	11	D+
Ecohealth score	**45**	**D-**	**34**	**F**

Dirty Creek

The macroinvertebrate community at DIRT1 received an overall grade of D+ for condition in 2019-20 (Table 3.14). Indicators varied from F to A+. Total Abundance was poor at 10/20 (D+). Richness scored 10/20 (D-) and only one EPT taxon was collected giving this indicator a very poor rating (2/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The Site Mean SIGNAL was 2.7 with the waterbug community comprising mostly low-scoring, pollution-tolerant taxa (SIGNAL2 score of Poor, 10/20). However, there was one high-scoring pollution-sensitive Trichopteran caddisfly present at this site.

The macroinvertebrate community at DIRT4 received an overall grade of C- for condition in 2020-21 (Table 3.14), an increase in condition from the overall score of D+, poor, in 2019-20. Indicators varied from F to A+. The Abundance criteria was fair at 11/20 (C-). Richness scored 12/20 (C-) and only a few EPT taxa were collected giving this indicator a very poor rating (5/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The SIGNAL2 scored was 12/20 with the waterbug community comprising mostly low-scoring, pollution-tolerant taxa. However, there were several high-scoring pollution-sensitive mayflies present at this site.

Table 3.14 *Summary of aquatic macroinvertebrate data for Dirty Creek #1. Indicators are out of 20.*

DIRT1				
	Survey Period 1		Survey Period 2	
Macroinvertebrate indicator	**Score**	**Grade**	**Score**	**Grade**
Family richness	10	D+	11	C-
Total abundance	10	D+	12	C-
EPT	2	F	4	F
Nativeness	20	A+	20	A+
Mean SIGNAL2 score	10	D+	12	C-
Ecohealth score	**53**	**D+**	**48**	**C-**

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 3.15). Very little of the subcatchment comprises midland hills; only 13% of the stream network comprises headwaters and 15% drains to confined discontinuous floodplains (Table 3.15). The catchment is underlain by Coramba Beds of the Coffs Harbour association metasediments consisting of siliceous mudstones, siltstones and greywacke (72%, Table 3.15), 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%) (Table 3.15).

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. 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 3.15).

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).

Table 3.15 *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 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 (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 66.6, a grade of C for BANK CONDITION and 72.0, a grade of C+ for BED CONDITION. The overall Ecohealth geomorphic condition for ARRA4 was 69.3, a grade of C.

In summary, ARRA4 was assessed as being in moderate 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.

ARRA1 is lower estuary with a River Style of laterally unconfined continuous tidal channel. Bed and bank sediments were fine-grained, with cobbles present as engineered rock walls. The southern bank was well vegetated, but the northern bank comprises a caravan park and receives significant pedestrian traffic. ARRA1 scored 72.0, a grade of B for BANK CONDITION and 84.0, a grade of C+ for BED CONDITION. The overall Ecohealth geomorphic condition for ARRA4 was 78.0, a grade of B-.

3.3.3 Riparian condition

ARRA4 Riparian Condition: T1 = 93.2 (A-) T2 = 91.4 (A-). Temporal difference = -1.8

Arrawarra Creek 4 was a low disturbance, freshwater system that supported a Coastal Paperbark - Swamp Oak Floodplain Forest (CH_FrW01) riparian zone (see dominant species list for full site details; Table 3.16). Immediate site surroundings were largely intact vegetation intersected by roads and a powerline easement, with some agricultural development to the southeast and northeast of the site. There was very little evidence of historic disturbance at the site. The site displayed good structural complexity with representative plant species of the remnant vegetation community present throughout all structural layers on site.

ARRA4 scored well for all subindices (Habitat, Native Species, Species Cover, Debris and Management). Riparian condition score was slightly reduced by limited native woody regeneration and only moderate amounts of large woody debris cover (Dead trees fallen). However, this site was in excellent condition.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Slight decrease in native woody regeneration
- Slight decrease in dead trees standing.

Why?

- A slight reduction in woody regeneration may have been attributed to flood flows in the period between T1 (September 2019) and T2 (March 2022), and temporarily suppressed (or overlooked) by the presence of dense, healthy native cover of understory species.

What else?

- It was noted in T1 survey that new blueberry farms had opened to the south-east of the site. If left unchecked the establishment of such developments pose potential risk to riparian vegetation through increased stream eutrophication which can lead to weed promotion if appropriate measures are not taken to mitigate these impacts.

Recommendations

- Ensure appropriate measures are taken to mitigate risks associated with catchment development
- Monitor for weeds and control/remove as necessary
- Keep waterway clean of rubbish
- Maintain current practices.

Table 3.16 *Site-level summary of riparian condition of Arrawarra Creek #4, including subindices and indicators.*

Arrawarra Creek #4	Survey 1	Survey 2	Change
HABITAT	**20.0**	**20.0**	**0.0**
Channel width	4.0	4.0	**0.0**
Proximity	4.0	4.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	2.0	2.0	**0.0**
NATIVE SPECIES	**20.0**	**20.0**	**0.0**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	4.0	4.0	**0.0**
Native herb/forb species	4.0	4.0	**0.0**
Native graminoid species	4.0	4.0	**0.0**
Native macrophyte species	4.0	4.0	**0.0**
SPECIES COVER	**16.0**	**16.3**	**0.3**
Canopy species	2.5	2.5	**0.0**
Midstory species	3.5	3.5	**0.0**
Herb/forb species	2.0	2.3	**0.3**
Graminoid species	4.0	4.0	**0.0**
Macrophyte species	4.0	4.0	**0.0**
DEBRIS	**18.5**	**17.5**	**-1.0**
Total leaf litter	3.0	3.0	**0.0**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	3.0	2.0	**-1.0**
Dead trees fallen	1.5	1.5	**0.0**
Lying logs	4.0	4.0	**0.0**
Fringing vegetation	4.0	4.0	**0.0**
MANAGEMENT	**18.7**	**17.6**	**-1.1**
Tree clearing	3.0	3.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	1.7	1.6	**-0.1**
Exposed tree roots	4.0	4.0	**0.0**
Native woody regeneration	2.0	1.0	**-1.0**
Weedy woody regeneration	2.0	2.0	**0.0**
TOTAL	**93.2**	**91.4**	**-1.8**

ARRA1 Riparian Condition: T1 = 71.0 (C+) T2 = 71.8 (C+). Temporal difference = +0.8

Arrawarra Creek 1 (Little Arrawarra Creek) was a mild disturbance, estuarine lagoon system that supported an Estuarine Mangrove Forest (CH_SW01), grading into an Estuarine Paperbark - Twig Rush Forest (CH_FrW11) riparian zone (Table 3.17). Immediate site surroundings were an area of intact vegetation in the form of Garby Nature Reserve, which was bounded by roads including the Pacific Highway. Suburban infrastructure lay within 150m of the site to the north, there was development on all sides of the nature reserve and a powerline easement intersects the reserve. Historic disturbances in the form of clearing were evident in the young age of most canopy species, and the presence of sometimes dense patches of exotic species throughout the structural layers. Native trees (regrowth) were present in less disturbed areas with representative plant species of the remnant vegetation community present throughout all structural layers on site.

ARRA1 scored well for the Habitat subindex and moderately for the Native Species, Species Cover, Debris and Management subindices. Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: senna (*Senna pendula*), groundsel bush (*Baccharis halimifolia*), asparagus fern (*Asparagus aethiopicus*) and common prickly pear (*Opuntia stricta*) (see dominant species list for full site details). Limited native herb/forb, graminoid and macrophyte species; a lack of current woody regeneration (weedy and native) and animal impacts also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2
What caused the difference?

- Slight increase in native midstory species
- Slight increase in canopy health
- Increase in dead standing trees
- Decrease in overall leaf litter, including slight reduction in native leaf litter.

Why?

- High rainfall and increased flows in the period between T1 (September 2019) and T2 (March 2022) likely removed leaf litter which has yet to re-establish.
- Increased soil moisture as a result of high rainfall likely supported establishment and expansion of exotic graminoids.

Recommendations

- Implement weed control measures, including identifying likely sources of infestation, invasion routes (i.e. powerline easement) and controlling spread.

Table 3.17 *Site-level summary of riparian condition of Arrawarra Creek #1, including subindices and indicators.*

Arrawarra Creek #1	Survey 1	Survey 2	Change
HABITAT	**20.0**	**20.0**	**0.0**
Channel width	4.0	4.0	**0.0**
Proximity	4.0	4.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	2.0	2.0	**0.0**
NATIVE SPECIES	**13.0**	**13.5**	**0.5**
Native canopy species	3.5	3.5	**0.0**
Native midstory species	0.0	0.5	**0.5**
Native herb/forb species	2.5	2.5	**0.0**
Native graminoid species	3.0	3.0	**0.0**
Native macrophyte species	4.0	4.0	**0.0**
SPECIES COVER	**11.5**	**12.0**	**0.5**
Canopy species	2.0	2.0	**0.0**
Midstory species	2.0	2.0	**0.0**
Herb/forb species	0.5	1.0	**0.5**
Graminoid species	3.0	3.0	**0.0**
Macrophyte species	4.0	4.0	**0.0**
DEBRIS	**13.5**	**13.0**	**-0.5**
Total leaf litter	3.0	2.0	**-1.0**
Native leaf litter	2.0	1.5	**-0.5**
Dead trees standing	1.0	2.0	**1.0**
Dead trees fallen	2.5	2.5	**0.0**
Lying logs	1.0	1.0	**0.0**
Fringing vegetation	4.0	4.0	**0.0**
MANAGEMENT	**13.0**	**13.3**	**0.3**
Tree clearing	2.0	2.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	1.0	1.3	**0.3**
Exposed tree roots	4.0	4.0	**0.0**
Native woody regeneration	0.0	0.0	**0.0**
Weedy woody regeneration	0.0	0.0	**0.0**
TOTAL	**71.0**	**71.8**	**0.8**

3.3.4 Water quality

Survey Period 1

In Survey Period 1 (2019 – 2020), Arrawarra Creek received a score of 68, a grade of C, for water quality, with similar water quality between estuary site ARRA1 and the freshwater site ARRA4 (Table 3.18). Water temperatures reflected seasonal climatic changes, ranging from winter minimums of 10.7°C at ARRA4 to summer maximums of 31.2°C at ARRA1 (Table 3.19). DO% ranged from 5.2 – 136.4% (Table 3.19). DO% was below the minimum estuarine guideline value once (November 2020); although below the guideline value, the minimum DO concentration at ARRA1 of 4.7mg/L remained above concentrations that would harm aquatic biota (See Table 2.4 for water quality guideline values). DO at ARRA1 exceeded the maximum estuarine guideline once (August 2020). This exceedance was likely wave-driven reaeration rather than an association with an algal bloom, given chl-a concentration was within guidelines for ARRA1. DO% at ARRA4 was below the freshwater guideline range on all sampling occasions except in December 2019; minimum concentrations were below 2mg/L in 4 out of 8 sampling occasions that harmed aquatic biota. pH ranged from 6.6 – 9.9 (Table 3.19). Except in September 2019, pH was recorded within the guidelines for healthy aquatic ecosystems in all sampling occasions. Turbidity ranged from 0.1 – 5.14NTU in ARRA1 and did not exceed the guideline. In contrast, turbidity in ARRA4 was recorded below the lowland freshwater guideline value in 6 of 8 sampling occasions, but a remarkably high turbidity of 816NTU was recorded in May 2020, well above the freshwater guideline value.

Chl-*a* ranged from 0.8 – 73.6µg/L (Table 3.19) and remained above the guideline value in the estuary (ARRA1) in July and December 2019. At ARRA4, chl-*a* exceeded the freshwater guideline value in all sampling occasions. TN ranged from 251 – 1375µg/L and exceeded the guideline value in all sampling periods except ARRA1 in January 2020. TP ranged from 13 – 267.67µg/L and exceeded the guideline value in all sampling periods except ARRA1 in August 2020. At ARRA1, NOx exceeded the estuarine guideline value in all sampling periods, whereas ARRA4 recorded NOx above the freshwater guideline value in 7 out of 8 sampling periods. On 7 occasions, SRP exceeded the estuarine guideline value at ARRA1, but SRP was below the freshwater guideline value at ARRA4 during all the sampling occasions. High concentrations of macronutrients N and P, particularly of the dissolved bioavailable forms, would contribute to the high algal biomass observed in both freshwater and estuarine reaches of Arrawarra Creek.

Survey Period 2

Water quality in Arrawarra Creek improved in the Survey Period 2 (2021 – 2022) from the Survey Period 1 (2019 – 2020), with the catchment receiving a score of 76, a grade of B (Table 3.18). The estuary site ARRA1 (B) recorded better water quality than the freshwater site ARRA4 (C). Water temperatures reflected seasonal climatic changes, ranging from winter minimums of 12.6°C at ARRA4 to summer maximums of 23.9°C at ARRA1 (Table 3.19). DO% ranged from 28.7 – 123.4% (Table 3.19). DO% at ARRA1 was below the minimum estuarine guideline value once (August 2020) and exceeded the maximum estuarine guideline value once (May 2021) (See Table 2.4 for water quality guideline values). This exceedance was likely wave-driven reaeration rather than an association with an algal bloom, given chl-*a* concentration was within guidelines for ARRA1. DO% at

ARRA4 was lower than the freshwater trigger range on all sampling occasions, but DO did not drop below 2mg/L. pH ranged from 6.5 – 9.5 (Table 3.19). On one occasion (May 2022), pH exceeded the maximum guideline value at ARRA1 and ARRA4. Turbidity ranged from 1 – 137.9NTU. Turbidity was recorded above the estuarine guideline value in May 2022 at ARRA1. In contrast, turbidity in ARRA4 was recorded above the lowland freshwater guideline value in 2 of 5 sampling occasions.

Chl-a ranged from 0.3 – 13.8µg/L (Table 3.19) and remained below the guideline value in the estuary (ARRA1). At ARRA4, chl-a exceeded the freshwater guideline value in May 2021. TN ranged from 214 – 637.7µg/L and exceeded the guideline value in ARRA1 in May 2021 and 2022, whereas it was above the freshwater guideline value in all sampling occasions in ARRA4. TP ranged from 19 – 522.7µg/L and exceeded the guideline value in all sampling periods in ARRA1. TP at ARRA4 exceeded the freshwater guideline value on 4 out of 5 sampling occasions. NOx ranged from 2.7 – 23.3µg/L (Table 3.19). At ARRA1, NOx exceeded the estuarine guideline value in one sampling period, whereas ARRA4 recorded NOx below the freshwater guideline value in all sampling periods. SRP ranged from 1 – 13.3µg/L with all the values below the guideline value at ARRA1 and ARRA4.

Table 3.18. *Water quality grades for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Arrawarra Creek subcatchment.*

	ARRA1		ARRA4	
	2019-2020	2021-2022	2019-2020	2021-2022
WQ Grade	63	81	63	77
Phys-Chem	23	23	23	23
Nutrients	21	25	21	24
Chl-a	19	33	19	30

Table 3.19. *Minimum and maximum (and mean) values of water quality variables for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Arrawarra Creek subcatchment.*

	ARRA1						ARRA4					
	Survey Period 1			Survey Period 2			Survey Period 1			Survey Period 2		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temp (°C)	17.6	31.2	22.4	14.5	23.9	19.7	10.7	25.4	18.2	12.6	21.8	16.5
pH	7.6	9.9	8.1	7.8	9.5	8.4	6.6	8.9	7.4	6.5	9.2	7.3
Cond (µS/cm)	33430	62378	51712.6	37849	48013.3	43044.5	162	466	248.6	118.3	193	140.4
Salinity (PPT)	20.4	42.1	32.8	24	31.3	27.8	0.1	0.2	0.1	0.1	0.1	0.1
DO (mg/L)	4.7	10.4	7	6.9	9.2	7.6	0.5	7.9	3.1	2.9	6.9	5.5
DO %	66	136.4	98	78.1	123.4	97.5	5.2	96	33	28.7	76	56.7
Turbidity (NTU)	0.1	5.1	2	1	7.7	4	3	816	137	21.9	137.9	60.2
TSS (mg/L)	9.1	41.9	22.1	10.5	38.7	22.7	6	27	13.6	12.1	54.8	23
Chl-a (µg/L)	0.8	12.4	4.6	0.3	2.8	1.3	4.3	73.6	22.2	0.3	13.8	3.5
TN (µg/L)	251	633	379.8	214	637.7	400.3	356	1375	658.5	454.7	629.3	556
TP (µg/L)	13	267.7	65.3	39	115	68.4	26	77	45.1	19	522.7	182.5
NOx (µg/L)	12.7	339	144.7	2.7	16	8.3	3	1960	318.4	2.7	23.3	14.4
SRP (µg/L)	3.3	21	12.9	1	6.3	3.5	4	14	8.9	2	13.3	4.8

3.3.5 Aquatic macroinvertebrates

The macroinvertebrate community at Arrawarra Creek received an overall grade of D+ for condition in 2019-20 (Table 3.20) which is an improvement from the overall score of F, very poor, in 2015. Indicators varied from F to A+. There was a total of 171 individual macroinvertebrates with Abundance very poor at 7/20 (F). Richness scored 11/20 (C-) and no EPT taxa were collected giving this indicator a very poor rating (0/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The Site Mean SIGNAL was 3.6 with the waterbug community comprising mostly low-scoring, pollution-tolerant taxa (SIGNAL2 score of 13/20). However, there were high-scoring pollution-sensitive Leptophlebiidae mayflies and Trichopteran caddisflies present at this site.

The macroinvertebrate community at Arrawarra Creek received an overall grade of C for condition in 2020-21 (Table 3.20) which is an improvement from the overall score of D, poor, in 2019-20. Indicators varied from F to A+. The Abundance criteria was Fair at 14/20 (C+). Richness scored 13/20 (C+) and only a few EPT taxa were collected giving this indicator a very poor rating (3/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The SIGNAL2 scored was 11/20 with the waterbug community comprising mostly low-scoring, pollution-tolerant taxa. However, there were several high-scoring pollution-sensitive mayflies present at this site.

Table 3.20 *Summary of aquatic macroinvertebrate data for Arrawarra Creek #4 (ARRA4). Indicators are out of 20.*

ARRA4				
	Survey Period 1		Survey Period 2	
Macroinvertebrate indicator	**Score**	**Grade**	**Score**	**Grade**
Family richness	7	F	14	C+
Total abundance	11	C-	13	C+
EPT	0	F	3	F
Nativeness	20	A+	20	A+
Mean SIGNAL2 score	13	C+	11	C-
Ecohealth score	**51**	**D+**	**61**	**C**

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 3.21), with a small area of lower midland hills. 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 3.21). The hilly soil landscapes units comprise kandosols 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 (Table 3.21). 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.

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.

Table 3.21 *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 Geomorphic condition

One site was located on Darkum Creek in the lagoon adjacent to Darkum Road. 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. DARK1 scored 68.4, a grade of C for BANK CONDITION and 81.0, a grade of B for BED CONDITION. The overall Ecohealth geomorphic condition for DARK1 was 75, a grade of C+, with the site in moderate geomorphic condition.

3.4.3 Riparian condition

DARK1 Riparian Condition: T1 = 64.8 (C-) T2 = 65.0 (C). Temporal difference = +0.2

Darkum Creek 1 was a moderately disturbed Intermittently Closed and Open Lagoon (ICOL) system that supported an Estuarine Mangrove Forest (CH_SW01), grading into a Coastal Headland Swamp Oak Shrubland (CH_H07) riparian zone (Table 3.22). Immediate site surroundings were a mix of cleared land and intact vegetation. There was a small residential development adjacent to the site, and the Woolgoolga RSL Golf Club lay on the southern bank. Darkum Creek ran through patches of intensive cropping in the upper and mid catchment. Historic disturbances were evident throughout with canopy species present as regrowth and the incursion of weed species throughout all structural layers. Mixed-age stands of native trees and shrubs were present in less disturbed areas along with representative plant species of the remnant vegetation communities were throughout all structural layers on site.

DARK1 scored well for the Habitat subindex, moderately for the Native Species, Species Cover and Management subindices and poorly for the Debris subindex. Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: camphor laurel (*Cinnamomum camphora*), lantana (*Lantana camara*), senna (*Senna pendula*), asparagus fern (*Asparagus aethiopicus*), paspalum (*Paspalum dilatatum*) and coastal morning glory (*Ipomoea cairica*) (see dominant species list for full site details). Limited native regeneration, reduced levels of cover in the understory and low levels of large woody debris also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2
What caused the difference?

- Increase in native woody regeneration
- Increase in large woody debris (Lying logs)
- Increase in overall cover of herb/forb and midstory species
- Increase in exotic species occurrence in both canopy and understory
- Decrease in Total leaf litter cover and Dead trees standing.

Why?

- Increased rainfall and flood flows occurring between T1 (September 2019) and T2 (March 2022) surveys may have removed leaf litter and possibly standing dead trees.
- Flood flows may also have deposited logs at the site.
- Improved soil moisture as a result of higher than average rainfall between T1 and T2 may have supported the growth of exotic graminoids at the expense of native graminoids and led to improved native woody regeneration and canopy health.

What else?

- The overstory in this site is in relatively good condition but midstory and understory are in relatively poor condition.
- Sites such as this one offer important linkages that support biodiversity, species persistence and species movement through otherwise developed, urban landscapes.

Recommendations

- Removing and controlling woody weeds, particularly camphor laurel, lantana, senna and asparagus fern, will reduce competition in the long-term and encourage natural regeneration of native shrubs.

Table 3.22 *Site-level summary of riparian condition of Darkum Creek #1, including subindices and indicators.*

Darkum Creek #1	Survey 1	Survey 2	Change
HABITAT	**16.0**	**16.0**	**0.0**
Channel width	2.0	2.0	**0.0**
Proximity	2.0	2.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	2.0	2.0	**0.0**
NATIVE SPECIES	**15.5**	**13.0**	**-2.5**
Native canopy species	4.0	3.0	**-1.0**
Native midstory species	1.5	2.0	**0.5**
Native herb/forb species	4.0	4.0	**0.0**
Native graminoid species	4.0	2.0	**-2.0**
Native macrophyte species	2.0	2.0	**0.0**
SPECIES COVER	**11.5**	**13.0**	**1.5**
Canopy species	4.0	4.0	**0.0**
Midstory species	1.0	1.5	**0.5**
Herb/forb species	0.5	1.5	**1.0**
Graminoid species	3.0	3.0	**0.0**
Macrophyte species	3.0	3.0	**0.0**
DEBRIS	**8.5**	**8.5**	**0.0**

Total leaf litter	3.0	1.5	**-1.5**
Native leaf litter	1.5	3.0	**1.5**
Dead trees standing	1.0	0.0	**-1.0**
Dead trees fallen	0.0	0.0	**0.0**
Lying logs	0.0	1.0	**1.0**
Fringing vegetation	3.0	3.0	**0.0**
MANAGEMENT	**13.3**	**14.5**	**1.2**
Tree clearing	2.0	2.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	1.3	1.5	**0.2**
Exposed tree roots	4.0	4.0	**0.0**
Native woody regeneration	0.0	1.0	**1.0**
Weedy woody regeneration	0.0	0.0	**0.0**
TOTAL	**64.8**	**65.0**	**0.2**

3.4.4 Water quality

Survey Period 1

In Survey Period 1 (2019 – 2020), the subcatchment of Darkum Creek received a score of 69, a grade of C, for water quality based on the data taken at site DARK1. Water temperatures reflected seasonal climatic changes, ranging from winter minimums of 16.7°C to summer maximums of 30.4°C (Table 3.23).

DO% ranged from 62.7 – 113.7% (Table 3.24). The minimum DO was recorded in July 2019, and the maximum in December 2019. This exceedance was likely wave-driven reaeration rather than an association with an algal bloom, given chl-a concentration (2.2µg/L) was within guidelines for DARK1 in December 2019. DO% dropped below the guideline value on 3 of 8 sampling occasions (see Table 2.4 for water quality guideline values); however, minimum DO concentrations were never recorded below 4.5mg/L. pH was recorded above the estuarine lagoon guideline range in September 2019 (9.45). Turbidity value exceeded the guideline value by around 3 times in May 2020 (15.65NTU).

Chl-*a* ranged from 0.5 – 8µg/L (Table 3.24). Chl-a value remained above the guideline value in 3 of 8 sampling occasions, likely associated with the large exceedance of the estuarine lagoon guideline value of TN, TP, NOx and SRP. TN ranged from 126µg/L in August 2020 to 555µg/L in January 2020, with values exceeding the guideline in 6 of 8 sampling occasions. TP ranged from 14 – 86.3µg/L, with all the values exceeding the estuarine lagoon TP guideline value of 13.3µg/L. On 6 of 8 occasions, NOx exceeded the estuarine lagoon guideline value. Maximum NOx was recorded in January 2020,

with the value exceeding the guideline by 40 times. SPR ranged from 2-12µg/L with values above the guideline recorded in July 2019, January, March and May 2020.

Survey Period 2

Water quality in Darkum Creek in Survey Period 2 (2021 – 2022) slightly dropped compared to Survey Period 1 (2019 – 2020), with the catchment receiving a score of 68, a grade of C based on the data taken at site DARK1 (Table 3.23). Water temperatures reflected seasonal climatic changes, ranging from winter minimums of 13.3°C to summer maximums of 25.5°C (Table 3.24).

DO% ranged from 64.3 – 106.3% (Table 3.24). DO% dropped below the guideline value in May and June 2022, with a minimum, DO concentration of 4.7µg/L in May 2022 (see Table 2.4 for water quality guideline values). The turbidity value slightly exceeded the guideline value in May (7.94NTU) and June 2022(7.14NTU).

Chl-*a* ranged from 0.4 – 8.5µg/L (Table 3.24). Chl-a value was recorded above the guideline value only in May 2021, despite the large exceedance of the estuarine lagoon guideline value of TN, TP, and NOx in all sampling occasions. TN ranged from 386µg/L in May 2021 to 845.7µg/L in June 2022. The highest recorded TN was over 2 times above the guideline value of 300µg/L. TP ranged from 19 – 105.67µg/L with a maximum value exceeding 8 times the guideline value. NOx and SRP were recorded within 18 – 24µg/L and 1.7 – 5.33µg/L, respectively. Even though NOx readings were above the guideline, SRP values were below the guideline value in all sampling occasions.

Table 3.23*. Water quality grades for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Darkum Creek subcatchment.*

	DARK1	
	2019-2020	2021-2022
WQ Grade	69	68
Phys-Chem	24	24
Nutrients	23	22
Chl-a	22	22

Table 3.24. *Minimum and maximum (and mean) values of water quality variables for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Darkum Creek subcatchment.*

	DARK1					
	Survey Period 1			Survey Period 2		
	Min	Max	Mean	Min	Max	Mean
Temp (°C)	16.7	30.4	24	13.3	25.5	20.9
pH	7.1	9.5	7.8	7	7.9	7.4
Cond (µS/cm)	6225	47879	35242	3573.3	41964.7	21698.9
Salinity (PPT)	3.4	31.2	22.5	1.9	27	15.1
DO (mg/L)	4.5	7.8	6.3	4.7	9.3	6.7
DO %	62.7	113.7	85.6	64.3	106.3	81
Turbidity (NTU)	2.2	15.7	5.3	2	7.9	4.6
TSS (mg/L)	6.3	33.9	16.1	5.1	280.8	65.9
Chl-a (µg/L)	0.5	8	4.1	0.4	8.5	3.1
TN (µg/L)	126	555	393.5	386	845.7	545.7
TP (µg/L)	14	86.3	28.3	19	105.7	57.7
NOx (µg/L)	3	204	76.3	18	24	20.7
SRP (µg/L)	2	12	6.6	1.7	5.3	3.1

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, and drain to confined discontinuous floodplains. 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 3.25).

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 3.25). These metasediments form kandosols (85%), 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.

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. Urban development (8%) is concentrated on the lower estuary. 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).

Table 3.25 *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 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 slumping on the right bank (5m combined length). Larger areas of bank slumping (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 50.2, a grade of D for BANK CONDITION and 72.0, a grade of C+ for BED CONDITION. The overall geomorphic condition for WOOL4 was 61.2, 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.

3.5.3 Riparian condition

WOOL4 Riparian Condition: T1 = 57.3 (D+) T2 = 61.4 (C-). Temporal difference = +4.1

Woolgoolga Creek 4 was a highly disturbed freshwater system that supported a Coast and Hinterland Riparian Flooded Gum - Bangalow Wet Forest (CH_WSF01) riparian zone (Table 3.26). Immediate site surroundings were a mixed landscape of land cleared for grazing, horticulture and cropping and intact native vegetation. Wedding Bells State Forest lay approximately 1km to the west (upstream) and vegetation at the site was connected to the State Forest via a narrow riparian strip. Historic disturbance in the form of clearing was evident throughout large sections of the immediate riparian zone where exotic species were common in both the mid- and understories. Mixed-age

stands of native trees and shrubs were present in less disturbed areas along with representative plant species of the remnant vegetation community throughout all structural layers on site.

WOOL4 scored well for the Habitat subindex, moderately for the Native Species and Management subindices and poorly for the Species Cover and Debris subindices. Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: lantana (*Lantana camara*), senna (*Senna pendula*), crofton weed (*Ageratina adenophora*) and paspalum (*Paspalum dilatatum*) (see dominant species list for full site details). Low levels of cover in all structural layers and low scores for native species occurrence in all but canopy and macrophyte species also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Significant reduction in animal impacts
- Increase in native species occurrence for midstory, herb/forb and graminoid species
- Increase in standing dead trees and native leaf litter (although note slight decline in canopy health)
- Decrease in leaf total leaf litter and fringing vegetation and increase in exposed tree roots.

Why?

- Flood flows experienced between T1 (September 2019) and T2 (March 2022) likely removed leaf litter and fringing vegetation which has yet to re-establish, leading to exposed tree roots.
- Higher than average rainfall and favourable growth conditions experienced between T1 and T2 likely promoted an increase in native leaf litter turnover and in overall herb/forb and graminoid species cover, particularly natives.

What else?

- T2 survey noted evidence of erosion. Low ground cover both on site and higher in the catchment can lead to flashier flood flows and poor resistance to scouring and erosion.

Recommendations:

- Removing and controlling woody weeds, particularly lantana, senna and crofton weed, will reduce competition in the long-term and encourage natural regeneration of native shrubs and improve ground.
- Active bank erosion was present along this riparian section and may be a result from historical clearing higher in the catchment, localised site disturbances, and heavy rainfall events and subsequent flashy flows experienced between T1 and T2. Efforts to stabilise and mitigate further erosion might consider native plantings in depauperate riparian sections and can assist natural regeneration and the expansion of riparian width).
- Suitable endemic species for restoration at this site would include; flooded gum *(Eucalyptus grandis),* tallowwood (*Eucalyptus microcorys*), blackbutt (*Eucalyptus pilularis*), water gum *(Tristaniopsis laurina*), bangalow palm (*Archontophoenix cunninghamiana*), cheese tree (*Glochidion ferdinandi* var. *ferdinandi*), and lomandra (*Lomandra longifolia*).
- Install and maintain wildlife friendly fencing to exclude grazing animals to increase up and downstream riparian width, and encourage regeneration of native vegetation. This will also aid in erosion management.

