Clarence Catchment Ecohealth Project

Assessment of River and Estuarine Condition 2014

Final Technical Report to the Clarence Valley Council

Darren Ryder

Sarah Mika, Max Richardson, Adrienne Burns, Rob Veal, Paul Lisle, John Schmidt and Max Osborne

Cover Photo: The Nymboida River at the Junction (S. Mika, 2013).

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April 2014

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Acknowledgements

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

In particular, Max Osborne and John Schmidt have been the champions for Ecohealth and maintained progress for the program despite tumultuous times in government agencies. The people below provided significant support for the project, our thanks to each of them.

Clarence Valley Council: Peter Wilson, Greg Wilkinson, Stuart Murphy & Adam Smith.

Coffs Harbour City Council: Malcolm Robertson & Judy Davies

OEH: John Schmidt, Josh Chivers & Ben Fitzgibbon

NRCMA: Max Osborne, Peter Corlis, Tony Broderick & Nigel Blake

NSW NPWS: Gina Hart

Guyra Shire Council: Geoff Dowden

Tenterfield Shire Council: Graham Kennett

Bellingen Shire Council: Daan Schieban

Richmond Laboratories: Allison Hawthorne

UNE: Karlie McDonald, Dorothy Bell, Bob Baker & Rhyan Gorman

This report should be cited as:

Ryder, D., Mika, S., Richardson, M., Burns, A., Veal, R., Schmidt, J. and Osborne, M. (2014) Clarence Catchment Ecohealth Project: Assessment of River and Estuarine Condition 2014. Final Technical Report to the Clarence Valley Council. University of New England, Armidale. 225 pp.

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Summary

The development of a standardised means of collecting, analysing and presenting riverine, coastal and estuarine assessments of ecological condition has been identified as a key need for coastal Catchment Management Authorities and Local Councils who are required to monitor natural resource condition, and water quality and quantity in these systems. This project was conducted over an 18 month period in the Clarence catchment and nearby coastal river systems covering 88 sites across 37 river systems to contribute to the assessment of the ecological condition of the catchment.

The Clarence catchment was divided into 4 hydrologic units for reporting; Clarence main stem, Northern Tributaries, Coastal Tributaries and the Mann-Nymboida-Boyd systems. In addition, 5 small coastal systems (7 sites) in the Clarence LGA (but not in the Clarence catchment) were sampled only for water chemistry. The project aimed to

- Assess the health of coastal catchments using standardised indicators and reporting for estuaries, and freshwater river reaches using hydrology, water quality, riparian vegetation and habitat quality, and macroinvertebrates assemblages as indicators of ecosystem health in streams of the Clarence catchment, and
- Contribute scientific information to the development of a report card system for communicating the health of the estuarine and freshwater systems in the Clarence region.

Main Findings

Water Chemistry

- Concentrations of nutrients exceeded the trigger guideline value at some point in all river systems. High nutrient concentrations were most pronounced in estuarine reaches of the Clarence and its tributaries, in the tablelands sites and in the separate coastal systems. High nutrients and algal concentrations were most frequent in pre-flood low flows in freshwater reaches, and in post-flood times in estuarine reaches.
- Changes in pH in the main stem of the Clarence followed trends of exceeding the upper threshold frequently in the freshwater reaches, decreasing sharply at the tidal limit, and increasing again at the well-flushed mouth of the estuary. Tributaries of the Clarence such as Swan, Shark, Sportsmans and Mangrove Creeks, and the Coldstream River consistently had very low pH.
- Low dissolved oxygen concentrations were not recorded in the Mann-Nymboida-Boyd system throughout the study. Low DO concentrations were most frequent in pre-flood low flows in freshwater reaches, and in post-flood times in estuarine reaches.
- The poorest water quality was recorded from sites closest to the tidal limit, highlighting their role as depositional environments for both freshwater and estuarine contaminants, and the importance of this zone as a focal point for future monitoring programs.

- Pre-flood water quality was poorest in freshwater reaches when discharge levels had been low for a prolonged period. In contrast, water quality was poorest in April 2013 in estuarine reaches, the first sample date after the large floods.
- Loads of suspended sediment and nutrients transported in river systems were strongly linked to rainfall events, with markedly increased sediment and nutrient loads during high flows. Very high sediment loads in the Clarence mainstream persisted for all 3 sample dates post-flood, whereas only the first sample date post-flood had very high sediment loads in the tributaries of the Clarence, highlighting the cumulative impact of tributary inputs to the Clarence River.

Macroinvertebrates

- Family level taxonomic richness ranged from a very low 7 in Sportsmans Creek to 45 in the Henry River. Similarly, the abundance of individuals ranged from a low 94 in the Boonoo Boonoo River (BOO2) to 1054 in the Henry River (HENRY1) when both sample periods were combined. The Nymboida River was the only system to display a longitudinal pattern of decreasing richness and abundance with distance downstream. The lack of a consistent pattern among all other systems indicates that site-specific issues may be the largest influence on macroinvertebrates.
- SIGNAL2 scores ranged from a maximum of 5.8 in the Timbarra River (TIMB3) to 3.8 in the Marylands River (MARY2). The Nymboida catchment displayed a consistently large range of SIGNAL2 scores, with 3 SIGNAL score 10 taxa only occurring in this system.
- The low variability in these scores throughout the 60 freshwater sites indicates low to moderate long-term degradation of water quality and instream habitat. The dominance of Chironomidae (midges), Atyidae shrimps and Notonectidae/Corixidae (waterbugs) (SIGNAL scores of 1-3) at the majority of other sites contributed to lower scores.
- There was a clear pattern of increased abundance and richness of macroinvertebrates in Autumn when compared to Spring, the reverse of the pattern observed in all other Ecohealth projects. The prolonged period of low flows in 2012 leading to Spring sampling led to a poor condition score, with the macroinvertebrates responding positively to the post-flood conditions with substantial increases in abundance and richness. This suggests that the macroinvertebrate assemblages in the freshwater reaches of the Clarence are resilient to flooding, and appear more impacted by prolonged periods of low flows.

Riparian Condition

- Riparian condition scores were generally poor throughout all regions of the Clarence, with the tablelands and estuary sites recording the poorest condition scores as they were often devoid of any extant overstorey streambank vegetation. Northern tributaries generally had poor condition, with Duck Creek and the Cataract and Timbarra Rivers particularly poor. In contrast, there were rivers with good condition riparian zones and channels, with Bookookoorara Creek scoring the highest of the region.
- Bank condition was poor in the majority of freshwater and estuarine sites with evidence of high bank slopes, bank slumping and exposed tree roots. The exception was the Nymboida River and its tributaries that had the highest vegetation and habitat scores and low disturbances in sites within conservation reserves.

- Coastal rivers such as the Orara and tributaries of the Clarence River were often dominated by weed species in the upper, mid- and understory layers. The presence of weed species, dominance of the organic litter layer by weed species, and reduced habitat and connectivity to remnant vegetation also reduced scores throughout sites not located in conservation reserves.

Report Card

The calculation and reporting of Ecohealth grades involves the synthesis all available indicators each with trigger values recorded up to 6 times during the program. Scores are calculated for individual sites, but also must fulfill the broader aims of hierachical reporting at river, sub-catchment, catchment and regional scales. To produce an Ecohealth grade, the value for each index – Water Quality, Zooplankton (Suthers et al 2013), Macroinvertebrates, Fish (Butler et al. 2013) and Riparian – must be transformed into standardized score that takes into account differing physical conditions, scales of measurement among indices and prevailing climate conditions. The result is a scoring system from 0 to 1, where 0 represents the most 'unhealthy' condition and 1 indicates a 'healthy' waterway.

A Total of 88 sites in 37 individual river systems in the Clarence catchment were used to calculate an overall score of 70.5 (C+) for the catchment. Average scores for water quality, aquatic macroinvertebrates and riparian systems consistently ranged from 60-66. A much higher average score of 91.5 for Fish improved the overall catchment score, suggesting that lower scores for other attributes in freshwater reaches are not adversely impacting native fish populations.

The scores for all 7 main river systems range only 13.5%, from 60.5 (C-) for coastal tributaries to 74 (C+) for the Mann-Nymboida-Boyd system. Excellent scores (>90) for fish assemblages were recorded from all systems except the Mann-Nymboida-Boyd which received 82.5, and contributed positively to the overall condition score. In contrast, Riparian and Macroinvertebrate grades were consistently low, with Coastal Tributaries scoring just 33 and the only system reporting an E grade. Unsurprisingly, the freshwater reaches of the Clarence catchment consistently recorded higher scores for all indicators than the estuary reaches and coastal lagoons.

Five coastal rivers in the Clarence LGA but not in the Clarence catchment were assessed in this study based only on water quality, and revealed consistent poor condition. Scores ranged from 38 (E) for Lake Arragan with poor water quality (high nitrogen, chlorophyll *a* and turbidity) to 66 (C-) for the Sandon River.

Future Monitoring

The 2012-13 Ecohealth program in the Clarence catchment was spatially intensive with 81 sites, but less temporally intensive with 6 sample dates over the 18 month period. There is limited evidence for reducing the number of sampling sites in freshwater reaches as the majority of systems with multiple sites did not show a consistent longitudinal pattern in indicators, suggesting local rather than catchment scale issues are influencing site condition. However, many of the northern and tableland systems had only one site to represent the end-of-system condition. These sub-catchments would benefit from increasing sites to 3 along each main river. Similarly, a number of smaller sub-catchmentrs (<600km^2) were not included in this study due to insufficient funding. Including these in future condition assessments would be beneficial for catchment-scale reporting.

Retaining the suite of water quality variables and sampling procedures (water column profiles in sites >1 m depth) is recommended as all variables positively contributed to the understanding of issues at each site and development of site-based scores for the report card.

The frequency of bimonthly sampling over a 12 month period was not feasible in this study due to large flood events. Rainfall in the region during the summer of 2012-13 sampling period was well above the long term mean, with 3 major flood peaks occurring throughout the catchment. We recommend targeting sampling to specific flow conditions (>80th percentile) in defined time periods (seasonal) over a multi-year timeframe. This will facilitate the capture of data from all sites under similar flow conditions and replicated temporal periods (seasons) within the four year reporting period (e.g., 1 sample/season, 4 seasons/year, for 3 years = 12 sample times). This recommendation removes the potential influence of flow extremes that may be encountered within a shorter 12 month period. Impact of floods on ecological condition and flood-recovery would require a separate sampling program.

Partnerships

The program incorporated field sampling from teams from the Clarence Valley Council, Office of Environment and Heritage, National Parks and Wildlife Service, Kyogle Shire Council and Richmond Laboratories, and the Northern Rivers CMA. Without these partnerships the Clarence Ecohealth project would not have achieved its aims. While these partnerships have many benefits well beyond the data collected, a number of issues with data quality and management emerged that could be better managed in future projects. Inconsistent or missing data and samples, QA issues with sample transport, and substantially increased costs for UNE to complete sampling were all outcomes from partner commitments that could not be met. Continued partnerships are essential, and these issues must be addressed in future projects if success is to be maximized.

PART 1

1 ECOHEALTH PROGRAM AND OBJECTIVES

1.1 Background

The NSW Natural Resources Monitoring Evaluation and Reporting (MER) Strategy was prepared by the Natural Resources and Environment CEO Cluster of the NSW Government in response to the Natural Resources Commission standard and targets and was adopted in August 2006. The purpose of the Strategy is to refocus the resources of NSW natural resource and environment agencies and coordinate their efforts with CMAs (now 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 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 Clarence River catchment to supplement the MER monitoring and is aligned with the objectives of regional Coastal 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 Catchment Management Authorities and Local Councils who are required to monitor natural resource condition, and water quality and quantity in these systems.

This project uses the Ecohealth framework which 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 proposed State of Catchments (SoC) reports, EHMP Healthy Waterways program; proposed estuary report cards from the NLWRA (through WA D of Water), NSW Estuary Management Policy and Coastal Zone Management Manual and relevant Estuary Management Plans, 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 in the Northern Rivers

CMA 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 coastal management of Northern NSW; State agencies (NRCMA, OEH, NSW Fisheries), Local Councils and University Researchers (UNE) to develop, refine, report and promote a standardised river and estuary health assessment tool for the Clarence catchment.

This report provides the initial baseline data for water quality, freshwater macroinvertebrates, fish, estuarine zooplankton and riparian condition in the Clarence catchment. This framework facilitates an effective reporting mechanism to communicate water quality and resource condition information to the general public stakeholders and managers through simple report cards. Additionally, this initial monitoring program in the Clarence catchment provides specific monitoring and management plans for the study area using the generic framework outlining a standardised (and trialled) 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, riparian vegetation and habitat quality, and macroinvertebrates assemblages as indicators of ecosystem health in streams of the Clarence catchment,

2. contribute scientific information to the development of a report card system for communicating the health of the estuarine and freshwater systems in the Clarence catchment.

1.4 Report structure

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

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

0 Study Design is detailed description of the study design and protocols developed for site selection are provided.

2.3 Study Sites provides site descriptions for the 88 study sites

2.4 Sampling Methods and Indicators includes the range of water quality conditions measured, physical measures of channel and bank characteristics, riparian features and local disturbance issues.

Part 3 of the report provides a detailed report on the bi-monthly water chemistry and biophysical data collected from August 2012 to August 2013. Results for water chemistry, macroinvertebrates and riparian condition are reported for each sub-catchment (i.e. Clarence Main Stem, Northern Tributaries, Mann-Nymboida-Boyd, Coastal Tributaries, and Coastal Systems). Water chemistry identifies trends in nutrient (nitrogen and phosphorus), chlorophyll *a* and suspended solids, as well as variables such as pH, salinity, dissolved oxygen and temperature. Sites that exceed NSW MER or ANZECC guideline thresholds are identified. Macroinvertebrate assemblages collected from freshwater sites in Autumn 2012 and Spring 2012 are used to assess long-term condition of in channel habitats and health indicators using SIGNAL2 scores and percent EPT are reported. Riparian Condition Assessment provides information for the freshwater sites on the cover, structure and habitat as indicators of a health riparian ecosystem at each site, as well as an identification of local-scale disturbances to riparian zones. The sites are divided accordingly:

3.1 Clarence Main Stem

3.2 Northern tributaries of the Clarence

3.3 Mann-Nymboida-Boyd subcatchments

3.4 Coastal Tributaries of the Clarence

3.5 Coastal Systems separate to the Clarence

Part 4 comprises a summary of Condition Scores. These form the basis of the report cards and are collated for Sites, Subcatchments and the Clarence catchment as a whole. Condition Scores include water chemistry, macroinvertebrates (freshwater sites), zooplankton (estuarine sites), fish, and riparian condition.

Part 5 provides management recommendations for the future management of the instream and riparian condition in rivers and estuaries of the region, and identifies priorities for future monitoring within the Ecohealth framework.

PART 2

2 STUDY AREA, DESIGN AND SITE DESCRIPTIONS

2.1 Study area

The Clarence River catchment is the largest coastal catchment in NSW with area of 22,700 km^2 on the far north coast of NSW (Figure 2.1). The catchment is bound by the MacPherson Ranges in the north, the Great Dividing Range in the west (Northern Tablelands), by Baldblair, the Doughboy Ranges and Dorrigo Plateau in the south, and by coastal ranges from Coffs Harbour to Yamba in the east. The catchment is characterized by sub-alpine forested tablelands in the west, to a large coastal floodplain containing sub-tropical rainforest in the east. The floodplain comprises 800 km^2 of low alluvial plains intersected by channels, lagoons and creeks. The Clarence River extends 250 km; 142 km are freshwater with the tidal limit extending 108 km upstream to Copmanhurst.

Geology is the primary control of many of the natural features and attributes of the area including soil characteristics and geomorphology. The study area falls within the Clarence Moreton Basin, a major sedimentary basin and a component of the larger New England Fold belt, which consists of blocks of continental crust. Topographically elevated areas in conjunction with high rainfall will produce deep soils due to high rates of weathering of parent materials. In turn, the geology, soil, and topography dictate the occurrence of vegetation communities across the catchment as well as the suitability of land use activities. The physiographic zones of the Clarence catchment are:

Mountains: The Great Dividing Range from Stanthorpe to Glen Innes and the Doughboy Ranges form the western boundary. The tablelands and plateau country where the Great Dividing Range in the west represents a low range of hills on the undulating or hilly plateau country, and the high country of the Dorrigo Plateau marks the southern boundary of the catchment.

Foothills: The catchment is bordered in the north by the Macpherson ranges. The terrain comprises large areas of hilly to steep and rugged country. Available agricultural land is confined by this steep topography to about one third of the catchment. The Macpherson Range and the northern end of the Great Dividing Range contain high ridges and rugged slopes. The north east border of the catchment is outlined by the Richmond Range.

Alluvial Plains: Downstream from Copmanhurst the Clarence River becomes tidal, the valley commences to open out with large areas of alluvial flats, marine sediments, and other delta characteristics including freshwater and estuarine wetlands, swamps, and salt marshes.

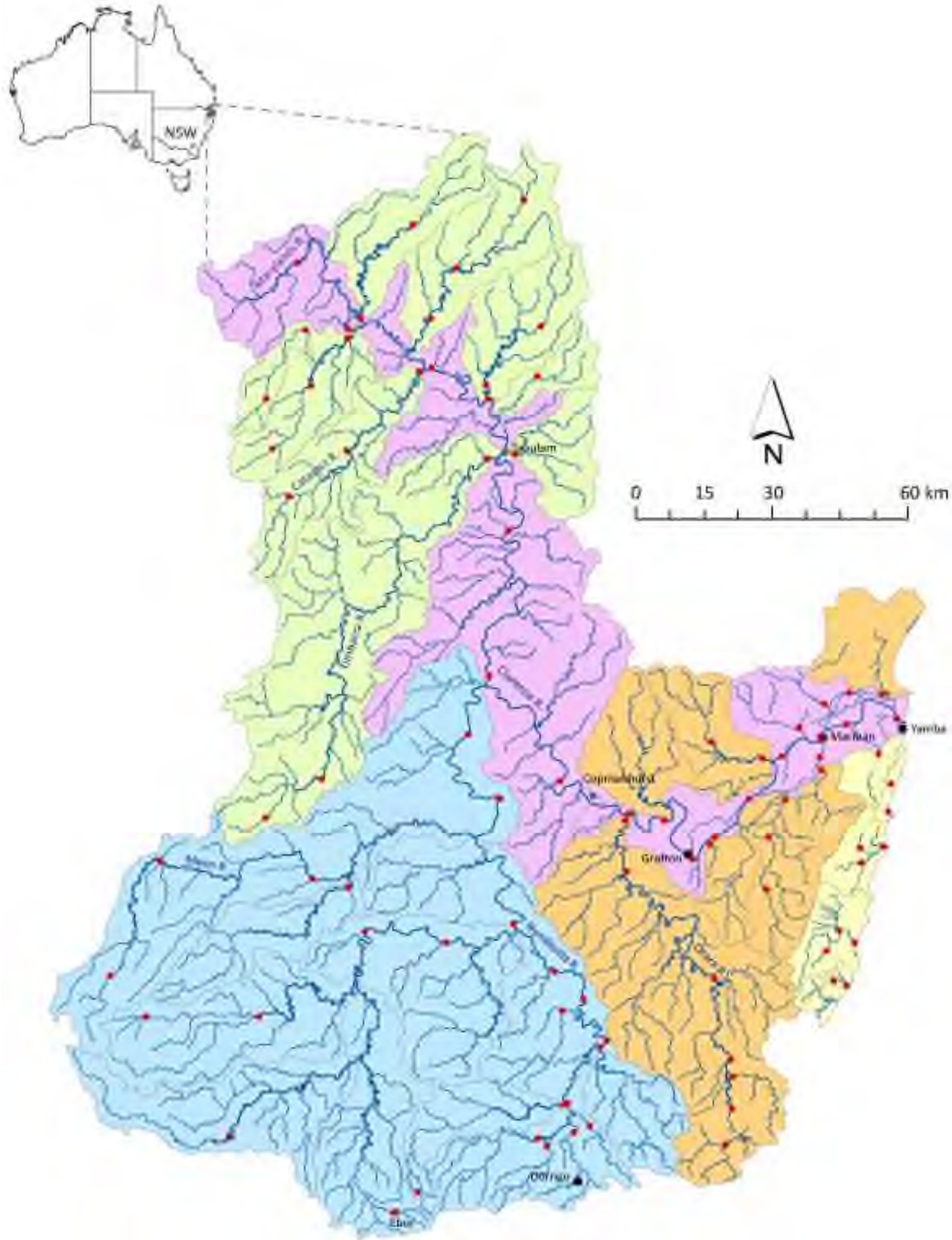


Figure 2.1 The Clarence catchment showing the Clarence main stem (pink) and subcatchments of the northern tributaries (lime), Mann-Nymboida-Boyd (blue), coastal tributaries (orange) and coastal systems (yellow).

The majority of soils within the catchment are dispersible with low wet strength. Dispersible soils occur with the granites and granodiorite of the New England Batholith and the sedimentary sequences of the Clarence Moreton Basin. The northern, south western (Glen Innes area) and southern margins (Dorrigo) of the catchment feature rich basaltic soils primarily used for intensive agricultural activities. Intensive agriculture also occurs on the fertile river flats of the Clarence Valley floodplain. Acid sulphate soils are a major land use issue for the Clarence Valley, underlying large sections of the floodplain.

The people of the Bundjalung, Gumbainggeri, Anaiwan, and Yaygir Nations are the original inhabitants of the Upper North Coast region of NSW. The main land uses include forestry and agriculture in the upper catchment , with sugar cane, beef production, commercial fishing and urban development dominating in the lower catchment. National Parks comprise 20 % and State Forests comprise 30 % of the catchment area. The historical land use activities of the catchment have persisted since settlement but have varied over the years. For instance, livestock production remains the dominant land use activity across the catchment. Sugarcane production has dominated land use in the lower reaches of the catchment since its inception in the 1850s. Commercial fishing has also remained an important industry for the lower Clarence since 1884. The fertile soils of the Dorrigo Plateau support intensive cropping activities, in particular potatoes.

Point and non-point source pollution in the Clarence River is dependent on freshwater inflows, land use activity, and geographical location within the catchment. Freshwater inflows are generated by runoff from steep landforms and areas of significant elevation. These inflows are significant in terms of water quality by influencing the time pollutants remain in the river. The activities affecting the health of the river include agricultural practices (particularly pesticide and fertiliser use); soil erosion from agricultural land and river banks; loss of aquatic habitat through wetland reclamation; drain and flood mitigation structures; urban runoff and sewerage discharge.

2.2 Study design

The design of the Ecohealth freshwater/estuarine monitoring program for the Clarence catchment was based on the NSW Monitoring, Evaluation, Reporting (MER) protocols for Rivers and Estuaries (NSW OEH 2012), and aligned for reporting outcomes used in the South-East Queensland Ecosystem Health Monitoring Program (EHMP) methodologies, as well as previous ecosystem health assessments undertaken within the local region. The number and location of sample sites were designed to assess spatial and temporal variability of the Clarence catchment with statistical robustness. The design was financially constrained to bi-monthly sampling of 88 sample locations.

Locations of 60 freshwater monitoring sites were selected to:

- Identify longitudinal change within the main stem of each river system
- Identify end of system flows from rivers entering the estuarine environment
- Represent major tributaries of each river system or were identified by stakeholders and tributaries of interest for management

- Facilitate comparison with historical datasets and additional information (e.g. discharge gauges)
- Compare River Styles, Condition and Recovery Potential, and elevations within and across catchments
- Locate ecological changes at the point of the tidal limit.

Locations of the 28 estuarine monitoring sites were selected to:

- Identify longitudinal change within the main stem of each river system and end of system flows
- Represent multiple sites within salinity categories of 0-15 ppt, 15-30 ppt and 30+ ppt
- Compare River Styles, Condition and Recovery Potential, and elevation within and across catchments
- Locate ecological changes at the point of the tidal limit.

The design of the Ecohealth program in the Clarence required prioritisation of sites and sub-catchments to optimize available resources. Only sub-catchments greater than 600km^2 were included in the study, with a priority for sub-catchments where council staff could contribute to sample collection, for sub-catchments with known water quality issues, and for larger systems where 3 sites could be placed along the river continuum to help interpret longitudinal changes in condition.

2.2.1 Sampling Schedule

Water chemistry was sampled bi-monthly, freshwater macroinvertebrates were sampled bi-annually in spring and autumn, and riparian condition was assessed once in August 2013 (Table 2.1). Each sampling event comprised an 8-day period, with multiple freshwater and estuarine sites sampled through this period 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. The boat and field personnel were supplied by OEH. All freshwater sites and upper estuarine sites were sampled via road access. Field personnel comprised CVC, CHC, NRCMA, NPWS and UNE staff, all of whom were trained in Ecohealth sampling procedures.

Table 2.1 The sampling regime for field collection of water chemistry, biota and riparian condition assessment in the Clarence catchment.

Event	Commencing Date	Variables from freshwater sites	Variables from estuary sites
1	02 August 2012	Water Chemistry	Water Chemistry
2	02 October 2012	Water Chemistry, Invertebrates	Water Chemistry
3	06 December 2012	Water Chemistry	Water Chemistry, Zooplankton
Flood	February 2013		Water Chemistry, Zooplankton
4	04 April 2013	Water Chemistry, Invertebrates	Water Chemistry, Zooplankton
5	03 June 2013	Water Chemistry	Water Chemistry
6	06 August 2013	Water Chemistry, Riparian	Water Chemistry, Riparian

2.2.1.1 *Regional climate conditions*

The average rainfall for the catchment is 1,000 mm with the majority of rainfall falling between December and April. Rainfall ranges from 1300 mm at Yamba, 900mm at Grafton, 1400mm at Woodenbong, and approximately 2000mm at Dorrigo. The climate is subtropical with temperatures ranging from an average 28˚C in summer to an average 20˚C in winter. Inland temperatures are higher in summer (13.3-24˚C) and cooler in winter (1.2-12˚C) (BoM)

The SOI fluctuated markedly during the study with the 2012 period characterised by highly negative values (up to -10.4), through to highly positive values (peaking at +14.6) in the first half of 2013. In spring 2012, rainfall in the Clarence catchment was below the long-term mean monthly total rainfall (Figure 2.2). However, the Clarence catchment experienced unprecedented flooding in the summer of 2012-13 with a single event peaking at 1,128,071 ML/day at Lilydale on January 29th 2013. This event was the largest recorded flood in the Clarence River, and was preseded by almost 12 months of very low flow conditions and no high flow events (Figure 2.3). Two successive flood peaks of 463,973 ML/day on February 23rd 2013 and 315,036 ML/day at Lilydale re-wetted much of the floodplain inundated by the initial pulse. The Ecohealth sampling was conducted at 3 times prior to the 3 flood peaks, and 3 times post flood peaks, allowing some comparison of the impacts and recovery of the river from major flooding.

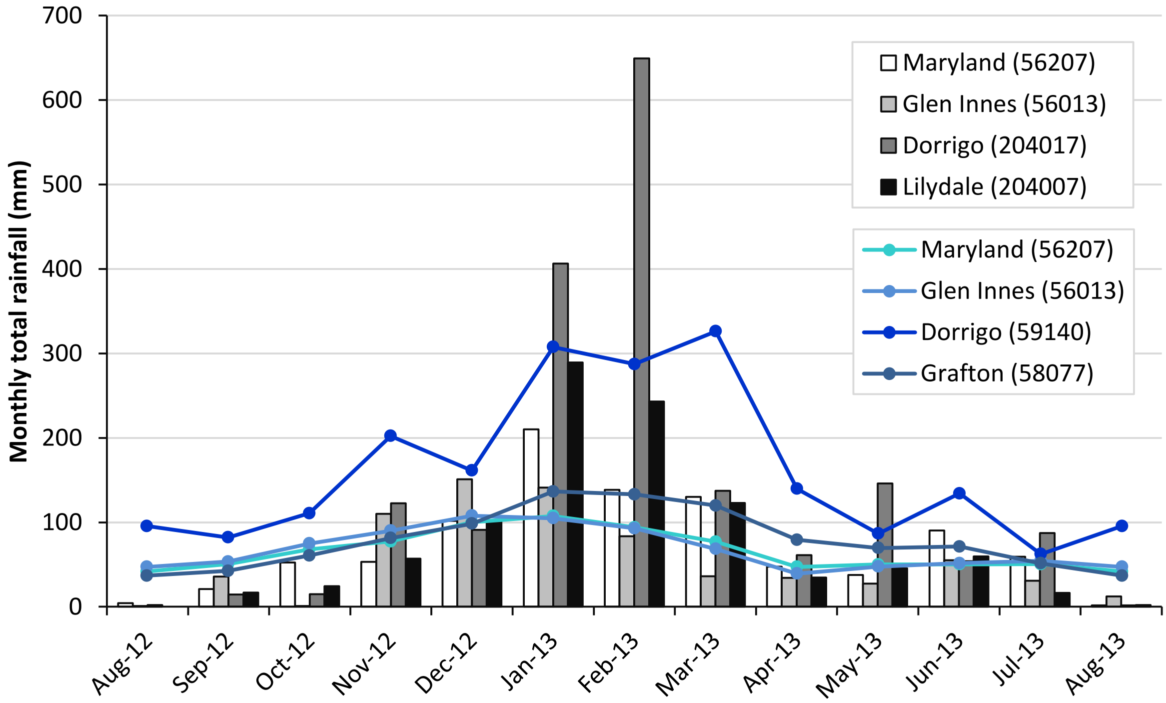


Figure 2.2 The long-term mean monthly total rainfall (lines, mm) and the monthly total rainfall during the sampling period (columns, mm). The northern part of the catchment is represented by Maryland (BOM gauge 56207), the western and Northern Tablelands by Glenn Innes (BOM gauge 56013), the south-eastern part of the catchment by Dorrigo, (BOM gauge 59140 for long-term data and Office of Water gauge 204017 for more accurate short-term data), and the coastal part of the catchment by Lilydale near Copmanhurst (BOM gauge 58077 for long-term data and Office of Water gauge 204007 for more accurate short-term data).

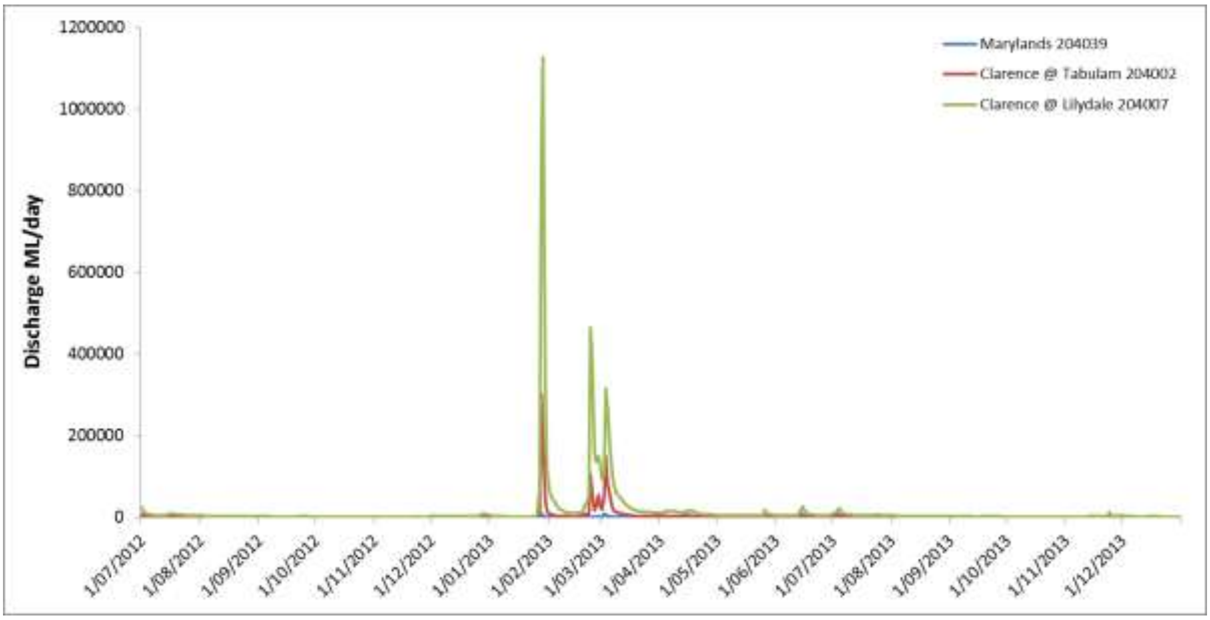


Figure 2.3 Discharge in the Clarence River throughout the study period at top of the catchment (Marylands gauge 204039), mid catchment (Tabulam gauge 204002) and lower catchment discharge into the estuary (Lilydale 204007).

Table 2.2 Mean, minimum and maximum monthly discharge in cubic meters per second August 2012 to August 2013 for the Marylands River (gauge 204039), the Mann River east of Glenn Innes (gauge 204031), the Bielsdown River downstream of Dorrigo (gauge 204017), and the Clarence River at Lilydale (gauge 204007). Data are from Office of Water gauges.

	Monthly discharge (m^3/s)											
Month	Maryland R. (204039)			Mann R. (204031)			Bielsdown R. (204017)			Clarence R. (204007)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Aug	0.57	0.25	2.97	1.48	0.24	21.13	2.31	1.49	5.50	76.45	43.83	348.64
Sep	0.15	0.05	0.33	0.32	0.24	0.55	1.13	0.84	1.53	28.56	19.95	45.07
Oct	0.03	0.00	0.22	0.22	0.16	0.45	0.70	0.50	0.97	16.98	14.00	20.13
Nov	0.00	0.00	0.33	0.19	0.08	0.59	0.43	0.28	0.61	11.46	7.91	16.05
Dec	0.02	0.00	0.00	0.32	0.05	8.29	0.52	0.27	1.44	12.12	7.18	24.76
Jan	5.10	0.00	0.14	0.86	0.09	7.78	0.86	0.32	16.41	36.21	16.94	120.30
Feb	4.18	0.00	147.39	3.84	0.06	103.80	4.64	0.48	72.06	962.66	9.07	18648.78
Mar	11.42	0.63	45.91	1.96	0.50	10.88	17.87	2.83	443.72	806.31	109.82	7406.64
Apr	0.72	0.93	209.62	1.97	0.33	21.43	7.71	2.33	29.23	652.03	112.79	3965.95
May	0.22	0.22	1.96	0.30	0.15	0.86	2.04	1.44	26.72	128.33	61.73	222.81
Jun	0.82	0.13	0.35	0.21	0.13	0.52	2.02	0.99	2.65	59.75	40.26	347.47
Jul	1.08	0.20	11.49	0.76	0.23	4.47	1.71	1.30	23.21	77.91	44.30	338.98
Aug	0.31	0.29	23.79	0.79	0.42	3.66	2.36	1.37	1.45	29.74	42.09	277.81

2.3 Study sites

The analysis of the large Clarence catchment has been divided into the following subcatchments: (1) the Clarence main stem including the Marylands River and The Broadwater, (2) The northern tributaries of the Clarence, (3) the Mann-Nymboida and Boyd Rivers and their tributaries, (4) the coastal tributaries of the Clarence, and (5) coastal systems that drain to the ocean.

2.3.1 Clarence main stem

Nineteen sites were sampled across two river systems in the Clarence main stem subcatchment (Figure 2.4, Table 2.3). Of these, 7 were freshwater and 12 were estuarine.

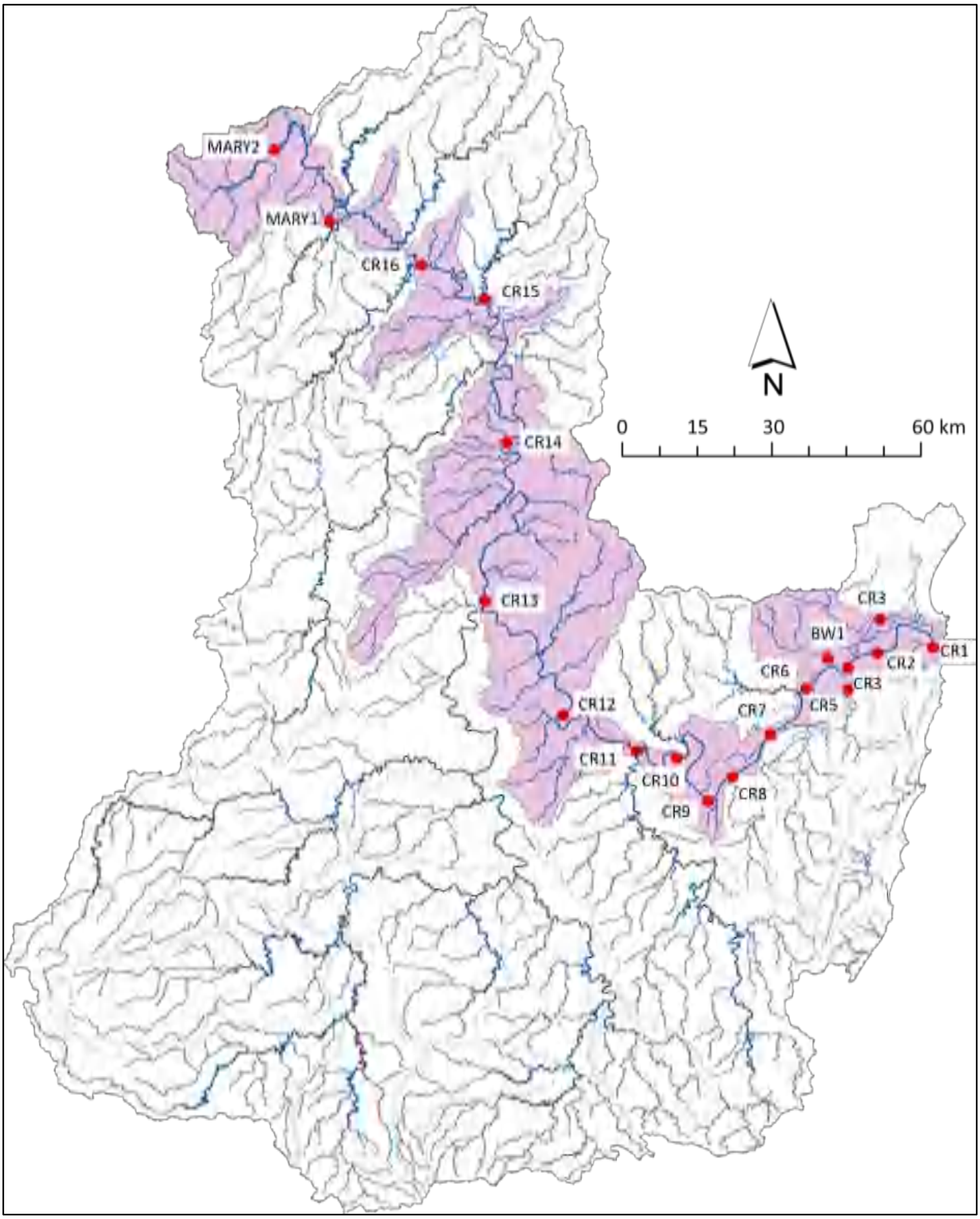


Figure 2.4 Ecohealth sampling sites in the Clarence main stem subcatchment (pink). See Table 2.3 for site details.

Table 2.3 Ecohealth sites in the Clarence Main Stem (including Marylands River and The Broadwater).

Site Name	Site Code	Easting	Northing	River Style	Condition - Recovery Potential
Marylands River 2	MARY2	417180 m E	6846095 m S	Gorge	Good
Marylands River 1	MARY1	427152 m E	6831550 m S	Gorge	Moderate
Clarence River 16	CR16	443342 m E	6823025 m S	Floodplain pockets	High recovery
Clarence River 15	CR15	454437 m E	6816168 m S	Bedrock controlled	Moderate
Clarence River 14	CR14	458834 m E	6787223 m S	Bedrock controlled	
Clarence River 13	CR13	454899 m E	6755033 m S	Gorge	Moderate
Clarence River 12	CR12	468183 m E	6731547 m S	Bedrock controlled	
Clarence River 11	CR11	481835 m E	6724723 m S	Tidal limit	
Clarence River 10	CR10	488817 m E	6723269 m S	Estuary (0-15ppt)	
Clarence River 9	CR9	494277 m E	6714673 m S	Estuary (0-15ppt)	
Clarence River 8	CR8	498557 m E	6719608 m S	Estuary (15-30ppt)	
The Broadwater 1	BW1	515414 m E	6743745 m S	Estuary (30+ppt)	
Clarence River 7	CR7	505143 m E	6728096 m S	Estuary (15-30ppt)	
Clarence River 6	CR6	511597 m E	6737418 m S	Estuary (30+ppt)	
Clarence River 5	CR5	518942 m E	6737146 m S	Estuary (30+ppt)	
Clarence River 4	CR4	518859 m E	6741653 m S	Estuary (30+ppt)	
Clarence River 3	CR3	524613 m E	6751377 m S	Estuary (30+ppt)	
Clarence River 2	CR2	524106 m E	6744496 m S	Estuary (30+ppt)	
Clarence River 1	CR1	533947 m E	6745382 m S	Estuary (30+ppt)	

Figure 2.5 Site MARY2 in Marylands River Looking downstream from the road crossing.

Figure 2.6 Site MARY1 in Marylands River looking upstream from the road crossing.

Figure 2.7 Site CR16 in the Clarence River looking downstream from the road crossing.

Figure 2.8 Site CR15 in the Clarence River looking downstream from the road crossing.

Figure 2.9 Site CR14 in the Clarence River looking upstream from the road crossing.

Figure 2.10 Site CR13 in the Clarence River looking upstream from the road crossing.

Figure 2.11 Site CR12 in the Clarence River taken from the left bank.

2.3.2 Northern tributaries

Twenty sites were sampled across nine river systems in the Northern tributaries subcatchments (Figure 2.12, Table 2.4). All sites were freshwater.

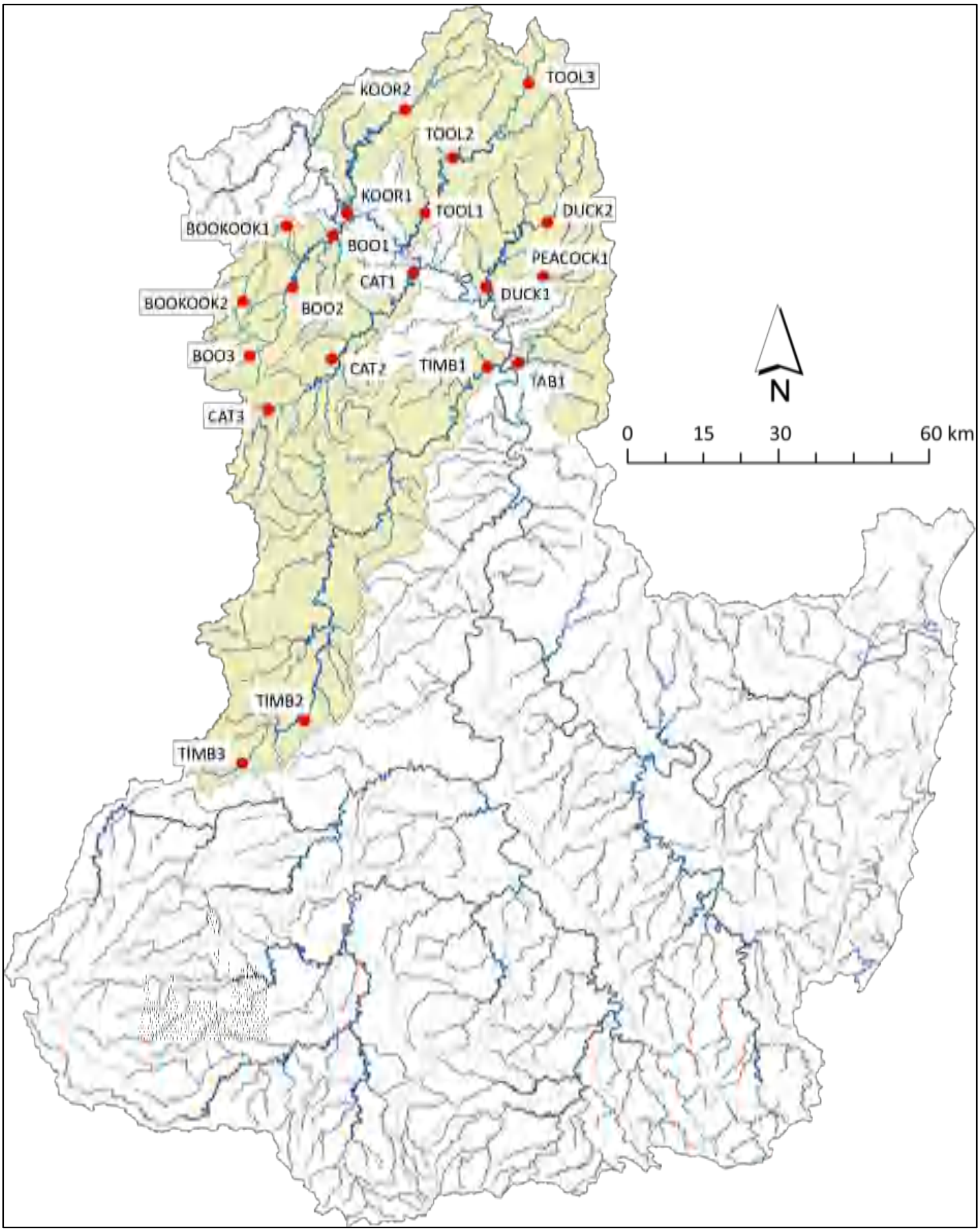


Figure 2.12 Ecohealth sampling sites in the Northern Tributaries subcatchment (green) of the Clarence catchment. See Table 2.4 for site details.

Table 2.4 Ecohealth sites in Northern tributaries of the Clarence catchment.

Site Name	Site Code	Easting	Northing	River Style	Condition - Recovery potential
Bookookoorara Creek 2	BOOKOOK2	411378 m E	6816040 m S	Floodplain pockets	
Bookookoorara Creek 1	BOOKOOK1	419204 m E	6831230 m S	Gorge	
Boonoo Boonoo River 3	BOO3	412606 m E	6805030 m S	Bedrock controlled	
Boonoo Boonoo River 2	BOO2	420214 m E	6819002 m S	Gorge	
Boonoo Boonoo River 1	BOO1	427120 m E	6829406 m S	Gorge	
Koreelah Creek 2	KOOR2	439678 m E	6854335 m S	Planform controlled, low sinuosity	High recovery
Koreelah Creek 1	KOOR1	429867 m E	6832942 m S	Floodplain pockets	High recovery
Tooloom Creek 3	TOOL3	461391 m E	6859941 m S	Planform controlled, meandering	Moderate recovery
Tooloom Creek 2	TOOL2	448138 m E	6845069 m S	Bedrock controlled	High recovery
Tooloom Creek 1	TOOL1	443469 m E	6833850 m S	Gorge	
Cataract River 3	CAT3	415972 m E	6794374 m S	Planform controlled, low sinuosity	low
Cataract River 2	CAT2	426465 m E	6800819 m S	Gorge	Moderate
Cataract River 1	CAT1	440821 m E	6822634 m S	Bedrock controlled	conservation
Duck Creek 2	DUCK2	464765 m E	6832240 m S	Planform controlled, low sinuosity	
Duck Creek 1	DUCK1	454075 m E	6821543 m S	Bedrock controlled	
Peacock Creek 1	PEACOCK1	464034 m E	6821036 m S	Planform controlled, meandering	
Tabulam River 1	TAB1	459721 m E	6804019 m S	Bedrock controlled	
Timbarra (Rocky) River 3	TIMB3	407180 m E	6720543 m S	Bedrock controlled	Moderate
Timbarra (Rocky) River 2	TIMB2	427185 m E	6770341 m S	Gorge	Good
Timbarra (Rocky) River 1	TIMB1	454499 m E	6803166 m S	Bedrock controlled	Moderate

Figure 2.13 Site BOOKOOK2 in Bookookoorara Creek looking downstream of the road crossing.

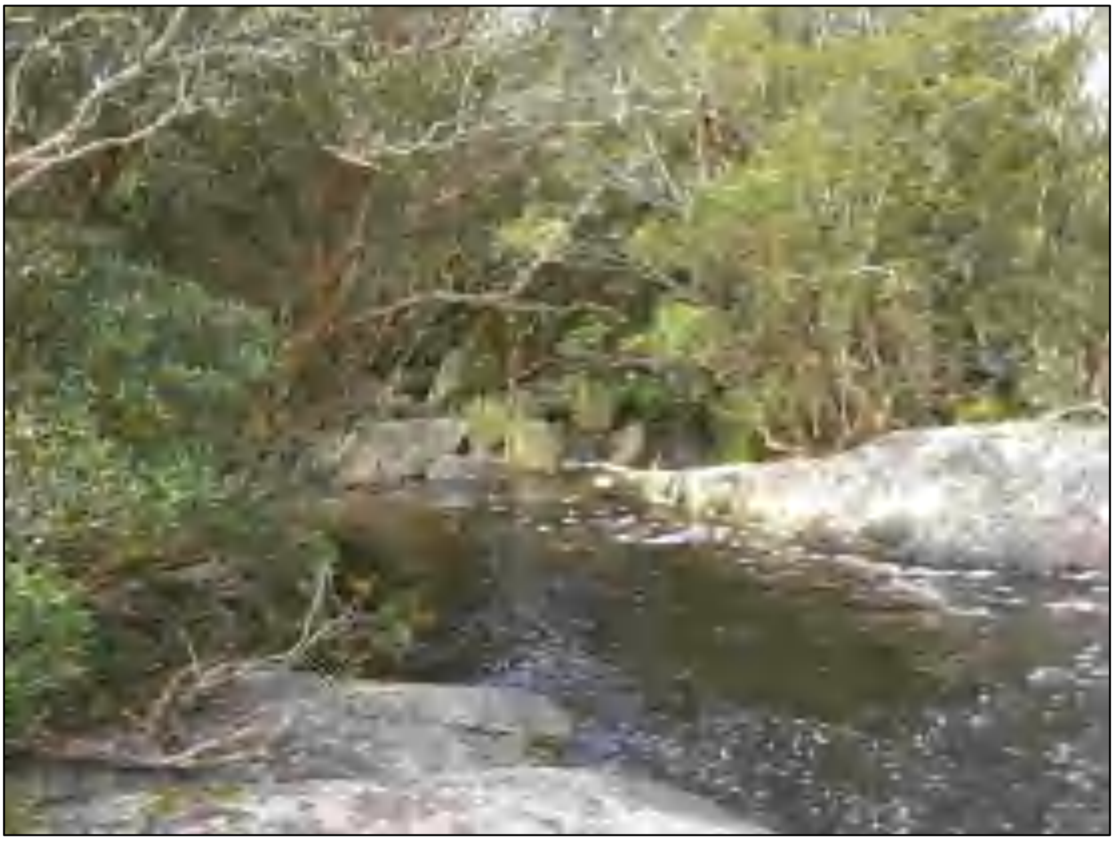


Figure 2.14 Site BOOKOOK1 in Bookookoorara Creek looking downstream (taken from left bank).

Figure 2.15 Site BOO3 in the Boonoo Boonoo River looking upstream (taken from the right bank).

Figure 2.16 Site BOO2 in the Boonoo Boonoo River looking upstream from the road crossing.

Figure 2.17 Site BOO1 in Boonoo Boonoo River looking downstream from the new road crossing.

Figure 2.18 Site KOOR2 in Koreelah Creek looking upstream (taken from the left bank).

Figure 2.19 Site KOOR1 in Koreelah Creek looking upstream from the road crossing.

Figure 2.20 Site TOOL3 in Tooloom Creek looking upstream (taken from the left bank).

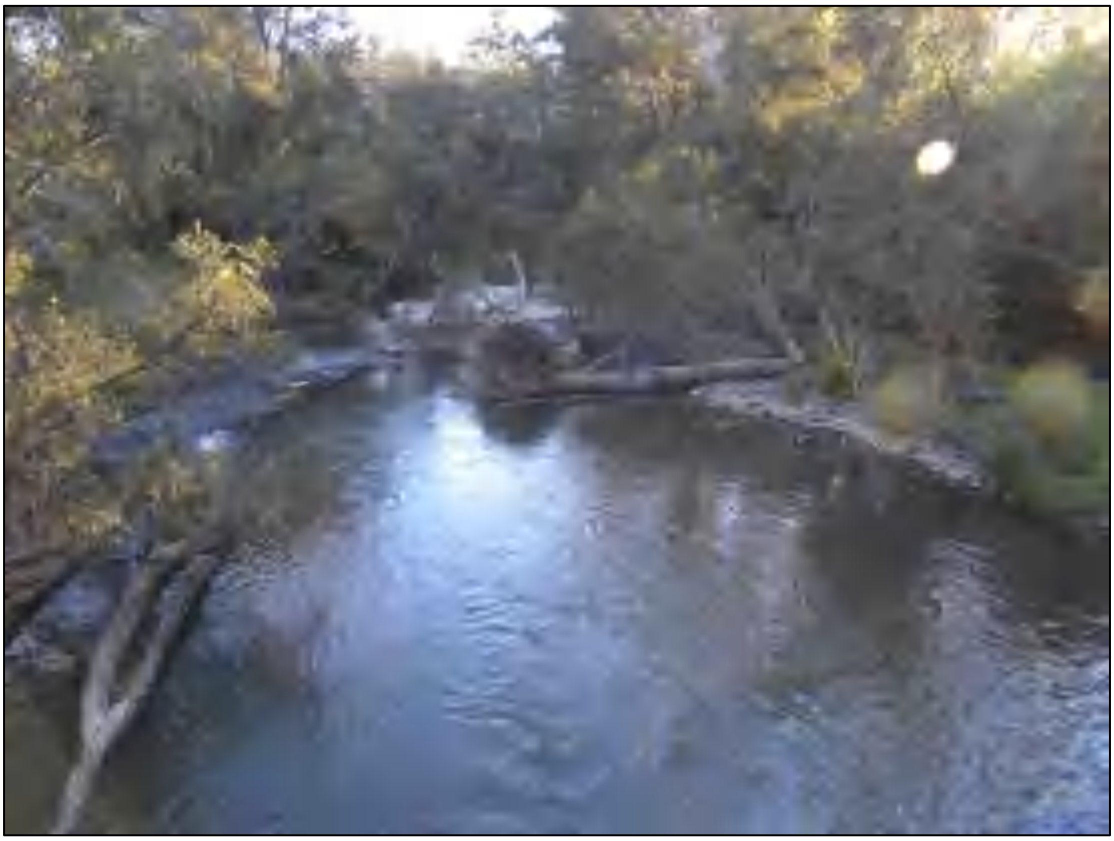


Figure 2.21 Site TOOL2 in Tooloom Creek looking downstream from the road crossing.

Figure 2.22 Site TOOL1 in Tooloom Creek looking downstream from the road crossing.

Figure 2.23 Site CAT3 in the Cataract River looking downstream from the road crossing.

Figure 2.24 Site CAT2 in the Cataract River looking downstream from the road crossing.

Figure 2.25 Site CAT1 in the Cataract River looking downstream from the ford.

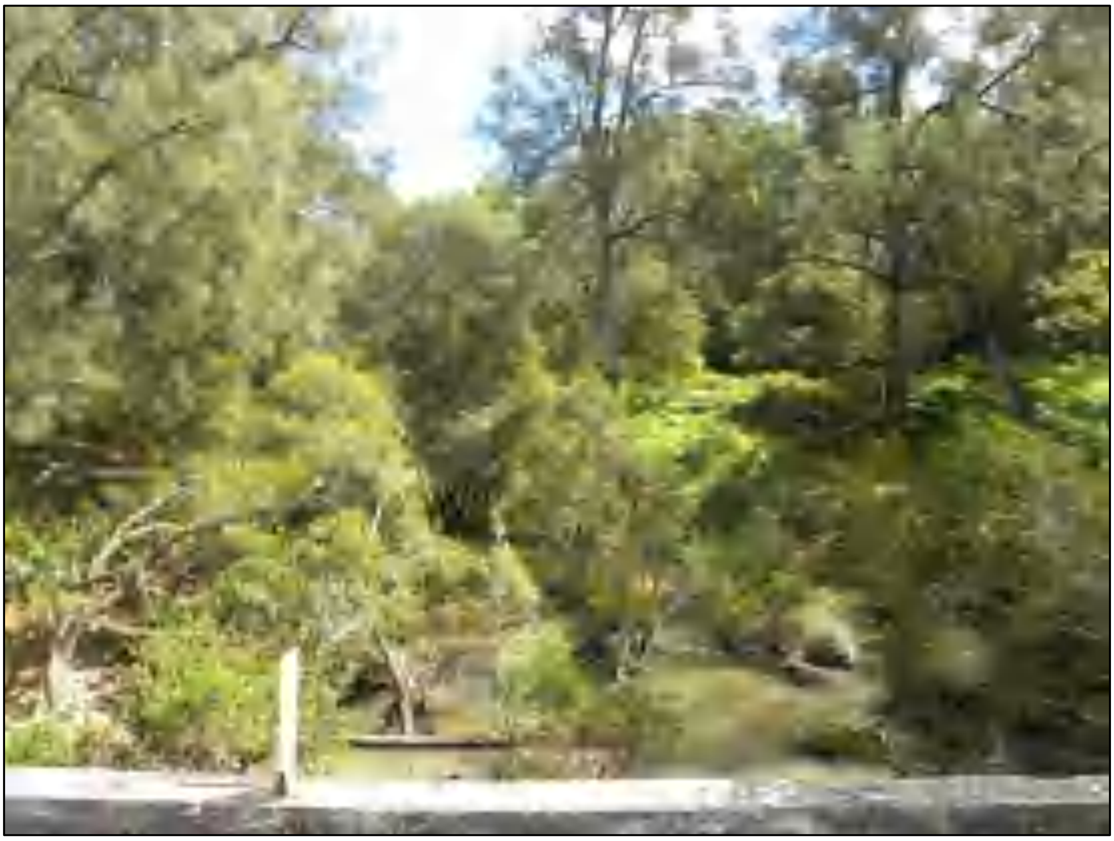


Figure 2.26 Site DUCK2 in Duck Creek looking downstream from the road crossing.

Figure 2.27 Site DUCK1 in Duck Creek looking upstream from the road crossing.

Figure 2.28 Site PEACOCK1 in Peacock Creek taken from the right bank.

Figure 2.29 Site TAB1 in Tabulam River looking upstream from the road crossing

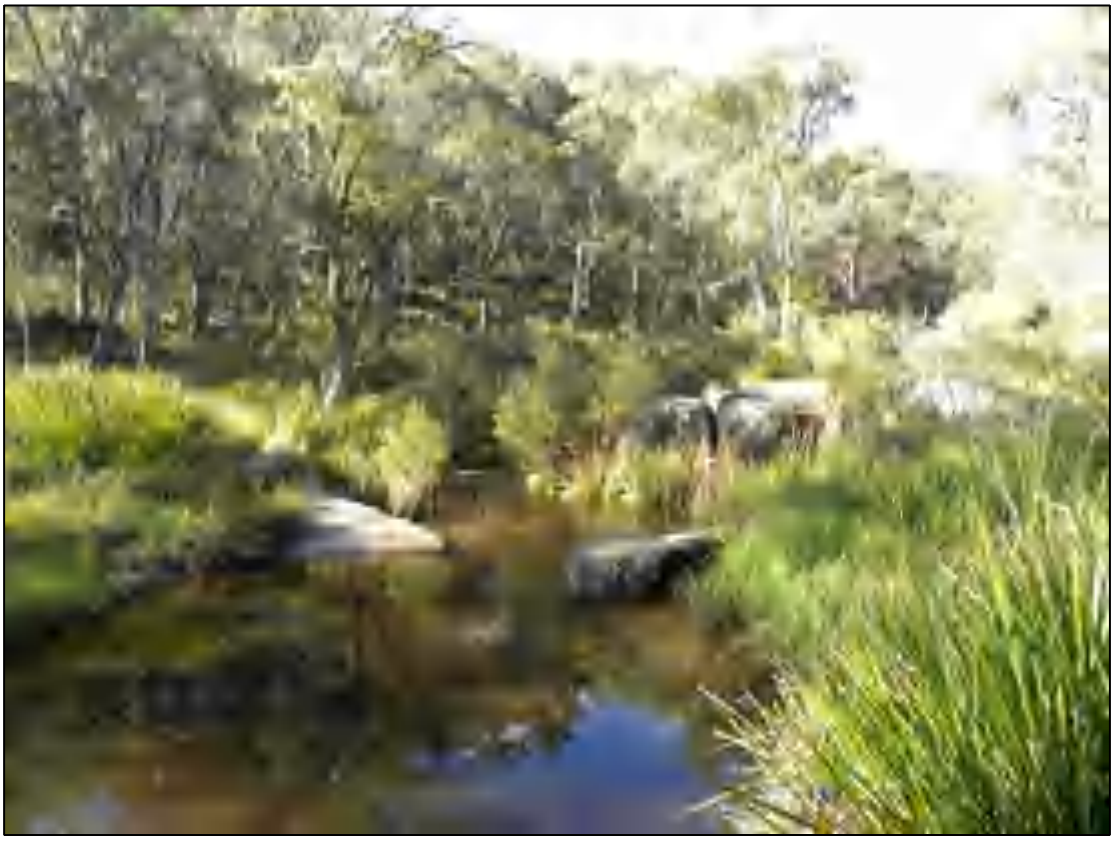


Figure 2.30 Site TIMB3 in Timbarra (Rocky) River looking downstream (taken from the right bank).

Figure 2.31 Site TIMB2 in Timbarra (Rocky) River looking downstream (taken from the left bank).

Figure 2.32 Site TIMB1 in Timbarra (Rocky) River looking downstream from the road crossing.

2.3.3 Nymboida-Boyd-Mann

Twenty five sites were sampled across thirteen river systems in the Nymboida, Boyd, and Mann subcatchment (Figure 2.33, Table 2.5). All sites were freshwater.

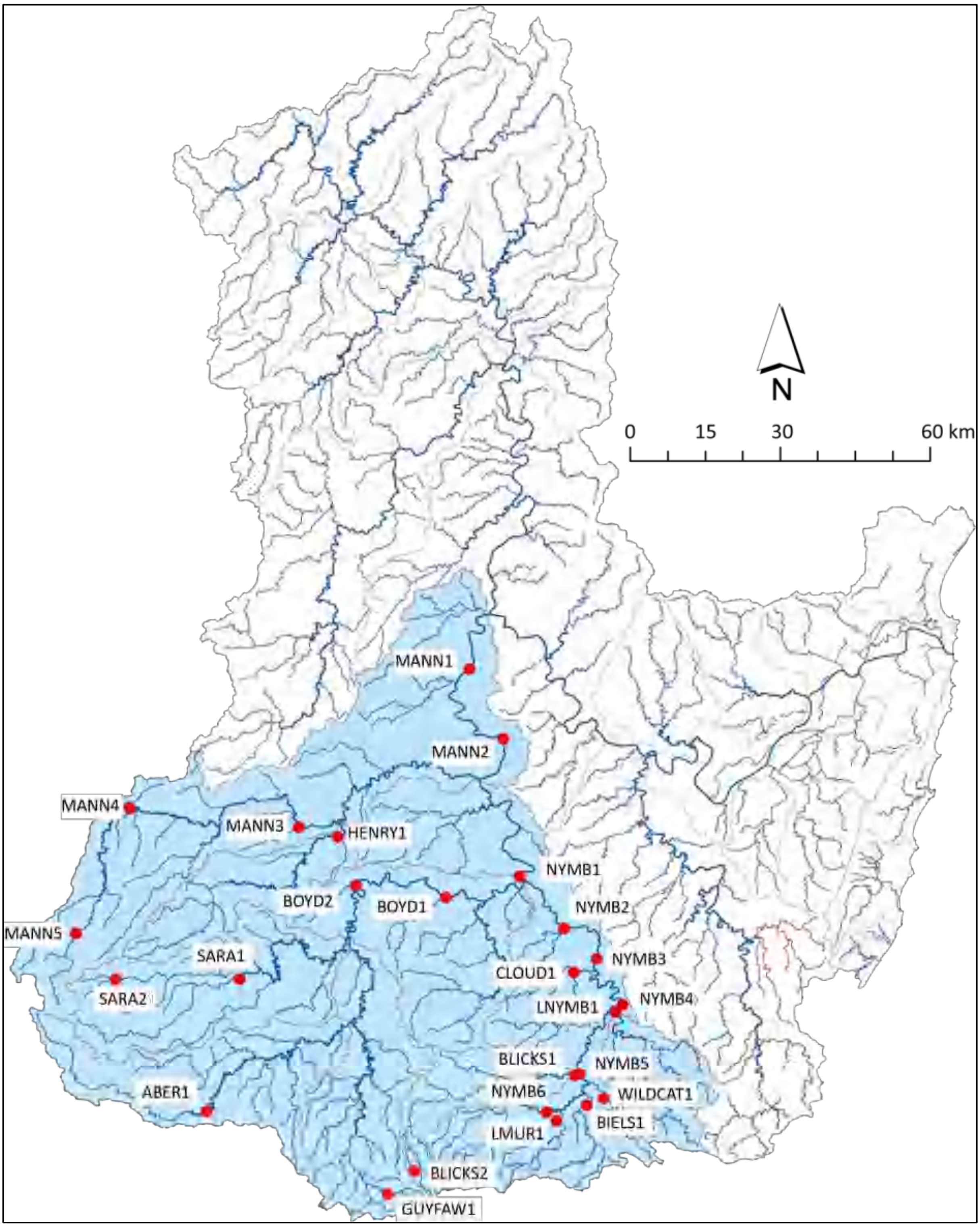


Figure 2.33 Ecohealth sampling sites in the Mann-Nymboida-Boyd subcatchments (blue) of the Clarence. See Table 2.5 and Table 2.6 for site details.

Table 2.5 Ecohealth sampling sites in the Nymboida subcatchment.

Site Name	Code	Easting	Northing	River Style	Condition - Recovery potential
Little Nymboioda 1	LNYMB1	476498 m E	6673432 m S	Gorge	
Wild cattle Creek 1	WILDCAT1	473147 m E	6657851 m S	Gorge	High
Bielsdown 1	BIELS1	471236 m E	6648425 m S	Gorge	
Blicks River 2	BLICKS2	441726 m E	6641121 m S	Planform controlled, meandering	
Blicks River 1	BLICKS1	469933 m E	6660313 m S	Gorge	
Little Murray 1	LMUR1	466274 m E	6651166 m S	Gorge	High Recovery
Clouds Creek 1	CLOUD1	469330 m E	6681115 m S	Gorge	Conservation
Nymboida 6	NYMB6	467615 m E	6653089 m S	Gorge	High recovery
Nymboida 5	NYMB5	470364 m E	6660658 m S	Gorge	Conservation
Nymboida 4	NYMB4	476584 m E	6673507 m S	Gorge	Conservation
Nymboida 3	NYMB3	473317 m E	6683874 m S	Bedrock controlled	High Recovery
Nymboida 2	NYMB2	467696 m E	6689898 m S	Bedrock controlled	High Recovery
Nymboida 1	NYMB1	459777 m E	6700388 m S	Floodplain Pockets	

Figure 2.34 Site LNYMB1 in Little Nymboida River looking downstream (taken from the right bank).

Figure 2.35 Site WILDCAT1 in Wild Cattle Creek looking upstream (taken from the right bank).

Figure 2.36 Site BIELS1 in Bielsdown River looking downstream (taken from the left bank at the ford).

Figure 2.37 Site BLICKS2 in Blicks River looking downstream of the road crossing.

Figure 2.38 Site BLICKS1 in Blicks River looking downstream of the ford (taken from the right bank).

Figure 2.39 Site LMUR1 in Little Murray River looking downstream of the road crossing.

Figure 2.40 Site CLOUD1 in Clouds Creek looking upstream (taken from the left bank).

Figure 2.41 Site NYMB6 in Nymboida River looking downstream (taken from the left bank).

Figure 2.42 Site NYMB5 in Nymboida River looking upstream (taken from the right bank).

Figure 2.43 Site NYMB4 in Nymboida River looking downstream (taken from the right bank).

Figure 2.44 Site NYMB3 in Nymboida River looking upstream (taken from the right bank).

Figure 2.45 Site NYMB2 in Nymboida River looking upstream (taken from the right bank).

Figure 2.46 Site NYMB1 in Nymboida River looking downstream of the road crossing.

Table 2.6 Ecohealth sampling sites in the Mann and Boyd subcatchments.

Site Name	Site Code	Easting	Northing	River Style	Condition - Recovery potential
Guy Fawkes River 1	GUYFAW1	437382 m E	6636263 m S	Planform controlled meandering/ Gorge	Rapid recovery
Aberfoyle River	ABER1	405303 m E	6652761 m S	Bedrock controlled	Moderate recovery
Sara River 2	SARA2	389375 m E	6679299 m S	Headwater	Moderate
Sara River 1	SARA1	407290 m E	6679581 m S	Gorge	High
Boyd River 2	BOYD2	433299 m E	6698590 m S	Bedrock controlled	
Boyd River 1	BOYD1	447436 m E	6695981 m S	Bedrock controlled	
Henry River 1	HENRY1	427616 m E	6708312 m S	Bedrock controlled	
Mann River 5	MANN5	382343 m E	6688426 m S	Planformed controlled, low sinuosity	Moderate recovery
Mann River 4	MANN4	391562 m E	6713791 m S	Floodplain Pockets	Moderate recovery
Mann River 3	MANN3	419854 m E	6711835 m S	Floodplain Pockets/ Bedrock controlled	High Recovery
Mann River 2	MANN2	456901 m E	6727485 m S	Bedrock controlled	Rapid recovery
Mann River 1	MANN1	450789 m E	6741986 m S	Beddrock controlled	Rapid recovery

Figure 2.47 Site GUYFAW1 in Guy Fawkes River looking downstream (taken from the left bank).

Figure 2.48 Site ABER1 in Aberfoyle River looking upstream from the road crossing.

Figure 2.49 Site SARA2 in Sara River looking downstream from the road crossing.

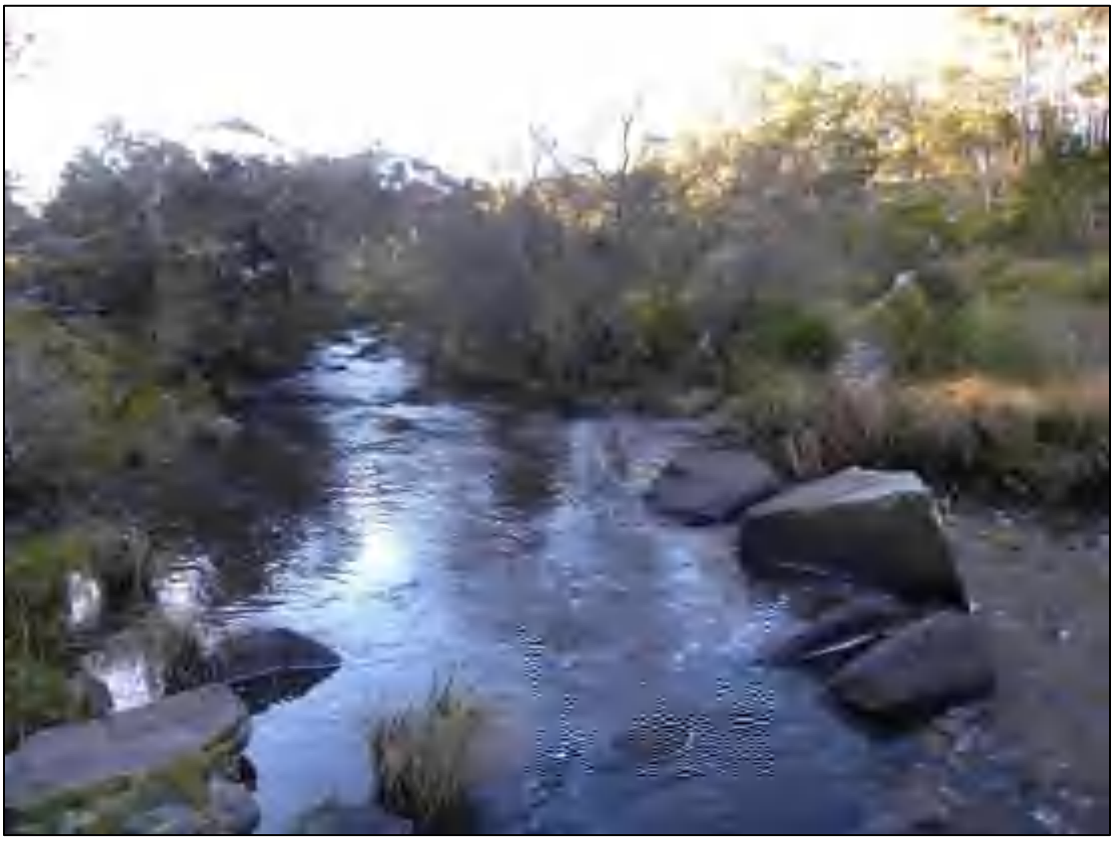


Figure 2.50 Site SARA1 in Sara River looking downstream from the road crossing.

Figure 2.51 Site BOYD2 in Boyd River looking upstream (taken from the left bank).

Figure 2.52 Site BOYD1 in Boyd River looking upstream (taken from the left bank).

Figure 2.53 Site HENRY1 in Henry River looking upstream from the road crossing.

Figure 2.54 Site MANN5 in Mann River looking downstream from the road crossing.

Figure 2.55 Site MANN4 in Mann River looking downstream from the road crossing.

Figure 2.56 Site MANN3 in Mann River looking downstream (taken from the right bank).

Figure 2.57 Site MANN2 in Mann River looking downstream (taken from the right bank).

Figure 2.58 Site MANN1 in Mann River looking upstream from the road crossing.

2.3.4 Coastal tributaries

Seventeen sites were sampled across eight river systems in the Coastal tributaries subcatchments (Figure 2.59, Table 2.7). Of these, 9 were freshwater and 8 were estuarine.

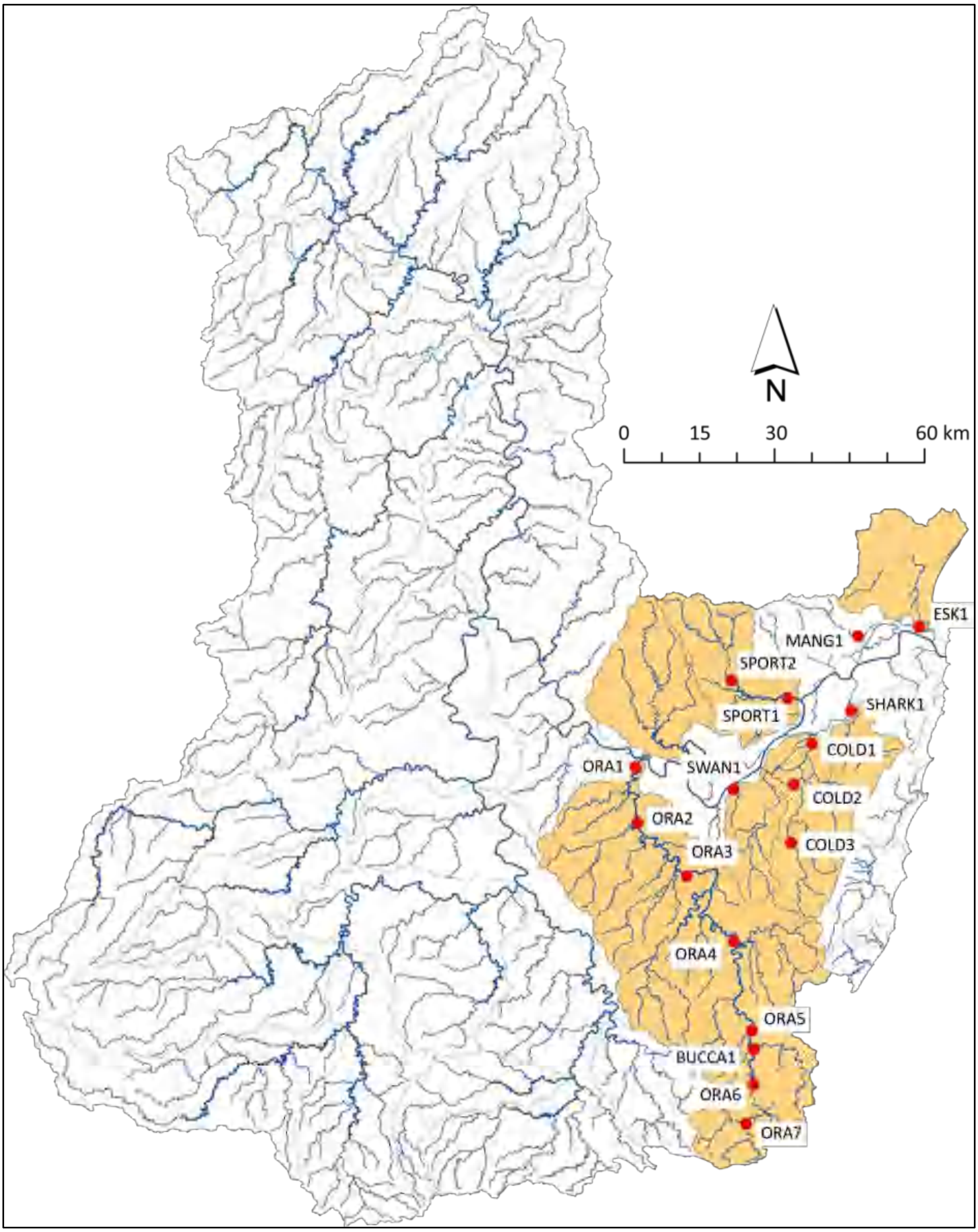


Figure 2.59 Ecohealth sampling sites in the coastal tributaries of the Clarence (orange). See Table 2.7 for site details.

Table 2.7 Ecohealth sampling sites in the coastal tributaries of the Clarence.

Site Name	Site Code	Easting	Northing	River Style	Condition - Recovery potential
Bucca Bucca Creek 1	BUCCA1	501709 m E	6666607 m S	Meandering, fine grained	High Recovery
Orara River 7	ORA7	501894 m E	6652348 m S	Planform controlled, low sinuosity	High Recovery
Orara River 6	ORA6	501527 m E	6656719 m S	Planform controlled, low Sinuosity	High Recovery
Orara River 5	ORA5	500722 m E	6666500 m S	Planform controlled, low sinuosity	High Recovery
Orara River 4	ORA4	498497 m E	6688221 m S	Gorge	Conservation/ rapid recovery
Orara River 3	ORA3	490233 m E	6701403 m S	Meandering	High recovery
Orara River 2	ORA2	481634 m E	6711971 m S	Gorge	Conservation
Orara River 1	ORA1	481268 m E	6723153 m S	Estuary (0-15ppt)	
Swan Creek 1	SWAN1	497681 m E	6717968 m S	Estuary (0-15ppt)	
Coldstream River 3	COLD3	508512 m E	6708012 m S	Anabranching, Swamp Belt	
Coldstream River 2	COLD2	508956 m E	6719609 m S	Tidal	
Coldstream River 1	COLD1	512193 m E	6727836 m S	Estuary (15-30ppt)	
Shark Creek 1	SHARK1	519119 m E	6734332 m S	Estuary (15-30ppt)	
Sportsmans Creek 2	SPORT2	498304 m E	6740433 m S	Bedrock controlled	
Sportsmans Creek 1	SPORT1	507718 m E	6736797 m S	Estuary (15-30ppt)	
Mangrove Creek 1	MANG1	519719 m E	6748980 m S	Estuary (15-30ppt)	
Esk River 1	ESK1	531109 m E	6751060 m S	Estuary (15-30ppt)	

Figure 2.60 Site BUCCA in Bucca Bucca Creek looking downstream from the road crossing.

Figure 2.61 Site ORA7 in the Orara River looking upstream (taken from the right bank).

Figure 2.62 Site ORA6 in the Orara River looking downstream from the pedestrian crossing.

Figure 2.63 Site ORA5 in Orara River looking downstream of the road crossing (from left bank).

Figure 2.64 Site ORA4 in Orara River looking downstream (taken from the right bank).

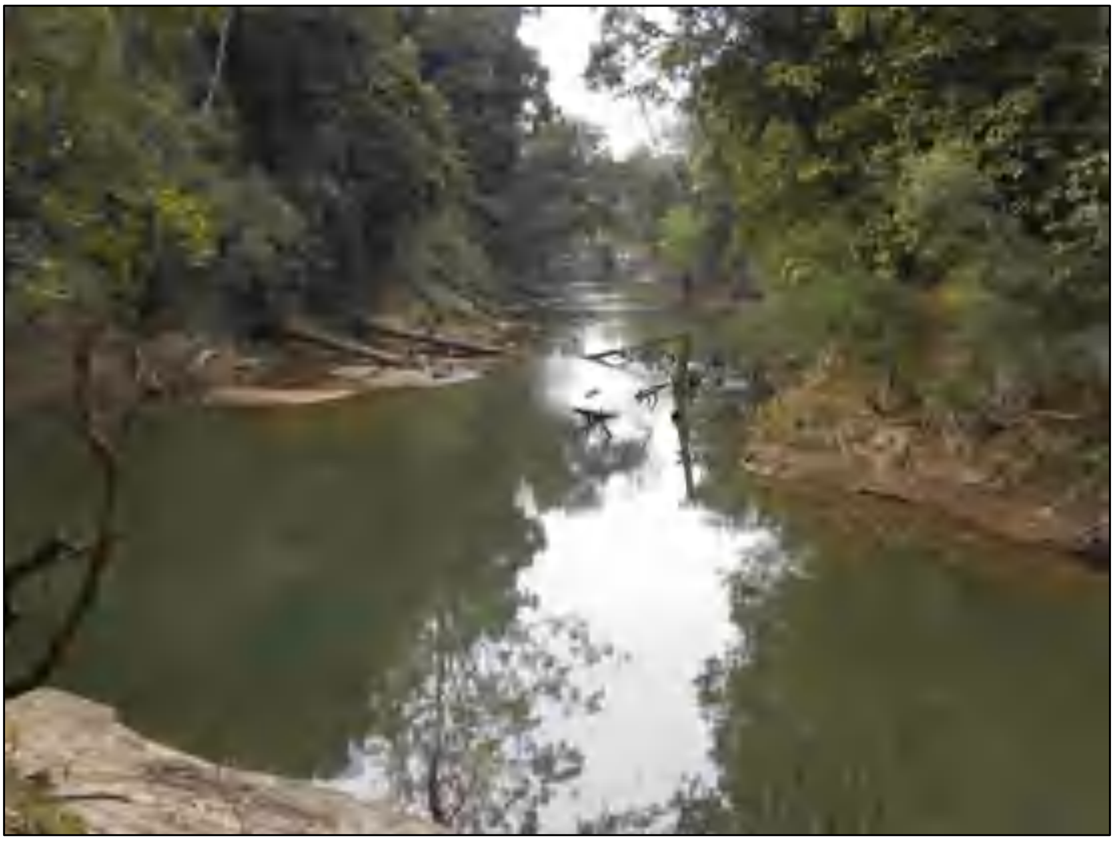


Figure 2.65 Site ORA3 in Orara River looking downstream (taken from the left bank).

Figure 2.66 Site ORA2 in the Orara River looking downstream (taken from the left bank).

Figure 2.67 Site ORA1 in Orara River looking upstream (taken from the right bank).

Figure 2.68 Site SWAN1 in Swan Creek looking upstream from the road crossing.

Figure 2.69 Site SPORT2 in Sportsmans Creek looking downstream (taken from the left bank).

2.3.5 Coastal systems

Nine sites were sampled across five river systems in the Coastal systems subcatchment (Figure 2.70, Table 2.8). All sites were estuarine.

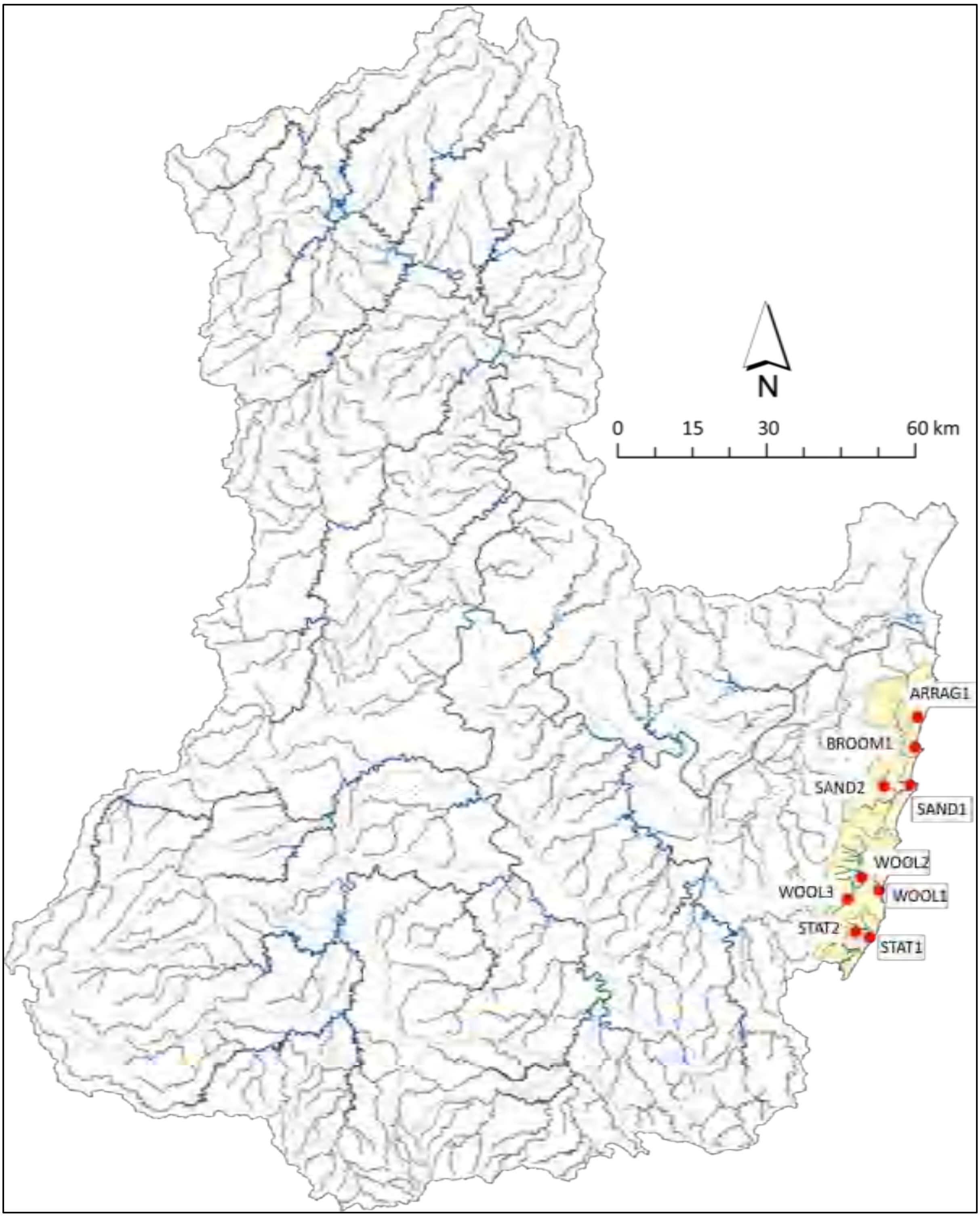


Figure 2.70 Ecohealth sampling sites in the coastal systems of the Clarence catchment. See Table 2.8 for site details.

Table 2.8 Ecohealth sampling sites in the coastal systems of the Clarence.

Site Name	Site Code	Easting	Northing
Lake Arragan 1	ARRAG1	532551 m E	6731277 m S
Cakora Lagoon 1	BROOM1	532088 m E	6725112 m S
Sandon River2	SAND2	526566 m E	6717252 m S
Sandon River 1	SAND1	531089 m E	6717512 m S
Wooli River 3	WOOL3	520121 m E	6694411 m S
Wooli River 2	WOOL2	522445 m E	6698901 m S
Wooli River 1	WOOL1	525548 m E	6696232 m S
Station Creek 2	STAT2	521442 m E	6687830 m S
Station Creek 1	STAT1	523920 m E	6686625 m S

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 indicators (and groupings of indicators) represents elements of the structure, function and composition of riverine and estuarine ecosystems.

2.4.1 Water Quality Indicators

Assessing the impacts of land-use change on the ecological health of rivers and streams is an important issue for the management of water resources in Australia. Traditionally, these assessments have been dominated by the measurement of patterns in species distribution and abundance which contribute important information such as the status of threatened species and their habitat requirements. However, many goals of river management refer to concepts of sustainability, viability and resilience that require an implicit knowledge of ecosystem or landscape-level interactions and 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 2.9). Nutrients such as nitrogen, phosphorus, and carbon can play an integral role in regulating rates of primary production 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 2.9 Water chemistry measurements taken bi-monthly from all sites.

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

2.4.2 Field and laboratory methods

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

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

2.4.4 Water Quality Sampling

Water samples were collected at each site for the determination of Chlorophyll *a*, total and dissolved nutrients, and total suspended solids. Samples were collected at near surface (<0.2m) and obtained with the use of a hand held sampling device to ensure sample is taken at least 1.5 m from the edge of the boat or riverbank. Samples were transferred to acid-washed and rinsed (thrice rinsed with sample water) 125mL containers. Duplicate samples for each parameter were taken from each site, and a third sample of each parameter was collected from a random subset of sites for quality assurance (QA) processing at an independent laboratory. The following procedures for sample collection and treatment are provided for each determination.

2.4.4.1 *Chlorophyll a*

Water column chlorophyll *a* is a measure of the photosynthetic biomass of algae/phytoplankton. These organisms are central to important nutrient and biogeochemical processes, and as such may respond to disturbance before effects on higher organisms are detected. This is because the higher organisms depend on processes mediated by algal communities. Consequently, they form the base of food webs supporting zooplankton, grazers such as crustaceans, insects, molluscs and some fish (Burns and Ryder 2001). The short generation time, responsiveness to environmental condition and the availability of sound, quantitative methodologies such as chlorophyll *a* make these measures of phytoplankton ideally suited as indicators of disturbance in aquatic systems. Information can be collected, processed and analysed at time scales relevant to both scientific and management interests.

In the field, a 1 litre bottle of water from a 0.2 m depth was collected using the hand held sampling device at each site, labelled, and placed on ice in an esky for transport to the laboratory. Sample processing was carried out within 48 hours of collection using the following steps;

1) Place a Whatman GF/C Glass Microfiber filter paper, using forceps, textured side up onto the filtration apparatus (EYELA Tokyo Rakahikai Coorperation Aspirator A-35) just prior to filtration.

2) Filter a sufficient amount of sample was filtered (100-1,000 mL measured with a graduated cylinder), to produce a green colour on the filter paper, or until the flow through the filter paper at ½ atmosphere pressure (approx. 7 PSI) is reduced to a trickle. When approximately 10-15mL of the sample remained on the filter, 5-10 drops of the $MgCO_3$ powder were added to preserve the chlorophyll. The filter apparatus and graduated cylinder were then rinsed thoroughly using a squirt bottle with deionised water and the filter drained to remove all signs of moisture.
3) The sample volume filtered was recorded. The amount of water filtered is subject to the level of turbidity at the sampling site.
4) Using forceps, the filter paper was folded and carefully placed into the bottom portion of the prelabled culture tube that was then sealed, wrapped in aluminium foil, placed into a labelled ziplock bag and refrigerated at below - 4 °C.
5) The filter paper was then placed in 10 mL of 90 % ethanol. The solution was refrigerated for 24 hours. The samples were then centrifuged. The absorption spectra were recorded using a UV-1700 Pharmaspec UV-visible spectrometer at 665 nm and 750 nm.

2.4.4.2 *Total Suspended Solids*

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

TSS were measured by filtering a sufficient amount of sample (100-1,000 mL measured with a graduated cylinder) through a Whatman GF/C Glass Microfiber filter paper, with a known weight, using a EYELA Tokyo Rakahikai Coorperation Aspirator A-35 at ½ atmosphere pressure (approx. 7 PSI). The volume of filtered sample was recorded and used to calculate mg/L of TSS. The filter apparatus and graduated cylinder were thoroughly rinsed using a squirt bottle with deionised water and the filter drained to remove all signs of moisture. The filter paper with retained material was then placed into a foil envelope and dried in an oven at 50 °C. They were reweighed after they dried to gain a measure of the weight of the TSS on each sample.

2.4.4.3 *Inorganic Nutrients*

For inorganic nutrients, we collected two 125 mL water samples from a 0.2 m depth at each site using the hand held sampling device. Samples for total nitrogen and total phosphorus remained unfiltered and were transferred into pre-rinsed, pre-labelled, 125 mL PET bottles and immediately placed in a cool dark esky. Samples remained frozen until time of analysis. Duplicate samples for quality assurance processing at an independent laboratory remained frozen until analyzed. For organic nutrients, we collected two 125 mL water samples from a 0.2 m depth at each site using the hand held sampling device. Approximately 125mL of water was passed through a Whatman GF/C filter paper (effective pore size 0.7 µm) in the field and collected into pre-rinsed, pre-labelled, 125 mL PET bottles and immediately placed in a cool dark esky. Samples remained frozen until time of analysis. Duplicate samples for quality assurance processing at an independent laboratory remained frozen until analyzed.

Nitrogen was measured by digesting an unfiltered water sample in a digestion tube with 10 mL of digestion mixture. This contained 40 g of di-potassium-peroxodisulfate ($K_2S_2O_8$) and 9 g of sodium hydroxide (NaOH) in 1000 mL of Milli Q water. This sample was then digested in the autoclave for 20 minutes. 5 mL of the sample was then placed into a 50 mL acid-washed measuring cylinder and diluted to 50 mL (Hosomi & Sudo 1986). 5 mL of buffer solution was added; 100 g of NH_4Cl, 20 g sodium tetra borate and 1 g EDTA to 1 L with Milli Q water. 50 mL of each sample was measured into a numbered jar. The samples were then filtered. Firstly, the cadmium reduction column was rinsed with 10 % buffer solution, making sure the cadmium granules remained covered at all times by either the 10 % buffer solution or the sample. The column was drained to 5 mm above the cadmium granules, and 25 mL of the first sample added. This was collected in a separate beaker as it drained through to rinse the column and was discarded. The column was then filled with the sample and 20 mL was collected in the same sample jar. 1 mL of sulfanilamide solution was added and mixed thoroughly. After 2 minutes, 1 mL of dihydrochloride solution was added and mixed. This was repeated for all water samples. After 10 minutes, the absorbance of each sample was measured using a UV-1700 Pharmaspec UV-visible spectrometer at 543 nm. This colormetric determination of nitrogen can be used when nitrogen is in the range 0.0125 to 2.25 μg/ml. Standards were also be prepared before analyzing the samples to calculate linear regression at 0 μg/ml, 0.05 μg/ml, 0.2 μg/ml, 0.5 μg/ml, 1 μg/ml, 2 μg/ml and 5 μg/ml of known nitrogen concentration.

Phosphorus was measured by digesting an unfiltered water sample in a digestion tube with 10 mL of digestion mixture. This contained 40 g of di-potassium-peroxodisulfate ($K_2S_2O_8$) and 9 g of sodium hydroxide (NaOH) in 1000 mL of Milli Q water. This sample was then digested in the autoclave for 20 minutes. 20 mL of sample was then added to a plastic SRP tube with 2 mL of colour reagent; 20 mL of ascorbic acid solution with 50 mL of molybdate antimony solution. This was repeated for all water samples. After 8 minutes, the absorbance of each sample was measured using a UV-1700 Pharmaspec UV-visible spectrometer at 705 nm. Standards were also be prepared before analyzing the samples to calculate linear regression at 0 μg/ml, 0.05 μg/ml, 0.2 μg/ml, 0.5 μg/ml, 1 μg/ml, 2 μg/ml and 5 μg/ml of known nitrogen concentration.

2.4.4.4 *Laboratory QA/QC*

Quality control was maintained with the laboratory by the use of standard analytical methods, analysis of 5 % random samples for QA/QC at the PMHC laboratories, and the regular calibration and maintenance of laboratory instrumentation. In addition, laboratory analyses of conductivity, turbidity and pH from stored water samples was used to confirm field measurements. An additional water chemistry sample was collected (via random number generator) from selected sites on each sample occasion and sent to an independent laboratory for analysis. These QA samples represented 5 % of the total number of samples collected. Results confirmed no significant difference between results for N and P between laboratories.

2.4.4.5 *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* was released in 1992, and developed using two approaches:

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

Trigger values are conservative thresholds or desired concentration levels for different water quality indicators. When an indicator is below the trigger value there is a low risk present to the protection of that environment. However, when an indicator is above the trigger value there is a risk that the ecosystem will not be protected. In cases where the trigger value is exceeded, further research and remediation of the risk identified should be conducted. Where a numerical value cannot be derived for a water quality indicator a target load may be set, for example the salinity guideline, or a descriptive statement for example for oil there should be no visible surface film, or an index of ecosystem health for example percentage cover of an algal bloom. The Australian and New Zealand Environment Conservation Council (ANZECC) Guidelines (2000 and 2006) provide threshold values for freshwater and estuarine systems for pH, dissolved oxygen (DO), electrical conductivity (EC), salinity and nutrients such as nitrogen (N) and phosphorus (P). In addition, we used region-based trigger values for estuarine chlorophyll and turbidity developed by DECCW as part of the MER program. A combination of ANZECC (2000,2006) and NSW MER developed trigger values were used to explore water quality across sites and sampling occasions (Table 2.10).

Table 2.10 ANZECC water quality guidelines for freshwater (above and below 150m elevation) and estuarine systems of south-east Australia.

ANZECC Guidelines (2000) and NSW MER - Min. and Max Values									
	pH	DO (%)	EC (µScm)	Turbidity (NTU)	Chla (µgL)	Nox (µgL)	SRP (µgL)	TN (µgL)	TP (µgL)
Freshwater sites >150m	6.5 - 8	80-110	125-2200	50	5	40	20	500	50
Freshwater sites <150m	6.5 - 8	80-110	125-2200	50	5L	40	20	500	50
Estuary sites	7 - 8.5	80-110	no ANZECC values	10	3.3	15	5	300	30

2.4.4.6 *Nutrient loads*

The loading of nutrients and suspended sediments transported or retained by freshwater reaches was calculated for sites with available hydrographic data. In the Clarence River catchment, loads of TN, TP and TSS were calculated for the Clarence main stem (Lilydale 204007, Tabulam 204002), Cataract Creek (Sandy Hill 204036) in the Northern Tributaries, Orara River in the Coastal tributaries (Bawden Bridge 204041), Nymboida River (204069) and the Mann River (204007). Mean daily discharge from each of these locations was used to calculate the load of TN, TP and TSS for the day of field sampling.

2.4.5 Macroinvertebrates

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

Macroinvertebrates have been widely used in broad scale assessments of 'river health'. The most common approach adopted for environmental monitoring has involved the analysis of the taxonomic richness of macroinvertebrates. SIGNAL 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.

2.4.5.1 *Field and laboratory methods*

Macroinvertebrates were sampled bi-annually (Autumn and Spring 2013) at the freshwater sites to align with the MER protocols. Kick net samples (250µm mesh) that comprise 10 linear meters of each of pool, riffle and edge habitats were taken from each of the 59 freshwater sites on each of the 2 sampling occasions. Only those habitats present at the time were sampled. Invertebrates were immediately preserved in 70 % ethanol on site and transported to the laboratory for analysis. Each sample was passed through 2 mm, 1 mm and 250 µm sieves. All taxa from the 2 mm and 1 mm sieves were recorded, with material retained on the 250 µm sieve sorted for a standardized 30-minute period. Macroinvertebrates were identified to Family/genera level and assigned a SIGNAL2 score for pollution tolerance, and EPT score calculated. Metrics of abundance, richness, diversity and composition were recorded. Data for each river, sites within rivers and season were collated to produce summary data on taxa richness, median signal score and EPT score.

2.4.6 Riparian and Mangrove/Seagrass condition assessment

2.4.6.1 *Riparian Assessment of freshwater sites*

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

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

2.4.6.2 *Rapid Assessment of Riparian Condition*

The sub-tropical rapid appraisal for riparian condition (STRARC) is a multi-metric index of riparian condition, which has been modified from the original Rapid Appraisal for Riparian Condition (RARC) (Jansen et al. 2007a) and the adapted Tropical Rapid Appraisal of Riparian Condition (TRARC) (Dixon et al. 2006). The STRARC is comprised of 24 indicators which are grouped into four sub-indices which when combined; calculate to an overall index of riparian condition. The four sub-indices help to identify the general components that contribute to the condition of a site (Dixon et al. 2006). Each sub-index has a reference condition created from the literature and extant riparian areas that is modified for different geographic areas (coastal, slopes, tablelends). These sub-indices and their indicators are listed below in Table 2.11. In summary the four sub-indices describe:

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

Riparian condition

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

Table 2.11 STRARC sub-indices and their indicators Sub-indices and their indicators Assessment (each given a score of 1-5).

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

Habitat

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

Bank condition

Bank condition is a measure of the overall bank stability of a river. The indicators used include undercutting, slumping and exposed tree roots. These attributes are essential in sub-tropical regions which have a history of forestry and agricultural land clearing and features steep asymmetrical floodplains.

Disturbances

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

Field methods

All 59 freshwater sites in the Clarence catchment were sampled in August 2013 using the STRARC method developed for the Ecohealth project. Data for each of the four indices were collected at the reach (200 m) scale as well as within 3, 25 m^2 quadrats within each study reach. Complete details of the STRARC methods are available in Southwell, E (2010) Development and application of a sub-tropical rapid assessment of riparian condition. Unpublished Honours Thesis, University of New England, Armidale NSW.

Mangrove cover/Seagrass/Saltmarsh

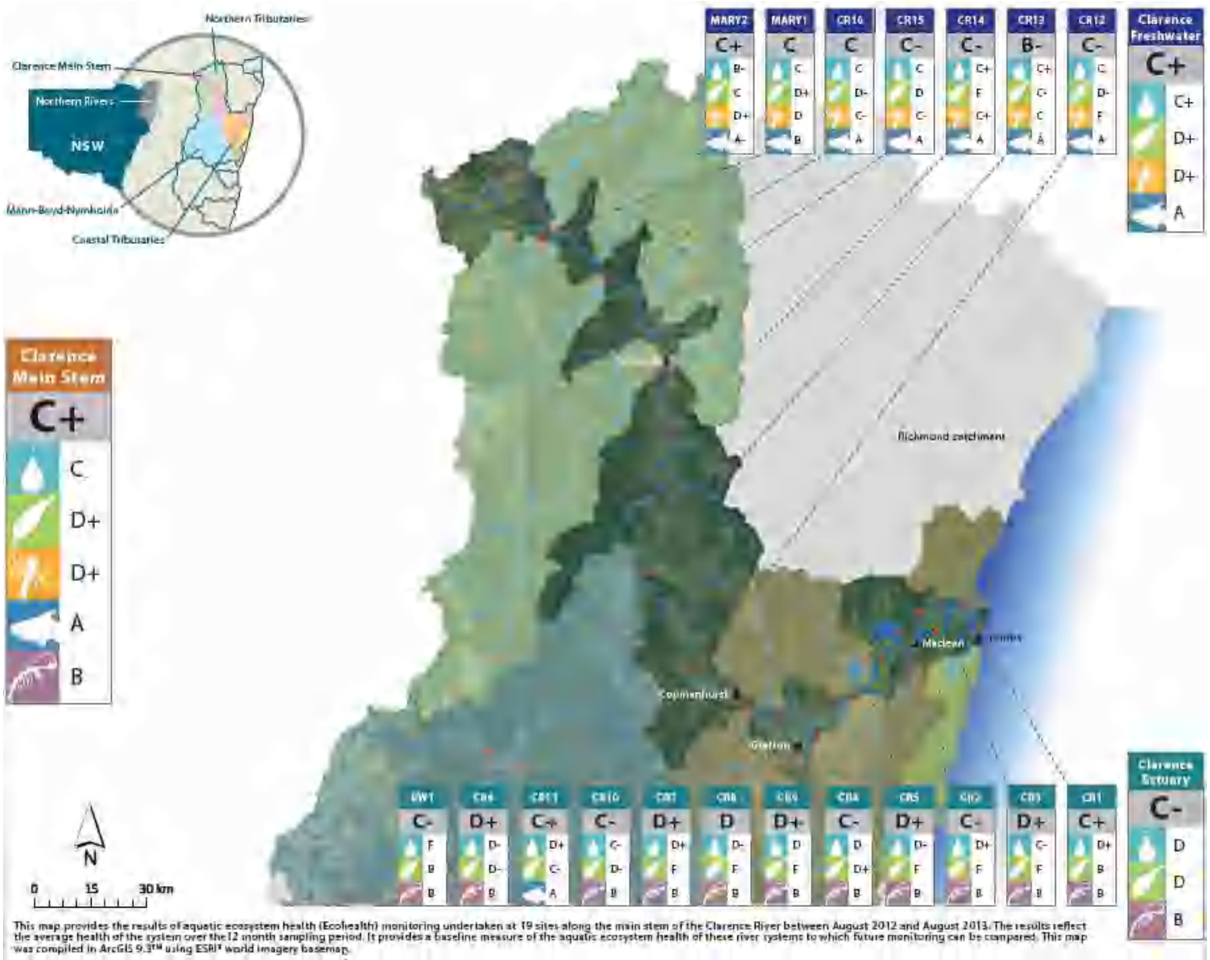
The cover of mangroves, seagrass and saltmarsh for each of the 21estuarine sites was calculated using spatial datasets provided by NRCMA. The site location was used as a centroid from which the cover of mangroves was determined for a 500-m reach of river bank upstream and downstream from the central point on both sides of the river. These data were used to calculate total proportion of mangrove cover for the study reach. Maximum and minimum width of mangrove cover within the study reach was also calculated using the spatial data.

PART 3

3 RESULTS

3.1 Clarence main stem

Overview



The Clarence River catchment is the largest coastal catchment in NSW and is over 250 km long with 142 km of freshwater reaches and the tidal limit extending 108 km upstream to Copmanhurst.

The Clarence River recorded a C+, the equal highest overall score for sub-catchments in the Clarence. The overall score for all freshwater sites of a C+, with high scores recorded for fish and water quality. In contrast, the overall score for the estuarine sites was a C- with consistently very poor water quality and riparian condition.

Condition scores of sites ranged from a high of a B- in the mid-Clarence River to a D at the tidal limit. There was no trend of increasing nutrients or reduced water quality along the river, suggesting local sources are an important influence on river condition.

Water quality was poor in the estuary throughout the study, with the region around the tidal limit with consistently the worst water quality reflecting the freshwater and tidal inputs at these sites.

Concentrations of nitrogen and phosphorus consistently exceeded the guideline values throughout the study. The highest phosphorus concentrations were recorded during prolonged low flows in freshwater reaches, and the highest nitrogen in estuarine reaches following flooding.

There were no algal blooms recorded during the study. However, algal concentrations were consistently above the guideline value in tablelands and estuary reaches.

Estuary tributaries (Swan, Mangrove, Shark) were in very poor overall condition, and contributed very poor water quality (low oxygen and acid water) to the Clarence River following flooding.

Diverse and abundant aquatic macroinvertebrate communities were found throughout the Clarence River but were dominated by organisms tolerant of poor water quality and poor habitat. Macroinvertebrate condition improved after flooding suggesting they are more affected by prolonged periods of low flows than floods.

Fish communities throughout the Clarence River were in excellent condition with an A grade recorded for all sites except the lower Marylands River that received a B. All sites were dominated by diverse communities of native fish.

Riparian condition was generally low from a poor diversity of native vegetation, reduced vegetation structure, generally occurring in isolated pockets with poor connectivity to other native vegetation, and evidence of eroding river banks and sediment deposited in the channel. Estuarine reaches from Grafton to Yamba were dominated by riverbanks with little or no vegetation present.

3.1.1 Water chemistry

3.1.1.1 *Chlorophyll a*

Mean chlorophyll *a* concentrations in the Marylands River were 2.24 µg/L in the upstream site MARY2 and 3.05 µg/L in the downstream site MARY1 (Figure 3.1). Minimum concentrations varied temporally: at MARY2, the minimum of 0.22 µg/L was observed in April 2013 and at MARY1, the minimum of <0.005 µg/L was observed earlier in October 2012. Maximum concentrations (8.69 and 11.77 µg/L for MARY 2 and MARY 1, respectively) were observed in August 2012 and these were the only exceedance of the upland freshwater trigger threshold of 4.00 µg/L).

Chlorophyll *a* concentrations in the freshwater reaches of the Clarence River generally increased longitudinally downstream (Figure 3.1), ranging from <0.005 µg/L (CR15 in October 2012) to 7.04 µg/L (CR12 in August 2012). This maximum observance was the only exceedance of the trigger thresholds for freshwater systems in the Clarence main stem.

In the tidal and estuarine reaches of the Clarence main stem (Figure 3.1), chlorophyll *a* concentrations ranged from <0.005 µg/L (CR10, CR4 and CR1 in August 2012, and CR2 in September 2012) through to 15.36 µg/L (CR5 in June 2013). Only sites CR11 and CR7 did not exceed the trigger threshold of 3.30 µg/L for any sampling period. Sites CR10, CR9, CR8 and CR4-CR1 all exceeded the trigger threshold once. For all sites in the lower estuary and CR10, this occurred in April 2013 whereas sites in the upper estuary (CR9, CR8) exceeded the trigger threshold during August 2013.

Two sites exceeded the trigger threshold multiple times. CR5 (at Woodford South Arm) and CR6 (500 m downstream of the Lawrence Ferry) exceeded chorophyll *a* trigger thresholds three (August 2012, and April and June 2013) and two (September 2012 and June 2013) times, respectively.

Chorophll *a* concentrations ranged from 0.55 – 12.45 µg/L (mean of 3.83 µg/L) for The Broadwater (BW1). Although chorophyll *a* concentrations were quite variable in BW1 (Figure 3.1), the trigger threshold was only exceeded twice: by a large spike in April 2013 (see maximum range above), and a much smaller exceedance in June 2013 (4.28 µg/L).

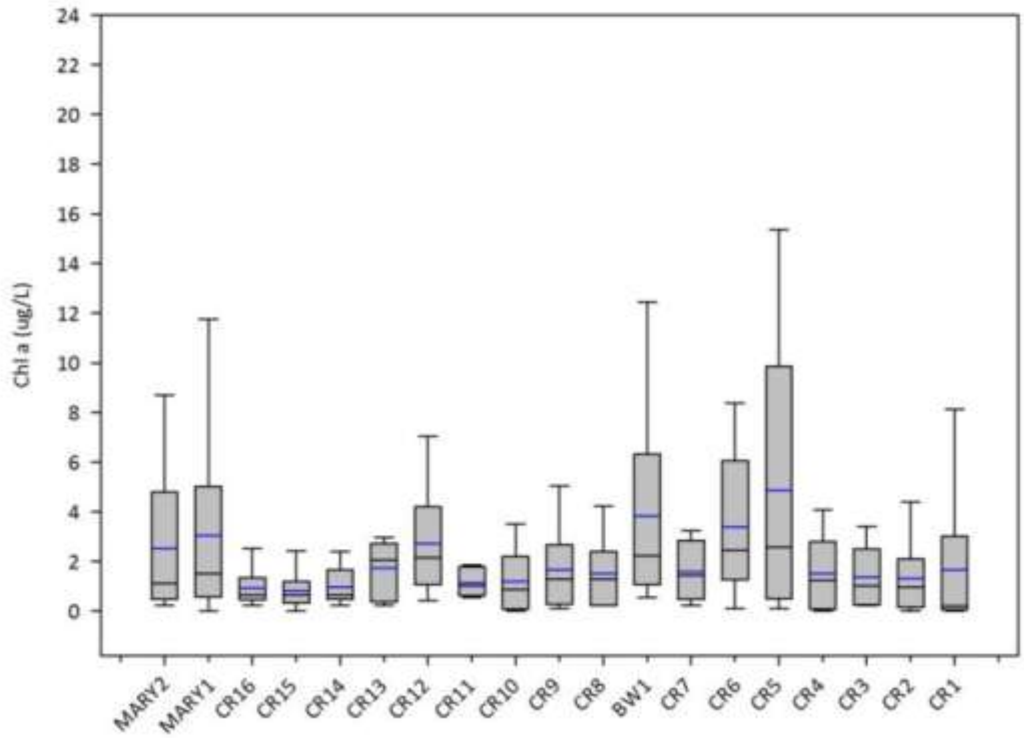


Figure 3.1 Mean (black line), median (blue line), 25th and 75th percentiles and range of chlorophyll *a* concentrations from sites in the Clarence Main Stem subcatchment from August 2012 to August 2013.

3.1.1.2 *Total Nitrogen (TN)*

Concentrations of total nitrogen (TN) increased longitudinally in the Marylands River (Figure 3.2), with means of 439.27 µg/L at MARY2 and 502.94 µg/L at MARY 1. TN concentrations ranged from 229.76 µg/L (MARY2) to 9.85.47 µg/L (MARY1). Trigger thresholds were exceeded once at each site and both of these occurred in June 2013.

In the freshwater reaches of the Clarence main stem, TN concentrations ranged from 0.452 µg/L at CR 13 (April 2013) to 1159.27 µg/L at CR14 (July 2013), although no site mean concentration exceeded the trigger threshold of 500 µg/L (Figure 3.2). Although there was not a clear longitudinal increase in TN concentrations along the freshwater reaches of the Clarence main stem, the frequency and magnitude of exceedance did increase from once at CR16 (696.70 µg/L in July 2013), through to four times at CR12 (maximum of 1060.18 µg/L in October 2012).

TN concentrations were high in the Clarence estuary (Figure 3.2), ranging from 31.73 µg/L (CR1 in September 2012) to 1247.37 µg/L (CR6 in December 2012). TN concentrations exceeded the estuarine trigger threshold of 300 µg/L at most sampling occasions throughout the estuary (the minimum frequency of exceedance was three sampling occasions and the maximum frequency of exceedance was five sampling occasions. The peak in the mean and range of TN concentrations seen at CR9 and CR8 (Figure 3.2) extended throughout the sampling period, with TN exceeding trigger thresholds on five sampling occasions.

TN concentrations ranged from 1.05 – 655.26 µg/L in BW1 (mean of 355.29 µg/L, Figure 3.2). Estuarine trigger thresholds were exceeded in four of six sampling periods. Two of these were double the trigger value (606.48 and 655.26 µg/L in August 2012 and December 2012, respectively), while two were lower (511.32 and 347.79 µg/L in June and August 2013, respectively).

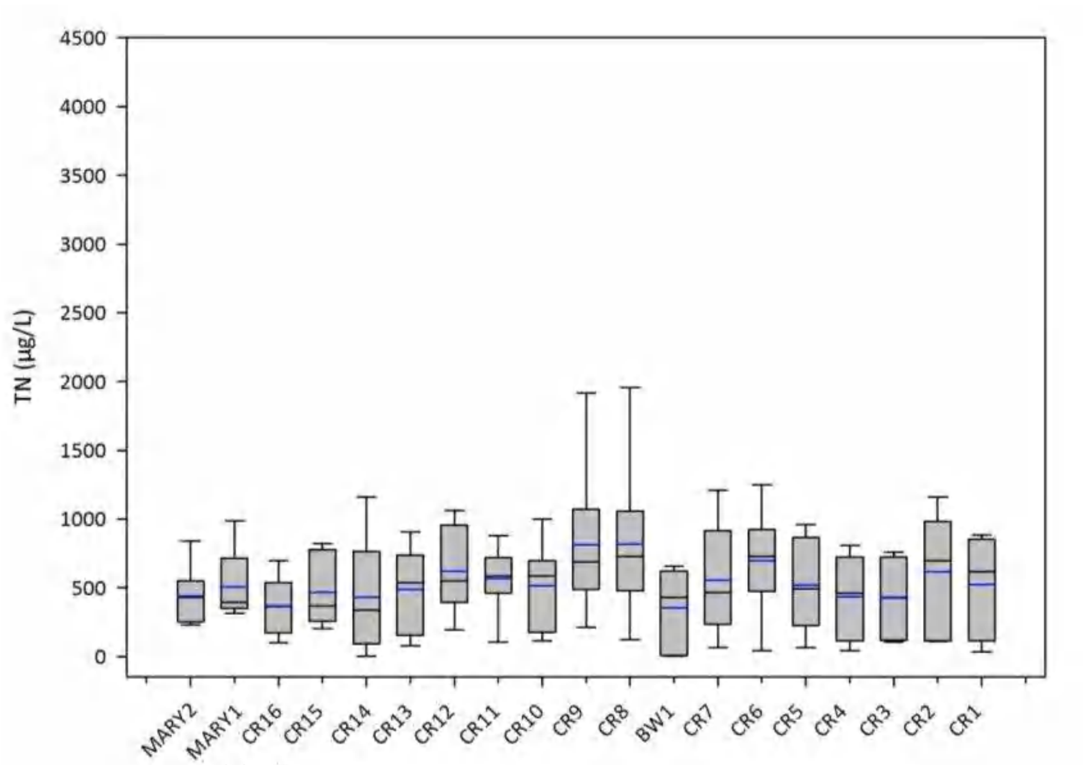


Figure 3.2 Mean (black line), median (blue line), 25th and 75th percentiles and range of TN concentrations from sites in the Clarence Main Stem subcatchment from August 2012 to August 2013.

3.1.1.3 *Bioavailable Nitrogen (NOx)*

In contrast to TN concentrations, bioavailable nitrogen (NOx) concentrations were more variable in the Marylands River and upstream freshwater reaches of the Clarence main stem (Figure 3.3). NOx concentrations ranged from <0.005 µg/L (MARY2 in October 2012) to 641.03 µg/L (MARY 2 in December 2012). NOx concentrations at both sites exceeded the trigger threshold of 40 µg/L in upland freshwater reaches twice with a large spike in December 2012 (641.03 and 470.09 µg/L for MARY2 and MARY1, respectively), followed by a smaller exceedance in April 2013 (60.00 and 53.96 µg/L for MARY2 and MARY1, respectively).

In the freshwater reaches of the Clarence main stem (Figure 3.3), NOx concentrations ranged from <0.005 µg/L (CR15 in October 2012, and CR12 in October and December 2012) to 448.72 µg/L (CR14 in December 2012). The trigger threshold was exceeded at all sites, but for most sites this occurred once or twice and at different sampling periods. The exception was CR 16 where the threshold was exceeded three times from December 2012 to July 2013).

In the estuarine reaches of the Clarence main stem (Figure 3.3), NOx concentrations ranged from <0.005 µg/L (CR4 in September 2012 and June 2013, and CR3 CR5, CR7-CR9 and CR11 in September 2012, and CR10 in September – November 2012), through to 384.62 µg/L (CR7 in December 2012). The lack of clear longitudinal trends in NOx concentrations was similar to TN concentrations (Figure 3.2). However, while mean NOx concentrations did not increase in the mid estuary like TN concentrations, the median and range of NOx concentrations did (Figure 3.3). This pattern extended further downstream for NOx concentrations than TN concentrations. Overall, NOx concentrations were high in the estuary and sites exceeded the estuarine trigger threshold of 15 µg/L on at least three sampling occasions and up to five occasions. There is no clear temporal pattern to the exceedance of NOx trigger thresholds.

All observed NOx concentrations in BW1 exceeded the estuarine trigger threshold (range 20.64 – 320.51 µg/L, mean 98.76 µg/L). The maximum NOx concentration (320.51 µg/L) was observed in December 2012, which was when the maximum NOx concentration was observed in the Clarence estuary (at the next downstream site, CR7).

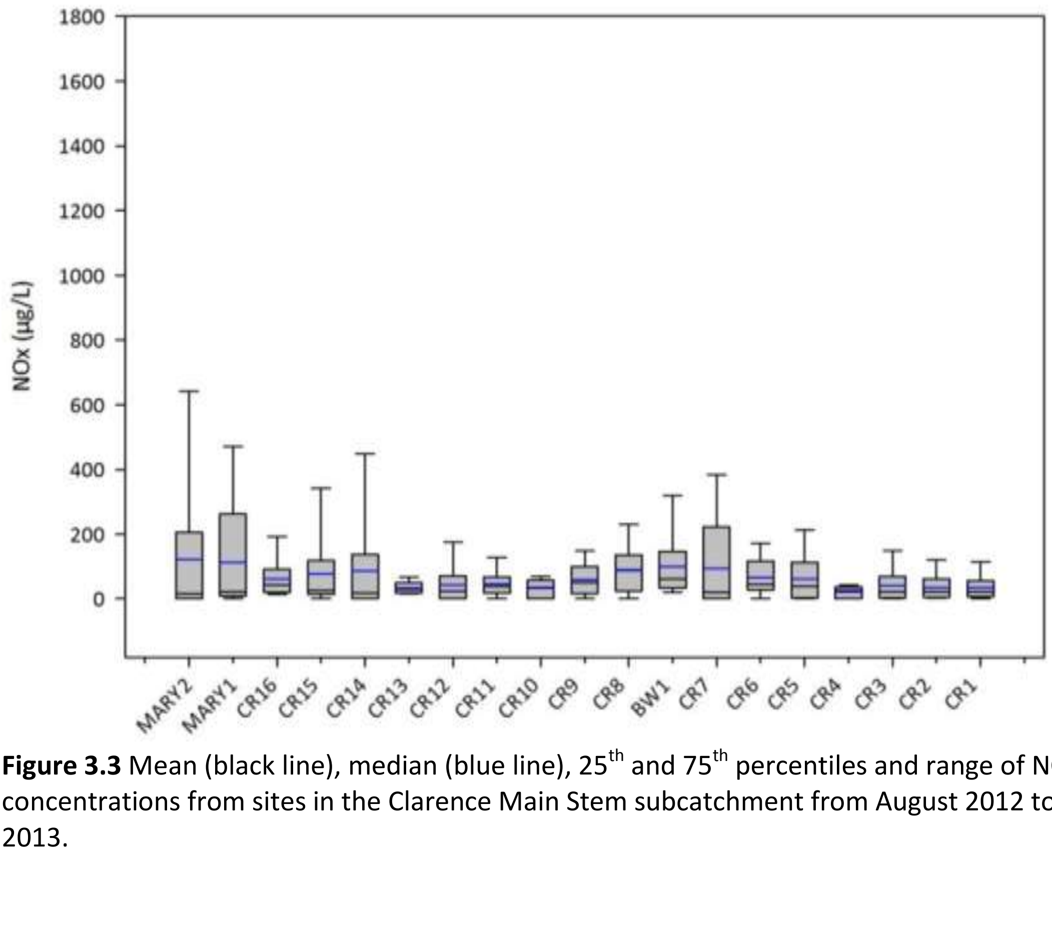


Figure 3.3 Mean (black line), median (blue line), 25th and 75th percentiles and range of NOx concentrations from sites in the Clarence Main Stem subcatchment from August 2012 to August 2013.

3.1.1.4 *Total Phosphorus (TP)*

Concentrations of TP in the Marylands River ranged from 1.00 µg/L (MARY1 in June 2013) to 128.00 µg/L (MARY1 in August 2012). Mean concentrations for both sites were below the exceedance trigger threshold of 50 µg/L for upland freshwater reaches (Figure 3.4). However, concentrations at both sites exceeded the trigger threshold in August 2012 (117.00 and 128.00 µg/L for MARY2 and MARY1, respectively).

In the freshwater reaches of the Clarence main stem (Figure 3.4), concentrations of TP ranged from <0.005 µg/L (CR16 in October 2012 and CR14 in December 2012) to 136.00 µg/L (CR12 in August 2012). Sites exceeded the freshwater trigger threshold of 50 µg/L either once in August 2012 (CR16 and CR13), or twice with a high exceedance in August 2012 and a much smaller exceedance in October 2012 (CR12) or July 2013 (CR15, CR14).

In the Clarence River estuary, TP concentrations ranged from <0.005 µg/L (CR10 in November 2012, CR8 and CR2 in September 2012, CR7 and CR5 in December 2012, and CR3 in September – December 2012), through to 187.00 µg/L (CR5 in August 2012). The majority of estuarine sites in the Clarence exceeded the estuarine trigger threshold of 30 µg/L once with a relatively large peak in August 2012 (ranging 137.00 µg/L at CR3 – 187.00 µg/L at CR5). Smaller exceedances (ranging 32.28 µg/L at CR8 – 66.42 µg/L at CR11) were observed in September 2012 (CR11, CR9, CR1), November 2012 (CR11, CR9, CR8) and August 2013 (CR8, CR7, CR5).

TP concentrations in BW1 ranged from 1.42 – 620.73 µg/L (mean of 146.41 µg/L). Half of the observed TP concentrations in BW1 exceeded the estuarine trigger threshold and these occurred from August 2012 – December 2012 peaking in December 2012.

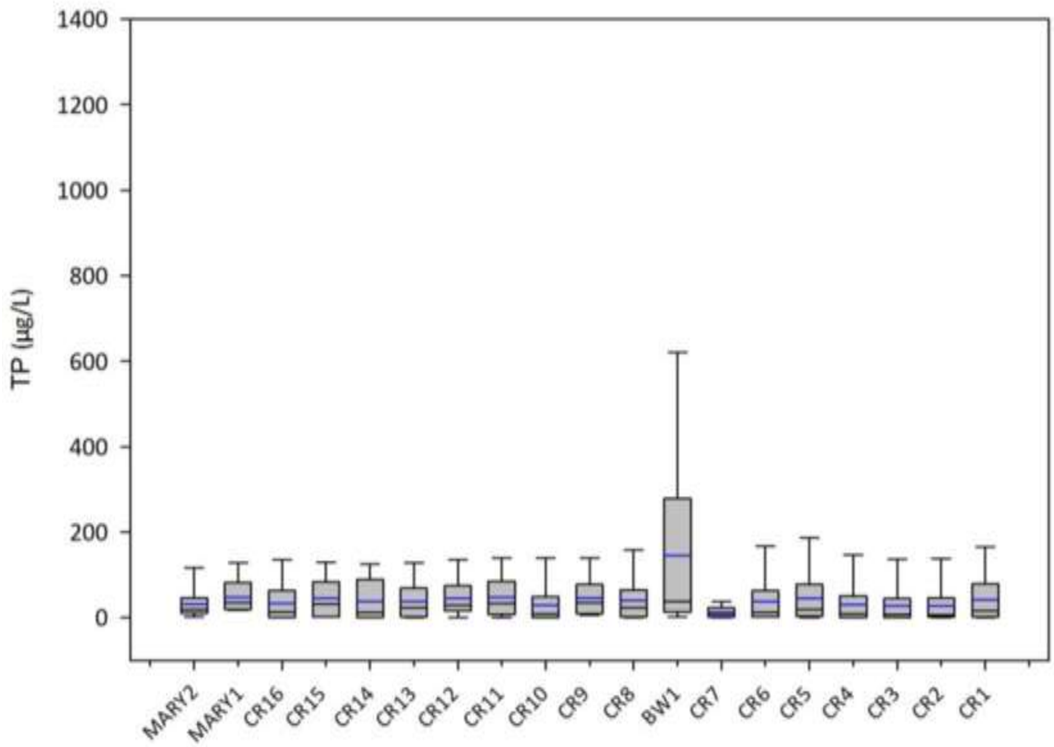


Figure 3.4 Mean (black line), median (blue line), 25th and 75th percentiles and range of TP concentrations from sites in the Clarence Main Stem subcatchment from August 2012 to August 2013.

3.1.1.5 *Soluble Reactive Phosphorus (SRP)*

Concentrations of SRP in the Marylands River (Figure 3.5) ranged from <0.005 µg/L (MARY2 in October 2012) to 37.46 µg/L (MARY2 in April 2013). Mean SRP concentration (averaged over all sampling occasions) was slightly greater in the downstream site (15.16 µg/L at MARY1) than the upstream site (12.13 µg/L at MARY2). The trigger threshold for upland freshwater reaches of 20 µg/L was exceeded at both sites in April 2013.

In the freshwater reaches of the Clarence River (Figure 3.5), SRP concentrations ranged from 0.02 µg/L (CR14 in April 2013) to 69.16 µg/L (CR13 in December 2012). There were two large exceedances of the freshwater trigger threshold of 20 µg/L in December 2012 (69.16 and 42.34 µg/Lat CR13 and CR12, respectively). This was the only recorded exceedance at both these sites. Lower exceedances were also observed in December 2012 at CR16 and CR15 (22.74 and 20.17 µg/L, respectively). SRP concentrations at CR16 also exceeded the trigger threshold in July 2013 (22.47 µg/L).

SRP concentrations in the estuarine reaches of the Clarence main stem (Figure 3.5) ranged from 0.66 µg/L (CR10 in September 2012) to 93.91 µg/L (CR9 in November 2012). Only four sites across the whole Clarence estuary recorded SRP concentrations below the estuarine trigger threshold of 5 µg/L: these occurred in September 2012 at CR10, CR8, CR4 and CR3. Hence, no mean site SRP concentrations were below the trigger value (mean concentrations ranged 13.33 – 25.83 µg/L at CR4 and CR9, respectively, Figure 3.5).