Table 3.26 *Site-level summary of riparian condition of Woolgoolga Creek #4, including subindices and indicators.*

Woolgoolga Creek #4	Survey 1	Survey 2	Change
HABITAT	**16.0**	**16.0**	**0.0**
Channel width	2.0	2.0	**0.0**
Proximity	2.0	2.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	2.0	2.0	**0.0**
NATIVE SPECIES	**11.5**	**13.8**	**2.3**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	2.5	3.0	**0.5**
Native herb/forb species	1.5	1.8	**0.3**
Native graminoid species	0.5	2.0	**1.5**
Native macrophyte species	3.0	3.0	**0.0**
SPECIES COVER	**7.0**	**8.9**	**1.9**
Canopy species	1.5	1.5	**0.0**
Midstory species	1.5	1.5	**0.0**
Herb/forb species	1.0	2.3	**1.3**
Graminoid species	1.0	1.6	**0.6**
Macrophyte species	2.0	2.0	**0.0**
DEBRIS	**11.0**	**10.0**	**-1.0**
Total leaf litter	3.0	1.0	**-2.0**
Native leaf litter	2.0	3.0	**1.0**
Dead trees standing	0.0	1.0	**1.0**
Dead trees fallen	0.0	0.0	**0.0**
Lying logs	4.0	4.0	**0.0**
Fringing vegetation	2.0	1.0	**-1.0**
MANAGEMENT	**11.8**	**12.7**	**0.9**
Tree clearing	2.0	2.0	**0.0**
Fencing	1.0	1.0	**0.0**
Animal impact	1.0	3.0	**2.0**
Species of interest	1.8	1.7	**-0.1**
Exposed tree roots	3.0	2.0	**-1.0**
Native woody regeneration	2.0	2.0	**0.0**
Weedy woody regeneration	1.0	1.0	**0.0**
TOTAL	**57.3**	**61.4**	**4.1**

WOOL3 Riparian Condition: T1 = 44.8 (F+) T2 = 41.1 (F+). Temporal difference = -3.7

Woolgoolga Creek 3 was a very highly disturbed Swamp Oak Forested Wetland (CH_FrW10) that likely graded into a Coast and Hinterland Riparian Flooded Gum - Bangalow Wet Forest (CH_WSF01) riparian zone (Table 3.27). Immediate site surroundings were dense suburban development, with a narrow band of riparian vegetation up and downstream. Historic disturbances throughout large sections of the immediate riparian zone were evident, particularly with the incursion of sometimes dense swathes of exotic species throughout all structural layers. Scattered native trees and shrubs were present in less disturbed areas along with representative plant species of the remnant vegetation communities throughout all structural layers on site.

WOOL3 scored moderately for the Habitat subindex and poorly for the Native Species, Species Cover, Debris and Management subindices. Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: camphor laurel (*Cinnamomum camphora*), lantana (*Lantana camara*), mickey mouse plant (*Ochna serrulata*), asparagus fern (*Asparagus aethiopicus*), trad (*Tradescantia fluminensis*), paspalum (*Paspalum dilatatum*), polka dot plant (*Hypoestes phyllostachya*) and maidera vine (*Anredera cordifolia*) (see dominant species list for full site details). Low proximity to intact vegetation, poor native species representation and low cover in all but the midstory also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Increase in overall herb/forb and graminoid species cover
- Increase in native woody regeneration
- Significant reduction in debris cover including Total leaf litter, Dead trees standing and Lying logs
- Reduction in canopy cover and macrophyte species cover.

Why?

- Flood flows experienced between T1 (September 2019) and T2 (March 2022) likely washed away leaf litter and lying logs and perhaps removed standing dead trees.
- Higher than average rainfall and favourable growth conditions may have supported the increase in native woody regeneration and overall herb/forb and graminoid cover.

What else?

- Both surveys noted mowing up to edge of creek bank. Regular mowing can favour the introduction and establishment of exotic species over natives, especially where removal of plants leaves open ground for colonisation. It can also reduce overall cover which limits erosion resistance.
- T2 survey noted presence of madeira vine (*Andredera cordifolia*). This is a Weed of National Significance and is listed as a Key Threatening Process in NSW.
- High trafficked urban riparian areas such as this one are prone to weed invasions, particularly from garden escapes that can get established and move further throughout the catchment if left unchecked.
- Sites such as this one offer important linkages that support biodiversity, species persistence and species movement through otherwise developed, urban landscapes.

Recommendations

- Removing and controlling woody weeds, particularly camphor laurel, lantana, senna, asparagus fern, trad, and maidera vine, will reduce competition in the long-term and encourage natural regeneration of native shrubs and improve ground cover. Where exotic species are providing bank stability (e.g. camphor laurel), staggered removal should be considered and complemented with endemic plantings to improve erosion resistance and to promote regeneration of native species, e.g. swamp oak (*Cassuarina glauca*), cheese tree (*Glochidion ferdinandi* var. *ferdinandi*), flooded gum *(Eucalyptus grandis),* water gum *(Tristaniopsis laurina*), bangalow palm (*Archontophoenix cunninghamiana*), and lomandra (*Lomandra longifolia*).
- Install bollards or fencing to limit machinery access or otherwise restrict mowing in the riparian zone.
- Ecological signage could be used to highlight the importance and roles of riparian vegetation.
- This site is a potential candidate for urban Bushcare or similar community programs aimed at weed removal and re-establishment of native vegetation.

Table 3.27 *Site-level summary of riparian condition of Woolgoolga Creek #3, including subindices and indicators.*

Woolgoolga Creek #3	Survey 1	Survey 2	Change
HABITAT	**13.0**	**13.0**	**0.0**
Channel width	1.0	1.0	**0.0**
Proximity	0.0	0.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	2.0	2.0	**0.0**
NATIVE SPECIES	**6.5**	**6.5**	**0.0**
Native canopy species	2.5	2.5	**0.0**
Native midstory species	1.5	1.5	**0.0**
Native herb/forb species	0.0	0.0	**0.0**
Native graminoid species	1.5	1.5	**0.0**
Native macrophyte species	1.0	1.0	**0.0**
SPECIES COVER	**8.0**	**9.0**	**1.0**
Canopy species	1.5	1.0	**-0.5**
Midstory species	3.0	3.0	**0.0**
Herb/forb species	1.0	2.5	**1.5**
Graminoid species	2.0	2.5	**0.5**
Macrophyte species	0.5	0.0	**-0.5**
DEBRIS	**12.0**	**7.0**	**-5.0**
Total leaf litter	2.5	0.5	**-2.0**

Native leaf litter	2.5	2.5	**0.0**
Dead trees standing	2.0	0.0	**-2.0**
Dead trees fallen	2.0	2.0	**0.0**
Lying logs	2.0	1.0	**-1.0**
Fringing vegetation	1.0	1.0	**0.0**
MANAGEMENT	**5.3**	**5.6**	**0.3**
Tree clearing	1.0	0.5	**-0.5**
Fencing	0.0	0.0	**0.0**
Animal impact	1.5	1.5	**0.0**
Species of interest	1.3	1.6	**0.3**
Exposed tree roots	1.5	1.0	**-0.5**
Native woody regeneration	0.0	1.0	**1.0**
Weedy woody regeneration	0.0	0.0	**0.0**
TOTAL	**44.8**	**41.1**	**-3.7**

WOOL1 Riparian Condition: T1 = 70.3 (C+) T2 = 71.4 (C+). Temporal difference = +1.1

Woolgoolga Creek 1 was a mildly disturbed estuarine system that supported an Estuarine Mangrove Forest (CH_SW01) riparian zone (Table 3.28). Immediate site surroundings were small areas of intact vegetation surrounded by suburban development. Historic disturbances in the form of clearing were evident throughout large sections of the immediate riparian zone in the high proportion of regrowth in canopy species, and the presence of exotic species throughout the mid- and understories. Mixed-age stands of native trees and shrubs were present along with representative plant species of the remnant vegetation community throughout all structural layers on site.

WOOL1 scored well for the Habitat and Debris subindices and moderately for the Native Species, Species Cover and Management subindices. Riparian condition was affected by the presence and regeneration of weed and noxious weed species which were present throughout the understory, and included: lantana (*Lantana camara*), groundsel bush (*Baccharis halimifolia*), senna (*Senna pendula*), asparagus fern (*Asparagus aethiopicus*), coastal morning glory (*Ipomoea cairica*) and buffalo grass (*Stenotaphrum secundatum*) (see dominant species list for full site details). Limited native regeneration, reduced levels of cover in the understory and low native species occurrence in the midstory also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2
What caused the difference?

- Increase in standing dead trees
- Slight increase in native midstory species
- Marginal increase in herb/forb species and canopy health
- Reduction in graminoid cover, especially native graminoids.

Why?

- Higher than average rainfall and favourable growth conditions between T1 (September 2019) and T2 (March 2022) have likely contributed to improvements in herb/forb cover, canopy health and native midstory species.
- The reduction in canopy health and increase in standing dead trees, particularly in *Melaleuca* spp. is a likely outcome of extended drought and increased salinity in the ICOL during dry times.

What else?

- Surveys noted community bushcare efforts with evidence of regeneration works in the form of native plantings. In the right circumstances additional native plantings can be an important aspect of restoring degraded plant communities and assist the natural re-establishment of native midstory and canopy species. However, follow-up weeding is important aspect of restoration activities to detect and avoid the introduction of exotic species.
- Both surveys noted dense cassia (*Senna pendula*) growth in the midstory. Cassia is a common weed in coastal catchments and can readily outcompete native plants and reduce habitat for native wildlife.
- Both surveys noted that the area was evidently commonly used for recreation (fishing, walking etc). Heavy foot traffic can reduce ground cover, induce erosion issues, expose tree roots and become a vector for weed introduction and spread.
- Sites such as this one offer important linkages that support biodiversity, species persistence and species movement through otherwise developed, urban landscapes.

Recommendations

- Removing and controlling woody weeds, particularly lantana, senna, groundsel bush and asparagus fern, will reduce competition in the long-term and encourage natural regeneration of native species.
- Site condition could be improved by clearing rubbish left by recreational users.
- Consider ecological signage to promote understanding of the importance and role of riparian vegetation and estuarine systems more broadly.

Table 3.28 *Site-level summary of riparian condition of Woolgoolga Creek #1, including subindices and indicators.*

Woolgoolga Creek #1	Survey 1	Survey 2	Change
HABITAT	**19.0**	**19.0**	**0.0**
Channel width	4.0	4.0	**0.0**
Proximity	4.0	4.0	**0.0**
Continuity	3.0	3.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	2.0	2.0	**0.0**
NATIVE SPECIES	**14.0**	**13.0**	**-1.0**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	0.5	1.0	**0.5**

Native herb/forb species	3.0	3.0	**0.0**
Native graminoid species	3.0	1.5	**-1.5**
Native macrophyte species	3.5	3.5	**0.0**
SPECIES COVER	**10.5**	**10.3**	**-0.2**
Canopy species	2.0	2.0	**0.0**
Midstory species	2.0	2.0	**0.0**
Herb/forb species	0.5	0.8	**0.3**
Graminoid species	3.0	2.5	**-0.5**
Macrophyte species	3.0	3.0	**0.0**
DEBRIS	**14.0**	**16.0**	**2.0**
Total leaf litter	2.0	2.0	**0.0**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	1.0	3.0	**2.0**
Dead trees fallen	3.0	3.0	**0.0**
Lying logs	1.0	1.0	**0.0**
Fringing vegetation	4.0	4.0	**0.0**
MANAGEMENT	**12.8**	**13.1**	**0.3**
Tree clearing	2.0	2.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	0.8	1.1	**0.3**
Exposed tree roots	3.0	3.0	**0.0**
Native woody regeneration	1.0	1.0	**0.0**
Weedy woody regeneration	0.0	0.0	**0.0**
TOTAL	**70.3**	**71.4**	**1.1**

3.5.4 Water quality

Survey Period 1

In Survey Period 1 (2019 – 2020) the Woolgoolga Creek subcatchment received a score of 75, a grade of C, for water quality. The lowland freshwater site (WOOL4) received the best water quality score in the subcatchment with 76 (B), the upper estuary site (WOOL3) received the lowest water quality score of 71 (C) and the estuarine lagoon (WOOL1) received a score of 74 (C) (Table 3.29).

pH ranged from 6.4 – 9.8 in the Woolgoolga Creek subcatchment in Survey Period 1 (Table 3.30). pH exceeded the maximum guideline value of 8.5 in September 2019, once in the upper estuary

(WOOL3; pH = 9.5) and once in the estuarine lagoon (WOOL1; pH = 9.8) (see Table 2.4 for water quality guideline values).

Water temperatures reflected seasonal climatic changes in Survey Period 1, ranging from a winter minimum of 14.7°C to a summer maximum of 28°C. The estuarine lagoon (WOOL1) was the most variable in temperature (Table 3.30). DO% fell outside the freshwater guidelines on several occasions in the Woolgoolga Creek subcatchment in Survey Period 1. Most notably, dissolved oxygen was 20.9% and 1.4mg/L at WOOL3 in July 2019, which is below the minimum DO% guideline value and below the 2mg/L threshold suitable for aquatic life. DO% also fell below the minimum guideline value at WOOL3 in September 2019 (75.4%), December (52.6%) and January 2020 (55.1%), however these levels were not below 2mg/L and therefore not detrimental to biota. DO% was below the minimum guideline value in the freshwater site (WOOL4) in September 2019 (64.3%), December 2019 (58.8%), January 2020 (50.2%) and November 2020 (52.2%). The maximum DO% guideline value was slightly exceeded at WOOL1 in March 2020 by 0.6% and in May 2020 by 10.9%. These exceedances were likely associated with wave-driven reaeration, since chl-*a* concentrations on the same sampling occasions were within the estuarine lagoon guidelines.

Chl-*a* concentration ranged from 0.3 – 51.1µg/L in the Woolgoolga Creek subcatchment in Survey Period 1 (Table 3.30). Chl-*a* concentration was 6 times greater than the freshwater guideline value at WOOL4 in November 2020 (18.2µg/L), 1.3 times in September 2019 (3.8µg/L) and 2.7 times greater than the guideline value in December 2019 (8µg/L). The upper estuary guideline value was also exceeded in WOOL3 in 7 of the 8 sampling periods by 0.2 – 46.3µg/L. In the estuarine lagoon (WOOL1) the guideline value was exceeded four times in July 2019 to January 2020 by 0.3 - 4µg/L.

Nutrient levels exceeded guidelines for TN, TP and NOx at several locations in Survey Period 1 (Table 3.30). In 6 of the 8 sampling occasions at WOOL4, from September 2019 to August 2020, TN concentrations exceeded the freshwater guideline value by 6 – 4104µg/L, with the August 2020 concentration 12 times that of the guideline value. The TN guideline for the upper estuary site (WOOL3) was exceeded in July 2019 by 164µg/L and in December 2019 by 302µg/L. In the four sampling occasions from December 2019 through May 2020, WOOL1 exceeded TN estuarine lagoon guideline values by 126 – 541µg/L.

TP concentrations at WOOL4 were 1.5 times greater than the freshwater guideline value in September 2019 (37µg/L), 5 times greater in December 2019 (126µg/L) and 2.3 times greater than the guideline November 2020 (57.3µg/L). TP concentrations at WOOL3 were 2.8 times greater than the upper estuary guideline value in September 2019 (42µg/L), 3.7 times greater in December 2019 (55µg/L), 1.5 times greater in January 2020 (23µg/L) and 18.6 times greater than the guideline November 2020 (279.7µg/L). In the estuarine lagoon of the Woolgoolga Creek subcatchment (WOOL1), the TP guideline value was exceeded on all sampling occasions in Survey Period 1, ranging from 15 – 174.7µg/L. The maximum concentration was 13 times greater than the guideline value.

NOx guideline values for freshwater sites were exceeded by 6 – 257µg/L at WOOL4 on 6 of the 8 sampling occasions, the maximum being 7.4 times greater than the guideline value. At WOOL 3 the upper estuary guideline value was also exceeded on 6 sampling occasions (July 2019 to May 2020) by 28 – 340µg/L, the maximum being 8.4 times greater than the guideline value. A similar pattern

was recorded at WOOL1, the estuarine lagoon guideline value was exceeded on 6 sampling occasions (July 2019 to May 2020) by 70.7 – 292.7µg/L, the maximum being 29 times greater than the guideline value. The SRP estuarine guideline value was also exceeded at WOOL1 in July and September 2019 by 0.7µg/L, and in March and May 2020 by 5.7µg/L.

Survey Period 2

In Survey Period 2 (2021 – 2022) the Woolgoolga Creek subcatchment received a score of 80, a grade of B, for water quality. Similar to Survey Period 1, the lowland freshwater site (WOOL4) received the best water quality score in the subcatchment with 82 (B), the upper estuary (WOOL3) received a score of 79 (B) and the estuarine lagoon (WOOL1) received the lowest water quality score of 73 (C) (Table 3.29).

pH ranged from 6.2 – 9.1 in the Woolgoolga Creek subcatchment in Survey Period 2 (Table 3.30). pH exceeded the maximum guideline value of 8.5 once in May 2022 once in the upper estuary (WOOL3; pH = 9.1) (see Table 2.4 for water quality guideline values). The minimum pH guideline value was also exceeded in February 2022 at WOOL3 (pH = 6.7) and in the lowland freshwater site (WOOL4; pH = 6.2).

Water temperatures reflected seasonal climatic changes in Survey Period 2, ranging from a winter minimum of 14.5°C to a summer maximum of 26.1°C. The upper estuary (WOOL3) was the most variable in temperature (Table 3.30). DO% fell outside the freshwater guidelines on several occasions in the Woolgoolga Creek subcatchment in Survey Period 2. Most notably, dissolved oxygen was 22.8% and 1.9mg/L at WOOL3 in August 2022, which is below the minimum DO% guideline value and below the 2mg/L threshold suitable for aquatic life. DO% also fell below the minimum guideline value at WOOL3 in February 2020 (71.3%) and in May 2020 (58.3%), however these levels were not below 2mg/L and therefore not detrimental to biota. DO% was also below the minimum guideline value in the freshwater site (WOOL4) in February 2020 (59.1%) and in May 2020 (79.3%) and in the estuarine lagoon (WOOL1) in May 2022 (70.8%). The maximum DO% guideline value was exceeded in WOOL1 by 3.6 – 26.2% in May 2021, February 2022 and May 2022, and in WOOL4 by 6.1% in May 2021. These exceedances were likely associated with wave-driven reaeration in the estuarine lagoon (WOOL1), with the exception of the exceedance in May 2021, which may have been associated with an algal bloom indicated by high chl-*a* concentrations on the same sampling occasion (8.2µg/L).

In Survey Period 2, Chl-*a* concentration ranged from 0.1 – 8.2µg/L in the Woolgoolga Creek subcatchment and only exceeded guidelines on two occasions in May 2021. Once at WOOL3 where concentrations were slightly greater than the upper estuary guideline value (4.9µg/L) and once at WOOL1 where concentrations were double the estuarine lagoon guideline value (8.2µg/L).

Nutrient levels exceeded guidelines for TN, TP and NOx at several locations in Survey Period 2 (Table 3.30), although SRP concentrations were within guidelines at all sites during Survey Period 2. TN concentrations exceeded the freshwater guideline value at WOOL4 by 16.3µg/L in May 2022 and by 58.7µg/L in August 2022. The TN guideline for the upper estuary site (WOOL3) was exceeded in May and June 2020 by 84.7µg/L and 143.3µg/L respectively. At WOOL1, the TN estuarine lagoon

guideline value was exceeded in February, May and August 2020 by 34µg/L, 114µg/L and 143.7µg/L respectively.

TP concentrations at WOOL4 exceeded the freshwater guideline value on 4 of the 5 sampling occasions by 17 – 550.7µg/L), the maximum concentration being 23 times greater than the guideline in May 2021. TP concentrations at WOOL3 exceeded the freshwater guideline value on 4 of the 5 sampling occasions by 9.7 – 82.7µg/L), the maximum concentration being 6.5 times greater than the guideline in August 2022. In the estuarine lagoon of the Woolgoolga Creek subcatchment (WOOL1), the TP guideline value was exceeded on all sampling occasions in Survey Period 2 (with the exception of June 2022), ranging from 3 – 2034.3µg/L. The maximum concentration was 153 times greater than the guideline value in August 2022.

NOx guideline values for freshwater sites were exceeded by 30 – 188.7µg/L at WOOL4 on all sampling occasions, the maximum being 5.7 times greater than the guideline value in August 2022. At WOOL 3 the upper estuary guideline value was also exceeded on all sampling occasions by 17.3 – 120.3µg/L, the maximum being 3.6 times greater than the guideline value in June 2022. A similar pattern was recorded at WOOL1, the estuarine lagoon guideline value was exceeded on 5 of the 6 sampling occasions (excluding February 2022; NOx = 10.3µg/L) by 1.7 – 13.7µg/L, the maximum being 2.3 times greater than the guideline value in May and June 2022.

Table 3.29. *Water quality grades for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Woolgoolga Creek sub-catchment.*

	WOOL1		WOOL3		WOOL4	
	2019-2020	2021-2022	2019-2020	2021-2022	2019-2020	2021-2022
WQ Grade	74	73	71	79	76	82
Phys-Chem	25	24	23	25	24	23
Nutrients	24	26	24	24	28	27
Chl-a	24	22	24	31	25	33

Table 3.30. *Minimum and maximum (and mean) values of water quality variables for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Woolgoolga Creek sub-catchment.*

	WOOL1						**WOOL3**					
	Survey Period 1			**Survey Period 2**			**Survey Period 1**			**Survey Period 2**		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temp (°C)	16.2	28	22.2	16.6	26.1	20.6	15.2	26.4	22.1	14.5	24.8	19.5
pH	7.6	9.8	8.1	7.8	8.7	8.2	7.1	9.5	7.7	6.7	9.1	7.5
Cond (µS/cm)	19698	66791	48384.8	30180	50178.3	38770.8	2919	69599	40761.5	552.3	43380	21644.5
Salinity (PPT)	11.7	45.4	31.9	18.7	32.9	24.8	1.5	47.7	26.7	0.3	28	14.2
DO (mg/L)	5.4	8.8	7.2	5.3	10.5	8.6	1.4	8.2	5.4	1.9	10.1	6.1
DO %	78.9	120.9	98.3	70.8	136.2	110.4	20.9	89.9	69.4	22.8	100	70.3
Turbidity (NTU)	0.9	5.9	2.9	2.4	7	4	1.4	6.1	3	3.1	13.9	5.6

TSS (mg/L)	14.7	40.9	20.9	6.3	47	20.9	5.3	45.8	17.7	1.4	15.2	6.9
Chl-a (µg/L)	1.1	7.9	4.1	0.4	8.2	2.8	3.4	51.1	15.6	0.1	4.9	1.5
TN (µg/L)	143	841	390.1	168	443.7	318.5	143	910	470.5	249.3	751.3	465.5
TP (µg/L)	15	174.7	41.3	9	2034.3	455.7	10	279.7	56.8	7.7	97.7	40.6
NOx (µg/L)	3	303	104.8	10.3	24	17.1	2.7	386	161.6	63.3	166.3	122.3
SRP (µg/L)	4	12	6.8	2.3	5	3.6	1	6	3.8	1.7	4.3	2.9

	WOOL4					
	Survey Period 1			**Survey Period 2**		
	Min	Max	Mean	Min	Max	Mean
Temp (°C)	14.7	23.2	19.1	15.2	21	17.8
pH	6.4	8.5	7.2	6.2	8.4	7
Cond (µS/cm)	144	396	281.8	155	188.7	170.9
Salinity (PPT)	0.1	0.2	0.1	0.1	0.1	0.1
DO (mg/L)	4.3	9.2	6.7	5.3	11.2	8.2
DO %	50.2	94.6	72.8	59.1	116.1	85.2
Turbidity (NTU)	0.5	12.7	3	0.9	9.1	5.3
TSS (mg/L)	0.5	10.2	3.9	0.5	5	1.7
Chl-a (µg/L)	0.3	18.2	4.9	0.1	1.1	0.4
TN (µg/L)	286.3	4454	1003.3	211	408.7	311.1
TP (µg/L)	4	126	32.8	12.3	575.7	181.2
NOx (µg/L)	5.3	297	116.7	70.3	228.7	145.7
SRP (µg/L)						

3.5.5 Aquatic macroinvertebrates

The macroinvertebrate community at the freshwater section of Woolgoolga Creek received an overall grade of C- for condition in 2019-20 (Table 3.31), a slight reduction in condition from C+ in 2015. Indicators varied from F to A+. Total Abundance was poor at 9/20 (D). Richness scored 13/20 (C) and only some EPT taxa were collected giving this indicator a very poor rating (2/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The Site Mean SIGNAL was 3.5 with the waterbug community comprising low-scoring, pollution-tolerant taxa (SIGNAL2 score of Fair, 13/20). However, there were some high-scoring pollution-sensitive mayfly and caddisfly taxa present at this site.

The macroinvertebrate community at WOOL4 received an overall grade of D for condition in 2020-21 (Table 3.31), a decrease in condition (score C-, good) from 2019-20. Indicators varied from F to A+. The Abundance criteria was very poor at 3/20 (F). Richness scored 11/20 (D+) and only a few EPT taxa were collected giving this indicator a very poor rating (5/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The SIGNAL2 scored was 15/20 with the waterbug community comprising mostly low-scoring, pollution-tolerant taxa. However, there were many high-scoring pollution-sensitive mayflies present at this site.

Table 3.31 *Summary of aquatic macroinvertebrate data for Woolgoolga Creek #4 (WOOL4). Indicators are out of 20.*

WOOL4				
	Survey Period 1		**Survey Period 2**	
Macroinvertebrate indicator	**Score**	**Grade**	**Score**	**Grade**
Family richness	9	D	3	F
Total abundance	13	C	11	D+
EPT	2	F	5	F
Nativeness	20	A+	20	A+
Mean SIGNAL2 score	13	C+	16	B-
Ecohealth score	**57**	**V-**	**53**	**D+**

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; 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% (Milford 1999), draining to confined discontinuous floodplains. 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 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. 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).

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 Geomorphic 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. 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+. 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.

3.6.3 Riparian condition

Hearnes Lake

HEAR4 Riparian Condition: T1 = 79.8 (B-) T2 = 75.4 (B-). Temporal difference = -4.4

Hearnes Lake 4 was a mildly disturbed freshwater system that supported a Foothills Turpentine - Grey Gum - Ironbark Moist Shrubby Forest (CH_WSF17), grading into Coast and Escarpment Blackbutt Dry Forest (CH_DOF01) riparian zone (Table 3.34). Immediate site surroundings were a mixed landscape of intact vegetation, land cleared for cropping and suburban development. Historic disturbance at the site was evidenced by the lower number of large mature trees, and the incursion of weeds in the midstory and understory. Mixed-age stands of native trees and shrubs were present across the riparian zone along with representative plant species of the remnant vegetation communities throughout all structural layers on site. This site has been monitored in previous Ecohealth programs. The score in 2015 (B+) was similar to those in the current reporting round and the difference explained by drought and flood disturbance.

HEAR4 scored well for the Habitat, Native Species and Management subindices and moderately for the Species Cover and Debris subindices. Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: lantana (*Lantana camara*), senna (*Senna pendula*), asparagus fern (*Asparagus aethiopicus*), elephant's ear (*Colocasia esculenta*) and crofton weed (*Ageratina adenophora*) (see dominant species list for full site details). Limited native regeneration, reduced levels of cover in the understory and limited fringing vegetation also contributed to the reduction in riparian grade at this site. However, overall this site was in relatively good condition with good structural complexity and diversity.

Temporal difference in riparian condition between T1 and T2
What caused the difference?

- Increase in large woody debris (Dead trees fallen)
- Decrease in native herb/forb and graminoid species
- Marginal decrease in total leaf litter
- Decrease in dead trees standing (although increase in fallen trees contributed to large woody debris).

Why?

- High rainfall and flood flows between T1 (September 2019) and T2 (March 2022) likely removed leaf litter and some groundcover which is yet to re-establish. Note that graminoid cover did not increase which indicates an increase in bare ground, a predictable response post flood.

What else?

- Given the proximity of development on all sides, the riparian zone at this site is in remarkably good condition. The largest threat to this site is further development and the risk of weed introduction and spread, and the potential for increased nutrient pollution (eutrophication) from nearby agricultural production.
- Although nutrient concentrations were graded as moderate during 2019-20, there were a few occasions where high algal biomass were observed during that time.

- Nutrient concentrations were high during 2021-22 when wet conditions resulted in higher flows.

Recommendations:

- Implement weed control measures, particularly for lantana, senna, asparagus fern and crofton weed.
- Manage for risks elsewhere in the catchment when considering new or expanded developments.
- Sites such as these have the potential to highlight the importance of riparian vegetation and its role in catchment health.
- Reduce nutrient inputs to waterway.

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

Hearnes Lake #4	Survey 1	Survey 2	Change
HABITAT	**19.0**	**19.0**	**0.0**
Channel width	3.0	3.0	**0.0**
Proximity	4.0	4.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	2.0	2.0	**0.0**
NATIVE SPECIES	**19.0**	**17.0**	**-2.0**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	3.0	3.0	**0.0**
Native herb/forb species	4.0	3.0	**-1.0**
Native graminoid species	4.0	3.0	**-1.0**
Native macrophyte species	4.0	4.0	**0.0**
SPECIES COVER	**10.0**	**10.0**	**0.0**
Canopy species	2.5	2.5	**0.0**
Midstory species	3.0	3.0	**0.0**
Herb/forb species	2.0	2.0	**0.0**
Graminoid species	0.5	0.5	**0.0**
Macrophyte species	2.0	2.0	**0.0**
DEBRIS	**14.0**	**12.5**	**-1.5**
Total leaf litter	3.0	2.5	**-0.5**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	2.0	0.0	**-2.0**
Dead trees fallen	2.0	3.0	**1.0**
Lying logs	3.0	3.0	**0.0**

Fringing vegetation	1.0	1.0	**0.0**
MANAGEMENT	**17.8**	**16.9**	**-0.9**
Tree clearing	3.0	3.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	1.8	1.9	**0.1**
Exposed tree roots	4.0	4.0	**0.0**
Native woody regeneration	2.0	1.0	**-1.0**
Weedy woody regeneration	1.0	1.0	**0.0**
TOTAL	**79.8**	**75.4**	**-4.4**

HEAR1 Riparian Condition: T1 = 72.7 (C+) T2 = 69.7 (C). Temporal difference = -3.0

Hearnes Lake 1 was a moderately disturbed Intermittently Closed and Open Lagoon (ICOL) system that supported a fringing gallery of Estuarine Paperbark - Twig Rush Forest (CH_FrW11), grading into a Coast Banksia Shrubland on Holocene Dunes (CH_H01) riparian zone (Table 3.35). Immediate site surroundings were predominantly cleared land with residential developments to the north and west of the site. A narrow strip of intact coastal vegetation extended approximately 1.5km south from the site to the suburb of Sandy Beach. The upstream catchment drained land predominantly used for intensive agriculture including banana and blueberry crops. Historic sand mining disturbances was evident in sections of the riparian zone with signs of clearing and the incursion of weeds in more disturbed areas. Mixed-age stands of native trees and shrubs were present in throughout the site along with representative plant species of the remnant vegetation communities throughout all structural layers on site.