SRP concentrations at BW1 ranged from 3.32 (September 2012) – 61.86 µg/L (April 2013) with a site mean of 17.91 µg/L (Figure 3.5). SRP concentrations exceeded the estuarine trigger threshold from December 2012 to August 2013, peaking at 61.86 µg/L in April 2013.

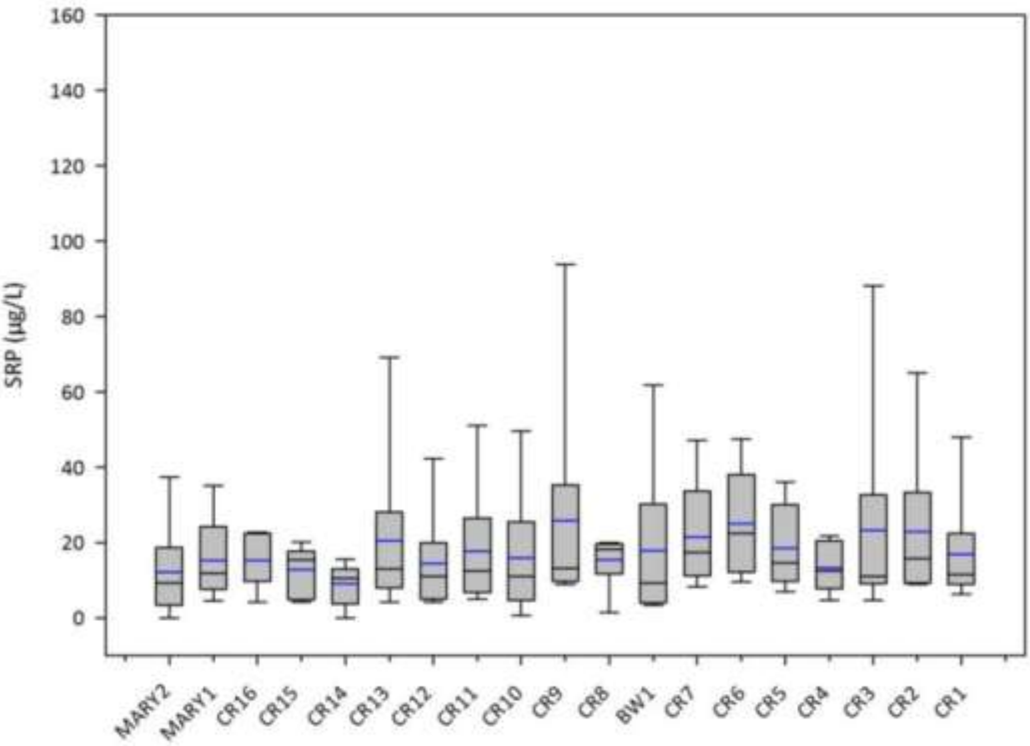


Figure 3.5 Mean (black line), median (blue line), 25th and 75th percentiles and range of SRP concentrations from sites in the Clarence Main Stem subcatchment from August 2012 to August 2013.

3.1.1.6 *Dissolved Oxygen (DO)*

Dissolved oxygen (DO) saturation in the Marylands River (Figure 3.6) ranged from 78.4 % (MARY2 in December 2012 and April 2013) to 122.9 % (MARY1 in October 2012). These minimum DO % saturations observed at MARY2 were below the lower upland freshwater trigger threshold of 80 %. DO % saturation also fell below the trigger threshold in April 2013 at MARY 1(78.6 %). Unlike MARY2 where no observations exceeded the upper trigger threshold of 110 %, DO % saturation in October 2012 at MARY1 exceeded the threshold (122.9 %).

In freshwater reaches of the Clarence River (Figure 3.6), DO % saturation ranged from 74.2 % (CR16 in April 2013) to 138.4 % (CR15 in December 2012). Although no site mean exceeded the trigger thresholds for freshwater reaches, both the lower and upper thresholds were exceeded several times. CR16-14 and CR12 exceeded the lower trigger threshold of 80 % in April 2013 (lowest observation was 74.2 % at CR16). DO % saturation exceeded the upper trigger threshold of 110 % in August 2012 (CR16, CR15, CR14, CR13 and CR12), December 2012 (CR16, CR15, CR13, CR12), July 2013 (CR12), and August 2013 (CR16, CR15, CR14, CR12).

DO % saturation was not measured in sites CR11-1 or BW1 that were sampled by boat.

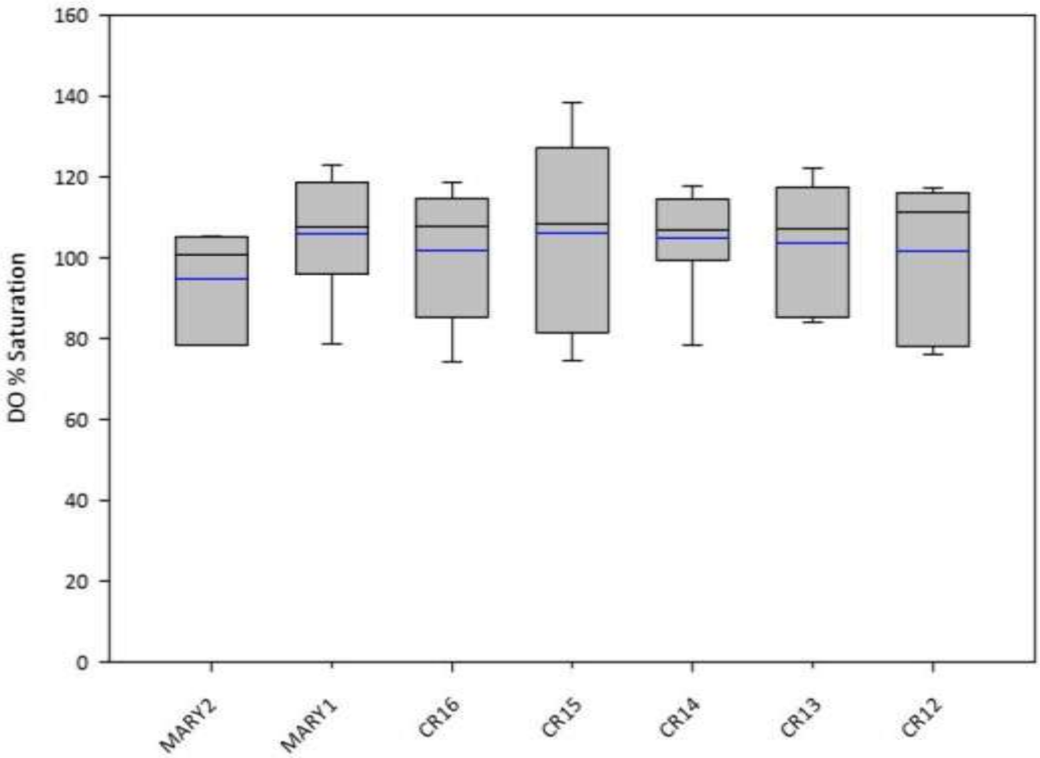


Figure 3.6 Mean (black line), median (blue line), 25th and 75th percentiles and range of DO saturation percentages from sites in the Clarence Main Stem subcatchment from August 2012 to August 2013.

3.1.1.7 *pH*

Mean pH was slightly higher at MARY1 than MARY 2 (5.60 and 8.41, respectively), but MARY2 experienced greater variability in pH values (7.64 – 9.49 and 8.17 – 9.09 for MARY2 and MARY1, respectively). No observed pH values in the Marylands River were more acidic than the lower trigger threshold for upland freshwater reaches (Figure 3.7). However, both Marylands sites exceeded the upper (alkaline) trigger threshold of 8.0: MARY2 in October and December 2012, and April and August 2013, and MARY1 was always more alkaline than the upper trigger threshold (Figure 3.7).

In the freshwater reaches of the Clarence River, pH consistently exceeded the upper trigger threshold of 8.0 for freshwater reaches (between 67 – 100 % of sampling periods). Consequently, mean site pH at all freshwater sites on the Clarence are greater than 8.0 (Figure 3.7). There are no clear longitudinal trends in pH along the freshwater reaches of the Clarence River.

pH patterns in the Clarence estuary show three noteworthy patterns. Firstly, pH dropped significantly at the tidal limit and continued to slightly decrease moving downstream to CR8 (upstream of Grafton, Figure 3.7). Secondly, BW1 had consistently higher pH (was more alkaline) than the adjacent upstream site (CR8), or most of the lower estuary. Thirdly, the marine influence clearly extended up the lower estuary as pH decreased with distance from the estuary mouth (Figure 3.7). Both the range and mean pH was lowest in the upper to mid estuary. The lower trigger threshold of 7.0 pH for estuarine reaches was exceeded three times in the Clarence estuary: at CR8 (pH of 6.12 in August 2012), at CR7 (pH of 6.30 in August 2012) and CR6 (pH of 5.59 in June 2013). The upper trigger threshold of 8.5 was exceeded more frequently: in December 2012 (8.76 at CR1), April 2013 (9.56 at CR1, 9.20 at CR2, 8.80 at CR3, and 8.69 at CR4), and August 2013 (9.285 at CR1, 9.08 at CR2, 8.83 at CR3, 8.58 at CR4, 8.99 at CR5, and 8.86 at CR10).

pH at BW1 never exceeded the lower trigger threshold for estuarine reaches (Figure 3.7). However, the upper trigger threshold was exceeded 44% of sampling periods, with the maximum pH of 10.44 recorded in April 2013. Nonetheless, the site mean of 8.28 was within the ANZECC and MER guidelines for estuarine reaches in Northern NSW.

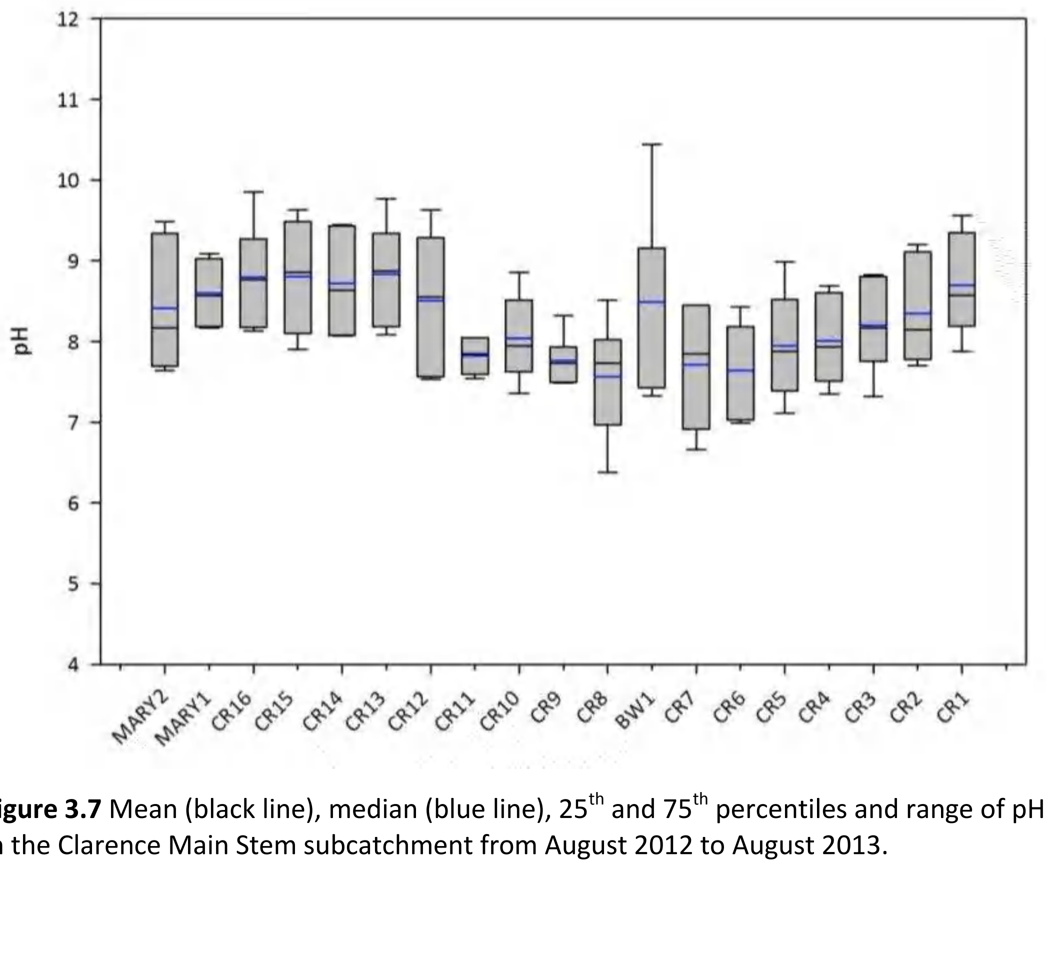


Figure 3.7 Mean (black line), median (blue line), 25th and 75th percentiles and range of pH from sites in the Clarence Main Stem subcatchment from August 2012 to August 2013.

3.1.1.8 *Turbidity*

Turbidity in the Marylands River ranged from 5.1 NTU (MARY1 in October 2012) to 42.5 NTU (MARY1 in June 2013). No turbidity measurements exceeded the upland freshwater trigger threshold of 50 NTU (Figure 3.8).Patterns in turbidity at MARY2 were similar to those of MARY1: a minimum in October 2012 (7.3 NTU), but the maximum turbidity of 39.3 NTU occurred in August 2013.

Turbidity is much greater in the freshwater reaches of the Clarence River than the estuarine reaches (Figure 3.8). Turbidity increases longitudinally downstream from CR 16 (mean of 24.42 NTU), to peak at CR14 (mean of 46.84 NTU), but then decreases (CR13 mean of 21.92 NTU and CR12 mean of 20.30 NTU). In July 2013, turbidity exceeded the trigger threshold of 50 NTU for freshwater reaches at CR16 (53.5 NTU), CR15 (60.1 NTU) and CR14 (185.00 NTU, Figure 3.8).

With the exception of sites CR5 (mean of 10.33 NTU) and BW1 (mean of 10.61 NTU), mean site turbidities in the Clarence estuary were below the trigger threshold of 10 NTU for estuarine reaches (Figure 3.8). Most turbidity exceedances occurred in August 2012 (CR7-CR4 and BW1 ranging from 13 – 17 NTU), and April 2013 (CR4, CR3 and BW1 ranging from 11 – 12 NTU).

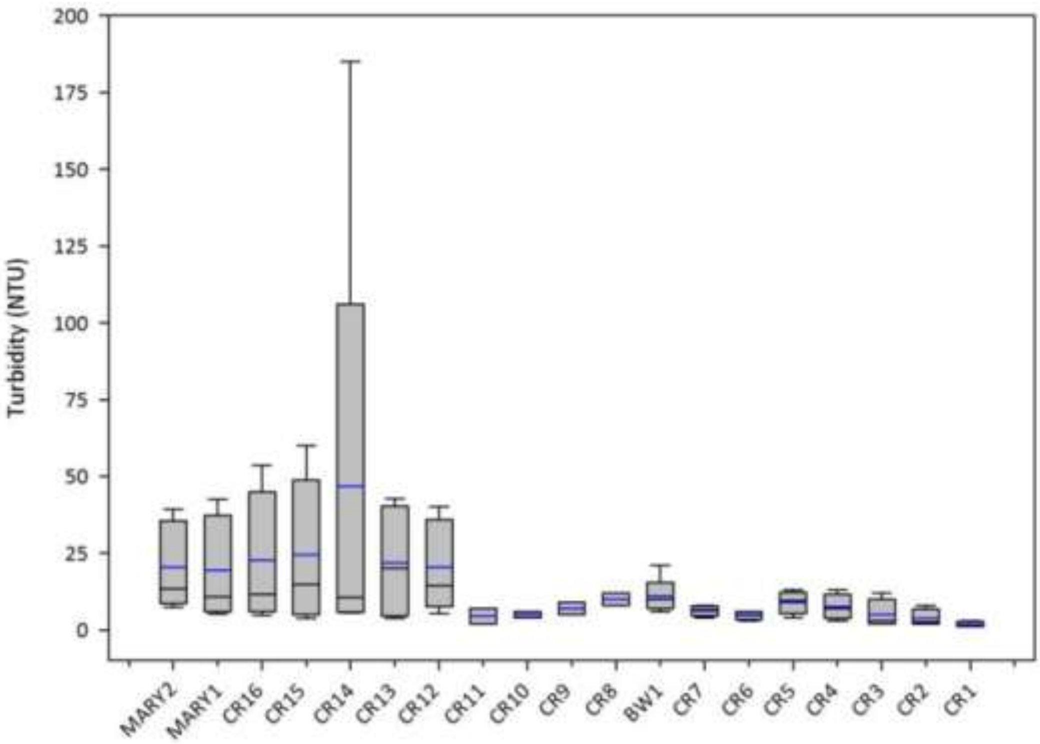


Figure 3.8 Mean (black line), median (blue line), 25th and 75th percentiles and range of turbidity from sites in the Clarence Main Stem subcatchment from August 2012 to August 2013.

3.1.1.9 *Water chemistry variables*

Table 3.1 provides the ranges of observed water temperatures, electrical conductivity, salinity, Secchi depth (for sites accessed by boat where a depth profile was taken) and total suspended sediments (TSS). The upstream site on the Marylands River, MARY2, was typically cooler and had lower conductivity and salinity, but had greater TSS (means of 5.00 and 3.52 g/L for MARY2 and MARY1, respectively). Conductivity at MARY1 exceeded the upper trigger threshold of 2.200 mS/cm for upland freshwater reaches in December 2012 (3.26 mS/cm).

There are no clear longitudinal trends in water temperature, electrical conductivity, salinity or TSS for the freshwater reaches of the Clarence (Table 3.1). Conductivity exceeded the lower trigger threshold of 0.125 mS/cm for freshwater reaches at CR14 (in April 2013) and CR12 (in April and July 2013, Table 3.1).

Conductivity decreased with distance from the mouth of the Clarence estuary (Table 3.1) and the observed salinity ranges suggest sampling occurred across the tidal period. Interestingly, peaks in mean site TSS concentrations do not closely follow the peaks in mean site turbidity. While turbidity is greatest in the freshwater sites CR16-14, TSS peaks at the tidal limit and upper estuary (sites CR12-10), and again at the estuary mouth (CR1, Table 3.1).

Table 3.1 Range of water chemistry variables at sites in the Clarence Main Stem.

Site	Water temp (°C)	Conductivity (mS/cm)	Salinity (ppt)	Secchi depth (m)	TSS (mg/L)
MARY2	9.9 - 23.5	0.161 - 0.202	0.08 - 0.10		1.58 - 14.28
MARY1	10.9 - 28.1	0.168 - 3.260	0.08 - 0.16		0.63 - 8.40
CR16	11.8 - 30.4	0.150 - 0.253	0.07 - 0.12		1.69 - 13.40
CR15	11.7 - 30.5	0.162 - 0.292	0.08 - 0.14		0.89 - 20.70
CR14	14.4 - 28.7	0.082 - 0.268	0.04 - 0.12		1.18 - 12.92
CR13	15.2 - 31.3	0.167 - 0.232	0.08 - 0.11		1.43 - 9.31
CR12	14.8 - 30.2	0.115 - 0.150	0.06 - 0.07		1.01 - 20.57
CR11	14.2 - 27.2	0.110 - 1.280	0.00 - 0.00	1.10 - 2.20	0.60 - 21.90
CR10	14.2 - 26.3	0.109 - 0.164	0.00 - 0.00	1.20 - 2.00	1.70 - 15.96
CR9	14.7 - 26.8	0.082 - 1.570	0.00 - 0.07	0.75 - 1.45	2.77 - 11.86
CR8	14.9 - 26.0	0.087 - 4.030	0.00 - 0.20	0.85 - 1.58	5.14 - 11.62
BW1	15.1 - 26.6	0.158 - 16.600		0.60 - 2.20	1.83 - 11.60
CR7	14.8 - 26.8	0.124 - 12.700	0.00 - 0.00	0.65 - 11.00	1.25 - 12.46
CR6	14.9 - 26.8	0.138 - 16.300		0.70 - 1.70	2.22 - 8.80
CR5	15.4 - 26.0	0.164 - 16.300		0.40 - 9.00	7.75 - 16.43
CR4	15.0 - 26.5	0.165 - 21.200		0.80 - 2.20	6.03 - 15.97
CR3	15.8 - 25.7	4.440 - 35.800		1.05 - 3.00	6.70 - 13.52
CR2	15.8 - 25.5	1.940 - 32.400		1.20 - 2.80	0.79 - 6.34
CR1	18.9 - 24.4	36.800 - 51.500		2.70 - 5.00	1.14 - 30.60

3.1.2 Transported loads of TSS, TN and TP

Peak low-flow discharge of 2,649 ML/day occurred during April 2013 at the upstream site on the Clarence River (CR15, a bedrock-controlled reach located at Hootens Road Bridge upstream of the Duck Creek confluence). This did not correlate with the peak TSS transport of 16.29 t/day (Figure 3.9a) as the latter occurred during June 2013 when discharge was 1,551 ML/day. However, TSS concentrations in June 2013 (10.50 mg/L) were almost double those in April 2013 (5.44 mg/L). Maximum TSS concentrations of 20.70 mg/L occurred in August 2013 when discharge was 391 ML/day. TSS loads at CR15 ranged from 0.152 t/day in December 2012 to 16.289 t/day in June 2013. The minimum TSS load correlated to the minimum mean daily discharge of 112 ML/day.

Total nutrient loads followed the temporal patterns in TSS loads at CR15 (Figure 3.9b). Minimum total nutrient transport of 1.099 kg TN/day and 0.003 kg TP/day (Figure 3.9b) occurred during the peak low-flow discharge in April 2013. Maximum total nutrient loads occurred in June 2013 when TSS loads peaked (1185.90 kg TN/day and 65.11 kg TP/day). Mean monthly nutrient loads were 265.93 kg TN/day and 24.36 kg TP/day.

The peak low-flow discharge (13,611 ML/day) at CR 12 (a discontinuous floodplain pocket reach located at Hieffer Station) also occurred during April 2013. Again, this did not correspond to peak TSS transport which occurred in June 2013 (139.37 t/day) when mean monthly discharge was 13,148 ML/day (Figure 3.10a). Temporal patterns in TSS concentrations were similar to CR15 where the maximum concentration of 20.57 mg/L occurred during the relatively low discharge of 2,084 ML/day. Minimum TSS transport (4.05 t/day) occurred during October 2012 (Figure 3.10a).

Total nutrient loads followed the temporal patterns in TSS loads at CR12 (Figure 3.10b). Minimum total nutrient transport of 7.548 kg TN/day and 0.007 kg TP/day occurred during the peak low-flow discharge in April 2013 (Figure 3.10b). Maximum total nutrient loads occurred in June 2013 when TSS loads peaked (6032 kg TN/day and 329 kg TP/day). Mean monthly nutrient loads were much greater in the downstream CR12 (1817 kg TN/day and 141 kg TP/day) than CR15. Interestingly, the proportion of TN to TP transported during the low flows from August – December 2012 is larger at CR12 than CR15, indicating a downstream increase in TN:TP transport that does not appear to extend beyond the 2012-2013 Austral summer.

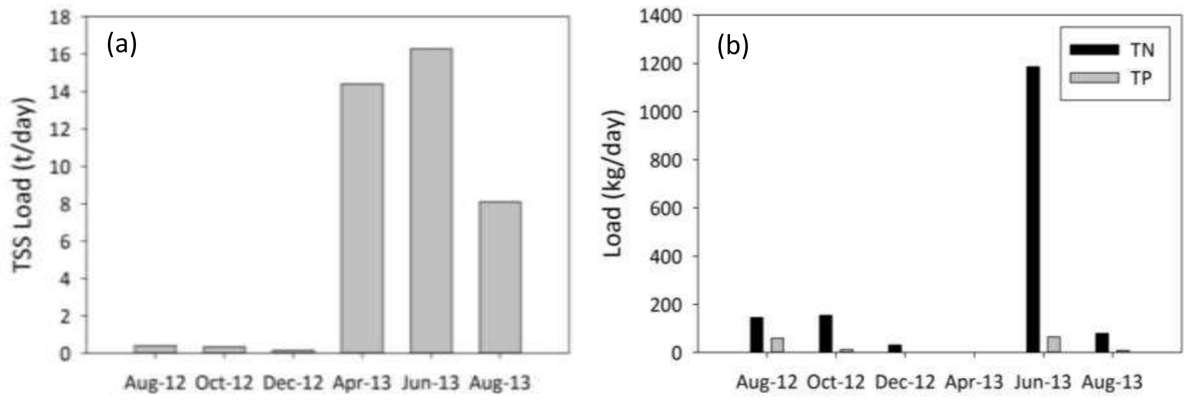


Figure 3.9 Loadings of (a) total suspended sediments and (b) TN and TP transported in the Clarence River at Site CR15 (Gauge 204007) from August 2012 to August 2013.

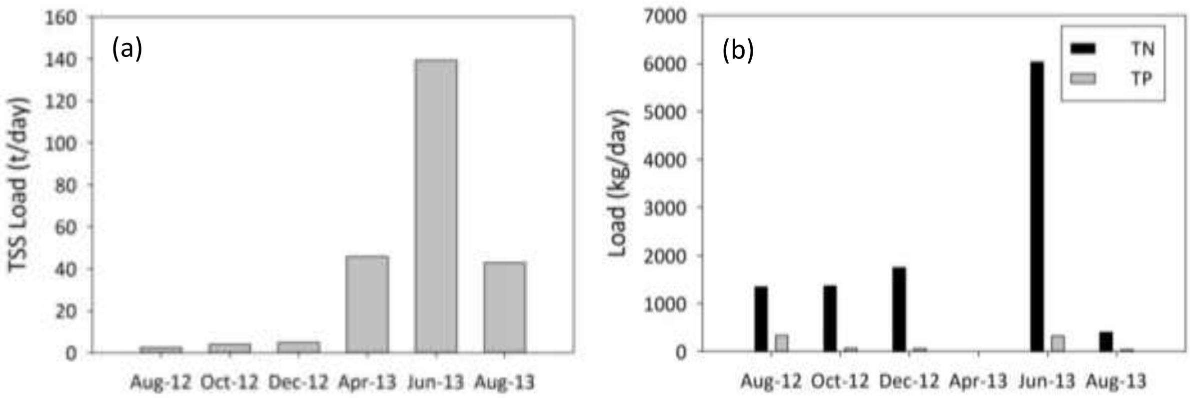


Figure 3.10 Loadings of (a) total suspended sediments and (b) TN and TP transported in the Clarence River at Site CR12 (Gauge 204007) from August 2012 to August 2013.

3.1.3 Macroinvertebrates

Thirty six macroinvertebrate families were recorded from Clarence River during the Autumn and Spring sampling in 2012-13, dominated by Trichoptera (Caddis Flies) with 9 families and Coleoptera (Beetles) with 5 families (Table 3.2). Family level richness was higher in Spring than Autumn due to the presence more Trichopteran, Ephemeropteran (Mayfly) and Dipteran families. The EPT index identifies approximately 42% of the families and 36% of the individuals recorded are from these families that require good habitat and water quality condition.

Of the 2401 individuals recorded from the Clarence River, more individuals (61.5%) were collected in Autumn potentially responding to post flood conditions compared to prolonged low flow conditions in Spring 2012. There was no clear longitudinal trend in the number of families recorded from each site, or patterns in the families present at each site. Family richness ranged from a high of 36 at CR13 to a low of 19 approximately 20km downstream at CR12. Chironomidae (midge larvae) and

Leptophlebiidae (mayfly nymph) were each dominant at 4 of the sites, and Palaemonidae and Atyidae shrimps found at 3 sites each along the Marylands-Clarence River system.

Mean SIGNAL2 score for the Marylands-Clarence River system was 4.4 with the scores ranging from 3.8 at the upper most site on the Marylands River to 4.8 at CR15 in the mid-reaches of the Clarence River. Chrinomidae and Atyidae each with a SIGNAL2 score of 3 were the most abundant taxa in 5 of the 7 sites (Table 3.2). Notonectidae (backswimmers) and Physidae (pond snails) with a SIGNAL2 score of 1 were present at all sites except CR15 contributing to lower overall scores. Helicophidae (caddis fly) was the only taxa found with a SIGNAL2 score of 10, recorded at MARY2 and CR14. The large range in SIGNAL2 scores in each site indicates a range of conditions were present throughout the river system that facilitated the occurrence of both pollution tolerant and pollution sensitive taxa.

Table 3.2 Macroinvertebrate richness, EPT richness, SIGNAL2 scores and dominant taxa at sites in the Marylands and Clarence Rivers. SIGNAL2 shown as mean value (range in brackets). The 5 numerically dominant taxa with greater than 10 individuals at each site are listed.

Site	No. Families	No. EPT families	SIGNAL2	Dominant taxa
MARY2	35	8	3.8(1-10)	Chironnomidae, Caenidae, Physidae, Leptophlebiidae, Corixidae
MARY1	30	10	4.6(1-8)	Chironnomidae, Gomphidae, Hydropsychidae, Elmidae
CR16	34	12	4.4 (1-8)	Atyidae, Hydropsychidae, Baetidae, Leptophlebiidae Philopotamidae
CR15	28	13	4.8(2-8)	Atyidae, Simuliidae, Hydropsychidae, Leptophlebiidae
CR14	34	12	4.5(1-10)	Atyidae, Calamoceratidae, Leptophlebiidae, Hydropsychidae, Atyidae
CR13	36	10	4.3(1-8)	Baetidae, Chironnomidae, Palaemonidae, Elmidae, Caenidae
CR12	19	6	4.1(1-8)	Hydrophilidae, Chironnomidae, Palaemonidae, Baetidae

3.1.4 Riparian condition

Riparian condition was better at the upstream (MARY2) than downstream site (MARY1) in the Marylands River (Table 3.3). This was driven by the vegetation composition, less disturbance and slightly better bank condition (Table 3.4). There were no clear longitudinal trends in vegetation composition, bank condition, habitat or disturbance in the freshwater reaches of the Clarence main stem (Table 3.3). While no site in the Clarence River scored well on all indices, high condition scores in vegetation composition are correlated with high habitat condition scores, and good bank condition scores are correlated with high disturbance scores (indicating limited disturbance, Table 3.3).

Table 3.3 Site level summary of riparian condition scores for Clarence River sites. Individual scores maximum of 5, total score out of 10.

	VEGETATION	BANK CONDITION	HABITAT	DISTURBANCE	Total/10
CR12	2.73	1.33	2.29	1.00	3.68
CR13	3.33	1.33	3.29	1.44	4.70
CR14	2.77	1.00	1.85	1.00	3.31
CR15	2.77	2.33	2.43	1.89	4.71
CR16	2.63	1.33	2.86	1.00	3.91
Mean	**2.29**	**1.46**	**2.54**	**1.27**	**4.06**
MARY1	2.50	2.00	2.95	1.00	4.23
MARY2	3.07	3.00	2.47	4.56	6.55
Mean	**2.79**	**2.50**	**2.71**	**2.78**	**5.39**

The vegetation community at all Clarence River sites was Weeping Bottlebrush shrubland; the Maryland River sites were dominated by River Oak (*Casuarina cunninghamiana*), either as River Oak – Weeping Bottlebrush layered woodland (MARY1) or River Oak grassy open Forest (MARY2, Table 3.6). Vegetation Condition index scores ranged from 2.50/5.00 to 3.33/5.00 (Table 3.4). The slightly higher index score for CR13 was a result of a few more large trees, and higher vegetation cover in all strata.

The midstorey on all Clarence River sites (Table 3.5) was dominated by Weeping Bottlebrush (*Callistemon viminalis*) with occasional regrowth River Oak (CR13), Cheese Tree (*Glochidion ferdinandi* var. *ferdinandi*) (CR13, CR15) or Sandpaper Fig (*Ficus coronata*) (CR13) but with no exotic woody plants present. Older Weeping Bottlebrush shrubs occurred at all but CR16 with stems wide enough at 1.3 m to be designated as Large Trees. The native grass Couch (*Cynodon dactylon*) was the only grass at all sites and there were no exotic grasses. Understorey native dominants included Common Rush (*Juncus usitatus*), Water Pepper (*Persicaria hyropiper*) and Creek Mat-rush (*Lomandra hystrix*). The exotic understorey species Fireweed (*Senecio madagascariensis*), Mexican Poppy (*Argemone ochroleuca* subsp. *ochroleuca*, Spear Thistle (*Cirsium vulgare*) and Blue Billygoat Weed (*Ageratum houstonianum*) occurred occasionally at most sites but in small numbers. The exotic vine Cat's Claw Creeper (*Dolichandra unguis-cati*, formerly *Macfadyena unguis-cati*) was present at two points at CR13.

The dominant midstorey species at the two Maryland River sites (Table 3.4) were Weeping Bottlebrush with regrowth River Oak (MARY1) or with sparse scattered Tantoon (*Leptospermum polgaliifolium* subsp. *cismontanum*), Blackthorn (*Bursaria spinosa* subsp. *spinosa*) and White Sally Wattle (*Acacia floribunda*). MARY1 had no exotic midstorey weeds; MARY2 had occasional small-leaved Privet (*Ligustrum sinense*). Native grasses present were Couch (MARY1) and Weeping Grass (*Microlaena stipoides*) (MARY2); exotics were Prairie Grass (*Bromus catharticus*) and Coolatai Grass (*Hyparrhenia hirta*). There was no native understorey at MARY1 but Creek Mat-rush (*Lomandra hystrix*) and young White Sally Wattle at MARY2. The exotic understorey species Fireweed (*Senecio madagascariensis*) and Spear Thistle (*Cirsium vulgare*) occurred occasionally at both sites with

Lantana (*Lantana camara*), Cobblers Pegs (*Bidens pilosa*) and Paddy's Lucerne (*Sida rhombifolia*) at MARY2 but in small numbers. The native vine Common Silkpod (*Parsonsia straminea)* and the exotic Moth Vine (*Araujia hortorum*) were seen at MARY2.

Bank Condition index scores were 3.00/5.00 at MARY2 and 2.00/5.00 at MARY1 (Table 3.4). This was predominantly due to fewer exposed tree roots in the banks at MARY2, and to a lesser degree due to less undercutting and slumping of banks. In the freshwater reaches of the Clarence River, Bank Condition index scores were below average, ranging from 1.00/5.00 at CR14 to 2.33/5.00 at CR15. The difference was driven by more exposed tree roots indicating greater bank erosion at CR14, and slightly less undercutting at CR15. However, all sites in the upper Clarence contained undercutting and slumping banks and exposed tree roots from bank erosion (Table 3.4).

MARY1 had higher Habitat index scores (2.95/5.00) than MARY 2 (2.47/5.00, Table 3.4). This was due to its relatively high numbers of standing dead trees, logs and fallen trees, and to a lesser extent, its reed habitats. In the Clarence River, site CR13 had the highest Habitat index score of all the sites (3.29/5.00, Table 3.4). This was predominantly due to the relatively high number of standing dead trees and reed habitat at the site and the absence of weed litter. The high score for standing dead trees was also correlated with moderate scores for logs and fallen trees. Conversely, site CR14 immediately upstream of CR13, had the lowest Habitat index score of all the sites in the Clarence main stem. This was due to the lack of trees, dead or alive, standing or fallen (Table 3.4). However, CR14 had an excellent reed habitat and lacked weed litter.

All sites in the Clarence River were highly disturbed (Table 3.4), as evidenced by tree clearing, the presence of stock or the absence of stock-exclusion fencing when the surrounding land use is grazing. In contrast, MARY2 was relatively undisturbed (4.56/5.00), with little evidence of recent tree clearing or the presence of stock (Table 3.4).

Table 3.4 Site level summary of riparian condition scores for each sub-index for Clarence and Maryland sites. Individual scores maximum of 5.

	CR12	CR13	CR14	CR15	CR16	MARY1	MARY2
Vegetation							
Large trees	1.00	1.33	1.00	1.00	1.00	1.00	1.00
Canopy Cover	1.00	2.33	1.33	1.00	1.00	1.00	2.00
Mid-storey Cover	4.33	4.33	4.33	5.00	3.00	2.33	3.00
Mid-storey Weeds	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Grass Cover	2.33	1.33	3.00	4.00	3.33	3.33	4.67
Grass Weeds	5.00	5.00	4.33	5.00	5.00	4.00	5.00
Understorey Cover	4.33	5.00	3.00	1.67	3.00	3.00	1.67
Understorey Weeds	1.33	3.33	2.33	1.67	2.33	2.00	3.00
Vines	1.00	2.33	1.00	1.00	1.00	1.00	2.33
Vegetation Layers	2.00	3.33	2.33	2.33	1.67	2.33	3.00
Total/5	**2.73**	**3.33**	**2.77**	**2.77**	**2.63**	**2.50**	**3.07**
Bank condition							
Undercutting	1.00	1.00	1.00	2.00	1.00	1.00	2.00
Exposed Tree Roots	2.00	2.00	1.00	4.00	2.00	4.00	5.00
Slumping	1.00	1.00	1.00	1.00	1.00	1.00	2.00
Total/5	**1.33**	**1.33**	**1.00**	**2.33**	**1.33**	**2.00**	**3.00**
Habitat							
Standing Dead Trees	0.00	5.00	0.00	0.00	5.00	5.00	5.00
Logs	1.00	3.00	1.00	2.00	3.00	4.00	2.00
Fallen Trees	3.00	3.00	0.00	3.00	0.00	3.00	0.00
Reeds	5.00	5.00	5.00	5.00	5.00	5.00	3.00
Large Trees	1.00	1.33	1.00	1.00	1.00	1.00	1.00
Organic Litter	1.00	1.33	1.00	1.00	1.00	1.00	1.33
Weed Litter	5.00	5.00	5.00	5.00	5.00	1.67	5.00
Total/5	**2.29**	**3.29**	**1.85**	**2.43**	**2.86**	**2.95**	**2.47**
Disturbance							
Tree Clearing	1.00	2.33	1.00	3.67	1.00	1.00	3.67
Fencing	1.00	1.00	1.00	1.00	1.00	1.00	5.00
Livestock	1.00	1.00	1.00	1.00	1.00	1.00	5.00
Total/5	**1.00**	**1.44**	**1.00**	**1.89**	**1.00**	**1.00**	**4.56**

Table 3.5 Dominant riparian vegetation for each stratum at Clarence River sites, CR12 to CR16. Emergents are large trees that rise above the tree canopy.

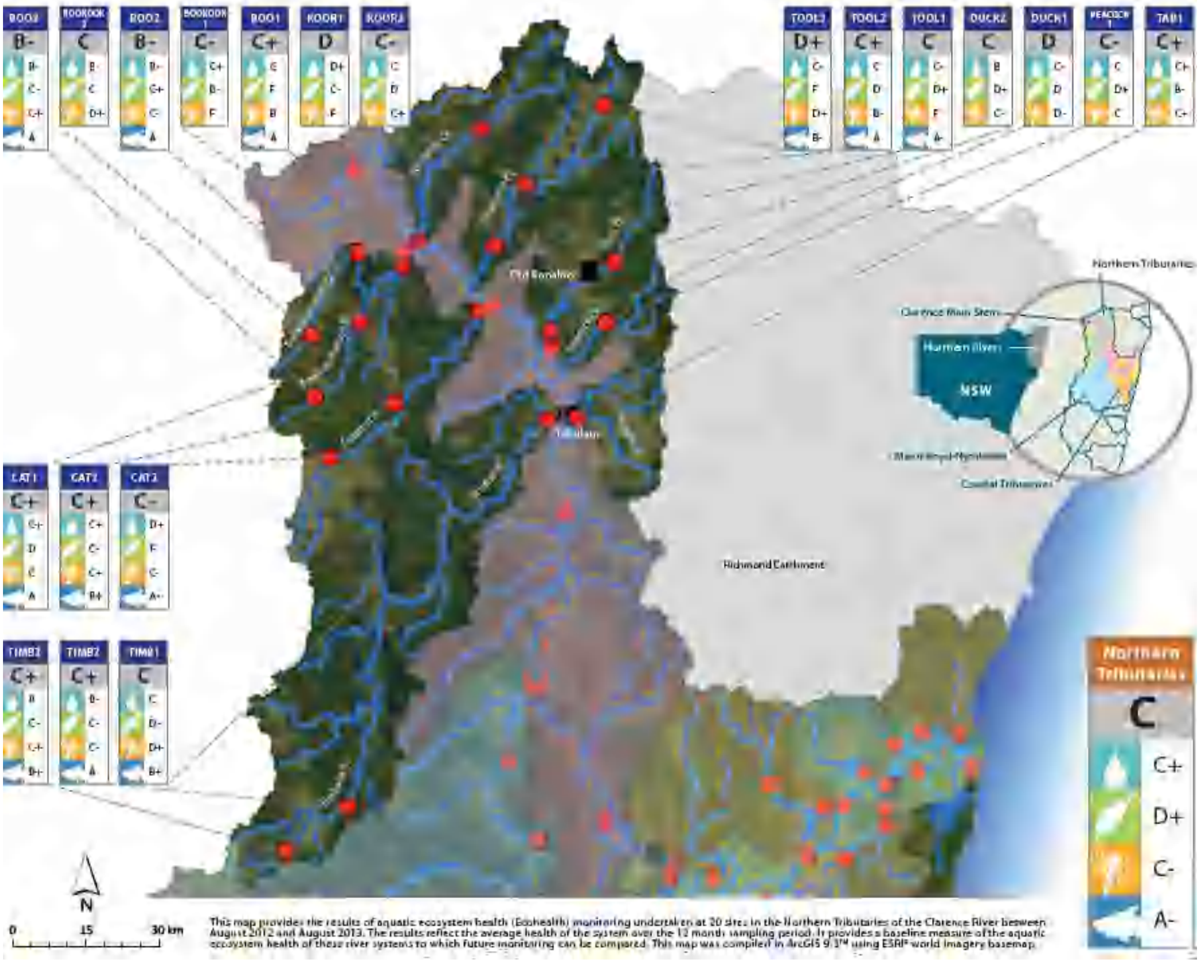
Vegetation Description	CR12	CR13	CR14	CR15	CR16
Left/Right bank (facing downstream)	L	L	R	R	L
Community Description	Weeping Bottlebrush Shrubland	Weeping Bottlebrush Shrubland	Weeping Bottlebrush Shrubland	Weeping Bottlebrush Shrubland	Weeping Bottlebrush Shrubland
Emergents	No emergents	No emergents	No emergents	No emergents	No emergents
Large Trees A	*Callistemon viminalis*	No large trees	No large trees	*Callistemon viminalis*	No large trees
Large Trees B	*Callistemon viminalis*	*Callistemon viminalis*	No large trees	*Callistemon viminalis*	no large trees
Large Trees C	*Callistemon viminalis*	*Callistemon viminalis*	*Callistemon viminalis*	*Callistemon viminalis*	No large trees
Mid-storey Cover (native)	*Callistemon viminalis*	*Callistemon viminalis*	*Callistemon viminalis*	*Callistemon viminalis*	*Callistemon viminalis*
	Waterhousea floribunda	*Casuarina cunninghamiana*		*Glochidion ferdinandi var. ferdinandi*	
		Ficus coronata			
		Glochidion ferdinandi var. ferdinandi			
Mid-storey Cover (weeds)	No midstorey weeds	No midstorey weeds	No midstorey weeds	No midstorey weeds	No midstorey weeds
Grass Cover (native)	*Cynodon dactylon*	*Cynodon dactylon*	*Cynodon dactylon*	*Cynodon dactylon*	*Cynodon dactylon*
Grass (weeds)	No grass weeds	No grass weeds	No grass weeds	No grass weeds	No grass weeds
Understorey Cover (native)	*Persicaria hydropiper,*	*Persicaria hydropiper*	*Juncus usitatus*	*Juncus usitatus,*	*Lomandra hystrix*
	Juncus usitatus	*Juncus usitatus*	*Persicaria hydropiper*	*Persicaria lapathifolia*	*Rumex brownii*
		Persicaria strigosa	*Ranunculus sessiliflorus*		
		Lomandra hystrix			
Understorey Cover (weeds)	*Cirsium vulgare*	*Cirsium vulgare*	*Cirsium vulgare*	*Senecio madagascariensis*	*Senecio madagascariensis*
	Senecio madagascariensis	*Senecio madagascariensis*	*Senecio madagascariensis*	*Argemone ochroleuca subsp. ochroleuca*	*Argemone ochroleuca subsp. ochroleuca*
	Ageratum houstonianum		*Argemone ochroleuca subsp. ochroleuca*		
Organic Litter (natives)				*Callistemon viminalis*	
Dominant Vines (exotic)	No vines	*Dolichandra unguis-cati*	No vines	No vines	No vines

Table 3.6 Dominant riparian vegetation for each stratum at Maryland River sites, MARY1 and MARY2. Emergents are large trees that rise above the tree canopy.

Vegetation Description	MARY1	MARY2
Left/Right bank (facing downstream)	L	R
Community Description	River Oak – Weeping Bottlebrush layered woodland	River Oak grassy open forest
Emergents	No emergents	No emergents
Dominant Large Trees A	No large trees	*Eucalyptus melliodora*
		Casuarina cunninghamiana
Dominant Large Trees B	No large trees	No large trees
Dominant Large Trees C	*Casuarina cunninghamiana*	*Casuarina cunninghamiana*
Dominant Mid-storey Cover (native)	*Callistemon viminalis*	*Casuarina cunninghamiana*
	Casuarina cunninghamiana	*Callistemon viminalis*
		Bursaria spinosa subsp. spinosa
		Leptospermum polygalifoium subsp. cismontanum
Dominant Mid-storey Cover (weeds)	No midstorey weeds	*Ligustrum sinense*
Dominant Grass Cover (native)	*Cynodon dactylon*	*Microlaena stipoides*
Dominant Grass Cover (weeds)	*Bromus catharticus*	*Hyparrhenia hirta*
Dominant Understorey Cover (native)	No native understorey	*Lomandra hystrix*
		Acacia floribunda
Dominant Understorey (weeds)	*Cirsium vulgare*	*Arauja hortorum*
	Senecio madagascariensis	*Bidens pilosa*
		Sida rhombifolia
		Lantana camara
Dominant Organic Litter (natives)		*Eucalypts, River Oak*
Dominant Vines (native)		*Parsonsia straminea*
Dominant Vines (exotic)	No vines	*Arauja hortorum*

3.2 Northern tributaries of the Clarence

Overview



The Northern tributaries region covers nine major river systems in catchments larger than 600km^2. Overall the region scored a grade of C, with excellent scores for fish communities, but lower scores for the other indicators.

Condition scores were highly variable within and among river systems in this region highlighting the influence of local conditions on the health of streams. At the river level, Boonoo Boonoo River scored the highest grade of a B- reflecting the large areas of conservation reserve in this catchment, to Koreelah Creek that has a predominantly cleared catchment and recorded a grade of a D+.

Water quality scores were also highly variable, ranging from a number of sites with a D+, to the Timbarra River and upper Duck Creek that received a grade of B. There were no trends of increasing nutrients or poor water quality along the rivers suggesting local sources are an important influence and driving the variability in water quality.

Concentrations of nitrogen and phosphorus consistently exceeded the guideline values throughout the study. The highest phosphorus concentrations were recorded during prolonged low flows suggesting instream sources, and the highest nitrogen concentrations were recorded following high flows suggesting catchment runoff as the main source.

No algal blooms were recorded during the study. However, a number of sites had levels of algae above guideline values; including the upper Bookookoorara Creek, upper Koreelah Creek, Tooloom Creek and lower Timbarra River.

Aquatic macroinvertebrate communities were consistently in poor condition and dominated by organisms tolerant of poor water quality and poor habitat. Examples of the importance of habitat for macroinvertebrates is the Bookookoorara Creek that recorded a B- and good water quality but a D+ and very poor macroinvertebrate condition. Macroinvertebrate condition improved after flooding suggesting they are more affected by prolonged periods of low flows than floods.

Fish communities throughout the Northern tributaries region were in excellent condition with for all sites recording an A or B grade. All sites were dominated by diverse communities of native fish.

Riparian condition was generally low from a poor diversity of native vegetation, reduced vegetation structure, generally occurring in isolated pockets with poor connectivity to other native vegetation, and evidence of eroding river banks and sediment deposited in the channel.

3.2.1 Water chemistry

3.2.1.1 *Chlorophyll a*

Mean chlorophyll *a* concentrations in Bookookooara Creek were 0.42 µg/L at the upstream site BOOKOOK2 and 2.70 µg/L at the downstream site BOOKOOK1 (Figure 3.11). Minimum concentrations occurred varied temporally: at BOOKOOK2, <0.005 µg/L chl-*a* was observed August – October 2012 and at BOOKOOK1, 0.22 µg/L occurred in October 2012. Maximum concentrations (0.97 and 9.06 µg/L at BOOKOOK2 and BOOKOOK1, respectively) occurred in August 2013. The maximum concentration observed at BOOKOOK1 was the only exceedance of the upland freshwater trigger threshold of 4.00 µg/L.

Chlorophyll *a* concentrations in the Boonoo Boonoo River ranged from <0.005 – 2.09 µg/L with site mean concentrations increasing slightly with distance downstream (0.54 µg/L at BOO3, 0.59 µg/L at BOO2 and 0.64 µg/L at BOO1 (Figure 2.1). Chlorophyll *a* concentrations in the Boonoo Boonoo River remained below recommended trigger thresholds.

Mean chl-*a* concentrations in Koreelah Creek were 2.13 µg/L at KOOR2 and 0.85 µg/L at KOOR 1 (Figure 2.1). Minimum concentrations of <0.005 µg/L at both sites occurred during October 2012. However, maximum concentrations varied temporally: in August 2013 at KOOR 2 (5.03 µg/L) and in December 2012 at KOOR1 (1.76 µg/L). The maximum concentration observed at KOOR2 was the only exceedance of the upland freshwater trigger threshold.

In Tooloom Creek, chl-*a* ranged from a minimum of 0.11 µg/L at TOOL2 (in August 2012) to a maximum of 7.01 µg/L at TOOL1 observed in August 2013 (Figure 2.1). Site mean concentrations ranged from 1.56 µg/L at TOOL2 to 2.03 µg/L at TOOL3. Chl-*a* concentrations exceeded upland trigger thresholds once at TOOL3 (5.85 µg/L in August 2012) and once at TOOL1 (7.01 µg/L in August 2013).

Chlorophyll *a* concentrations were also low in the Cataract River (Figure 2.1), ranging from 0.22 µg/L at CAT3 (October 2012) and CAT2 (August 2012), to 4.18 µg/L at CAT2 (December 2012). Mean site concentrations ranged from 0.63 µg/L at CAT1 to 1.18 µg/L at CAT2. The maximum observation of 4.18 µg/L was the only exceedance of the upland trigger threshold.

Chl-*a* concentrations were similar in Duck Creek, with site means of 1.60 µg/L at DUCK2 and 1.05 µg/L at DUCK1. Measurements ranged from 0.22 µg/L at DUCK1 (August 2012) to 5.50 µg/L at DUCK2 (Ocotober 2012). This maximum observation was the only exceedance of the freshwater trigger threshold.

Concentrations of chl-*a* were very low in Peacock Creek, ranging from 0.11 µg/L (October 2012) to 0.77 µg/L (December 2012) with PEACOCK1 having a site mean of 0.41 µg/L. These observations were below the upland freshwater trigger threshold. Low concentrations were also observed in Tabulam River albeit over differing temporal patterns. Concentrations at TAB1 ranged from

<0.005 µg/L (October 2012) to 2.31 µg/L (August 2012), with a site mean of 0.71 µg/L (Figure 2.1). These observations were also below the lowland freshwater trigger threshold of 4.00 µg/L.

Mean site concentrations of chl-*a* increased longitudinally downstream in the Timbarra River (Figure 2.1), from 0.36 µg/L at TIMB3, 0.74 µg/L at TIMB2 and 1.81 at TIMB1. Minimum concentrations of <0.005 µg/L were observed at all sites (in August 2012 for TIMB2 and October 2012 for TIMB3 and TIMB1). Maximum concentrations ranged from 1.20 µg/L at TIMB3 (June 2013) and TIMB2 (April 2013) to 7.70 µg/L at TIMB1 (April 2013). This maximum concentration was the only exceedance of the lowland freshwater trigger threshold.

Generally for the northern tributaries, chl-*a* concentrations were highest in Tooloom Creek, although the most downstream sites in Bookookooara Creek and Timbarra River also had high concentrations at individual sampling periods.

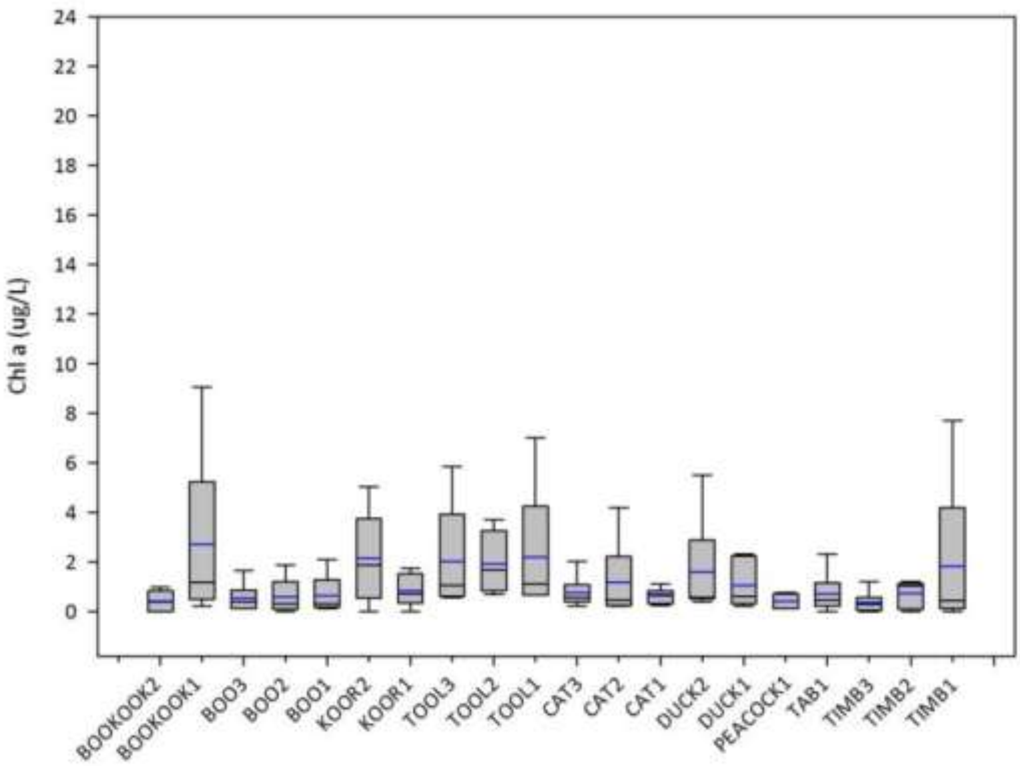


Figure 3.11 Mean (black line), median (blue line), 25th and 75th percentiles and range of chlorophyll *a* concentrations from sites in the northern tributaries of the Clarence from August 2012 to August 2013.

3.2.1.2 *Total Nitrogen (TN)*

Mean TN concentrations in Bookookooara Creek ranged from 555.30 µg/L at BOOKOOK1 to 590.17 µg/L at BOOKOOK2 (Figure 3.12). These exceeded the upland freshwater trigger threshold of 500 µg/L. Concentrations ranged from 9.85 µg/L at BOOKOOK1 (October 2012) to 1050.00 µg/L at BOOKOOK2 (December 2012). Concentrations exceeded the trigger threshold 50 % of sampling occasions at BOOKOOK2 and 67 % of sampling occasions at BOOKOOK1.

TN concentrations were similarly high in Boonoo Boonoo River. Site means were 656.16 µg/L at BOO3, 540.89 µg/L at BOO2 and 677.87 µg/L at BOO1 and these all exceeded the upland freshwater trigger threshold (Figure 3.12). Concentrations in the Boonoo Boonoo River were most variable at Site BOO3, and concentrations for the site and river ranged from 9.85 µg/L in October 2012 to 1957.89 µg/L in December 2012. The trigger threshold was exceeded in 50 % of sampling occasions at BOO3 and BOO2, and 75 % of sampling occasions at BOO1.

TN concentrations in Koreelah Creek were the highest observed for the northern tributaries subcatchment. Site mean concentrations were 996.93 µg/L at KOOR2 and 1558.98 µg/L at KOOR 1, the latter site also being the most variable (minimum of 9.85 µg/L in October 2012 and maximum of 3972.01 µg/L in April 2013,Figure 3.12). Site means exceeded the upland freshwater trigger threshold for both sites in Koreelah Creek and observed concentrations exceeded the trigger threshold for 50 % and 67 % of sampling periods at KOOR2 and KOOR1, respectively.

The mean and range of TN concentrations decreased longitudinally downstream Tooloom Creek (Figure 3.12). Site means ranged from 564.29 µg/L at TOOL3, 491.34 µg/L at TOOL2 and 415.05 µg/L at TOOL3. All site means exceeded the upland freshwater trigger threshold and observed concentrations exceeded the trigger threshold in two sampling periods (33 %) at all sites. TN concentrations ranged from 34.46 µg/L (TOOL2 in August 2012) to 1339.47 µg/L (TOOL2 in December 2012). Minimum and maximum TN concentrations were temporally similar at TOOL3 and TOOL2 (August 2012 and December 2012, respectively), but not TOOL1 (October 2012 and June 2013, respectively).

There was no clear longitudinal trend in TN concentrations in the Cataract River (Figure 3.12). Site mean concentrations were 485.40 µg/L at CAT3, 401.16 µg/L at CAT2 and 851.14 µg/L at CAT1. TN concentrations were most variable at CAT1, and ranged from 65.65 µg/L (October 2012) to 3399.91 µg/L (June 2013) for the site and river system. Upland freshwater trigger thresholds were exceeded in 50 % of sampling periods at CAT3 (December 2012 – June 2013), and 33 % of sampling periods at CAT 2 and CAT1 (April 2013 – June 2013 for both).

In Duck Creek, the site mean TN concentration was higher at the downstream site, DUCK1 (430.86 µg/L) than the upstream site, DUCK 2 (257.73 µg/L). Concentrations were more variable at DUCK2 (Figure 3.12) , ranging from 0.47 µg/L (April 2013) to 760.53 µg/L (October 2012). TN concentrations exceeded the upland freshwater trigger threshold once at DUCK2 (in October 2012), and twice at DUCK1 (in December 2012 and June 2013, the latter was 702.94 µg/L which was the maximum concentration recorded for the site).

The site mean TN concentration in Peacock Creek was 575.53 µg/L. Concentrations ranged from 125.56 µg/L in August 2013 to 995.96 µg/L in April 2013 (Figure 3.12). TN concentrations exceeded the upland freshwater trigger threshold 60 % of sampling periods from October 2012 – April 2013. The mean site TN concentration for Tabulam River was 397.22 µg/L. Concentrations ranged from 9.85 µg/L in October 2012 to 882.00 µg/L in April 2013. The lowland freshwater trigger threshold was exceeded on two sampling occasions (33 %) in April – June 2013.

Site mean TN concentrations increased longitudinally in the Timbarra River (Figure 3.12), ranging from 383.06 µg/L in TIMB3, 483.53 µg/L in TIMB2 and 659.82 µg/L in TIMB1. Variability in concentrations also increased downstream, ranging 31.73 – 806.81 µg/L in TIMB3 to 217.71 – 1747.37 µg/L in TIMB1. Freshwater trigger thresholds were exceeded once at TIMB3 (in April 2013), three times at TIMB2 (December 2012 – June 2013), and twice at TIMB1 (April – June 2013).

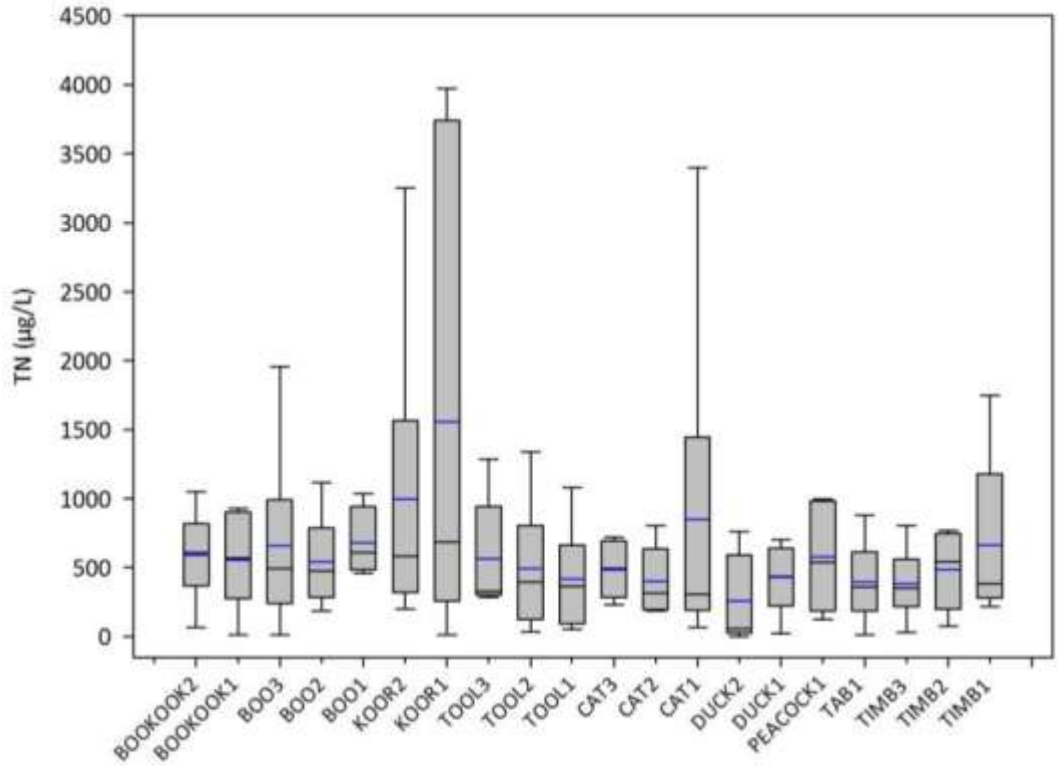


Figure 3.12 Mean (black line), median (blue line), 25th and 75th percentiles and range of TN concentrations from sites in the northern tributaries of the Clarence from August 2012 to August 2013.

3.2.1.3 *Bioavailable Nitrogen (NOx)*

Patterns in NOx concentrations did not follow TN concentrations. In Bookookooara Creek, the site mean NOx concentration was lower at the downstream site BOOKOOK1 (25.18 µg/L) than the upstream site BOOKOOK2 (72.13 µg/L). Concentrations ranged from <0.005 µg/L observed in

October 2012 at both sites, to 341.88 µg/L observed in December 2012 at BOOKOOK2 (Figure 3.13). Concentrations exceeded the freshwater trigger threshold twice during December 2012 – April 2013 at both sites.

There was no longitudinal trend in NOx concentrations in the Boonoo Boonoo River (Figure 3.13). Site mean concentrations ranged from 59.76 µg/L at BOO3, 39.82 µg/L at BOO2 and 53.64 µg/L at BOO1. Concentrations were most variable at BOO3, and site and river concentrations ranged from <0.005 µg/L in October 2012, to 213.68 µg/L in December 2012. Site mean concentrations at BOO3 and BOO1 exceeded the freshwater trigger threshold. Concentrations exceeded the trigger threshold in two sampling periods at all sites (December 2012 and August 2013 for BOO3 and BOO1, and December 2012 and April 2013 for BOO2).

In Koreelah creek, the site mean NOx concentration was higher at the upstream site KOOR2 (80.65 µg/L) than the downstream site KOOR1 (37.29 µg/L,Figure 3.13). KOOR2 also had more variability in NOx concentrations, ranging from <0.005 µg/L in October 2012 to 363.25 µg/L in December 2012). Despite the increased variability observed at KOOR2, concentrations only exceeded the upland freshwater trigger threshold once (in December 2012). In contrast, concentrations at KOOR1 exceeded the trigger threshold for 3 sampling periods (50 %) during December 2012 – June 2013.

There were no longitudinal trends in NOx concentrations in Tooloom Creek (Figure 3.13). Site mean concentrations ranged from 49.65 µg/L at TOOL3, 208.94 µg/L at TOOL2 and 35.53 µg/L at TOOL1. Concentrations were most variable at TOOL2, where the minimum and maximum concentrations for the river were observed (<0.005 and 1068.38 µg/L, respectively). NOx concentrations exceeded upland freshwater trigger thresholds three times at TOOL3 (December 2012 – June 2013) and TOOL2 (December 2012, June – August 2013), and twice at TOOL1 (June – August 2013).

NOx concentrations increased slightly with distance downstream in the Cataract River (Figure 3.13). Site means ranged from 26.09 µg/L at CAT3, 33.89 µg/L at CAT2 and 40.98 µg/L at CAT1. Concentrations ranged from <0.005 µg/L at CAT3 (October – December 2012) to 179.03 µg/L at CAT1 (October 2012). Upland freshwater trigger thresholds were exceeded on two sampling occasions (33 %) at CAT3 (April 2013 and August 2013) and CAT 2 (December 2012 and April 2013), and once at CAT1 (October 2012).

Site mean concentrations and variability were less at the downstream site (41.30 µg/L at DUCK1) than the upstream site (86.42 µg/L at DUCK2) in Duck Creek (Figure 3.13). Concentrations ranged from <0.005 µg/L in October at DUCK1 to 384.62 µg/L in October at DUCK2. The freshwater trigger threshold was exceeded once at DUCK2 (in October 2012) and twice at DUCK1 (December 2012 with 149.57 µg/L, and June 2013).

NOx concentrations ranged from <0.00 µg/L (December 2012) to 84.17 µg/L (April 2013) in Peacock Creek (PEACOCK1 site mean of 24.54 µg/L,Figure 3.13). Observed concentrations exceeded the upland freshwater trigger threshold once in April 2013. NOx concentrations in Tabulam River also exceeded the (lowland) freshwater trigger threshold once (in December 2012). The site mean concentration at TAB1 was 41.22 µg/L, with concentrations ranging from 1.82 µg/L in October 2012 to 170.94 µg/L in December 2012 (Figure 3.13).

There was no clear longitudinal trend in NOx concentrations in the Timbarra River (Figure 3.13). Site means ranged from 55.33 µg/L at TIMB3, 148.19 µg/L at TIMB2 and 7.17 µg/L at TIMB1. Concentrations ranged from <0.005 µg/L at TIMB2 and TIMB3 in October 2012 to 811.97 µg/L at TIMB2 (in December 2012). However, the frequency of exceeding the trigger threshold decreased downstream: all concentrations at TIMB1 were below the trigger threshold, concentrations at TIMB2 exceeded the threshold twice (December 2012 – April 2013), and concentrations at TIMB3 exceeded the threshold three times (October – December 2012 and June 2013).

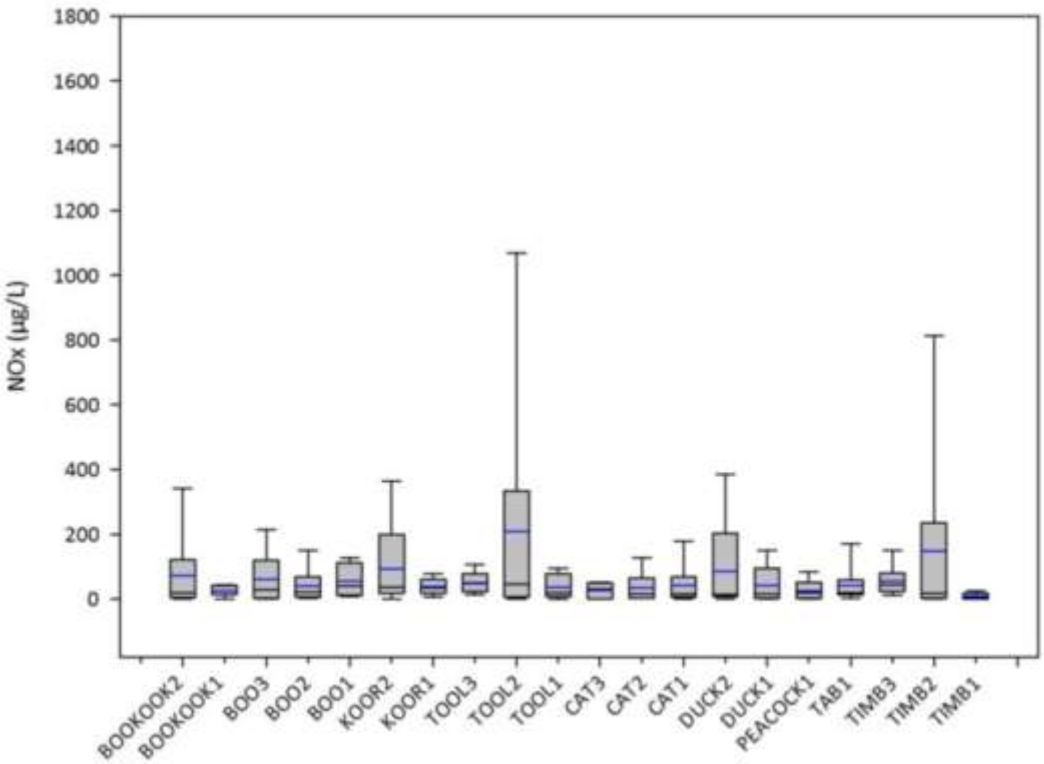


Figure 3.13 Mean (black line), median (blue line), 25th and 75th percentiles and range of NOx concentrations from sites in the northern tributaries of the Clarence from August 2012 to August 2013.

3.2.1.4 *Total Phosphorus (TP)*

In Bookookooara Creek, site mean concentrations of TP were 30.55 µg/L at the upstream site BOOKOOK2 and 25.18 µg/L at the downstream site BOOKOOK1 (Figure 3.14). Concentrations ranged from <0.005 µg/L in October 2012 at both sites to 135.00 µg/L at BOOKOOK2 in December 2012. Concentrations exceeded the upland freshwater trigger threshold once in August 2012 at both site.

There was no clear longitudinal trend in TP concentrations in Boonoo Boonoo River (Figure 3.14). Site means ranged from 42.02 µg/L at BOO3, 32.27 µg/L at BOO2 and 44.63 µg/L at BOO1. Concentrations ranged from 0.62 µg/L at BOO2 (December 2012) to 135.00 µg/L at BOO1 (August

2012). At BOO3, concentrations exceeded the upland freshwater trigger threshold twice in August – October 2012. At BOO2 and BOO1, the trigger threshold was exceeded once, both in August 2012.

TP concentrations were very similar at both sites in Koreelah Creek (Figure 3.14). Site means were 47.43 µg/L at KOOR2 and 54.66 µg/L at KOOR1. Concentrations ranged from <0.005 µg/L at KOOR2 in October 2012 to 142.00 µg/L at KOOR1 in August 2012. The upland freshwater trigger threshold was exceeded twice at KOOR2 (August 2012 and June 2013), and three times (50 % of sampling periods) at KOOR1 (August – October 2012 and June 2013).

There were no clear longitudinal trends in TP concentrations in Tooloom Creek (Figure 3.14). Site means ranged from 50.62 µg/L at TOOL3, 41.33 µg/L at TOOL2 and 51.53 µg/L at TOOL1. Concentrations ranged from 4.42 µg/L at TOOL2 (October 2012) to 118.00 µg/L at TOOL3 (August 2012). This concentration of 118.00 µg/L at TOOL3 was the only exceedance of the upland freshwater trigger threshold (in August 2012). The maximum concentration of 108.00 µg/L observed in August 2012 was the only exceedance at TOOL2. However, concentrations at TOOL1 exceeded the trigger threshold twice in August 2012 (112.00 µg/L) and June 2013 (64.04 µg/L).

TP concentrations decreased longitudinally downstream in the Cataract River (Figure 3.14). Site means ranged from 63.18 µg/L at CAT3, 41.85 µg/L at CAT2 and 25.67 µg/L at CAT1. Concentrations in the Cataract River ranged from 0.52 µg/L at CAT1 (April 2013) to 136.00 µg/L at CAT3 (August 2012). Corresponding to the decreasing longitudinal TP concentrations, there was only one exceedance of the upland freshwater trigger threshold at CAT1 (111.00 µg/L in August 2012). The trigger threshold was exceeded twice at CAT2 (94.00 µg/L in August 2012 and 61.17 µg/L in April 2013), and four times at CAT3 (August 2012 – April 2013.

TP concentrations were much higher at the downstream than upstream site in Duck Creek (Figure 3.14). Site means were 14.51 µg/L at DUCK2 and 52.53 µg/L at DUCK1. Concentrations ranged 0.06 µg/L (April 2013) to 20.77 µg/L (August 2013) at DUCK2, and 17.57 µg/L (August 2013) to 124.00 µg/L (August 2012) at DUCK1. Concentrations at DUCK2 did not exceed the freshwater trigger threshold, but the trigger threshold was exceeded twice at DUCK1 (August – October 2012).

TP concentrations ranged 9.55 µg/L (April 2013) to 550.59 µg/L (December 2012) in Peacock Creek. The site mean was 136.00 µg/L. The upland freshwater trigger threshold was exceeded twice in October – December 2012 (50.73 and 550.59 µg/L, respectively). This site had the largest variability in and median TP concentration in the northern tributaries subcatchment (Figure 3.14). TP concentrations were much lower in the Tabulam River (Figure 3.14), with a site mean at TAB1 of 39.22 µg/L. Concentrations at TAB1 ranged 8.07 µg/L (December 2012) to 131.00 µg/L (August 2012). The lowland freshwater trigger threshold was exceeded twice, in August 2012 and June 2013.

There was no clear longitudinal trend in TP concentrations in the Timbarra River (Figure 3.14). Site means ranged from 34.09 µg/L at TIMB3, 30.67 µg/L at TIMB2 and 42.91 µg/L at TIMB1. Concentrations in the Timbarra River ranged <0.005 µg/L (all sites in December 2012) to 145.00 µg/L at TIMB3 in December 2012. At TIMB3 and TIMB2, TP concentrations exceeded the freshwater trigger thresholds once in August 2012. Concentrations at TIMB1 exceeded the trigger thresholds twice, in August – October 2012.

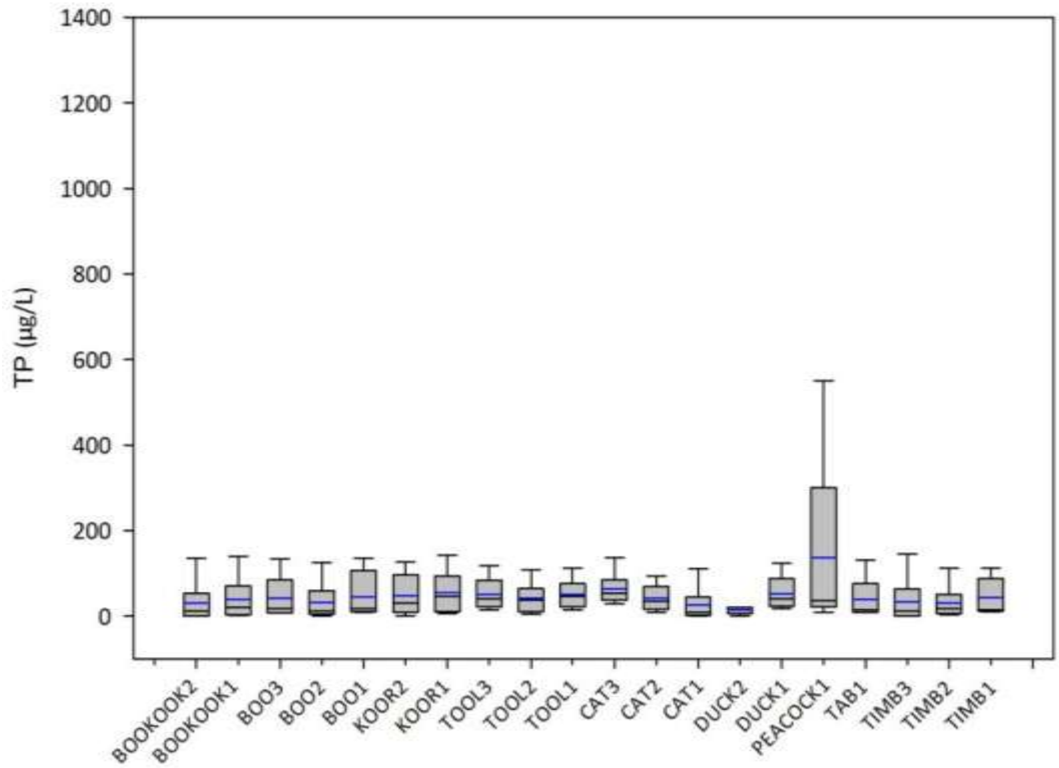


Figure 3.14 Mean (black line), median (blue line), 25^{th} and 75^{th} percentiles and range of TP concentrations from sites in the northern tributaries of the Clarence from August 2012 to August 2013.

3.2.1.5 *Soluble Reactive Phosphorus (SRP)*

Concentrations of soluble reactive phosphorus (SRP) increased with distance downstream in Bookookooara Creek (Figure 3.15). Site means were 14.88 µg/L at BOOKOOK2 and 20.46 µg/L at BOOKOOK1. Concentrations ranged from 6.30 – 28.42 µg/L at BOOKOOK2, only exceeding the upland freshwater trigger threshold once in December 2012. At BOOKOOK1, concentrations ranged from 7.62 – 49.56 µg/L, exceeding the trigger threshold twice (December 2012 and April 2013).

There was no clear longitudinal trend in SRP concentrations in the Boonoo Boonoo River (Figure 3.15). Site means ranged from 20.41 µg/L at BOO3, 21.65 µg/L at BOO2 and 15.78 µg/L at BOO1. SRP concentrations in the Boonoo Boonoo River ranged from 2.98 µg/L (BOO3 in October 2012) to 69.16 µg/L (BOO3 in December 2012). The upland freshwater trigger threshold was exceeded once in December 2012 at BOO3 and BOO1 (37.18 µg/L), and twice at BOO2 (August 2012 and December 2012).

SRP concentrations were greater at the downstream site (KOOR1) than the upstream site (KOOR2) in Koreelah Creek (Figure 3.15). Site means were 18.69 µg/L at KOOR2 and 27.07 µg/L at KOOR1. SRP concentrations in Koreelah Creek ranged from 5.00 µg/L at both sites in August 2012 to 55.75 µg/L in December 2012 at KOOR1. The upland freshwater trigger threshold was exceeded twice at KOOR2 (April – June 2013) and three times (50 % of sampling periods) at KOOR1 (April – August 2013).

SRP concentrations decreased longitudinally downstream in Tooloom Creek (Figure 3.15). Site means ranged from 44.77 µg/L at TOOL3, 33.21 µg/L at TOOL2 and 21.63 µg/L at TOOL1. Concentrations of SRP in Tooloom Creek ranged from 3.98 µg/L at TOOL1 (October 2012) to 119.19 µg/L at TOOL3 (December 2012). These were the highest SRP concentrations observed in the northern tributaries subcatchment. Despite decreasing variability in and mean SRP concentrations with distance downstream, all sites on Tooloom Creek exceeded the freshwater threshold three times December 2012 – June 2013 (50 % of sampling period).

There were no clear longitudinal trends in SRP concentrations in the Cataract River (Figure 3.15). Site mean concentrations ranged from 23.49 µg/L at CAT3, 12.16 µg/L at CAT2 and 20.29 µg/L at CAT1. SRP concentrations in the Cataract River ranged from 1.33 µg/L at CAT2 (October 2012) to 72.77 µg/L at CAT3 (December 2012). Concentrations exceeded the upland freshwater trigger threshold twice at CAT3 and CAT1 (December 2012 and April 2013), and once at CAT2 (June 2013).

SRP concentrations were higher at the downstream site (DUCK1) than the upstream site (DUCK2) in Duck Creek (Figure 3.15). Mean site concentrations were 11.89 µg/L at DUCK2 and 22.57 µg/L at DUCK1. SRP concentrations ranged from 0.03 µg/L (April 2013) to 43.37 µg/L (October 2012) at DUCK2. This maximum was the only exceedance of the uplands freshwater trigger threshold. SRP concentrations ranged from 8.62 µg/L (October 2012) to 50.59 (December 2012) at DUCK1. Trigger thresholds were exceeded twice at DUCK1 (August 2012 and December 2012).

SRP concentrations ranged 1.97 µg/L (October 2012) to 32.77 µg/L (April 2013) in Peacock Creek (Figure 3.15). The site mean of PEACOCK1 was 16.70. The upland freshwater trigger threshold was exceeded twice, in December 2012 and April 2013. SRP concentrations in Tabulam River ranged from 4.50 µg/L (August – October 2012) to 48.53 µg/L (December 2012). This maximum was the only exceedance of the lowland freshwater trigger threshold. The site mean for TAB1 was 15.27 µg/L (Figure 3.15).

There was no clear longitudinal trend in SRP concentrations in the Timbarra River (Figure 3.15). Site means were 13.630 µg/L at TIMB3, 10.41 µg/L at TIMB2 and 20.52 µg/L at TIMB1. SRP concentrations were most variable (with the highest site mean) at TIMB1, ranging from 4.50 µg/L (October 2012) to 38.73 µg/L (April 2013). Concentrations were least variable at TIMB2, ranging from <0.005 µg/L (October 2012) to 26.35 µg/L (December 2012). The upland freshwater trigger threshold was exceeded once at TIMB3 (April 2013) and TIMB2 (December 2012), and twice at TIMB1 (December 2012 and April 2013).

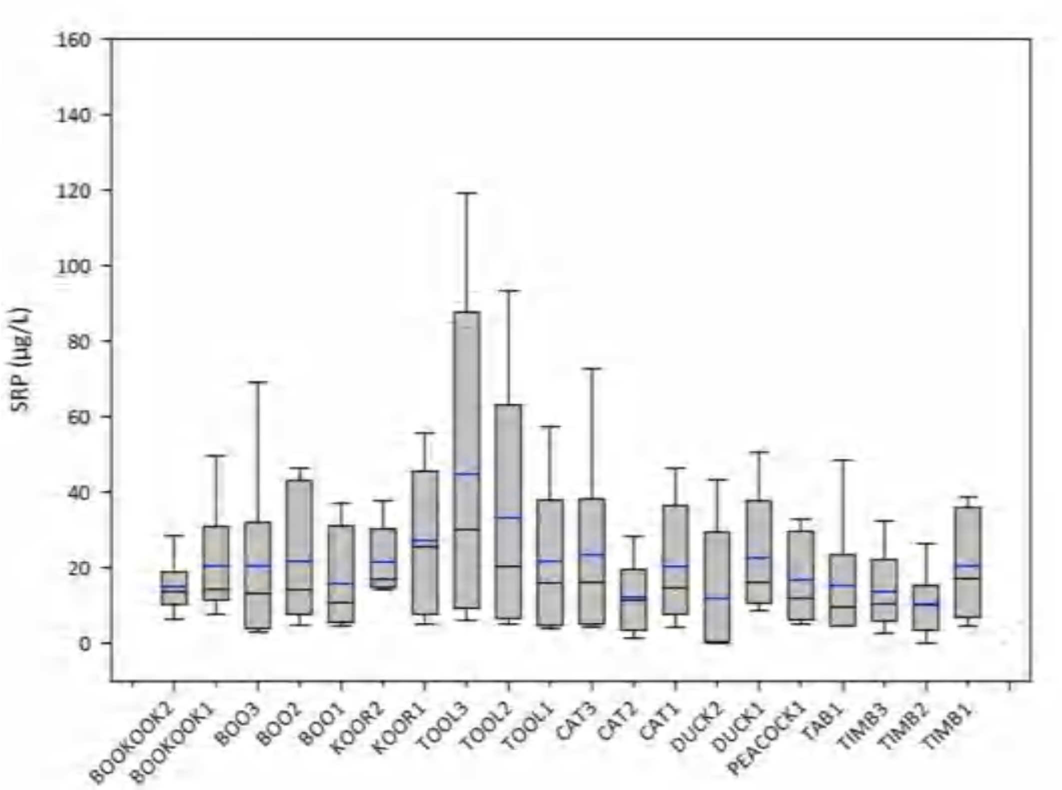


Figure 3.15 Mean (black line), median (blue line), 25th and 75th percentiles and range of SRP concentrations from sites in the northern tributaries of the Clarence from August 2012 to August 2013.

3.2.1.6 *Dissolved Oxygen (DO)*

In Bookookooara Creek and the Boonoo Boonoo River, dissolved oxygen (DO) saturation percentages increased downstream. Site means were 84.45 % for BOOKOOK2 and 98.83 % for BOOKOOK1 (Figure 3.16). Percentages ranged from 56.00 % at BOOKOOK2 to 112.80 % at BOOKOOK1. Observations exceeded the lower upland freshwater trigger threshold twice at BOOKOOK2 (in December 2012 and April 2013). The upper trigger threshold was not exceeded at BOOKOOK2. In contrast, the lower trigger threshold was not exceeded at BOOKOOK1, but the upper trigger threshold was (once in August 2012).

Site mean DO % in the Boonoo Boonoo River increased from 88.20 % at BOO3, 100.82 % at BOO2, to 108.98 % at BOO1 (Figure 3.16). At BOO3, DO % ranged from 66.50 % (April 2013) to 104.70 % (August 2012), falling below the lower trigger threshold once in April 2013. At BOO2, DO % ranged from 79.90 % (April 2013) to 110.60 % (December 2012), exceeding the upper trigger threshold once in December 2012. At BOO1, DO % ranged from 100.70 % (June 2013) to 123.50 % (October 2012), exceeding the upper trigger threshold twice (August – October 2012).

Patterns of DO % were similar at both sites in Koreelah Creek (Figure 3.16), with site means of 98.32 % at KOOR2 and 97.43 % at KOOR1. DO % ranged from 73.50 % (April 2013) to 115.10 % (August 2012) at KOOR2, exceeding both the lower and upper trigger thresholds once each with these minimum and maximum observations. DO % at KOOR1 ranged from 76.20 % (December 2012) to 116.70 % (October 2012), also exceeding the lower and upper trigger thresholds once each with the minimum and maximum observations.

There were no clear longitudinal trends in DO % saturation in Tooloom Creek (Figure 3.16). Site means were 85.36 % at TOOL3, 78.83 % at TOOL2 and 99.78 % at TOOL1. DO % at TOOL3 ranged from 47.00 % (December 2012) to 109.60 % (August 2012). These observations fell below the lower uplands freshwater trigger threshold twice (in December 2012 and April 2013). DO % at TOOL2 ranged from 56.70 % (December 2012) to 96.10 % (August 2013). These observations fell below the lower trigger threshold twice (also in December 2012 and April 2013).DO % at TOOL1 ranged from 69.80 % (April 2013) to 121.50 % (August 2013). While the lower trigger threshold was exceeded only during the minimum observation, DO % at TOOL1 exceeded the upper trigger threshold twice (in August 2012 and August 2013).

There were no clear longitudinal trends in DO % saturation in Cataract River (Figure 3.16). Site means were 102.68 % at CAT3, 98.18 % at CAT2 and 105.33 % at CAT1. DO % in the Cataract River ranged from 64.60 % (CAT3 in April 2013) to 125.10 % (CAT1 in August 2012). The lower upland freshwater trigger threshold was exceeded once at all sites; this occurred in April 2013. The upper trigger threshold was exceeded once at CAT 2 (August 2012), twice at CAT1 (August 2012 and December 2012), and three times (50 % of sampling periods) at CAT3 (August – October 2012 and August 2013).

DO % was similar at both sites in Duck Creek (Figure 3.16). Site means were 93.88 % at DUCK 2 and 98.07 % at DUCK1. DO % at DUCK2 ranged from 72.50 % (December 2012) to 103.90 % (August 2013), and exceeded the lower upland freshwater trigger threshold once (in December 2012). DO % ranged from 83.00 % (April 2013) to 114.20 % (August 2012) at DUCK1, and exceeded the upper freshwater trigger threshold once (in August 2012).

DO % ranged from 78.30 % (April 2013) to 104.60 % (August 2013) at PEACOCK1 in Peacock Creek (site mean of 93.42 %, Figure 3.16). The minimum observation fell below the upland freshwater trigger threshold. DO % was much lower in Tabulam River (site mean of 88.00 %, Figure 3.16). DO % never exceeded the upper lowland freshwater trigger threshold, but fell below the lower trigger threshold twice (October – December 2012).

There was a clear longitudinal increase in DO % in the Timbarra River (Figure 3.16). Site means were 92.57 % at TIMB3, 102.88 % at TIMB2 and 112.76 % at TIMB1. The lower upland freshwater trigger threshold was exceeded once at TIMB3 (April 2013), while the upper trigger threshold was exceeded once at TIMB2 (October 2012) and three times at TIMB1 (October 2012, April 2013 and August 2013).

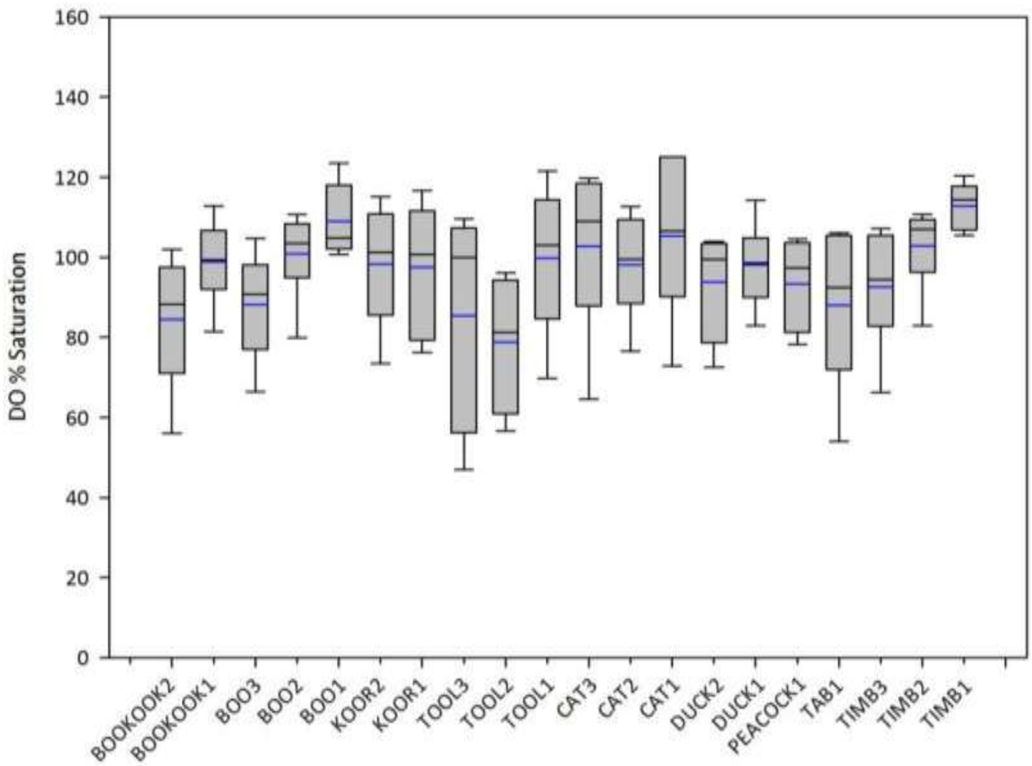


Figure 3.16 Mean (black line), median (blue line), 25th and 75th percentiles and range of DO saturation percentages from sites in the northern tributaries of the Clarence from August 2012 to August 2013.

3.2.1.7 *pH*

There were few differences in pH among the two sites on Bookookooara Creek (Figure 3.17). Site means were 8.11 at BOOKOOK2 and 8.29 at BOOKOOK1. pH ranged from 7.47 (October – December 2012) to 8.77 (April 2013) at BOOKOOK2, and from 7.86 (August 2012) to 8.86 (April 2013) at BOOKOOK1. The lower upland freshwater trigger threshold was not exceeded at either site, but both sites exceeded the upper trigger threshold: BOOKOOK2 from April – August 2013 and BOOKOOK1 from December 2012 – August 2013.

There were no clear longitudinal trends in pH in the Boonoo Boonoo River (Figure 3.17). Site means were 8.12 at BOO3, 8.68 at BOO2 and 8.56 at BOO1. pH ranged from 7.13 (BOO3 in October 2012) to 9.66 (BOO2 in December 2012). The lower upland freshwater trigger threshold was never exceeded in the Boonoo Boonoo River, but the upper trigger threshold was regularly exceeded at all sites: 3 times at BOO3 (April – August 2013), four times at BOO2 (December 2012 – August 2013), and five times (100 % of sampling periods) at BOO1.

pH decreased from the upstream site (KOOR2) to the downstream site (KOOR1) in Koreelah Creek (Figure 3.17). Site means were 9.11 at KOOR2 and 8.84 at KOOR1, with minimum pH of 8.59 and

8.14, respectively. All observations at both sites exceeded the upper upland freshwater trigger threshold.

There was no clear longitudinal trend in pH in Tooloom Creek (Figure 3.17). Site means were 8.66 at TOOL3, 8.29 at TOOL2 and 8.41 at TOOL1. All observations at TOOL1 exceeded the upper upland freshwater trigger threshold, with a maximum pH of 10.22. At TOOL2, the upper trigger threshold was exceeded three times (December 2012, April 2013 and the maximum pH of 9.34 in August 2013). The upper trigger threshold was exceeded four times at TOOL3 with a maximum pH of 9.74 (August 2012 – April 2013 and August 2013). Maximum pH values were recorded in August 2013 at all sites.

There was no clear longitudinal trend in pH in the Cataract River (Figure 3.17). Site means were 8.90 at CAT3, 8.64 at CAT2 and 8.73 at CAT1. All observations at CAT3 and CAT2 exceeded the upper upland freshwater trigger threshold with maximum pH of 9.94 and 9.57 (respectively) occurring in August 2013. pH at CAT1 exceeded the upper trigger threshold on five sampling occasions (83 %) from October 2012 to August 2013).

Site mean pH was similar at both sites in Duck Creek (8.62 at DUCK2 and 8.64 at DUCK1, Figure 3.17). At DUCK2, pH ranged 7.70 (April 2013) to 9.20 (August 2013) and exceeded the upper upland freshwater trigger threshold three times (October – December 2012 and August 2013). At DUCK1, pH ranged 7.61 (August 2012) to 9.68 (August 2013) and exceeded the upper trigger threshold five times (83 % of sampling periods) from October 2012 to August 2013.

Similar observations were made for Peacock Creek (Figure 3.17) where the site mean at PEACOCK1 was 8.83. pH ranged from 8.10 (October 2012) to 9.60 (August 2013) and all observations exceeded the upper upland freshwater trigger threshold. This pattern was also observed in Tabulam River (Figure 3.17). The site mean pH at TAB1 was 8.72 and pH ranged from 8.13 (August 2012) to 9.85 (August 2013). All observations exceeded the upper lowland freshwater trigger threshold.

There was a clear longitudinal increase (downstream) in the Timbarra River (Figure 3.17). Site mean pH was 8.16 at TIMB3, 8.61 at TIMB2 and 8.83 at TIMB1. pH ranged from 7.72 at TIMB2 (August 2012) to 9.60 at TIMB1 (August 2013). No observations in the Timbarra River fell below the lower freshwater trigger threshold, but the upper trigger threshold was exceeded several times at each site. At TIMB3, it was exceeded three times from April 2013 to August 2013. At TIMB2 and TIMB1, it was exceeded five times from October 2012 to August 2013).

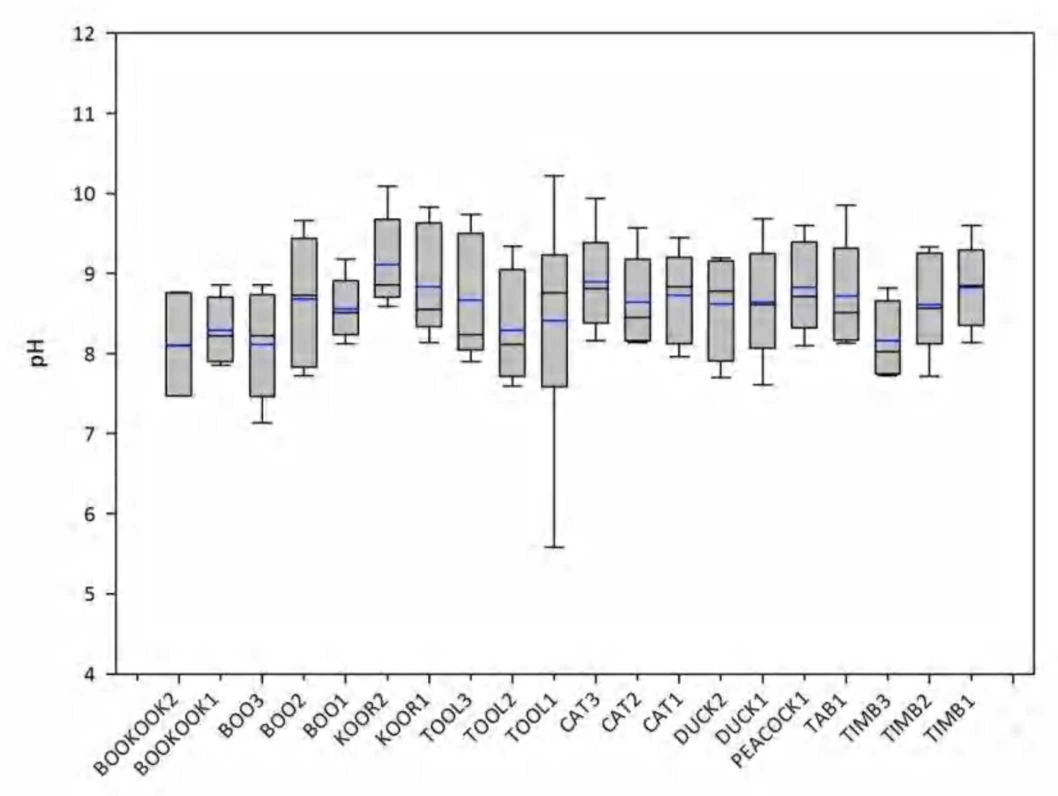


Figure 3.17 Mean (black line), median (blue line), 25th and 75th percentiles and range of pH from sites in the northern tributaries of the Clarence from August 2012 to August 2013.

3.2.1.8 *Turbidity*

Turbidity decreased with distance downstream in Bookookoorara Creek (Figure 3.18). The site mean turbidity was 35.35 NTU at BOOKOOK2 and 22.73 NTU at BOOKOOK1. Turbidity ranged from 6.4 NTU at BOOKOOK1 (October 2012) to 53.5 NTU at BOOKOOK2 (August 2013). This maximum observation was the only exceedance of the upland freshwater trigger threshold in Bookookoorara Creek.

Turbidity also decreased with distance downstream in the Boonoo Boonoo River (Figure 3.18). Site mean turbidities were 25.90 NTU at BOO3, 19.72 NTU at BOO2 and 15.23 NTU at BOO1. Turbidity ranged from 2.70 NTU at BOO1 (October 2012) to 44.00 NTU at BOO3 and no observations in the sampling period in the Boonoo Boonoo River exceeded the upland freshwater trigger threshold.

In contrast, turbidity was higher in the downstream site (KOOR1) than the upstream site (KOOR2) in Koreelah Creek (Figure 3.18). Site mean turbidity was 23.56 NTU at KOOR2 and 32.70 NTU at KOOR1. Turbidity in Koreelah Creek ranged from 1.30 NTU at KOOR2 (October 2012) to 106.00 NTU at KOOR1 (June 2013. This maximum represents the only exceedance of the upland freshwater trigger threshold at KOOR1; the trigger threshold was also exceeded once at KOOR2 (50.50 NTU), also in June 2013.

Although there was no longitudinal trend in mean turbidity in Tooloom Creek, the variability increased longitudinally downstream (Figure 3.18). Site mean turbidities were 22.80 NTU at TOOL3, 32.33 NTU at TOOL2 and 32.38 NTU at TOOL1. Turbidity in Tooloom Creek ranged from 5.90 NTU at TOOL1 (October 2012) to 87.20 NTU at TOOL1 (June 2013). This maximum observation was the only exceedance of the upland freshwater trigger threshold for Tooloom Creek.

There was no clear longitudinal trend in turbidity in the Cataract River (Figure 3.18). Site mean turbidities ranged from 20.38 NTU at CAT3, 20.88 NTU at CAT2 and 17.02 NTU at CAT1. Turbidity in the Cataract River ranged from 4.10 NTU at CAT2 (October 2012) to 37.10 NTU at CAT2 (August 2013). No observations in the Cataract River exceeded the upland freshwater trigger threshold.

The variability in and mean turbidity was greater at the downstream site (DUCK1) than the upstream site (DUCK2) in Duck Creek (Figure 3.18). Site mean turbidity was 29.70 NTU at DUCK2 and 44.50 NTU at DUCK1. Turbidity in Duck Creek ranged from 6.30 NTU at DUCK1 (December 2012) to 68.40 NTU at DUCK1 (April 2013). While turbidity did not exceed the upland freshwater trigger threshold at DUCK2, it was exceeded three times at DUCK1 (December 2012 – June 2013).

Turbidity in Peacock Creek remained below the upland freshwater trigger threshold (Figure 3.18). The site mean at PEACOCK1 was 28.88 NTU and turbidity ranged from 6.20 NTU (October 2012) to 43.1 NTU (August 2013). The same pattern occurred in Tabulam River (Figure 3.18), where the site mean at TAB1 was 28.32 NTU, turbidity ranged from 5.90 NTU (October 2012) to 46.10 NTU (April 2013), and turbidity did not exceed the lowland freshwater trigger threshold for the duration of the sampling period.

Turbidity decreased longitudinally down the Timbarra River (Figure 3.18). Site mean turbidities were 26.54 NTU at TIMB3, 18.84 NTU at TIMB2 and 15.80 NTU at TIMB1. Turbidity ranged from 3.80 NTU at TIMB2 (October 2012) to 38.50 NTU at TIMB3 (June 2013), but it never exceeded the upland freshwater trigger threshold in the Timbarra River.

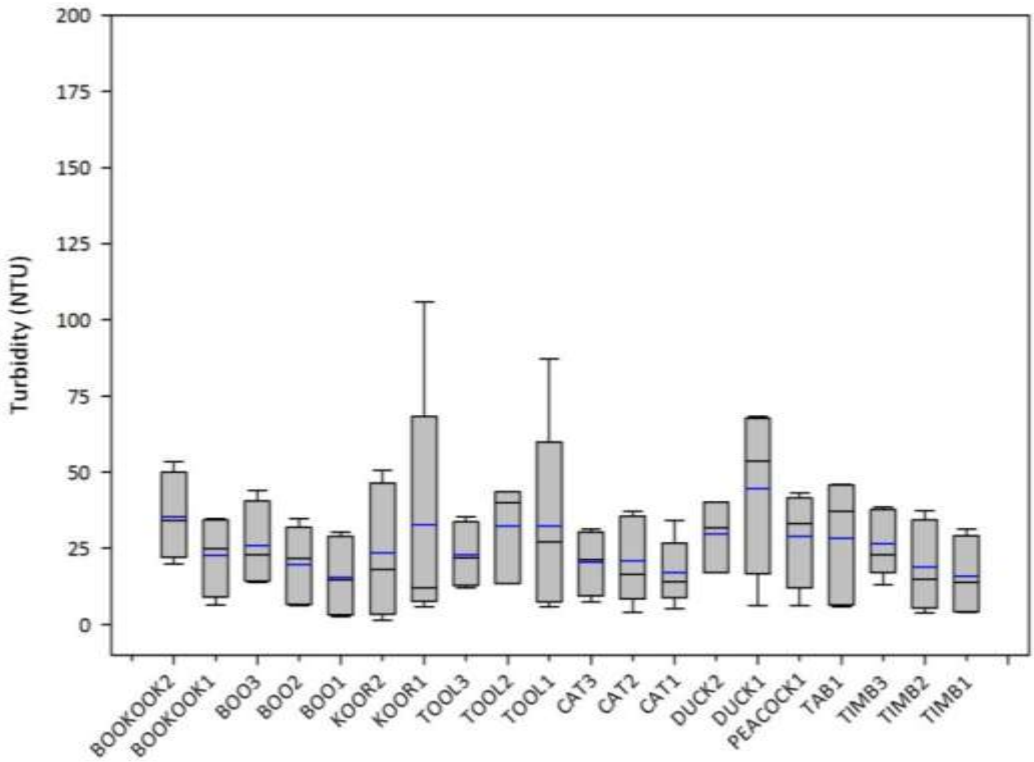


Figure 3.18 Mean (black line), median (blue line), 25th and 75th percentiles and range of turbidity from sites in the northern tributaries of the Clarence from August 2012 to August 2013.

3.2.1.9 *Water chemistry variables*

Table 3.7 provides the ranges of observed water temperatures, electrical conductivity, salinity, Secchi depth and total suspended sediments (TSS) for the northern tributaries of the Clarence River. The upstream site on Bookookoorara Creek (BOOKOOK2) was typically cooler and had more variability in electrical conductivity (EC) and TSS than the downstream site BOOKOOK1. EC at both sites consistently fell below the lower upland freshwater trigger threshold. Baseline TSS concentrations were consistently higher but less variable in Bookookoorara Creek than most of the other northern tributaries.

EC and salinity increased but TSS concentrations decreased longitudinally downstream in the Boonoo Boonoo River (Table 3.7). EC in the Boonoo Boonoo River fell below the lower freshwater trigger threshold at all times. In Koreelah Creek, the downstream site (KOOR1) was slightly warmer, and EC, salinity and TSS concentrations were typically less than the upstream site (KOOR2). EC remained within upland freshwater trigger thresholds at all times (Table 3.7). Water temperatures, EC and salinity were similar along Tooloom Creek, although TSS concentrations showed slight longitudinal increases downstream (Table 3.7). EC in Tooloom Creek remained within upland freshwater trigger thresholds at all times.

There was a clear downstream longitudinal warming trend in the Cataract River (Table 3.7). EC remained within upland freshwater trigger thresholds at CAT3, but fell below the lower limit at CAT2 and CAT1 in April 2013 – June 2013. The site on Lower Duck Creek (DUCK1) had significantly higher EC, salinity and TSS concentrations than did the site on the Upper Duck Creek (DUCK2, Table 3.7). EC in Duck Creek remained within upland freshwater trigger thresholds at all times. Relative to other northern tributaries, Peacock Creek had high EC, salinity and TSS concentrations (Table 3.7), but EC remained within upland freshwater trigger thresholds at all times. However, Tabulam River recorded the highest EC and salinity of all northern tributaries (Table 3.7), and exceeded the upper lowland freshwater trigger threshold once (in August 2012). Tabulam River was the only river system to exceede the upper trigger threshold in the northern tributaries.

There was a clear downstream longitudinal increase in EC and salinity in the Timbarra River (Table 3.7). However, EC remained below the lower upland freshwater trigger threshold across all sites for all sampling times. TSS concentrations were generally higher at the upland site (TIMB3) than the most downstream site TIMB1.

Table 3.7 Range of water chemistry variables at sites in the northern tributaries of the Clarence.

Site	Water temp (°C)	Conductivity (mS/cm)	Salinity (ppt)	Secchi depth (m)	TSS (mg/L)
BOOKOOK2	7.9 - 24.0	0.059 - 0.085	0.03 - 0.04	0.30 - 0.50	2.09 - 7.67
BOOKOOK1	8.9 - 25.3	0.060 - 0.081	0.03 - 0.04		1.94 - 10.03
BOO3	8.2 - 24.5	0.048 - 0.067	0.02 - 0.04		0.31 - 7.51
BOO2	8.1 - 27.5	0.049 - 0.069	0.02 - 0.04		0.70 - 2.61
BOO1	11.8 - 27.8	0.072 - 0.101	0.04 - 0.05		0.00 - 1.47
KOOR2	10.1 - 26.2	0.295 - 0.666	0.14 - 0.32		0.28 - 23.47
KOOR1	12.0 - 26.6	0.238 - 0.635	0.11 - 0.31		1.40 - 9.35
TOOL3	13.1 - 22.6	0.178 - 0.406	0.09 - 0.20		0.00 - 8.00
TOOL2	12.4 - 24.0	0.234 - 0.439	0.11 - 0.21		1.96 - 12.92
TOOL1	11.1 - 27.8	0.221 - 0.545	0.10 - 0.26		0.37 - 15.01
CAT3	7.2 - 25.0	0.193 - 0.304	0.09 - 0.15		1.63 - 8.08
CAT2	8.1 - 25.6	0.090 - 0.189	0.04 - 0.09		0.19 - 9.88
CAT1	10.5 - 31.5	0.097 - 0.189	0.05 - 0.09		0.50 - 13.62
DUCK2	13.3 - 28.0	0.181 - 0.285	0.09 - 0.14	0.15 - 0.30	1.58 - 19.11
DUCK1	10.2 - 29.3	0.251 - 0.645	0.12 - 0.32		3.10 - 23.09
PEACOCK1	10.6 - 26.1	0.299 - 0.628	0.14 - 0.31		0.72 - 11.13
TAB1	9.3 - 25.1	0.679 - 11.930	0.32 - 1.59	0.20 - 0.30	0.42 - 15.55
TIMB3	7.7 - 20.3	0.044 - 0.062	0.02 - 0.03	0.20 - 0.40	3.12 - 12.42
TIMB2	12.4 - 26.1	0.064 - 0.109	0.03 - 0.05		0.42 - 17.16
TIMB1	11.4 - 27.8	0.086 - 0.105	0.04 - 0.05		0.68 - 4.64

3.2.2 Transported loads of TSS, TN and TP

Peak low-flow discharge of 50.634 ML/day occurred during April 2013 at the middle site on the Cataract River (CAT2, a discontinuous floodplain reach on Boorook Road). This correlated with the peak TSS transport of 0.50 t/day (Figure 3.19a). The large peak in TSS transport in April 2013 was due both to peak discharge and peak TSS concentration (9.88 mg/L). The minimum TSS load in August 2013 (0.001 kg/day) was driven by the very low discharge (0.0001 ML/day).

Total nutrient loads did not follow the temporal patterns in TSS loads at CAT2 (Figure 3.19b). The maximum TN load (2.01 kg/day) occurred in June 2013 while the maximum TP load (0.21 kg/day) occurred in August 2012 with a low-flow discharge of 2.23 ML/day). Mean monthly nutrient loads were 0.48 kg TN/day and 0.07 kg TP/day.

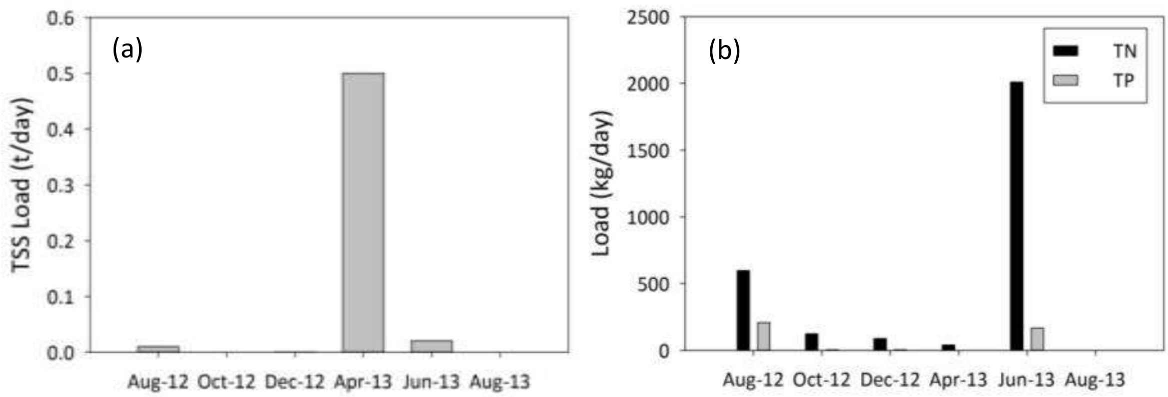


Figure 3.19 Loadings of (a) total suspended sediments and (b) TN and TP transported in the northern tributary Cataract River at Site CAT2 (Gauge 204036) from August 2012 to August 2013.

3.2.3 Macroinvertebrates

Thirty nine macroinvertebrate families were recorded from Northern tributaries during the Autumn and Spring sampling in 2012-13, dominated by Trichoptera (Caddis Flies) with 11 families and Coleoptera (Beetles) with 7 families (Table 3.8). Family level richness was higher in Spring than Autumn due to the presence more Trichopteran, Ephemeropteran (Mayfly) and Dipteran families although the abundances were much lower in Spring. The EPT index identifies between 15 and 50% of the families and 26% of the individuals recorded are from these families that require good habitat and water quality condition.

Of the 7171 individuals recorded from the 9 river systems in the Northern tributaries, substantially more individuals (71%) were collected in Autumn potentially responding to post flood conditions compared to prolonged low flow conditions in Spring 2012. In rivers with 3 sites, there was no clear longitudinal trend in the number of families recorded from each site, with Boonoo Boonoo River having the lowest number of families in the mid-reaches, with the other rivers having the opposite trend. Abundances ranged from 817 individuals at TOOL2 to just 94 at BOO2 for all sample times combined. In Spring 2012 during low flow conditions, abundances ranged from 42 to 309 individuals, with 12 of the 20 sites recording fewer than 100 individuals across all habitats within the site.

Similarly, there were no clear patterns in the families present at each site. Family richness ranged from a high of 35 at TAB1 to a low of 15 at BOOKOOK2. Atyidae shrimps with a SIGNAL2 score of 3 were the most abundant taxa at 8 of the 20 sites. Chironomidae (midge larvae) were in the top 5 most abundant taxa at 13 sites, Atyidae at 12 sites, Baetidae (Mayfly) at 9 sites and Corixide (waterbugs) at 7 sites. Each of these taxa has a SIGNAL score of 3, indicating macroinvertebrates with very low SIGNAL2 scores are dominating the majority of sites.

Mean SIGNAL2 score for the Northern tributaries river systems was 4..7 with the scores ranging from 4 at TOOL1 to 5.8 at TIMB3, higher average and range of scores than recorded in the main stem of the Clarence River (Table 3.8). Notonectidae (backswimmers) and Physidae (pond snails) with a SIGNAL2 score of 1 were present at all sites except BOO2, TIMB1, 2 and 3, and CAT1 contributing to lower overall scores. Ptilodactylidae (Beetle) was the only taxa found with a SIGNAL2 score of 10, recorded at DUCK1, PEACOCK1, and TIMB2 and 3, and was only recorded in the Northern tributaries of the Clarence catchment. The large range in SIGNAL2 scores in each site indicates a range of conditions were present throughout the river system that facilitated the occurrence of both pollution tolerant and pollution sensitive taxa.

Table 3.8 Macroinvertebrate richness, EPT richness, SIGNAL2 scores and dominant taxa at sites in the northern tributaries of the Clarence River. SIGNAL2 shown as mean value (range in brackets). The 5 numerically dominant taxa at each site The 5 numerically dominant taxa with greater than 10 individuals at each site are listed.

Site	No. Families	No. EPT families	SIGNAL2	Dominant taxa
BOOKOOK2	18	7	5.2 (1-8)	Helicophidae, Leptophlebiidae , Atyidae , Corixidae , Notonectidae
BOOKOOK1	15	6	4.4 (1-8)	Corixidae , Notonectidae, Physidae
BOO3	26	13	5 (1-8)	Baetidae, Atyidae,Corixidae, Chironnomidae, Leptophlebiidae
BOO2	18	7	5.2 (2-8)	Philopotamidae, Chironnomidae, Leptophlebiidae
BOO1	29	11	5.3 (1-8)	Atyidae, , Chironnomidae, Hydropsychidae, Baetidae, Simuliidae
KOOR2	33	10	4.5 (1-8)	Atyidae, Hydrophilidae, Caenidae, Chironnomidae, Leptophlebiidae
KOOR1	18	5	4.4 (1-8)	Hydrophilidae, Notonectidae, Calamoceratidae, Corduliidae
TOOL3	28	9	4.1 (1-8)	Baetidae, Corixidae, Atyidae, Chironnomidae, Caenidae
TOOL2	34	13	4.9 (1-8)	Hydropsychidae, Atyidae, Baetidae, Hydrophilidae, Chironnomidae
TOOL1	26	4	4 (1-8)	Atyidae, Hydrophilidae, Baetidae, Elmidae, Leptophlebiidae
CAT3	22	9	4.9 (1-8)	Notonectidae,Chironnomidae, Physidae, Hydropsychidae, Corixidae
CAT2	26	11	5 (1-8)	Corixidae, Philopotamidae, Gerridae, Atyidae, Leptoceridae
CAT1	26	9	4.8 (2-8)	Atyidae, Hydropsychidae, Palaemonidae, Chironnomidae, Caenidae
DUCK2	24	9	4.7 (1-8)	Simuliidae, Baetidae, Chironomidae, Leptophlebiidae
DUCK1	27	6	4.3 (1-10)	Atyidae, Corixidae, Hydrophilidae
PEACOCK1	35	10	4.4 (1-10)	Atyidae, Chironnomidae, Caenidae, Elmidae, Notonectidae
TAB1	35	11	4.5 (1-8)	Atyidae, Baetidae, Calamoceratidae, Caenidae, Simuliidae
TIMB3	22	11	5.8 (2-10)	Ptilodactylidae, Chironnomidae, Elmidae, Leptophlebiidae, Corixidae
TIMB2	28	10	4.9 (2-10)	Atyidae, Palaemonidae, Hydrophilidae, Baetidae, Chironnomidae
TIMB1	23	8	4.6 (2-8)	Elmidae, Chironnomidae, Hydrophilidae, Baetidae, Dytiscidae

3.2.4 Riparian condition

Riparian condition in Bookooroorara Creek was very good and among the best in the northern tributaries (7.24/10.00, Table 3.9). Boonoo Boonoo River had good riparian condition (6.04/10.00, Table 3.9), as did Koreelah Creek (5.02/10.00) and the upstream site (TIMB3) on the Timbarra River (4.56/10.00). Tooloom Creek, the Cataract River, Duck Creek, Peacock Creek and Tabulam River all scored below average (i.e. poor or very poor) riparian condition (Table 3.9).

Bookookoorara Creek

The downstream site (BOOKOOK1) had better riparian condition than the upstream site (BOOKOOK2), primarily due to better vegetation composition and habitat (Table 3.10). The vegetation community at BOOKOOK1 was described as Water Gum shrubland with emergent Broad-leaved Apple (*Angophora subvelutina*) (index score 3.50; Table 3.10). The community at BOOKOOK2 was Carex Sedgeland with New England Peppermint (index score 2.93). The lower vegetation score at BOOKOOK2 was due to less canopy and midstorey cover, no vines and fewer vegetation layers (Table 3.13).

Large trees were Broad-leaved Apple (*Angophora subvelutina*) and Water Gum (*Tristaniopsis laurina*) at BOOKOOK1 and New England Peppermint (*Eucalyptus nova-anglica*) at BOOKOOK2. The midstorey was dominated at BOOKOOK1 by Water Gum and Blackthorn (*Bursaria spinosa* subsp. *spinosa*) and by Tantoon (*Leptospermum polygalifolium* subsp. *montanum*) at BOOKOOK2. The exotic Plum (*Prunus* sp.) occurred at BOOKOOK1. Snow Grass (*Poa sieberiana*), Couch (*Cynodon dactylon*) and Weeping Grass (*Microlaena stipoides*) formed the grass groundcover at BOOKOOK1 with Swamp Millet (*Isachne globosa)* and Blady Grass (*Imperata cylindrica)* at BOOKOOK2. There were no grass weeds at BOOKOOK1 but the exotic Whisky Grass (*Andropogon virginicus*) at BOOKOK2. Spiny-headed Mat-rush (*Lomandra longifolia*) and Rock Felt Fern (*Pyrrosia rupestris*) were dominant in the understorey at BOOKOOK1 with the typical Carex Sedgeland dominant Fen Sedge (*Carex gaudichaudiana*) and seedling Tantoon at BOOKOOK2. There were no exotic understorey species at BOOKOOK1 but Purple Top (*Verbena bonariensis*) at BOOKOOK2. The native Headache Vine (*Clematic glycinoides* subsp. *glycinoides*) and the exotic Japanese Honeysuckle (*Lonicera japonica*) occurred at BOOKOOK1 where organic litter was dominated here by Water Gum.

Bank Condition index scores were 5.00/5.00 at BOOKOOK2 and 4.00/5.00 at BOOKOOK1 (Table 3.10). There were no undercutting or slumping of banks or exposed tree roots at BOOKOOK2, with some bank undercutting and exposed tree roots at BOOKOOK1. Habitat scored poorly at both sites on Bookookoorara Creek (Table 3.10), primarily due to the lack of dead trees either standing or fallen, and the absence of reed habitat although this is expected for bedrock-controlled reaches. Both sites were relatively undisturbed (Table 3.10).

Table 3.9 Site level summary of riparian condition scores for sites in the northern tributaries of the Clarence River. Individual scores maximum of 5, total score out of 10.

	VEGETATION	BANK CONDITION	HABITAT	DISTURBANCE	Total/10
BOOKOOK1	3.50	4.00	2.19	5.00	7.35
BOOKOOK2	2.93	5.00	1.33	5.00	7.13
Mean	3.22	4.50	1.76	5.00	7.24
BOO1	2.27	2.33	1.81	1.00	3.71
BOO2	3.13	5.00	2.29	5.00	7.71
BOO3	2.77	4.33	1.71	4.56	6.69
Mean	2.72	3.89	1.94	3.52	6.03
KOOR1	2.90	2.33	2.90	1.89	5.01
KOOR2	2.17	2.33	1.86	3.67	5.02
Mean	2.54	2.33	2.38	2.78	5.01
TOOL1	2.57	2.57	1.33	2.52	4.50
TOOL2	2.57	2.57	2.00	2.76	4.95
TOOL3	2.03	2.03	2.00	1.52	3.79
Mean	2.39	2.39	1.78	2.27	4.41
CAT1	2.83	2.83	2.33	2.14	5.07
CAT2	3.33	3.33	2.67	2.57	5.95
CAT3	2.13	2.13	2.67	1.43	4.18
Mean	2.76	2.76	2.56	2.05	5.07
DUCK1	3.10	3.10	1.67	2.14	5.01
DUCK2	2.97	2.97	1.00	2.33	4.64
Mean	3.04	3.04	1.34	2.24	4.82
PEACOCK1	2.67	2.67	2.33	2.24	4.96
TAB1	3.90	3.90	2.33	3.10	6.62
TIMB1	2.50	2.50	1.00	2.76	4.38
TIMB2	2.60	2.60	4.33	3.29	6.41
TIMB3	2.80	2.80	4.00	1.81	5.71
Mean	2.63	2.63	3.11	2.62	5.50

Boonoo Boonoo River

The vegetation community at BOO1 was Cleared River Oak grassy open forest, (index score 2.27; Table 3.10) that at BOO2 Broadleaved Apple and Forest Red Gum emergents over a rainforest midstorey (index score 3.13) and at BOO3, Carex Sedgeland with New England Peppermint (index score 2.77, Table 3.14). The higher vegetation score at BOO2 was due to increased midstorey cover, no grass weeds, the presence of vines and more vegetation layers.

The emergents at BOO1 were River Oak with Broad-leaved Apple (*Angophora subvelutina*) and Forest Red Gum (*Eucalyptus tereticornis*) at BOO2. River Oak and Weeping Bottlebrush (*Callistemon viminalis*) formed the midstorey at BOO1 with Tantoon (*Leptospermum polygalifolium* subsp. *montanum*) at BOO3. The diverse rainforest shrub midstorey of BOO2 included Red Ash (*Alphitonia excelsa),* Sandpaper Fig (*Ficus coronata*), Blackthorn (*Bursaria spinosa* subsp. *spinosa*) and Lilly Pilly (*Acmena smithii)* with Tea Tree (*Leptospermum brachyandrum*) and Weeping Bottlebrush (*Callistemon viminalis*), BOO1 had the exotic shrubs Wild Tobacco Bush (*Solanum mauriteanum*) and Lantana in the midstorey; there were no midstorey weeds at BOO2 or BOO3.

The native grass Couch (*Cynodon dactylon*) occurred at BOO1–2 with Creeping Beard Grass (*Oplismenus imbecillis*) and Slender Bamboo Grass (*Austrostipa verticillata)* at BOO1, Hastings River Reed (*Potamophila parviflora*) also at BOO2 and Snow Grass (*Poa sieberiana*) at BOO3. The exotic grasses Kikuyu (*Pennisetum clandestinum*) and Paspalum (*Paspalum dilatatum)* occurred at BOO1 with African Lovegrass (*Eragrostis curvula*) and Whisky Grass (*Andropogon virginicus*) at BOO3 and no grass weeds at BOO2. Pale Knotweed (*Persicaria lapathifolia*) and Common Rush (*Juncus usitatus*) dominated the understorey at BOO1 and the dominant Fen Sedge (*Carex gaudichaudiana*) at BOO3 with occasional Spiny-headed Mat-rush (*Lomandra longifolia*). Seedling River Oak and Native Olive (*Olea paniculata*) occurred in the understorey of BOO2 along with Creek Mat-rush (*Lomandra hystrix*) and Common Bracken (*Pteridium esculentum).* Exotic understorey species were Mexican Poppy (*Argemone ochroleuca* subsp. *ochroleuca*), Spear Thistle (*Cirsium vulgare*) and Lantana at BOO1, Cobblers Pegs (*Bidens pilosa*) and Flaxleaf Fleabane (*Conyza bonariensis*) at BOO2 with no understorey weeds at BOO3. The native vine Common Silkpod (*Parsonsia straminea*) occurred at BOO2 where the dominant species in the organic litter at BOO2 was Broad-leaved Apple (*Angophora subvelutina*).

Bank Condition was excellent at BOO2 and very good at BOO3, but poor at BOO1 due to undercutting and slumping of the banks (Table 3.10). Habitat scored very poorly at all sites in the Boonoo Boonoo River (Table 3.10), due to the lack of large wood either standing or fallen. BOO3 and BOO2 were relatively undisturbed but BOO1 had been heavily cleared, showed evidence of stock grazing and a lack of exclusion fencing (Table 3.10).

Koreelah Creek

Vegetation communities at both Koreelah Creek sites were dominated by River Oak, with River Oak – Weeping Bottlebrush layered woodland at KOOR1 (index score 2.90; Table 3.10), and River Oak grassy open forest at KOOR2 (index score 2.17). The lower vegetation score at KOOR2 was due to the lack of midstorey cover, less grass cover and more understorey weeds (Table 3.15).

Large trees at both sites were River Oak. At KOOR2 there was no midstorey, either native or exotic, but KOOR1 midstorey was dominated by the natives Water Gum (*Tristaniopsis with* the exotic shrub Small-leaved Privet (*Ligustrum sinense*). KOOR2 had no native grasses but at KOOR1 Weeping Grass (*Microlaena stipoides*) was the dominant species. KOOR1 had a variety of native understorey species including Creek Mat-rush (*Lomandra hystrix*), Common Rush (*Juncus usitatus*) and Water Pepper (*Persicaria hydropiper*) whereas the only native understorey species at KOOR2 was Nettle (*Urtica incisa*). KOOR1 understorey also had occasional exotics such as (*Senecio madagascariensis*), Spear Thistle (*Cirsium vulgare*) and Variegated Thistle (*Silybum marianum*). KOOR2 understorey had been recently disturbed and was dominated by exotic herbaceous species including Annual Ragweed (*Ambrosia artemisioides*), and Black-berrry Nightshade (*Solanum nigrum*).Water Gum (KOOR1) and River Oak (KOOR2) were the dominant sources of organic litter (native). Vines were absent at both sites.

Koreelah Creek had average bank condition (Table 3.10), predominantly due to undercutting and slumping of banks. KOOR1 scored better than KOOR2 in the Habitat index due to the former having more standing dead trees and logs and less weed litter (Table 3.10). Conversely, KOOR2 was less disturbed and although trees had been cleared along the reach, there was fencing and no recent stock activity (Table 3.10).

Table 3.10 Site level summary of riparian condition scores for each sub-index for sites in Bookookoorara Creek, Boonoo Boonoo River and Koreelah Creek. Individual scores maximum of 5.