HEAR1 scored well for the Native Species and Management subindices and moderately for the Habitat, Species Cover and Debris subindices. Riparian condition was affected by presence and regeneration of weed and noxious weed species which were present throughout the understory, and included: lantana (*Lantana camara*), bitou bush (*Chrysanthemoides monilifera* subsp. *rotundata*), senna (*Senna pendula*), asparagus fern (*Asparagus aethiopicus*), paspalum (*Paspalum dilatatum*) and whisky grass (*Andropogon virginicus*) (see dominant species list for full site details). A lack of hollow-bearing trees, limited native midstory species occurrence and poor canopy health also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Increase in herb/forb species, although note decrease in native herb/forb species
- Slight increase in large woody debris (Lying logs)
- Reduction in overall debris cover, particularly Total leaf litter and Dead trees standing
- Reduction in canopy health.

Why?

- Higher than average rainfall between T1 (September 2019) and T2 (March 2022) likely supported increased growth of exotic herb/forb species at the expense of native species.
- Heavy rains experienced between T1 and T2 likely removed leaf litter.
- The reduction in canopy health, particularly in *Melaleuca* spp. is a likely outcome of extended drought and increased salinity in the ICOL during dry times.

What else?

- T2 survey noted a significant increase in *Phragmites* spp. density compared to T1. This indicates that high rainfall and flood flows have contributed fresh water to the ICOL and salinity levels may have become more favourable to plant growth (slthough *Melaleuca* spp. do not appear to have responded yet).
- Sites such as this one offer important linkages that support biodiversity, species persistence and species movement through otherwise developed, urban landscapes.
- High algal biomass was observed during the 2021-22 survey. Nutrient concentrations were measured as moderate during the same time.

Recommendations

- Removing and controlling woody weeds, particularly lantana, senna, bitou bush and asparagus fern, will reduce competition in the long-term and encourage natural regeneration of native shrubs.
- Monitor algal biomass to assess longevity of high algal production. Further investigation into nutrient and algae dynamics may help determine management actions to reduce algal biomass.

Table 3.35 *Site-level summary of riparian condition of Hearnes Lake #1, including subindices and indicators.*

Hearnes Lake #1	Survey 1	Survey 2	Change
HABITAT	**13.0**	**13.0**	**0.0**
Channel width	3.0	3.0	**0.0**
Proximity	0.0	0.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	0.0	0.0	**0.0**
NATIVE SPECIES	**17.0**	**16.5**	**-0.5**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	1.0	1.0	**0.0**
Native herb/forb species	4.0	3.5	**-0.5**

Native graminoid species	4.0	4.0	**0.0**
Native macrophyte species	4.0	4.0	**0.0**
SPECIES COVER	**10.5**	**11.5**	**1.0**
Canopy species	2.5	2.5	**0.0**
Midstory species	2.0	2.0	**0.0**
Herb/forb species	1.0	2.0	**1.0**
Graminoid species	2.0	2.0	**0.0**
Macrophyte species	3.0	3.0	**0.0**
DEBRIS	**16.0**	**13.0**	**-3.0**
Total leaf litter	3.0	1.0	**-2.0**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	1.5	0.0	**-1.5**
Dead trees fallen	3.0	3.0	**0.0**
Lying logs	1.5	2.0	**0.5**
Fringing vegetation	4.0	4.0	**0.0**
MANAGEMENT	**16.2**	**15.7**	**-0.5**
Tree clearing	2.0	2.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	1.2	0.7	**-0.5**
Exposed tree roots	4.0	4.0	**0.0**
Native woody regeneration	2.0	2.0	**0.0**
Weedy woody regeneration	1.0	1.0	**0.0**
TOTAL	**72.7**	**69.7**	**-3.0**

Willis Lake

WILS1 1 Riparian Condition: T1 = 73.7 (C+) T2 = 72.1 (C+). Temporal difference = -1.6

Willis Lake 1 was a mildly disturbed Intermittently Closed and Open Lagoon (ICOL) system that supported an Estuarine Paperbark - Twig Rush Forest (CH_FrW11) riparian zone (Table 3.36). Immediate site surroundings were a mix of intact vegetation and light industrial and suburban development. Willis Lake is located at the southern end of the Woolgoolga Beach and Headland section of the Coffs Coast Regional Park, and development is within approximately 500m to the south, west and north. Historic disturbances in the form of clearing for sand mining and roads were evident on site with large stands of regrowth and the incursion of weeds throughout the mid- and understories. Mixed-age stands of native trees and shrubs were present along with representative plant species of the remnant vegetation community throughout all structural layers on site.

WILS1 scored well for the Habitat subindex and moderately for the Native Species, Species Cover, Debris and Management subindices. Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: lantana (*Lantana camara*), senna (*Senna pendula*), bitou bush (*Chrysanthemoides monilifera* subsp. *rotundata*), asparagus fern (*Asparagus aethiopicus*), glory lily (*Gloriosa superba*), coastal morning glory (*Ipomoea cairica*) and paspalum (*Paspalum dilatatum*) (see dominant species list for full site details). Limited native regeneration, reduced levels of cover in all but canopy species and a lack of hollow-bearing trees also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Slight increase in graminoid species cover
- Slight reduction in native herb/forb species occurrence and canopy health
- Reduction in overall debris scores (Total leaf litter and Lying logs).

Why?

- Flood flows experienced between T1 (September 2019) and T2 (March 2022) likely washed away leaf litter and large woody debris which is yet to re-establish.
- Higher than average rainfall and favourable growth conditions between T1 and T2 may have supported an increase in overall graminoid cover at the expense of native herb/forb species.

What else?

- Both T1 and T2 surveys noted the poor health in the fringing common reed beds (*Phragmites australis*) in T1, and the adjacent stand of mangrove fern (*Acrostichum speciosum*) in T2. However, new growth and recovery was also observed in both species in T2. These declines in health are likely reflective of changes in salinity and water levels in the ICOL, with dramatic changes in both water quality and salinity possible and based on inflows and outflows.
- Sites such as this one offer important linkages that support biodiversity, species persistence and species movement through otherwise developed, urban landscapes.

Recommendations

- Removing and controlling weeds, particularly lantana, senna, bitou, glory lily, and asparagus fern, will reduce competition in the long-term and encourage natural regeneration of native shrubs.

Table 3.36 *Site-level summary of riparian condition of Willis Lake #1, including subindices and indicators.*

Willis Lake #1	Survey 1	Survey 2	Change
HABITAT	**18.0**	**18.0**	**0.0**
Channel width	4.0	4.0	**0.0**
Proximity	4.0	4.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**

Hollow-bearing trees	0.0	0.0	**0.0**
NATIVE SPECIES	**15.0**	**14.5**	**-0.5**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	1.5	1.5	**0.0**
Native herb/forb species	4.0	3.5	**-0.5**
Native graminoid species	1.5	1.5	**0.0**
Native macrophyte species	4.0	4.0	**0.0**
SPECIES COVER	**10.5**	**10.8**	**0.3**
Canopy species	2.5	2.5	**0.0**
Midstory species	2.0	2.0	**0.0**
Herb/forb species	1.0	1.0	**0.0**
Graminoid species	1.0	1.3	**0.3**
Macrophyte species	4.0	4.0	**0.0**
DEBRIS	**16.0**	**15.0**	**-1.0**
Total leaf litter	2.5	2.0	**-0.5**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	2.0	2.0	**0.0**
Dead trees fallen	3.0	3.0	**0.0**
Lying logs	1.5	1.0	**-0.5**
Fringing vegetation	4.0	4.0	**0.0**
MANAGEMENT	**14.2**	**13.8**	**-0.4**
Tree clearing	2.0	2.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	1.2	0.8	**-0.4**
Exposed tree roots	4.0	4.0	**0.0**
Native woody regeneration	1.0	1.0	**0.0**
Weedy woody regeneration	0.0	0.0	**0.0**
TOTAL	**73.7**	**72.1**	**-1.6**

3.6.4 Water quality

Survey Period 1

In Survey Period 1 (2019 – 2020) the Hearnes Lake subcatchment received an overall score of 69, a grade of B, for water quality and the Willis Creek subcatchment received a score of 64 (grade C). The lowland freshwater site (HEAR4) recorded the best water quality in the sub-catchment, with a score

of 69 (B). The estuarine lagoon (HEAR1) received a score of 68 (C) and the lower estuary (WILL1) recording the lowest water quality score of the two subcatchments (64, C) (Table 3.37).

pH ranged from 6.79 – 9.20 in the Hearnes Lake subcatchment and 7.13 – 10.09 in the Willis Creek subcatchment (Table 3.38), exceeding guideline values on several occasions in Survey Period 1. pH exceeded the maximum guideline value in the estuarine lagoon (HEAR1) in September 2019 (9.21) and December 2019 (8.62) and once at the lower estuary site in Willis Creek (WILL1) in September 2019 (10.1) (see Table 2.4 for water quality guideline values).

Water temperatures reflected seasonal climatic changes. Temperatures in Willis Creek ranged from a winter minimum of 17.7°C to a summer maximum of 30.4°C. In Hearnes Lake, temperatures ranged from a winter minimum of 14.2°C at HEAR4, to a summer maximum of 31.9°C at HEAR1. Temperatures were consistently higher in the estuarine lagoon (HEAR1) than the freshwater inflow (HEAR4) (Table 3.38).

DO% fell outside the guideline values in the Hearnes Lake subcatchment and Willis Creek subcatchment on multiple sampling occasions in Survey Period 1. DO% was below the minimum guideline value during 5 of the 8 occasions in the lowland freshwater site HEAR4 (ranging from 40.3 – 75.6%; Table 3.38) but did not fall below the concentration level of 2mg/L which can result in negative consequences for aquatic biota. DO% exceeded the maximum guideline value during all sampling occasions in the estuarine lagoon (HEAR1) and at the lowland freshwater site (WILL1) on 5 of the 8 sampling occasions. This high DO% could be correlated with high chl-*a* concentrations indicating an algal bloom at these sites.

Chl-*a* concentration ranged from 0.2 – 30.1µg/L in the Hearnes Lake subcatchment and 2.5 – 14.9µg/L in Willis Creek during Survey Period 1 (Table 3.38). Chl-*a* at HEAR4 was 5 times greater than the lowland freshwater guideline in November 2020, 1 – 8 times greater than the estuarine lagoon guideline at HEAR1 from December 2019 through to November 2020, and 1 – 6 times greater than the lower estuary guideline at WILL1 across all sampling occasions. High chl-*a* concentrations may have contributed to exceedances of turbidity guidelines at HEAR 1 in January 2020 (10.7NTU) and at WILL1 in July 2019 (19.55NTU), and in March (9.9NTU) and May 2020 (10NTU).

Exceedance of nutrient guidelines across the two subcatchments likely contributed to the chl-*a* exceedances reported above in Survey Period 1. TN readings exceeded guideline values during all sampling occasions and all sites, with the exception of Willis Creek (WILL1) in August 2020 when TN was below the lower estuary guideline value (45µg/L) and HEAR1 when TN was below the estuarine lagoon guideline in July 2019 and August 2020 (287 µg/L and 207µg/L respectively) (Table 3.38). TN ranged from 356 – 3498µg/L in the lowland freshwater site (HEAR4), with the highest reading 10 times greater than the guideline value in August 2020. TN ranged from 207 – 977µg/L in the estuarine lagoon (HEAR1), with the highest reading 3 times greater than the guideline value in January 2020, and in lower estuary of Willis Creek TN ranged from 45 – 941µg/L, 4.5 times greater than the guideline value in Jan 2020. TP ranged from 8 – 46.3µg/L in the lowland freshwater site (HEAR4), with the highest reading twice the guideline value in November 2020. In the estuarine lagoon (HEAR1), TP ranged from 20 – 59µg/L, 4 times greater than the guideline value in January 2020, and in lower estuary of Willis Creek TP ranged from 17 – 130.7µg/L, 13 times greater than the

guideline value in November 2020. At HEAR4, NOx ranged from 29 - 2374µg/L, 59 times greater than the lowland freshwater guideline value in March and May 2020. NOx ranged from 3 – 508µg/L in HEAR1, 49 times greater than the guideline value in January 2020, and at WILL1 NOx ranged from 8.3 - 303µg/L, 59 times greater than the lower estuary guideline value in July 2019. SRP was recorded above the estuarine lagoon guideline value 3 times in July 2019 (10µg/L), and in March (8µg/L) and May 2020 (8µg/L). And twice in the lowland freshwater site (WILL1) also in March (12µg/L) and May 2020 (12µg/L).

Survey Period 2

In Survey Period 2 (2021 – 2022) Hearnes Lake subcatchment received an overall score of 68 (grade of C) for water quality and the Willis Creek subcatchment received a score of 67 (grade C). The lowland freshwater site (HEAR4) recorded the best water quality in the sub-catchment, with a score of 69 (B). The estuarine lagoon (HEAR1) received a score of 68 (C) and the lower estuary (WILL1) recording the lowest water quality score of the two subcatchments (64, C) (Table 3.37).

pH ranged from 7.2 – 9.01 in the Hearnes Lake subcatchment and 7.18 – 8.68 in the Willis Creek subcatchment (Table 3.38) in Survey Period 1. In May 2022 pH exceeded the maximum guideline value in the estuarine lagoon (HEAR1) (8.89) and in the lowland freshwater site (HEAR4) (9.01) (see Table 2.4 for water quality guideline values).

Water temperatures reflected seasonal climatic changes in Survey Period 2 (Table 3.38). Temperatures in Willis Creek ranged from a winter minimum of 14.23°C to a summer maximum of 26.8°C. In Hearnes Lake, temperatures ranged from a winter minimum of 13.07°C at HEAR4, to a summer maximum of 27.4°C at HEAR1. Temperatures were consistently higher in the estuarine lagoon (HEAR1) than the freshwater inflow (HEAR4) (Table 3.38).

DO% fell outside the guideline values in the estuarine lagoon (HEAR1) on all sampling occasions in Survey Period 2. DO% exceeded the maximum guideline value by 3 – 29% four times (May 2021 and February, June and August 2022), which could be associated with an algal bloom indicated by high chl-*a* concentrations recorded on these sampling occasions (except for in August 2022 which may have been the result of wave-driven reaeration rather than an association with an algal bloom given chl-*a* concentrations were within guidelines). In May 2022 however, HEAR1 dropped below the minimum DO guideline value to 76.67%, but not to a level harmful to biota. DO% was below the minimum guideline value in Willis Creek (WILL1) during sampling in February (79.07%) and May 2022 (64.47) and above the maximum guideline value in May 2021 (124.07%) which could be associated with an algal bloom indicated by high chl-*a* concentrations recorded on that sampling occasion.

Chl-*a* concentration ranged from 0.06 – 11.3µg/L in the Hearnes Lake subcatchment and 2.33 – 12.79µg/L in Willis Creek during Survey Period 2 (Table 3.38) at HEAR1 and on all sampling occasions chl-*a* concentrations exceeded the lower estuary guideline value by 0.03 – 10.49µg/L in Willis Creek (WILL1). High chl-*a* concentrations may have contributed to exceedances of turbidity guideline values at HEAR 1 in May 2021 (11.53NTU) and February (6.5NTU) and at WILL1 in May 2021 (8.15NTU), and in February (8.35NTU) and May 2022 (12.61NTU).

Exceedance of nutrient guidelines across the two subcatchments likely contributed to the chl-*a* exceedances reported above for Survey Period 2. TN, TP and NOx readings exceeded guideline values during all sampling occasions and all sites, with the exception of Willis Creek (WILL1) in February 2022 when TN, TP and NOx were below the lower estuary guideline value (26µg/L, 9µg/L and 3µg/L respectively) (Table 3.38). TP was also below the freshwater guideline value once in August 2022 (HEAR4; 14.33µg/L). TN ranged from 684.7 – 1508µg/L in the lowland freshwater site (HEAR4), with the highest reading 4 times greater than the guideline value in August 2022. TN ranged from 317 – 1095.3µg/L in the estuarine lagoon (HEAR1), with the highest reading 4 times greater than the guideline value in June 2022, and in lower estuary of Willis Creek TN ranged from 26 – 1042.7µg/L, 5 times greater than the guideline value in June 2022. TP ranged from 14.3 – 615.3µg/L in the lowland freshwater site (HEAR4), with the highest reading 25 times greater than the guideline value in May 2021. In the estuarine lagoon (HEAR1), TP ranged from 27.7 – 236µg/L, 18 times greater than the guideline value in August 2022, and in lower estuary of Willis Creek TP ranged from 9 – 172µg/L, 17 times greater than the guideline value in August 2022. At HEAR4, NOx ranged from 432.7 – 1269µg/L, 32 times greater than the guideline value. NOx ranged from 11.7 – 198.7µg/L in HEAR1, 19 times greater than the guideline value, and at WILL1 NOx ranged from 2.7 – 105.3µg/L, 21 times greater than the guideline value.

Table 3.37. *Water quality grades for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Hearnes Lake/Willis Creek subcatchment*

	HEAR1		HEAR4		WILL1	
	2019-2020	2021-2022	2019-2020	2021-2022	2019-2020	2021-2022
WQ Grade	68	63	69	71	64	67
Phys-Chem	26	22	24	21	22	25
Nutrients	23	24	21	18	21	21
Chl-a	19	18	24	33	21	21

Table 3.38. *Minimum and maximum (and mean) values of water quality variables for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Hearnes Lake/Willis Creek subcatchment.*

	HEAR1						**HEAR4**					
	Survey Period 1			**Survey Period 2**			**Survey Period 1**			**Survey Period 2**		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temp (°C)	17.2	31.9	23.9	15.5	27.4	20.3	14.2	24.6	18.8	13.1	25.2	17.3
pH	8	9.2	8.3	7.9	8.9	8.2	6.8	8.5	7.5	7.2	9	7.7
Cond (µS/cm)	2842	46133	23897	10114.3	50146.7	25814.1	50	747	473.2	238.3	373.3	280.9
Salinity (PPT)	1.5	30	14.8	6.9	32.9	16.7	0	0.4	0.2	0.1	0.2	0.1
DO (mg/L)	8.5	11.5	9.9	5.5	11.4	9.4	3.5	9.5	6.5	6.8	11	8.9
DO %	110.1	165.8	127.2	76.7	139	112.5	40.3	93.9	70.1	80.1	109.5	91.1
Turbidity (NTU)	2.1	10.7	5.3	1.4	11.5	4.9	0.1	12.7	3.5	0.9	42.4	13
TSS (mg/L)	7.2	23.2	15	5.4	121.7	34.2	0.2	2.2	1	1.3	31.5	8.5
Chl-a (µg/L)	0.2	30.2	8.8	1	11.3	5.5	0.3	14.9	2.7	0.1	0.7	0.2

TN (µg/L)	207	977	520.6	317	1095.3	561.1	356	3498	2033.6	684.7	1508	1026
TP (µg/L)	20	59	36.9	27.7	236	103.8	8	46.3	18.2	14.3	615.3	209.5
NOx (µg/L)	3	508	155.1	11.7	198.7	90.1	29	2374	1096	432.7	1269	855.7
SRP (µg/L)	3	10	5.7	2	5.3	3.2	1	7	4.3	4	10.3	6.2

	WILL1					
	Survey Period 1			**Survey Period 2**		
	Min	Max	Mean	Min	Max	Mean
Temp (°C)	17.7	31.8	23.8	14.2	26.8	19.4
pH	7.1	10.1	8.2	7.2	8	7.7
Cond (µS/cm)	3370	46830.5	25171.3	10497	31952.3	19213.9
Salinity (PPT)	1.9	30.4	15.7	6.1	20.1	12.1
DO (mg/L)	6.4	10.4	8.8	5.2	10.4	8.3
DO %	84.9	140.1	113.1	64.5	124.1	94.4
Turbidity (NTU)	0.1	19.6	6.9	1.6	12.6	6.5
TSS (mg/L)	3	39.7	14.4	4.7	19.4	11.7
Chl-a (µg/L)	2.5	14.9	6.5	2.3	12.8	6.2
TN (µg/L)	45	941	417.9	26	1042.7	559.3
TP (µg/L)	17	130.7	44.7	9	172	72.5
NOx (µg/L)	8.3	303	121.7	2.7	105.3	43.1
SRP (µg/L)	2.7	12	6.3	1	4.3	3

3.6.5 Aquatic macroinvertebrates

The macroinvertebrate community at the freshwater site of Hearnes Lake received an overall grade of C- for condition in 2019-20 (Table 3.39), an improvement from the score of F in 2015. Indicators varied from F to A+. Total Abundance was very poor at 7/20 (F). Richness scored 9/20 (D-) and only five EPT taxa were collected giving this indicator a very poor rating (6/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The Site Mean SIGNAL was 3.9 with the waterbug community comprising mostly low-scoring, pollution-tolerant taxa (SIGNAL2 score of Fair, 15/20). However, there were a five high-scoring pollution-sensitive Trichopteran caddisflies present at this site.

The macroinvertebrate community at HEAR44 received an overall grade of D for condition in 2020-21 (Table 3.39) a decrease in condition from the overall score of C-, poor, in 2019-20. Indicators varied from F to A+. The Abundance criteria was very poor at 6/20 (F). Richness scored 7/20 (F) and only a few EPT taxa were collected giving this indicator a very poor rating (1/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The SIGNAL2 scored was 13/20 with the waterbug community comprising mostly low-scoring, pollution-tolerant taxa. However, there were several high-scoring pollution-sensitive mayflies present at this site.

Table 3.39 *Summary of aquatic macroinvertebrate data for Hearnes Lake #4 (HEAR4). Indicators are out of 20.*

HEAR4				
	Survey Period 1		Survey Period 2	
Macroinvertebrate indicator	**Score**	**Grade**	**Score**	**Grade**
Family richness	7	F	6	F
Total abundance	9	D-	7	F
EPT	6	F	1	F
Nativeness	20	A+	20	A+
Mean SIGNAL2 score	15	B-	13	C
Ecohealth score	**56**	**C-**	**47**	**D**

3.7 Moonee Creek6

3.7.1 Catchment descrip20tion

Moonee Creek has a catchment area of approximately 42km^2 (Table 3.40), 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, and drain to confined discontinuous floodplains. The underlying geology is the Coramba Beds of the Coffs Harbour association metasediments, consisting of siliceous mudstones, siltstones and greywacke (76%, Table 3.40). These metasediments form kandosols (60%), 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.

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 3.40) 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.

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).

Table 3.40 *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 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 79.2, a grade of B-, for BANK CONDITION and 90, a grade of B+ for BED CONDITION. The overall Ecohealth geomorphic condition for MOON4 was 84.6, a grade of B. MOON4 was assessed as being in good geomorphic condition. Revegetation of the right bank with native vegetation has improved bank stability at this site.

3.7.3 Riparian condition

MOON4 Riparian Condition: T1 = 82.4 (B) T2 = 80.3 (B). Temporal difference = -2.1

Moonee Creek 4 was a low disturbance freshwater system that supported a Coastal Swamp Mahogany Forest (CH_FrW02), grading into a Coast and Escarpment Blackbutt Dry Forest (CH_DOF01) riparian zone (Table 3.41). Immediate site surroundings were a mixed landscape of predominantly intact vegetation intersected by mountain bike tracks and roads to the west and semi-rural housing developments to the north. The Pacific Highway, under which Moonee Creek passed downstream of the site, lay less than 100m to the east. Historic disturbances in the form of clearing for recreation and development were evident throughout the riparian zone with the some weed species also present in the midstory and understory. Mixed-age stands of native trees and shrubs along with native understory species representative of the remnant vegetation communities were present throughout all structural layers on site. This site was monitored in previous Ecohealth

programs. The score for 2015 (B+) was essentially unchanged, although the 2015 report states there was no active bank erosion at MOON4 whereas bank erosion was significant in the current reporting period.

MOON4 scored well for the Habitat, Native Species and Debris subindices and moderately for the Species Cover and Management subindices. Riparian condition was affected by the presence and regeneration of weed species, including; lantana (*Lantana camara*), paspalum (*Paspalum dilatatum*) and whisky grass (*Andropogon virginicus*) (see dominant species list for full site details). Erosion leading to exposed tree roots (10-30% exposed in some areas) and low overall cover in the understory (herb/forb species and graminoid species) also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Increase in standing dead trees
- Increase in exposed tree roots
- Decrease in native graminoids, fringing vegetation and native woody regeneration.

Why?

- Flood flows occurring between T1 (September 2019) and T2 (March 2022) surveys may have scoured fringing vegetation (graminoids) and have contributed to significant bank erosion in some parts of the site.
- Flood flows may have delivered propagules of weedy species from higher in the catchment.
- Higher than average rainfall between T1 and T2 likely improved canopy health but may also have supported weedy woody regeneration at the expense of native species.

What else?

- There was evidence of significant bank erosion during T2.
- T1 survey noted rubbish in the creek.
- T2 survey noted that despite some weed encroachment and erosion, this site has good diversity and richness.
- Algal biomass was high during the 2019-20 survey but not the 2021-22 survey.

Recommendations

- Remove weeds, particularly Lantana and monitor for new incursions and spread of weedy grass species. Mountain bike tracks and nearby road are potential points of introduction.
- Active bank erosion was present along this riparian section and may be a result from historical clearing and other localised site disturbances, and heavy rainfall events and subsequent flashy flows experienced between T1 and T2. Efforts to stabilise and mitigate further erosion might include planting out Lomandra *(Lomandra longifolia)* in actively eroding bank sections.
- This site is a potential candidate for ecological signage highlighting the role and importance of riparian vegetation. Signage could incorporate education on weed spread and a weed check station for recreational users.
- Old tyres, bottles and other refuse were sometimes common in Coffs catchment creeks and could be removed during periods of low flow.
- Monitor nutrient inputs to this site. Bank stabilisation will assist by reducing the input of fine sediments to the waterway.

Table 3.41 *Site-level summary of riparian condition of Moonee Creek #4, including subindices and indicators.*

Moonee Creek #4	Survey 1	Survey 2	Change
HABITAT	**20.0**	**20.0**	**0.0**
Channel width	4.0	4.0	**0.0**
Proximity	4.0	4.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	2.0	2.0	**0.0**
NATIVE SPECIES	**18.0**	**17.0**	**-1.0**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	3.0	3.0	**0.0**
Native herb/forb species	3.0	3.0	**0.0**
Native graminoid species	4.0	3.0	**-1.0**
Native macrophyte species	4.0	4.0	**0.0**
SPECIES COVER	**13.8**	**13.8**	**0.0**
Canopy species	4.0	4.0	**0.0**
Midstory species	4.0	4.0	**0.0**
Herb/forb species	1.0	1.0	**0.0**
Graminoid species	0.8	0.8	**0.0**
Macrophyte species	4.0	4.0	**0.0**
DEBRIS	**15.5**	**15.5**	**0.0**
Total leaf litter	3.0	3.0	**0.0**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	2.0	3.0	**1.0**
Dead trees fallen	1.5	1.5	**0.0**
Lying logs	3.0	3.0	**0.0**
Fringing vegetation	3.0	2.0	**-1.0**
MANAGEMENT	**15.1**	**14.0**	**-1.1**
Tree clearing	2.5	2.5	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	1.6	2.0	**0.4**
Exposed tree roots	3.0	2.5	**-0.5**
Native woody regeneration	2.0	1.0	**-1.0**
Weedy woody regeneration	0.0	0.0	**0.0**
TOTAL	**82.4**	**80.3**	**-2.1**

MOON3 Riparian Condition: T1 = 83.0 (B) T2 = 84.7 (B). Temporal difference = +1.7

Moonee Creek 3 was a low disturbance estuarine system that supported an Estuarine Mangrove Forest (CH_SW01), grading into a Coast Sand Blackbutt - Bloodwood - Apple Forest (CH_D0F09) riparian zone (Table 3.42). Immediate site surroundings were predominantly intact vegetation in the form of Moonee Beach Nature Reserve which surrounded the site to the north, east and south. On the western bank there were some cleared areas with housing and rural infrastructure and to the southwest was cleared agricultural land. Historic disturbance in the form of clearing was evident within the riparian zone where mature trees were interspersed with regrowth, and limited weed species in the midstory. Mixed-age stands of native trees and shrubs were present along with representative plant species of the remnant vegetation communities throughout all structural layers on site.

MOON3 scored well for the Habitat, Native Species, Debris and Management subindices and moderately for the Species Cover subindex. Riparian condition was affected by low cover scores in the understory, a paucity of standing dead trees and by the presence and regeneration of limited weed species, including; senna (*Senna pendula*) (see dominant species list for full site details). Limited native woody regeneration also contributed to a reduction in riparian condition score at this site. Overall this site was in excellent condition and weed incursion was observed to be very low.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Slight increase in graminoid species cover
- Increase in standing dead trees.

Why?

- High rainfall and back to back seasons of good conditions between T1 (September 2019) and T2 (March 2022) likely promoted the increase of graminoid species cover.
- The increase in score for Dead trees standing may be due to observer bias, that is these trees were present in T1 but not recorded, or could reflect natural processes and a real increase in standing stags.

What else?

- Very little changed at this site between survey periods and the site remained in excellent condition.

Recommendations

- Monitor and control for weeds. The nearby Tiki Walking Track is a probable entry point for weeds. Implementing control measures if and when weed incursion is low will reduce long-term management efforts and associated costs.

Table 3.42 *Site-level summary of riparian condition of Moonee Creek #3, including subindices and indicators.*

Moonee Creek #3	Survey 1	Survey 2	Change
HABITAT	**20.0**	**20.0**	**0.0**
Channel width	4.0	4.0	**0.0**
Proximity	4.0	4.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	2.0	2.0	**0.0**
NATIVE SPECIES	**20.0**	**20.0**	**0.0**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	4.0	4.0	**0.0**
Native herb/forb species	4.0	4.0	**0.0**
Native graminoid species	4.0	4.0	**0.0**
Native macrophyte species	4.0	4.0	**0.0**
SPECIES COVER	**10.5**	**11.3**	**0.8**
Canopy species	4.0	4.0	**0.0**
Midstory species	2.0	2.0	**0.0**
Herb/forb species	1.0	1.0	**0.0**
Graminoid species	0.5	1.3	**0.8**
Macrophyte species	3.0	3.0	**0.0**
DEBRIS	**16.0**	**17.0**	**1.0**
Total leaf litter	3.0	3.0	**0.0**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	0.0	1.0	**1.0**
Dead trees fallen	3.0	3.0	**0.0**
Lying logs	4.0	4.0	**0.0**
Fringing vegetation	3.0	3.0	**0.0**
MANAGEMENT	**16.5**	**16.4**	**-0.1**
Tree clearing	3.0	3.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	1.5	1.4	**-0.1**
Exposed tree roots	3.0	3.0	**0.0**
Native woody regeneration	1.0	1.0	**0.0**
Weedy woody regeneration	2.0	2.0	**0.0**
TOTAL	**83.0**	**84.7**	**1.7**

MOON1 Riparian Condition: T1 = 61.8 (C-) T2 = 58.9 (D+). Temporal difference = -2.9

Moonee Creek 1 was a highly disturbed estuarine system that supported a Lowlands Swamp Box - Paperbark - Red Gum Dry Forest (CH_DOF06) riparian zone (Table 3.43). Immediate site surroundings were a large area of intact vegetation to the south and the Moonee Beach Nature Reserve on the northern bank. The site was connected to the large expanse of vegetation to the south by a narrow corridor of vegetation and suburban development was encroaching heavily on the site. Historic disturbance in the form of clearing for development and recreation was evident within the riparian zone and weed incursion into the midstory and particularly the understory was high. Mixed-age stands of native trees and shrubs were present in less disturbed areas along with representative plant species of the remnant vegetation community throughout all structural layers on site.