	BOOKOOK1	BOOKOOK2	BOO1	BOO2	BOO3	KOOR1	KOOR2
Vegetation							
Large trees	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Canopy Cover	4.00	1.00	1.33	1.67	1.33	2.33	2.67
Mid-storey Cover	3.00	1.67	1.67	3.67	1.67	2.33	1.00
Mid-storey Weeds	4.67	5.00	4.00	5.00	5.00	4.33	5.00
Grass Cover	2.67	3.00	4.00	2.00	1,67	3.33	2.00
Grass Weeds	5.00	4.67	2.67	5.00	4.00	5.00	1.00
Understorey Cover	3.00	5.00	3.00	3.00	5.00	3.67	5.00
Understorey Weeds	5.00	5.00	2.33	5.00	5.00	3.00	1.00
Vines	3.00	1.00	1.00	2.33	1.00	1.00	1.00
Vegetation Layers	3.67	2.00	1.67	2.67	2.00	1.00	1.00
Total/5	3.50	2.93	2.27	3.13	2.77	2.90	2.17
Bank condition							
Undercutting	3.00	5.00	1.00	5.00	4.00	2.00	2.00
Exposed Tree Roots	4.00	5.00	5.00	5.00	5.00	3.00	2.00
Slumping	5.00	5.00	1.00	5.00	4.00	2.00	3.00
Total/5	4.00	5.00	2.33	5.00	4.33	2.33	2.33
Habitat							
Standing Dead Trees	0.00	0.00	0.00	0.00	0.00	5.00	0.00
Logs	2.00	1.00	4.00	4.00	2.00	3.00	2.00
Fallen Trees	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reeds	5.00	1.00	5.00	5.00	3.00	5.00	5.00
Large Trees	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Organic Litter	2.33	1.33	1.00	1.00	1.67	1.33	1.33
Weed Litter	5.00	5.00	1.67	5.00	4.33	5.00	3.67
Total/5	2.19	1.33	1.81	2.29	1.71	2.90	1.86
Disturbance							
Tree Clearing	5.00	5.00	1.00	5.00	3.67	3.67	1.00
Fencing	5.00	5.00	1.00	5.00	5.00	1.00	5.00
Livestock	5.00	5.00	1.00	5.00	5.00	1.00	5.00
Total/5	5.00	5.00	1.00	5.00	4.56	1.89	3.67

Cataract River

Two of the vegetation communities on the Cataract River sites were River Oak dominated with River Oak – Weeping Bottlebrush layered woodland at CAT1 (index score 2.83; Table 3.11) and River Oak grassy open forest at CAT2 (index score 3.33). CAT3 had occasional Snow Gum (*Eucalyptus pauciflora*) and River Oak over Exotic Grassland (index score 2.13). CAT3 lower Vegetation score was due to fewer vegetation layers, lower canopy and midstorey cover, more cover of midstorey weeds and dominant exotic grasses (Table 3.17).

Large trees were River Oak (CAT2) and Snow Gum (*Eucalyptus pauciflora*) (CAT3). CAT1 had regrowth River Oak and Weeping Bottlebrush (*Callistemon viminalis*) in the midstorey, CAT2 had Tree Violet (*Melicytis dentatus*) and Green Wattle (*Acacia irrorata* subsp. *irrorata*) and CAT3 the exotic shrubs Small-leaved Privet (*Ligustrum sinense*) and Himalayan Firethorn (*Pyracantha crenulata*). Couch (*Cynodon dactylon*) occurred at CAT1 and CAT2 with Weeping Grass (*Microlaena stipoides*) (CAT2) and Creeping Beard Grass (*Oplismenus imbecillis*) (CAT1). CAT1 had no exotic grasses but Narrow-leaved Carpet Grass (*Axonopus fissifolius*) occurred at both CAT2 and CAT3 with African Lovegrass (*Eragrostis curvula*) and Meadow Fescue (*Fectuca pratensis*) at CAT3. Creek Mat-rush (*Lomandra hystrix*) occurred at both CAT1 and CAT2 with Common Rush (*Juncus usitatus*) at both CAT2 and CAT3 with Common Buttercup (*Ranunculus lappaceus*) also at CAT3. CAT2 had no understorey weeds, CAT1 had Fireweed (*Senecio madagascariensis*) and Mexican Poppy (*Argemone ochroleuca* subsp. *ochroleuca*) and CAT3 had Spear Thistle (*Cirsium vulgare*) and Curled Dock (*Rumex crispus*).

Bank condition was good in the Cataract River with small areas of undercutting (Table 3.11). With the exception of reed habitat and weed organic litter, habitat indices scored very poorly in all sites in the Cataract River (Table 3.11). All sites were also highly disturbed by tree clearing, stock access and the lack of exclusion fencing (Table 3.11).

Duck Creek

The vegetation community at both Duck Creek sites were described as River Oak – Weeping Bottlebrush layered woodland (Table 3.11). The slightly lower vegetation score at DUCK2 (Index score 2.97) compared to DUCK1 (index score 3.10) was due to more grass and understorey weeds.

Weeping Bottlebrush (*Callistemon viminalis*) dominated the midstorey at both sites with Liily Pilly (*Acmena smithii*) also at both sites and Whalebone Tree (*Streblus brunonianus*) at DUCK1 and Sandpaper Fig (*Ficus coronatus*) at DUCK2 (Table 3.18). There were no midstorey weeds. Creeping Beard Grass (*Oplismenus imbecillis*) occurred in the groundcover at both sites with Couch (*Cynodon dactylon*) at DUCK1 and Weeping Grass (*Microlaena stipoides*) at DUCK2 with the exotic grass Broad-leaved Paspalum (*Paspalum mandiocanum*).

Spiny-headed Mat-rush (*Lomandra longifolia*) was a dominant native understorey species at both sites with Common Rush (*Juncus usitatus*) at DUCK1 and Water Pepper (*Persicaria hydropiper*) and the Downy Ground Fern (*Hypolepis glandulifera*) at DUCK2. Exotic understorey weeds included Tropical Chickweed (*Drymaria cordata* subsp. *cordata*) and Pink Wood Sorrel (*Oxalis debilis* var.

corymbosa) at DUCK1 and Spear Thistle (*Cirsium vulgare*) and Fireweed (*Senecio madagascariensis*) at DUCK2.

River Oak and native shrubs were the dominant source of organic litter. The native vines present were Common Silkpod (*Parsonia straminea*) and Cockspur Thorn (*Maclura cochinchinensis*) with the exotic vine Cat's Claw Creeper (*Dolichandra unguis-cati)* (all at DUCK2).

Bank condition was very poor in Duck Creek, with large areas of bank undercutting and slumping, and many exposed tree roots (Table 3.11). Habitat was slightly better at both sites, due to the present of logs and reed habitat, and the absence of weed organic litter (Table 3.11). Both sites were highly disturbed by tree clearing, stock access and limited exclusion fencing (Table 3.11).

Peacock Creek

The vegetation at the Peacock Creek site was a River Oak – Weeping Bottlebrush layered woodland (index score 2.67; Table 3.12). The vegetation score was negatively affected by the high cover of understorey weeds.

Large trees were River Oak and the midstorey consisted of regrowth River Oak, Weeping Bottlebrush (*Callistemon viminalis*) and Sandpaper Fig (*Ficus coronata*). Creeping Beard Grass (*Opismenus imbecillis*), Creek Mat-rush (*Lomandra hystrix*) and Nettle (*Urtica incisa*) were the native species in the understorey which was dominated by the exotic grasses South African Pigeon Grass (*Setaria sphacelata*) and Kikuyu (*Pennisetum clandestinum*) and by Castor Oil Plant (*Ricinus communis*), Wandering Jew (*Tradescantia fluminensis*), Fireweed (*Senecio madagascariensis*), Wild Tobacco Bush (*Solanum mauriteanum*) and Spear Thistle (*Cirsium vulgare*). There were no vines (Table 3.18).

Bank condition was moderate at PEACOCK1, due predominantly to bank undercutting and slumping (Table 3.12). The lack of logs and fallen trees, and organic litter resulted in Habitat index score of 2.24/5.00 (Table 3.12). The site was fenced and undisturbed by stock (Table 3.12).

Table 3.11 Site level summary of riparian condition scores for each sub-index for sites in Tooloom Creek, Cataract River and Duck Creek. Individual scores maximum of 5.

	TOOL1	TOOL2	TOOL3	CAT1	CAT2	CAT3	DUCK 1	DUCK 2
Vegetation								
Large trees	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.33
Canopy Cover	2.00	2.67	2.00	1.33	2.33	1.00	2.67	3.00
Mid-storey Cover	5.00	1.67	1.67	5.00	4.33	3.67	5.00	3.00
Mid-storey Weeds	2.33	5.00	3.67	5.00	5.00	2.33	5.00	5.00
Grass Cover	1.67	2.00	4.33	2.33	4.67	5.00	2.00	3.00
Grass Weeds	2.33	5.00	1.00	5.00	3.67	1.00	5.00	3.67
Understorey Cover	5.00	2.33	1.67	2.33	3.67	2.33	2.33	2.33
Understorey Weeds	1.67	2.00	1.67	2.67	5.00	2.33	4.00	3.00
Vines	1.67	1.00	1.00	1.00	1.00	1.00	1.00	2.33
Vegetation Layers	3.00	3.00	2.33	2.67	2.67	1.67	3.00	3.00
Total/5	2.57	2.57	2.03	2.83	3.33	2.13	3.10	2.97
Bank condition								
Undercutting	1.00	2.00	1.00	2.00	1.00	1.00	2.00	1.00
Exposed Tree Roots	2.00	3.00	4.00	3.00	5.00	5.00	2.00	1.00
Slumping	1.00	1.00	1.00	2.00	2.00	2.00	1.00	1.00
Total/5	1.33	2.00	2.00	2.33	2.67	2.67	1.67	1.00
Habitat								
Standing Dead Trees	5.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00
Logs	2.00	2.00	1.00	3.00	3.00	2.00	3.00	4.00
Fallen Trees	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00
Reeds	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Large Trees	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.33
Organic Litter	1.00	1.33	1.33	1.00	1.00	1.00	1.00	1.00
Weed Litter	3.67	5.00	2.33	5.00	5.00	1.00	5.00	5.00
Total/5	2.52	2.76	1.52	2.14	2.57	1.43	2.14	2.33
Disturbance								
Tree Clearing	1.00	2.33	1.00	1.00	2.33	1.00	1.00	1.00
Fencing	5.00	1.00	1.00	1.00	3.67	1.00	1.00	1.00
Livestock	5.00	1.00	1.00	1.00	2.33	1.00	1.00	1.00
Total/5	3.67	1.44	1.00	1.00	2.78	1.00	1.00	1.00

Tabulam River

The vegetation at the Tabulam River site was Water Gum forest with emergent Forest Red Gum (index score 3.90; Table 3.12). The high vegetation score was due to high canopy and midstorey cover, no midstorey, grass and few understorey weeds, the presence of native vines and multiple vegetation layers (Table 3.18).

Large trees were Forest Red Gum (*Eucalyptus tereticornis*), Water Gum (*Tristaniopsis laurina*), Grey Myrtle (*Backhousia myrtifolia*) and Three-veined Cryptocarya (*Cryptocarya triplinervis* var. *pubens*). The midstorey consisted of the native species Water Gum, Three-veined Cryptocarya (*Cryptocarya triplinervis* var. *pubens*), Blackthorn (*Bursaria spinosa* subsp. *spinosa*) and Brush Cherry (*Syzygium australe*) with no midstorey weeds. The native Creeping Beard Grass (*Opismenus imbecillis*) and Weeping Grass (*Microlaena stipoides*) were the dominant grasses with no grass weeds. Seedling Brush Cherry (*Syzygium australe*), Creek Mat-rush (*Lomandra hystrix*) and Kidney Weed (*Dichondra repens*) dominated the understorey with occasional seedlings of the exotic Small-leaved Privet (*Ligustrum sinense*). The native vines Cockspur Thorn (*Maclura cochinchinensis*), Lawyer Vine (*Smilax australis*) and Wonga Wonga Vine (*Pandorea pandorana*) were present with an occasional plant of the exotic Cat's Claw Creeper (*Dolichandra unguis-cati*).

Bank condition was moderate at TAB1, due predominantly to bank undercutting and slumping (Table 3.12). The lack of fallen trees and large trees, and the presence of weed litter resulted in Habitat index score of 1.10/5.00 (Table 3.12). The site was fenced and undisturbed by stock (Table 3.12).

Timbarra River

The vegetation community at TIMB1 was River Oak – Weeping Bottlebrush layered woodland (index score 2.50; Table 3.12), that at TIMB2 Water Gum – Weeping Bottlebrush shrubland (index score 2.60) and at TIMB3 Snow Gum Woodland with Carex Sedgeland (index score 2.80). The higher vegetation score at TIMB3 was due to higher understorey cover and fewer understorey weeds (Table 3.19).

Large trees were River Oaks at TIMB1 with no large trees at the other Timbarra River sites. Weeping Bottlebrush was dominant in the understorey at TIMB1 and TIMB2 with regrowth River Oak at TIMB1 and Water Gum (*Tristaniopsis laurina*) at TIMB2. Tantoon (*Leptospermum polygalifolium* subsp. *montanum*) was dominant in the understorey at TIMB3. There were no midstorey weeds at any Timbarra site. The native grass Couch (*Cynodon dactylon*) occurred at TIMB1 and TIMB2 with Weeping Grass (*Microlaena stipoides*) and Blady Grass (*Imperata cylindrica*) at TIMB2 and Snow Grass (*Poa sieberiana*) at TIMB3. There were no grass weeds at TIMB1 and TIMB2. The exotic grasses Paspalum (*Paspalum dilatatum*), Yorkshire Fog (*Holcus lanatus*) and Whisky Grass (*Andropogon virginicus*) occurred at TIMB3.

The native Pale Knotweed (*Persicaria lapathifolia*) was dominant in the understorey at TIMB1, with Common Bracken (*Pteridium esculentum*), Nettle (*Urtica incisa*) and seedling *Acacia* spp. at TIMB2 and Fen Sedge (*Carex gaudichaudiana*), Common Rush (*Juncus usitatus*) and Spiny-headed Mat-rush

(*Lomandra longifolia*) at TIMB3. Understorey weeds were occasional Fireweed (*Senecio madagascariensis*) at TIMB1 and Chickweed (*Stellaria media*) at TIMB2. Organic litter was dominated by Weeping Bottlebrush and Water Gum leaves at TIMB2 with seed pods of the exotic vine Cat's Claw Creeper (*Dolichandra unguis-cati*) at TIMB1 and Whisky Grass at TIMB3.

Bank condition was very good at TIMB2 and TIMB3, but very poor at TIMB1 with bank undercutting and slumping, and high numbers of exposed tree roots (Table 3.12). Although habitat was good at TIMB2 (3.29/5.00) because of standing and fallen large wood, and reed habitat, the Habitat index was less at TIMB1 due to the lack of fallen trees, and worst at TIMB2 due to the lack of standing and fallen large wood (Table 3.12). In contrast, TIMB3 was relatively undisturbed by tree clearing or stock access and was fenced, but TIMB1 was highly disturbed (Table 3.12).

Table 3.12 Site level summary of riparian condition scores for each sub-index for sites in Peacock Creek, Tabulam River and Timbarra River. Individual scores maximum of 5.

	PEACOCK1	TAB1	TIMB1	TIMB2	TIMB3
Vegetation					
Large trees	1.00	1.67	1.00	1.00	1.00
Canopy Cover	2.00	3.33	1.33	1.00	1.33
Mid-storey Cover	2.33	3.67	2.33	5.00	1.67
Mid-storey Weeds	5.00	5.00	5.00	5.00	5.00
Grass Cover	3.00	3.33	3.67	1.00	2.00
Grass Weeds	2.33	5.00	5.00	5.00	4.00
Understorey Cover	4.33	3.00	1.00	1.00	5.00
Understorey Weeds	3.00	4.67	1.67	3.00	5.00
Vines	1.00	5.00	1.67	1.00	1.00
Vegetation Layers	2.67	4.33	2.33	3.00	2.00
Total/5	2.67	3.90	2.50	2.60	2.80
Bank condition					
Undercutting	1.00	1.00	1.00	5.00	2.00
Exposed Tree Roots	5.00	4.00	1.00	5.00	5.00
Slumping	1.00	2.00	1.00	3.00	5.00
Total/5	2.33	2.33	1.00	4.33	4.00
Habitat					
Standing Dead Trees	5.00	5.00	5.00	5.00	0.00
Logs	1.00	3.00	3.00	3.00	2.00
Fallen Trees	0.00	0.00	0.00	3.00	0.00
Reeds	5.00	5.00	5.00	5.00	3.00
Large Trees	1.00	1.67	1.00	1.00	1.00
Organic Litter	1.33	2.00	1.00	1.00	2.00
Weed Litter	2.33	5.00	4.33	5.00	4.67
Total/5	2.24	3.10	2.76	3.29	1.81
Disturbance					
Tree Clearing	1.00	5.00	1.00	5.00	3.67
Fencing	5.00	1.00	1.00	1.00	5.00
Livestock	5.00	1.00	1.00	1.00	5.00
Total/5					

Table 3.13 Dominant riparian vegetation for each stratum at Bookookoorara Creek sites.

Vegetation Description	BOOKOOK1	BOOKOOK2
Left/Right bank (facing downstream)	L	L
Community Description	Cleared River Oak grassy open forest	Carex Sedgeland with New England Peppermint
Emergents	No emergents	No emergents
Dominant Large Trees A	No large trees	No large trees
Dominant Large Trees B	No large trees	No large trees
Dominant Large Trees C	No large trees	Eucalyptus nova-anglica
Dominant Mid-storey Cover (native)	Casuarina cunninghamiana	Leptospermum polygalifolium subsp. montanum
	Acacia dealbata	
Dominant Mid-storey Cover (weeds)	Solanum mauriteanum	No midstorey weeds
	Lantana camara	
Dominant Grass Cover (native)	Cynodon dactylon	Poa sieberiana
	Oplismenus imbecillis	Microlaena stipoides
	Austrostipa verticillata	
Dominant Grass Cover (weeds)	Pennisetum clandestinum	Eragrostis curvula
	Paspalum dilatatum	Andropogon virginicus
Dominant Understorey Cover (native)	Persicaria lapathifolia	Carex gaudichaudiana
	Juncus usitatus	Lomandra longifolia
Dominant Understorey Cover (weeds)	Argemone ochroleuca subsp. ochroleuca	No understorey weeds
	Cirsium vulgare	
	Lantana camara	
Dominant Vines (native)	No vines	

Table 3.14 Dominant riparian vegetation for each stratum at Boonoo Boonoo River sites.

Vegetation Description	BOO1	BOO2	BOO3
Left/Right bank (facing downstream)	R	R	R
Community Description	Cleared River Oak grassy open forest	Broad-leaved Apple and Forest Red Gum emergents with rainforest midstorey	Carex Sedgeland with New England Peppermint
Emergents	No emergents	Angophora subvelutina	No emergents
		Eucalytus tereticornis	
Dominant Large Trees A	No large trees	Angophora subvelutina	No large trees
Dominant Large Trees B	No large trees	Eucalytus tereticornis	No large trees
Dominant Large Trees C	No large trees	No large trees	Eucalyptus nova-anglica
Dominant Mid-storey Cover (native)	Casuarina cunninghamiana	Casuarina cunninghamiana	Leptospermum polygalifolium subsp. montanum
	Acacia dealbata	Alphitonia excelsa	
		Leptospermum brachyandrum	
		Ficus coronata	
		Callistemon viminalis	
		Bursaria spinosa subsp. spinosa	
		Syzygium smithii	
Dominant Mid-storey Cover (weeds)	Solanum mauriteanum	No midstorey weeds	No midstorey weeds
	Lantana camara		
Dominant Grass Cover (native)	Cynodon dactylon	Cynodon dactylon	Poa sieberiana
	Oplismenus imbecillis	Potamophila parvflora	
	Austrostipa verticillata		Microlaena stipoides
Dominant Grass Cover (weeds)	Pennisetum clandestinum	No grass weeds	Eragrostis curvula
	Paspalum dilatatum		Andropogon virginicus
Dominant Understorey Cover (native)	Persicaria lapathifolia	Lomandra hystrix	Carex gaudichaudiana
	Juncus usitatus	Pteridium esculentum	Lomandra longifolia
		Casuarina cunninghamiana	
		Olea paniculata	

Dominant Understorey Cover (weeds)	Argemone ochroleuca subsp. ochroleuca	Bidens pilosa	No understorey weeds
	Cirsium vulgare		
	Lantana camara		
Dominant Organic Litter		Angophora subvelutina	
Dominant Vines (native)	No vines	Parsonsia straminea	No vines

Table 3.15 Dominant riparian vegetation for each stratum at Koreelah Creek sites.

Vegetation Description	KOOR1	KOOR2
Left/Right bank (facing downstream)	R	L
Community Description	River Oak – Weeping Bottlebrush layered woodland	River Oak grassy open forest
Emergents	No emergents	No emergents
Dominant Large Trees A	arina cunninghamiana	Casuarina cunninghamiana
Dominant Large Trees B	Casuarina cunninghamiana	Casuarina cunninghamiana
Dominant Large Trees C	Callistemon viminalis	Casuarina cunninghamiana
Dominant Mid-storey Cover (native)	Tristaniopsis laurina	No native midstorey
	Callistemon viminalis	
	Ficus coronata	
Dominant Mid-storey Cover (weeds)	Ligustrum sinense	No midstorey weeds
Dominant Grass Cover (native)	Microlaena stipoides	No native grasses
Dominant Grass Cover (weeds)	No grass weeds	Bromus catharticus
Dominant Understorey Cover (native)	Lomandra hystrix	Urtica incisa
	Ficus coronata	
	Juncus usitatus	
	Persicaria hydropiper	
Dominant Understorey Cover (weeds)	Senecio madagascariensis	Ambrosia artemisifolia
	Cirsium vulgare	Solanum nigrum
	Silybum marianum	Galinsoga parvilfora
	Stellaria media	Stellaria media
Dominant Organic Litter	Tristaniopsis laurina	Casuarina cunninghamiana
Dominant Vines	No vines	No vines

Table 3.16 Dominant riparian vegetation for each stratum at Tooloom Creek sites.

Vegetation Description	TOOL1	TOOL2	TOOL3
Left/Right bank (facing downstream)	R	L	R
Community Description	River Oak – Weeping Bottlebrush layered woodland	River Oak – Weeping Bottlebrush layered woodland	Exotic grassland/River Oak with *Eucalyptus dunnii*
Emergents	No emergents	No emergents	No emergents
Dominant Large Trees A	Casuarina cunninghamiana	Angophora subvelutina	No large trees
Dominant Large Trees B	No large trees	Angophora subvelutina	Eucalyptus dunnii
Dominant Large Trees C	No large trees	Casuarina cunninghamiana	No large trees
		Callistemon viminalis	
Dominant Mid-storey Cover (native)	Callistemon viminalis	Callistemon viminalis	Casuarina cunninghamiana
	Acacia spp.	Leptospermum brachyandrum	
Dominant Mid-storey Cover (weeds)	Ligustrum sinense	No midstorey weeds	Pyracantha crenulata
	Lantana camara		
Dominant Grass Cover (native)	Olismenus imbecillis	Cynodon dactylon	No native grasses
Dominant Grass Cover (weeds)	Bromus catharticus	Pennisetum clandestinum	Pennisetum clandestinum
Dominant Understorey Cover (native)	Persicaria hydropiper	Juncus usitatus	Urtica incisa
			Persicaria decipiens
Dominant Understorey Cover (weeds)	Rumex crispus	Ligustrum sinense	Ambrosia artemisioides
	Senecio madagascariensis		Senecio madagascariensis
	Stellaria media		Stellaria media
	Sida rhombifolia		Argemone ochroleuca subsp. ochroleuca
	Tradescantia fluminensis		Datura stramonium
Dominant Organic Litter (native)		Callistemon viminalis	
Dominant Vines	No vines	No vines	No vines

Table 3.17 Dominant riparian vegetation for each stratum at Cataract River sites.

Vegetation Description	CAT1	CAT2	CAT3
Left/Right bank (facing downstream)	R	L	L
Community Description	River Oak – Weeping Bottlebrush layered woodland	River Oak grassy open forest	Exotic Grassland with Snow Gum and River Oak
Emergents	No emergents	No emergents	No emergents
Dominant Large Trees A	No large trees	Casuarina cunninghamiana	No large trees
Dominant Large Trees B	Casuarina cunninghamiana	No large trees	No large trees
Dominant Large Trees C	No large trees	Casuarina cunninghamiana	Eucalyptus pauciflora
Dominant Mid-storey Cover (native)	Callistemon viminalis	Melicytus dentatus	No native midstorey
	Casuarina cunninghamiana	Acacia irrorata	
Dominant Mid-storey Cover (weeds)	No midstorey weeds	No midstorey weeds	Pyracantha crenulata
			Ligustrum sinense
Dominant Grass Cover (native)	Cynodon dactylon	Cynodon dactylon	No native grasses
	Oplismenus imbecillis	Microlaena stipoides	
Dominant Grass Cover (weeds)	No grass weeds	Axonopus fissifolius	Eragrostis curvula
			Axonopus fissifolius
			Festuca pratensis
Dominant Understorey Cover (native)	Callistemon viminalis	Juncus usitatus	Juncus usitatus
	Lomandra hystrix	Lomandra hystrix	Ranunculus lappaceus
Dominant Understorey Cover (weeds)	Senecio madagascariensis	No understorey weeds	Rumex crispus
	Argemone ochroleuca subsp. ochroleuca		Cirsium vulgare
Dominant Organic Litter			
Dominant Vines	No vines	No vines	

Table 3.18 Dominant riparian vegetation for each stratum at sites in Duck Creek, Peacock Creek and Tabulam River.

Vegetation Description	DUCK1	DUCK2	PEACOCK1	TAB1
Left/Right bank (facing downstream)	L	R	R	R
Community Description	River Oak – Weeping Bottlebrush layered woodland	River Oak – Weeping Bottlebrush layered woodland	River Oak – Weeping Bottlebrush layered woodland	Water Gum forest with emergent Forest Red Gum
Emergents	No emergents	No emergents	No emergents	Eucalyptus tereticornis
Dominant Large Trees A	No large trees	Casuarina cunninghamiana	Casuarina cunninghamiana	Eucalyptus tereticornis
				Backhousia myrtifolia
Dominant Large Trees B	Casuarina cunninghamiana	Casuarina cunninghamiana	No large trees	Tristaniopsis laurina
				Cryptocarya triplinervis var. pubens
Dominant Large Trees C	Casuarina cunninghamiana	Casuarina cunninghamiana	Casuarina cunninghamiana	Tristaniopsis laurina
Dominant Mid-storey Cover (native)	Callistemon viminalis	Callistemon viminalis	Casuarina cunninghamiana	Cryptocarya triplinervis var. pubens
	Acmena smithii	Acmena smithii	Callistemon viminalis	Tristaniopsis laurina
	Streblus brunonianus	Ficus coronata	Ficus coronata	Bursaria spinosa subsp. spinosa
				Syzygium australe
Dominant Mid-storey Cover (weeds)	No midstorey weeds	No midstorey weeds	No midstorey weeds	No midstorey weeds
Dominant Grass Cover (native)	Cynodon dactylon	Oplismenus imbecillis	Oplismenus imbecillis	Oplismenus imbecillis
	Oplismenus imbecillis	Microlaena stipoides		Microlaena stipoides
Dominant Grass Cover (weeds)	No grass weeds	Paspalum mandiocanum	Setaria sphacelata	No grass weeds
		Bromus catharticus	Pennisetum clandestinum	Syzygium australe
Dominant Understorey Cover (native)	Juncus usitatus	Lomandra hystrix	Lomandra hystrix	Lomandra hystrix

	Lomandra hystrix	Persicaria hydropiper	Urtica incisa	Dichondra repens
		Hypolepis glandulosa		
Dominant Understorey Cover (weeds)	Drymaria cordata subsp. cordata	Lantana camara	Ricinus communis	Ligustrum sinense
	Oxalis debilis var. corymbosa	Cirsium vulgare	Tradescantia fluminensis	
	Lantana camara	Senecio madagascariensis	Senecio madagascariensis	
			Solanum mauriteanum	
			Cisium vulgare	
Dominant Organic Litter		Casuarina cunninghamiana		Native woody species
		Native shrubs		
Dominant Vines (native)	No vines	Parsonsia straminea	No vines	Maclura cochinchinensis
		Maclura cochinchinensis		Smilax australis
Dominant Vines (exotic)				Pandorea pandorana
				Dolichandra unguis-cati

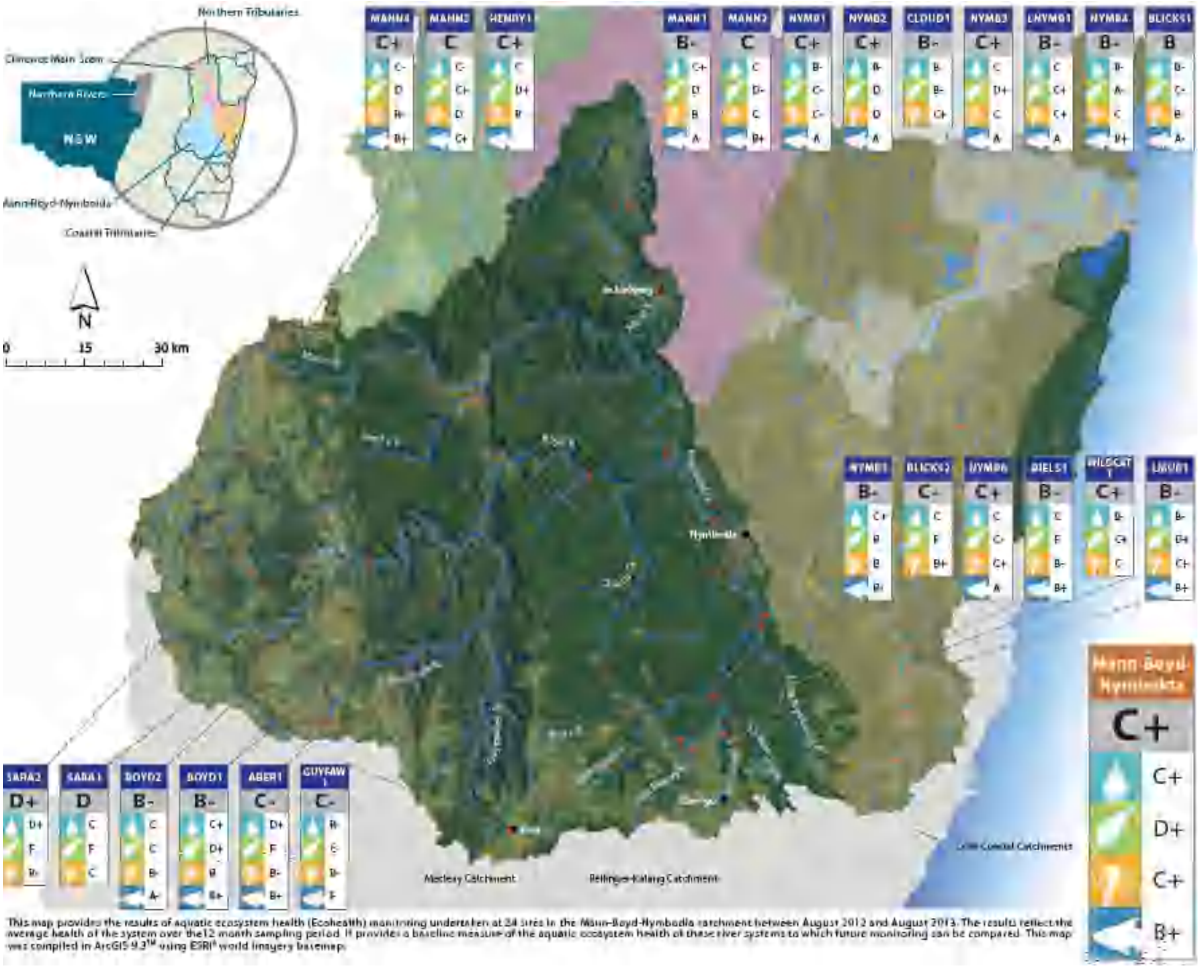
Table 3.19 Dominant riparian vegetation for each stratum at sites in Tabulam River and the Timbarra River.

Vegetation Description	TAB1	TIMB1	TIMB2	TIMB3
Left/Right bank (facing downstream)	R	R	L	L
Community Description	Water Gum forest with emergent Forest Red Gum	River Oak – Weeping Bottlebrush layered woodland	Water Gum – Weeping Bottlebrush layered woodland	Snow Gum Woodland/Carex Sedgeland
Emergents	Eucalyptus tereticornis	No emergents	No emergents	No emergents
Dominant Large Trees A	Eucalyptus tereticornis	No large trees	No large trees	No large trees
	Backhousia myrtifolia	Casuarina cunninghamiana	No large trees	
Dominant Large Trees B	Tristaniopsis laurina	Casuarina cunninghamiana	No large trees	No large trees
	Cryptocarya triplinervis var. pubens	Callistemon viminalis	Callistemon viminalis	
Dominant Large Trees C	Tristaniopsis laurina	Casuarina cunninghamiana	Tristaniopsis laurina	No large trees
Dominant Mid-storey Cover (native)	Cryptocarya triplinervis var. pubens	No midstorey weeds	No midstorey weeds	Leptospermum polygalifolium subsp. montanum
	Tristaniopsis laurina	Lantana camara		
	Bursaria spinosa subsp. spinosa	Cynodon dactylon	Cynodon dactylon	
	Syzygium australe		Microlaena stipoides	
Dominant Mid-storey Cover (weeds)	No midstorey weeds		Imperata clylindrica	No midstorey weeds
Dominant Grass Cover (native)	Oplismenus imbecillis	No grass weeds	No grass weeds	Poa sieberiana
	Microlaena stipoides			
Dominant Grass Cover (weeds)	No grass weeds			Paspalum dilatatum
				Andropogon virginicus
				Holcus lanatus

Dominant Understorey Cover (native)	Syzygium australe	Persicaria lapathifolia	Pteridium esculentum	Carex gaudichaudiana
	Lomandra hystrix		Urtica incisa	Lomandra longifolia
	Dichondra repens		Acacia spp.	Juncus usitatus
Dominant Understorey Cover (weeds)	Ligustrum sinense	Senecio madagascariensis	Stellaria media	No understorey weeds
Dominant Litter	Native woody species		Callistemon viminalis	Andropogon virginicus
Dominant Vines (native)	Maclura cochinchinensis		Tristaniopsis laurina	No vines
	Smilax australis	Dolichandra unguis-cati		
	Pandorea pandorana	No vines	No vines	
Dominant Vines (exotic)	Dolichandra unguis-cati			

3.3 Mann-Nymboida-Boyd subcatchment

Overview



The Mann-Boyd-Nymboida river systems recorded a C+, the equal highest overall score in the Clarence catchment.

The condition scores of river systems ranged from D+ for the westerly Sara and Aberfoyle Rivers on the tablelands, to B+ for the forested Little Nymboida River and Clouds Creek.

In the Mann River, condition improved with distance downstream, driven by the poor condition of tableland sites (no native riparian vegetation, eroding stream channels). In the Nymboida River, the upper forested reaches had better condition than the downstream reaches which were influenced by vegetation clearing and the altered hydrology downstream of the Nymboida Weir.

Nitrogen concentrations were consistently high in the Mann-Boyd-Nymboida Rivers, exceeding guideline values on multiple occasions at all sites. Concentrations of phosphorus also exceeded the guideline values in tributary streams and tableland rivers of the region. There were no trends of increasing nutrients along the rivers suggesting local sources are an important influence on nutrients.

There were no algal blooms recorded during the study. However, algal concentrations were consistently above the guideline value in the Mann and lower Nymboida Rivers. Concentrations of dissolved oxygen were very good in the Mann-Boyd-Nymboida Rivers, and pH values was also within the guideline values suggesting this region is a source of good water quality to the Clarence River.

Aquatic macroinvertebrate communities in the Mann-Boyd-Nymboida Rivers were the most abundant and diverse of the Clarence catchment, and contained many biota indicative of very good water quality. Macroinvertebrate abundance and richness increased significantly after the floods of Jan-Feb 2013, suggesting they bounce back well following floods and were more affected by the low flows experienced in 2012.

Fish communities throughout the Nymboida River were in excellent condition with an A grade recorded for all sites except for mid-river reaches that received a B grade. All sites were dominated by diverse communities of native fish.

The Nymboida River and its tributaries had the highest vegetation scores in the Clarence catchment, with good native vegetation cover and habitat and low disturbances in sites within conservation reserves. Sites downstream of Nymboida weir have lower scores due to vegetation clearing, altered land use and eroding river banks.

3.3.1 Water chemistry

3.3.1.1 *Chlorophyll a*

In the Little Nymboida River (LNYMB1) chlorophyll *a* concentrations ranged from 0.220 µg/L (October 2012) to 2.640 µg/L (December 2012, Figure 3.20). The site mean concentration was 0.84 µg/L and no observations exceeded the upland freshwater trigger threshold of 4.00 µg/L. The site mean concentration at Wild Cattle Creek (WILDCAT1) was 0.680 µg/L and concentrations ranged from 0.055 µg/L (August 2013) to 1.430 µg/L (December 2012, Figure 3.20). No observations exceeded the upland freshwater trigger threshold. Concentrations of chl-*a* in the Bielsdown River (BIELS1) also did not exceed the upland freshwater trigger threshold. The site mean was 1.14 µg/L and concentrations ranged from 0.220 µg/L (October 2012) to 2.695 (August 2013).

Site mean chl-*a* concentrations in the Blicks River were similar between sites (0.90 and 0.92 µg/L at BLICKS2 and BLICKS1, respectively), but were less variable at the downstream site BLICKS1 (0.110 µg/L in October 2012 to 1.991 µg/L in August 2013) than the upstream site BLICKS2 (0.121 µg/L in August 2013 to 2.640 µg/L in December 2012. No observed concentrations exceeded the upland freshwater trigger threshold (Figure 3.20).

Site mean chl-*a* concentrations and range were low for both LMUR1 (mean of 0.280 µg/L) and CLOUD1 (mean of 0.239 µg/L, Figure 3.20). Chl-a ranged from <0.005 µg/L (August – October 2012) to 0.550 µg/L (December 2012) at LMUR1 and <0.005 µg/L (August 2012) to 0.407 µg/L (August 2013) at CLOUD1. No observed concentrations exceeded the upland freshwater trigger threshold at either site.

Chl-*a* concentrations increased longitudinally downstream the upper reaches of the Nymboida River (NYMB6-4), but the trend was not consistent in lower reaches (Figure 3.20). Chl-*a* ranged from <0.001 µg/L at NYMB6-5 (August 2012) to 7.370 µg/L at NYMB1 (August 2012). This maximum concentration was the only exceedance of the freshwater trigger threshold for the Nymboida River.

The site mean chl-*a* was 0.97 µg/L at GUYFAW1, ranging from <0.001 µg/L (August – October 2012) to 3.509 µg/L (June 2013). The site mean concentration was higher at ABER1 at 1.318 µg/L and ranged from 0.330 µg/L (August 2012) to 2.629 µg/L (June 2013). The site mean concentration increased further at HENRY1 (1.490 µg/L), ranging 0.407 µg/L (June 2013) to 2.750 µg/L (December 2012). Chl-*a* concentrations in at GUYFAW1, ABER1 or HENRY1 were not observed to exceed the upland freshwater trigger threshold (Figure 3.20).

There were no clear upstream-downstream trends between sites on the Sara River or Boyd River (Figure 3.20). Site mean chl-*a* was 0.610 µg/L at SARA2 and 0.520 µg/L at SARA1. Chl-*a* ranged from <0.001 µg/L at SARA1 (October 2012) to 1.573 µg/L at SARA2 (August 2013), but did not exceed the upland freshwater trigger threshold. Site mean chl-*a* was 0.340 µg/L at BOYD2 and 0.370 µg/L at BOYD1. Chl-*a* ranged from <0.001 µg/L at BOYD2 (October 2012) to 0.814 µg/L at BOYD2 (April 2013), and did not exceed the upland freshwater trigger threshold.

Chl-*a* concentrations ranged from <0.001 µg/L at MANN1 (August 2012) to 5.973 µg/L at MANN3 (August 2013). This maximum concentration was the only observation that exceeded the upland freshwater trigger threshold (Figure 3.20).

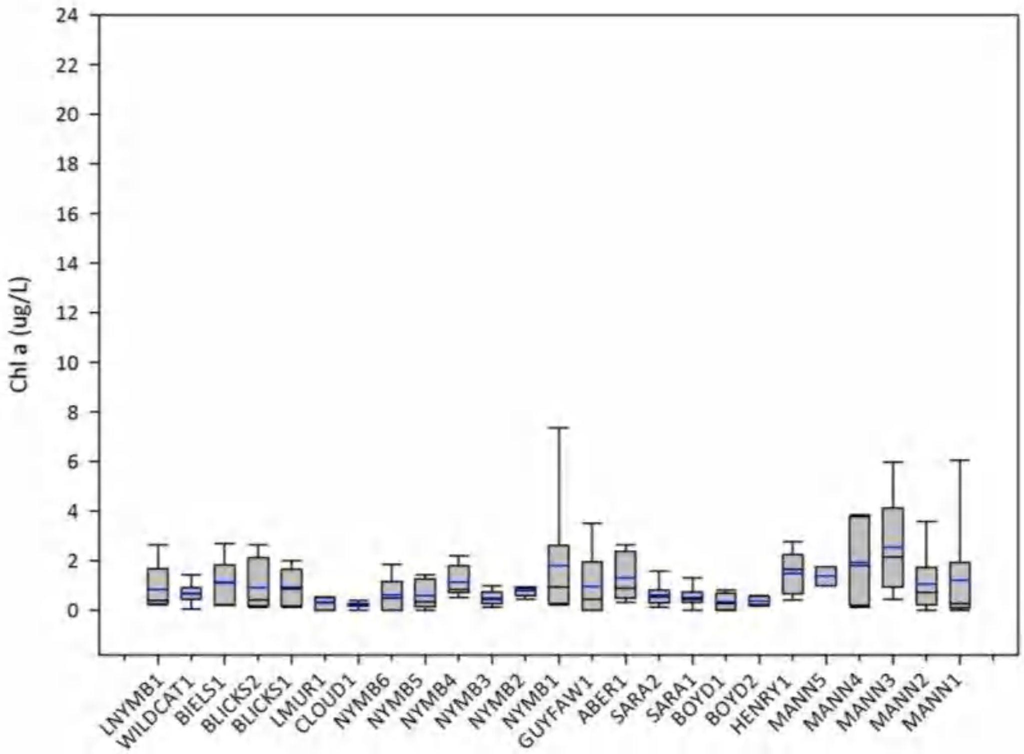


Figure 3.20 Mean (black line), median (blue line), 25th and 75th percentiles and range of chlorophyll *a* concentrations from sites in the Mann-Nymboida-Boyd tributaries of the Clarence from August 2012 to August 2013.

3.3.1.2 *Total Nitrogen (TN)*

There were no clear longitudinal trends in total nitrogen (TN) in either the Nymboida or Mann Rivers (Figure 3.21). TN ranged from 257.45 mg/L (August 2013) to 1721.05 mg/L (December 2012) at LNYMB1 (site mean of 808.64 mg/L, Figure 3.21). The upland freshwater trigger threshold was exceeded three times at LYMB1 from December 2012 to June 2013. TN ranged from 226.73 mg/L (April 2013) to 865.79 mg/L (December 2012) at WILDCAT1 (site mean of 510.81 mg/L, Figure 3.21). The upland freshwater trigger threshold was exceeded twice (in December 2012 and June 2013). TN ranged from 280.78 mg/L (October 2012) to 1011.74 mg/L (August 2013) at BIELS1 (site mean of 702.96 mg/L, Figure 3.21). The upland freshwater trigger threshold was exceeded on four sampling occasions (67 %).

TN was higher at the upstream site on the Blicks River, BLICKS2 (mean of 806.94 µg/L, range of 373.98 µg/L(August 2013) to 1612.68 µg/L (August 2012)) than the downstream site BLICKS1 (mean of 288.43 µg/L, range of 9.85 µg/L (October 2012) to 729.68 µg/L (June 2013)). Hence, upland freshwater trigger thresholds were exceeded twice at BLICKS2 (August 2012 – December 2012) and once at BLICKS1 (June 2013, Figure 3.21). The site mean TN at LMUR1 was 478.01 µg/L and TN ranged from 142.23 µg/L (October 2012) to 826.32 µg/L (December 2012). Upland freshwater trigger thresholds were exceeded in December 2012 and June 2013. TN concentrations were also high at CLOUD1 (site mean 466.65 µg/L), ranging from 53.661 µg/L (October 2012) to 1109.46 µg/L (April 2013). The upland freshwater trigger threshold was exceeded three times (August 2012, December 2012 and April 2013).

TN was initially high in the upper reaches of the Nymboida River (NYMB6-5 site means 495.25 and 509.07 µg/L, respectively), but then dropped significantly at NYMB4 (site mean 408.11 µg/L) and increased longitudinally downstream to NYMB1 (site mean 484.04 µg/L, Figure 3.21). Freshwater trigger thresholds were exceeded in December 2012 and June 2013 at NYMB1-3, but exceedances became temporally variable at upstream sites.

TN ranged <0.001 µg/L (October 2012) to 1602.63 µg/L (December 2012) at GUYFAW1 (site mean of 579.29 µg/L, Figure 3.21). The upland freshwater trigger threshold was exceeded three times, in August 2012, December 2012 and June 2013. TN concentrations were higher in ABER1 (Figure 3.21), ranging from 589.47 µg/L (December 2012) to 1359.80 µg/L (June 2013). The site mean was 875.40 µg/Land all observed concentrations exceeded the upland freshwater trigger threshold. TN ranged from 423.67 µg/L (August 2013) to 1194.74 µg/L at HENRY1, with a site mean of 748.48 µg/L (Figure 3.21). The upland freshwater trigger threshold was exceeded three times (75 % of sampling occasions) from December 2012 to June 2013.

TN concentrations were generally high in the Sara River, ranging from 97.37 µg/L (SARA2 in October 2012) to 1589.47 µg/L (SARA2 in December 2012). The site mean was higher at the downstream site SARA1 (934.50 µg/L) than the upstream site SARA2 (785.56 µg/L), Figure 3.21). The upland freshwater trigger threshold was exceeded four times at both sites but the temporal patterns of exceedance differed. In contrast, the site mean TN at the downstream site on the Boyd River, BOYD1 was lower (479.31 µg/L) than the upstream site BOYD2 (640.58 µg/L). TN concentrations in the Boyd River ranged from 42.67 µg/L (BOYD2 in October 2012) to 2089.47 µg/L (BOYD 2 in December 2012). The upland freshwater trigger threshold was exceeded on three sampling occasions at each site (in August 2012, December 2012 and June 2013).

TN concentrations were greatest in the upper reaches of the Mann River (Figure 2.21), peaking at 1786.84 µg/L at MANN4 (in December 2012). While observed TN exceeded freshwater trigger thresholds at all sites, the middle reaches (MANN3-4) had the most exceedance (67 % of sampling periods) although this varied temporally between sites.

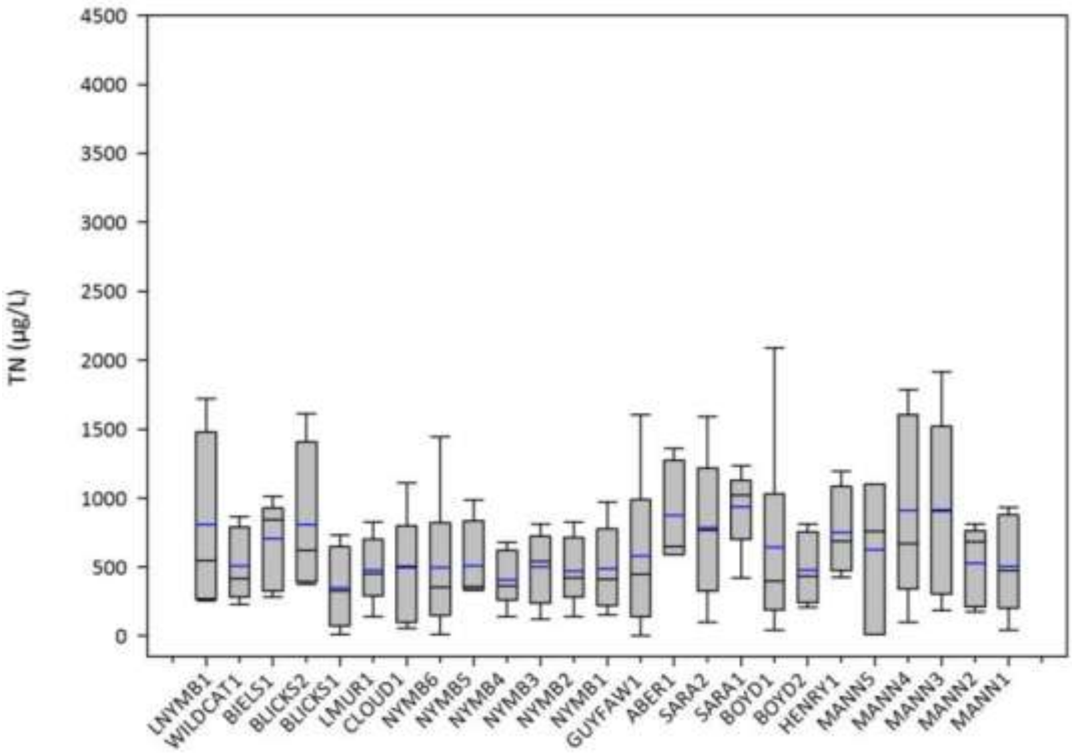


Figure 3.21 Mean (black line), median (blue line), 25th and 75th percentiles and range of TN concentrations from sites in the Mann-Nymboida-Boyd tributaries of the Clarence from August 2012 to August 2013.

3.3.1.3 *Bioavailable Nitrogen (NOx)*

With the exception of the Mann River, all sites in this subcatchment exceeded freshwater trigger thresholds for at least 40 % of sampling periods (Figure 3.22). Site means consistently exceeded the freshwater trigger threshold at LYMB1 (77.90 µg/L), WILDCAT1 (1054.82 µg/L), BIELS1 (195.43 µg/L), BLICKS2 (138.23 µg/L), LMUR1 (145.88 µg/L), NYMB1-6 (45.60 – 111.72 µg/L), GUYFAW1 (147.56 µg/L), ABER1 (60.02 µg/L), SARA1-2 (49.57 – 72.59 µg/L), BOYD2 (42.40 µg/L) and MANN5 (49.20 µg/L). GUYFAW1 had the largest range in the Mann River subcatchment (14.07 µg/L (June 2013) to 683.76 µg/L (December 2012, Figure 3.22). Overall, though, NOx concentrations were higher and more variable in the Nymboida River and its tributaries than the Mann River and its tributaries (Figure 3.22).

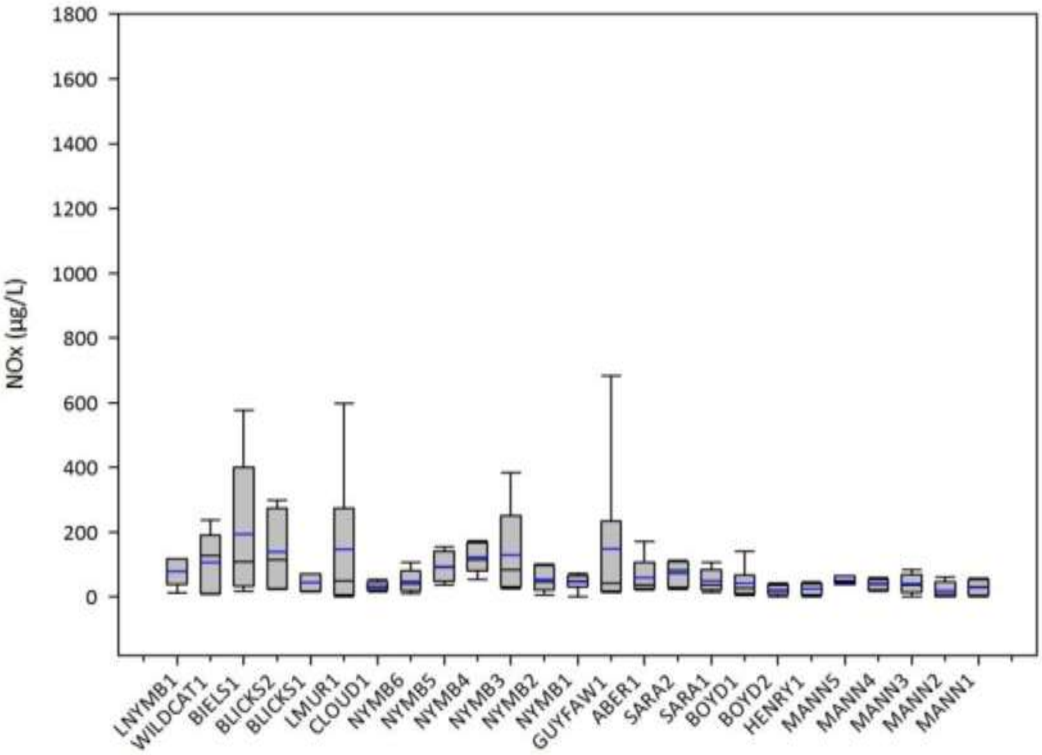


Figure 3.22 Mean (black line), median (blue line), 25th and 75th percentiles and range of NOx concentrations from sites in the Mann-Nymboida-Boyd tributaries of the Clarence from August 2012 to August 2013.

3.3.1.4 *Total Phosphorus (TP)*

Similar to patterns in TN, total phosphorus (TP) concentrations were bi-modal in the Nymboida River, increasing longitudinally downstream from NYMB6 to NYMB5, then dropping significantly at NYMB4 and increasingly slowly again to NYMB1 (Figure 3.23). TP ranged from <0.001 µg/L at NYMB6 (December 2012) to 168.00 µg/L at NYMB5 (August 2012). All sites except NYMB4 exceeded the upland freshwater trigger threshold at once, in August 2012, and the trigger threshold was also exceeded in October 2012 at NYMB6.

There was no clear longitudinal trend in TP in the Mann River, but concentrations were typically higher than those in the Nymboida River (the exception is NYMB5, Figure 3.23). TP ranged from <0.001 µg/L at MANN4 (October 2012) to 221.00 µg/L at MANN3 (August 2012). With the exception of MANN1 (1 exceedance in August 2012), sites in the Mann River exceeded TP freshwater trigger thresholds at least twice: in August 2012 and June 2013 for MANN5-4, and in August 2012 and December 2012 for MANN3-2.

Although there were no clear spatial patterns in tributaries of the Nymboida River, tributaries of the Mann River located on the Ebor Plateau had high concentrations of TP (Figure 3.23). TP at ABER1 ranged from 6.00 µg/L (April 2013) to 230 µg/L (December 2012) and the upland freshwater trigger threshold was exceeded on four occasions (80 % of sampling periods). TP in the Sara River ranged from <0.001 µg/L (December 2012) to 239.00 µg/L (August 2012). At both sites, the upland freshwater trigger threshold was exceeded twice (in August 2012 and October 2012).

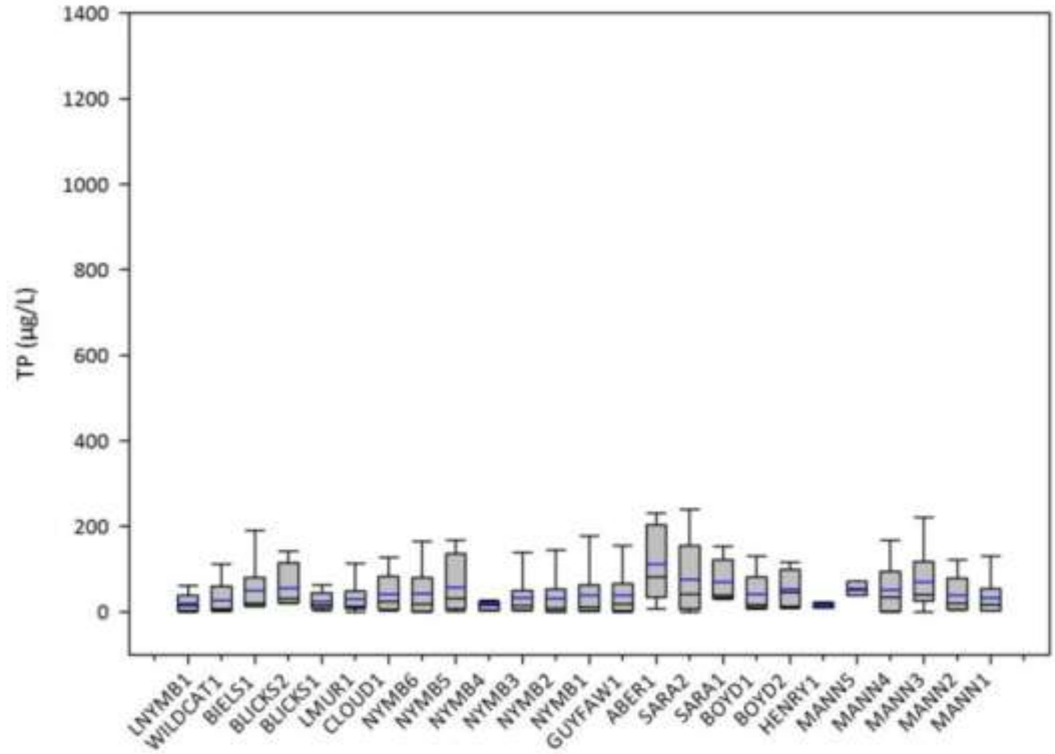


Figure 3.23 Mean (black line), median (blue line), 25th and 75th percentiles and range of TP concentrations from sites in the Mann-Nymboida-Boyd tributaries of the Clarence from August 2012 to August 2013.

3.3.1.5 *Soluble Reactive Phosphorus (SRP)*

Patterns in soluble reactive phosphorus (SRP) were similar to those for TP. SRP concentrations were bi-modal in the Nymbodia River with a significant drop at NYMB4 (Figure 3.24).SRP concentrations were highly variable in tributaries of the Nymboida River, with maximum SRP concentrations observed at BIELS1 (site mean of 35.86 µg/L), BLICKS2 (site mean of 34.83 µg/L) and LMUR1 (23.13 µg/L). Only CLOUD1 did not exceed the upland freshwater trigger threshold during the sampling period (Figure 3.24). At most tributary sites, the SRP trigger threshold was exceeded in April 2013.

Similar to spatial patterns in TP concentrations in the Mann River subcatchment, SRP concentrations were greatest at tributary sites draining the Ebor Plateau (Figure 3.24). The highest SRP concentrations were recorded at ABER1 (site mean of 47.672, range of 23.00 – 126.00 µg/L), where upland freshwater trigger thresholds were exceeded on all sampling occasions (Figure 3.24). SRP concentrations were also high in the Sara and Boyd Rivers and the tableland sites of the upper Mann (Figure 3.24). SRP ranged from 6.00 – 73.29 µg/L in the Sara River, with the upland freshwater trigger threshold exceeded in December 2012 and April 2013. SRP peaked in December 2012 at both

SARA1 and SARA2. In the Boyd River, site means were 17.80 and 15.47 µg/L for BOYD2 and BOYD1, respectively (Figure 3.24). SRP ranged from 2.65 – 38.73 µg/L with concentrations at both sites exceeding the upland freshwater trigger threshold twice (in December 2012 and April 2013).

Similar to spatial patterns in TP concentrations, the tableland sites in the upper Mann had the largest range of SRP (Figure 3.24). SRP ranged from 3.65 µg/L at MANN4 (October 2012) to 51.62 µg/L at MANN2 (December 2012). The freshwater trigger threshold was exceeded twice for most sites: in December 2012 and April 2013 for MANN4-3, and October – December 2012 at MANN2.

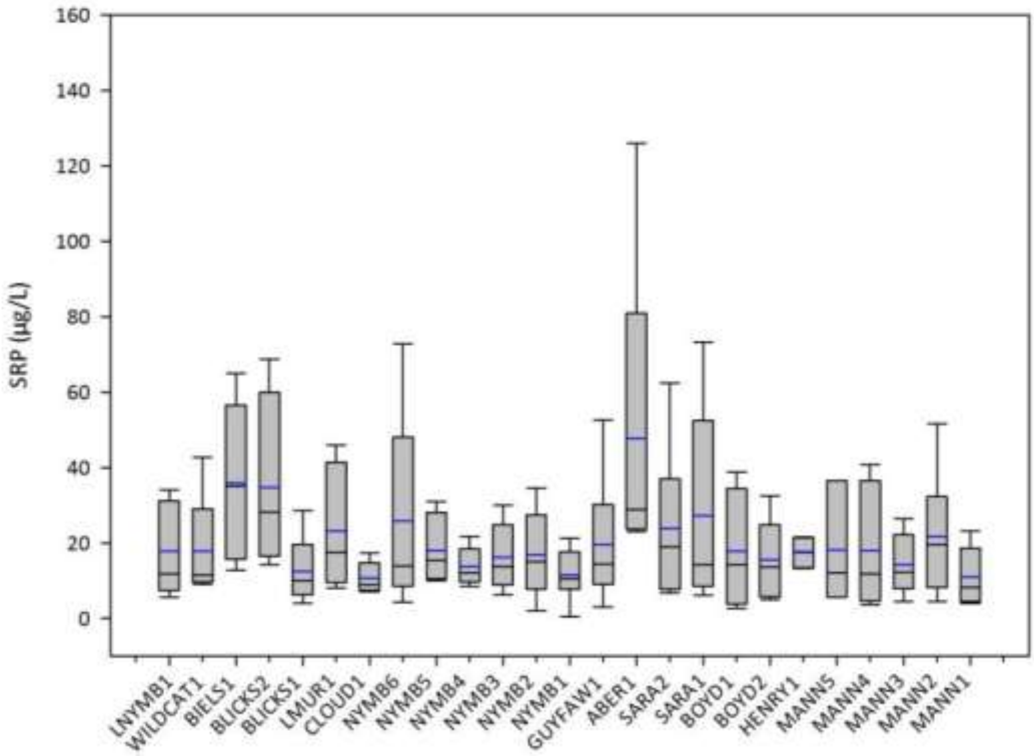


Figure 3.24 Mean (black line), median (blue line), 25th and 75th percentiles and range of SRP concentrations from sites in the Mann-Nymboida-Boyd tributaries of the Clarence from August 2012 to August 2013.

3.3.1.6 *Dissolved Oxygen (DO)*

There were few temporal or spatial patterns in dissolved oxygen (DO). DO % saturation declined slightly with distance downstream in the Nymboida River (Figure 3.25): the site mean at NYMB6 was 107.82 % (range 97.00 – 135.5 %) and the site mean at NYMB1 was 99.30 % (range 88.30 – 106.40 %). The upper limit of the upland freshwater trigger threshold was exceeded twice (in August 2012 – October 2012) at NYMB6-5. With the exception of BIELS1, tributaries of the Nymboida had low variability in DO % saturation, likely to their high gradient and bedrock controls that produce highly turbulent flows.

DO % saturation was more variable in the tributaries of the Mann River, likely due to their lower gradients. This is supported by the low variability in at the bedrock-controlled GUYFAW1 at Ebor, and the large variability at the highly disturbed sand-bed SARA2 (Figure 3.25). Only MANN5 had no exceedances of trigger thresholds. All other sites on the Mann River exceeded the upper freshwater trigger threshold at least twice, typically for two sampling periods from August – December 2012.