MOON1 scored well for the Habitat subindex, moderately for the Native Species and Management subindices, and poorly for the Species Cover and Debris subindices. Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: lantana (*Lantana camara*), senna (*Senna pendula*), asparagus fern (*Asparagus aethiopicus*), coastal morning glory (*Ipomoea cairica*), buffalo grass (*Stenotaphrum secundatum*), kikuyu (*Cenchrus clandestinus*) and whisky grass (*Andropogon virginicus*) (see dominant species list for full site details). Limited native regeneration, limited fringing vegetation and generally low cover in the mid and understories also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Slight increase in native graminoid species
- Marginal increase in canopy health
- Decrease in native midstory and herb/forb species
- Decrease in native woody regeneration and increase in weedy woody regeneration.

Why?

- Heavy rainfall between T1 (September 2019) and T2 (March 2022) may have reduced litter and fringing vegetation as well as understory cover.
- Subsequent high rainfall and back to back seasons of good conditions may have promoted the growth of graminoids (native and exotic) in favour of herb/forb species in the understory.
- High trafficked areas such as these are prone to weed invasions. This combined with a high rainfall events may have supported establishment of weedy woody species over natives.

What else?

- The strip of vegetation here is narrow with development and recreation (walking paths, parks etc) encroaching heavily.

Recommendations

- Removing and controlling woody weeds, particularly camphor laurel, lantana, senna and asparagus fern, will reduce competition in the long-term and encourage natural regeneration of native shrubs.
- Consider ecological signage to promote understanding of the importance and role of riparian vegetation and estuarine systems more broadly.

Table 3.43 *Site-level summary of riparian condition of Moonee Creek #1, including subindices and indicators.*

Moonee Creek #1	Survey 1	Survey 2	Change
HABITAT	**16.0**	**16.0**	**0.0**
Channel width	2.0	2.0	**0.0**
Proximity	4.0	4.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	3.0	3.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	1.0	1.0	**0.0**
NATIVE SPECIES	**14.5**	**13.0**	**-1.5**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	4.0	2.5	**-1.5**
Native herb/forb species	2.0	1.5	**-0.5**
Native graminoid species	0.5	1.0	**0.5**
Native macrophyte species	4.0	4.0	**0.0**
SPECIES COVER	**9.5**	**9.5**	**0.0**
Canopy species	2.0	2.0	**0.0**
Midstory species	2.0	2.0	**0.0**
Herb/forb species	0.5	0.5	**0.0**
Graminoid species	3.0	3.0	**0.0**
Macrophyte species	2.0	2.0	**0.0**
DEBRIS	**8.5**	**7.8**	**-0.7**
Total leaf litter	3.0	2.5	**-0.5**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	0.0	0.0	**0.0**
Dead trees fallen	0.0	0.0	**0.0**
Lying logs	0.5	1.3	**0.8**
Fringing vegetation	2.0	1.0	**-1.0**
MANAGEMENT	**13.3**	**12.6**	**-0.7**
Tree clearing	2.0	2.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	1.3	1.6	**0.3**
Exposed tree roots	1.0	2.0	**1.0**
Native woody regeneration	2.0	1.0	**-1.0**
Weedy woody regeneration	1.0	0.0	**-1.0**
TOTAL	**61.8**	**58.9**	**-2.9**

3.7.4 Water quality

Survey Period 1

In Survey Period 1 (2019 – 2020), Moonee Creek received a score of 68, a grade of C, for water quality. The freshwater site MOON3 recorded the best water quality in the sub-catchment, with a score of 75 (B). The lower estuary (MOON1) received a score of 74 (C), with the lowland freshwater site (MOON4) recording the lowest water quality score in the subcatchment (61, C) (Table 3.44).

pH ranged from 6.2 – 10.6 in Moonee Creek (Table 3.45). pH was slightly below the minimum estuarine guideline value at MOON4 in March 2020 with a reading of 6.2. pH exceeded the maximum guideline value during September 2019 at MOON3 (9.2) and MOON1 (10.6) (See Table 2.4 for water quality guideline values).

Water temperatures reflected seasonal climatic changes, but the freshwater site was the most variable, ranging from a winter minimum of 11.9°C to a summer maximum of 26.0°C (Table 3.45). DO% fell outside the guideline values in Moonee Creek at all three sites (Table 3.45). DO% was below the minimum guideline value during all sampling occasions in the freshwater site MOON4 (ranging from 4.6 – 79.5%; Table 3.45). In 6 of the 8 sampling occasions at MOON4, DO concentrations were also recorded below 2mg/L which can result in negative consequences for aquatic biota such as fish. DO% was below the minimum guideline MOON3 in December 2019 (73.1%), March 2020 (63.5%) and August 2020 (47.8%). DO% at MOON1 exceeded the maximum estuarine guideline value during 6 of the 8 sampling occasions by 0.4 – 16.7% with the only observations within the guidelines in September 2019 (93.7%) and November 2020 (101.8%). These exceedances were likely wave-driven reaeration rather than associated with an algal bloom, given Chl-*a* concentrations were within guidelines for MOON1 apart from a small peak in Chl-*a* in December 2019 and March 2020 described below (Table 3.45).

Chl-*a* ranged from 0.3 – 102.5µg/L in the Moonee Creek in Survey Period 1, with greater variability in the freshwater site (Table 2). Chl-*a* exceeded the freshwater guideline value 5 times at MOON4, and these exceedances reached a maximum of 102.5µg/L in July 2019 (Table 3.45). At MOON3, chl-*a* exceeded the estuarine guideline value in December 2019 and January 2020 with reading of 8.8µg/L and 12.7µg/L respectively. In MOON1, chl-*a* exceeded the lower estuarine guideline value by 1.3µg/L in December 2019 and 1.8µg/L in March 2020: these are both low-magnitude exceedances. Turbidity also exceeded the guideline value during these two sampling occasions in MOON1, significantly so in March 2020 with a reading of 44NTU (Table 3.45).

The overall high mean chl-*a* concentration at MOON4 was likely associated with the large exceedance of the freshwater guideline value of TN and TP during all but one sampling occasion at this site. Guidelines were exceeded by 195 – 733µg/L for TN and 30 – 93µg/L for TP. NOx also exceeded the guideline value at MOON4 by 34 – 291µg/L, and only fell within the guidelines during sampling in August and September 2020. Although not correlated with high chl-*a* concentrations, mean TN, TP, NOx and SRP exceeded upper and lower estuary guideline values at MOON3 and MOON1 (Table 3.45).

Survey Period 2

In Survey Period 2 (2021 – 2022) Moonee Creek received a score of 80, a grade of B, for water quality. The freshwater site MOON4 recorded the best water quality in the subcatchment, with a score of 82 (B). The lower estuary (MOON1) received a score of 79 (B), with the upper estuary (MOON3) received a water quality score of 77 (B) (Table 3.44). Overall, this was an improvement in water quality for the subcatchment compared with Survey Period 1.

Water temperature was within expected seasonal ranges with a winter minimum of 12.1°C in the freshwater site (MOON4) to a summer maximum of 28.4°C in the lower estuary (MOON1) (Table 3.45). Like the trend in Survey Period 1, DO% was below the minimum guideline during all sampling occasions in the freshwater site MOON4 (ranging from 16.07% – 79.6%) and on 2 of these sampling occasions (February and June 2022) DO concentration was also below 2mg/L which can result in negative consequences for aquatic biota such as fish. DO% was below the minimum guideline on all but one sampling occasion in MOON3, ranging between 59.93% and 79.57% (Table 3.45). In the lower estuary (MOON1), DO% exceeded the maximum estuarine guideline value during 3 of the 5 sampling occasions by 2.47– 33.8% with the only observations within the guidelines in June 2022 (98.5%) and August 2022 (92.37%). These exceedances were likely wave-driven reaeration rather than an associated with an algal bloom given Chl-*a* concentrations were within guidelines for MOON1 apart from a peak in Chl-*a* in May 2021 of 3.27µg/L (Table 3.45).

Chl-*a* ranged from 0.25 – 6.01µg/L in Moonee Creek in Survey Period 2, an improvement from Survey Period 1 (Table 3.45). Chl-*a* exceeded the freshwater guideline value once at MOON4 in May 2021 by 0.97µg/L and exceeded the upper estuary guideline value once at MOON3 in May 2022 by 3.71µg/L, which may be associated with the turbidity exceedance of 10.28 NTU recorded at the same time (Table 3.45).

As with Survey Period 1, there was substantial exceedance of nutrient guideline values across the Moonie creek subcatchment during Survey Period 2 (Table 3.45). TP exceeded guideline values across all sites and sampling occasions except one (MOON4, August 22). Guideline values were exceeded in the upper estuary (MOON3) by 18.67 – 1947µg/L, in the lower estuary (MOON1) by 11.03 – 902.7µg/L and by 5.67 – 860.33µg/L in the freshwater site (MOON4).

The TN guideline value was exceeded on 3 of the 5 sampling occasions in the lower estuary (MOON1) from February through June 2022 and ranged from 279 – 390µg/L. In the upper Moonee estuary (MOON3), the guideline value was exceeded once in June 2022 by 250µg/L, whereas in the lowland freshwater site (MOON4), the TN guideline value was exceeded on 4 sampling occasions February to August 2022 by 242µg/L on average.

NOx measurements were within the guideline value for MOON4 but were exceeded once in June 2022 at MOON3 by 11.33µg/L and on 3 sampling occasions in MOON1 by 6.9µg/L in May 2021, 8.75µg/L in February 2022 and 19.23µg/L in June 2022. SRP concentrations were within guideline values for all sites in the Moonee Creek subcatchment (Table 3.45).

Table 3.44. *Water quality scores for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Moonee Creek subcatchment.*

	MOON1		MOON3		MOON4	
	2019-2020	2021-2022	2019-2020	2021-2022	2019-2020	2021-2022
WQ Grade	74	79	75	77	61	82
Phys-Chem	24	25	23	23	20	23
Nutrients	22	24	23	24	25	26
Chl-a	28	30	29	30	16	33

Table 3.45. *Minimum and maximum (and mean) values of water quality variables for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Moonee Creek subcatchment.*

	MOON1						MOON3					
	Survey Period 1			Survey Period 2			Survey Period 1			Survey Period 2		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temp (°C)	16.9	23.9	21.4	14.3	28.4	21.2	17.1	31	22.2	15.5	26.1	19.7
pH	7.8	10.6	8.4	7.8	8.8	8.2	7.4	9.2	7.8	7.3	8.8	7.8
Cond (µS/cm)	35364	73972	56179.2	32975	53767.3	45915.7	33758.5	69085.5	50885.1	16693	46361.3	30794.7
Salinity (PPT)	22.3	51.1	37.5	20.7	35.6	29.9	21	47.2	33.6	9.9	30.2	19.3
DO (mg/L)	6.5	9.1	8	7.4	10.6	8.4	3.4	7	5.7	4.5	8.2	6.2
DO %	93.7	126.7	112.6	92.4	143.8	112.5	47.8	99.1	79	59.9	106.5	75.2
Turbidity (NTU)	0.6	44	6.8	1	6.7	2.9	4.5	8	5.9	0.4	10.3	4.2
TSS (mg/L)	15.3	35.6	22	14.2	57.1	31.7	13.4	66.5	32.5	16.1	91	35.6
Chl-a (µg/L)	0.3	4.1	1.9	0.4	3.3	1.2	2.4	12.7	5	0.6	6	3.1
TN (µg/L)	23	545	291.6	105	390	239.3	143	1048	431.1	149.3	858	399.7
TP (µg/L)	11	181	37.6	21.3	913	283.1	18	117.7	39	33.7	1962	441.7
NOx (µg/L)	3	488	146.9	3	24.3	11.4	3.7	389	126.2	2.7	57.3	18.9
SRP (µg/L)	1	10	6.6	2	10.7	5.3	1.3	8	4.3	1	4.7	2.6

	MOON4					
	Survey Period 1			Survey Period 2		
	Min	Max	Mean	Min	Max	Mean
Temp (°C)	11.9	26	18.1	12.1	21.9	16.4
pH	6.2	8.9	7.1	6.3	8.8	7
Cond (µS/cm)	82	335	210	135	242	173.8
Salinity (PPT)	0	0.2	0.1	0.1	0.1	0.1
DO (mg/L)	0.5	8.1	2.1	1.5	7.8	4
DO %	4.6	79.5	21.8	16.1	79.6	40.7
Turbidity (NTU)	3.6	60.3	19.5	9.6	19.9	14.4
TSS (mg/L)	5.1	47.1	15.6	8.7	372.4	83.3

Chl-a (µg/L)	0.6	102.5	32.4	0.3	2.1	1.3
TN (µg/L)	23	1083	677.5	218	817.7	517.4
TP (µg/L)	20	118	69	10.3	885.3	240.7
NOx (µg/L)	3	331	94.6	12.7	19.3	15.4
SRP (µg/L)	2	11	7.2			

3.7.5 Aquatic macroinvertebrates

The macroinvertebrate community at Moonee Creek received an overall grade of D for condition in 2019-20 (Table 4.46), an improvement from very poor (F) recorded in 2015. Indicators varied from F to A+. Total Abundance was very poor at 4/20 (F). Richness scored 9/20 (D-) and only two EPT taxa were collected giving this indicator a very poor rating (2/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The Site Mean SIGNAL was 4.1 with the waterbug community comprising low-scoring, pollution-tolerant taxa (SIGNAL2 score of Good, 15/20). However, there were two high-scoring pollution-sensitive mayfly taxa present at this site.

The macroinvertebrate community at MOON4 received an overall grade of C for condition in 2020-21 (Table 3.46) an increase in condition from the overall score of D, poor, in 2019-20. Indicators varied from F to A+. The Abundance criteria was poor at 10/20 (D+). Richness scored 15/20 (B-) and only a few EPT taxa were collected giving this indicator a very poor rating (5/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The SIGNAL2 scored was 13/20 with the waterbug community comprising mostly low-scoring, pollution-tolerant taxa. However, there were several high-scoring pollution-sensitive mayflies present at this site.

Table 3.46 *Summary of aquatic macroinvertebrate data for Moonee Creek #4 (MOON4). Indicators are out of 20.*

MOON4				
	Survey Period 1		**Survey Period 2**	
Macroinvertebrate indicator	**Score**	**Grade**	**Score**	**Grade**
Family richness	4	F	10	D+
Total abundance	9	D-	15	B-
EPT	2	F	4	F
Nativeness	20	A+	20	A+
Mean SIGNAL2 score	15	B-	13	C+
Ecohealth score	**50**	**D**	**62**	**C**

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 3.47). Headwaters are in steep midland hills (33-56% slopes), and drain confined valleys lacking floodplains (Table 3.47). 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 3.47). 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).

Table 3.47 *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 Geomorphic condition

The River Style at COFFS4 is partially confined valley setting: planform controlled, meandering, fine grained. 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. COFFS4 scored 48.6, a grade of D- for BANK CONDITION and 66, a grade of C for BED CONDITION. The overall Ecohealth geomorphic condition for COFFS4 was 57.3, a grade of D+. COFFS4 was assessed as being in poor geomorphic condition. The banks are well vegetated, albeit with exotic vegetation, 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.

3.8.3 Riparian condition

COFFS4 Riparian Condition: T1 = 44.9 (F+) T2 = 43.0 (F+). Temporal difference = -1.9

Coffs Creek 4 was a very highly disturbed freshwater system that likely supported a Coast and Hinterland Riparian Flooded Gum - Bangalow Wet Forest (CH_WSF01), riparian zone (Table 3.48). Immediate site surroundings were predominantly dense urban development with narrow bands of vegetation along the streamline up and downstream. The nearest significant stands of vegetation were approximately 2.5km to the north and southwest. Historic disturbances in the form of clearing for development and recreation were evident in the incursion of weed species in all structural layers. Mixed-age stands of native and exotic trees and shrubs were present in less disturbed areas along with representative plant species of the remnant vegetation community throughout all structural layers on site. This site was monitored in previous Ecohealth programs. Scores in 2011 (C+) and 2015 (D+) indicated a trend of decline in overall riparian condition which has continued into 2022.

COFFS4 scored moderately for the Management subindex and poorly for the Habitat, Native Species, Species Cover and Debris subindices. Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: camphor laurel (*Cinnamomum camphora*), senna (*Senna pendula*), mickey mouse plant (*Ochna serrulata*), small-leaved privet (*Ligustrum sinense*), wild tobacco (*Solanum mauritianum*), crofton weed (*Ageratina adenophora*), elephant's ear (*Colocasia esculenta*) (see dominant species list for full site details). Poor cover in all layers, a paucity of debris cover and fringing vegetation and a lack of native woody regeneration also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2:
What caused the difference?

- Marginal increase in large woody debris (Lying logs)
- Decrease in native woody regeneration and native herb/forb species occurrence

Why?

- Flood flows between T1 (September 2019) and T2 (March 2022) may have deposited some logs in the site.

What else?

- T1 survey noted evidence of mowing. Regular mowing can favour the introduction and establishment of exotic species over natives, especially where removal of plants leaves open ground for colonisation. It can also impede native woody regeneration which declined at this site between surveys.
- T2 survey noted that site merged into backyard space which may indicate regular management of the creek area as domestic space.
- Interesting remnant midstory and canopy species were present in this riparian zone and could be further encouraged with the staggered removal of competing weed species.
- Sites such as this one offer important linkages that support biodiversity, species persistence and species movement through otherwise developed, urban landscapes.

Recommendations

- Remove and control weeds, particularly camphor laurel, small-leaved privet, senna and crofton weed.
- Restrict mowing in the riparian zone.
- This site is a potential candidate for urban Bushcare or similar community programs aimed at weed removal and re-establishment of native vegetation.

Table 3.48 *Site-level summary of riparian condition of Coffs Creek #4, including subindices and indicators.*

Coffs Creek #4	Survey 1	Survey 2	Change
HABITAT	**9.0**	**9.0**	**0.0**
Channel width	1.0	1.0	**0.0**
Proximity	0.0	0.0	**0.0**
Continuity	3.0	3.0	**0.0**
Layers	3.0	3.0	**0.0**
Large native trees	1.0	1.0	**0.0**

Hollow-bearing trees	1.0	1.0	**0.0**
NATIVE SPECIES	**9.5**	**8.5**	**-1.0**
Native canopy species	2.5	2.5	**0.0**
Native midstory species	2.0	2.0	**0.0**
Native herb/forb species	1.5	0.5	**-1.0**
Native graminoid species	0.5	0.5	**0.0**
Native macrophyte species	3.0	3.0	**0.0**
SPECIES COVER	**8.5**	**8.5**	**0.0**
Canopy species	3.0	3.0	**0.0**
Midstory species	3.0	3.0	**0.0**
Herb/forb species	1.0	1.0	**0.0**
Graminoid species	0.5	0.5	**0.0**
Macrophyte species	1.0	1.0	**0.0**
DEBRIS	**5.5**	**6.0**	**0.5**
Total leaf litter	1.0	1.0	**0.0**
Native leaf litter	0.5	0.5	**0.0**
Dead trees standing	1.0	1.0	**0.0**
Dead trees fallen	0.0	0.0	**0.0**
Lying logs	2.0	2.5	**0.5**
Fringing vegetation	1.0	1.0	**0.0**
MANAGEMENT	**12.4**	**11.0**	**-1.4**
Tree clearing	2.0	2.0	**0.0**
Fencing	2.0	2.0	**0.0**
Animal impact	1.0	1.0	**0.0**
Species of interest	1.4	2.0	**0.6**
Exposed tree roots	4.0	4.0	**0.0**
Native woody regeneration	2.0	0.0	**-2.0**
Weedy woody regeneration	0.0	0.0	**0.0**
TOTAL	**44.9**	**43.0**	**-1.9**

COFFS3 Riparian Condition: T1 = 60.0 (C-) T2 = 57.1 (D+). Temporal difference = -2.9

Coffs Creek 3 was a highly disturbed estuarine system that supported an Estuarine Mangrove Forest (CH_SW01), grading into a Swamp Oak Forested Wetland (CH_FrW10) riparian zone (Table 3.49). Immediate site surroundings were predominantly dense light industrial development, sporting facilities and some small stands of intact vegetation downstream. The nearest significant stand of vegetation was approximately 3km to the north. Historic disturbances in the form of clearing for

forestry, development and recreation were evident in the incursion of weed species in all structural layers. Mixed-age stands of native trees and shrubs were present in less disturbed areas along with representative plant species of the remnant vegetation communities throughout all structural layers on site.

COFFS3 scored moderately for the Habitat, Native Species, Debris and Management subindices and poorly for the Species Cover subindex. Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: camphor laurel (*Cinnamomum camphora*), poinciana (*Caesalpinia decapetala*), asparagus fern (*Asparagus aethiopicus*) and coastal morning glory (*Ipomoea cairica*) (see dominant species list for full site details). Poor cover in all layers, a general lack of large woody debris and poor canopy health also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Increase in understory species cover, including native herb/forb and graminoid species
- Increase in native woody regeneration
- Significant decrease in overall debris cover including Total leaf litter and Lying logs.

Why?

- Flood flows between T1 (September 2019) and T2 (March 2022) likely removed accumulated debris which is yet to re-establish.
- Higher than average rainfall and favourable conditions between T1 and T2 may have supported increased native woody regeneration and herb/forb and graminoid occurrence.

What else?

- T1 survey noted evidence of mowing and spraying. Regular mowing can favour the introduction and establishment of exotic species over natives, especially where removal of plants leaves open ground for colonisation. It can also reduce overall cover which limits erosion resistance.
- Sites such as this one offer important linkages that support biodiversity, species persistence and species movement through otherwise developed, urban landscapes.
- High algal biomass was recorded during the low flows of 2019-20 but not 2021-22. In contrast, higher nutrient concentrations were observed during the wetter 2021-22 survey when runoff was greater.

Recommendations

- Remove and control woody weeds, particularly camphor laurel (staggered approach) and asparagus fern.
- Planting out Lomandra *(Lomandra longifolia)* along upper banks and near transition to parkland may reduce the need to spray-out weedy grasses, improve cover and slow runoff. If glyphosate is being used as a control measure this should be carefully evaluated and a clear management plan laid out to avoid overspraying and damage to native species. Glyphosate is non-selective and broad spectrum so the likelihood of incidental damage is high. Also note that although glyphosate itself is considered non-toxic to fish and other aquatic organisms, some commercial preparations contain surfactants that are toxic to fish. Choice and application of herbicide must be carefully managed in this system.
- Ecological signage could be used to highlight the importance and roles of riparian vegetation.

- Reduce nutrient (N, P) inputs during wet periods by increasing terrestrial ground cover and riparian understory.

Table 3.49 *Site-level summary of riparian condition of Coffs Creek #3, including subindices and indicators.*

Coffs Creek #3	Survey 1	Survey 2	Change
HABITAT	**13.0**	**13.0**	**0.0**
Channel width	2.0	2.0	**0.0**
Proximity	0.0	0.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	1.0	1.0	**0.0**
NATIVE SPECIES	**9.5**	**10.1**	**0.6**
Native canopy species	4.0	3.1	**-0.9**
Native midstory species	3.5	2.5	**-1.0**
Native herb/forb species	0.5	2.0	**1.5**
Native graminoid species	0.5	1.5	**1.0**
Native macrophyte species	1.0	1.0	**0.0**
SPECIES COVER	**9.0**	**9.2**	**0.2**
Canopy species	1.0	1.0	**0.0**
Midstory species	2.0	1.7	**-0.3**
Herb/forb species	1.0	1.3	**0.3**
Graminoid species	2.0	2.2	**0.2**
Macrophyte species	3.0	3.0	**0.0**
DEBRIS	**15.0**	**11.5**	**-3.5**
Total leaf litter	3.0	2.5	**-0.5**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	1.0	1.0	**0.0**
Dead trees fallen	0.0	0.0	**0.0**
Lying logs	4.0	1.0	**-3.0**
Fringing vegetation	4.0	4.0	**0.0**
MANAGEMENT	**13.5**	**13.3**	**-0.2**
Tree clearing	2.0	2.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	1.0	1.0	**0.0**
Species of interest	1.5	1.3	**-0.2**
Exposed tree roots	4.0	4.0	**0.0**

Native woody regeneration	1.0	2.0	**1.0**
Weedy woody regeneration	1.0	0.0	**-1.0**
TOTAL	**60.0**	**57.1**	**-2.9**

COFFS1 Riparian Condition: T1 = 61.8 (C-) T2 = 58.7 (D+). Temporal difference = -3.1

Coffs Creek 1 was a highly disturbed estuarine system that supported a Coast Banksia Shrubland on Holocene Dunes (CH_H01) riparian zone (Table 3.50). Immediate site surroundings were predominantly dense urban development with some areas of intact vegetation on either bank. This site was almost at the mouth of Coffs Creek discharging to the ocean and the riparian zone sat adjacent to North Wall Beach. The nearest significant stand of vegetation was approximately 5km to the northwest. Historic disturbances in the form of clearing for development and recreation were evident in the incursion of weed species in the midstory and understory. Mixed-age stands of native trees and shrubs were present in less disturbed areas along with representative plant species of the remnant vegetation community throughout all structural layers on site.

COFFS1 scored moderately for all subindices (Habitat, Native Species, Species Cover, Debris and Management). Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: asparagus fern (*Asparagus aethiopicus*), bitou bush (*Chrysanthemoides monilifera* subsp. *rotundata*), mother of millions (*Bryophyllum delagoense*), cobblers pegs (*Bidens pilosa*) and kikuyu (*Cenchrus clandestinus*) (see dominant species list for full site details). Limited understory cover, both native and exotic, a general lack of debris cover and animal impacts also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Significant improvement in exposed tree roots from >50% exposed to fewer than 5% exposed
- Increase in herb/forb species cover
- Slight increase in native midstory species occurrence
- Decrease in weedy woody regeneration
- Decrease in native woody regeneration
- Significant decrease in overall debris cover including Total leaf litter, Dead trees standing and Lying logs.

Why?

- Root exposure reflected erosion event in T1, by T2 vegetation had been washed away and sand redeposited.
- A highly visible and trafficked area dissected by walking tracks are prone to increased weed invasion.
- Lantana observed in T1 had been removed in T2.

What else?

- T2 survey noted community bushcare efforts with evidence of weeding and general maintenance, which is likely helping midstory and canopy species re-establish.

- The site was seen to be heavily trafficked by recreational users resulting in accumulation of refuse/litter. Heavy traffic can also contribute to reduced ground cover which was notably low at this site.
- Sites such as this one offer important linkages that support biodiversity, species persistence and species movement through otherwise developed, urban landscapes.
- Nutrient concentrations were high during the higher flows observed in 2021-22. This did not result in higher algal biomass suggesting the system was being adequately flushed.

Recommendations

- Continue weed management practices, particularly for mother of millions, bitou bush and asparagus fern.
- Ecological signage could be used to highlight the importance and roles of riparian vegetation.
- Investigate and reduce nutrient inputs to the catchment.

Table 3.50 *Site-level summary of riparian condition of Coffs Creek #1, including subindices and indicators.*

Coffs Creek #1	Survey 1	Survey 2	Change
HABITAT	**11.5**	**11.5**	**0.0**
Channel width	2.0	2.0	**0.0**
Proximity	0.0	0.0	**0.0**
Continuity	3.0	3.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	1.5	1.5	**0.0**
Hollow-bearing trees	1.0	1.0	**0.0**
NATIVE SPECIES	**15.5**	**14.0**	**-1.5**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	3.0	3.5	**0.5**
Native herb/forb species	2.0	2.0	**0.0**
Native graminoid species	2.5	2.0	**-0.5**
Native macrophyte species	4.0	2.5	**-1.5**
SPECIES COVER	**9.5**	**10.5**	**1.0**
Canopy species	2.5	2.5	**0.0**
Midstory species	3.0	3.0	**0.0**
Herb/forb species	1.0	2.0	**1.0**
Graminoid species	1.0	1.0	**0.0**
Macrophyte species	2.0	2.0	**0.0**
DEBRIS	**17.0**	**10.5**	**-6.5**
Total leaf litter	3.0	2.5	**-0.5**
Native leaf litter	3.0	3.0	**0.0**

Dead trees standing	3.0	0.0	**-3.0**
Dead trees fallen	3.0	3.0	**0.0**
Lying logs	4.0	1.0	**-3.0**
Fringing vegetation	1.0	1.0	**0.0**
MANAGEMENT	**8.3**	**12.2**	**3.9**
Tree clearing	2.0	2.0	**0.0**
Fencing	2.0	2.0	**0.0**
Animal impact	1.0	1.0	**0.0**
Species of interest	1.3	1.2	**-0.1**
Exposed tree roots	0.0	4.0	**4.0**
Native woody regeneration	2.0	1.0	**-1.0**
Weedy woody regeneration	0.0	1.0	**1.0**
TOTAL	**61.8**	**58.7**	**-3.1**

3.8.4 Water quality

Survey Period 1

In Survey Period 1 (2019 – 2020), Coffs Creek received a score of 67, a grade of C, for water quality. All three sites got a grade of C; however, water quality at the upper estuary site COFFS3 (59) was poorer than the other two sites COFFS1 (70) and COFFS4 (70) (Table 3.51). Water temperatures reflected seasonal climatic changes, ranging from winter minimums of 14°C at COFFS4 to summer maximums of 26.8°C at COFFS1. pH ranged from 6.6 – 9.9 in Coffs Creek (Table 3.52). pH was slightly above the maximum guideline value at all the sites in September 2019, with a reading greater than 9. pH was below the minimum guideline in COFF3 (6.61) in March 2020 (see Table 2.4 for water quality guideline values). DO ranged between 11.5-117.9mg/L (Table 3.52). Maximum DO was recorded at COFFS1 in September 2019. This exceedance was likely wave-driven reaeration rather than an association with an algal bloom, given chl-*a* concentration was within guidelines for COFFS1. DO in COFFS3 was recorded as significantly lower than the minimum guideline in 7 of 8 sampling occasions, with DO concentrations falling below 2mg/L in July 2019 and May 2020. DO% in COFFS4 also dropped below the guideline value on three sampling occasions, with DO concentration below 2mg/L in January 2020.

Chl-*a* ranged from 0.3 – 96.6µg/L in the Coffs Creek in Survey Period 1 (Table 3.52), with values above the guideline in 6 of 8 sampling occasions in the upper estuary site COFFS3. The overall high mean chl-*a* concentration at COFFS3 was likely associated with the large exceedance of the freshwater guideline value of nutrients in the site (Table 3.52). Chl-*a* exceeded the guideline value at lowland freshwater site COFFS4 in 2 of 8 sampling occasions (December 2019 and November 2020) and lower estuary site COFFS1 in 3 of 8 sampling occasions (December 2019, January and March

2020). Turbidity also exceeded the guideline value during 5 of 8 sampling occasions in COFFS3, significantly in September 2019, with a reading of 23NTU (Table 3.52).

TN ranged between 126 – 871µg/L. Freshwater site COFFS4 exceeded the TN guideline in all the sampling occasions, with a maximum recorded value 2 times higher than the guideline. Lower estuary site COFFS1 also exceeded the guideline value in 6 of 8 sampling occasions, with the maximum value being 2 times higher than the guideline. TN value was also higher than the guideline value in COFFS3 on 2 sampling occasions, with a value of 781µg/L in March and May 2020. TP ranged between 18 – 235µg/L with the values above guideline in COFFS1 and COFFS3 in all sampling occasions. COFFS4 also recorded TP values above the guideline in 4 of 8 sampling occasions. NOx values were recorded within 4.7 – 386µg/L and only fell within the guidelines once in COFFS3 in November 2020. SPR values were within the guideline value in COFFS4 but exceeded the guideline value in 6 of 8 sampling occasions in COFFS3 and 4 of 8 occasions in COFFS1. The maximum SRP recorded was 19µg/L at site COFFS3 in September 2019 (Table 3.52).

Survey Period 2

In Survey Period 2 (2021 – 2022), Coffs Creek received a score of 74, a grade of C, for water quality. The freshwater site COFFS4 recorded the best water quality in the subcatchment, with a score of 81 (B), compared to the lower estuary (COFFS1), which received a score of 66 (C), and the upper estuary (COFFS3), with a water quality score of 69 (C) (Table 3.51). Overall, this was an improvement in water quality for the subcatchment compared with Survey Period 1. Water temperatures reflected seasonal climatic changes, ranging from winter minimums of 13.7°C at COFFS4 to summer maximums of 27.6°C at COFFS1. pH ranged from 6.6 – 8.2 in Coffs Creek (Table 3.52), with all the sites having pH within the guideline (see Table 2.4 for water quality guideline values). DO ranged between 51.5 – 142mg/L (Table 3.52). Unlike the trend in Survey Period 1, DO% was below the minimum guideline only during 3 of 5 sampling occasions in the upper estuary site COFFS3; however, DO concentrations in those occasions were above 2mg/L. A maximum DO of 142% was recorded at site COFFS1 in May 2021, which could result from an algal boom as the recorded chl-a value (5.16µg/L) was 2 times above the guideline value in the month.

Chl-*a* ranged from 0.1 – 9.8µg/L in the Coffs Creek in Survey Period 2 (Table 3.52), with values above guideline only in COFFS1 (5.16µg/L) and COFFS3 (9.8µg/L) in May 2021. Turbidity in the creek ranged from 0.7 – 12.9NTU, with values exceeding the guideline value during 2 of 8 sampling occasions in COFFS3. The turbidity value exceeded the guideline value once at COFFS1 (6.15NTU) in May 2021.

TN ranged between 150.3 – 1289µg/L. Freshwater site COFFS4 exceeded the TN guideline in all the sampling occasions as in Survey Period 1, with a maximum recorded value above 2 times the guideline value. Lower estuary site COFFS1 also exceeded the guideline value in 4 of 5 sampling occasions, with the maximum value above 4 times the guideline value. TN value was also higher than the guideline value in COFFS3 on 2 sampling occasions, with a value of 812µg/L in May 2020 and 1289µg/L in June 2022. TP ranged between 15 – 1091µg/L with the values above guideline in COFFS1 and COFFS3 in all sampling occasions as in Survey Period 1. COFFS4 also recorded TP values above the guideline in 4 of 5 sampling occasions. A maximum value of 1091µg/L was recorded in COFFS4 in May 2021. NOx values were recorded within the range of 20.3 – 691.7µg/L, with all the values lying

above the guideline. As Survey Period 1, SRP was within guideline in COFFS4 but exceeded 3 of 5 times in COFFS1 and COFFS3, with a maximum of 12.3µg/L recorded at COFFS3 in May 2022 (Table 3.52).

Table 3.51. *Water quality scores for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Coffs Creek subcatchment.*

	COFFS1		COFF3		COFF4	
	2019-2020	**2021-2022**	**2019-2020**	**2021-2022**	**2019-2020**	**2021-2022**
WQ Grade	70	66	59	69	70	81
Phys-Chem	25	20	21	24	22	27
Nutrients	20	19	20	17	25	21
Chl-a	25	27	18	28	23	33

Table 3.52. *Minimum and maximum (and mean) values of water quality variables for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Coffs Creek subcatchment.*

	COFFS1						COFFS3					
	Survey Period 1			**Survey Period 2**			**Survey Period 1**			**Survey Period 2**		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temp (°C)	18.1	26.8	21.9	16.3	27.6	21	15.8	26.5	21.7	14.1	23	18.1
pH	7.7	9.9	8.2	6.6	8.2	7.7	6.6	9	7.4	7	7.3	7.2
Cond (µS/cm)	33660	75562.5	53163.7	21365	53399.3	37591.3	6056	64933.5	30750.3	643	31051.3	9030.9
Salinity (PPT)	21.1	50.1	34.3	13.3	35.3	23.6	3.3	44.1	19.8	0.3	19.4	5.4
DO (mg/L)	6.3	8.7	7.1	7	10.5	8.3	1	9.2	3.9	4.3	9.3	7.1
DO %	86.4	117.9	99	91.2	142	107.6	14.2	94.9	47.8	51.5	91.4	76.2
Turbidity (NTU)	0.9	3	2	0.7	6.2	3.9	2.2	23.4	8.8	1.9	12.9	6.8
TSS (mg/L)	10.8	19.1	16.1	10.6	54.6	25.7	3.1	83.1	19.6	3.3	63.5	18
Chl-a (µg/L)	0.9	8.3	3.6	0.4	5.2	1.6	1.6	96.6	39.6	0.2	9.8	2.9
TN (µg/L)	126	427	260.1	150.3	994.3	487.2	356	781	551.8	406.7	1289.3	717.9
TP (µg/L)	18	119.3	41.2	69	247	117.8	28	211	69.8	35.3	143.3	70.3
NOx (µg/L)	10.7	217	85.8	20.3	97	51.9	4.7	303	148.8	202	473.7	307.7
SRP (µg/L)	3	13	7.7	4.3	9.3	6.9	6	19	11.3	1	12.3	6.7

	COFFS4					
	Survey Period 1			**Survey Period 2**		
	Min	Max	Mean	Min	Max	Mean
Temp (°C)	14	24.9	19.1	13.7	21.1	16.8
pH	7	9.1	7.6	7.1	7.7	7.3
Cond (µS/cm)	172	652	266.3	125.3	174	151.9
Salinity (PPT)	0.1	0.3	0.1	0.1	0.1	0.1
DO (mg/L)	0.1	9.8	6.3	6.9	11.6	9.2

DO %	11.5	97.1	66.8	77	115	93.5
Turbidity (NTU)	1.3	7.4	3.8	1.6	7.2	4.2
TSS (mg/L)	1	21.8	7.2	1.7	87.3	20
Chl-a (µg/L)	0.3	19.4	5.2	0.1	0.8	0.3
TN (µg/L)	391	871	586.5	562	902	650
TP (µg/L)	20	235	64.8	15	1091	293.7
NOx (µg/L)	133.7	386	263.2	353.7	691.7	479
SRP (µg/L)	3	15.3	8.9	3	8.3	5.3

3.8.5 Aquatic macroinvertebrates

The macroinvertebrate community at the freshwater section of Coffs Creek received an overall grade of D+ for condition in 2019-20 (Table 3.53), an improvement from very poor (F) recorded in 2015. Indicators varied from F to A+. Total Abundance was very poor at 8/20 (F). Richness scored 10/20 (D-) and only three EPT taxon was collected giving this indicator a very poor rating (2/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The Site Mean SIGNAL was 3.6 with the waterbug community comprising mostly low-scoring, pollution-tolerant taxa (SIGNAL2 score of Fair, 13/20). However, there was one high-scoring pollution-sensitive Baetid mayfly and two Trichopteran caddisflies present at this site.

The macroinvertebrate community at COFFS4 received an overall grade of C- for condition in 2020-21 (Table 3.53), an increase in condition from the overall score of D+, poor, in 2019-20. Indicators varied from F to A+. The Abundance criteria was very poor at 4/20 (F). Richness scored 12/20 (C-) and only a few EPT taxa were collected giving this indicator a very poor rating (4/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The SIGNAL2 scored was 18/20 with the waterbug community comprising of low-scoring, pollution-tolerant taxa, as well as high-scoring pollution-sensitive mayflies and caddiflies present at this site.

Table 3.53 *Summary of aquatic macroinvertebrate data for Coffs Creek #4 (COFF4). Indicators are out of 20.*

COFF4				
	Survey Period 1		**Survey Period 2**	
Macroinvertebrate indicator	**Score**	**Grade**	**Score**	**Grade**
Family richness	8	F	4	F
Total abundance	10	D	12	C-
EPT	2	F	4	F
Nativeness	20	A+	20	A+
Mean SIGNAL2 score	13	C+	18	A
Ecohealth score	**53**	**D+**	**58**	**C-**

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 3.54). Headwaters lie in steep midland hills (33-56% slope) with small areas of escarpment ranges at the subcatchment divide, and drain confined valleys lacking floodplains. 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) 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. 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). 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 3.54). Significant land use changes are expected to continue within the catchment with residential, rural and industrial development.

Table 3.54 *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 Geomorphic condition

The River Style at BOAM4 is partially confined valley setting: planform controlled, meandering, fine grained. 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 64.8, a grade of C- for BANK CONDITION and 72.0, a grade of C+, for BED CONDITION. The overall Ecohealth geomorphic condition for BOAM4 was 68.4, a grade of C. BOAM4 was assessed as being in moderate geomorphic condition. Management strategies should focus on maintaining and improving well-vegetated streambanks to improve the geomorphic condition of this reach.

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 72, a grade of C+, for BANK CONDITION and 60, a grade of D+ for BED CONDITION. The overall Ecohealth geomorphic condition for NEW3 was 66, a grade of C. NEW3 was assessed as being in moderate geomorphic condition. Management strategies should focus on native revegetation of the left bank.

3.9.3 Riparian condition

Boambee Creek

BOAM4 Riparian Condition: T1 = 65.9 (C) T2 = 64.8 (C-). Temporal difference = -1.1

Boambee Creek 4 was a moderately disturbed freshwater system that supported a Coast and Hinterland Riparian Flooded Gum - Bangalow Wet Forest (CH_WSF01) riparian zone (Table 3.55). Immediate site surroundings were a small area of vacant land to the east and southeast, with medium density housing development nearby on all remaining sides. The nearest significant stand of intact vegetation lay approximately 2km to the west. There was evidence of historic disturbance in the form of clearing and development at this site where ornamental or 'garden escape' plants were common in the riparian zone. Native trees were present in less disturbed areas along with representative plant species of the remnant vegetation community throughout all structural layers on site. This site was monitored in previous Ecohealth programs (see reports for 2011 and 2015) and the riparian condition score remains essentially unchanged.

BOAM4 scored moderately for the Habitat, Native Species, Debris and Management subindices and poorly for the Species Cover subindex. Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: lantana (*Lantana camara*), senna (*Senna pendula*), Bamboo (*Bambusa* sp.), mistflower (*Ageratina riparia*), elephant's ear (*Colocasia esculenta*), paspalum (*Paspalum dilatatum*), pigeon grass (*Setaria* sp) (see dominant species list for full site details). Low native species occurrence in midstory and graminoid species and reduced cover in all layers also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Decrease in weedy woody regeneration
- Slight increase in large woody debris (Lying logs) and canopy health
- Reduction in native midstory, herb/forb and graminoid species occurrence
- Decrease in leaf litter and increase in exposed tree roots.

Why?

- Flood flows occurring between T1 (September 2019) and T2 (March 2022) may have removed leaf litter which has not yet re-established and which has left tree roots exposed.
- High flows may have deposited additional large woody debris within site.
- Good rainfall conditions and high soil moisture between T1 and T2 surveys may have supported the slight increase in canopy health.

What else?

- T2 survey noted eroding bank sections as a result of recent flooding
- Mangrove fern (*Acrostichum speciosum*) present
- Sites such as this one offer important linkages that support biodiversity, species persistence and species movement through otherwise developed, urban landscapes.

Recommendations

- Implement weed control measures particularly for bamboo, lantana and senna.

- This site is a potential candidate for Bushcare or similar community programs aimed at weed removal and re-establishment of native vegetation.

Table 3.55 *Site-level summary of riparian condition of Boambee Creek #4, including subindices and indicators.*

Boambee Creek #4	Survey 1	Survey 2	Change
HABITAT	**15.0**	**15.0**	**0.0**
Channel width	2.0	2.0	**0.0**
Proximity	1.0	1.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	2.0	2.0	**0.0**
NATIVE SPECIES	**15.0**	**13.5**	**-1.5**
Native canopy species	4.0	3.5	**-0.5**
Native midstory species	2.5	2.0	**-0.5**
Native herb/forb species	4.0	3.5	**-0.5**
Native graminoid species	1.5	1.5	**0.0**
Native macrophyte species	3.0	3.0	**0.0**
SPECIES COVER	**8.3**	**8.1**	**-0.2**
Canopy species	2.0	2.0	**0.0**
Midstory species	2.5	2.3	**-0.2**
Herb/forb species	1.3	1.3	**0.0**
Graminoid species	1.5	1.5	**0.0**
Macrophyte species	1.0	1.0	**0.0**
DEBRIS	**12.5**	**12.5**	**0.0**
Total leaf litter	3.0	2.5	**-0.5**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	1.0	1.0	**0.0**
Dead trees fallen	1.0	1.0	**0.0**
Lying logs	1.5	2.0	**0.5**
Fringing vegetation	3.0	3.0	**0.0**
MANAGEMENT	**15.1**	**15.7**	**0.6**
Tree clearing	2.5	2.5	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	2.0	2.0	**0.0**
Species of interest	1.6	1.7	**0.1**
Exposed tree roots	4.0	3.5	**-0.5**

Native woody regeneration	2.0	0.0	**-2.0**
Weedy woody regeneration	0.0	0.0	**0.0**
TOTAL	**44.9**	**43.0**	**-1.9**

BOAM3 Riparian Condition: T1 = 76.2 (B-) T2 = 76.0 (B-). Temporal difference = -0.2

Boambee Creek 3 was a mild disturbance, estuarine system that supported an Estuarine Mangrove Forest (CH_SW01), grading into Coast and Escarpment Blackbutt Dry Forest (CH_DOF01) riparian zone (Table 3.56). Immediate site surroundings were a small area of intact vegetation to the south extending northeast of the site, with significant urban development nearby on all remaining sides. The upper catchment of Boambee Creek lay within suburban developments and the site was within 100m of the Pacific Highway, under which Boambee Creek passes immediately upstream of this site. The relatively small size of canopy tree species and presence of weed species indicated historic clearing activities, and recreational use is common in the area. Native trees along with representative plant species of the remnant vegetation communities were present throughout all structural layers on site.

BOAM3 scored well for the Habitat and Native Species subindices and moderately for the Species Cover, Debris and Management subindices. Riparian condition was affected by the presence and regeneration of weed and noxious weed species which were present throughout all structural layers, and included: camphor laurel (*Cinnamomum camphora*), coral tree (*Erythrina* x *sykesii*), mickey mouse plant (*Ochna serrulata*), asparagus fern (*Asparagus aethiopicus*), whisky grass (*Andropogon virginicus*) and paspalum (*Paspalum dilatatum*) (see dominant species list for full site details). A low canopy health score and few hollow bearing trees also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Increase in native woody regeneration
- Slight increase in canopy health
- Reduction in native graminoid species occurrence
- Increase in weedy woody regeneration.

Why?

- Good rainfall conditions between T1 (September 2019) and T2 (March 2022) resulting in high soil moisture between T1 and T2 surveys may have supported an increase in native and weedy woody regeneration and supported the establishment of new exotic graminoid species.

What else?

- T2 survey noted rubbish, evidence of fishing and camping including a small structure and firewood collection.

Recommendations

- Monitor for weeds and remove as necessary. Implementing control measures while weed incursion is low will reduce long-term management efforts and associated costs.
- Manage rubbish resulting from recreational use and consider restricting, redirecting or formalising, managing and monitoring access.

Table 3.56 *Site-level summary of riparian condition of Boambee Creek #3, including subindices and indicators.*

Boambee Creek #3	Survey 1	Survey 2	Change
HABITAT	**16.0**	**16.0**	**0.0**
Channel width	3.0	3.0	**0.0**
Proximity	2.0	2.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	1.0	1.0	**0.0**
NATIVE SPECIES	**18.5**	**17.0**	**-1.5**
Native canopy species	4.0	3.5	**-0.5**
Native midstory species	2.5	2.5	**0.0**
Native herb/forb species	4.0	4.0	**0.0**
Native graminoid species	4.0	3.0	**-1.0**
Native macrophyte species	4.0	4.0	**0.0**
SPECIES COVER	**13.5**	**14.0**	**0.5**
Canopy species	3.0	3.0	**0.0**
Midstory species	3.0	3.0	**0.0**
Herb/forb species	0.5	1.0	**0.5**
Graminoid species	3.0	3.0	**0.0**
Macrophyte species	4.0	4.0	**0.0**
DEBRIS	**15.0**	**14.5**	**-0.5**
Total leaf litter	3.0	3.0	**0.0**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	0.0	0.0	**0.0**
Dead trees fallen	3.0	3.0	**0.0**
Lying logs	2.0	2.0	**0.0**
Fringing vegetation	4.0	3.5	**-0.5**
MANAGEMENT	**13.2**	**14.5**	**1.3**
Tree clearing	2.0	2.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**

Species of interest	1.2	1.5	**0.3**
Exposed tree roots	2.0	2.0	**0.0**
Native woody regeneration	0.0	2.0	**2.0**
Weedy woody regeneration	2.0	1.0	**-1.0**
TOTAL	**76.2**	**76.0**	**-0.2**

BOAM1 Riparian Condition: T1 = 78.8 (B-) T2 = 78.3 (B-). Temporal difference = -0.5

Boambee Creek 1 was a mild disturbance, estuarine system that predominantly supported a Coastal Swamp Mahogany Forest (CH_FrW02) riparian zone (Table 3.57). Immediate site surroundings were a small area of intact vegetation to the north with significant urban development nearby on all remaining sides. Coffs Harbour airport lay approximately 1km to the north, and the suburbs of Toormina and Sawtell lay within several hundred metres of the site to the west and south. There was limited evidence of historic disturbance in the form of clearing at this site. However, there was evidence of weed incursion and current recreational use. Native trees (regrowth) along with representative plant species of the remnant vegetation community were present throughout all structural layers on site.

BOAM1 scored well for the Habitat, Native Species and Management subindices and moderately for the Species Cover and Debris subindices. Riparian condition was affected by the presence and regeneration of weed and noxious weed species which were present throughout the midstory and understory, and included: senna (*Senna pendula*), asparagus fern (*Asparagus aethiopicus*), whisky grass (*Andropogon virginicus*) and coastal morning glory (*Ipomoea cairica*) (see dominant species list for full site details). Limited midstory and herb/forb species cover also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Slight increase in midstory species cover
- Increase in large woody debris cover (lying logs)
- Reduction in weedy woody regeneration
- Decrease in overall leaf litter, including slight reduction in native leaf litter
- Decrease in native graminoid species.

Why?

- High rainfall and increased flows in the period between T1 (September 2019) and T2 (March 2022) likely removed leaf litter which has yet to re-establish.
- The reduction in Canopy Species cover score is a result of several large trees coming down between T1 and T2 surveys.

What else?

- Large amounts of rubbish and evidence of camping were noted in T2 survey.

Recommendations

- Monitor for weeds and remove as necessary.

- Manage rubbish resulting from recreational use and consider restricting, redirecting or formalising, managing and monitoring access.

Table 3.57 *Site-level summary of riparian condition of Boambee Creek #1, including subindices and indicators.*

Boambee Creek #1	Survey 1	Survey 2	Change
HABITAT	**20.0**	**20.0**	**0.0**
Channel width	4.0	4.0	**0.0**
Proximity	4.0	4.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	2.0	2.0	**0.0**
NATIVE SPECIES	**20.0**	**17.5**	**-2.5**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	4.0	3.5	**-0.5**
Native herb/forb species	4.0	4.0	**0.0**
Native graminoid species	4.0	2.0	**-2.0**
Native macrophyte species	4.0	4.0	**0.0**
SPECIES COVER	**11.5**	**10.5**	**-1.0**
Canopy species	3.0	1.5	**-1.5**
Midstory species	1.0	1.5	**0.5**
Herb/forb species	2.0	2.0	**0.0**
Graminoid species	3.0	3.0	**0.0**
Macrophyte species	2.5	2.5	**0.0**
DEBRIS	**13.5**	**13.3**	**-0.2**
Total leaf litter	3.0	1.8	**-1.2**
Native leaf litter	3.0	2.5	**-0.5**
Dead trees standing	2.0	2.0	**0.0**
Dead trees fallen	1.5	1.5	**0.0**
Lying logs	0.0	1.5	**1.5**
Fringing vegetation	4.0	4.0	**0.0**
MANAGEMENT	**13.8**	**17.0**	**3.2**
Tree clearing	3.0	3.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	1.3	2.0	**0.7**
Exposed tree roots	1.5	2.0	**0.5**

Native woody regeneration	2.0	2.0	**0.0**
Weedy woody regeneration	0.0	2.0	**2.0**
TOTAL	**78.8**	**78.3**	**-0.5**

Newports Creek

NEWC3 Riparian Condition: T1 = 66.2 (C) T2 = 60.3 (C-). Temporal difference = -5.9

Newports Creek 3 was a moderately disturbed freshwater system that supported a Coast and Hinterland Riparian Flooded Gum - Bangalow Wet Forest (CH_WSF01) riparian zone (Table 3.58). Immediate site surroundings were predominantly dense light industrial development with narrow bands of vegetation along the streamline up and downstream. This riparian corridor connected NEWC3 to the Coffs Coast State Park approximately 1.5km to the east (downstream). Historic disturbances were evident in the form of clearing for development and the presence of instream refuse. Mixed-age stands of native and exotic trees and shrubs were present along with representative plant species of the remnant vegetation community throughout all structural layers on site. This site was monitored in previous Ecohealth programs, although the site has been moved since 2011 so comparisons are only valid with the 2015 report and overall score remains unchanged (C-).

NEWC3 scored moderately for all subindices (Habitat, Native Species, Species Cover, Debris and Management). Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: lantana (*Lantana camara*), small-leaved privet (*Ligustrum sinense*), senna (*Senna pendula*), wild tobacco (*Solanum mauritianum*), mistflower (*Ageratina riparia*), paspalum (*Paspalum dilatatum*) and camphor laurel seedlings (*Cinnamomum camphora*) (see dominant species list for full site details). Poor cover in most layers, low native species occurrence and limited native woody regeneration also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2
What caused the difference?

- Increase in graminoid cover and native herb/forb species occurrence
- Decrease in weedy woody regeneration
- Decrease in native woody regeneration and native graminoid species occurrence
- Significant decrease in debris score overall (Total leaf litter, Native leaf litter and Fringing vegetation).

Why?

- Flood flows between T1 (September 2019) and T2 (March 2022) may have removed leaf litter and scoured fringing vegetation which has yet to re-establish. This also likely accounts for the slight increase in exposed tree roots in T2.

What else?

- T1 survey noted evidence of adjacent mowing. Mowing encroachment and regular mowing promotes weedy species and reduces native biodiversity over time. It can also reduce

overall cover which limits erosion resistance and impede native woody regeneration which has declined at this site between surveys.
- Sites such as this one offer important linkages that support biodiversity, species persistence and species movement through otherwise developed, urban landscapes.

Recommendations

- Removing and controlling woody weeds, particularly camphor laurel, lantana, small-leaved privet and senna will reduce competition in the long-term and encourage natural regeneration of native shrubs and improve ground cover.
- In mown riparian sections at this site undertake native plantings of midstory and understory species to improve cover and encourage native regeneration; e.g. watergum (*Tristaniopsis laurina*), cheese tree (*Glochidion ferdinandi*) and lomandra (*Lomandra longifolia*).
- Install bollards or signage to limit machinery access or otherwise restrict mowing in the riparian zone.
- This site is a potential candidate for urban Bushcare or similar community programs aimed at weed removal and re-establishment of native vegetation.
- Manage rubbish on nearby industrial land entering creek.

Table 3.58 *Site-level summary of riparian condition of Newports Creek #3, including subindices and indicators.*

Newports Creek #3	Survey 1	Survey 2	Change
HABITAT	**15.0**	**15.0**	**0.0**
Channel width	3.0	3.0	**0.0**
Proximity	1.0	1.0	**0.0**
Continuity	3.0	3.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	2.0	2.0	**0.0**
NATIVE SPECIES	**15.0**	**13.5**	**-1.5**
Native canopy species	4.0	3.5	**-0.5**
Native midstory species	2.5	2.5	**0.0**
Native herb/forb species	1.5	2.0	**0.5**
Native graminoid species	4.0	2.5	**-1.5**
Native macrophyte species	3.0	3.0	**0.0**
SPECIES COVER	**9.0**	**10.0**	**1.0**
Canopy species	1.5	1.5	**0.0**
Midstory species	3.0	3.0	**0.0**
Herb/forb species	2.5	2.5	**0.0**
Graminoid species	1.0	2.0	**1.0**
Macrophyte species	1.0	1.0	**0.0**
DEBRIS	**15.5**	**10.8**	**-4.7**

Total leaf litter	3.0	1.3	**-1.7**
Native leaf litter	3.0	1.0	**-2.0**
Dead trees standing	2.5	2.5	**0.0**
Dead trees fallen	0.0	0.0	**0.0**
Lying logs	4.0	4.0	**0.0**
Fringing vegetation	3.0	2.0	**-1.0**
MANAGEMENT	**11.7**	**11.0**	**-0.7**
Tree clearing	1.0	1.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	1.0	1.0	**0.0**
Species of interest	1.7	1.5	**-0.2**
Exposed tree roots	3.0	2.5	**-0.5**
Native woody regeneration	2.0	1.0	**-1.0**
Weedy woody regeneration	0.0	1.0	**1.0**
TOTAL	**66.2**	**60.3**	**-5.9**

NEWC2 Riparian Condition: T1 = 74.1 (C+) T2 = 72.0 (C+). Temporal difference = -2.1

Newports Creek 2 was a mildly disturbed estuarine system that supported an Estuarine Mangrove Forest (CH_SW01), grading into a Coastal Swamp Mahogany Forest (CH_FrW02) on the lower side and a Coast and Escarpment Blackbutt Dry Forest (CH_DOF01) riparian zone on the higher side (Table 3.59). Immediate site surroundings were light industrial development and recreation (Coffs Harbour Kart Club). A riparian corridor approximately 50m wide on either bank connected this reach to the Coffs Coast State Park, a significant stand of intact vegetation approximately 500m downstream. Historic disturbances throughout the riparian zone were evidenced by the regrowth of tree species and the establishment of weeds throughout the midstory and understory. Mixed-age stands of native trees and shrubs were present along with representative plant species of the remnant vegetation communities throughout all structural layers on site.

NEWC2 scored well for the Management subindex, moderately for the Habitat, Native Species, Species Cover and Debris subindices. Riparian condition was affected by the presence and regeneration of weed and noxious weed species which were present throughout the understory, and included: camphor laurel (*Cinnamomum camphora*), lantana (*Lantana camara*), senna (*Senna pendula*), wild tobbaco (*Solanum mauritianum*) and paspalum (*Paspalum dilatatum*) (see dominant species list for full site details). Distance from intact vegetation and generally low cover in all layers also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2
What caused the difference?

- Decrease in weedy woody regeneration

- Slight improvement in canopy health
- Reduction in overall leaf litter
- Reduction in graminoid species cover, especially native species.

Why?

- Flood flows between T1 (September 2019) and T2 (March 2022) likely removed leaf litter which has yet to re-establish.
- Subsequent high rainfall and back to back seasons of good conditions may have provided favourable growth conditions and supported the expansion of weedy shrubs and grasses and outcompeted native graminoid species in the understory.

What else?

- T2 survey noted many lantana (*Lantana camara*) and camphor laurel (*Cinnamomum camphora*) recruits.
- There was evidence of significant bank erosion during T2. Ground cover scores are generally low at this site. Low ground cover both on site and higher in the catchment can lead to flashier flood flows and poor resistance to scouring and erosion.
- Sites such as this one offer important linkages that support biodiversity, species persistence and species movement through otherwise developed, urban landscapes.

Recommendations:

- Staggered removal and control of woody weeds, particularly camphor laurel, lantana, senna and wild tobacco, will reduce competition in the long-term and encourage natural regeneration of native shrub and improve ground cover.

Table 3.59 *Site-level summary of riparian condition of Newports Creek #2, including subindices and indicators.*

Newports Creek #2	Survey 1	Survey 2	Change
HABITAT	**15.0**	**15.0**	**0.0**
Channel width	4.0	4.0	**0.0**
Proximity	1.0	1.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	3.0	3.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	1.0	1.0	**0.0**
NATIVE SPECIES	**16.5**	**15.0**	**-1.5**
Native canopy species	4.0	3.5	**-0.5**
Native midstory species	2.0	2.0	**0.0**
Native herb/forb species	4.0	4.0	**0.0**
Native graminoid species	2.5	1.5	**-1.0**
Native macrophyte species	4.0	4.0	**0.0**
SPECIES COVER	**11.5**	**11.0**	**-0.5**
Canopy species	2.0	2.0	**0.0**
Midstory species	2.0	2.0	**0.0**

Herb/forb species	1.5	1.5	**0.0**
Graminoid species	3.0	2.5	**-0.5**
Macrophyte species	3.0	3.0	**0.0**
DEBRIS	**16.0**	**14.5**	**-1.5**
Total leaf litter	3.0	2.0	**-1.0**
Native leaf litter	3.0	2.5	**-0.5**
Dead trees standing	2.0	2.0	**0.0**
Dead trees fallen	1.0	1.0	**0.0**
Lying logs	4.0	4.0	**0.0**
Fringing vegetation	3.0	3.0	**0.0**
MANAGEMENT	**15.1**	**16.5**	**1.4**
Tree clearing	3.0	3.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	1.1	2.0	**0.9**
Exposed tree roots	3.0	2.5	**-0.5**
Native woody regeneration	2.0	2.0	**0.0**
Weedy woody regeneration	0.0	1.0	**1.0**
TOTAL	**74.1**	**72.0**	**-2.1**

3.9.4 Water quality

Survey Period 1

In Survey Period 1 (2019 – 2020) the Boambee/Newports Creek subcatchment received an overall score of 74, a grade of C, for water quality. The lowland freshwater site BOAM4 had the best water quality in the sub-catchment, with a score of 77 (B). The upper estuary sites (BOAM3 and NEW3) and the lower estuary site (BOAM1) had a water quality score of 74 (B). The freshwater site NEW2 received the lowest water quality score in the subcatchment of 70 (C) (Table 3.60).

pH ranged from 6.2 – 10.1 in Boambee/Newports Creek subcatchment (Table 3.61), falling outside guidelines on several sampling occasions in Survey Period 1. pH exceeded the maximum guideline value at all sites in September 2019 with an average pH across sites of 9.3 (see Table 2.4 for water quality guideline values). pH was slightly below the minimum guideline value in the upper estuary site NEW3 in 4 of the 8 sampling occasions (pH 6.6 – 6.9) and below the lowland freshwater minimum guideline value at BOAM4 in May 2020 (pH 6.17).