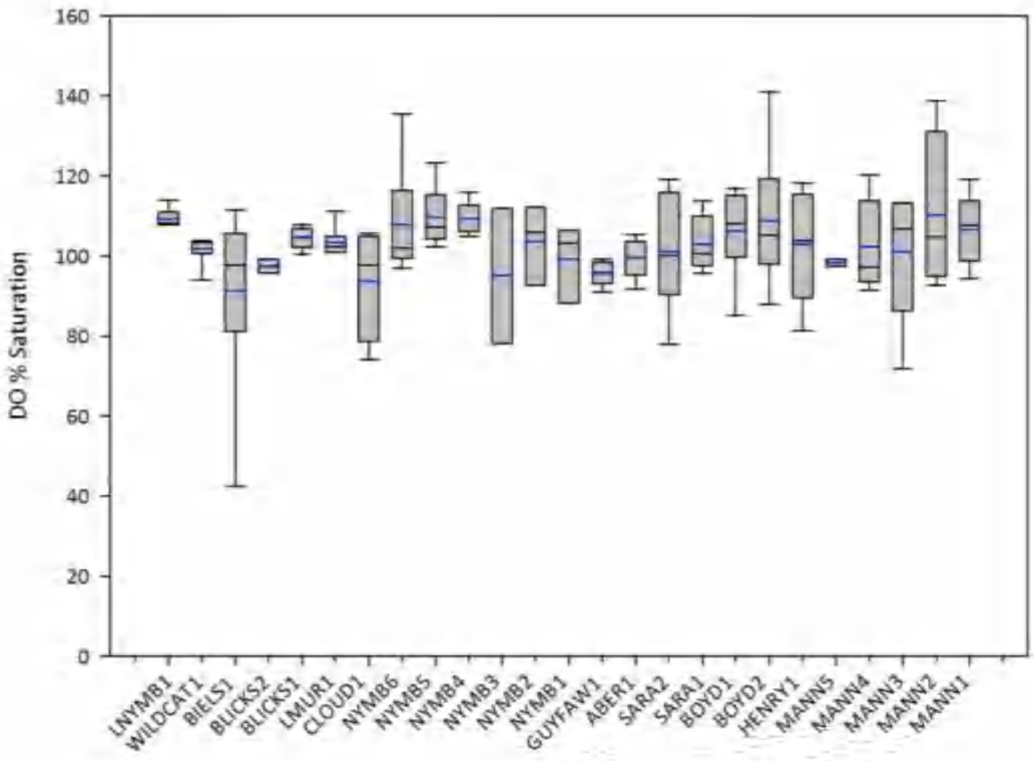


Figure 3.25 Mean (black line), median (blue line), 25th and 75th percentiles and range of DO saturation percentages from sites in the Mann-Nymboida-Boyd tributaries of the Clarence from August 2012 to August 2013.

3.3.1.7 *pH*

There are two subcatchment-scale spatial patterns in pH. Firstly, in both the Nymboida and Mann Rivers, pH decreased longitudinally downstream (Figure 3.26). Secondly, pH was higher and less variable in the Mann subcatchment than the Nymboida subcatchment (Figure 3.26). In the Nymboida River, pH ranged from 6.06 at NYMB1 (June 2013) to 9.37 at NYMB2 (April 2013). While upland freshwater trigger thresholds were exceeded at all Nymboida sites, the patterns of exceedance are informative. The upper limit of the trigger threshold was exceeded five times at NYMB6-5 (from October 2012 to August 2013), four times at NYMB4 (also from October 2012 to August 2013), and twice at NYMB3-1 (December 2012 to April 2013). At NYMB1 though, the lower limit of the freshwater trigger threshold was also exceeded in June 2013 (pH of 6.06). In the Mann River, pH ranged from 8.01 (MANN1 in October 2012) to 10.1 (MANN4 in April 2013). All observed pH values in the Mann River exceeded the upper limit of the freshwater trigger threshold (Figure 3.26).

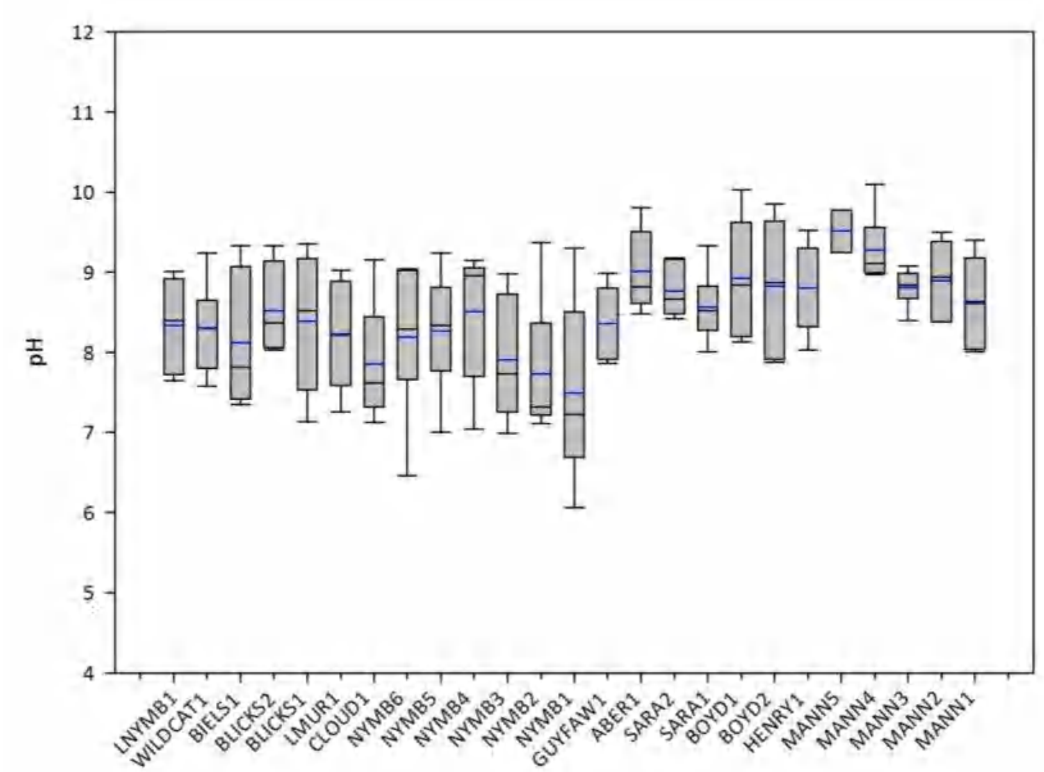


Figure 3.26 Mean (black line), median (blue line), 25th and 75th percentiles and range of pH from sites in the Mann-Nymboida-Boyd tributaries of the Clarence from August 2012 to August 2013.

3.3.1.8 *Turbidity*

Turbidity demonstrated a bi-modal longitudinal pattern in the Nymboida River, where upper reaches had more variable and higher turbidity than lowland sites (Figure 3.27). For this variable only, though, the minimum turbidity occurs at NYMB3 (site mean of 4.50 NTU). Turbidity varied the most at the downstream site on the Blicks River (BLICKS2, site mean 22.95 NTU, range of 11.30 – 34.60 NTU). Sites in tributaries of the Mann River that drain the Ebor Plateau were particularly turbid: site means were 32.60 NTU (GUYFAW1), 31.28 NTU (ABER1) and 35.73 NTU (SARA2). Unlike the Nymboida River, turbidity decreased longitudinally downstream in the Mann River (site mean of 32.70 NTU at MANN5 and 16.60 NTU at MANN1).

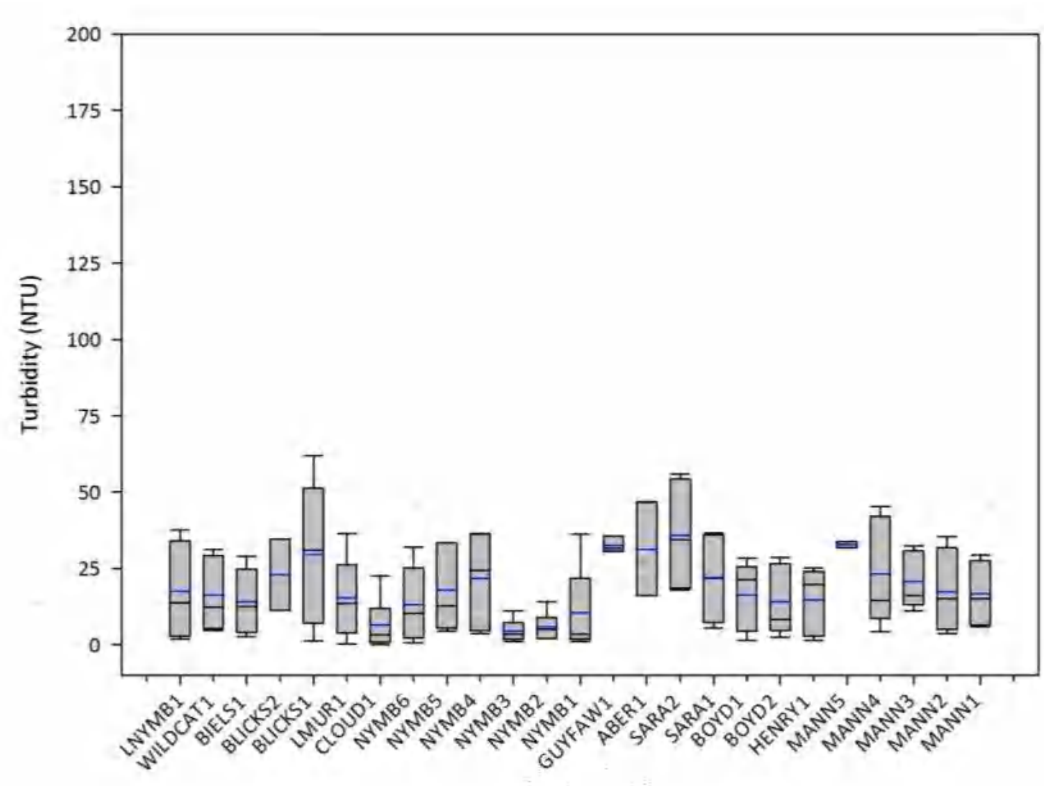


Figure 3.27 Mean (black line), median (blue line), 25th and 75th percentiles and range of turbidity from sites in the Mann-Nymboida-Boyd tributaries of the Clarence from August 2012 to August 2013.

3.3.1.9 *Water chemistry variables*

The Nymboida River tributaries located on or near the Dorrigo Plateau (WILDCAT1, BIELS1, BLICKS1, BLICKS2, LMUR1, CLOUD1 and NYMB6-5) and the Mann River tributaries on the New England Tablelands (GUYFAW1, ABER1, SARA1-2, MANN5) experienced the coldest water temperatures in the Clarence catchment (Table 3.20, Table 3.21). Water temperature warmed longitudinally downsream the Mann River (Table 3.21).

For most of the sites in the Nymboida subcatchment, EC remained below the lower limit of the freshwater trigger threshold (LMUR1 and CLOUD1 are the exceptions, although EC at LMUR1 was within the lower limit once (August 2012) and EC at CLOUD1 was within the lower limit twice (October 2012 and April 2013). EC and salinity increased longitudinally downstream in the Nymboida River (Table 3.20), but at all times EC remained below the lower limit of the freshwater trigger threshold. Minimum EC values at all sites on tributaries of the Mann River fell below the lower freshwater trigger threshold for EC, and it only ABER1 experienced EC within the trigger threshold (Table 3.21). Conductivity decreases longitudinally downstream in the Mann River and the two downstream sites MANN2-1 fall below the lower freshwater trigger threshold at all times (Table 3.21). Salinity peaks in the tableland sites in the Mann River (MANN5-4).

Ranges of TSS concentrations varied significantly among sites on the Nymboida River and its tributaries. The lowest site mean (1.00 mg/L) occurred at WILDCAT1, followed by BLICKS1 (1.24 mg/L) which also had the smallest range (0.46 – 1.95 mg/L, Table 3.20). There was no clear longitudinal trend in TSS concentrations along the Nymboid River (sites NYMB6-1, Table 3.20). There was also no clear longitudinal trend in TSS concentrations along the Mann River (sites MANN5-1, Table 3.21). Maximum TSS concentrations were lower in the Mann River (sites MANN5-1), than the Nymboida River (Table 3.21). The exceptions were sites on tributaries that drained the Ebor Plateau, and MANN1, the most downstream site in the Mann subcatchment (Table 3.21).

Table 3.20 Range of water chemistry variables at sites in the Nymboida subcatchment including its tributaries.

Site	Water temp (°C)	Conductivity (mS/cm)	Salinity (ppt)	Secchi depth (m)	TSS (mg/L)
LNYMB1	12.1 - 26.2	0.053 - 0.086	0.03 - 0.04		0.93 - 2.70
WILDCAT1	9.7 - 22.3	0.040 - 0.052	0.02 - 0.03		0.01 - 2.10
BIELS1	8.1 - 19.4	0.038 - 0.044	0.02 - 0.03		0.62 - 13.17
BLICKS2	5.8 - 17.5	0.003 - 0.050	0.01 - 0.02		0.98 - 15.08
BLICKS1	6.7 - 23.7	0.054 - 0.072	0.03 - 0.04		0.46 - 1.95
LMUR1	7.7 - 19.5	0.039 - 0.410	0.02 - 0.20		0.96 - 5.05
CLOUD1	8.3 - 20.6	0.082 - 0.930	0.00 - 0.07		0.01 - 5.25
NYMB6	6.6 - 22.1	0.041 - 0.053	0.02 - 0.03		1.27 - 6.41
NYMB5	8.0 - 23.5	0.042 - 0.053	0.02 - 0.03		0.13 - 6.40
NYMB4	10.4 - 26.1	0.047 - 0.064	0.00 - 0.03		2.68 - 13.06
NYMB3	10.3 - 27.4	0.050 - 0.062	0.00 - 0.04		1.19 - 10.61
NYMB2	11.0 - 25.7	0.051 - 0.084	0.00 - 0.04		0.32 -6.20
NYMB1	10.5 - 25.5	0.060 - 0.084	0.00 - 0.04		1.10 - 8.53

Table 3.21 Range of water chemistry variables at sites in the Mann subcatchment and its tributaries including the Boyd River.

Site	Water temp (°C)	Conductivity (mS/cm)	Salinity (ppt)	Secchi depth (m)	TSS (mg/L)
GUYFAW1	4.8 - 18.0	0.030 - 0.039	0.02 - 0.02		0.79 - 19.62
ABER1	6.4 - 24.9	0.017 - 0.177	0.07 - 0.08		2.02 - 9.09
SARA2	6.8 - 23.0	0.055 - 0.067	0.03 - 0.04		1.84 - 10.71
SARA1	8.4 - 22.6	0.050 - 0.074	0.02 - 0.04	0.20 - 0.40	1.72 - 8.47
BOYD2	12.7 - 24.9	0.088 - 0.107	0.04 - 0.05		1.30 - 8.13
BOYD1	12.6 - 25.5	0.042 - 0.114	0.04 - 0.06		0.80 - 7.04
HENRY1	11.5 - 25.5	0.080 - 0.111	0.04 - 0.08		0.20 - 3.99
MANN5	7.0 - 9.3	0.256 - 0.312	0.12 - 0.15		4.62 - 5.57
MANN4	7.5 - 21.7	0.215 - 0.373	0.10 - 0.18	0.30 - 0.40	1.14 - 9.31
MANN3	10.5 - 23.6	0.131 - 0.264	0.06 - 0.13	0.10 - 0.80	0.65 - 4.12
MANN2	13.7 - 30.6	0.059 - 0.105	0.03 - 0.05		0.42 - 7.32
MANN1	14.3 - 32.3	0.065 - 0.099	0.03 - 0.05		0.23 - 14.95

3.3.2 Transported loads of TSS, TN and TP

Peak low-flow discharge of 2,204.07 ML/day occurred during April 2013 at the middle site on the Nymboida River (NYMB3, a bedrock controlled reach at Nymboida Village upstream of the weir). This did not correlate with the peak TSS transport of 2.80 t/day (Figure 3.28a), as the latter occurred during August 2013 when discharge was 848.82 ML/day. However, TSS concentrations in August 2013 (3.30 mg/L) were more than double those in April 2013 (1.19 mg/L). TSS loads at NYMB3 ranged from 0.36 t/day in December 2012 to 2.80 t/day in August 2013, with a site mean of 1.75 t/day. The minimum TSS load correlated to the minimum mean daily discharge of 275.48 ML/day.

Total nutrient loads did not follow the temporal patterns in TSS loads at NYMB3 (Figure 3.28b). Minimum total nutrient transport of 1.528 kg TN/day and 0.032 kg TP/day occurred during the peak low-flow discharge in April 2013 (Figure 3.28b). Maximum total nutrient loads of 785.320 kg TN/day and 17.643 kg TP/day occurred in June 2013 but this did not correspond to the peak in TSS loads. Mean monthly total nutrient loads were 285.199 kg TN/day and 26.259 kg TP/day.

The peak low-flow discharge (11,882.878 ML/day) occurred in June 2013 at MANN2 (a partly confined, bedrock-controlled reach with floodplain pockets located at Jackadgery). This correlated with the peak TSS transport of 52.29 t/day (Figure 3.28a). This was due predominantly to the high discharge as the TSS concentration was 4.40 mg/day. TSS loads at MANN2 ranged from 0.43 t/day (August 2013) to 52.29 t/day in June 2013. The minimum TSS load did not correlate with the minimum discharge or TSS concentration, but rather was a interaction of the two. The site mean TSS load was 11.49 t/day.

Total nutrient loads followed the temporal patterns in TSS loads at MANN2 (Figure 3.28b). Maximum total nutrient loads of 8,490.673 kg TN/day and 241.935 kg TP/day occurred in June when low-flow discharge and TSS loads both peaked. Minimum total nutrient loads of 3.637 kg TN/day and 0.030 kg TP/day occurred in April 2013 when TSS loads were low but not at their minimum, and low-flow discharge was the second highest (5,343.47 ML/day). Mean monthly total nutrient loads were 1,718.179 kg TN/day and 80.072 kg TP/day.

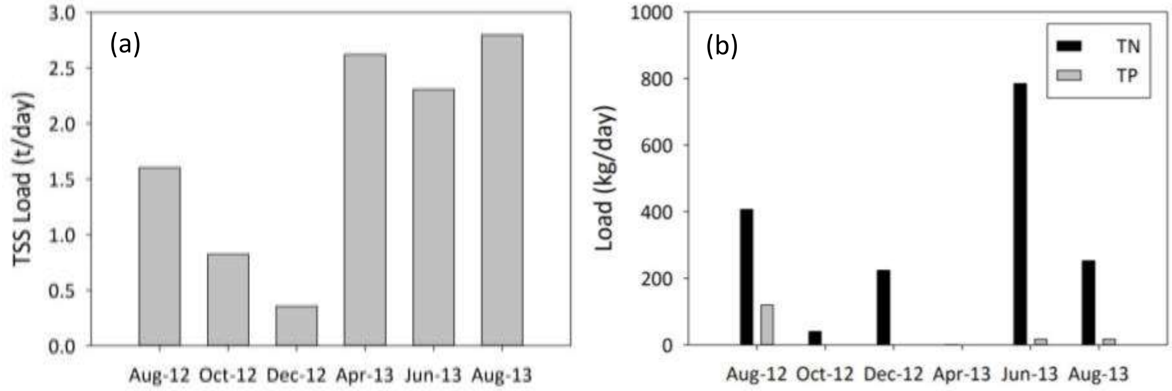


Figure 3.28 Loadings of (a) total suspended sediments and (b) TN and TP transported in the Nymboida River at Site NYMB3 (Gauge 204069) from August 2012 to August 2013.

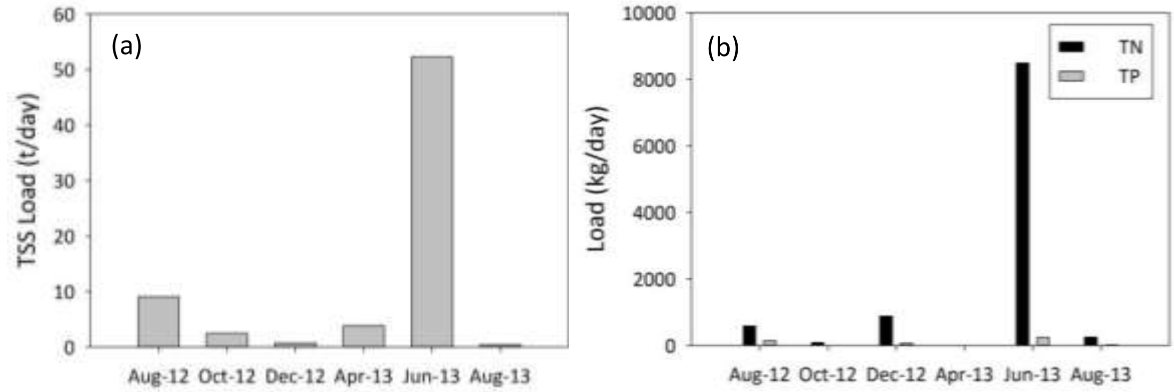


Figure 3.29 Loadings of (a) total suspended sediments and (b) TN and TP transported in the Mann River at Site MANN2 (Gauge 204004) from August 2012 to August 2013.

3.3.3 Macroinvertebrates

Forty six macroinvertebrate families were recorded from the Nymboida catchment during the Autumn and Spring sampling in 2012-13, dominated by Trichoptera (Caddis Flies) with 17 families (Table 3.22). Family level richness was higher in Spring than Autumn due to the presence more Trichopteran, Ephemeropteran (Mayfly) and Dipteran families although the abundances were much lower in Spring. The EPT index identifies between 27 and 49% of the families and 52 % of the individuals recorded are from these families that require good habitat, flow and water quality condition.

Of the 4753 individuals recorded from the 7 rivers sampled in the Nymboida systems, an equal number of individuals (50%) were collected in each season. This pattern is not seen in the Clarence main stem or Northern tributaries, and suggests the taxa are resilient to both low flow and flood conditions. In the Nymboida River there was a clear longitudinal trend with a reduced number of individuals recorded from each site from NYMB6 (604 individuals) to NYMB1 (270 individuals) near the confluence with the Mann River. Abundances ranged from 604 individuals at NYMB6 to just 142 at LNYMB1 for all sample times combined.

Similarly, was a clear longitudinal trend in the families present at each site. Family richness ranged from a high of 36 in the Nymboida headwaters to 22 at the end of the river system at NYMB1. Highest family richness in the catchment was 38 at BIELS1. Unlike the Clarence main stem and Northern tributaries, rivers in the Nymboida catchment had a diversity of dominant taxa, with dominance by a diversity of taxa from Atyidae shrimps with a SIGNAL2 score of 3 to Leptophlebiidae with a SIGNAL2 score of 8. Chironomidae (midge larvae) were in the top 5 most abundant taxa at 10 sites, Leptophlebiidae at 9 sites and Baetidae (Mayfly) and Atyidae at 7 sites.

Mean SIGNAL2 score for the Nymboida catchment was 5.1 (highest of any system) with the scores ranging from 4.6 at NYMB4 to 5.5 at LNYMB1 and BLICKS2 (Table 3.22). Notonectidae (backswimmers) and Physidae (pond snails) with a SIGNAL2 score of 1 were present at 8 sites contributing to lower overall scores. Three taxa with SIGNAL2 scores of 10 were recorded across 10 sites in the Nymboida system, the most of all systems studied. Ptilodactylidae (Beetle) was recorded only at BIELS1, Helicophidae (Caddis fly) at BLICKS1 and 2, LMURR1, and NYMB1,3 and 6, and Nannochoristidae (Scorpionfly) recorded at LNYMB1, WILDCAT1, BIELS1, LMURR1 and BLICKS1. Nannochoristidae was only recorded in these tributary streams of the Nymboida catchment. The large range in SIGNAL2 scores in each site indicates a range of conditions were present throughout the river system that facilitated the occurrence of both pollution tolerant and pollution sensitive taxa.

Table 3.22 Macroinvertebrate richness, EPT richness, SIGNAL2 scores and dominant taxa at sites in the Nymboida River and its tributaries. SIGNAL2 shown as mean value (range in brackets). The 5 numerically dominant taxa at each site The 5 numerically dominant taxa with greater than 10 individuals at each site are listed.

Site	No. Families	No. EPT families	SIGNAL2	Dominant taxa
LNYMB1	21	8	5.5 (1-10)	Atyidae, Chironnomidae, Leptoceridae
WILDCAT1	28	10	5.1 (2-10)	Leptophlebiidae, Chironnomidae, Leptoceridae, Calamoceratidae, Hydrophilidae
BIELS1	38	14	5.3 (1-10)	Baetidae, Hydropsychidae, Corixidae, Leptophlebiidae, Hydrophilidae
BLICKS2	27	13	5.5	Baetidae, Chironnomidae, Corixidae, Simuliidae, Leptophlebiidae
BLICKS1	38	16	5.1 (1-10)	Baetidae, Leptophlebiidae, Atyidae, Helicophidae, Hydrophilidae
LMURR1	31	13	5.4 (1-10)	Atyidae, Leptophlebiidae, Baetidae, Chironnomidae, Corixidae
CLOUD1	32	11	4.9 (1-8)	Calamoceratidae, Atyidae, Chironnomidae, Elmidae, Gripopterygidae
NYMB6	34	14	4.9 (1-10)	Leptophlebiidae, Baetidae, Atyidae, Chironnomidae, Hydrophilidae
NYMB5	36	16	5.4 (1-10)	Leptophlebiidae, Chironnomidae, Baetidae, Physidae, Hydrophilidae
NYMB4	26	7	4.6 (1-8)	Chironnomidae, Atyidae, Hydropsychidae, Corixidae, Leptoceridae
NYMB3	28	12	5.3 (2-10)	Hydropsychidae, Philopotamidae, Leptophlebiidae, Chironnomidae, Atyidae
NYMB2	25	9	4.9 (2-8)	Hydropsychidae, Chironnomidae, Corixidae, Calamoceratidae, Atyidae
NYMB1	22	9	4.9 (2-10)	Elmidae, Baetidae, Caenidae, Leptophlebiidae, Psephenidae

Fifty two macroinvertebrate families were recorded from the Mann-Boyd catchment during the Autumn and Spring sampling in 2012-13, dominated by Trichoptera (Caddis Flies) with 14 families (Table 3.23). Family level richness was higher in Spring than Autumn due to the presence more Trichopteran, Ephemeropteran (Mayfly), Coleopteran (Beetles) and Dipteran families although the abundances were much lower in Spring. The EPT index identifies between 34 and 47% of the families and 37 % of the individuals across all sites.

Of the 5008 individuals recorded from the 6 rivers sampled in the Mann-Boyd systems, substantially more individuals (57%) were collected in Autumn potentially responding to post flood conditions compared to prolonged low flow conditions in Spring 2012. In the Mann River with 4 sites from Tablelands to confluence with the Clarence, there was no clear longitudinal trend with the lowest family richness and abundance of individuals in the mid-reaches. Abundances ranged from 1054 individuals at HENRY1 (highest of all sites) to just 171 at MANN2 for all sample times combined.

Family richness mirrored the trends in abundance, ranging from a high of 45 in HENRY1 (highest of all sites) to 17 at MANN2. Similar to the Nymboida catchment, sites in the Mann-Boyd system had a diversity of dominant taxa, with dominance by a diversity of taxa from Corixidae (waterbugs) with a SIGNAL2 score of 2 to Leptophlebiidae with a SIGNAL2 score of 8. Corixidae were in the top 5 most abundant taxa at 9 sites, Chironomidae (midge larvae) at 7 sites, Leptophlebiidae at 6 sites but none in the Mann, and Baetidae (Mayfly) at 5 sites.

Mean SIGNAL2 score for the Nymboida catchment was 4.8 with the scores ranging from 4.1 at MANN3 to 5.3 at BOYD1 (Table 3.23). The Mann-Boyd system had the highest diversity and abundance of macroinvertebrates with a SIGNAL2 score of 1, with Notonectidae (backswimmers), Physidae (pond snails), Hirudinea (leeches) Glossiphonidae (snails) and Lymnaeidae (snails) present throughout the study sites (except BOYD1) contributing to lower overall scores. Three taxa with SIGNAL2 scores of 10 were recorded across 6 sites in the system, although none were recorded in the Mann River. The large range in SIGNAL2 scores in each site indicates a range of conditions were present throughout the river system that facilitated the occurrence of both pollution tolerant and pollution sensitive taxa.

Table 3.23 Macroinvertebrate richness, EPT richness, SIGNAL2 scores and dominant taxa at sites in the Mann and Boyd Rivers and their tributaries. SIGNAL2 shown as mean value (range in brackets). The 5 numerically dominant taxa at each site The 5 numerically dominant taxa with greater than 10 individuals at each site are listed.

Site	No. Families	No. EPT families	SIGNAL2	Dominant taxa
GUYFAW1	37	14	4.9 (1-10)	Leptophlebiidae, Chironnomidae, Psephenidae, Hydropsychidae, Corixidae
ABER1	44	15	5 (1-10)	Leptophlebiidae, Psephenidae, Corixidae, Atyidae, Elmidae
SARA2	27	12	4.8 (1-10)	Corixidae, Chironnomidae, Leptophlebiidae, Elmidae, Leptoceridae
SARA1	39	15	4.7 (1-10)	Chironnomidae, Corixidae, Baetidae, Leptophlebiidae, Elmidae
BOYD2	35	15	5 (1-8)	Hydropsychidae, Elmidae, Corixidae, Leptophlebiidae, Atyidae
BOYD1	38	14	5.3 (2-10)	Corixidae, Hydropsychidae, Psephenidae, Philopotamidae, Chironnomidae
HENRY1	45	18	4.8 (1-10)	Baetidae, Hydrophilidae, Chironnomidae, Elmidae Leptophlebiidae
MANN4	27	9	4.7 (1-8)	Corixidae, Notonectidae, Hydropsychidae, Chironnomidae, Baetidae
MANN3	24	5	4.1 (1-8)	Corixidae, Notonectidae, Hydrophilidae, Dytiscidae, Leptoceridae
MANN2	17	8	4.5 (1-8)	Chironnomidae, Atyidae, Corixidae, Baetidae, Caenidae
MANN1	30	12	4.8 (1-8)	Hydropsychidae, Hydrophilidae, Baetidae, Atyidae, Elmidae

3.3.4 Riparian condition

Riparian condition was high in the Mann-Nymboida-Boyd subcatchment in comparison to the rest of the Clarence catchment (Table 3.24). Vegetation composition did not score highly at any site (3.03/5.00 at WILDCAT1 and 3.77/5.00 for CLOUD1 are the best two examples), but bank condition was generally good (1.67/5.00 at LMUR1 and 1.33/5.00 at NYMB5 are the worst two examples). Sites in the upper subcatchment were undisturbed (Table 3.24).

Table 3.24 Site level summary of riparian condition scores for sites in the Nymboida River and its tributaries. Individual scores maximum of 5, total score out of 10.

	VEGETATION	BANK CONDITION	HABITAT	DISTURBANCE	Total/10
LNYMB1	2.87	4.00	3.19	5.00	7.53
WILDCAT1	3.03	4.33	2.43	5.00	7.40
BIELS1	2.13	3.00	1.67	1.44	4.12
BLICKS1	2.53	4.00	1.90	5.00	6.72
BLICKS2	1.93	3.67	0.86	1.00	3.73
Mean	**2.23**	**3.83**	**1.38**	**3.00**	**5.22**
LMUR1	2.20	1.67	3.10	3.67	5.31
CLOUD1	3.77	2.67	3.05	5.00	7.24
NYMB1	2.50	4.00	1.86	1.00	4.68
NYMB2	2.83	1.33	3.14	1.00	4.15
NYMB3	2.30	5.00	2.90	1.00	5.60
NYMB4	2.67	4.00	3.24	5.00	7.45
NYMB5	2.70	3.00	2.05	5.00	6.37
NYMB6	1.67	5.00	1.33	5.00	6.50
Mean	**2.45**	**3.72**	**2.42**	**3.00**	**5.79**

Wild Cattle Creek

The vegetation at the Wild Cattle River site was Water gum shrubland with a vegetation score of 3.03 (Table 3.25). The rocky platform substrate accounted for the low understorey cover but there were no midstorey, grass or understorey weeds (Table 3.27).

There were no large trees. The midstorey was dominated by Water Gum (*Tristaniopsis laurina*) with scattered native shrubs including Grey Myrtle (*Backhousia myrtifolia*) and River Bottlebrush (*Callistemon sieberi*). Snow Grass (*Poa sieberiana*) and Creek Mat-rush (*Lomandra hystrix*) formed the sparse understorey.

Bank condition was very good (4.00/5.00) with only minor bank undercutting (Table 3.25). Habitat was good (3.00/5.00) although there were few large trees or standing dead trees (Table 3.25). The site was undisturbed (5.00/5.00, Table 3.25).

Bielsdown River

The vegetation at the Bielsdown River site was Small-leaved Privet shrubland with an exotic grass understorey and a vegetation score of 2.13 (Table 3.25).

There were no large trees, no canopy cover and a midstorey dominated by Small-leaved Privet (*Ligustrum sinense*). The exotic grasses Prairie Grass (*Bromus catharticus*) and Cocksfoot (*Dactylis glomerata*) dominated the understorey with sparse native herbs Nettle (*Urtica incisa*), Common Buttercup (*Ranunculus lappaceus*) and Native Geranium (*Geranium solanderi* var. *solanderi*) and the exotic herbs Watercress (*Rorippa nasturtium-aquaticum)* and Curled Dock (*Rumex crispus*). The exotic vine Japanese Honeysuckle (*Lonicera japonica*) was also present (Table 3.27).

Bank condition was very good (4.33/5.00) with only few exposed tree roots (Table 3.25). Habitat was very poor (1.67) as was disturbance (1.44/5.00, Table 3.25), as the highly disturbed reach had little large wood either standing or fallen, and had been significantly cleared with no current exclusion fencing.

Blicks River

BLICKS1 vegetation community was River Oak grassy open forest with Water Gum (index score 2.53; Table 3.25); BLICKS2 was cleared Snow Gum woodland (index score 1.93). BLICKS1 higher Vegetation score was due to more vegetation layers and higher canopy and understorey cover (Table 3.27).

Large trees were River Oak and Flooded Gum (*Eucalyptus grandis*) at BLICKS1 and sparse Snow Gum (*Eucalyptus pauciflora*) at BLICKS2. BLiCKS2 had no midstorey cover but BLICKS1 had Tea Tree (*Leptospermum brachyandrum*) and Water Gum in the midstorey with the exotics Small-leaved Privet (*Ligustrum sinense*) and Wild Tobacco Bush (*Solanum mauritianum*). Weeping Grass (*Microlaena stipoides*) and Creeping Beard Grass (*Oplismenus imbecillis*) occurred at BLICKS1 with Swamp Foxtail (*Pennisetum alopecuroides*) at BLICKS2. Exotic grasses were Kikuyu (*Pennisetum clandestinum*) (BLICKS1) and Meadow Fescue (*Festuca pratensis*) and Perennial Ryegrass (*Lolium perenne*) (BLICKS2). Native understorey species were Indian Weed (*Sigesbeckia orientalis* subsp. *orientalis*) at BLICKS1 and Fen Sedge (*Carex gaudichaudiana*), Variable Willow-herb (*Epilobium billardierianum* subsp. *cinereum*) and Common Bracken (*Pteridium esculentum*) at BLICKS2. The exotics Spear Thistle (*Cirsium vulgare*) and Wandering Jew (*Tradescantia fluminensis*) were part of the understorey at BLICKS1 with Birdsfoot Trefoil (*Lotus uliginosus*) at BLICKS2.

Bank condition was better at the downstream site BLICKS1 (4.00/5.00) with only minimal bank undercutting, than the upstream site BLICKS2 (3.67/5.00, Table 3.25), which was heavily disturbed by grazing and tree clearing, and had slumped banks. Habitat was poor at both sites (Table 3.25), but especially at BLICK2 where there was very few trees, dead or alive, standing or fallen.

Little Murray River

The vegetation at the Little Murray River site was River Oak grassy open forest with a vegetation score of 2.20 (Table 3.25). The relatively low score was a result of low midstorey cover, grass and understorey weeds and no vines (Table 3.27).

Large trees were River Oak. The midstorey was dominated by Small-leaved Privet (*Ligustrum sinense*). Grasses were predominantly exotic and included Cocksfoot (*Dactylis glomerata*) and Kikuyu (*Pennisetum clandestinum*). The understorey consisted of the native Common Rush (*Juncus usitatus*); exotics included Creeping Buttercup (*Ranunculus repens*), Annual Ragweed (*Ambrosia artemisifolia*) and Chickweed (*Stellaria media*).

Bank condition was poor due to bank undercutting and slumping (Table 3.25). Although the site was relatively undisturbed (3.67/5.00), habitat condition was moderate due to a lack of large trees, dead or alive, and the lack of organic litter (Table 3.25).

Clouds Creek

The vegetation at the Clouds Creek site was a riparian strip of Water gum shrubland with River Oak with dense Subtropical Rainforest further up the slope (index score 3.77; Table 3.26). The relatively high vegetation score was due to high canopy and midstorey cover, few weeds, the presence of vines and multiple vegetation layers (Table 3.28).

Emergents were Silky Oak (*Grevillea robusta* and River Oak with large trees Water Gum (*Tristianiopsis laurina*) and River Oak. The midstorey was dominated by various rainforest species such as Sandpaper Fig (*Ficus coronata*), Hairy-leaved Bolly Gum (*Neolitsea dealbata*), Wild Yellow Jasmine (*Pittosporum revolutum*) and Guioa (*Guioa semiglauca*). There were no midstorey or grass weeds. The understorey consisted of Creeping Beard Grass (*Oplismenus imbecillis*), Creek Mat-rush (*Lomandra hystrix*), Harsh Ground Fern (*Hypolepis muelleri*) and low-growing Rose-leaf Bramble (*Rubus rosifolius* var. *rosifolius*) and the exotic Lantana (*Lantana camara)*. The native Water Vine (*Cissus antarctica*) occurred in both the undersotrey and the canopy.

Bank condition was 2.67/5.00 due to substantial bank undercutting and some exposed tree roots (Table 3.26). Although the site was undisturbed (5.00/5.00), a lack of large trees alive or dead reduced the habitat index score (3.05/5.00, Table 3.26).

Table 3.25 Site level summary of riparian condition scores for each sub-index for sites in tributaries of the Nymboida subcatchment. Individual scores maximum of 5.

	LNYMB1	WILDCAT 1	BIELS1	BLICKS1	BLICKS2	LMUR1
Vegetation						
Large trees	1.00	1.00	1.00	1.00	1.00	2.00
Canopy Cover	2.33	2.67	1.00	3.00	1.00	3.00
Mid-storey Cover	5.00	5.00	3.67	3.00	1.00	1.00
Mid-storey Weeds	3.33	5.00	2.33	3.67	5.00	3.67
Grass Cover	1.00	1.00	3.00	3.00	5.00	3.33
Grass Weeds	4.67	5.00	1.00	2.33	1.00	1.00
Understorey Cover	2.33	1.67	1.67	3.67	1.00	3.67
Understorey Weeds	5.00	5.00	3.67	1.67	2.33	1.00
Vines	1.00	1.00	1.67	1.00	1.00	1.00
Vegetation Layers	3.00	3.00	2.33	3.00	1.00	2.33
Total/5	**2.87**	**3.03**	**2.13**	**2.53**	**1.93**	**2.20**
Bank condition						
Undercutting	3.00	5.00	2.00	2.00	4.00	1.00
Exposed Tree Roots	4.00	3.00	5.00	5.00	5.00	3.00
Slumping	5.00	5.00	2.00	5.00	2.00	1.00
Total/5	**4.00**	**4.33**	**3.00**	**4.00**	**3.67**	**1.67**
Habitat						
Standing Dead Trees	0.00	0.00	0.00	0.00	0.00	0.00
Logs	5.00	2.00	3.00	2.00	2.00	3.00
Fallen Trees	5.00	3.00	0.00	0.00	0.00	5.00
Reeds	5.00	5.00	5.00	5.00	1.00	5.00
Large Trees	1.00	1.00	1.00	1.00	1.00	2.00
Organic Litter	1.33	1.00	1.67	1.00	1.00	2.00
Weed Litter	5.00	5.00	1.00	4.33	1.00	4.67
Total/5	**3.19**	**2.43**	**1.67**	**1.90**	**0.86**	**3.10**
Disturbance						
Tree Clearing	5.00	5.00	1.00	5.00	1.00	1.00
Fencing	5.00	5.00	1.00	5.00	1.00	5.00
Livestock	5.00	5.00	2.33	5.00	1.00	5.00
Total/5	**5.00**	**5.00**	**1.44**	**5.00**	**1.00**	**3.67**

Little Nymboida and Nymboida Rivers

Vegetation communities on the Nymboida River ranged from Weeping Bottlebrush shrubland with River Oak (NYMB2) and River Oak dominated communities such as cleared River Oak grassy open forest (NYMB1, NYMB5), River Oak– Weeping Bottlebrush layered woodland (NYMB3), River Oak with rainforest midstorey (NYMB4) or Small-leaved Privet midstorey (NYMB6) (Table 3.26). The community on the Little Nymboida River (LNYMB1) was Water Gum shrubland with rainforest midstorey. Vegetation Condition index scores ranged from 1.67 for NYMB6 to 2.83 (NYMB2) and 2.87 (LNYMB1, Table 3.25). Higher scores for NYMB2 and LNYMB1 were due to high midstorey cover and few understorey weeds (Table 3.28,Table 3.29).

For the three northerly Nymboida Sites (NYMB1–3) there were only large trees (River Oak) at NYMB3. Regrowth River Oak and Weeping Bottlebrush formed midstoreys with Tea Tree (*Leptospermum brachyandrum*) at NYMB2. Small-leaved Privet (*Ligustrum sinense*) occurred at NYMB3; at other sites there were no midstorey weeds. Couch (*Cynodon dactylon*) was the common native grass in the three northerly sites (NYMB1–3) with the exotic grass Kikuyu (*Pennisetum clandestinum*) at NYMB3. Understorey native dominants included Water Pepper (*Persicaria hydropiper*), Creek Mat-rush (*Lomandra hystrix*) and Indian Pennywort (*Centella asiatica*). Exotic understorey species included Mexican Poppy (*Argemone ochroleuca* subsp. *ochroleuca*), Spear Thistle (*Cirsium vulgare*), Fireweed (*Senecio madagascariensis*) and Common Thornapple (*Datura stramonium*).

For the southerly Nymboida sites, large River Oak trees occurred at NYMB4–6 with large Water Gum (*Tristaniopsis laurina*) at LNYMB1. Midstoreys consisted of regrowth River Oak, Water Gum and Tea Tree (*Leptospermum brachyandrum*) with *Acacia* spp. And other rainforest shrubs such as Red Ash (*Alphitonia excelsa*), Sandpaper Fig (*Ficus coronata*), Silky Oak (*Grevillea robusta*), Native Peach (*Trema tomentosa* var, *aspera*) and Hard Quandong (*Elaeocarpus obovatus*) in the midstorey at LNYMB1. Small-leaved Privet (*Ligustrum sinense*) occurred at NYMB4, NYMB6 and LNYMB1. Native grasses included Creeping Beard Grass (*Oplismenus imbecillis*) and Couch (*Cynodon dactylon*) with Hastings River Reed (*Potamophila parviflora*) at LNYMB1. There were no exotic grasses apart from Prairie Grass (*Bromus catharticus*) at NYMB6. Creek Mat-rush (*Lomandra hystrix*) was the most common understorey native. Understorey weeds included Annual Ragweed (*Ambrosia artemisifolia*) (NYMB4).

Banks in the Nymboida River sites were in good - excellent condition with the exception of NYMB2 which had bank undercutting and slumping and exposed tree roots (1.33/5.00, Table 3.26). Habitat scored poorly at NYMB1 and NYMB6 due to the absence of large trees, alive or dead, standing or fallen (Table 3.26). The upper reaches of the Nymboida River were undisturbed, but tree clearing, recent stock activity and the absence of exclusion fencing at NYMB1 and NYMB2 meant these were highly disturbed sites (1.00/5.00, Table 3.26).

Table 3.26 Site level summary of riparian condition scores for each sub-index for sites in Clouds Creek and the Nymboida River. Individual scores maximum of 5.

	CLOUD1	NYMB1	NYMB2	NYMB3	NYMB4	NYMB5	NYMB6
Vegetation							
Large trees	1.67	1.00	1.00	1.33	1.00	1.00	1.00
Canopy Cover	4.00	1.33	1.00	1.33	2.00	2.67	1.67
Mid-storey Cover	3.67	2.33	5.00	3,67	3.67	1.67	5.00
Mid-storey Weeds	5.00	5.00	5.00	4.33	4.33	5.00	1.00
Grass Cover	2.00	3.33	1.67	1.67	1.33	1.67	1.00
Grass Weeds	5.00	5.00	5.00	1.00	3.67	5.00	1.00
Understorey Cover	3.00	1.67	1.67	3.00	4.33	1.00	1.67
Understorey Weeds	5.00	2.33	5.00	3.00	2.33	5.00	1.00
Vines	3.67	1.00	1.00	1.00	1.00	1.00	1.00
Vegetation Layers	4.67	2.00	2.00	2.67	3.00	3.00	2.33
Total/5	**3.77**	**2.50**	**2.83**	**2.30**	**2.67**	**2.70**	**1.67**
Bank condition							
Undercutting	1.00	5.00	1.00	5.00	3.00	2.00	5.00
Exposed Tree Roots	2.00	5.00	2.00	5.00	5.00	5.00	5.00
Slumping	5.00	2.00	1.00	5.00	4.00	2.00	5.00
Total/5	**2.67**	**4.00**	**1.33**	**5.00**	**4.00**	**3.00**	**5.00**
Habitat							
Standing Dead Trees	0.00	0.00	5.00	0.00	0.00	0.00	0.00
Logs	4.00	1.00	2.00	3.00	5.00	2.00	1.00
Fallen Trees	3.00	0.00	3.00	5.00	5.00	0.00	0.00
Reeds	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Large Trees	1.67	1.00	1.00	1.33	1.00	1.00	1.00
Organic Litter	2.67	1.00	1.00	1.00	1.67	1.33	1.33
Weed Litter	5.00	5.00	5.00	5.00	5.00	5.00	1.00
Total/5	**3.05**	**1.86**	**3.14**	**2.90**	**3.24**	**2.05**	**1.33**
Disturbance							
Tree Clearing	5.00	1.00	1.00	1.00	5.00	5.00	5.00
Fencing	5.00	1.00	1.00	1.00	5.00	5.00	5.00
Livestock	5.00	1.00	1.00	1.00	5.00	5.00	5.00
Total/5	**5.00**	**1.00**	**1.00**	**1.00**	**5.00**	**5.00**	**5.00**

Table 3.27 Dominant riparian vegetation for each stratum at sites on the tributaries of the Nymboida River. Emergents are large trees that rise above the tree canopy.

Vegetation Description	WILDCAT1	BIELS1	BLICKS1	BLICKS2	LMUR1
Left/Right bank (facing downstream)	L	L	L	L	L
Community Description	Water Gum shrubland	Small-leaved Privet shrubland	River Oak – Weeping Bottlebrush layered woodland	River Oak grassy open forest	River Oak grassy open forest
Emergents	No emergents	No emergents	No emergents	No emergents	No emergents
Dominant Large Trees A	No large trees	No large trees	*Casuarina cunninghamiana*	No large trees	*Casuarina cunnghamiana*
Dominant Large Trees B	No large trees	No large trees	*Casuarina cunninghamiana*	No large trees	*Casuarina cunnghamiana*
Dominant Large Trees C	No large trees	No large trees	*Casuarina cunninghamiana*	*Eucalyptus pauciflora*	*Casuarina cunnghamiana*
			Eucalyptus grandis		
Dominant Mid-storey Cover (native)	*Tristaniopsis laurina*	No native midstorey	*Leptospermum brachyandrum*	No midstorey cover	No native midstorey
	Backhousia myrtifolia		*Tristaniopsis laurina*		
	Callistemon sieberi				
Dominant Mid-storey Cover (weeds)	No midstorey weeds	*Ligustrum sinense*	*Ligustrum sinense*	No midstorey weeds	*Ligustrum sinense*
			Solanum mauriteanum		
Dominant Grass Cover (native)	*Poa sieberiana*	No native grasses	*Microlaena stipoides*	*Pennisetum alopecuroides*	No native grasses
			Oplismenus imbecillis		
Dominant Grass Cover (weeds)	No grass weeds	*Bromus catharticus*	*Pennisetum clandestinum*	*Festuca pratensis*	*Dactylis glomerata*
		Dactylis glomerata			*Pennisetum clandestinum*
Dominant Understorey Cover (native)	*Lomandra hystrix*	*Urtica incisa*	*Sigesbeckia orientalis*	*Pteridium esculentum*	*Juncus usitatus*
		Ranunculus lappaceus		*Epilobium billardierianum* subsp. *cinereum*	
		Geranium solanderi var. *solanderi*		*Carex gaudichaudiana*	
Dominant Understorey Cover (weeds)	No understorey weeds	*Rorippa nasturtium-aquaticum*	*Cirsium vulgare*	*Trifolium repens*	*Ranunculus repens*

		Rumex crispus	*Tradescantia fluminensis*	*Lotus uliginosus*	*Stellaria media*
			Galinsoga parviflora		*Ambrosia artemisifolia*
Dominant Organic Litter (weeds)		*Ligustrum sinense*			
Dominant Vines	No vines	*Lonicera japonica*	No vines	No vines	No vines

Table 3.28 Dominant riparian vegetation for each stratum at sites in Clouds Creek, Little Nymboida River and the two downstream sites in the Nymboida River (NYMB1–2). Emergents are large trees that rise above the tree canopy.

Vegetation Description	CLOUD1	LNYMB1	NYMB1	NYMB2
Left/Right bank (facing downstream)	L	R	L	R
Community Description	Water Gum shrubland with River Oak	Water Gum shrubland with rainforest midstorey	Cleared River Oak grassy open forest	Weeping Bottlebrush shrubland with River Oak
Emergents	*Grevillea robusta*		No emergents	No emergents
	Casuarina cunninghamiana			
Large Trees A	*Tristaniopsis laurina*	No large trees	No large trees	No large trees
Large Trees B	*Casuarina cunninghamiana*	*Tristaniopsis laurina*	No large trees	No large trees
Large Trees C	*Tristaniopsis laurina*	*Tristaniopsis laurina*	*Callistemon vinimalis*	No large trees
Mid-storey Cover (native)	*Tristaniopsis laurina*	*Casuarina cunninghamiana*	*Casuarina cunninghamiana*	*Callistemon vinimalis*
	Ficus coronata	*Alphitonia excelsa*		*Casuarina cunninghamiana*
	Neolitsea dealbata	*Ficus coronata*		*Leptospermum brachyandrum*
	Pittosporum revolutum	*Grevillea robusta*		
	Guioa semiglauca	*Acacia fimbriata*		
		Trema tomentosa var. *aspera*		
		Elaeocarpus obovatus		
Mid-storey Cover (weeds)	No midstorey weeds	*Ligustrum sinense*	No midstorey weeds	No midstorey weeds
		Lantana camara		
Grass Cover (native)	*Oplismenus imbecillis*	*Oplismenus imbecillis*	*Cynodon dactylon*	*Cynodon dactylon*
		Potamophila parviflora		
Grass (weeds)	No grass weeds	No grass weeds	No grass weeds	No grass weeds
Understorey Cover (native)	*Lomandra hystrix*	*Lomandra hystrix*	*Persicaria hydropiper*	*Persicaria hydropiper*
	Hypolepis muelleri		*Lomandra hystrix*	*Centella asiatica*
	Rubus rosifolius var *rosifolius*			
Understorey Cover (weeds)	*Lantana camara*	No understorey weeds	*Argemone ochroleuca* subsp. *ochroleuca*	*Argemone ochroleuca* subsp. *ochroleuca*
			Cirsium vulgare	*Cirsium vulgare*
			Datura stramonium	*Ligustrum sinense*
				Oxalis debilis var. *corymbosa*

				Senecio madagascariensis
Organic Litter (natives)	Native rainforest trees & shrubs			*Callistemon viminalis*
				Casuarina cunninghamiana
Dominant Vines	*Cissus antarctica*	No vines	No vines	No vines

Table 3.29 Dominant riparian vegetation for each stratum at the four upstream Nymboida River sites (NYMB3–6). Emergents are large trees that rise above the tree canopy.

Vegetation Description	NYMB3	NYMB4	NYMB5	NYMB6
Left/Right bank (facing downstream)	R	R	R	L
Community Description	River Oak – Weeping Bottlebrush layered woodland	River Oak with rainforest midstorey	River Oak grassy open forest	River Oak with Small-leaved Privet midstorey
Emergents	No emergents	No emergents	No emergents	No emergents
Large Trees A	No large trees	No large trees	*Casuarina cunninghamiana*	No large trees
Large Trees B	*Casuarina cunninghamiana*	*Casuarina cunninghamiana*	*Casuarina cunninghamiana*	No large trees
Large Trees C	*Casuarina cunninghamiana*	*Casuarina cunninghamiana*	*Casuarina cunninghamiana*	*Casuarina cunninghamiana*
		Callistemon vimiinalis		
Mid-storey Cover (native)	*Callistemon vinimalis*	*Casuarina cunninghamiana*	*Leptospermum brachyandrum*	No native midstorey
		Tristaniopsis laurina	*Acacia floribunda*	
		Alphitonia excelsa		
		Leptospermum brachyandrum		
Mid-storey Cover (weeds)	No midstorey weeds	*Ligustrum sinense*	No midstorey weeds	*Ligustrum sinense*
Grass Cover (native)	*Cynodon dactylon*			
Grass (weeds)	*Pennisetum clandestinum*			
Understorey Cover (native)	*Persicaria hydropiper*			
Understorey Cover (weeds)	*Argemone ochroleuca* subsp. *ochroleuca*			
	Cirsium vulgare			
	Senecio madagascariensis			
	Stellaria media			
Organic Litter (natives)	*Callistemon viminalis*			
	Casuarina cunninghamiana			
Dominant Vines	No vines	No vines	No vines	No vines

In the Mann subcatchment, the Guyfawkes River (GUYFAW1) and MANN3 scored the highest Vegetation Condition scores of 7.07/10.00 (Table 3.30). At GUYFAW1, this was due to excellent bank condition and low disturbance, whereas at MANN3, it was driven by good scores across all indices. The Sara River had the lowest Vegetation Condition score of 3.60/10.00, due to low scores across all indices, especially for habitat condition and disturbance level (Table 3.30).

Table 3.30 Site level summary of riparian condition scores for sites in the Mann and Boyd Rivers and their tributaries. Individual scores maximum of 5, total score out of 10.

	VEGETATION	BANK CONDITION	HABITAT	DISTURBANCE	Total/10
GUYFAW1	2.47	4.67	2.00	5.00	7.07
ABER1	1.90	2.33	1.14	1.00	3.19
SARA1	2.20	2.67	1.00	1.00	3.43
SARA2	2.53	2.33	1.67	1.00	3.77
Mean	**2.37**	**2.50**	**1.33**	**1.00**	**3.60**
BOYD1	2.60	5.00	2.00	1.44	5.52
BOYD2	3.03	5.00	2.71	2.33	6.54
Mean	**2.82**	**5.00**	**2.36**	**1.89**	**6.03**
HENRY1	2.77	3.00	2.71	1.44	4.96
MANN1	3.10	1.67	2.57	1.00	4.17
MANN2	2.77	1.67	2.43	1.00	3.93
MANN3	3.13	3.67	3.24	4.11	7.07
MANN4	2.57	2.67	1.67	2.78	4.84
MANN5	1.93	3.33	0.86	1.00	3.56
Mean	**2.70**	**2.60**	**2.15**	**1.98**	**4.72**

Guy Fawkes River

The vegetation at the Guy Fawkes River site was New England Peppermint Woodland with a vegetation score of 2.47 (Table 3.31). Low canopy cover and no midstorey cover, a predominance of exotic grasses and between one and two vegetation layers contributed to the low score (Table 3.33). Large trees were New England Peppermint (*Eucalyptus nova-anglica*). Exotic grasses Meadow Fescue (*Festuca pratensis*) and Cocksfoot (*Dactylis glomerata*) and the native Fen Sedge (*Carex gaudichaudiana*) and Large-headed Club-rush (*Scirpus polystachyus*) dominated the understorey. Other occasional herbs were the natives Winged Everlasting (*Ammobium alatum*) and Common Rush (*Juncus usitatus*) and the exotics Oxeye Daisy (*Leucanthemum vulgare*), Broadleaf Dock (*Rumex obtusifolius*) and .Birds-foot Trefoil (*Lotus uliginosus*).

Bank condition was very good at GUYFAW1 (4.67/5.00) with only minimal bank undercutting observed (Table 3.31). Despite the site being undisturbed (5.00/5.00), Habitat scored poorly

(2.00/5.00) due to the lack of large trees, fallen trees, and organic litter that was not derived from weeds (Table 3.31).

Aberfoyle River

The vegetation at the Aberfoyle River site was Exotic Grassland with a vegetation score of 1.90 (Table 3.31). The low score was a result of the dominance of an exotic grass, no canopy cover, low midstorey and understorey cover and a single vegetation layer (Table 3.33).

The native shrub Tantoon (*Leptospermum polygalifolium* subsp *montanum*) occurred in the midstorey. The exotic grass Meadow Fescue (*Festuca pratensis*) dominated the understorey with occasional native grasses Tussock (*Poa labillardieri* var. *labillardieri*) and Blady Grass (*Imperata cylindrica*). Sparse herbs such as the natives Spiny-headed Mat-rush (*Lomandra longifolia)* and Common Rush (*Juncus usitatus)* and the exotics Purple Top (*Verbena bonariensis*) and Umbrella Sedge (*Cyperus eragrostis*) occurred in the understorey.

Bank condition (2.33/5.00) was reduced by bank undercutting and slumping (Table 3.31). The site was highly disturbed (1.00/5.00) and Habitat condition was poor in all indices (Table 3.31).

Sara River

The vegetation at both Sara River sites was grassland with African Lovegrass grassland at SARA1 with a vegetation score of 2.20/5.00 and Native grassland with Carex Sedgeland (an Endangered Ecological Community under the NSW TSC ACT) at SARA2 and a vegetation score of 2.53 (Table 3.31). The lower score at SARA1 was due to less grass cover, more grass weed and more understorey weeds (Table 3.33).

There were no large trees at either site and no midstorey cover whether native or exotic. Couch (*Cynodon dactylon*) occurred at both sites with Common Reed (*Phragmites australis*) and Slender Rat's Tail Grass (*Sporobolus elongatus*) also at SARA2. Paspalum (*Paspalum dilatatum*) occurred at both sites, the exotic grasses African Lovegrass (Eragrostis curvula) and Whisky Grass (*Andropogon virginicus*) were dominant at SARA1 with Perennial Ryegrass (Lolium perenne) at SARA2.

Native understorey species were Common Bracken (*Pteridium esculentum*) at SARA1 with species typical of Carex Sedgelands: Fen Sedge (*Carex gaudichaudiana*), Large-headed Club-rush (*Scirpus polystachyos*), Swamp Billy-buttons (*Leiocarpa* sp. Uralla) and Variable Willow-herb (*Epilobium billardierianum* subsp. *cinereum*) at SARA2. The exotic herb Cudweed (*Gamochaeta coarctata*) occurred at both sites with the ubiquitous Catsear (*Hypochaeris radicata*) at SARA1 and Oxeye Daisy (*Leucanthemum vulgare*) at SARA2.

Although both SARA1 and SARA2 were highly disturbed (1.00/5.00) and had poor habitat (Table 3.31), bank condition was moderate at both sites due to the absence of exposed tree roots even with bank undercutting and slumping (Table 3.31).

Boyd River

Both vegetation communities on the Boyd River sites were River Oak dominated with BOYD1 River Oak – Weeping Bottlebrush layered woodland (index score 2.60; Table 3.31) and BOYD2 River Oak grassy open forest (Index score 3.03). BOYD2 had a higher vegetation score due to more large trees and higher canopy and understorey cover (Table 3.34).

Large trees were River Oak at both sites with regrowth River Oak and Weeping Bottlebrush in the midstorey. Lantana occurred at BOYD2 with no midstorey weeds at BOYD1. Couch (*Cynodon dactylon*) and Weeping Grass (*Microlaena stipoides*) occurred at both sites with Creeping Beard Grass (*Oplismenus imbecillis*) at BOYD2. Small-flowered Buttercup (*Ranunculus sessiliflorus* var.*sessiliflorus*) was common at both sites with Water Pepper (*Persicaria hydropiper*) at BOYD1 and Nettle (*Urtica incisa*) and Common Buttercup (*Ranunculus lappaceus*) at BOYD2. The understorey exotics Wild Tobacco Bush (*Solanum mauritianum*), Mexican Poppy (*Argemone ochroleuca* subsp. *ochroleuca*), and Spear Thistle (*Cirsium vulgare*) occurred at both sites with Common Thornapple (*Datura stramonium*) at BOYD2.

Bank condition was excellent at both sites on the Boyd River (Table 3.31). However, habitat condition was reduced at both sites by the lack of standing dead trees or fallen trees and the lack of organic litter (Table 3.31). Both sites were unfenced with current stock access (Table 3.31).

Henry River

The vegetation at the Henry River site was River Oak grassy open forest with a vegetation score of 2.77 (Table 3.32). Low midstorey cover and grass and understorey weeds contributed to the relatively low score (Table 3.34).

Large trees were River Oak with regrowth River Oak in the midstorey. The native grass Couch (*Cynodon dactylon*) and the exotic Prairie Grass (*Bromus catharticus*) formed the grassy understorey with occasional exotic herbs Mexican Poppy (*Argemone ochroleuca* subsp. *ochroleuca*) and Common Chickweed (*Stellaria media*) and the natives Native Geranium (*Geranium solanderi* var. *solanderi*) and Nettle (*Urtica incisa*). The native herbs Spotted Knotweed (*Persicaria strigosa*) and Bog Bulrush (*Schoenoplectus mucronatus)* were found in a small wet patch.

Bank condition (3.00/5.00) was compromised by bank undercutting and slumping, likely due to the high disturbance experienced by the site (Table 3.32). There were few large trees, fallen trees or logs and this reduced the habitat condition (2.71/5.00, Table 3.32).

Table 3.31 Site level summary of riparian condition scores for each sub-index for sites in tributaries of the Mann River including Boyd River.

	GUYFAW1	ABER1	SARA1	SARA2	BOYD1	BOYD2
Vegetation						
Large trees	1.67	1.00	1.00	1.00	1.00	3.00
Canopy Cover	1.33	1.00	1.00	1.00	1.67	4.00
Mid-storey Cover	1.00	1.00	1.00	1.00	3.00	1.00
Mid-storey Weeds	5.00	5.00	5.00	5.00	5.00	5.00
Grass Cover	3.67	4.67	3.67	4.67	3.67	3.67
Grass Weeds	1.00	1.00	4.33	1.00	4.33	2.67
Understorey Cover	3.67	1.00	3.00	1.00	2.33	5.00
Understorey Weeds	5.00	2.33	4.33	2.33	1.67	2.67
Vines	1.00	1.00	1.00	1.00	1.00	1.00
Vegetation Layers	1.33	1.00	1.00	1.00	2.33	2.33
Total/5	**2.47**	**1.90**	**2.20**	**2.53**	**2.60**	**3.03**
Bank condition						
Undercutting	4.00	1.00	1.00	1.00	5.00	5.00
Exposed Tree Roots	5.00	5.00	5.00	5.00	5.00	5.00
Slumping	5.00	1.00	2.00	1.00	5.00	5.00
Total/5	**4.67**	**2.33**	**2.67**	**2.33**	**5.00**	**5.00**
Habitat						
Standing Dead Trees	5.00	0.00	0.00	0.00	0.00	0.00
Logs	1.00	1.00	1.00	1.00	2.00	5.00
Fallen Trees	0.00	0.00	0.00	0.00	0.00	0.00
Reeds	3.00	3.00	3.00	3.00	5.00	5.00
Large Trees	1.67	1.00	1.00	1.00	1.00	3.00
Organic Litter	1.33	2.00	1.00	1.67	1.00	1.00
Weed Litter	2.00	1.00	1.00	5.00	5.00	5.00
Total/5	**2.00**	**1.14**	**1.00**	**1.67**	**2.00**	**2.71**
Disturbance						
Tree Clearing	5.00	1.00	1.00	1.00	2.33	5.00
Fencing	5.00	1.00	1.00	1.00	1.00	1.00
Livestock	5.00	1.00	1.00	1.00	1.00	1.00
Total/5	**5.00**	**1.00**	**1.00**	**1.00**	**1.44**	**2.33**

Mann River

Vegetation communities on the upland sites (MANN4–5) were grasslands dominated by exotic grasses; on the lowland sites Weeping Bottlebrush (*Callistemon viminalis*) and River Oak (MANN1–3). Vegetation Condition index scores ranged from 1.93/5.00 at the pasture (exotic grassland) site at MANN5 to 3.13/5.00 at the lowland MANN3 site (Table 3.32). The lower scores at MANN4–5 score were a result of low midstorey cover, high exotic grass cover and only one to two vegetation layers (Table 3.35).

Large trees ranged from River Oak at MANN2–4 and large Weeping Bottlebrush at MANN1. MANN3 also had large Rough-barked Apple (*Angophora floribunda*) and Red Gum (*Eucalyptus tereticornis*). There were no large trees at the two upland Mann River sites with little or no canopy cover. Weeping Bottlebrush was the dominant midstorey species at MANN1–3, with some regrowth River Oak and with Sandpaper Fig (*Ficus coronata*) at MANN1. There were no lowland midstorey weeds. The upland MANN5 had sparse Tantoon (*Leptospermum polygaliifolium* subsp. *montanum*) in the midstorey with Blackberry at MANN4.

Couch (*Cynodon dactylon*) was the common native grass in the three lowland sites (MANN1–3) with Snow Grass (*Poa sieberiana*) common in the two upland sites (MANN4–5). MANN1 had Broad-leaved Paspalum (*Paspalum mandiocanum*). The pasture grass Fescue (*Festuca pratensis*) was common in both upland sites while African Lovegrass (*Eragrostis curvula*) was dominant at MANN4. Understorey native dominants included Water Pepper (*Persicaria hydropiper*), Common Rush (*Juncus usitatus*) and Bracken (*Pteridium esculentum*). Small-flowered Buttercup (*Ranunculus sessiliflorus* var.*sessiliflorus*) occurred at lowland sites with Creek Mat-rush (*Lomandra hystrix*) at MANN1. Tall Sedge (*Carex appressa*) and Spiny-headed Mat-rush (*Lomandra longifolia*) occurred at the upland MANN5. Understorey exotics were common on the lowland MANN1–2 and included Fireweed (*Senecio madagascariensis*), Blue Billygoat Weed (*Ageratum houstonianum*) and Spear Thistle (*Cirsium vulgare*) with Common Thornapple (*Datura stramonium*) and Parrots Feather (*Myriophyllum aquaticum*) at MANN2. MANN3 had Cobblers Pegs (*Bidens pilosa*) and the upland MANN5 had Oxeye Daisy (*Leucanthemum vulgare*). The exotic vine Cat's Claw Creeper (*Dolichandra unguis-cati*) occurred at lowland MANN1.

Bank condition in the Mann River was highest at MANN3 (3.67/5.00) due to limited bank slumping at the site (Table 3.32). This corresponded to the least level of disturbance for any site on the Mann River. The downstream sites MANN1-2 and MANN5 were highly disturbed (1.00/5.00). Habitat condition was worst at MANN5 on the tablelands due to the absence of trees, alive or dead, standing or fallen (Table 3.32).

Table 3.32 Site level summary of riparian condition scores for each sub-index for sites in the Henry and Mann Rivers.

	HENRY1	MANN1	MANN2	MANN3	MANN4	MANN5
Vegetation						
Large trees	2.00	1.00	1.00	1.67	1.00	1.00
Canopy Cover	2.00	1.33	1.33	1.67	1.00	1.00
Mid-storey Cover	1.67	5.00	4.33	3.00	1.67	1.00
Mid-storey Weeds	5.00	5.00	5.00	5.00	3.67	5.00
Grass Cover	3.33	3.00	4.33	4.67	5.00	5.00
Grass Weeds	4.00	4.33	5.00	5.00	3.00	1.00
Understorey Cover	3.67	5.00	2.33	3.00	3.00	1.00
Understorey Weeds	3.00	2.33	1.00	3.33	4.67	2.33
Vines	1.00	1.67	1.00	1.00	1.00	1.00
Vegetation Layers	2.00	2.33	2.33	3.00	1.67	1.00
Total/5	**2.77**	**3.10**	**2.77**	**3.13**	**2.57**	**1.93**
Bank condition						
Undercutting	2.00	1.00	1.00	2.00	2.00	3.00
Exposed Tree Roots	5.00	3.00	3.00	5.00	5.00	5.00
Slumping	2.00	1.00	1.00	4.00	1.00	2.00
Total/5	**3.00**	**1.67**	**1.67**	**3.67**	**2.67**	**3.33**
Habitat						
Standing Dead Trees	5.00	0.00	0.00	5.00	0.00	0.00
Logs	1.00	3.00	2.00	1.00	2.00	1.00
Fallen Trees	0.00	3.00	3.00	3.00	0.00	0.00
Reeds	5.00	5.00	5.00	5.00	5.00	1.00
Large Trees	2.00	1.00	1.00	1.67	1.00	1.00
Organic Litter	1.00	1.00	1.00	2.00	2.00	1.00
Weed Litter	5.00	5.00	5.00	5.00	1.67	2.00
Total/5	**2.71**	**2.57**	**2.43**	**3.24**	**1.67**	**0.86**
Disturbance						
Tree Clearing	2.33	1.00	1.00	5.00	1.00	1.00
Fencing	1.00	1.00	1.00	3.67	3.67	1.00
Livestock	1.00	1.00	1.00	3.67	3.67	1.00
Total/5	**1.44**	**1.00**	**1.00**	**4.11**	**2.78**	**1.00**

Table 3.33 Dominant riparian vegetation for each stratum at sites in the Guy Fawkes, Aberfoyle and Sara Rivers. Emergents are large trees that rise above the tree canopy.

Vegetation Description	GUYFAW1	ABER1	SARA1	SARA2
Left/Right bank (facing downstream)	R	L	R	L
Community Description	New England Peppermint Woodland	Exotic Grassland	Exotic Grassland (African Lovegrass)	Grassland (Native)/Carex Sedgeland
Emergents	No emergents	No emergents	No emergents	No emergents
Dominant Large Trees A	No large trees	No large trees	No large trees	No large trees
Dominant Large Trees B	*Eucalyptus nova-anglica*	No large trees	No large trees	No large trees
Dominant Large Trees C	No large trees	No large trees	No large trees	No large trees
Dominant Mid-storey Cover (native)	No midstorey cover	*Leptospermum polgalifolium* subsp. *montanum*	No midstorey cover	No midstorey cover
Dominant Mid-storey Cover (weeds)	No midstorey weeds	No midstorey weeds	No midstorey weeds	No midstorey weeds
Dominant Grass Cover (native)	No native grasses	*Poa labillardieri*	*Cynodon dactylon*	*Cynodon dactylon*
		Imperata cylindrica		*Sporobolus elongatus*
				Phragmites australis
Dominant Grass Cover (weeds)	*Festuca pratensis*	*Festuca pratensis*	*Eragrostis curvula*	*Paspalum dilatatum*
	Dactylis glomerata		*Andropogon virginicus*	*Lolium perenne*
			Paspalum dilatatum	
Dominant Understorey Cover (native)	*Scirpus polystachyos*	*Lomandra longifolia*	*Pteridium esculentum*	*Carex gaudichaudiana*
	Juncus usitatus	*Juncus usitatus*		*Scirpus polystachyos*
	Ammobium alatum			*Leiocarpa* sp. Uralla
	Carex gaudichaudiana			*Epilobium billardierianum* subsp. *cinereum*
Dominant Understorey Cover (weeds)	*Leucanthemum vulgare*	*Verbena bonariensis*	*Gamochaeta coarctata*	*Gamochaeta coarctata*
	Lotus uliginosus	*Cyperus eragrostis*	*Hypochaeris radicata*	*Leucanthemum vulgare*
	Rumex obtusifolia			
Dominant Organic Litter (weeds)			Exotic grasses	Exotic grass
Dominant Vines	No vines	No vines	No vines	No vines

Table 3.34 Dominant riparian vegetation for each stratum at sites in the Boyd and Henry Rivers. Emergents are large trees that rise above the tree canopy.

Vegetation Description	BOYD1	BOYD2	HENRY1
Left/Right bank (facing downstream)	L	L	L
Community Description	River Oak – Weeping Bottlebrush layered woodland	River Oak grassy open forest	River Oak grassy open forest
Emergents	No emergents	No emergents	No emergents
Dominant Large Trees A	No large trees	*Casuarina cunninghamiana*	*Casuarina cunnghamiana*
Dominant Large Trees B	*Casuarina cunninghamiana*	*Casuarina cunninghamiana*	*Casuarina cunnghamiana*
Dominant Large Trees C	*Casuarina cunninghamiana*	*Casuarina cunninghamiana*	*Casuarina cunnghamiana*
Dominant Mid-storey Cover (native)	*Callistemon viminalis*	*Callistemon viminalis*	*Casuarina cunnghamiana*
	Casuarina cunninghamiana	*Casuarina cunninghamiana*	
		Grevillea robusta	
Dominant Mid-storey Cover (weeds)	No midstorey weeds	*Lantana camara*	No midstorey weeds
Dominant Grass Cover (native)	*Cynodon dactylon*	*Cynodon dactylon*	*Cynodon dactylon*
	Microlaena stipoides	*Microlaena stipoides*	
		Oplismenus imbecillis	
Dominant Grass Cover (weeds)	*Bromus catharticus*	*Bromus catharticus*	*Bromus catharticus*
Dominant Understorey Cover (native)	*Ranunculus sessiliflorus* var. *sessiliflorus*	*Ranunculus sessiliflorus* var. *sessiliflorus*	*Persicaria strigosa*
	Persicaria hydropiper	*Urtica incisa*	*Geranium solanderi var. solanderi*
		Ranunculus lappaceus	*Urtca incisa*
			Schoenoplectus mucronatus
Dominant Understorey Cover (weeds)	*Argemone ochroleuca* subsp. *ochroleuca*	*Argemone ochroleuca* subsp. *ochroleuca*	*Argemone ochroleuca* subsp. *ochroleuca*
	Stellaria media	*Stellaria media*	
	Cirsium vulgare	*Cirsium vulgare*	
	Solanum mauritianum	*Solanum mauritianum*	
		Datura stramonium	
Dominant Organic Litter (natives)	*Eucalyptus grandis*	*Eucalyptus grandis*	*Casuarina cunnghamiana*
	Syzygium australe	*Lophostemon confertus*	
Dominant Vines	No vines	No vines	No vines

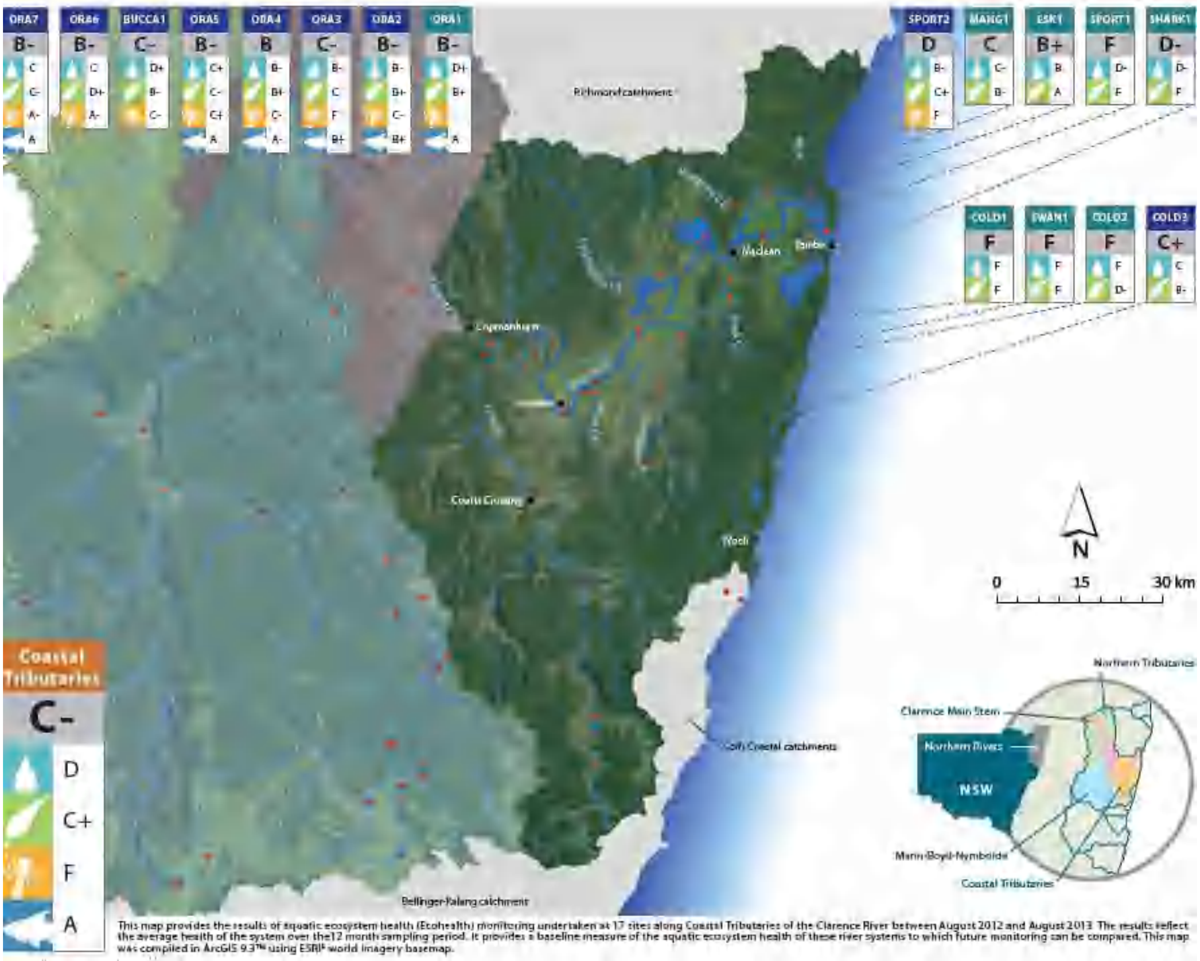
Table 3.35 Dominant riparian vegetation for each stratum at sites in the Mann River. Emergents are large trees that rise above the tree canopy.

Vegetation Description	MANN1	MANN2	MANN3	MANN4	MANN5
Left/Right bank (facing downstream)	L	L	R	R	L
Community Description	Weeping Bottlebrush shrubland with River Oak	Weeping Bottlebrush shrubland with River Oak	River Oak – Weeping Bottlebrush layered woodland	Grassland (native and exotic)	Pasture (Exotic grassland)
Emergents	No emergents	No emergents	No emergents	No emergents	No emergents
Large Trees A	No large trees	No large trees	*Casuarina cunninghamiana*	No large trees	No large trees
Large Trees B	No large trees	*Casuarina cunninghamiana*	*Angophora floribunda*	No large trees	No large trees
			Casuarina cunninghamiana		
			Eucalyptus tereticornis		
Large Trees C	*Callistemon viminalis*	No large trees	No large trees	No large trees	No large trees
Mid-storey Cover (native)	*Callistemon viminalis*	*Callistemon viminalis*	*Callistemon viminalis*	*Leptospermum polygalifolium subsp. montanum*	No midstorey natives
	Ficus coronata				
	Casuarina cunninghamiana				
Mid-storey Cover (weeds)	No midstorey weeds	No midstorey weeds	No midstorey weeds	*Rubus anglocandicans*	No midstorey weeds
Grass Cover (native)	*Cynodon dactylon*	*Cynodon dactylon*	*Imperata cylindrica*	*Poa sieberiana*	*Poa sieberiana*
		Microlaena stipoides	*Microlaena stipoides*	*Imperata cylindrica*	
			Cynodon dactylon	*Phragmites australis*	
Grass (weeds)	*Paspalum mandiocanum*	No grass weeds	*Bromus catharticus*	*Eragrostis curvula*	*Festuca pratensis*
	Bromus catharticus			*Festuca pratensis*	*Dactylis glomerata*
					Phalaris aquatica
					Lolium perenne

Understorey Cover (native)	*Persicaria hydropiper*	*Persicaria hydropiper*	*Urtica incisa*	*Pteridium esculentum*	*Carex appressa*
	Juncus usitatus	*Juncus usitatus*	*Pteridium esculentum*	*Geranium solanderi* var. *solanderi*	*Lomandra longifolia*
	Ranunculus sessiliflorus var. *sessiliflorus*	*Ranunculus sessiliflorus* var. *sessiliflorus*		*Juncus usitatus*	*Geranium solanderi* var. *solanderi*
	Lomandra hystrix				
Understorey Cover (weeds)	*Senecio madagascariensis*	*Senecio madagascariensis*	*Bidens pilosa*	No understorey weeds	*Leucanthemum vulgare*
	Cirsium vulgare	*Cirsium vulgare*			*Plantago lanceolata*
	Ageratum houstonianum	*Ageratum houstonianum*			
	Oxalis debilis var. *corumbosa*	*Datura stramonium*			
		Myriophyllum aquaticum			
Organic Litter (natives)	*Callistemon viminalis*	*Callistemon viminalis*			
	Casuarina cunninghamiana				
Dominant Vines (exotic)	*Dolichandra unguis-cati*				

3.4 Coastal tributaries of the Clarence

Overview



The coastal tributaries region covers seven major river systems that drain directly into the Clarence River. Overall the region scored a grade of C-, with excellent scores for fish communities in the freshwater reaches, but very low scores for water quality in downstream sites adjacent to the estuary.

Condition scores were highly variable in this region highlighting the influence of local conditions on the health of streams. The Esk River scored the highest grade of a B+ reflecting the large areas of conservation reserve in this catchment, with the highly developed lower Swan Creek that has a predominantly cleared catchment recording a grade of F.

Water quality scores were also highly variable, ranging from very good at a number of sites in the mid-upper Orara River that received a grade of B, to a number of systems recording an F. There were no trends of increasing nutrients or poor water quality along the larger rivers suggesting local sources are an important influence on water quality.

Concentrations of nitrogen and phosphorus consistently exceeded the guideline values throughout the study and were the highest recorded in the Clarence catchment. The highest phosphorus concentrations were recorded during prolonged low flows suggesting instream sources, and the highest nitrogen concentrations were recorded following high flows suggesting catchment runoff as the main source.

A number of sites had very high levels of algae well above guideline values; including the lower Orara River lower Swan, Shark, Coldstream and Sportsmans Creeks. Consistently very high algal and nutrient levels were recorded from the lower Orara River and Shark Creek.

Estuary tributaries (particularly Swan, Mangrove and Shark Creeks) were in very poor overall condition, and contributed very poor water quality (low oxygen and acid water) to the Clarence River following flooding.

Aquatic macroinvertebrate communities in freshwater sites ranged from excellent in the mid-upper Orara River to very poor in the upper Sportsmans Creek which recorded the lowest score of the Clarence catchment. Macroinvertebrate condition improved after flooding in the Orara River suggesting they are more affected by prolonged periods of low flows than floods.

Fish communities in the Orara River were in excellent condition with for all sites recording an A or B grade. All sites were dominated by diverse communities of native fish.

Riparian condition in the Orara River was the best of the coastal tributaries. Condition in the lower reaches of most rivers was generally low from a poor diversity of native vegetation generally occurring in isolated pockets with poor connectivity to other native vegetation, with many sites absent of any river bank vegetation.

3.4.1 Water chemistry

3.4.1.1 *Chlorophyll a*

In the Bucca and Orara Rivers chlorophyll *a* concentrations ranged from 0.09 µg/L (August 2013) to 23.43 µg/L at ORA1 (August 2013,Figure 3.30). The upper most site in the Orara (ORA1) downstream of Karangi Dam was the only site in the Orara to consistently exceed trigger values, with a mean concentration of 5.24 µg/L. Chlorophyll concentrations in the Coldstream increased with distance downstream, from a concentration of 1.28 µg/L at COLD3 to 5.88 µg/L at COLD1. A similar pattern was evident in Sportsmans Creek with low concentrations in SPORT2 and 50% of samples exceeding the trigger value at SPORT1. Trigger value concentrations of chlorophyll a were only exceeded once at Mangrove Creek and the Esk River, with mean concentrations well below trigger values. Concentrations of chl-*a* in estuarine reaches of coastal tributaries consistently exceeded trigger values in the three dates post-flood, compared to few exceedences in pre-flood sample dates at these sites.

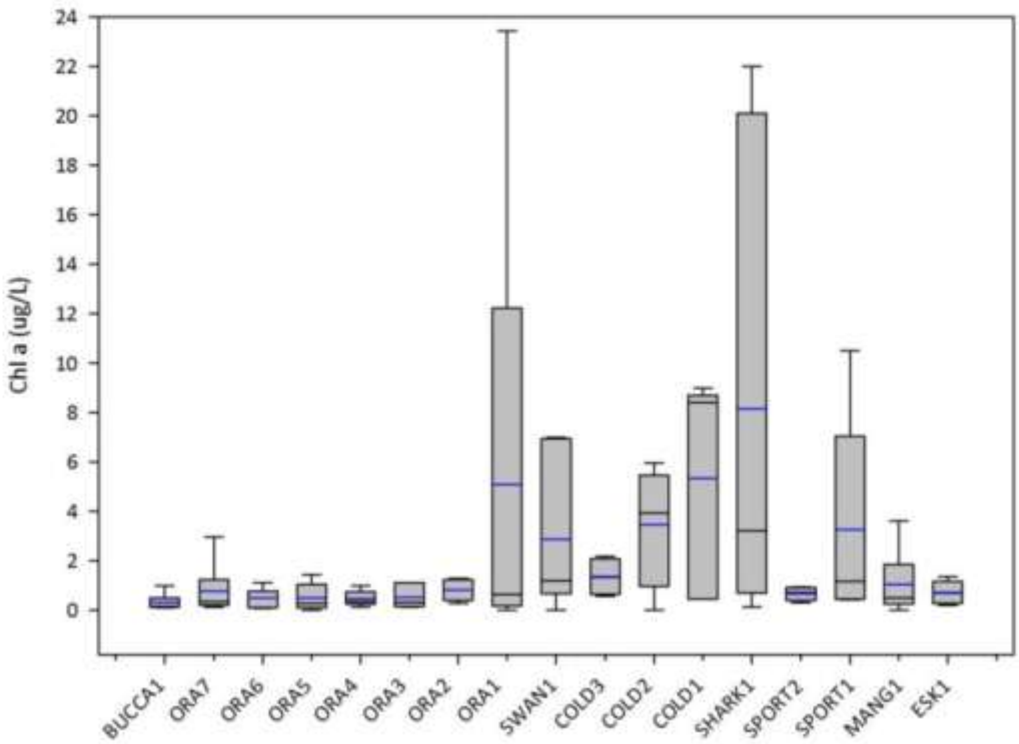


Figure 3.30 Mean (black line), median (blue line), 25th and 75th percentiles and range of chlorophyll *a* concentrations from sites in the coastal tributaries of the Clarence from August 2012 to August 2013.

3.4.1.2 *Total Nitrogen (TN)*

Concentrations ranged from to 20.8 µg/L in BUCCA1 to 1891.9 µg/L in SWAN1 (Figure 3.31). Unlike chlorophyll a concentrations, there were no clear longitudinal patterns in River systems, and highly variable concentrations over time, with estuarine reaches of coastal tributaries consistently exceeded trigger values in the three dates post-flood, compared to few exceedences in pre-flood sample dates at these sites. Total Nitrogen concentrations exceeded trigger values in the Bucca and Orara Rivers between 33 and 67% of sample events, and more frequently in 2012 sample dates in freshwater sites. Swan Creek had the highest mean TN concentration of 986.22 µg/L, and exceeded trigger values 83% of the time.

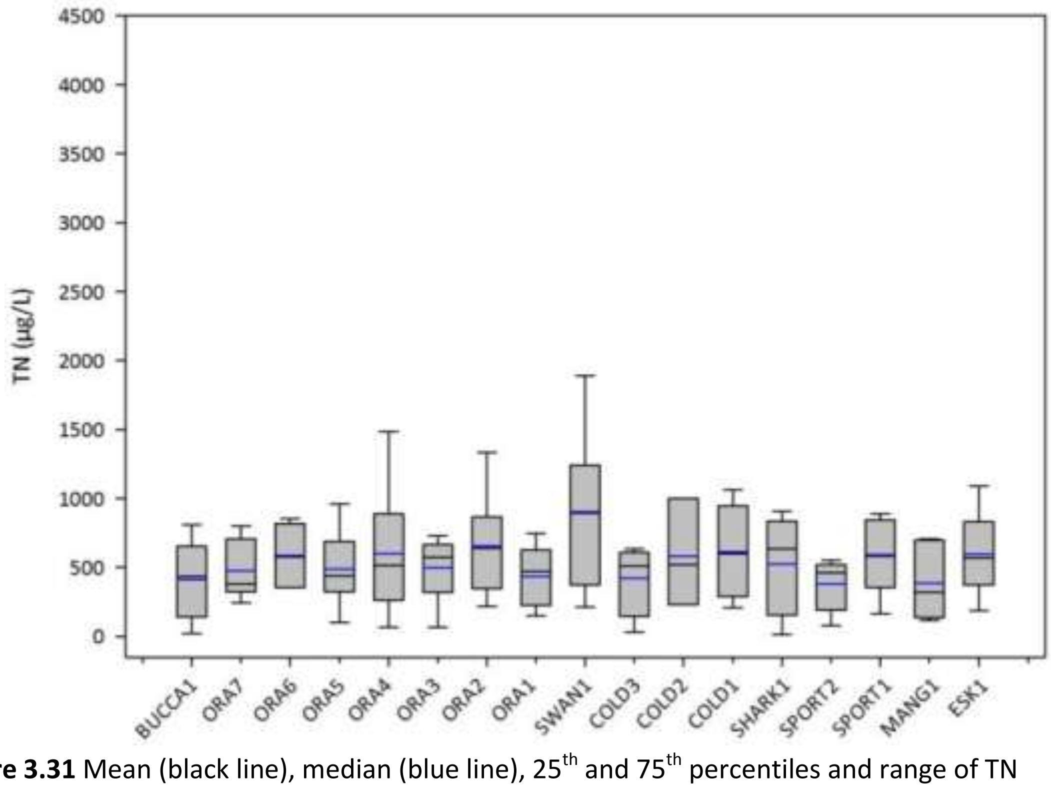


Figure 3.31 Mean (black line), median (blue line), 25th and 75th percentiles and range of TN concentrations from sites in the coastal tributaries of the Clarence from August 2012 to August 2013.

3.4.1.3 *Bioavailable Nitrogen (NOx)*

Mimicking the trends evident in TN concentrations, ORA1 and SPORT2 had consistently high concentrations of NOx, both peaking during low flow conditions of at 405.98 µg/L in November 2012 at ORA1 and 1538.46 µg/L at SPORT2 in December 2012 (Figure 3.32). Total Nitrogen concentrations exceeded trigger values in the Bucca and Orara Rivers between 29 and 100% of sample events, and more frequently in 2012 sample dates in freshwater sites. The estuarine reach of the Orara (ORA1) exceeded the trigger value on all sample dates.

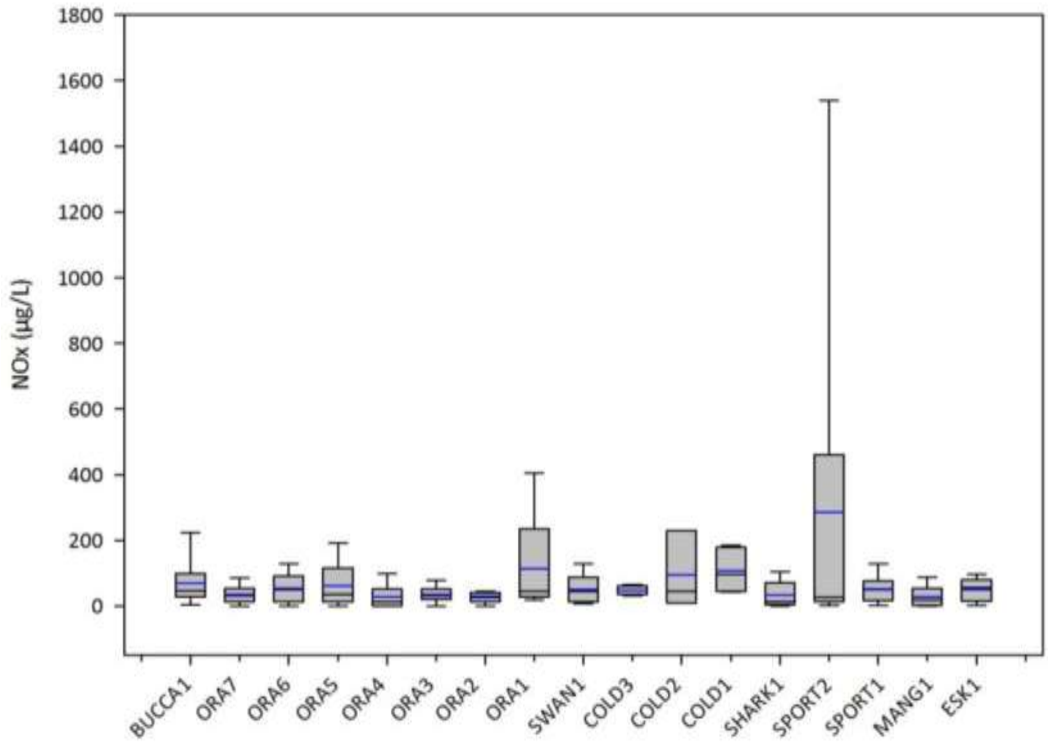


Figure 3.32 Mean (black line), median (blue line), 25th and 75th percentiles and range of NOx concentrations from sites in the coastal tributaries of the Clarence from August 2012 to August 2013.

3.4.1.4 *Total Phosphorus (TP)*

Concentrations ranged from to 2.19 µg/L in BUCCA1 to a very high 1542.41 µg/L in SHARK1 immediately following the flood events (Figure 3.33). Similar to TN concentrations, there were no clear longitudinal patterns in River systems, and highly variable concentrations over time, with estuarine reaches of coastal tributaries exceeded trigger values in the first date post-flood, compared to increased exceedences in pre-flood sample dates at freshwater sites.

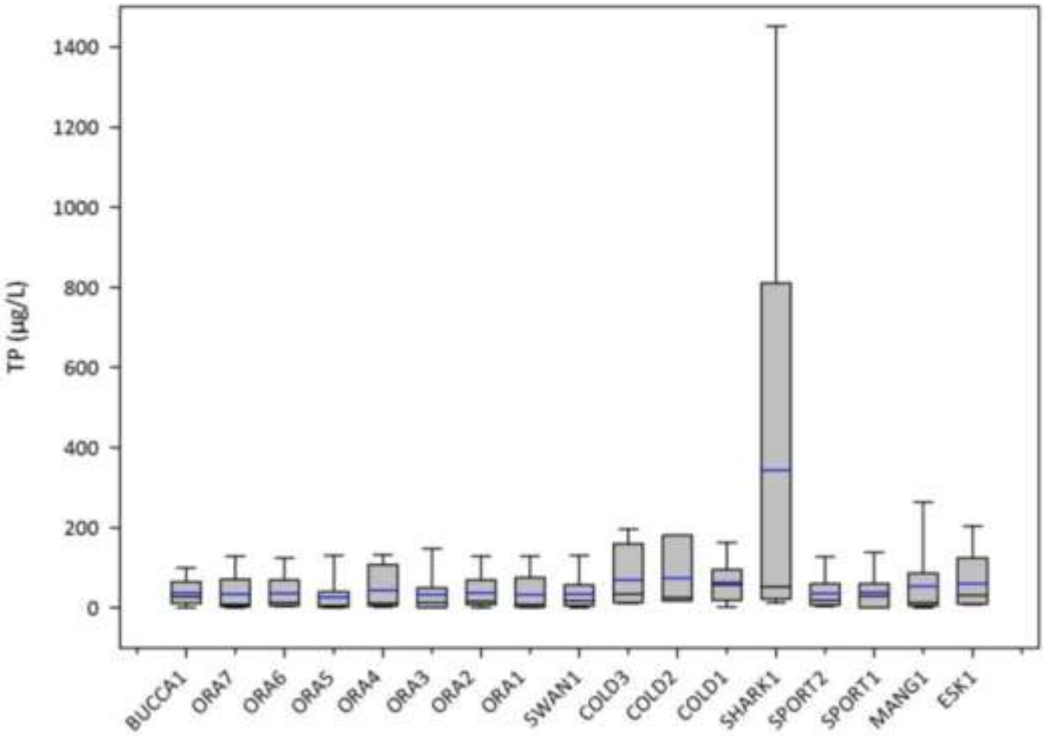


Figure 3.33 Mean (black line), median (blue line), 25th and 75th percentiles and range of TP concentrations from sites in the coastal tributaries of the Clarence from August 2012 to August 2013.

3.4.1.5 *Soluble Reactive Phosphorus (SRP)*

Concentrations of SRP ranged from to 1.33 µg/L in ORA7 to a high 93.43 µg/L in ORA5 (Figure 3.34). Similar to other nutrients, there were no clear longitudinal patterns in SRP concentrations in the Orara River, with highly variable concentrations throughout the study period and trigger value exceedence in freshwater reaches only occurring in 2012 pre-flood conditions. ORA1 exceeded the estuarine SRP trigger value on all sampling occasions. Swan Creek and the Esk River recorded very high mean concentrations of SRP, at 26.57 µg/L and 31.48 µg/L respectively. All estuarine sites of the coastal tributaries had SRP values exceeding trigger values between 80 and 100% of sample dates.

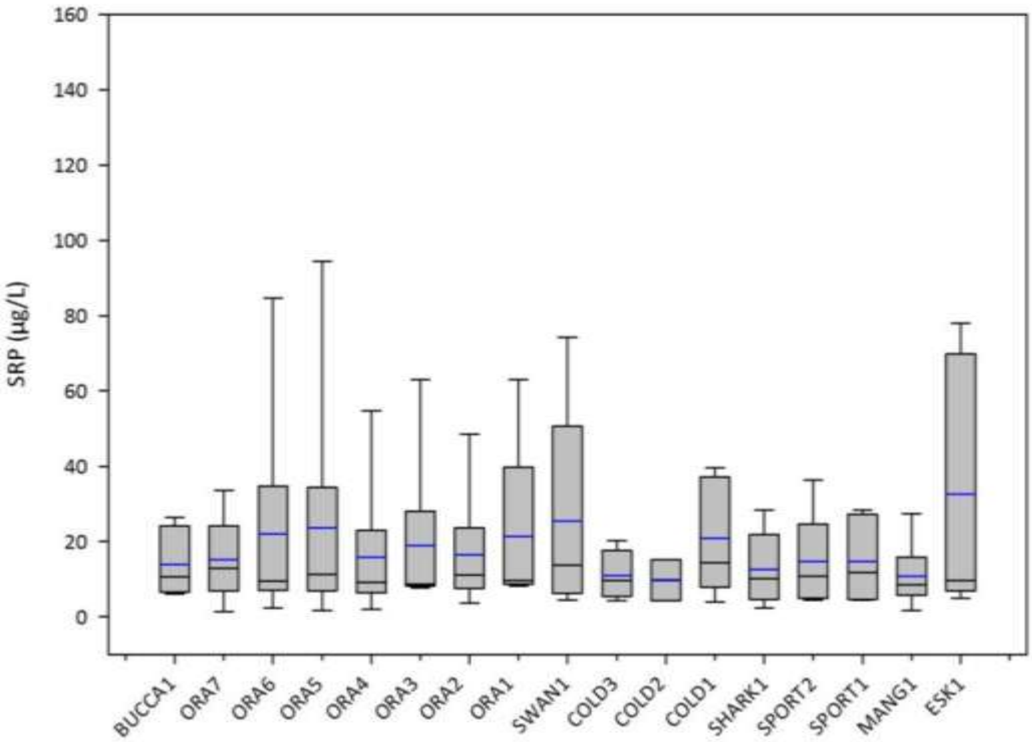


Figure 3.34 Mean (black line), median (blue line), 25th and 75th percentiles and range of SRP concentrations from sites in the coastal tributaries of the Clarence from August 2012 to August 2013.

3.4.1.6 *Dissolved Oxygen (DO)*

Dissolved Oxygen values were not recorded for a number of estuarine sites due to equipment used being unable to record percent saturation that is used in the ANZECC guidelines (Figure 3.35). The majority of sites (except ORA2 and 3) recoded DO concentrations below the 80% trigger value, and ORA4 was the only site to record a value above the trigger value of 110%. Freshwater sites had low DO concentration in the period prior to the January flooding (August – December 1012), whereas estuary sites displayed lowest DO concentrations following the flood events, with lowest DO concentrations at the bottom of the water column.

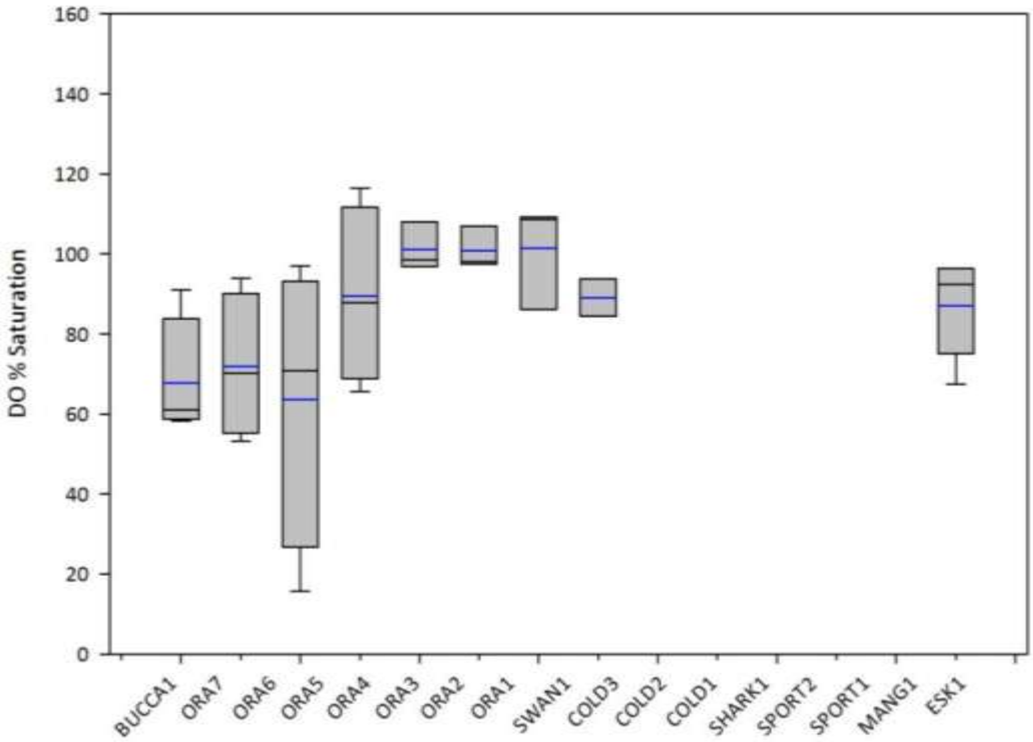


Figure 3.35 Mean (black line), median (blue line), 25th and 75th percentiles and range of DO saturation percentages from sites in the coastal tributaries of the Clarence from August 2012 to August 2013.

3.4.1.7 *pH*

Values for pH were consistently below the trigger value in estuarine reaches, and particularly low in following the flood event in January 2013; Swan Creek (4.38 August 2013), Shark Creek (3.47 June 2013) and Sportsmans Creek (4.35 in August 2013) (Figure 3.36). Swan Creek had a mean pH value of 5.73 that was well below the trigger value of 7.0 for estuaries. These estuarine sites had highly variable pH values throughout the study, such as Shark Creek that ranged from 4.13 to 8.82 at the surface, whereas benthic pH values (3m depth) were consistently acidic and coincided with low DO concentrations.

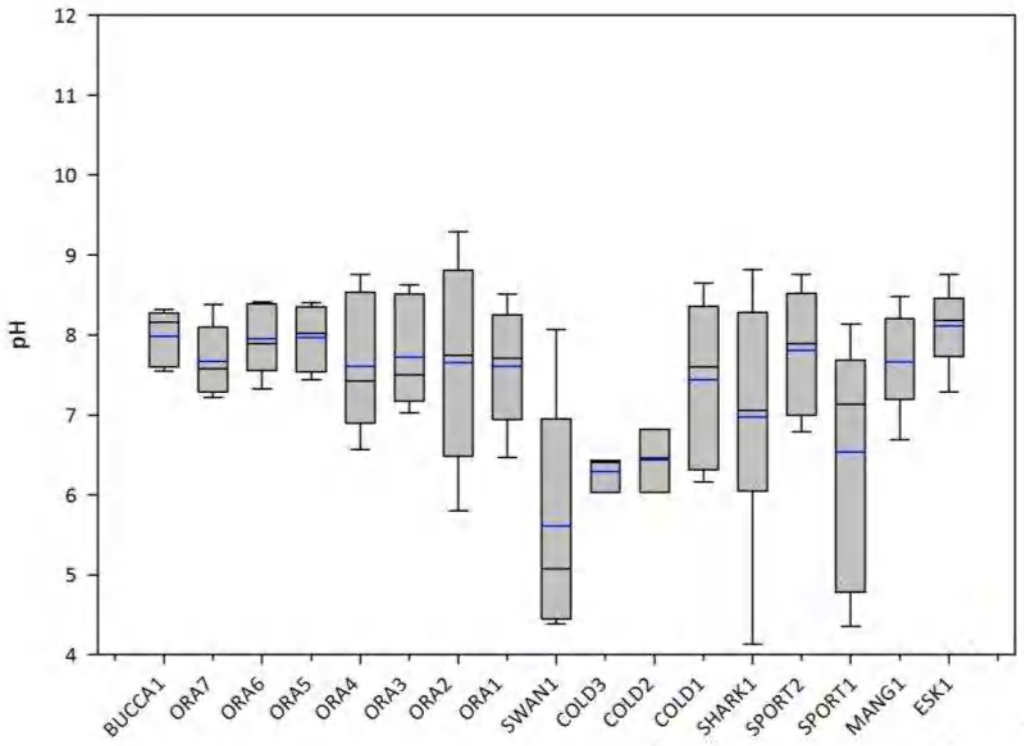


Figure 3.36 Mean (black line), median (blue line), 25th and 75th percentiles and range of pH from sites in the coastal tributaries of the Clarence from August 2012 to August 2013.

3.4.1.8 *Turbidity*

Freshwater sites were consistently more turbid than estuarine sites showing clear longitudinal trends of decreasing turbidity with distance downstream (Figure 3.37). High turbidity in the Orara River both upstream and downstream of ORA3 suggests the sediment slug in this reach is both a source and a trap for suspended sediments during flood periods. Turbidity ranged from 0 at Bucca Creek to 94.6 NTU at ORA5, with freshwater sites substantially higher in turbidity during high flow periods.

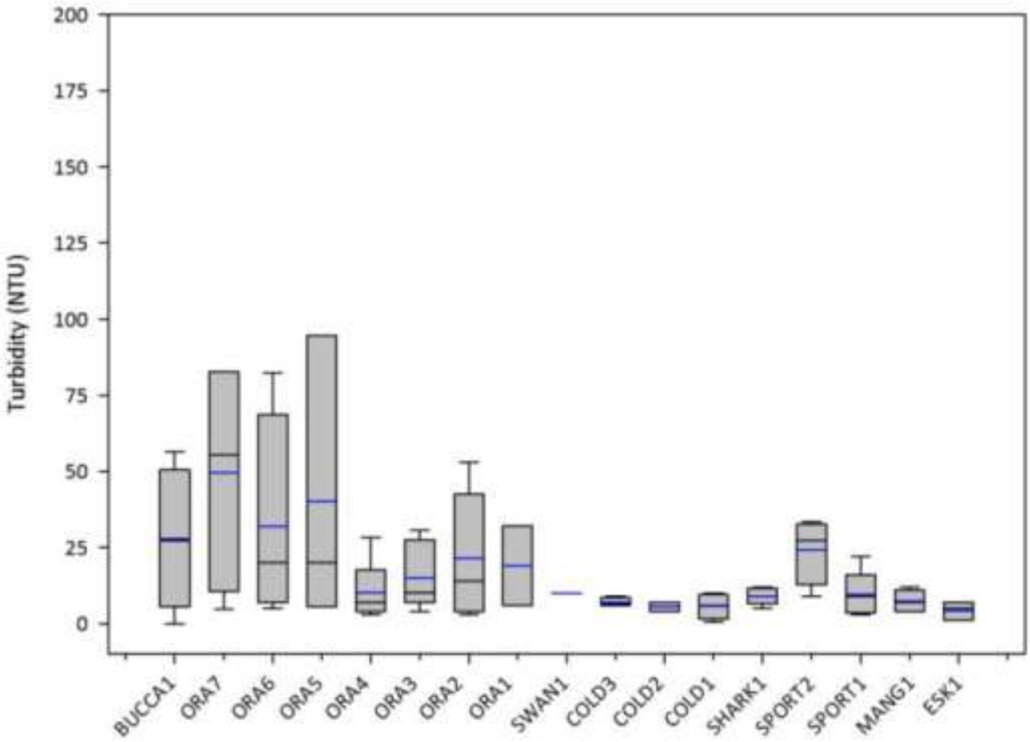


Figure 3.37 Mean (black line), median (blue line), 25th and 75th percentiles and range of turbidity from sites in the coastal tributaries of the Clarence from August 2012 to August 2013.

3.4.1.9 *Water chemistry variables*

Water temperature showed a clear pattern of increasing maximum temperatures from the headwaters of the Orara (ORA7 22.1˚C) to the confluence with the Clarence River (ORA1 29.7 ˚C) (Table 3.36). A similar pattern was evident in the Coldstream River of 18.4 ˚C at COLD3 to 26.1 ˚C at COLD1. Salinity and Conductivity were highly variable and dependant on freshwater flows, with increasing salinity in the 3 dates prior to the January 2013 floods. Estuarine sites displayed clear patterns of vertical stratification, with fresher and warmer water in surface layers, and colder and saline water in deeper layers. Turbidity mimicked patterns seen in turbidity, with very high concentrations recorded at ORA5 (30.87 mg/L) and the Esk River (22.84 mg/L).

Table 3.36 Range of water chemistry variables at sites in coastal tributaries of the Clarence River.

Site	Water temp (°C)	Conductivity (mS/cm)	Salinity (ppt)	Secchi depth (m)	TSS (mg/L)
BUCCA1	15.9 - 22.2	0.024 - 0.211	0.08 - 11.77	0.10 - 0.50	0.95 - 10.15
ORA7	14.2 - 22.1	0.010 - 0.081	0.03 - 0.04		0.50 - 5.25
ORA6	14.5 - 23.6	0.030 - 0.087	0.04 - 0.05		0.20 - 6.26
ORA5	16.4 - 23.9	0.040 - 0.109	0.04 - 0.06	0.20 - 0.60	0.50 - 30.87
ORA4	11.0 - 25.2	0.118 - 0.144	0.00 - 0.07	0.50 - 2.10	1.58 - 6.48
ORA3	12.6 - 27.6	0.129 - 0.188	0.00 - 0.09		0.26 - 10.00
ORA2	10.2 - 28.3	0.126 - 0.184	0.00 - 0.08	0.20 - 0.50	0.68 - 10.70
ORA1	11.5 - 29.7	0.113 - 0.204	0.00 - 0.07	0.40 - 1.65	1.79 - 16.18
SWAN1	13.5 - 27.9	0.605 - 1.380	0.02 - 0.06	0.70 - 1.30	0.18 - 7.58
COLD3	10.6 - 18.4	0.125 - 0.181	0.00 - 0.01	0.50 - 1.00	2.83 - 21.32
COLD2	13.2 - 21.1	0.32 - 0.510	0.01 - 0.02	0.70 - 1.40	2.31 - 6.86
COLD1	14.9 - 26.1	0.311 - 0.781		0.60 - 4.50	0.98 - 8.92
SHARK1	13.9 - 26.1	0.103 - 1.060		0.70 - 1.90	0.00 - 12.92
SPORT2	11.6 - 26.2	0.128 - 0.242	0.06 - 0.11		1.03 - 6.68
SPORT1	14.7 - 26.5	0.104 - 0.712		0.40 - 1.90	2.91 - 7.61
MANG1	14.5 - 25.8	0.105 - 0.295		0.65 - 2.00	0.84 - 11.21
ESK1	15.9 - 25.8	0.225 - 0.883		0.30 - 1.20	1.42 - 22.84

3.4.2 Transported loads of TSS, TN and TP

Peak low-flow discharge of 1,932.44 ML/day occurred during April 2013 at the most downstream site on the Orara River (ORA1, the tidal limit). This correlated with a maximum TSS concentration of 16.18 mg/L to give the maximum TSS load of 31.267 t/day (Figure 3.38a). The minimum TSS load was 0.643 t/day (October 2012) and the mean monthly TSS load was 7.337 t/day.

Maximum total nutrient loads of 177.760 kg TN/day and 48.931 kg TP/day (August 2012) did not correlate with peak discharge or maximum TSS concentrations (Figure 3.38b). Minimum total nutrient loads were 0.584 kg TN/day (April 2013) and < 10 g TP/day (October – December 2012). Thus, the minimum TN load correlated with the peak low-flow discharge and the maximum TSS load. Mean monthly nutrient loads at ORA1 were 158.221 kg TN/day and 9.938 kg TP/day.

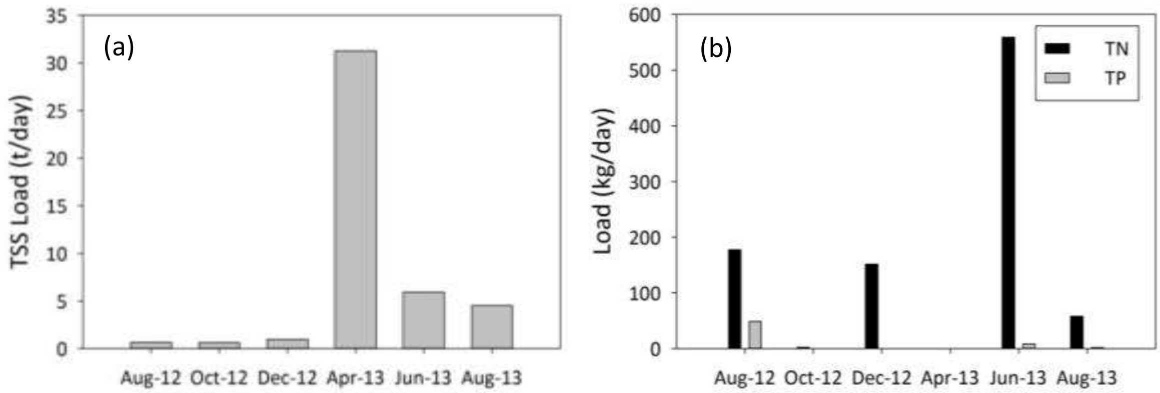


Figure 3.38 Loadings of (a) total suspended sediments and (b) TN and TP transported in the Orara River at Site ORA1 (Gauge 204041) from August 2012 to August 2013.

3.4.3 Macroinvertebrates

Forty two macroinvertebrate families were recorded from the Costal tributaries during the Autumn and Spring sampling in 2012-13, dominated by Trichoptera (Caddis Flies) with 8 families and Coleoptera (beetles) with 7 families (Table 3.37). Unlike the other river systems in the Clarence catchment, family level richness was similar in both Spring than Autumn. The EPT index identifies between 28 and 48% of the families and 45 % of the individuals across all sites.

Of the 2498 individuals recorded from the 3 coastal tributaries, substantially more individuals (65%) were collected in Autumn potentially responding to post flood conditions compared to prolonged low flow conditions in Spring 2012. In the Orara River with 6 freshwater sites from just below Karangi Dam to confluence with the Clarence, there was a clear impact of the sediment slug with the lowest family richness of 7, only 2 EPT taxa and the lowest abundance of individuals at ORA3. Abundances ranged from 593 individuals at ORA6 to just 114 at ORA3 for all sample times combined.

Unlike the other systems in the Clarence catchment, the costal tributaries did not have a diversity of dominant taxa, with 4 sites only having 2 taxa with more than 10 individuals. Leptophlebiidae with a SIGNAL2 score of 8 were the dominant taxa upstream of the sediment slug in the Orara River, switching to a dominance by Chironomidae (midge larvae) and Atyidae shrimps (SIGNAL2 score 2) at the remainder of the sites. Chironomidae were in the 5 most abundant individuals in 5 of the 8 sites.

Mean SIGNAL2 score for the coastal tributaries was 4.8 with the scores ranging from 3.5 at SPORT2 to 5.6 at BUCCA1 (Table 3.37). Despite the low abundance and diversity of families compared with other sites, only 2 sites on the coastal tributaries recorded taxa with a SIGNAL2 score of 1 from Lymnaeidae (snails). Two taxa with SIGNAL2 scores of 10 were recorded across system at ORA6 and 7. The sites in this system had the lowest range but not the lowest mean of SIGNAL2 scores in the Clarence catchment, suggesting conditions were present throughout the river system that facilitated the occurrence of both pollution tolerant and pollution sensitive taxa.

Table 3.37 Macroinvertebrate richness, EPT richness, SIGNAL2 scores and dominant taxa at sites in the coastal tributaries of the Clarence River. SIGNAL2 shown as mean value (range in brackets). The 5 numerically dominant taxa at each site The 5 numerically dominant taxa with greater than 10 individuals at each site are listed.

Site	No. Families	No. EPT families	SIGNAL2	Dominant taxa
BUCCA1	21	10	5.6 (2-8)	Chironnomidae, Baetidae, Leptophlebiidae
ORA7	35	15	5.5 (1-10)	Leptophlebiidae, Hydrophilidae, Philopotamidae Elmidae, Chironnomidae
ORA6	39	14	5.3 (2-10)	Leptophlebiidae, Chironnomidae, Simuliidae, Hydrophilidae, Baetidae
ORA5	28	11	4.9 (1-8)	Leptophlebiidae, Hydrophilidae, Hydropsychidae, Ecnomidae, Elmidae
ORA4	22	11	5.1 (2-8)	Simuliidae, Chironnomidae, Elmidae, Philopotamidae, Baetidae
ORA3	7	2	4.2 (2-8)	Atyidae, Helicophidae
ORA2	13	6	4.5 (2-8)	Chironnomidae, Elmidae
SPORT2	4	0	3.5 (2-6)	Atyidae

3.4.4 Riparian condition

Bucca Bucca Creek had the best vegetation condition of the coastal tributaries subcatchment (7.01/10.00, Table 3.38). This was predominantly driven by very good bank condition and minimal site disturbance. The mean vegetation condition for the Orara River was 6.41/10.00 (Table 3.38), driven by good vegetation composition and very little disturbance at most sites. ORA4 (a headwater gorge) had the best vegetation condition score (7.45/10.00) for the coastal tributaries subcatchment (Table 3.38). SPORT2 on Sportsmans Creek also scored well (6.74/10.00, Table 3.38), primarily due to the vegetation composition and limited disturbance.

Table 3.38 Site level summary of riparian condition scores for sites in the coastal tributaries of the Clarence River. Individual scores maximum of 5, total score out of 10.

	VEGETATION	BANK CONDITION	HABITAT	DISTURBANCE	Total/10
BUCCA1	3.53	4.33	2.05	4.11	7.01
ORA2	3.57	1.67	3.14	5.00	6.69
ORA3	3.17	1.33	2.67	3.22	5.19
ORA4	3.67	3.00	3.24	5.00	7.45
ORA5	3.05	2.67	2.81	4.11	6.32
ORA6	2.39	3.67	1.71	5.00	6.39
ORA7	2.87	2.67	2.33	5.00	6.43
Mean	**3.12**	**2.50**	**2.65**	**4.56**	**6.41**
SPORT2	3.93	2.67	2.76	4.11	6.74

The vegetation communities at the northern Orara River sites (ORA2–4) and Sportmans Creek (SPORT2) varied from a narrow strip of Water Gum forest backed by rainforest at ORA2 to forests featuring eucalypts and angophoras with rainforest midstorey. The ORA3 community was Sparse River Oak, Flooded Gum and Red Gum forest, ORA4, dense Flooded Gum moist open forest and SPORT2, River Oak with emergent Angophora species with rainforest midstorey. Vegetation Condition index scores ranged from 3.17/5.00 at ORA3 to 3.57/5.00 at ORA2 (Table 3.39). The higher score at SPORT2 was a result of higher canopy and midstorey cover (Table 3.40).

Communities at the southern Orara River sites were River Oak with planted trees and shrubs at ORA5, Camphor Laurel – River Oak forest at ORA6 and Camphor Laurel forest with Water Gum and River Oak at ORA6 The southern Orara River sites generally had lower Vegetation Condition index scores than the northern sites and ranged from 2.27/5.00 at ORA6 to 2.87/5.00 at ORA5. The higher score of 3.30/5.00 at the single Bucca Creek site (BUCCA1) was attributed to more large trees and less exotic grass and understorey cover. Southern Orara River sites had more vines and thus more vegetation layers and less grass or understorey weed cover than northern Orara River sites (Table 3.41).

Large emergent trees were present at two northern sites: ORA4 had emergent Flooded Gum (*Eucalyptus grandis*) and SPORT2 had emergent Narrow-leaved Apple (*Angophora bakeri*). ORA2 had no large trees but ORA3 had large Red Gum (*Eucalyptus tereticornis*), River Oak and Flooded Gum (*Eucalyptus grandis*) and ORA4 had large Flooded Gum (*Eucalyptus grandis*), Water Gum (*Tristaniopsis laurina*) and Silky Oak (*Grevillea robusta*). SPORT2 had large Narrow-leaved Apple (*Angophora bakeri*), Broad-leaved Apple (*Angophora subvelutina*), River Oak and Thick-leaved Mahogany (*Eucalyptus carnea*).

Both southern and northern Orara river sites and SPORT2 and BUCCA1 featured native rainforest shrubs in the midstorey. Commonly seen species were Lilly Pilly (*Acmena smithii*), Grey Myrtle (*Backhousia myrtifolia*), Sandpaper Fig (*Ficus coronata*), Wild Yellow Jasmine (*Pittosporum revolutum*) and Cheese Tree (*Glochidion ferdinandi* var. *ferdinandi*). Weeping Grass (*Microlaena* *stipoides*) and Creeping Beard Grass (*Oplismenus imbecillis*) were the most common native grasses. Northern Orara River sites had no grass weeds but Broadleaf Paspalum (*Paspalum mandiocanum*) occurred at the three Orara River southern sites. Understorey native dominants included Creek Mat-rush (*Lomandra hystrix*), Water Pepper (*Persicaria hydropiper*) and Spotted Knotweed (*Persicaria strigosa*) with the native ferns Common Bracken (*Pteridium esculentum*), Harsh Ground Fern (*Hypolepis muelleri*) and Downy Maiden Fern (*Cyclosorus dentatus*). Northern Orara sites and SPORT2 had no understorey weeds but Small-leaved Privet (*Ligustrum sinense*), Lantana, Wandering Jew (*Tradescantia fluminensis*) and Blue Billygoat Weed (*Ageratum houstonianum*) occurred in southern Orara sites. Native vines were a feature of northern sites and included Common Silkpod (*Parsonsia straminea*), Lawyer Vine (*Smilax australis*), Sweet Morinda (*Morinda jasminoides*), White Supplejack (*Ripogonum album*) and Cockspur Thorn (*Maclura cochinchinensis*). Only Common Silkpod (ORA7) and Lawyer Vine (BUCCA1) occurred in southern Orara and the Bucca Creek site.

Bank condition was best at BUCCA1 with minimal bank undercutting or slumping (Table 3.39). In contrast, the downstream sites on the Orara River (ORA1-2) had poor bank condition due to extensive bank undercutting and slumping, and the presence of exposed tree roots (Table 3.39). The best habitat condition in the coastal tributaries subcatchment occurred at ORA2 (3.14/5.00) due to the presence of fallen trees (Table 3.39) while the worst habitat condition was found at ORA6 (1.71/5.00) due to the lack of trees, standing or fallen, alive or dead, and the abundance of organic litter derived from weeds (Table 3.39). All sites were relatively undisturbed in terms of stock access, the presence of fencing and the lack of tree clearing (Table 3.39).

Table 3.39 Site level summary of riparian condition scores for each sub-index for coastal tributaries of the Clarence River. Individual scores maximum of 5.

	BUCCA1	ORA2	ORA3	ORA4	ORA5	ORA6	ORA7	SPORT 2
Vegetation								
Large trees	3.30	1.00	1.33	1.33	2.87	2.27	2.70	1.00
Canopy Cover	1.00	2.00	3.00	3.00	3.00	4.00	3.00	3.67
Mid-storey Cover	4.33	3.67	2.33	4.33	3.00	4.33	5.00	5.00
Mid-storey Weeds	5.00	5.00	1.00	5.00	5.00	1.00	1.00	5.00
Grass Cover	2.33	1.33	1.33	1.00	2.00	1.00	1.33	1.67
Grass Weeds	5.00	5.00	5.00	5.00	3.67	2.33	3.67	5.00
Understorey Cover	4.33	3.67	3.67	3.67	5.00	3.67	5.00	3.67
Understorey Weeds	4.33	5.00	5.00	5.00	2.33	1.33	1.33	5.00
Vines	2.33	5.00	5.00	3.67	1.00	1.00	2.33	5.00
Vegetation Layers	3.33	4.00	4.00	4.67	2.67	3.00	3.33	4.33
Total/5	**3.53**	**3.57**	**3.17**	**3.67**	**3.05**	**2.39**	**2.87**	**3.93**
Bank Conditions								
Undercutting	4.00	1.00	1.00	3.00	1.00	2.00	2.00	1.00
Exposed Tree Roots	5.00	3.00	2.00	4.00	3.00	5.00	1.00	5.00
Slumping	4.00	1.00	1.00	2.00	4.00	4.00	5.00	2.00
Total/5	**4.33**	**1.67**	**1.33**	**3.00**	**2.67**	**3.67**	**2.67**	**2.67**
Habitat								
Standing Dead Trees	0.00	5.00	5.00	5.00	5.00	0.00	5.00	5.00
Logs	2.00	2.00	1.00	2.00	3.00	2.00	2.00	2.00
Fallen Trees	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00
Reeds	5.00	5.00	5.00	5.00	5.00	5.00	5.00	3.00
Large Trees	1.00	1.00	1.33	1.33	1.00	1.00	1.00	1.00
Organic Litter	1.33	1.00	1.33	4.33	1.33	3.00	2.33	3.33
Weed Litter	5.00	5.00	5.00	5.00	4.33	1.00	1.00	5.00
Total/5	**2.05**	**3.14**	**2.67**	**3.24**	**2.81**	**1.71**	**2.33**	**2.76**
Disturbance								
Tree Clearing	2.33	5.00	1.00	5.00	2.33	5.00	5.00	3.67
Fencing	5.00	5.00	5.00	5.00	5.00	5.00	5.00	3.67
Livestock	5.00	5.00	3.67	5.00	5.00	5.00	5.00	5.00
Total/5	**4.11**	**5.00**	**3.22**	**5.00**	**4.11**	**5.00**	**5.00**	**4.11**

Table 3.40 Dominant riparian vegetation for each stratum at northern Orara River sites (ORA2–4) and Sportman Creek (SPORT2). Emergents are large trees that rise above the tree canopy.

Vegetation Description	ORA2	ORA3	ORA4	SPORT2
Left/Right bank (facing downstream)	L	R	R	L
Community Description	Water Gum forest	Sparse River Oak, Flooded Gum, Red Gum forest	Flooded Gum moist open forest	River Oak with emergent Angophora spp., Rf midstorey
Emergents	No emergents	No emergents	*Eucalyptus grandis*	*Angophora bakeri*
Large Trees A	No large trees	*Eucalyptus tereticornis*	*Eucalyptus grandis*	*Angophora bakeri*
Large Trees B	No large trees	*Casuarina cunninghamiana*	*Eucalyptus grandis*	*Angophora subvelutina*
			Tristaniopsis laurina	*Casuarina cunninghamiana*
			Grevillea robusta	*Eucalyptus carnea*
Large Trees C	No large trees	*Eucalyptus grandis*	*Eucalyptus grandis*	No large trees
Mid-storey Cover (native)	*Tristaniopsis laurina*	*Acacia fimbriata*	*Backhousia myrtifolia*	*Acmena smithii*
	Callistemon viminalis	*Glochidion ferdinandi var. ferdinandi*		*Alphitonia excelsa*
	Syzygium smithii	*Backhousia myrtifolia*		*Allocasuarina littoralis*
		Pittosporum revolutum		*Duboisea myoporoides*
	Leptospermum brachyandrum	*Endiandra virens*		*Bursaria spinosa subsp. spinosa*
	Pittosporum revolutum			*Dodonaea triquetra*
Mid-storey Cover (weeds)	No midstorey weeds	*Cinnamomum camphora*	No midstorey weeds	No midstorey weeds
Grass Cover (native)	*Cynodon dactylon*	*Oplismenua imbecillis*	*Oplismenua imbecillis*	*Cynodon dactylon*
		Microlaena stipoides		*Imperata cylindrica*
Grass (weeds)	No grass weeds	No grass weeds	No grass weeds	No grass weeds
Understorey Cover	*Lomandra hystrix*	*Lomandra hystrix*	*Backhousia myrtifolia*	*Lomandra hystrix,*

(native)				
		Adianthum aethiopicum	*Adianthum aethiopicum*	*Acacia floribunda*
				Pteridium esculentum
				Lepironia articulata
Understorey Cover (weeds)	No understorey weeds	No understorey weeds	No understorey weeds	No understorey weeds
Organic Litter (natives)	*Tristaniopsis laurina*	Vines, eucalypts	Rf trees & vines	Native woody species
Organic Litter (weeds)				
Dominant Vines native)	*Morinda jasmiinoides*	*Maclura cochinchinensis*	*Smilax australis*	*Parsonsia straminea*
		Parsonsia straminea	*Morinda jasmiinoides*	*Stephania japonica* var. *discolor*
		Smilax australis	*Calystegia marginata*	
			Ripogonum album	

Table 3.41 Dominant riparian vegetation for each stratum at southern Orara River sites (ORA 5–7) and Bucca Creek (BUCCA1). Emergents are large trees that rise above the tree canopy.