Water temperatures reflected seasonal climatic changes in Boambee/Newports Creek subcatchment, ranging from a winter minimum of 12.3°C to a summer maximum of 29.6°C in Survey

Period 1 (Table 3.61). DO% fell outside the guideline values at multiple sites (Table 3.61). DO% was below the minimum guideline value on all sampling occasions in the freshwater site NEW2 (ranging from 46.4 – 78.8%) and on 5 of the 8 sampling occasions at BOAM4. DO concentrations were also recorded below 2mg/L at BOAM4 in May 2020 (1.5mg/L), which can result in negative consequences for aquatic biota such as fish. DO% was below the guideline value in the upper estuary sites, with DO% ranging from 43.8 – 75.9% on all but one sampling occasion at BOAM3 (January 2020 was within the guidelines with 101% DO recorded), and DO% ranged from 9.2 – 75.4% at NEW3 on five sampling occasions. On two of these occasions (December 2019 and January 2020), DO concentrations were below the 2mg/L threshold suitable for aquatic biota at NEW3 (0.8mg/L and 1.4mg/L respectively). The lower estuary (BOAM1) exceeded the maximum estuarine guideline value for DO% on 7 of the 8 sampling occasions by 3.6 – 14.6%, with the only observations within the guidelines in November 2020 (100.7%). These exceedances were likely wave-driven reaeration and/or associated with high chl-*a* concentrations recorded on four sampling occasions at BOAM1.

Chl-*a* concentrations exceeded the lower estuary guideline value by 0.5 – 4.1µg/L in September 2019 through to March 2020 in BOAM1, as well as in the upper estuary at BOAM 3 over the same period by 0.5 – 23.6µg/L. The other upper estuary site, NEW3, exceeded the chl-*a* guideline once by 11.8µg/L in December 2019. The lowland freshwater guideline was exceeded at BOAM4 in December 2019 by 125µg/L and January 2020 by 40.3µg/L. Exceedances were also recorded at NEW2 on 6 of the 8 sampling occasions by 3.1 – 42.2µg/L, with chl-*a* concentrations only recorded within guidelines in May and August 2020 (1.2µg/L and 2.2µg/L respectively).

Turbidity was up to 2.5 greater than the upper estuary guideline value on 6 of the 8 sampling occasions at BOAM3 and once at NEW3 in December 2019 (12.8NTU) (Table 3.61). Exceedances of turbidity guidelines could be associated with exceedance of chl-*a* guidelines on the same sampling occasions as described above and/or reflect flow events.

Nutrient guidelines were exceeded at all sites in the Boambee/Newports Creek subcatchment during Survey Period 1 (Table 3.61). The lowland freshwater TN guideline was exceeded at BOAM4 by 6 - 457µg/L on all except two sampling occasions (i.e. July 2019 and August 2020) and by 41 – 259.3µg/L at NEW2 on all except three sampling occasions (i.e. July 2019, September 2019, August 2020). TN in the upper estuary was within guidelines at BOAM3 but exceeded the guideline value at NEW3 in December 2019 by 129µg/L and in January 2020 by 275µg/L. The lower estuary TN guideline was exceeded at BOAM1 on four sampling occasions from December 2019 to May 2020 by 13 – 48µg/L.

The lowland freshwater TP guideline value was exceeded at BOAM4 in September 2019 (by 14µg/L), December 2019 (by 103µg/L) and January 2020 (by 71µg/L) and on all sampling occasions NOx was 2 – 7 times greater than the guideline value. At the other freshwater site (NEW2) the TP guideline value was exceeded on all except 3 sampling occasions (i.e. September 2019, August 2020 and November 2020) and NOx was 1.7 – 8.3 times greater than the guideline value on five sampling occasions. SRP was within the freshwater guideline at BOAM4 and NEW2.

TP in the upper estuary exceeded the guideline value at both sites (BOAM3 and NEW3) on every sampling occasion in Survey Period 2. At BOAM3 the guideline value was exceeded by 7 – 185.3µg/L and at NEW3 the guideline value was exceeded by 1 – 143µg/L. NOx was also 1.8 – 4.7 times greater

than the guideline value at BOAM3 on five sampling occasions and 1.4 – 6.2 times greater on all except one sampling occasion at NEW3 in November 2020. SRP values exceeded the guideline by 1.6 – 3.6µg/L at BOAM3 on four sampling occasions (September 2019, and March, May and November 2020) and by 1.6 – 5.6µg/L on four sampling occasions at NEW3 in September 2019, January through to May 2020.

The lower estuary guideline for TP was exceeded at BOAM1 on all sampling occasions by 1.7 – 359.7µg/L and NOx was 4.1 – 35.3 times greater than the guideline value on all except one sampling occasion (the greatest exceedance being in January 2020). SRP values exceeded the guideline by 0.5 – 9.5µg/L in January through to May, and November 2020 at BOAM1.

Survey Period 2

In Survey Period 2 (2021 – 2022) the Boambee/Newports Creek subcatchment received an overall score of 80, a grade of B, for water quality. The lowland freshwater sites BOAM4 and NEW2 had the best water quality in the subcatchment, with a score of 80 (B) and 81 (B) respectively. The upper estuary sites, BOAM3 and NEW3, had a water quality score of 79 (B) and 78 (B) respectively, and the lower estuary site (BOAM1) also received a score of 78 (B) (Table 3.60).

In Survey Period 2, pH ranged from 4.8 – 8.2 in the Boambee/Newports Creek subcatchment (Table 3.61), falling below guidelines on several sampling occasions. pH was below the lowland freshwater minimum guideline at BOAM4 in February (pH 6.4) and May 2022 (pH 4.8), and below the upper estuary minimum guideline at NEW3 in May 2021 (pH 6.4) and May 2020 (pH 6.9). June 2022, pH was 6.8 in the lower estuary (BOAM1).

Water temperatures reflected seasonal climatic changes, ranging from a winter minimum of 13.9°C to a summer maximum of 22.4°C in Survey Period 2 (Table 3.61). DO% fell outside the guideline values at multiple sites (Table 3.61). DO% was below the minimum guideline value on all except one sampling occasion in the freshwater site NEW2 (ranging from 20.3 – 73.2%) and DO concentrations were below 2mg/L in February 2022 (1.7mg/L), which can result in negative consequences for aquatic biota. An exceedance of the maximum freshwater guideline was recorded at BOAM4 in May 2021 (120.1% DO), which was likely wave-driven reaeration rather than associated with an algal bloom given Chl-*a* concentrations were within guidelines on this sampling occasion. DO% was below the minimum guideline value in the upper estuary (BOAM3) with DO% ranging from 27.8 – 74.3% in all but one sampling occasion (August 2022 was within the guidelines with 92.8% DO recorded). The lower estuary (BOAM1) was also below the minimum guideline value in June 2022 (52.2% DO) but exceeded the maximum guideline value for DO% in May 2021 (140.4%), which was likely wave-driven reaeration since chl-*a* concentrations were within the guidelines at BOAM1 on this sampling occasion.

Chl-*a* concentration guidelines were exceeded at two sites in Survey Period 2 (Table 3.61). In May 2021 in the lower estuary at BOAM3 by 2.5µg/L and at the freshwater site NEW2 in May 2021 by 1.8µg/L, June 2022 by 0.7µg/L and August 2022 by 3µg/L.

Nutrient guidelines were exceeded at all sites in the Boambee/Newports Creek subcatchment during Survey Period 2 (Table 3.61). The lowland freshwater TN guideline was exceeded at BOAM4 by 61.3 - 173µg/L on all sampling occasions and at NEW2 by 20.3µg/L in June 2022 and by 76.7µg/L in August 2022. TN in the upper estuary was within guidelines at both sites (BOAM3 and NEW3), while the lower estuary TN guideline was exceeded at BOAM1 on 3 of the 4 sampling occasions; in February 2022 by 16µg/L, in May 2022 by 85µg/L and in June 2022 by 105µg/L.

The lowland freshwater TP guideline value was exceeded at BOAM4 on all sampling occasions by 29.7 – 768.3µg/L except in August 2022 (20.7µg/L) and on all sampling occasions NOx was 3 – 8 times greater than the guideline value. At the other freshwater site (NEW2) the TP guideline value was exceeded on all sampling occasions by 7.7 – 1124µg/L (the maximum being 46 times greater than the guideline value) and NOx was 1.8 – 11 times greater than the guideline value on all sampling occasions except in May 2021 (16µg/L). SRP was within the freshwater guideline at BOAM4 and NEW2.

TP in the upper estuary exceeded the guideline value at both sites (BOAM3 and NEW3) on every sampling occasion in Survey Period 2 except one (August 2022 at NEW3). At BOAM3 the guideline value was exceeded by 4 – 77µg/L and at NEW3 the guideline value was exceeded by 28.3 – 625.3µg/L (the maximum being 43 times greater than the guideline value). NOx was also 1.1 – 2.6 times greater than the guideline value at BOAM3 on all sampling occasions and 1.7 – 4.5 times greater on all sampling occasions at NEW3. SRP values were within the upper estuary guideline at BOAM3 and NEW3.

The lower estuary guideline for TP was exceeded at BOAM1 on all sampling occasions by 15.4 – 113µg/L and NOx was 1.2 – 9 times greater than the guideline value on all sampling occasions. SRP values at BOAM1 exceeded the guideline by 1.5 – 2.2µg/L in February through to August 2022, with the exception of May 2021 which was within the guideline (5.7µg/L).

Table 3.60. *Water quality scores for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Boambee/Newports Creek subcatchment.*

	BOAM1		**BOAM3**		**BOAM4**	
	2019-2020	**2021-2022**	**2019-2020**	**2021-2022**	**2019-2020**	**2021-2022**
WQ Grade	74	78	74	79	77	80
Phys-Chem	24	26	23	24	20	24
Nutrients	23	22	24	26	27	24
Chl-a	27	31	27	29	30	33

	NEW2		**NEW3**	
	2019-2020	**2021-2022**	**2019-2020**	**2021-2022**
WQ Grade	70	81	74	78
Phys-Chem	19	22	24	23
Nutrients	27	29	22	23
Chl-a	24	29	28	33

Table 3.61. *Minimum and maximum (and mean) values of water quality variables for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Boambee/Newports Creek subcatchment.*

	BOAM1						BOAM3					
	Survey Period 1			Survey Period 2			Survey Period 1			Survey Period 2		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temp (°C)	19.1	23.8	21.2	19.3	20.7	20.1	17.9	29.1	22	16.7	22.4	19.4
pH	7.9	10.1	8.4	8	8.2	8.1	7	9.1	7.7	6.8	7.6	7.2
Cond (µS/cm)	35118.7	74022.5	56541.1	38901.3	53326	48221.5	20767.7	68298	44141.2	17625.7	37618	27352
Salinity (PPT)	22.2	51.2	37.8	24.8	35.3	31.5	13	46.7	28.8	10.8	24.1	17
DO (mg/L)	7.3	9.4	8.3	3.9	10.3	7.5	3.1	7.4	4.7	2.4	8.1	4.8
DO %	100.7	124.6	116	52.5	140.4	100	43.8	101	63.3	27.8	92.8	56.9
Turbidity (NTU)	0.1	1.7	1.2	1.1	1.4	1.2	3.1	14.6	7.4	2	8	4.4
TSS (mg/L)	9.9	34.2	20	9.3	43.6	21.9	9.7	84.3	24.3	7.7	1274.6	330.8
Chl-a (µg/L)	0.3	6.4	2.8	0.3	1.6	1	3.1	28.4	12.1	1.5	7.3	3.8
TN (µg/L)	23	253	159	6.3	310	206.8	143	585	387.3	228.3	473.7	360.8
TP (µg/L)	12	370	62.8	25.7	123.3	69.8	22	200.3	58.3	19.3	92	52.6
NOx (µg/L)	3	180	70.5	6.3	46	17.6	3	217	87.8	51.7	119.7	93.7
SRP (µg/L)	3	16	8.3	5.7	8.7	7.7	1	10	5.6	2.7	5.7	4.8
	BOAM4						NEW2					
	Survey Period 1			Survey Period 2			Survey Period 1			Survey Period 2		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temp (°C)	13.9	29.6	20.9	14.2	21.9	17.6	16.8	27.6	21	16	22	17.7
pH	6.2	9	7	4.8	7.8	6.6	7.1	9.3	7.7	7.2	7.5	7.3
Cond (µS/cm)	570	43230	13918.5	123	687	251.6	18310.3	67469.7	42890.5	21857.7	36957.7	28553.5
Salinity (PPT)	0.3	27.8	8.5	0.1	0.3	0.1	11	46	27.9	13.2	23.3	17.8
DO (mg/L)	1.5	9.7	5.4	7.2	11.5	9.2	3.3	6.4	4.7	1.7	6.9	4.6
DO %	20.2	94.2	60.2	82.1	120.1	95.5	46.4	78.8	61.8	20.3	84.3	53.8
Turbidity (NTU)	1.8	6.9	4	1.2	2.8	2.1	2.4	9.9	6.3	2.1	5.4	3.4
TSS (mg/L)	0.6	85.1	15	1	8.4	2.9	9.8	31.6	17.6	4.3	33.7	15.3
Chl-a (µg/L)	0.5	128	22.8	0.2	0.6	0.4	1.2	45.2	13.3	0.8	6	3.8
TN (µg/L)	288	807	520.8	275	523	428.7	23	609.3	367.5	213.3	426.7	308
TP (µg/L)	9	128	42	20.7	793.3	204.7	17	209.3	62.8	32.7	1149	338.5
NOx (µg/L)	85.3	353	218.2	131	385.3	269.9	3	331	95.4	16	222	81.9

SRP (µg/L)	2	9	5.7	1.5	5.7	3.8	4	16	9	2.7	5.7	4.4

	NEW3					
	Survey Period 1			Survey Period 2		
	Min	Max	Mean	Min	Max	Mean
Temp (°C)	12.3	24.8	18.3	13.9	19.5	16.2
pH	6.6	9.2	7.2	6.4	7.9	7.2
Cond (µS/cm)	143.3	221	175.9	109	149	129.9
Salinity (PPT)	0.1	0.1	0.1	0.1	0.1	0.1
DO (mg/L)	0.8	10	6.2	7.9	11.3	9.7
DO %	9.2	97	63.9	85.6	115.9	98.1
Turbidity (NTU)	0.8	12.8	4.5	1.1	5.2	3.2
TSS (mg/L)	0.4	10	3.3	1	9.1	3.7
Chl-a (µg/L)	0.3	16.6	3.8	0.2	0.6	0.4
TN (µg/L)	114	883	451.1	219	574.3	341.4
TP (µg/L)	16	158	62.3	6	640.3	193.6
NOx (µg/L)	21	286	150.9	77.3	205	133.8
SRP (µg/L)	4	12	7.7	1	4.7	2.9

3.9.5 Aquatic macroinvertebrates

Boambee Creek

The macroinvertebrate community at Boambee Creek received an overall grade of D for condition in 2019-20 (Table 3.62), no change with the same score as in 2015. Indicators varied from F to A+. Total Abundance was very poor at 7/20 (F). Richness scored 7/20 (F) and only three EPT taxa were collected giving this indicator a very poor rating (2/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The Site Mean SIGNAL was 4.0 with the waterbug community comprising mostly low-scoring, pollution-tolerant taxa (SIGNAL2 score of Good, 15/20). However, there were a few high-scoring pollution-sensitive Leptophlebiidae mayflies, Gripopteryidae stoneflies and Trichopteran caddisflies present at this site.

The macroinvertebrate community at BOAM4 received an overall grade of C for condition in 2020-21 (Table 3.62), which is an improvement from the overall score of D, poor, in 2019-20. Indicators varied from F to A+. The Abundance criteria was very good at 19/20 (A+). Richness scored 12/20 (C) and only a few EPT taxa were collected giving this indicator a very poor rating (3/20, F). Nativeness

was very good (20/20), with no exotic taxa collected. The SIGNAL2 scored was 10/20 with the waterbug community comprising mostly low-scoring, pollution-tolerant taxa. However, there were several high-scoring pollution-sensitive mayflies present at this site.

Table 3.62 *Summary of aquatic macroinvertebrate data for Boambee Creek #4 (BOAM4). Indicators are out of 20.*

BOAM4				
	Survey Period 1		Survey Period 2	
Macroinvertebrate indicator	**Score**	**Grade**	**Score**	**Grade**
Family richness	4	F	19	A+
Total abundance	7	F	12	C
EPT	2	F	3	F
Nativeness	20	A+	20	A+
Mean SIGNAL2 score	15	B-	10	D
Ecohealth score	**47**	**D**	**64**	**C**

Newports Creek

The macroinvertebrate community on Newports Creek received an overall grade of D for condition in 2019-20 (Table 3.63), an improvement from the score of F in 2015. Indicators varied from F to A+. Total Abundance was very poor at 3/20 (F). Richness scored 9/20 (D-) and three two EPT taxa were collected giving this indicator a very poor rating (1/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The Site Mean SIGNAL was 4.4 with the waterbug community comprising low-scoring, pollution-tolerant taxa and two high-scoring pollution-sensitive Leptophlebiidae mayflies and one Trichopteran caddisfly present at this site (SIGNAL2 score of Good, 16/20).

The macroinvertebrate community at NEW3 received an overall grade of D+ for condition in 2020-21 (Table 3.63), which is an improvement from the overall score of D, poor, in 2019-20. Indicators varied from F to A+. The Abundance criteria was very poor at 4/20 (F). Richness scored 8/20 (D-) and only some EPT taxa were collected giving this indicator a very poor (5/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The SIGNAL2 scored was 16/20 with the waterbug community comprising of low-scoring, pollution-tolerant taxa, as well as high-scoring pollution-sensitive mayflies and caddiflies present at this site.

Table 3.63 *Summary of aquatic macroinvertebrate data for Newports Creek #3 (NEWC3). Indicators are out of 20.*

NEWC3				
	Survey Period 1		Survey Period 2	
Macroinvertebrate indicator	**Score**	**Grade**	**Score**	**Grade**
Family richness	3	F	4	F
Total abundance	9	D-	8	D-
EPT	1	F	5	F
Nativeness	20	A+	20	A+
Mean SIGNAL2 score	16	B+	16	B
Ecohealth score	**49**	**D**	**53**	**D+**

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 3.64), 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. These escarpment ranges form extremely steep terrain with slopes exceeding 30%, and headwaters drain confined valleys lacking floodplains. The ranges give way to steep midland hills, with upper reaches draining confined valleys with significant bedrock outcropping (Table 3.64). 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. The coastal plain is predominantly alluvial sediments (35%, Table 3.64).

The northern section of the upper reaches of Bonville Creek lie within Tuckers Nob State Forest. 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.

Table 3.64 *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 Geomorphic condition

The River Style at BONV4 is classified as partially confined valley setting: planform controlled, meandering, fine grained. 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. 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 66.6, a grade of C, for BANK CONDITION and 72, a grade of C+, for BED CONDITION. The overall Ecohealth geomorphic condition for BONV4 was 69.3, a grade of C, which is an improvement from 2015. 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 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.

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 59.4, a grade of D+ for BANK CONDITION and 63, a grade of C- for BED CONDITION. The overall Ecohealth geomorphic condition for PINE3 was 61.2, a grade of C-. PINE3 was 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.

3.10.3 Riparian condition

Bonville Creek

BONV4 Riparian Condition: T1 = 49.8 (D-) T2 = 49.1 (D-). Temporal difference = -0.7

Bonville Creek 4 was a very highly disturbed freshwater system that predominantly supported a Coast and Hinterland Riparian Flooded Gum - Bangalow Wet Forest (CH_WSF01) riparian zone (Table 3.65). Immediate site surroundings were low density housing intersected by roads and infrastructure in a predominantly cleared landscape with scattered patches of canopy species. Much of the upper catchment of Bonville Creek ran through cleared rural land with only a narrow riparian corridor remaining. The nearest significant stand of vegetation was approximately 500m to the south. Historic disturbances in the form of clearing for development were evident throughout the immediate riparian zone, particularly where exotic species, including garden escapes, were abundant in all structural layers. Mixed-age stands of native trees and shrubs were present in less disturbed areas along with representative plant species of the remnant vegetation community throughout all structural layers on site. This site was monitored in previous Ecohealth programs. Scores in 2011 (C-) and 2015 (C) were essentially unchanged however the score for this report indicates a significant decline in riparian condition since 2015.

BONV4 scored moderately for the Habitat and Native Species subindices and poorly for the Species Cover, Debris and Management subindices. Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: camphor laurel (*Cinnamomum camphora*), small-leaved privet (*Ligustrum sinense*), lantana (*Lantana camara*), mickey mouse plant (*Ochna serrulata*), crofton weed (*Ageratina adenophora*), mistflower (*Ageratina riparia*), blue billy goat weed (*Ageratum houstonianum*), paspalum (*Paspalum dilatatum*) (see dominant species list for full site details). A lack of fencing and subsequent animal impacts, as well as low native species occurrence and limited native woody regeneration also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Increase in overall understory cover (herb/forb and graminoid species)
- Slight increase in native graminoid species occurrence
- Marginal improvement in canopy health
- Decrease in native woody regeneration
- Decrease in overall litter cover including leaf litter and large woody debris.

Why?

- Flood flows occurring between T1 (September 2019) and T2 (March 2022) may have removed leaf litter and large woody debris which has not yet re-established.
- Good rainfall conditions post drought and high soil moisture between T1 and T2 surveys may have supported the slight increase in canopy health and increases in understory species both native and exotic.
- The reduction in native woody regeneration may be a result of increased ground cover between T1 and T2 which is suppressing native woody regeneration or obscuring it from view.

What else?

- T2 survey noted significant bank erosion and evidence of mowing right up to creek bank. Regular mowing can favour the introduction and establishment of exotic species over natives, reduce overall cover which limits erosion resistance and impair native woody regeneration.
- Evidence of spraying in localised sections of riparian zone may be suppressing weedy species growth, but also native species recovery.

Recommendations

- Install and maintain fencing 30m or more from creek edge to limit livestock access. This will encourage regeneration of native cover and bank stabilisation and expand the width of the riparian zone.
- Implement weed control measures, particularly for camphor laurel, small-leaved privet and lantana.
- Expand riparian corridor width throughout catchment to achieve whole-of-system ecological and land management benefits. Not only does the expansion of riparian zones increase biodiversity, increased riparian zone width and density of cover reduces runoff and flash flood flows which can cause significant erosion issues.

Table 3.65 *Site-level summary of riparian condition of Bonville Creek #4, including subindices and indicators.*

Bonville Creek #4	Survey 1	Survey 2	Change
HABITAT	**15.0**	**15.0**	**0.0**
Channel width	2.0	2.0	**0.0**
Proximity	2.0	2.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	1.0	1.0	**0.0**

NATIVE SPECIES	**11.5**	**12.0**	**0.5**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	2.5	2.5	**0.0**
Native herb/forb species	1.5	1.5	**0.0**
Native graminoid species	1.5	2.0	**0.5**
Native macrophyte species	2.0	2.0	**0.0**
SPECIES COVER	**8.0**	**10.0**	**2.0**
Canopy species	1.5	1.5	**0.0**
Midstory species	2.0	2.0	**0.0**
Herb/forb species	1.5	2.5	**1.0**
Graminoid species	2.0	3.0	**1.0**
Macrophyte species	1.0	1.0	**0.0**
DEBRIS	**9.0**	**6.5**	**-2.5**
Total leaf litter	2.0	1.5	**-0.5**
Native leaf litter	2.5	3.0	**0.5**
Dead trees standing	2.5	1.0	**-1.5**
Dead trees fallen	0.0	0.0	**0.0**
Lying logs	1.0	0.0	**-1.0**
Fringing vegetation	1.0	1.0	**0.0**
MANAGEMENT	**6.3**	**5.6**	**-0.7**
Tree clearing	2.0	2.0	**0.0**
Fencing	0.0	0.0	**0.0**
Animal impact	0.0	0.0	**0.0**
Species of interest	1.3	1.6	**0.3**
Exposed tree roots	1.0	1.0	**0.0**
Native woody regeneration	2.0	1.0	**-1.0**
Weedy woody regeneration	0.0	0.0	**0.0**
TOTAL	**49.8**	**49.1**	**-0.7**

BONV3 Riparian Condition: T1 = 66.9 (C) T2 = 63.7 (C-). Temporal difference = -3.2

Bonville Creek 3 was a moderately disturbed estuarine system that predominantly supported a Coast and Hinterland Riparian Flooded Gum - Bangalow Wet Forest (CH_WSF01) riparian zone (Table 3.66). Immediate site surroundings were a semi-rural landscape of predominantly cleared land with low density housing interspersed with some horticultural production. Historic disturbance in the form of clearing was evident throughout the riparian zone, which was very narrow (<20m) along most of the creek, and was interspersed with dense patches of weed species. Native trees were present along

with representative plant species of the remnant vegetation community throughout all structural layers on site.

BONV3 scored moderately for all subindices (Habitat, Native Species, Species Cover, Debris and Management). Riparian condition was affected by the presence and regeneration of weed and noxious weed species which were present throughout all structural layers, and included: camphor laurel (*Cinnamomum camphora*), small-leaved privet (*Ligustrum sinense*), lantana (*Lantana camara*), paspalum (*Paspalum dilatatum*) and pigeon grass (*Setaria* sp) (see dominant species list for full site details). A lack of fencing, animal impacts and low native species occurrence in the midstory and graminoid species also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Decrease in weedy woody regeneration
- Slight increase in native graminoid and native midstory species
- Reduction in overall leaf litter
- Removal of fencing leading to increased animal impact.

Why?

- Removal of riparian fencing has allowed livestock to access riparian zone.
- Good rainfall conditions and high soil moisture between T1 (September 2019) and T2 (March 2022) surveys may have supported an increase in native graminoid and midstory species.

What else?

- T2 survey noted banana bush (*Tabernaemontana pandacaqui*) in site.
- Evidence of recent cattle grazing in riparian zone noted in T2.

Recommendations

- Reinstall and maintain riparian fencing to exclude stock. This will also assist in regeneration of canopy and midstory species and increase the width of the riparian zone.
- Implement weed control measures, particularly removal of camphor laurel, small-leaved privet and lantana.

Table 3.66 *Site-level summary of riparian condition of Bonville Creek #3, including subindices and indicators.*

Bonville Creek #3	Survey 1	Survey 2	Change
HABITAT	**13.0**	**13.0**	**0.0**
Channel width	2.0	2.0	**0.0**
Proximity	1.0	1.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	3.0	3.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	1.0	1.0	**0.0**
NATIVE SPECIES	**13.0**	**14.0**	**1.0**
Native canopy species	3.0	3.0	**0.0**

Native midstory species	1.5	2.0	0.5
Native herb/forb species	4.0	4.0	0.0
Native graminoid species	0.5	1.0	0.5
Native macrophyte species	4.0	4.0	0.0
SPECIES COVER	**12.0**	**12.0**	**0.0**
Canopy species	3.0	3.0	0.0
Midstory species	2.0	2.0	0.0
Herb/forb species	1.0	1.0	0.0
Graminoid species	4.0	4.0	0.0
Macrophyte species	2.0	2.0	0.0
DEBRIS	**15.5**	**14.0**	**-1.5**
Total leaf litter	3.0	1.5	-1.5
Native leaf litter	1.5	1.5	0.0
Dead trees standing	2.0	2.0	0.0
Dead trees fallen	1.0	1.0	0.0
Lying logs	4.0	4.0	0.0
Fringing vegetation	4.0	4.0	0.0
MANAGEMENT	**13.4**	**10.7**	**-2.7**
Tree clearing	2.0	2.0	0.0
Fencing	3.0	1.0	-2.0
Animal impact	3.0	1.0	-2.0
Species of interest	1.9	1.7	-0.2
Exposed tree roots	3.5	4.0	0.5
Native woody regeneration	0.0	0.0	0.0
Weedy woody regeneration	0.0	1.0	1.0
TOTAL	**66.9**	**63.7**	**-3.2**

BONV1 Riparian Condition: T1 = 69.8 (C) T2 = 71.0 (C+). Temporal difference = +1.2

Bonville Creek 1 was a mildly-to-moderately disturbed, estuarine system that supported an Estuarine Mangrove Forest (CH_SW01) riparian zone, grading into a Swamp Oak Forested Wetland (CH_FrW10) riparian zone (Table 3.67). Immediate site surroundings were intact vegetation in the form of Bongil Bongil National Park. There was urban development (Sawtell township) within approximately 500m of the northern bank but otherwise limited development for several kilometres in other directions. Evidence of historic sand mining disturbance was apparent where tree clearing and subsequent weed invasion had occurred. Native trees were present along with representative plant species of the remnant vegetation communities throughout all structural layers on site.

BONV1 scored well for the Habitat and Management subindices and subindex and moderately for the Native Species, Species Cover and Debris subindices. Riparian condition was affected by the presence and regeneration of weed species which were present in the mid and understories, and included: lantana (*Lantana camara*), senna (*Senna pendula*), bitou bush (*Chrysanthemoides monilifera* subsp. *rotundata*), asparagus fern (*Asparagus aethiopicus*), buffalo grass (*Stenotaphrum secundatum*), glory lily (*Gloriosa superba*) and coastal morning glory (*Ipomoea cairica*) (see dominant species list for full site details). Limited native midstory and graminoid and a paucity of large woody debris also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Decrease in weedy woody regeneration
- Slight increase in large woody debris (Lying logs)
- Slight increase in canopy health
- Decrease in native species occurrence in midstory, graminoid and herb/forb groups.

Why?

- High rainfall and favourable growth conditions in the period between T1 (September 2019) and T2 (March 2022) may have supported the expansion of weedy shrubs and vines at the expense of native mid and understory species.
- Recovery of drought-affected canopy health following above average rainfall between T1 and T2.
- High flows may have deposited large woody debris within site.

What else?

- Recognised efforts of bitou bush and lantana removal.

Recommendations

- Continue with weed control measures
- Maintain current management practices.

Table 3.67 *Site-level summary of riparian condition of Bonville Creek #1, including subindices and indicators.*

Bonville Creek #1	Survey 1	Survey 2	Change
HABITAT	**17.0**	**17.0**	**0.0**
Channel width	4.0	4.0	**0.0**
Proximity	4.0	4.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	1.0	1.0	**0.0**
Hollow-bearing trees	0.0	0.0	**0.0**
NATIVE SPECIES	**16.0**	**14.0**	**-2.0**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	2.5	1.5	**-1.0**
Native herb/forb species	4.0	3.5	**-0.5**

Native graminoid species	1.5	1.0	**-0.5**
Native macrophyte species	4.0	4.0	**0.0**
SPECIES COVER	**12.5**	**11.5**	**-1.0**
Canopy species	2.5	2.5	**0.0**
Midstory species	2.0	2.0	**0.0**
Herb/forb species	1.0	1.0	**0.0**
Graminoid species	4.0	3.0	**-1.0**
Macrophyte species	3.0	3.0	**0.0**
DEBRIS	**9.0**	**10.0**	**1.0**
Total leaf litter	1.0	1.5	**0.5**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	0.0	0.0	**0.0**
Dead trees fallen	0.0	0.0	**0.0**
Lying logs	1.0	1.5	**0.5**
Fringing vegetation	4.0	4.0	**0.0**
MANAGEMENT	**15.3**	**18.5**	**3.2**
Tree clearing	2.0	2.5	**0.5**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	1.3	2.0	**0.7**
Exposed tree roots	4.0	4.0	**0.0**
Native woody regeneration	2.0	2.0	**0.0**
Weedy woody regeneration	0.0	2.0	**2.0**
TOTAL	**69.8**	**71.0**	**1.2**

Pine Creek

PINE3 Riparian Condition: T1 = 69.3 (C) T2 = 67.3 (C). Temporal difference = -2.0

Pine Creek 3 was a moderately disturbed freshwater system that supported a Coast and Hinterland Riparian Flooded Gum - Bangalow Wet Forest (CH_WSF01) riparian zone (Table 3.68). Immediate site surroundings were a mixed landscape of intact vegetation in the form of Bongil Bongil National Park, land cleared for grazing and transport infrastructure. The site lay immediately west of two major roads, Pine Creek Way and the Pacific Highway under which Pine Creek ran immediately downstream of the site. Bongil Bongil National Park was adjacent the highway to the east. To the west there was approximately 1km of cleared grazing land between the site and the eastern section of Pine Creek State Forest. Historic disturbances in the form of clearing for grazing and development were evident in the in the density of regrowth and incursion of weeds into the mid- and

understories. Mixed-age stands of native trees and shrubs were present in less disturbed areas along with representative plant species of the remnant vegetation community throughout all structural layers on site. PINE3 was assessed in previous Ecohealth programs and scores remain essentially unchanged.

PINE3 scored well for the Habitat subindex and moderately for the Native Species, Species Cover, Debris and Management subindices. Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: camphor laurel (*Cinnamomum camphora*), lantana (*Lantana camara*), senna (*Senna pendula*) and paspalum (*Paspalum dilatatum*) (see dominant species list for full site details). Limited native woody regeneration, animal impacts and low debris cover scores also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Installation of fencing on one side and subsequent reduction in animal impact
- Increase in overall herb/forb species cover, although significant reduction in natives
- Decrease in native woody regeneration and increase in weedy woody regeneration
- Reduction in overall debris score, particularly Total leaf litter.

Why?

- Flood flows between T1 (September 2019) and T2 (March 2022) likely removed leaf litter which has not yet re-established.
- Flood flows may have deposited propagules of exotic species from upstream which has favoured the establishment of exotics over natives.
- Higher than average rainfall and favourable conditions between T1 and T2 likely supported the expansion of herb/forb species and midstory species (mostly exotic).

What else?

- Both surveys noted evidence of cattle accessing creek. Elevated nutrient levels in agricultural landscapes from fertiliser application and runoff over time, along with grazing selection pressures promote weedy species.
- Coastal morning glory (*Ipomoea cairica*) which is a common weed in the Coffs catchment was noted at this site. This weed can smother native plants and reduce biodiversity by replacing native species. Coastal morning glory spreads easily and management in the upper catchment is important.
- High macrophyte diversity recorded at this site.

Recommendations

- Removing and controlling woody weeds, particularly camphor laurel, lantana and senna, will reduce competition in the long-term and encourage natural regeneration of native shrubs and improve ground cover.
- Additional plantings may assist natural regeneration and the expansion of riparian width in suitable areas with endemic species such as flooded gum *(Eucalyptus grandis),* water gum *(Tristaniopsis laurina),* bangalow palm (*Archontophoenix cunninghamiana*), blueberry ash (*Elaeocarpus reticulatus*), lilly pilly (*Acmena smithii*), and lomandra (*Lomandra longifolia*).
- Install wildlife friendly fencing >30m from creek bank to exclude livestock. This will aid in native regeneration, reduce potential for weed spread, aid in erosion management and increase the riparian zone width.

Table 3.68 *Site-level summary of riparian condition of Pine Creek #3, including subindices and indicators.*

Pine Creek #3	Survey 1	Survey 2	Change
HABITAT	**19.0**	**19.0**	**0.0**
Channel width	3.0	3.0	**0.0**
Proximity	4.0	4.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	2.0	2.0	**0.0**
NATIVE SPECIES	**14.0**	**12.5**	**-1.5**
Native canopy species	3.0	3.0	**0.0**
Native midstory species	2.5	2.5	**0.0**
Native herb/forb species	4.0	2.5	**-1.5**
Native graminoid species	1.5	1.5	**0.0**
Native macrophyte species	3.0	3.0	**0.0**
SPECIES COVER	**13.0**	**14.8**	**1.8**
Canopy species	3.0	3.0	**0.0**
Midstory species	2.0	2.3	**0.3**
Herb/forb species	1.0	2.5	**1.5**
Graminoid species	3.0	3.0	**0.0**
Macrophyte species	4.0	4.0	**0.0**
DEBRIS	**12.5**	**10.5**	**-2.0**
Total leaf litter	2.5	1.0	**-1.5**
Native leaf litter	3.0	2.5	**-0.5**
Dead trees standing	0.0	0.0	**0.0**
Dead trees fallen	0.0	0.0	**0.0**
Lying logs	4.0	4.0	**0.0**
Fringing vegetation	3.0	3.0	**0.0**
MANAGEMENT	**10.8**	**10.5**	**-0.3**
Tree clearing	2.0	2.0	**0.0**
Fencing	0.0	1.0	**1.0**
Animal impact	0.0	1.0	**1.0**
Species of interest	1.8	1.5	**-0.3**
Exposed tree roots	4.0	4.0	**0.0**
Native woody regeneration	2.0	1.0	**-1.0**
Weedy woody regeneration	1.0	0.0	**-1.0**
TOTAL	**69.3**	**67.3**	**-2.0**

PINE2 Riparian Condition: T1 = 79.8 (B-) T2 = 80.5 (B). Temporal difference = -0.3

Pine Creek 2 was a mildly to moderately disturbed estuarine system that supported a Coastal Paperbark - Swamp Oak Floodplain Forest (CH_FrW01), grading into a Coastal Swamp Mahogany Forest (CH_FrW02) riparian zone (Table 3.69). Immediate site surroundings were predominantly intact vegetation in the form of Bongil Bongil National Park, which was partially intersected by roads. Cleared areas for sparse rural housing and small acreage grazing lay within 500m to the north, east and west. Historic disturbances throughout large sections of the immediate riparian zone were evident in the in the density of canopy species regrowth and through the incursion of weeds into the midstory and understory layers. Mixed-age stands of native trees and shrubs along with representative plant species of the remnant vegetation communities were common throughout all structural layers on site.

PINE2 scored well for the Habitat, Native Species and Management subindices and moderately for the Species Cover and Debris subindices. Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: lantana (*Lantana camara*), senna (*Senna pendula*) and paspalum (*Paspalum dilatatum*) (see dominant species list for full site details). A low herb/forb cover score and reduced debris cover also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Slight increase in midstory species cover including native species
- Increase in herb/forb species cover
- Reduction in overall debris score, particularly Total leaf litter.

Why?

- Flood flows between T1 (September 2019) and T2 (March 2022) likely removed leaf litter and some lying logs and debris cover has not yet re-established.
- Higher than average rainfall and favourable conditions between T1 and T2 likely supported the expansion of herb/forb species and midstory species (native and exotic).

What else?

- Both surveys noted dense, healthy regrowth indicative of recovery from previous clearing. This density will self-thin over time.

Recommendations

- Implement weed control measures including strategic removal of existing weeds, particularly lantana and senna, and monitor site for new introductions. Implementing control measures while weed incursion is low will reduce long-term management efforts and associated costs.
- Maintain current practices.

Table 3.69 *Site-level summary of riparian condition of Pine Creek #2, including subindices and indicators.*

Pine Creek #2	Survey 1	Survey 2	Change
HABITAT	**17.0**	**17.0**	**0.0**
Channel width	4.0	4.0	**0.0**
Proximity	4.0	4.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	3.0	3.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	0.0	0.0	**0.0**
NATIVE SPECIES	**18.5**	**19.0**	**0.5**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	2.5	3.0	**0.5**
Native herb/forb species	4.0	4.0	**0.0**
Native graminoid species	4.0	4.0	**0.0**
Native macrophyte species	4.0	4.0	**0.0**
SPECIES COVER	**13.0**	**14.5**	**1.5**
Canopy species	3.0	3.0	**0.0**
Midstory species	3.0	3.5	**0.5**
Herb/forb species	0.0	1.0	**1.0**
Graminoid species	4.0	4.0	**0.0**
Macrophyte species	3.0	3.0	**0.0**
DEBRIS	**16.0**	**13.5**	**-2.5**
Total leaf litter	3.0	1.0	**-2.0**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	2.0	2.0	**0.0**
Dead trees fallen	1.0	1.0	**0.0**
Lying logs	3.0	2.5	**-0.5**
Fringing vegetation	4.0	4.0	**0.0**
MANAGEMENT	**15.3**	**15.5**	**1.2**
Tree clearing	2.0	2.0	**1.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	1.8	2.0	**0.2**
Exposed tree roots	2.5	2.5	**0.0**
Native woody regeneration	2.0	2.0	**0.0**
Weedy woody regeneration	1.0	1.0	**0.0**
TOTAL	**79.8**	**79.5**	**0.3**

3.10.4 Water quality

Survey Period 1

In Survey Period 1 (2019 – 2020), the subcatchment of the Bonville and Pine Creek received a score of 74, a grade of C, for water quality, with lowland freshwater site BONV4 having better water quality (grade B) compared to all other sites with the water quality grade of C (Table 3.70). Water temperatures reflected seasonal climatic changes, ranging from winter minimums of 12.6°C at PINE3 to summer maximums of 32.5°C at PINE2 (Table 3.71).

DO% ranged from 12.2 – 163.6% (Table 3.71). The minimum DO was recorded at the upper estuary site PINE2 in November 2020. The maximum level of DO recorded at lowland freshwater site PINE3 in December 2019 was likely associated with an algal bloom, given chl-a concentration (121.9µg/L) during the month was significantly above the guideline value. Even though lower estuary site BONV1 had DO% within the guideline limit in all sampling occasions (see Table 2.4 for water quality guideline values), DO levels in upper estuary site BONV3 were recorded below 80% on 7 of 8 sampling occasions with DO concentration falling below 2mg/L in November 2020. Low land freshwater site BONV4 also had DO% below 80% in December 2019 and November 2020, however, DO concentrations were above 2mg/L in all sampling occasions. In Pine Creek, DO% never met the minimum guideline value at upper estuary site PINE2 in 7 of 8 sampling occasions, with DO concentration falling below 2mg/L in July 2019, May 2020 and November 2020. PINE3 also had DO% below the guideline value in 5 of 8 sampling occasions but DO concentrations were above 2mg/L in all sampling occasions. pH ranged from 6 – 10.3 (Table 3.71). pH was recorded below the lowland freshwater guideline range in BONV4 in December 2019(6.35); PINE3 in July 2019 (6.35), March 2020 (6.31) and November 2020 (6.47). Contrastingly, pH exceeded the maximum upper estuary guideline value in September 2019 in BONV3 (9.2) and PINE2 (9.2). pH exceeded the lower estuary guideline value at the lower estuary site BONV1 (10.29) in September 2019. Turbidity ranged from 0.5 – 13.1NTU, with turbidity greater than the guideline value, recorded only in upper estuary sites BONV3 (13.07) and PINE2 (7.02) once in March 2020.

Chl-*a* ranged from 0.6 – 121.9µg/L (Table 3.71). Chl-a value remained above the guideline value in all sampling occasions in PINE3, likely associated with the large exceedance of the freshwater guideline value of TN, TP and NOx. Upper estuary sites BONV3 and PINE2 also had chl-a above guideline value in 6 of 8 and 5 of 8 sampling occasions, respectively. Higher chl-a readings were also recorded in the lower estuary site BONV1 but dropped below the guideline value after march 2020. TN ranged from 149 – 3756µg/L. PINE3, a lowland freshwater site, had higher TN content than all other sites at the subcatchment of the Bonville and Pine Creek. TN higher than the guideline value was recorded in PINE3 in 6 of 8 sampling occasions. TN also exceeded the lowland freshwater guideline value in 4 of 8 sampling occasions in BONV4. TN exceeded the guideline value in 5 of 8 sampling occasions at the lower estuary site BONV1; values were below guideline values in upper estuary sites (BONV3 and PINE 2). TP ranged from 11 – 170.7µg/L. The lower estuary site BONV1 recorded TP values above the guideline in all sampling occasions. Among the lowland freshwater sites, BONV3 had TP below the guideline value in 7 of 8 sampling occasions, but PINE3 recorded higher TP values in 5 of 8. At upper estuary site BONV3, TP exceeded the estuarine guideline value in 5 out of 8 sampling periods, whereas PINE2 recorded TP above the guideline value in 6 out of 8 sampling periods. SPR ranged

from 1-21µg/L, and NOx ranged from 2 – 275µg/L. On 7 of 8 occasions, NOx exceeded the estuarine guideline value at BONV1. NOx was also recorded above guideline values in upper estuary sites BONV3 and PINE2 in 5 of 8 and 6 of 8 sites, respectively. NOx values were consistently above the guideline value at lowland freshwater site BONV3, and PINE3 had the exceedance on 6 of 8 sampling occasions.

Survey Period 2

Water quality in Bonville/Pine Creek in Survey Period 2 (2021 – 2022) improved compared to Survey Period 1 (2019 – 2020), with the catchment receiving a score of 80, a grade of B (Table 3.70). Water temperatures reflected seasonal climatic changes, ranging from winter minimums of 13.6°C at PINE3 to summer maximums of 22.6°C at PINE2 (Table 3.71). DO% ranged from 29.4 – 127.7% (Table 3.71). The lowland freshwater site BONV4 has a DO level above the minimum guideline value in all sampling occasions (see Table 2. 4 for water quality guideline values). The exceedance in May 2021 was likely due to reaeration due to turbulence rather than an association with an algal bloom, given chl-a concentration was within guideline value in BONV4. Another lowland freshwater site PINE3 had DO recorded below the guideline value in 3 of 5 sampling occasions. Upper estuary site BONV3 had DO below the guideline in 3 of 4 sampling occasions, whereas PINE2 never met the DO guideline. At BONV1, DO dropped below the guideline value once in Jun 2022. pH ranged from 5.7 – 8.1 (Table 3.71). pH was recorded below the guideline value in BONV3 twice, PINE2 thrice, and BONV4 thrice on 4 sampling occasions. Turbidity ranged from 0.6 – 10.1NTU.

Chl-a ranged from 0.1 – 9.4µg/L (Table 3.71). Chl-a was recorded within the guideline value in all upper estuary sites BONV3, PINE2 and a lowland freshwater site BONV4, but lower estuary site BONV1 exceeded the guideline value twice in May 2021 (4.2) and February 2022 (2.77). Chl-a content rose above the guideline value once in lowland freshwater site PINE3 (9.37) in May 2021. TN ranged from 106 – 704.3µg/L and exceeded the lowland freshwater guideline value in BONV4 and PINE3 in all sampling occasions except June 2022. TN in upper estuary site PINE2 only exceeded the guideline value once in June 2022 (704.3µg/L). TP ranged from 4 – 920µg/L and exceeded the lower estuary guideline value in all sampling periods in BONV1. TP at BONV3 exceeded the upper estuary guideline value in all sampling occasions, whereas PINE2 recorded higher TP in 3 of 4 sampling occasions with a maximum of 920µg/L recorded on August 2022, more than 143 times higher than the guideline value. TP in BONV4 and PINE3 also exceeded the lowland freshwater guideline in 3 of 5 and 4 of 5 sampling occasions. NOx ranged from 15.7 – 383µg/L (Table 3.71). NOx was always above the guideline value at lowland freshwater BONV4, PINE 3, lower estuary site BONV1 and upper estuary site BONV3. PINE 2 only recorded above estuary guideline NOx value in 2 of 4 sampling periods. SRP ranged from 1.3 – 11µg/L (Table 3.71), with the value exceeding the guideline value once at BONV1 (11µg/L).

Table 3.70. *Water quality scores for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Bonville/Pine Creek subcatchment.*

	BONV1		BONV3		BONV4		PINE2		PINE3	
	2019-2020	2021-2022	2019-2020	2021-2022	2019-2020	2021-2022	2019-2020	2021-2022	2019-2020	2021-2022
WQ Grade	69	78	71	82	86	80	69	87	69	79
Phys-Chem	25	28	21	23	27	22	22	26	24	26
Nutrients	23	24	27	26	28	25	24	28	22	27
Chl-a	21	26	23	33	31	33	23	33	23	26

Table 3.71. *Minimum and maximum (and mean) values of water quality variables for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Bonville/Pine Creek subcatchment.*

	BONV1						BONV3					
	Survey Period 1			Survey Period 2			Survey Period 1			Survey Period 2		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temp (°C)	18.7	24.5	21.1	18.9	22.3	20.1	20.7	32.2	24.9	14.9	22	19.1
pH	7.6	10.3	8.3	7.8	8.1	7.9	6.4	9.2	7.5	6.7	7.1	6.9
Cond (µS/cm)	34401.5	73146.2	52980.7	25850.7	46139.3	38366.2	2438.7	66955	43821.2	831.3	39152.7	21370
Salinity (PPT)	20.3	50.4	34.9	24.7	29.9	26.7	1.2	45.6	29.2	0.5	25.2	13.6
DO (mg/L)	6.9	9.7	7.9	3.8	9.6	7.1	1.7	5.5	3.4	2.4	8.9	5.1
DO %	90.6	130	108.7	47.9	125.8	92	24.8	86.3	47.5	29.4	88.6	54.9
Turbidity (NTU)	0.5	2.4	1.1	0.6	2.3	1.3	2.1	13.1	4.5	1.2	6	3.6
TSS (mg/L)	10.3	23.5	15.7	11.2	36.2	20.5	4.8	18.1	11	1.5	5.5	3.4
Chl-a (µg/L)	1.2	10.5	5.6	0.4	4.2	2	3	34.1	15	0.2	2.2	1.2
TN (µg/L)	149	467	303.2	106	390	227.8	240	585	395.3	230.7	366.3	308.7
TP (µg/L)	11	86.7	26.2	43	150	85.7	13	170.7	43.1	25	59.5	43.1
NOx (µg/L)	2	165	90.8	18.3	69	38.7	8	217	94.9	106	257.7	182.9
SRP (µg/L)	1	7	4.1	2.7	11	5.7	2	4.7	3.3	2.5	6	3.9
	BONV4						PINE2					
	Survey Period 1			Survey Period 2			Survey Period 1			Survey Period 2		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temp (°C)	14.1	26.4	19.6	14	20.7	17.3	19.1	32.5	24.4	13.7	22.6	17.4
pH	6.4	8.7	7.1	5.7	7.9	6.7	6.5	9.2	7.5	6.7	7.2	6.9
Cond (µS/cm)	57	106	83.8	56.3	78	69.3	910	67284.7	42988.4	1723.7	29948.7	15572.7
Salinity (PPT)	0	0.1	0	0	0	0	0.6	45.9	28.3	1.4	19.3	9.9
DO (mg/L)	6	10.6	8.6	8.3	12.4	9.8	0.8	8.4	3.6	2.7	7.8	5.1

DO %	74	104.1	92.2	92.6	127.2	102.2	12.2	95	47.7	31.1	76.6	54
Turbidity (NTU)	0.6	1.6	1.1	1.4	2.6	2	1.7	7.2	4.3	1.2	3.8	2.5
TSS (mg/L)	0.3	2.3	1.3	1.4	53.3	12.2	4	25.9	11.4	4.4	12.6	7.5
Chl-a (µg/L)	0.6	4.1	1.9	0.1	1.3	0.4	1.1	50.7	14.3	0.4	2.9	1.2
TN (µg/L)	256	624	442.9	283	579	415	149	545	379	171	704.3	388.8
TP (µg/L)	11	64	20.8	8	574.7	145.2	12	124.3	36.3	4	920	243.1
NOx (µg/L)	53	275	148.5	212.3	383	273.9	3	246	130	15.7	78.7	46.6
SRP (µg/L)	3	10	5.2	3	6	4.2	3	9	6.2	2.3	6	3.7

	PINE3					
	Survey Period 1			**Survey Period 2**		
	Min	Max	Mean	Min	Max	Mean
Temp (°C)	12.6	29.2	19.6	13.6	20.3	16.5
pH	6	8.3	7	5.8	7.7	6.5
Cond (µS/cm)	57	126	96.3	57.3	106	87.5
Salinity (PPT)	0	0.1	0	0	0.1	0
DO (mg/L)	5	12.5	7.6	5.9	11.2	8.2
DO %	53.6	163.6	83.4	63.2	112.5	83.1
Turbidity (NTU)	0.7	4.8	3.3	3.8	10.1	5.7
TSS (mg/L)	1.3	55.7	14.3	3.1	17	6.4
Chl-a (µg/L)	3.1	121.9	33.9	0.3	9.4	2.6
TN (µg/L)	218	3756	1333.3	129.3	484.7	342
TP (µg/L)	20	114	51.3	11	544	151.3
NOx (µg/L)	3	246	101.3	62	98.7	74.9
SRP (µg/L)	3	21	8.5	1.3	5.7	3.2

3.10.5 Aquatic macroinvertebrates

Bonville Creek

The macroinvertebrate community at Bonville Creek received an overall grade of very good (A-) for condition in 2019-20 (Table 3.72), the same condition as recorded in 2015. Indicators varied from B- to A+. Total Abundance was very good at 18/20 (A-). Richness scored 17/20 (A-) and many EPT taxa were collected giving this indicator a good rating (14/20, B-). Nativeness was very good (20/20), with no exotic taxa collected. The Site Mean SIGNAL was 4.7 with the waterbug community comprising both low-scoring, pollution-tolerant taxa and high-scoring pollution-sensitive taxa (SIGNAL2 score of good, 17/20).

The macroinvertebrate community at BONV4 received an overall grade of A for condition in 2020-21 (Table 3.72), a slight increase in condition (score A-, good), in 2019-20. Indicators varied from B+ to A+. The Abundance criteria was very good at 19/20 (A). Richness scored 17/20 (B+) and only many EPT taxa were collected giving this indicator a very good rating (18/20, A). Nativeness was very good (20/20), with no exotic taxa collected. The SIGNAL2 scored was 19/20 with the waterbug community comprising of low-scoring, pollution-tolerant taxa, as well as high-scoring pollution-sensitive mayflies and caddiflies present at this site.

Table 3.72 *Summary of aquatic macroinvertebrate data for Bonville Creek #4 (BONV4). Indicators are out of 20.*

BONV4				
	Survey Period 1		**Survey Period 2**	
Macroinvertebrate indicator	**Score**	**Grade**	**Score**	**Grade**
Family richness	18	A-	19	A
Total abundance	17	A-	17	B+
EPT	14	B-	18	A
Nativeness	20	A+	20	A+
Mean SIGNAL2 score	17	B+	19	A
Ecohealth score	**86**	**A-**	**93**	**A**

Pine Creek

The macroinvertebrate community at Pine Creek received an overall grade of D+ for condition in 2019-20 (Table 3.73), the same condition as in 2015. Indicators varied from F to A+. Total Abundance was very poor at 4/20 (F). Richness scored 8/20 (D-) and only two EPT taxa were collected giving this indicator a very poor rating (2/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The Site Mean SIGNAL was 4.2 with the waterbug community comprising low-scoring, pollution-tolerant taxa (SIGNAL2 score of Good, 15/20). However, there were three high-scoring pollution-sensitive mayfly and caddisfly taxa present at this site.

The macroinvertebrate community at PINE3 received an overall grade of D+ for condition in 2020-21 (Table 3.73), the same condition score in 2019-20. Indicators varied from F to A+. The Abundance criteria was poor at 4/20 (F). Richness scored 13/20 (C) and only a few EPT taxa were collected giving this indicator a very poor rating (2/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The SIGNAL2 scored was 14/20 with the waterbug community comprising mostly low-scoring, pollution-tolerant taxa. However, there were several high-scoring pollution-sensitive mayflies present at this site.

Table 3.73 *Summary of aquatic macroinvertebrate data for Pine Creek #3 (PINE3). Indicators are out of 20.*

PINE3				
	Survey Period 1		Survey Period 2	
Macroinvertebrate indicator	**Score**	**Grade**	**Score**	**Grade**
Family richness	4	F	4	F
Total abundance	8	D-	13	C
EPT	2	F	2	F
Nativeness	20	A+	20	A+
Mean SIGNAL2 score	15	B	14	C+
Ecohealth score	**50**	**D+**	**53**	**D+**

3.11 Orara River and Bucca Bucca Creek

3.11.1 Geomorphic condition

There was significant active erosion of the macro channel and right bank at ORAR7, associated with major flooding. Some undercutting on the left and right banks was associated with bridge scour at the upstream end of the reach. However, recent riverworks have been completed to stabilize the banks. There was no evidence of stock access. ORAR7 scored 68.4, a grade of C, for BANK CONDITION and 78, a grade of B-, for BED CONDITION. The overall Ecohealth geomorphic condition for ORAR7 was 73.2, a grade of C+. Geomorphic condition remained stable at ORAR6, with the most noticeable local impact compaction and trampling due to regular recreational activities. Minor bank erosion occurred on the left bank adjacent to the parking area and could benefit from some small bank stabilization works. ORAR6 scored 57.6, a grade of D+, for BANK CONDITION and 78, a grade of B-, for BED CONDITION. The overall Ecohealth geomorphic condition for ORAR6 was 67.8, a grade of C+. There was bank erosion associated with bridge scour at ORAR5 but banks remained well vegetated and the extensive macrophyte beds at the site promoted bed stability. ORAR5 scored 61.2, a grade of C-, for BANK CONDITION and 78, a grade of B-, for BED CONDITION. The overall Ecohealth geomorphic condition for ORAR5 was 69.6, a grade of C.

Extensive riparian revegetation and dense small-leaved privet stands promoted bank stability at BUCC1. The site also supported extensive macrophyte beds, indicating stable bed substrates. BUCC1 scored 81, a grade of B, for BANK CONDITION and 84, a grade of B, for BED CONDITION. The overall Ecohealth geomorphic condition for ORAR5 was 82.5, a grade of B.

3.11.2 Riparian condition

Orara River

ORAR7 Riparian Condition: T1 = 59.8 (D+) T2 = 58.2 (D+). Temporal difference = -1.6

ORAR7 was a highly disturbed freshwater system that supported a River Oak Riparian Forest of The Orara River Valley (CH_FrW07) grading into a mixed Coast and Hinterland Riparian Flooded Gum - Bangalow Wet Forest (CH_WSF01) and Hinterland White Booyong Floodplain Forest (CH_RF09) riparian zone (Table 3.74). Immediate site surroundings were a mixed landscape of intact vegetation and cleared grazing land. In this part of the catchment the Orara River ran through a largely cleared valley intersected by roads, transport networks and rural settlements and bordered by state forest. At ORAR7 the cleared valley area was less than 1km wide and the riparian vegetation was nearly contiguous with nearby state forest to the east. Historic disturbances in the form of clearing for development, agriculture and forestry were evident throughout the riparian zone in the dominance of regrowth in canopy species and incursion of weeds throughout all structural layers. Mixed-age stands of native trees and shrubs were present in less disturbed areas along with

representative plant species of the remnant vegetation communities throughout all structural layers on site.

ORAR7 scored well for the Habitat subindex, moderately for the Native Species subindex and moderately to poorly for the Species Cover, Debris and Management subindices. Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: camphor laurel (*Cinnamomum camphora*), lantana (*Lantana camara*), small-leaved privet (*Ligustrum sinense*), crofton weed (*Ageratina adenophora*), mistflower (*Ageratina riparia*), trad (*Tradescantia fluminensis*) and paspalum (*Paspalum dilatatum*) (see dominant species list for full site details). Limited native regeneration, low levels of cover in the understory and poor native species representation in all but canopy species also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Decrease in weedy woody regeneration and exposed tree roots
- Slight increase in herb/forb and graminoid species cover
- Decrease in macrophyte species cover and reduction in debris cover
- Increased animal impact.

Why?

- Flood flows between T1 (September 2019) and T2 (March 2022) likely reduced macrophytes and removed leaf litter which have yet to re-establish.
- Higher than average rainfall and favourable conditions experienced between T1 and T2 may have supported marginal improvement in herb/forb and graminoid species cover.

What else?

- Both surveys note occurrence of large remnant rainforest trees representative of the recognised EEC 'Lowland Rainforest on Floodplain'.
- T2 survey noted evidence of livestock accessing creek and lots of rubbish at site.
- Sites such as this one offer important linkages that support biodiversity, species persistence and species movement through otherwise developed, urban landscapes.

Recommendations

- Removing and controlling woody weeds, particularly camphor laurel, lantana and small-leaved privet, will reduce competition in the long-term and encourage natural regeneration of native shrubs and improve ground cover. Where exotic species are providing bank stability (e.g. camphor laurel), staggered removal should be considered and complemented with endemic plantings to improve erosion resistance, e.g. flooded gum *(Eucalyptus grandis),* water gum *(Tristaniopsis laurina),* Bangalow palm (*Archontophoenix cunninghamiana*), and lomandra (*Lomandra longifolia*).
- Install and maintain wildlife friendly fencing to exclude grazing animals to increase up and downstream riparian width, and encourage regeneration of native vegetation. This will also aid in long-term erosion management.

Table 3.74 *Site-level summary of riparian condition of Orara River #7, including subindices and indicators.*

Orara River #7	Survey 1	Survey 2	Change
HABITAT	**16.0**	**16.0**	**0.0**
Channel width	2.0	2.0	**0.0**
Proximity	3.0	3.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	3.0	3.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	2.0	2.0	**0.0**
NATIVE SPECIES	**11.0**	**11.0**	**0.0**
Native canopy species	3.0	3.0	**0.0**
Native midstory species	2.0	2.0	**0.0**
Native herb/forb species	2.5	2.5	**0.0**
Native graminoid species	1.5	1.5	**0.0**
Native macrophyte species	2.0	2.0	**0.0**
SPECIES COVER	**10.5**	**10.0**	**-0.5**
Canopy species	3.0	3.0	**0.0**
Midstory species	3.5	3.5	**0.0**
Herb/forb species	1.0	1.5	**0.5**
Graminoid species	1.0	1.5	**0.5**
Macrophyte species	2.0	0.5	**-1.5**
DEBRIS	**12.0**	**10.5**	**-1.5**
Total leaf litter	3.0	2.0	**-1.0**
Native leaf litter	1.0	0.5	**-0.5**
Dead trees standing	0.0	0.0	**0.0**
Dead trees fallen	3.0	3.0	**0.0**
Lying logs	2.0	2.0	**0.0**
Fringing vegetation	3.0	3.0	**0.0**
MANAGEMENT	**10.3**	**10.7**	**0.4**
Tree clearing	1.5	1.5	**0.0**
Fencing	1.0	1.0	**0.0**
Animal impact	3.0	2.0	**-1.0**
Species of interest	1.8	1.2	**-0.6**
Exposed tree roots	2.0	3.0	**1.0**
Native woody regeneration	1.0	1.0	**0.0**
Weedy woody regeneration	0.0	1.0	**1.0**
TOTAL	**59.8**	**58.2**	**-1.6**

ORAR6 Riparian Condition: T1 = 52.8 (D) T2 = 52.5 (D). Temporal difference = -0.3

ORAR6 was a highly disturbed freshwater system that supported a Coast and Hinterland Riparian Flooded Gum - Bangalow Wet Forest (CH_WSF01) riparian zone (Table 3.75). Immediate site surroundings were a mixed landscape of intact vegetation and cleared grazing land, with the small township of Coramba immediately adjacent the site. The Orara River ran through a largely cleared valley intersected by roads, transport networks and rural settlements and bordered by state forest. At ORAR6 the cleared valley area was narrow and the riparian vegetation was nearly contiguous with nearby state forest. Historic disturbances in the form of clearing for development, agriculture and forestry were evident throughout the riparian zone in the dominance of regrowth in canopy species and incursion of weeds throughout all structural layers. Mixed-age stands of native trees and shrubs were present along with representative plant species of the remnant vegetation community throughout all structural layers on site.

ORAR6 scored moderately for the Habitat subindex and poorly for the Native Species, Species Cover, Debris and Management subindices. Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: camphor laurel (*Cinnamomum camphora*), coral tree (*Erythrina* x *sykesii*), lantana (*Lantana camara*), small-leaved privet (*Ligustrum sinense*), senna (*Senna pendula*), mistflower (*Ageratina riparia*), trad (*Tradescantia fluminensis*) and paspalum (*Paspalum dilatatum*) (see dominant species list for full site details). A lack of native regeneration, low levels of cover in the mid- and understories and poor native species scores in all but macrophytes also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Increase in large woody debris (Lying logs)
- Marginal increases in midstory species cover and canopy health
- Decrease in native woody regeneration
- Reduction in fringing vegetation and graminoid species (native and exotic).

Why?

- Flood flows between T1 (September 2019) and T2 (March 2022) likely removed fringing vegetation including graminoids and deposited large woody debris.
- Higher than average rainfall and favourable conditions experienced between T1 and T2 may have supported increased midstory cover and marginal improvement in canopy health, but also provided favourable growth conditions and supported the expansion of existing weedy woody regeneration at the expense of native species.

What else?

- Sites such as this one offer important linkages that support biodiversity, species persistence and species movement through otherwise developed, urban landscapes.

Recommendations

- Removing and controlling woody weeds, particularly camphor laurel, coral tree, lantana, small-leaved privet, senna and trad, will reduce competition in the long-term and encourage natural regeneration of native shrubs and improve ground cover.
- Additional plantings may assist natural regeneration and the expansion of riparian width in suitable areas with endemic species such as flooded gum *(Eucalyptus grandis),* water gum *(Tristaniopsis laurina),* Bangalow palm (*Archontophoenix cunninghamiana*), and lomandra (*Lomandra longifolia*).

- Monitor for introduction of new weeds from nearby roads, gardens and recreational users. Implementing control measures while weed incursion is low will reduce long-term management efforts and associated costs.

Table 3.75 *Site-level summary of riparian condition of Orara River #6, including subindices and indicators.*

Orara River #6	Survey 1	Survey 2	Change
HABITAT	**16.0**	**16.0**	**0.0**
Channel width	2.0	2.0	**0.0**
Proximity	3.0	3.0	**0.0**
Continuity	3.0	3.0	**0.0**
Layers	4.0	4.0	**0.0**
Large native trees	2.0	2.0	**0.0**
Hollow-bearing trees	2.0	2.0	**0.0**
NATIVE SPECIES	**9.5**	**9.0**	**-0.5**
Native canopy species	2.5	2.5	**0.0**
Native midstory species	1.0	1.0	**0.0**
Native herb/forb species	1.5	1.5	**0.0**
Native graminoid species	1.5	1.0	**-0.5**
Native macrophyte species	3.0	3.0	**0.0**
SPECIES COVER	**9.5**	**9.5**	**0.0**
Canopy species	3.0	3.0	**0.0**
Midstory species	2.0	2.5	**0.5**
Herb/forb species	1.5	1.5	**0.0**
Graminoid species	1.0	0.5	**-0.5**
Macrophyte species	2.0	2.0	**0.0**
DEBRIS	**9.0**	**10.0**	**1.0**
Total leaf litter	1.0	1.0	**0.0**
Native leaf litter	1.0	1.0	**0.0**
Dead trees standing	2.0	2.0	**0.0**
Dead trees fallen	0.0	0.0	**0.0**
Lying logs	2.0	4.0	**2.0**
Fringing vegetation	3.0	2.0	**-1.0**
MANAGEMENT	**8.8**	**8.0**	**-0.8**
Tree clearing	2.0	2.0	**0.0**
Fencing	1.0	1.0	**0.0**
Animal impact	1.0	1.0	**0.0**
Species of interest	1.8	2.0	**0.2**

Exposed tree roots	2.0	2.0	**0.0**
Native woody regeneration	1.0	0.0	**-1.0**
Weedy woody regeneration	0.0	0.0	**0.0**
TOTAL	**52.8**	**52.5**	**-0.3**

ORAR5 Riparian Condition: T1 = 65.3 (C) T2 = 57.9 (D+). Temporal difference = -7.4

Orara River 5 was a highly disturbed freshwater system that supported a River Oak Riparian Forest of The Orara River Valley (CH_FrW07) grading into a Coast and Hinterland Riparian Flooded Gum - Bangalow Wet Forest (CH_WSF01) riparian zone (Table 3.76). Immediate site surroundings were predominantly cleared grazing land intersected with roads and rural infrastructure, with small townships approximately 500m to the south and the east. Historic disturbances in the form of clearing were evident throughout the riparian zone in the lack of mature native trees and the incursion of weeds throughout all structural layers. Also evident were past environmental rehabilitation planting efforts from approximately 10 years ago. Mixed-age stands of native trees and shrubs were present in less disturbed areas along with representative plant species of the remnant vegetation communities throughout all structural layers on site.

ORAR5 scored moderately for the Habitat, Native Species, Species Cover and Management subindices and poorly for the Debris subindex. Riparian condition was affected by the presence and regeneration of weed and noxious weed species which were present throughout the understory, and included: camphor laurel (*Cinnamomum camphora*), small-leaved privet (*Ligustrum sinense*), mistflower (*Ageratina riparia*), trad (*Tradescantia fluminensis*) and parrots feather (*Myriophyllum aquaticum*) (see dominant species list for full site details). Limited native regeneration, low graminoid cover and limited debris cover also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2

What caused the difference?

- Increase in native graminoids
- Significant reduction in overall debris and fringing vegetation cover.

Why?

- Flood flows between T1 (September 2019) and T2 (March 2022) likely removed leaf litter, lying logs and fringing vegetation and may even account for loss of standing dead trees, particularly where banks have eroded.
- Higher than average rainfall and favourable growth conditions between T1 and T2 may have led to an increase in native graminoids.

What else?

- T1 and T2 surveys both noted a thick mat of Trad (*Tradescantia fluminensis*) throughout more disturbed sections of this site which can inhibit growth of other understory species.
- T2 survey noted active erosion at the site, although established plantings undertaken during previous rehabilitation works will assist in maintaining bank stability.

- Surveys noted community bushcare efforts with evidence of weeding (e.g. low disturbance cut/stump painting of camphor laurels) and general maintenance, which in the long-term will assist the natural re-establishment of native midstory and canopy species.
- Sites such as this one offer important linkages that support biodiversity, species persistence and species movement through otherwise developed, urban landscapes.

Recommendations

- Remove and control for weeds, particularly camphor laurel, small-leaved privet, trad and potentially parrots feather during contracted low flow events (see pictures below). Note that where exotic species are providing bank stability staggered removal should be considered and complemented with ongoing native plantings.
- Removing and controlling woody weeds and weedy ground cover species will reduce competition in the long-term and encourage natural regeneration of native species. Plantings of lomandra (*Lomandra longifolia*) can assist in establishing native ground cover.

Table 3.76 *Site-level summary of riparian condition of Orara River #5, including subindices and indicators.*

Orara River #5	Survey 1	Survey 2	Change
HABITAT	**12.5**	**12.5**	**0.0**
Channel width	3.0	3.0	**0.0**
Proximity	1.0	1.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	3.0	3.0	**0.0**
Large native trees	1.5	1.5	**0.0**
Hollow-bearing trees	0.0	0.0	**0.0**
NATIVE SPECIES	**10.0**	**11.0**	**1.0**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	3.0	3.0	**0.0**
Native herb/forb species	2.0	2.0	**0.0**
Native graminoid species	0.0	1.0	**1.0**
Native macrophyte species	1.0	1.0	**0.0**
SPECIES COVER	**13.5**	**13.5**	**0.0**
Canopy species	3.0	3.0	**0.0**
Midstory species	3.0	3.0	**0.0**
Herb/forb species	4.0	4.0	**0.0**
Graminoid species	0.5	0.5	**0.0**
Macrophyte species	3.0	3.0	**0.0**
DEBRIS	**16.0**	**8.0**	**-8.0**
Total leaf litter	3.0	1.0	**-2.0**
Native leaf litter	3.0	3.0	**0.0**
Dead trees standing	3.0	2.0	**-1.0**

Dead trees fallen	0.0	0.0	**0.0**
Lying logs	4.0	0.0	**-4.0**
Fringing vegetation	3.0	2.0	**-1.0**
MANAGEMENT	**13.3**	**12.9**	**-0.4**
Tree clearing	2.0	2.0	**0.0**
Fencing	3.0	3.0	**0.0**
Animal impact	3.0	3.0	**0.0**
Species of interest	1.8	1.4	**-0.4**
Exposed tree roots	2.5	2.5	**0.0**
Native woody regeneration	1.0	1.0	**0.0**
Weedy woody regeneration	0.0	0.0	**0.0**
TOTAL	**65.3**	**57.9**	**-7.4**

Bucca Bucca Creek

BUCC1 Riparian Condition: T1 = 59.4 (D+) T2 = 59.1 (D+). Temporal difference = -0.3

Bucca Bucca Creek 1 was a highly disturbed freshwater system that supported a fringing gallery of Watergum transitioning into a Coast and Hinterland Riparian Flooded Gum - Bangalow Wet Forest (CH_WSF01) riparian zone (Table 3.77). Immediate site surroundings were predominantly cleared rural land intersected by roads and infrastructure. The township of Nana Glen lay approximately 150m to the west across Morrows Rd, under which Bucca Bucca Creek flowed immediately upstream of the site. Significant stands of intact vegetation exist in the landscape within 600-800m to the north and south. Historic disturbances in the form of clearing for agriculture and development were evident in the narrow width of the riparian zone and incursion of weed species throughout all structural layers. Mixed-age stands of native trees and shrubs were present along with representative plant species of the remnant vegetation community throughout all structural layers on site.

BUCC1 scored moderately for all subindices (Habitat, Native Species, Species Cover, Debris and Management. Riparian condition was affected by the presence and regeneration of weed and noxious weed species, and included: camphor laurel (*Cinnamomum camphora*), small-leaved privet (*Ligustrum sinense*), wild tobacco (*Solanum mauritianum*), senna (*Senna pendula*) and trad (*Tradescantia fluminensis*) (see dominant species list for full site details). Limited native species occurrence, reduced levels of cover in the understory, particularly graminoid species, and poor fencing and subsequent animal impacts also contributed to the reduction in riparian grade at this site.

Temporal difference in riparian condition between T1 and T2
What caused the difference?

- Increase in canopy species cover and marginal improvement in canopy health
- Increase in native leaf litter (although see note re canopy health)
- Decrease in native herb/forb and graminoid species occurrence

- Increased animal impact.

Why?

- Higher rainfall and flood flows between T1 (September 2019) and T2 (March 2022) may have removed leaf litter overall which has yet to re-establish.
- Improved soil moisture as a result of higher than average rainfall between T1 and T2 likely supported the marginal improvement in canopy health, although note that the overall score remains low and the increase in native leaf litter noted in T2 could be a symptom of poor tree health.
- Grazing can exert a selection pressure on understory species resulting in a shift towards exotic over native species. It is possible that the increased animal impacts noted in T2 account for the reduction in native herb/forb and graminoid species.

What else?

- Surveys noted community bushcare efforts with evidence of weeding and general maintenance, which in the long-term will assist the natural re-establishment of native midstory and canopy species.
- Sites such as this one offer important linkages that support biodiversity, species persistence and species movement through otherwise developed, urban landscapes.

Recommendations

- Remove and control for weeds, especially small-leaved Privet. This species is an issue in creeks and rivers throughout the region and requires management at a catchment scale to minimise spread.
- Install and maintain riparian fencing 30m or more from creek bank to exclude livestock to aid with native regeneration and expand the riparian corridor.
- Consider locally endemic native plantings to increase understory cover e.g. Creeping Beard Grass (*Oplismenus imbecillis*) and Lomandra (*Lomandra longifolia*).

Table 3.77 *Site-level summary of riparian condition of Bucca Bucca Creek #1, including subindices and indicators.*

Bucca Bucca Creek #1	Survey 1	Survey 2	Change
HABITAT	**14.5**	**14.5**	**0.0**
Channel width	3.0	3.0	**0.0**
Proximity	2.0	2.0	**0.0**
Continuity	4.0	4.0	**0.0**
Layers	3.0	3.0	**0.0**
Large native trees	1.5	1.5	**0.0**
Hollow-bearing trees	1.0	1.0	**0.0**
NATIVE SPECIES	**11.5**	**10.0**	**-1.5**
Native canopy species	4.0	4.0	**0.0**
Native midstory species	1.5	1.5	**0.0**
Native herb/forb species	2.0	1.5	**-0.5**
Native graminoid species	3.0	2.0	**-1.0**
Native macrophyte species	1.0	1.0	**0.0**

SPECIES COVER	**10.5**	**11.5**	**1.0**
Canopy species	2.0	3.0	**1.0**
Midstory species	4.0	4.0	**0.0**
Herb/forb species	3.0	3.0	**0.0**
Graminoid species	0.5	0.5	**0.0**
Macrophyte species	1.0	1.0	**0.0**
DEBRIS	**11.5**	**12.0**	**0.5**
Total leaf litter	2.0	1.5	**-0.5**
Native leaf litter	2.0	3.0	**1.0**
Dead trees standing	2.0	2.0	**0.0**
Dead trees fallen	1.0	1.0	**0.0**
Lying logs	2.5	2.5	**0.0**
Fringing vegetation	2.0	2.0	**0.0**
MANAGEMENT	**11.4**	**11.1**	**-0.3**
Tree clearing	2.5	2.5	**0.0**
Fencing	1.0	1.0	**0.0**
Animal impact	1.0	0.0	**-1.0**
Species of interest	1.4	1.6	**0.2**
Exposed tree roots	3.5	4.0	**0.5**
Native woody regeneration	2.0	2.0	**0.0**
Weedy woody regeneration	0.0	0.0	**0.0**
TOTAL	**59.4**	**59.1**	**-0.3**

3.11.3 Water quality

Survey Period 1

In Survey Period 1 (2019 – 2020) the Orara River subcatchment received a score of 84, a grade of B, for water quality. BUCC1 received a score of 78 (B), ORAR5 received a score of 84 (B), ORAR6 received the best water quality score in the lowland freshwater subcatchment of 88 (B) and ORAR7 received a score of 85 (B) (Table 3.78).

pH ranged from 6.53 – 9.17 in the Orara River subcatchment in Survey Period 1 (Table 3.79). pH exceeded the maximum lowland freshwater guideline value of 8.5 in September 2019 at BUCC1 (9.2), ORAR5 (8.79), ORAR7 (8.93) and (see Table 2.4 for water quality guideline values).

Water temperatures reflected seasonal climatic changes. BUCC1 was the most variable, ranging from a winter minimum of 9.6°C to a summer maximum of 26.1°C (Table 3.79). DO% fell outside the freshwater guidelines on several occasions in the Orara River subcatchment in Survey Period 1. Most

notably, dissolved oxygen was 9.5% and 0.75mg/L at BUCC1 in December 2019, which is below the minimum DO% guideline value and below the 2mg/L threshold suitable for aquatic life. DO% also fell below the minimum guideline value at BUCC1 in September 2019 (67.1%), January 2020 (46.2%) and November 2020 (63.5%). ORAR5 was below the minimum DO% guideline value in December 2019 (52.9%), slightly below in November 2020 at ORAR6 (78.8%), as well as at ORAR7 in December 2019 (71.6%) and in November 2020 (79.4%), however, these levels were not below 2mg/L and therefore not harmful to biota.

Chl-*a* ranged from 0.3 – 70.2µg/L in the Orara River subcatchment in Survey Period 1. BUCC1 was 23 times the guideline value in December 2019 (70.2µg/L) and slightly exceeded the guideline value in August 2020 (3.3µg/L). The freshwater guideline was also exceeded in ORAR5 in September 2019 by 0.2µg/L, in December 2019 by 8.6µg/L and in January 2020 by 2.9µg/L. ORAR6 exceeded the guideline by 2.5µg/L in December 2019 and in January 2020 by 6.7µg/L. And one exceedance was recorded in ORAR7 in December 2019 by 4.5µg/L.

Nutrient levels exceeded the lowland freshwater guidelines for TN, TP and NOx at several locations in Survey Period 1. In the four sampling occasions from December 2019 through May 2020, BUCC1 exceeded TN, TP and NOx guideline values by 195 – 287µg/L (TN), 1 – 106µg/L (TP) and 58 – 177µg/L (NOx). NOx was also 3.5, 4.7 and 3.2 times the guideline value at BUCC1 in July and September 2019, and August 2020 respectively. At ORAR5, the TN guideline value was exceeded in January, March and May 2020 by 130 – 205µg/L. The TP guideline value was exceeded once in November by 4µg/L and the NOx guideline value was exceeded on all except one sampling occasion (i.e. November 2020; NOx = 3µg/L) in ORAR5 ranging from 41 – 286µg/L. At ORAR6, the TN guideline value was also exceeded in January, March and May 2020 by 12-111µg/L. The TP guideline value was exceeded once in November by 33.7µg/L and the NOx guideline value was exceeded on 5 of the 8 sampling occasions ranging from 66 – 165µg/L. At ORAR7, the TN guideline value was exceeded in December 2019 by 6µg/L and January 2020 by 100µg/L. The TP guideline value was exceeded once in November by 10µg/L and the NOx guideline value was exceeded on 6 of the 8 sampling occasions from July 2019 to May 2020 and ranged from 46 – 145µg/L. SRP was within guidelines at all locations in Survey Period 1.

Survey Period 2

In Survey Period 2 (2021 – 2022) the Orara River subcatchment received a score of 81, a grade of B, for water quality. BUCC1 received a score of 79 (B), ORAR5 received a score of 81 (B), and ORAR6 and ORAR7 received the best water quality score in the subcatchment with 82 (B) each (Table 3.78).

pH ranged from 5.93 – 8.66 in the Orara River subcatchment in Survey Period 2 (Table 3.79). pH exceeded the maximum lowland freshwater guideline value of 8.5 in May 2022 at BUCC1 (9.2). The minimum pH guideline value of 6.5 was exceeded in May 2021 at ORAR5 (6.12), ORAR6 (5.9) and ORAR7 (6.11), also in February 2022 at ORAR7 (6.38) (See Table 2.4 for water quality guideline values).

Water temperatures reflected seasonal climatic changes. BUCC1 was the most variable, ranging from a winter minimum of 13.0°C to a summer maximum of 20.0°C (Table 3.79). DO% was above the minimum guideline for DO% Orara River subcatchment in Survey Period 2. The maximum guideline was exceeded at each site in May 2021, which was likely associated with reaeration due to turbulence and/or oxygen input from extensive macrophyte beds, rather than an algal bloom since chl-*a* concentrations were within the guidelines at all sites in Survey Period 2.

Nutrient levels exceeded the lowland freshwater guidelines for TN, TP and NOx at several locations in Survey Period 2, with the exception of SRP readings which were within guidelines at all locations (Table 3.79). At BUCC1 the TN guideline value was exceeded in February by 192.7µg/L and in May 2022 by 288.7µg/L. The TP guideline value was exceeded on 3 of the 5 sampling occasions by 24 times in May 2021, 6.6 times in February 2022 and by 8.8 times the guideline value in June 2022. NOx exceeded the guideline value at BUCC1 on all sampling occasions, ranging from 57.3 – 121.7µg/L. At ORAR5, the TN guideline value was exceeded in May 2021 by 147.3µg/L and in May 2022 by 213µg/L. The TP guideline value was exceeded on four sampling occasions from May 2021 to June 2022 by 24.3 – 464µg/L (the maximum being 20 times greater than the guideline value). NOx also exceeded the guideline value at ORAR5 on three sampling occasions, in May 2022 by 31.7µg/L, in June 2022 by 47.3µg/L and in August 2022 by 48.3µg/L. At ORAR6, TN readings were within the guidelines for Survey Period 2. The TP guideline value was exceeded at ORAR6 on all sampling occasions except one (August 2022; TP = 4.7µg/L), notably by 24.5 times the guideline value in May 2021 (range = 69.3 – 611.3µg/L). And NOx exceeded the guideline value on 3 of the 5 sampling occasions ranging from 55.7µg/L in May 2022 to 128.3µg/L in August 2022 (3 times the guideline value). At ORAR7, the TN guideline value was exceeded by 25.7 – 47.7µg/L on three sampling occasions (May 2021, February 2022 and August 2022). The TP guideline value was exceeded on all except one sampling occasion (i.e. August 2022; TP = 8.7µg/L) by 3 – 23 times the guideline value (the highest reading was recorded in May 2021). NOx guideline value was exceeded on three sampling occasions from May to August 2022 and ranged from 10 – 128.3µg/L.

Table 3.78. *Water quality grades for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Orara River sub-catchment.*

	BUCC1		ORAR5		ORAR6		ORAR7	
	2019-2020	2021-2022	2019-2020	2021-2022	2019-2020	2021-2022	2019-2020	2021-2022
WQ Grade	78	79	84	81	88	82	85	82
Phys-Chem	23	21	24	22	29	22	26	22
Nutrients	27	26	30	26	30	27	30	27
Chl-a	28	33	30	33	29	33	29	33

Table 3.79. *Minimum and maximum (and mean) values of water quality variables for Survey Period 1 (2019-2020) and Survey Period 2 (2021-2022) in the Orara River subcatchment.*

	BUCC1						ORARA5					
	Survey Period 1			Survey Period 2			Survey Period 1			Survey Period 2		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temp (°C)	9.6	26.1	17.6	13	20.2	16	11.1	28	19.2	14.1	21.5	16.9
pH	6.5	9.2	7.1	6.9	8.7	7.4	6.5	8.8	7.1	6.1	8.5	7.1
Cond (µS/cm)	143	423	222.9	127	163	147.8	77	158	107.4	70	96.3	84.5
Salinity (PPT)	0.1	0.2	0.1	0.1	0.1	0.1	0	0.1	0	0	0	0
DO (mg/L)	0.8	11.1	7	7.3	12.1	9.4	4.4	11.5	8.5	8.2	12.7	10
DO %	9.5	99	70	80.2	120.8	94.8	52.9	106.6	89.6	89.7	129	103
Turbidity (NTU)	2.2	32.5	9.1	5.4	10.5	7.1	0.4	2.2	1.3	2.1	6.9	3.3
TSS (mg/L)	1.4	17.3	6.8	4	91.6	22.8	1.1	5.3	2.1	2.1	31.1	9.1
Chl-a (µg/L)	0.3	70.2	10	0.1	0.6	0.3	1.2	11.6	4.3	0	1.6	0.4
TN (µg/L)	149	637	404.7	182.3	638.7	379.5	23	555	317.3	109.7	563	348
TP (µg/L)	17	131	38.5	6.7	609	202.3	8	29	17.4	3	489	158.1
NOx (µg/L)	5.3	217	139.9	57.3	121.7	85.8	3	286	115.1	25.3	88.3	60.2
SRP (µg/L)	2	20	8.8	1.7	4	2.5	2	7	4.8	2	5	3.1
	ORAR6						ORAR7					
	Survey Period 1			Survey Period 2			Survey Period 1			Survey Period 2		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temp (°C)	12.4	27.3	19.5	14.1	21	17	13.7	25.1	19.1	13.7	20.1	16.7
pH	6.6	8.5	7.1	5.9	8	7	6.5	8.9	7.4	6.1	8.4	7.2
Cond (µS/cm)	55	108	86.4	59.3	84	73.3	50	145	86.8	52	77	66
Salinity (PPT)	0	0.1	0	0	0	0	0	0.1	0	0	0	0
DO (mg/L)	7	10.8	8.9	8.4	12.5	10	6.1	10.3	8.4	8.4	12.1	9.8
DO %	78.8	104.5	95.5	88.3	129.1	102.9	71.6	103.5	90.2	88.3	125.3	100.7
Turbidity (NTU)	0.2	1.6	0.8	1.3	2.4	1.6	0.1	4.6	1.2	0.8	1.7	1.2
TSS (mg/L)	0.5	1.7	1	1.7	7.3	3.4	0.5	4.3	1.8	1	3.3	1.9
Chl-a (µg/L)	0.6	6.7	2.8	0.1	0.3	0.2	0.8	7.5	2.2	0	0.3	0.2
TN (µg/L)	23	461	260.2	106	522	298.4	23	450	253.9	102	397.7	319.9
TP (µg/L)	6	58.7	16.8	4.7	611.3	176.4	8	35	14.6	8.7	567	167.9
NOx (µg/L)	3	379	108.2	22.7	116.3	66.7	3	145	87.5	10	128.3	60.1
SRP (µg/L)	2	6	3.9	2	3	2.4	2	8	4.4	1	4.3	2.5

3.11.4 Aquatic macroinvertebrates

Orara River

The macroinvertebrate community at ORAR7 received an overall grade of B- for condition in 2019-20 (Table 3.80). Indicators varied from D+ to A+. Total Abundance was Poor at 11/20 (A). Richness scored 17/20 (A-) and only some EPT taxa were collected giving this indicator a Poor rating (9/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The Site Mean SIGNAL was 4.7 with the waterbug community comprising both low-scoring, pollution-tolerant taxa and high-scoring pollution-sensitive taxa (SIGNAL2 score of Good, 74/20).

The macroinvertebrate community at ORAR7 received an overall grade of A for condition in 2020-21 (Table 3.80) a slight increase in condition from the overall score of A+, excellent, in 2019-20. Indicators varied from A- to A+. The Abundance criteria was very good at 18/20 (A-). Richness scored 20/20 (A+) and many EPT taxa were collected giving this indicator a very good rating (17/20, A-). Nativeness was very good (20/20), with no exotic taxa collected. The SIGNAL2 scored was 19/20 with the waterbug community comprising of low-scoring, pollution-tolerant taxa, as well as high-scoring pollution-sensitive mayflies and caddiflies present at this site.

Table 3.80 *Summary of aquatic macroinvertebrate data for Orara River #7 (ORAR7). Indicators are out of 20.*

ORAR7				
	Survey Period 1		Survey Period 2	
Macroinvertebrate indicator	**Score**	**Grade**	**Score**	**Grade**
Family richness	11	D+	18	A-
Total abundance	17	A-	20	A+
EPT	9	D-	17	A-
Nativeness	20	A+	20	A+
Mean SIGNAL2 score	17	A-	19	A
Ecohealth score	**74**	**B-**	**93**	**A**

The macroinvertebrate community at ORAR6 received an overall grade of A+ for condition in 2019-20 (Table 3.81). Indicators varied from A to A+. Total Abundance was Good at 18/20 (A). Richness scored 20/20 (A+) and many EPT taxa were collected giving this indicator an Excellent rating (20/20, A+). Nativeness was excellent (20/20), with no exotic taxa collected. The Site Mean SIGNAL was 6.1 with the waterbug community comprising both low-scoring, pollution-tolerant taxa and high-scoring pollution-sensitive taxa (SIGNAL2 score of Excellent, 20/20).

The macroinvertebrate community at ORAR6 received an overall grade of A for condition in 2020-21 (Table 3.81) a slight increase in condition from the overall score of A+, excellent, in 2019-20. Indicators varied from B+ to A+. The Abundance criteria was good at 17/20 (B+). Richness scored

19/20 (A) and many EPT taxa were collected giving this indicator a very good rating (19/20, A+). Nativeness was very good (20/20), with no exotic taxa collected. The SIGNAL2 scored was 20/20 with the waterbug community comprising of low-scoring, pollution-tolerant taxa, as well as high-scoring pollution-sensitive mayflies and caddiflies present at this site.

Table 3.81 *Summary of aquatic macroinvertebrate data for Orara River #6 (ORAR6). Indicators are out of 20.*

ORAR6				
	Survey Period 1		Survey Period 2	
Macroinvertebrate indicator	**Score**	**Grade**	**Score**	**Grade**
Family richness	18	A	17	B+
Total abundance	20	A+	19	A
EPT	20	A+	19	A+
Nativeness	20	A+	20	A+
Mean SIGNAL2 score	20	A+	20	A+
Ecohealth score	**98**	**A+**	**95**	**A**

The macroinvertebrate community at ORAR5 received an overall grade of A for condition in 2019-20 (Table 3.82). Indicators varied from B+ to A+. Total Abundance was Good at 18/20 (A-). Richness scored 17/20 (A-) and many EPT taxa were collected giving this indicator a Good rating (16/20, B+). Nativeness was very good (20/20), with no exotic taxa collected. The Site Mean SIGNAL was 5.5 with the waterbug community comprising both low-scoring, pollution-tolerant taxa and high-scoring pollution-sensitive taxa (SIGNAL2 score of very good, 19/20).

The macroinvertebrate community at ORAR5 received an overall grade of A for condition in 2020-21 (Table 3.82) a slight increase in condition from the overall score of A+, excellent, in 2019-20. Indicators varied from A- to A+. The Abundance criteria was good at 18/20 (A-). Richness scored 20/20 (A+) and many EPT taxa were collected giving this indicator a very good rating (19/20, A+). Nativeness was very good (20/20), with no exotic taxa collected. The SIGNAL2 scored was 18/20 with the waterbug community comprising of low-scoring, pollution-tolerant taxa, as well as high-scoring pollution-sensitive mayflies and caddiflies present at this site.

Table 3.82 *Summary of aquatic macroinvertebrate data for Orara River #5 (ORAR5). Indicators are out of 20.*

ORAR5				
	Survey Period 1		Survey Period 2	
Macroinvertebrate indicator	**Score**	**Grade**	**Score**	**Grade**
Family richness	18	A-	18	A-
Total abundance	17	A-	20	A+
EPT	16	B+	19	A+
Nativeness	20	A+	20	A+
Mean SIGNAL2 score	19	A+	18	A-
Ecohealth score	**90**	**A**	**95**	**A**

Bucca Bucca Creek

The macroinvertebrate community at BUCC1 received an overall grade of B- for condition in 2019-20 (Table 3.82). Indicators varied from C to A+. Total Abundance was poor at 8/20 (D-). Richness scored 15/20 (B) and many EPT taxa were collected giving this indicator a fair rating (13/20, C). Nativeness was very good (20/20), with no exotic taxa collected. The Site Mean SIGNAL was 5.2 with the waterbug community comprising both low-scoring, pollution-tolerant taxa and high-scoring pollution-sensitive taxa (SIGNAL2 score of Good, 74/20).

The macroinvertebrate community at BUCC1 received an overall grade of B+ for condition in 2020-21 (Table 3.82) a slight increase in condition from the overall score of B-, good, in 2019-20. Indicators varied from C to A+. The Abundance criteria was fair at 12/20 (C). Richness scored 18/20 (B-) and several EPT taxa were collected giving this indicator a good rating (14/20, F). Nativeness was very good (20/20), with no exotic taxa collected. The SIGNAL2 scored was 19/20 with the waterbug community comprising of low-scoring, pollution-tolerant taxa, as well as high-scoring pollution-sensitive mayflies and caddiflies present at this site.

Table 3.82 *Summary of aquatic macroinvertebrate data for Bucca Bucca Creek #1 (BUCC1). Indicators are out of 20.*

BUCC1				
	Survey Period 1		Survey Period 2	
Macroinvertebrate indicator	**Score**	**Grade**	**Score**	**Grade**
Family richness	8	D-	12	C
Total abundance	15	B	18	A-
EPT	13	C	14	B-
Nativeness	20	A+	20	A+
Mean SIGNAL2 score	18	A-	19	A
Ecohealth score	**74**	**B-**	**83**	**B+**

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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*	*virginicus*	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*	*Ageratina*	*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