Vegetation Description	ORA5	ORA6	ORA7	BUCCA1
Left/Right bank (facing downstream)	L	R	L	L
Community Description	River Oak with planted trees and shrubs	Camphor Laurel – River Oak forest	Camphor Laurel forest with Water Gum, River Oak	Water Gum with planted trees and shrubs
Emergents	No emergents	No emergents	No emergents	No emergents
Large Trees A	No large trees	*Cinnamomum camphora*	*Cinnamomum camphora*	No large trees
		Casuarina cunninghamiana	*Casuarina cunninghamiana*	
Large Trees B	*Casuarina cunninghamiana*	*Cinnamomum camphora*	*Tristaniopsis laurina*	No large trees
Large Trees C	No large trees	*Cinnamomum camphora*	*Cinnamomum camphora*	No large trees
Mid-storey Cover (native)	*Tristaniopsis laurina*	No native midstorey	*Pittosporum revolutum*	*Tristaniopsis laurina*
	Ficus coronata		*Ficus coronata*	*Ficus coronata*
	Aphananthe phillipensis		*Backhousia myrtifolia*	*Syzygium smithii*
			Glochidion ferdinandi var. ferdinandi	*Backhousia myrtifolia*
			Melicope micrococca	
Mid-storey Cover (weeds)	No midstorey weeds	*Ligustrum sinense*	*Ligustrum sinense*	No midstorey weeds
Grass Cover (native)	*Oplismenua imbecillis*	No native grasses	No native grasses	*Oplismenua imbecillis*
	Microlaena stipoides			*Microlaena stipoides*
Grass (weeds)	*Paspalum mandiocanum*	*Paspalum mandiocanum*	*Paspalum mandiocanum*	No grass weeds
Understorey Cover (native)	*Pteridium esculentum*	*Christella dentata*	*Lomandra hystrix*	*Lomandra hystrix*
	Persicaria hydropiper			*Persicaria strigosa*
				Dichondra repens

				Hypolepis muelleri
Understorey Cover (weeds)	*Tradescantia fluminensis*	*Ligustrum sinense*	*Ligustrum sinense*	*Tradescantia fluminensis*
	Ligustrum sinense	*Tradescantia fluminensis*	*Lantana camara*	
	Ageratum houstonianum			
Organic Litter (natives)				
Organic Litter (weeds)		*Cinnamomum camphora*	*Cinnamomum camphora*	
Dominant Vines native)			*Parsonsia straminea*	*Smilax australis*

3.5 Coastal systems separate to the Clarence

Overview

A number of Coastal systems outside the Clarence catchment were included to assess the condition of short but often highly utilised coastal rivers. These included Lake Arragan, Cakora Lagoon, Sandon and Wooli Rivers and Station Creek.

Condition grades were developed for these sites based only on water quality information, and not other indicators that were used throughout the Clarence catchment. Overall scores for these systems were very poor ranging from a grade of F at Lake Arragan and upper Station Creek, to a maximum grade of C- at Wooli.

Nitrogen and phosphorus concentrations were consistently above the guideline values for coastal rivers, often three times greater than the trigger values, particularly in Wooli River and Station Creek. This was reflected in very high algal concentrations in many rivers, with Station Creek recording concentrations over five times the trigger value.

A number of the rivers recorded very low pH values with Wooli River, Station Creek and Lake Cakora all having mean pH values that were acidic.

Turbidity was also very high in these rivers, consistently higher than trigger values for a change in ecosystem condition. Turbidity often mirrored the change in salinity with systems such as Lake Arragan ranging from 5% to 25% seawater throughout the study when sampled at the same mean high tide.

3.5.1 Water chemistry

3.5.1.1 *Chlorophyll a*

Chlorophyll *a* concentrations were very low at BROOM1 (site mean of 0.88 µg/L), SAND1 (0.54 µg/L) and SAND2 (0.33 µg/L), and WOOL3-2 (0.22 and 1.46 µg/L, respectively). Of these, only WOOL2 exceeded the estuarine trigger threshold of 3.3 µg/L once (in August 2012 with 3.86 µg/L). Although the site mean chl-*a* at ARRAG1 was 2.56 µg/L (Figure 3.39), it too exceeded the estuarine trigger threshold once (in October 2012 with 5.06 µg/L). Likewise, STAT1 had a site mean of 1.17 µg/L, but exceeded the estuarine trigger threshold once in October 2012 (with 3.08 µg/L). STAT2 also exceeded the estuarine trigger threshold once (again in October 2012), but high observed value of 17.60 µg/L skewed the site mean to 5.97 µg/L. In contrast, the estuarine trigger threshold was exceeded three times at WOOL1 (August 2012, April 2013 and August 2013), and the mean and range was 3.56 and 0.66 – 10.41 µg/L, respectively.

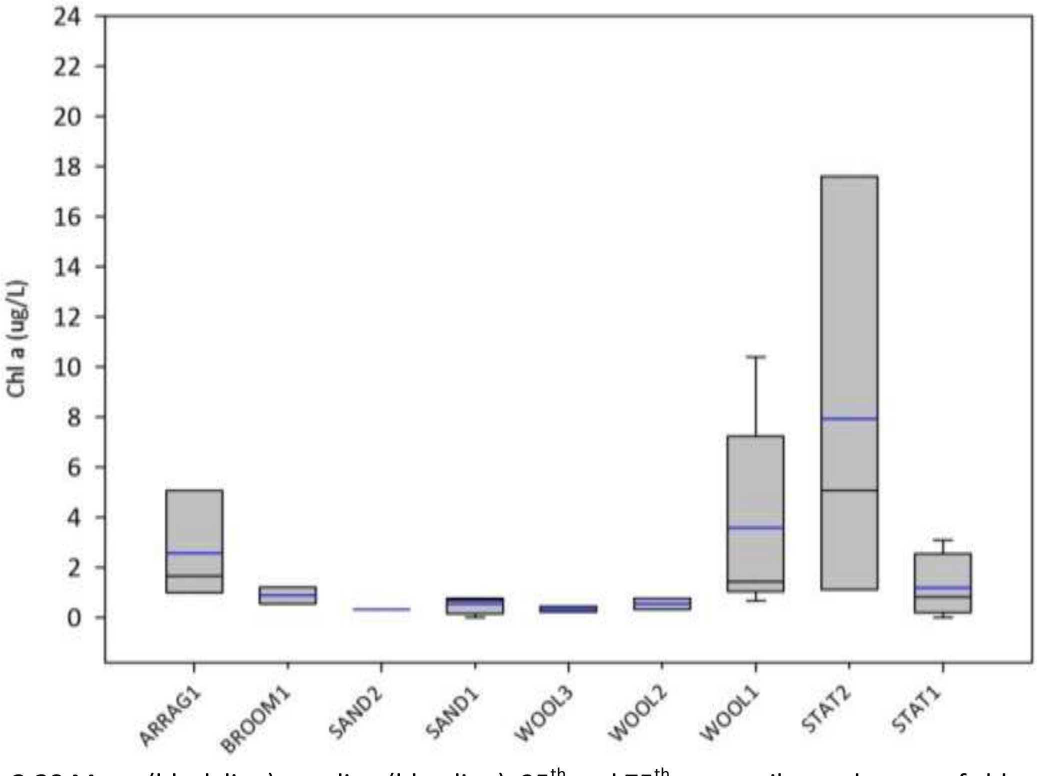


Figure 3.39 Mean (black line), median (blue line), 25th and 75th percentiles and range of chlorophyll *a* concentrations from sites in coastal systems that are separate to the Clarence from August 2012 to August 2013.

3.5.1.2 *Total Nitrogen (TN)*

All observed TN concentrations at ARRAG1 (site mean 848.225 mg/L), BROOM1 (727.649 mg/L), SAND2 (433.80 mg/L), and STAT2 (650.23 mg/L) exceeded the estuarine trigger threshold of 300 mg/L (Figure 3.40). At SAND1 (341.98 mg/L), the trigger threshold was exceeded for 50 % of the sampling periods. There was a slight longitudinal increase from WOOL3 to WOOL1 (site mean of 369.16 mg/L at WOOL3, 401.95 mg/L at WOOL2 and 421.92 mg/L at WOOL1 (Figure 3.40). TN concentrations exceeded estuarine trigger thresholds three times at WOOL1, and twice at WOOL2 and WOOL3 (representing 50 % of sampling periods for both sites). TN concentrations exceeded estuarine trigger thresholds three times at STAT1 which had a site mean of 556.57 mg/L.

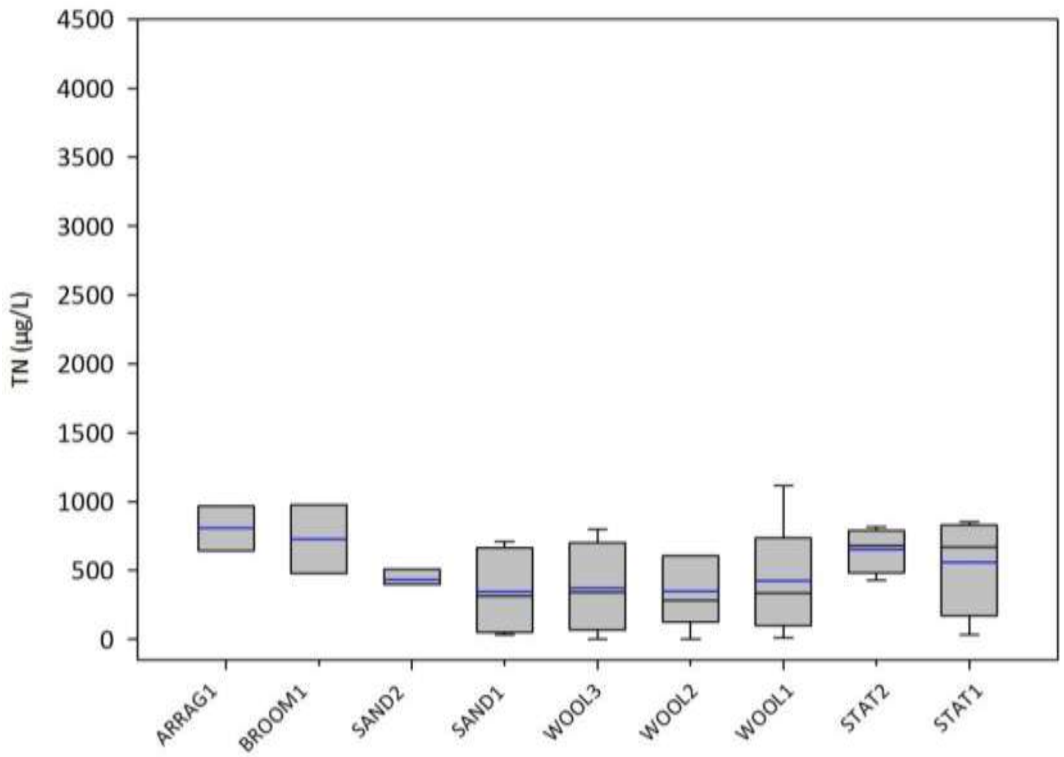


Figure 3.40 Mean (black line), median (blue line), 25th and 75th percentiles and range of TN concentrations from sites in coastal systems that are separate to the Clarence from August 2012 to August 2013.

3.5.1.3 *Bioavailable Nitrogen (NOx)*

Similar spatial and temporal patterns were observed for bioavailable nitrogen (NOx). Only SAND2 did not exceed the estuarine trigger threshold of 15 mg/L (Figure 3.41). The trigger threshold was exceeded between 50-100 % of sampling periods for all other sites in the separate coastal systems.

NOx concentrations were highest in WOOL1 (site mean of 108.06 mg/L), STAT 2 (153.56 mg/L) and STAT1 (111.10 mg/L)

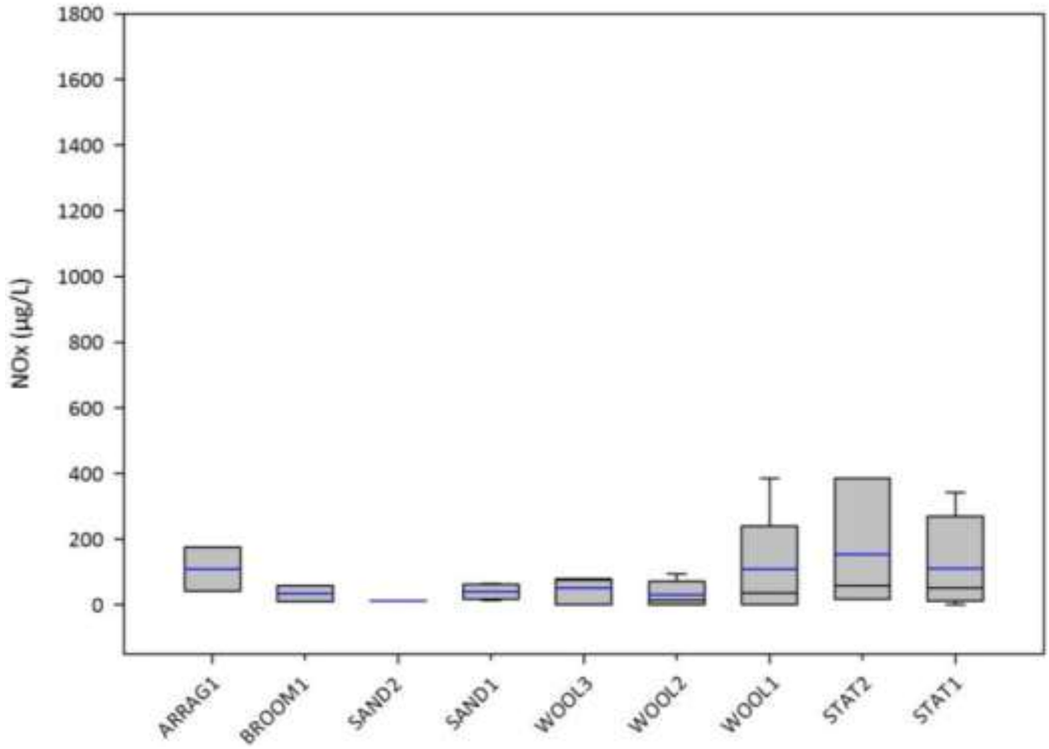


Figure 3.41 Mean (black line), median (blue line), 25th and 75th percentiles and range of NOx concentrations from sites in coastal systems that are separate to the Clarence from August 2012 to August 2013.

3.5.1.4 *Total Phosphorus (TP)*

Concentrations of TP were consistently low across all river systems except for Wooli Creek that exceeded the TP threshold between 33 and 50% of sample dates, generally in the low flow period of August to December 2012 (Figure 3.42). Concentrations in Wooli Creek ranged from 1.62 µg/L (WOOL1 October 2012) to 241.00 µg/L (WOOL3 August 2012).

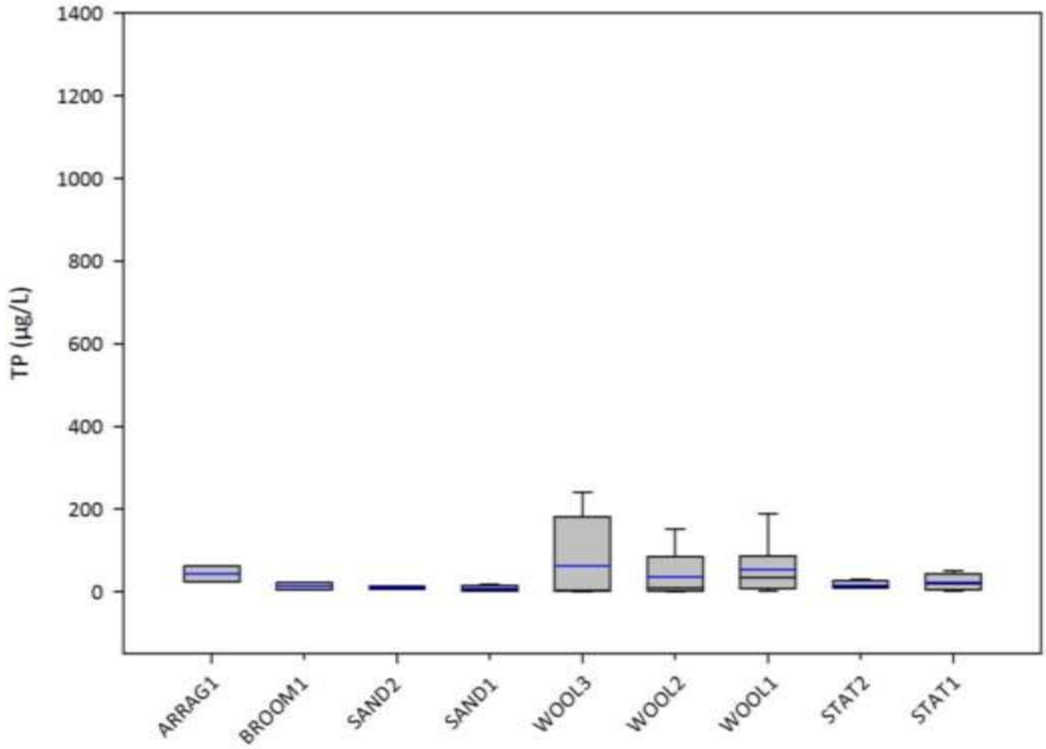


Figure 3.42 Mean (black line), median (blue line), 25th and 75th percentiles and range of TP concentrations from sites in coastal systems that are separate to the Clarence from August 2012 to August 2013.

3.5.1.5 *Soluble Reactive Phosphorus (SRP)*

Concentrations of SRP were highly variable throughout the study period, exceeding the trigger value between 33 and 100% of sample dates. Lake Arragan, Cakora Lagoon, Sandon River and the upstream sites on Station Creek exceeded the trigger value on all sample dates (Figure 3.43). The highest recorded value of 48.53 µg/L at STAT1 in December 2012 is almost 10 times the trigger value for coastal lagoons. A longitudinal trend of increasing SRP with distance downstream was evident in Wooli Creek, ranging from a mean of 7.12 µg/L at WOOL3 to 13.89 µg/L at WOOL3.

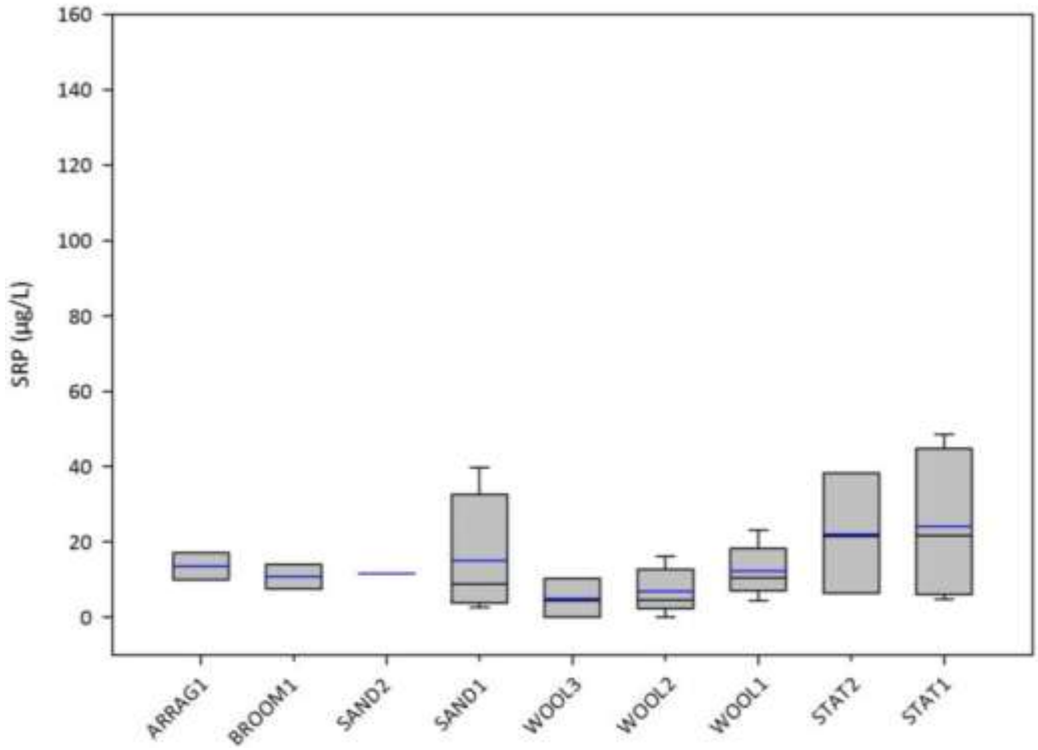


Figure 3.43 Mean (black line), median (blue line), 25th and 75th percentiles and range of SRP concentrations from sites in coastal systems that are separate to the Clarence from August 2012 to August 2013.

3.5.1.6 *Dissolved Oxygen (DO)*

DO % saturation was not measured in any of the coastal systems. This was because none of the agencies who sampled these systems had a probe that could measure DO % saturation.

3.5.1.7 *pH*

Mean site pH at ARRAG was 7.81 (Figure 3.44). The lower estuarine trigger threshold of 7.0 was exceeded once in September 2013 (pH of 6.95). The site mean pH at Brooms Head was 7.32 (Figure 3.44). While pH varied significantly at BROOM1, it only fell below the lower estuarine trigger threshold once, in May 2013 (pH of 5.88). The site mean pH at SAND1 was 7.85 and there was little variability at the site level (Figure 3.44). pH remained within the estuarine trigger threshold for the duration of the sampling period. In the Wooli River, pH increase longitudinally downstream (Figure 3.44). Site means were 7.21 at WOOL3, 7.35 at WOOL2 and 8.40 at WOOL1. Although the estuarine trigger thresholds were exceeded at all sites, the patterns of exceedance follow the general trend. At WOOL3, pH fell below the lower estuarine trigger threshold twice (in August – October 2012, pH of 6.99 and 6.90, respectively). At WOOL2, pH fell below the lower estuarine trigger thresholds once in

December 2012 (pH of 6.59). But, at WOOL1, observed values exceeded the upper estuarine trigger threshold twice (in April and August 2013, with pH 9.18 and 8.91, respectively). pH was lower at the downstream site STAT1 (site mean of 6.95) than the upstream site STAT2 (site mean of 7.39, Figure 3.44). However, both sites exceeded the estuarine trigger threshold. At STAT1, the lower trigger threshold was exceeded twice (in April and August 2013 with 5.63 and 6.66, respectively). However, at STAT2, the lower trigger threshold was exceeded once in August 2013 (6.27 pH) and the upper trigger threshold was exceeded once in August 2012 (8.14 pH).

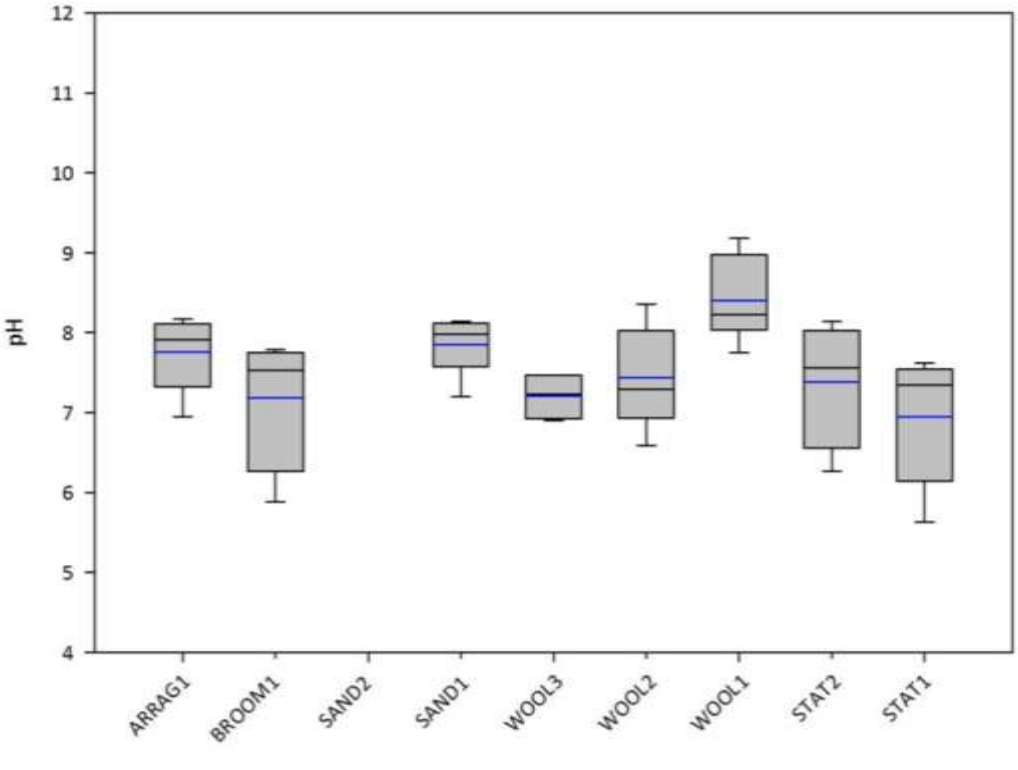


Figure 3.44 Mean (black line), median (blue line), 25th and 75th percentiles and range of pH from sites in coastal systems that are separate to the Clarence from August 2012 to August 2013.

3.5.1.8 *Turbidity*

Turbidity increased longitudinally downstream in the Wooli River and Station Creek (Figure 3.45). In the Wooli River, site means were 7.16 NTU at WOOL3, 16.47 NTU at WOOL2 and 37.00 NTU at WOOL1. The estuarine trigger threshold of 10 NTU was exceeded once at WOOL3 (October 2012), three times at WOOL2 (December 2012 to June 2013), and on all sampling occasions at WOOL1. Likewise, the site mean was 16.35 NTU at the upstream site on Station Creek STAT2, and 35.09 NTU at the downstream site STAT1. The estuarine trigger threshold was exceeded three times at STAT2

(August – October 2012 and August 2013) and four times at STAT1 (only December 2012 was below the threshold).

Mean site turbidity at SAND1 on the Sandon River was 3.58 and did not exceed the estuarine trigger threshold at any sampling period. In contrast, the mean site turbidity at Brooms Head was 27.55 NTU (Figure 3.45) and exceeded the estuarine trigger threshold twice (in May and September 2013). Mean site turbidity in Lake Arragan was 11.72 NTU and measured turbidity exceeded the estuarine trigger threshold three times (December 2012 – September 2013).

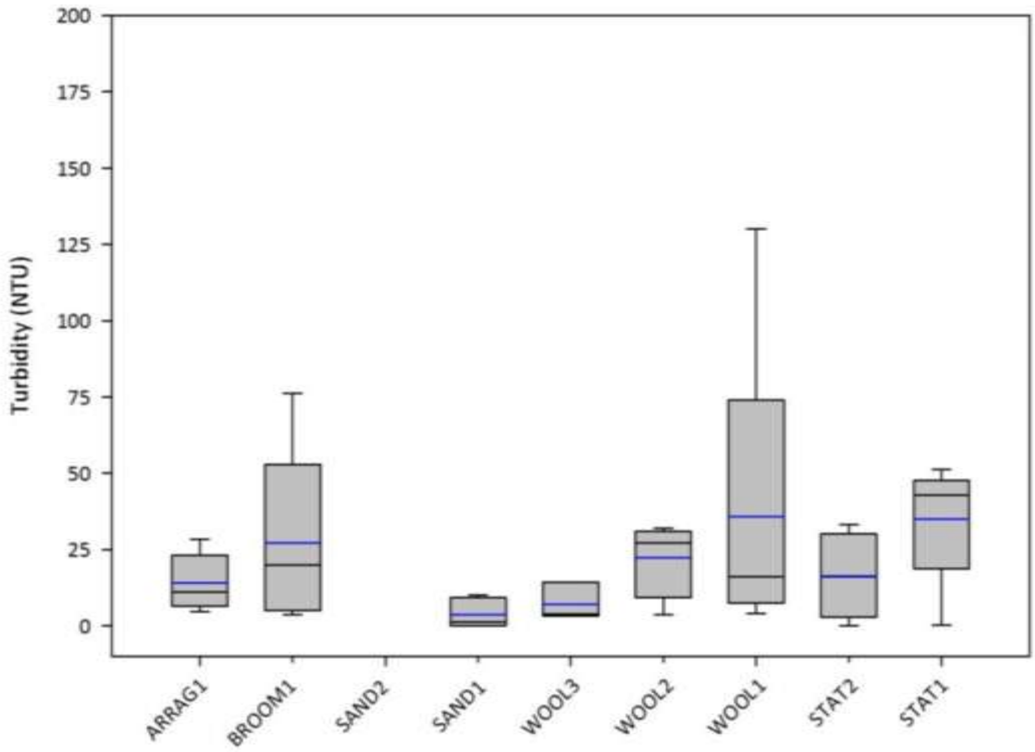


Figure 3.45 Mean (black line), median (blue line), 25th and 75th percentiles and range of turbidity from sites in coastal systems that are separate to the Clarence from August 2012 to August 2013.

3.5.1.9 *Water chemistry variables*

Table 3.42 provides the ranges of water temperature, EC, salinity, Secchi depth and TSS concentrations for the coastal systems separate to the Clarence River. EC and salinity varied from freshwater in the upstream site of Station Creek (STAT2), to marine at WOOL2 and BROOM1. The upstream sites on the Wooli River (WOOL3) and Station Creek (STAT2) had very small Secchi depths (0.30 and 0.20 m, respectively). TSS concentrations were highly variable in these systems, ranging from <0.001 mg/L in the Wooli River to 27.60mg/L in the Wooli River and 32.87 mg/L in Lake Arragan (Table 3.42).

Table 3.42 Range of water chemistry variables at sites in the coastal systems that are separate to the Clarence River.

Site	Water temp (°C)	Conductivity (mS/cm)	Salinity (ppt)	Secchi depth (m)	TSS (mg/L)
ARRAG1	19.7 - 26.2	1.571 - 6.044	8.29 - 30.24		5.62 - 32.87
BROOM1	21.4 - 25.7	1.597 - 6.677	7.99 - 33.52		1.73 - 24.74
SAND2					
SAND1	20.0 - 23.9	2.064 - 2.426	10.25 - 12.13	2.50 - 2.50	2.23 - 13.71
WOOL3	9.5 - 19.3	0.705 - 2.640	3.54 - 13.58	0.10 - 0.30	0.00 - 27.60
WOOL2	18.9 - 24.6	1.886 - 5.562	8.36 - 36.28	0.30 - 1.00	0.00 - 5.63
WOOL1	14.5 - 25.0	1.380 - 4.830		0.30 - 1.30	0.00 - 25.80
STAT2	18.4 - 26.8	0.433 - 1.057	0.21 - 0.48	0.10 - 0.20	2.80 - 20.90
STAT1	18.2 - 26.2	1.636 - 2.236	8.03 - 10.96		4.39 - 16.31

PART 4

4 ECOHEALTH REPORT CARDS

The calculation and reporting of Ecohealth grades involves the synthesis all available indicators each with trigger values recorded up to 6 times during the program. Scores are calculated for individual sites, but also must fulfill the broader aims of wider-scale reporting at river, sub-catchment, catchment and regional scales. To produce an Ecohealth grade, the value for each index – Water Quality, Zooplankton, Macroinvertebrates, Fish and Riparian – must be transformed into standardized score that takes into account differing physical conditions, scales of measurement among indices and prevailing climate conditions. The result is a scoring system from 0 to 1, where 0 represents the most 'unhealthy' condition and 1 indicates a 'healthy' waterway.

4.1 Indicators

4.1.1 Water Quality

A trigger value is formally the value that compliance against a guideline value is commonly used to assess the ecological condition of a waterbody 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 4.1). For water quality variables with only upper limits for trigger values, the number of times each indicator recorded a value between 1-1.5 times, and greater than 1.5 times each collection was used to examine changes in water quality. Exceedance of trigger values by less than 0.5 times or between 1-1.5 times, and greater than 1.5 times each collection was used for variables that have both upper and lower thresholds.

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.

Table 4.1 ANZECC water quality guidelines for freshwater (above and below 150m elevation) and estuarine systems of south-east Australia. * Revised trigger values for reference condition coastal systems were used.

ANZECC Guidelines (2000) and NSW MER - Min. and Max Values									
	pH	DO %	EC µS/cm	Turbidity NTU	Chl *a* µg/L	NOx* µg/L	SRP* µg/L	TN* µg/L	TP* µg/L
Freshwater sites >150m	6.5 - 7.5	80 - 110	30 - 350	25	4	25	15	250	20
Freshwater sites <150m	6.5 – 8.0	80 - 110	125 - 2200	50	4	40	20	500	50
Estuary sites	7.0 – 8.5	80 - 110	No values	10	3.3	15	5	300	30

4.1.2 Zooplankton

Two indices of water quality were developed from the zooplankton size data (see Suthers et al. 2012). Firstly the slope of the NBSS (from the least-squares regression) was used as an index of zooplankton production (Zhou & Huntly 1997). The theoretical slope is around -1 and is observed in clear tropical waters (Suthers et al. 2006), but steeper slopes up to -2.5 are apparent in estuaries (Moore & Suthers 2006). Steeper slopes indicate greater predation and transfer to large size categories, and is an index of production. The slopes were therefore assigned scores from 1 to 5 where a shallow slope of <-0.75 was scored as "very poor", as such a slope indicates a low rate of biomass transfer to higher trophic levels and ultimately fish. A typical slope of -1 to -1.25 was scored as "fair", and a slope steeper than -1.75 (i.e. more negative) was scored as "very good". The score ranging from 0 to 5 was then converted to a score ranging from 0 to 1 through simple division.

Secondly the concentration of chlorophyll-a relative to zooplankton was used as an index of assimilation of nutrient input. If zooplankton is not grazing the phytoplankton, then eutrophication becomes apparent. In this study, environmental assimilation of chlorophyll-a was indexed by a ratio of chlorophyll to the normalised biomass of small zooplankton, estimated from the NBSS regression at a size of x=-1.5. This size is approximately 0.4 mm ESD (equivalent spherical diameter) which approximates the biomass of nauplii, copepodites and cyclopoid copepods. A larger ratio indicates excess phytoplankton relative to zooplankton, indicating that zooplankton are not responding to the nutrient supply. Scores were assigned as a low ratio of <0.5 as "very good - 5", while a ratio of 1.5 to 3 was scored as "fair – 2 to 4" and a ratio >5 was scored as "very poor - 1". The score ranging from 0 to 5 was then standardised to a score ranging from 0 to 1 through simple division.

Scores for each index were calculated for each sample collection date. Each index was standardized to a score ranging from 0 to 1, and standardised to an overall Zooplankton score ranging from 0 to 1 through simple division. Sores provided in Suthers et al (2014) are composited among 5 sites, so no scores for individual sites are available.

4.1.3 Macroinvertebrates

Regional trigger values must be developed from literature and past studies for taxa richness (number of families), SIGNAL2 Score (pollution tolerance index), 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, SIGNAL2 and EPT score. 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 macroinvertebrate attribute against corresponding guideline value and WEV scenario.

4.1.4 Fish

Reference condition estimates (Reference Condition for Fish (RC-F)) for fish community is derived using similar protocols as applied in the Sustainable Rivers Audit (SRA) Program. The process involves estimating the presence/absence and rarity (the probability of collecting a species at a selected site if it were sampled using the standard protocol prior to 1770) for each fish species within each valley and altitude zone based on historical and current data, reference material, museum collections and expert knowledge (Davies et al. 2008) Rarity was scored as: 0.05 (estuarine/marine vagrants = low probability of occurrence), 1 (rare = median probability of occurrence of 0.1), 3 (occasional = 0.45) or 5 (common = 0.85). The score ranging from 0 to 5 was then standardised to a score ranging from 0 to 1 through simple division.

The Expectedness Indicator (SR-FIe) represents the proportion of native species that historically occupied the river that are still present and is calculated by combining two input metrics; the observed native species richness (at sites) over the zones RC-F value corrected for rarity (OE) and the total native species richness within zones over the zones uncorrected RC-F (OP) using Expectedness Indicator Expert Rules (Davies et al. 2008). The Nativeness Indicator (SR-FIn) represents the proportion of native versus alien fishes within the river and is calculated from three input metrics;

proportion native biomass, proportion native abundance and proportion native species, combined using Nativeness Indicator Expert Rules (Davies et al. 2008). The Recruitment Indicator represents the three indicators and are combined using Index Expert Rules (Davies et al. 2008) to calculate an overall Fish Condition Index (SR-FI). Expert Rules analysis was undertaken using the Fuzzy Logic toolbox in MatLab (The Mathworks Inc. USA). Sites were rated individually for each of the four Indicators and scored as either “Excellent” (81-100), “Good” (61-80), “Moderate” (41-60), “Poor” (21-40), or “Very Poor” (0-20). The score ranging from 0 to 100 was then standardised to a score ranging from 0 to 1 through simple division.

All indices were afforded equal weighting in the calculation of the Ecohealth grade, with the 3 scores standardised to a score ranging from 0 to 1 through simple division. A detailed report on sites, methods and calculations is available in Butler et al. (2013).

4.1.5 Riparian Condition

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 pristine condition. The scores recorded in the field were combined to produce summary scores for each sub-index and an overall condition index. Indicators that were assessed at three points along the transect require averaging to give only one number for each indicator; those recorded at the transect level will have only one value for each site. The indicators are then grouped into the four sub-indices and summary scores for each grouping are calculated through simple averaging to produce a condition score out of 5 for each sub-index (i.e. riparian condition, bank condition, habitat and disturbance). These scores are then summed to a total score out of 20, and through simple division are standardised to a score ranging from 0 to 1.

4.2 Spatial Scales

The above process provides the methods for calculating standardized scores for each indicator 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 indicators used. The scores can then be ‘pooled’ at spatial scales relevant to reporting requirements such as site, river/lagoon, sub-catchment, freshwater or estuarine, catchment and region.

4.3 Calculating grades

The condition scores were grouped in ranges and given a corresponding grade (see Table 4.2). 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 E. Secondary grades of + and – are included to provide greater resolution within a grade, and to better help show improvements over time.

Table 4.2 Standardised scores from 0 to 1 and corresponding Ecohealth grade

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	E	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)

4.4 Clarence Catchment Ecohealth Grades

4.4.1 Catchment Scale

A Total of 88 sites in 37 individual river systems in the Clarence catchment were used to calculate an overall score of 70.5 (C+) for the catchment (Table 4.3). Average scores for water quality, aquatic macroinvertebrates and riparian systems were consistently in a range from 60-66. A much higher average score of 91.5 for Fish improved the overall catchment score, suggesting that lower scores for other attributes in freshwater reaches are not adversely impacting native fish populations.

4.4.2 River System Scale

The scores for all 7 main river systems range only 13.5%, from 60.5 (C-) for coastal tributaries to 74 (C+) for the Mann-Nymboida-Boyd system (Table 4.4). Excellent scores (>90) for fish assemblages were recorded from all systems except the Mann-Nymboida-Boyd which received 82.5, and contributed positively to the overall condition score. In contrast, Riparian and Macroinvertebrate grades were consistently low, with Coastal tributaries scoring just 33 and the only system reporting an E grade. Unsurprisingly, the freshwater reaches of the Clarence catchment consistently recorded higher scores for all indicators when compared with the estuary reaches and coastal lagoons.

Table 4.3 Ecohealth scores and grades for the Clarence catchment calculated as an average of 90 individual site scores.

	WQ Score	WQ Grade	Bug Score	Bug Grade	Fish Score	Fish Grade	Plankton Score	Plankton Grade	Riparian Score	Riparian Grade	Overall Catchment Score	Overall Catchment Grade
Clarence	66	C	65	C	91.5	A-			60	C-	70.5	C+

Table 4.4 Ecohealth scores and grades for the major river systems in the Clarence catchment calculated as an average of individual site scores.

	WQ Score	WQ Grade	Bug Score	Bug Grade	Fish Score	Fish Grade	Plankton Score	Plankton Grade	Riparian Score	Riparian Grade	Overall Catchment Score	Overall Catchment Grade
Clarence Main Stem	65	C	58	D+	95.5	A	80	B	58	D+	71.5	C+
Clarence Freshwater sites	69	C+	59	D+	95.5	A			56	D+	70	C+
Clarence Estuary sites	53	D					80	B	52	D	62	C-
Coastal tributaries	54	D	33	F	95	A			74	C+	60.5	C-
Mann-Nymboida-Boyd main stem	69	C	73	C+	90.5	A-			58	D+	74	C+
Mann-Nymboida-Boyd tributaries	71	C+	71	C+	82.5	B			56	D+	69	C
Northern tributaries	70	C+	62	C-	92.5	A-			59	D+	67	C

4.4.3 Individual River systems

Following the longitudinal pattern displayed in the main stem of the Clarence, the Marylands River at the top of the Clarence catchment recorded a higher overall grade of 70 (C+) compared with the Clarence (64, C) (Table 4.5). However, only the water quality and riparian indicators in the Marylands were higher than in the Clarence.

Coastal tributaries recorded some of the lowest condition scores in the Clarence system, with consistently poor water quality and riparian condition (Table 4.5). Outliers included the Esk River that recorded the highest riparian and water quality scores based on its location in Bundjalung National Park. The Orara River also recorded riparian and water quality scores higher than other coastal rivers, with the mid-reaches of the river contributing to improved scores.

At the other end of the spectrum are Shark and Swan Creeks, both of which had consistently poor water quality (pH, nutrients and algal blooms) and riparian vegetation that was largely absent, leading to overall scores of 45 (D-) for Shark Creek and 39.5 (E) for Swan Creek (Table 4.5). Swan Creek was the only individual river to record a fail grade in the Clarence catchment.

The Mann-Nymboida-Boyd river systems recorded the highest overall score of 74 in the Clarence catchment (Table 4.5). Of these, the Boyd and Nymboida recorded the highest river system scores of 76 (B-) and 75.5 (B-) respectively. The score for the Mann River was lower at 70 (C+), but included sites on the New England Tablelands that were in poor condition and lowered the average grade for the river. Ten tributaries of these systems were sampled with those in forested catchments such as the Little Nymboida and Clouds Creek recording the highest grades of B-. At the other end of the condition spectrum, the westerly Sara and Aberfoyle Rivers in highly disturbed landscapes recorded the lowest scores (D+). Riparian vegetation at these sites was often absent and river channels highly eroded, contributing to poor water quality.

The tributaries in the north and north-east of the Clarence catchment varied widely in their condition scores, from 57 for Koreelah Creek to 76 for the Boonoo Boonoo River that benefits from sites located in conservation reserves (Table 4.6). Water quality was consistently good in these rivers, but was not translated to good macroinvertebrate scores, suggesting habitat and channel condition may be contributing to lower scores. This is supported by consistently low riparian condition scores throughout this region.

Five coastal rivers in the Clarence LGA but not in the Clarence catchment were assessed in this study based only on water quality, and revealed consistent poor condition (Table 4.6). Scores ranged from 38 (E) for Lake Arragan with poor water quality (high nitrogen, chlorophyll *a* and turbidity) to 66 (C-) for Sandon River.

Table 4.5 Ecohealth scores and grades for individual river systems in the Clarence catchment calculated as an average of individual site scores.

RIVER	WQ Score	WQ Grade	Bug Score	Bug Grade	Fish Score	Fish Grade	Plankton Score	Plankton Grade	Riparian Score	Riparian Grade	Overall River Score	Overall River Grade
Clarence Main Stem												
Clarence RIver	58	D+	60	C-	98	A	80	B	52	D	64	C
Marylands RIver	72	C+	55	D+	89	B+			64	C-	70	C+
Coastal Tributaries												
Esk River	77	B-							96	A	86.5	B+
Mangrove Creek	63	C-							73	C+	68	C+
Shark Creek	47	D-							43	F	45	D-
Swan Creek	44	F							35	F	39.5	F
Sportsmans Creek	62	C-	26	F					56	D+	59	D+
Coldstream RIver	50	D							53	D	51.5	D
Orara RIver	70	C+	59	D+	95	A			68	C	76.5	B-
Mann-Nymb-Boyd												
Mann RIver	66	C	70	C	87.5	B+			58	D+	70	C+
Nymboida RIver	73	C+	68.9	C+	91.5	A-			66.2	C+	75.5	B-
Boyd RIver	69	C	78	B-	93	A-			60	C-	76	C
Little Nymboida RIver	69	C	69	C	96	A			73	C+	78	B-
Bielsdown RIver	69	C	69	C	89.5	B+			58	D+	71.5	C+
Blicks RIver	71	C+	71	C+	93	A-			50	D	71.5	C+
Clouds Creek	80	B	80	B-					76	B-	78.5	B-
Little Murray RIver	76	B-	76	B-	89.5	B+			55	D+	72.5	C+
Wild Cattle Creek	77	B-	77	B-					70	C+	74.5	C+
Sara RIver	63	C-	63	C-					44	F	56.5	D+
Aberfoyle RIver	58	D+	58	D+	85.5	B+			35	F	59	D+
Guyfawkes RIver	77	B-	77	B-	41	F			63	C-	64.5	C-
Henry RIver	68	C	68	C					55	D+	63.5	C-

Table 4.6 Ecohealth scores and grades for individual river systems in the Clarence catchment calculated as an average of individual site scores.

RIVER	WQ Score	WQ Grade	Bug Score	Bug Grade	Fish Score	Fish Grade	Riparian Score	Riparian Grade	Overall River Score	Overall River Grade
Northern Tributaries										
Cataract RIver	67	C	67	C	92.5	A-	51	D	69	C
Boonoo Boonoo	73	C+	71.5	C	97	A	59	D+	75	B-
Bookookoorara	74	C+	48	D-			72	C+	64	C-
Timbarra	75	B-	64	C-	90.5	A-	58	D+	71.5	C+
Duck	72	C+	55	D-			53	D	60	C-
Koreelah	63	C-	55	D+			54	D	57	D+
Tooloom	65	C	62	C-	89	B+	49	D-	66.5	C
Tabulam	72	C+	73	C+			76	B-	73.5	C+
Peacock	69	C	69	C			56	D+	64.5	C-
Coastal Systems										
All Coastal systems	52	D							52	D
Lake Arragan	38	F							38	F
Wooli	63	C-							63	C-
Sandon	66	C							66	C
Station	43	F							43	E
Cakora Lagoon	52	D							52	D

4.4.4 Individual Site Scores

A total of 81 sites in 32 individual river systems in the Clarence catchment, plus 7 sites in 5 coastal river catchments within the Clarence LGA were assessed for condition using water quality at all sites, aquatic macroinvertebrates at freshwater sites, riparian condition at all Clarence catchment sites, fish in a subset of Clarence catchment sites, and zooplankton at a subset of Clarence estuary sites.

The condition of sites along the Clarence River follows a longitudinal pattern seen in other NSW coastal rivers (Table 4.7). Upper reaches and sites immediately adjacent to the estuary mouth that are well-flushed by tides have the highest condition scores. Sites in floodplain reaches and approaching the tidal limit are in the poorest condition. The Orara River does not follow this pattern, with consistent condition scores throughout the length of the river (Table 4.8). The exception is a lower grade at ORA3 associated with the sediment slug moving through the system.

Longitudinal patterns of condition in the Mann River system show improving condition with distance downstream with the poor condition of tablelands sites driving the pattern (Table 4.9). Conversely, the Nymboida River system has higher condition scores in sites in the upper forested catchments, with lower condition scores at downstream reaches influenced by clearing and altered hydrology from Nymboida Weir.

In the Northern tributaries, there were no consistent longitudinal patterns in condition among rivers (Table 4.10). Cataract and Boonoo Boonoo Rivers had improved condition in lower reaches, Timbarra River had decreasing condition with distance downstream, and Tooloom Creek had the highest condition score in the mid-reaches. This suggests that condition in these rivers is influenced mostly by local influences.

Each of the major river systems had sites with good to very good condition. In the main stem of the Clarence, CR13 upstream of the gorge scored 76, Coastal tributaries had limited sites with good condition with the Esk River scoring the highest of all sites at 86.5, Nymboida River NYMB4 and 5 in conservation reserves each scored 79.5 and the nearby Blicks River 1 scored 82.5. Boonoo Boonoo River Site 3 had the highest score of the northern tributaries of 77. Coastal systems not in the Clarence catchment generally scored poorly, with the maximum score at Sandon River Site 1 at 71 (Table 4.11).

At the opposite end of the grades, all of the major river systems also had sites that were in poor and very poor condition. In the main stem of the Clarence, CR8 at the tidal limit scored 54.5, Coastal tributaries had multiple sites in poor condition with Swan Creek Site 1 the lowest in the catchment at 39.5, and the Aberfoyle River Site 1 scored the lowest in the Mann-Nymboida-Boyd system with a score of 63.5. Koreelah Creek Site 1 had the lowest score of the northern tributaries of 52.5. Coastal systems not in the Clarence catchment generally scored poorly, with the lowest score at Station Creek Site 1 of just 38.

Table 4.7 Ecohealth scores and grades for individual sites on the main stem of the Clarence and Marylands Rivers.

CLARENCE	Site Code	WQ Score	WQ Grade	Bug Score	Bug Grade	Fish/*plankton* Score	Fish/*plankton* Grade	Riparian Score	Riparian Grade	Overall Site Score	Overall Site Grade
Clarence	CR1	55	D+			80	B	82	B	72.5	C+
Clarence	CR2	57	D+			80	B	44	F	60.5	C-
Clarence	CR3	61	C-			80	B	38	F	59.5	D+
Wooloweyah	WOOL1	72	C+					58	D+	65	C
Clarence	CR4	52	D			80	B	48	D-	60	C-
Clarence	CR5	46	D-			80	B	42	F	56	D+
Clarence	CR6	48	D-			80	B	45	D-	57.5	D+
Clarence	CR7	58	D+			80	B	41	E	59.5	D+
The Broadwater	BW1	44	F					83	B	63.5	C-
Clarence	CR8	45	D-			80	B	38	F	54.5	D
Clarence	CR9	51	D			80	B	44	F	58.5	D+
Clarence	CR10	64	C-			80	B	45	D-	63	C-
Clarence	CR11	57	D+			95.5	A	63	C-	72	C+
Clarence	CR12	65	C	36	F	95.5	A	47	D-	61	C-
Clarence	CR13	72	C+	70	C	99.5	A	64	C-	76	B-
Clarence	CR14	70	C+	75	C+	98.5	A	44	F	72	C-
Clarence	CR15	68	C	60	C-	99.5	A	54	D	70.5	C-
Clarence	CR16	66	C	61	C-	99	A	50	D-	69	C
Marylands	MARY1	67	C	54	D	84.5	B	58	D+	66	C
Marylands	MARY2	78	B-	56	D+	93	A-	69	C	74.0	C+

Table 4.8 Ecohealth scores and grades for individual sites within Coastal Tributaries of the Clarence River.

COASTAL TRIBUTARIES	Site Code	WQ Score	WQ Grade	Bug Score	Bug Grade	Fish Score	Fish Grade	Riparian Score	Riparian Grade	Overall Site Score	Overall Site Grade
Esk	ESK1	77	B					96	A	86.5	B+
Mangrove Creek	MANG1	63	C-					73	B-	68	C
Shark Creek	SHARK1	47	D-					43	F	45	D-
Swan Creek	SWAN1	44	F					35	F	39.5	F
Sportsmans Creek	SPORT1	45	D-					38	F	41.5	F
Sportsmans	SPORT2	78	B-	11	F			73	C+	54	D
Coldstream	COLD1	37	F					35	F	36	F
Coldstream	COLD2	42	F					45	D-	43.5	F
Coldstream	COLD3	69	C					77	B-	73	C+
Orara	ORA1	57	D+			95.5	A	85	B+	79.5	B-
Orara	ORA2	77	B-	64	C-	88.5	B+	87	B+	79	B-
Orara	ORA3	81	B-	21	F	89.5	B+	67	C	64.5	C-
Orara	ORA4	82	B-	61	C-	91.5	A-	85	B+	80	B
Orara	ORA5	71	C+	66	C+	99.5	A	64	C-	75	B-
Orara	ORA6	67	C	90	A-	99.5	A	56	D+	78	B-
Orara	ORA7	65	C	89	A-	99.5	A	62	C-	79	B-
Bucca Bucca Ck	BUCCA1	57	D+	63	C-			75	B-	65	C-

Table 4.9 Ecohealth scores and grades for individual sites within the Mann-Nymboida-Boyd tributaries of the Clarence River.

MANN-NYMBOIDA-BOYD	Site Code	WQ Score	WQ Grade	Bug Score	Bug Grade	Fish Score	Fish Grade	Riparian Score	Riparian Grade	Overall Site Score	Overall Site Grade
Mann	MANN1	70	C+	85	B	98.5	A	57	D	77.5	B-
Mann	MANN2	66	C	67	C	88	B+	50	D-	67.5	C
Mann	MANN3	63	C-	51	D	74	C+	72	C+	65	C
Mann	MANN4	63	C-	77	B-	89	B+	51	D	70	C+
Nymboida	NYMB1	77	B-	64	C-	95	A	60	C-	74	C+
Nymboida	NYMB2	78	B-	60	D	96.5	A	54	D	72	C+
Nymboida	NYMB3	69	C	69	C	95.5	A	57	D+	71.5	C+
Nymboida	NYMB4	76	B-	67	C	85.5	B+	90	A-	79.5	B-
Nymboida	NYMB5	70	C+	82	B	81.5	B-	83	B	79.5	B-
Nymboida	NYMB6	69	C	71	C+	96	A	63	C-	75	C+
Boyd River	BOYD1	72	C+	82	B	93	B+	55	D+	76.5	B-
Boyd River	BOYD2	67	C	75	B-	93	A-	65	C	75	B-
Little Nymboioda	LNYMB1	69	C	73	C+	96	A	73	C+	77.5	B-
Bielsdown	BIELS1	69	C	79	B-	89.5	B+	43	F	75	B-
Blicks River	BLICKS1	75	B-	81	B-	93	A-	62	C-	82.5	B
Blicks River	BLICKS2	67	C	88	B+			37	F	64	C-
Clouds Creek	CLOUD1	80	B	71	C+			76	B-	75.5	B-
Little Murray	LMUR1	76	B-	71	C+	89.5	B+	55	D+	75	B-
Wild cattle Creek	WILDCAT1	77	B-	66	C			70	C+	71	C+
Sara	SARA1	67	C	67	C			37	F	57.5	D
Sara	SARA2	58	D+	77	B-			44	F	58	D+
Aberfoyle River	ABER1	58	D+	75	B-	85	B+	35	F	63.5	C-
Guy Fawkes River	GUYFAW1	77	B-	76	B-	41	F	63	C-	64.5	C-
Henry River	HENRY1	68	C	80	B			55	D+	67.5	C+

Table 4.10 Ecohealth scores and grades for individual sites within Northern Tributaries of the Clarence River.

NORTHERN TRIBUTARIES	Site Code	WQ Score	WQ Grade	Bug Score	Bug Grade	Fish Score	Fish Grade	Riparian Score	Riparian Grade	Overall Site Score	Overall Site Grade
Cataract River	CAT1	74	C+	65	C	96.5	A	50	D	71.5	C+
Cataract River	CAT2	70	C+	74	C+	89.5	B+	63	C-	74	C+
Cataract River	CAT3	56	D+	60	C-	91.5	A-	40	F	62	C-
Boonoo Boonoo	BOO1	65	C	82	B	96.5	A	43	F	71.5	C+
Boonoo Boonoo	BOO2	76	B-	62	C-	96	A	72	C+	76.5	B-
Boonoo Boonoo	BOO3	78	B-	71	C+	98.5	A	62	C-	77.5	B-
Bookookoorara	BOOKOOK1	72	C+	38	F			79	B-	63	C-
Bookookoorara	BOOKOOK2	75	B-	57	D+			64	C	65.5	C
Timbarra (Rocky) River	TIMB1	67	C	59	D+	89.5	B+	47	D-	65.5	C
Timbarra (Rocky) River	TIMB2	76	B-	63	C-	95.5	A	64	C-	74.5	C+
Timbarra	TIMB3	81	B	70	C+	85.5	B+	62	C-	74.5	C+
Lower Duck Creek	DUCK1	64	C-	49	D-			51	D	54.5	D
Upper Duck Creek	DUCK2	80	B	61	C-			56	D+	65.5	C
Koreelah	KOOR1	59	D+	40	F			58	C-	52.5	D
Koreelah	KOOR2	66	C	70	C+			50	D	62	C-
Tooloom	TOOL1	63	C-	49	F	93.5	A-	58	D+	66	C
Tooloom	TOOL2	69	C	78	B-	96	A	52	D	74	C+
Tooloom	TOOL3	64	C-	59	D+	78	B-	37	F	59.5	D+
Tabulam	TAB1	72	C+	73	C+			76	B-	73.5	C+
Peacock	PEACOCK1	69	C	69	C			56	D+	64.5	C-

Table 4.11 Ecohealth scores and grades for individual sites within Coastal systems outside the Clarence catchment.

COASTAL SYSTEMS	Site Code	WQ Score	WQ Grade	Overall Site Score	Overall Site Grade
Lake Arragan	ARRAG1	38	F	38	F
Wooli	WOOL1	63	C-	63	C-
Sandon	SAND1	71	C+	71	C+
Sandon	SAND2	60	C-	60	C-
Station Creek	STAT1	47	D-	47	D-
Station Creek	STAT2	38	F	38	F
Cakora Lagoon	BROOM1	52	D	52	D

PART 5

5 SUMMARY OF MAIN FINDINGS, MANAGEMENT ISSUES AND RECOMMENDATIONS

Eighty one study sites were selected within the Clarence catchment, 60 freshwater sites and 21 estuarine sites. The Clarence catchment was divided into 4 hydrologic units; Clarence main stem, Northern Tributaries, Coastal Tributaries and the Mann-Nymboida-Boyd systems. In addition, 5 small coastal systems (7 sites) in the Clarence LGA (but not in the Clarence catchment) were sampled only for water chemistry. The Clarence main stem included 20 sites from the Marylands River in the north-west of the catchment to the river mouth at Yamba. The Northern Tributaries included the Cataract River (3), Boonoo Boonoo River (3), Bookookoorara Creek (2), Timbarra River (3), Duck Creek (2), Korelah Creek (2), Tooloom Creek (3), Tabulam River (1) and Peacock Creek (1). The Coastal Tributaries included the Esk River, Mangrove Creek (1), Shark Creek (1), Swan Creek (1), Sportsmans Creek (2), Coldstream River (3), Orara River (7) and Bucca Bucca Creek (1). The Mann-Nymboida-Boyd system included the Mann River (4), Boyd River (2), Nymboida River (6), Little Nymboida River (1), Bielsdown River (1), Blicks River (2), Clouds Creek (1), Little Murray River (1), Wild Cattle Creek (1), Sara River (2), Aberfoyle River (1), Guy Fawkes River (1) and Henry River (1). The 5 Coastal systems included Lake Arragan (1), Wooli River (1), Sandon River (2), Station Creek (2), and Cakora (1).

Sites in the Clarence catchment were sampled on 6 occasions at approximately bimonthly intervals. Samples were taken in August, October and December 2012 and April, June and August 2013. In late January 2013, a single event peaking at 1,128,071 ML/ was the largest recorded flood in the Clarence River, and was preceded by almost 12 months of very low flow conditions. Two successive flood peaks ocurred of 463,973 ML/day on February 23rd 2013 and 315,036 ML/day on March 3rd 2013. As a result, Ecohealth sampling was conducted 3 times prior to the 3 flood peaks, and 3 times post flood peaks, allowing some comparison of the impacts and recovery of the river from major flooding.

5.1 Main Findings

5.1.1 Water Chemistry

- Concentrations of Total Nitrogen (TN) and oxides of nitrogen (NOx) exceeded the guideline value at some point in all river systems. High nitrogen concentrations were most pronounced in estuarine reaches of the Clarence and its tributaries, in the Mann-Nymboida-

Boyd system, and in the coastal systems. The Northern tributaries had very few sites that exceeded the trigger values Concentrations did not show any longitudinal patterns suggesting local influences on water chemistry, but were consistently higher after the flood among most sites.

- Concentrations of Total Phosphorus (TP) and SRP (the form directly usable by aquatic algae and plants) exceeded the guideline value in most river systems but there were no consistent longitudinal trends. High concentrations were recorded consistently in the estuarine reaches of the Clarence and its tributaries, in Wooli Creek of the Coastal systems, and in the tributaries and tableland rivers in the Mann-Nymboida-Boyd system. There was no temporal pattern with values exceeding the trigger values pre and post-flood.
- Concentrations of Chlorophyll *a* (algal biomass) exceeded the guideline value in few river systems. High concentrations were recorded consistently in the estuarine reaches of the Clarence and its tributaries increasing in concentration from the tidal limit to CR2, in Wooli Creek, Lake Arragan and Station Creek in Coastal systems, in Mann and lower Nymboida Rivers and in very few sites in the Northern tributaries.
- Low dissolved oxygen concentrations were not recorded in the Mann-Nymboida-Boyd system throughout the study. Low DO concentrations were most frequent in pre-flood low flows in freshwater reaches, and in post-flood times in estuarine reaches. Low dissolved oxygen levels recoreded in estuary and coastal tributary sites can lead to stress on biota and chemically reduced environments in the water column that are linked to release of phosphorus and subsequent algal blooms.
- Changes in pH in the main stem of the Clarence followed trends of exceeding the upper threshold frequently in the freshwater reaches, decreasing sharply at the tidal limit, and increasing again at the well-flushed mouth of the estuary. Tributaries of the Clarence such as Swan, Shark, Sportsmans and Mangrove Creeks, and the Coldstream River consistently had very low pH.
- Pre-flood water quality was poorest in freshwater reaches when discharge levels had been low for a prolonged period. In contrast, water quality was poorest in April 2013, the first sample date after the large flood.
- Loads of suspended sediment and nutrients transported in river systems were strongly linked to rainfall events, with markedly increased sediment and nutrients during high flows. Very high sediment loads in the Clarence persisted for all 3 sample dates post-flood, whereas only the first sample date post-flood had very high sediment loads in the tributaries of the Clarence, highlighting the cumulative impact of the tributary inputs.

Recommendations

- Total and available nitrogen was consistently high throughout the catchment and should be a focus for future water quality monitoring. Nitrogen concentrations were highest after the Jan-Feb 2013 flood, suggesting landscape/diffuse sources.
- With widespread high nitrogen concentrations, phosphorus concentrations will limiting quatic productivity (algal blooms). There was no temporal or spatial pattern to

concentrations, suggesting the identification of point sources of high phosphorus concentrations should be a management priority.

- High algal concentrations were most frequent in pre-flood low flows in freshwater reaches, and in post-flood times in estuarine reaches. Chlorophyll *a* (algal biomass) should be monitored in estuarine and freshwater reaches at these times to optimize capacity to detect algal blooms.
- Low DO concentrations and low pH were a feature of estuarine reaches post-flood. Focal reaches for monitoring are from the tidal limit (Copmanhurst) to Maclean. Depth profiles for these attributes are important to maintain, with the lowest values for each consistently recorded at depth.
- The poorest water quality was recorded from the sites closest to the tidal limit, highlighting their role as depositional environments for both freshwater and estuarine contaminants, and the importance of this zone as a focal point for future monitoring programs.

5.1.2 Macroinvertebrates

Aquatic macroinvertebrates are non-vertebrate aquatic animals that are visible to the naked eye and which live at least part of their life within a body of freshwater. Because many macroinvertebrates live in a river reach for an extended period of time they can integrate the impacts on the ecosystem over an extended period of time, rather than just at the time of sampling. Macroinvertebrates were collected from 60 freshwater sites in 28 stream systems in Spring 2012 and Autumn 2013.

- Family level taxonomic richness ranged from 7 in Sportsmans Creek to 45 in the Henry River. Similarly, the abundance of individuals ranged from 94 in the Boonoo Boonoo River (BOO2) to 1054 in the Henry River (HENRY1) when both sample periods were combined. The Nymboida River was the only system to display a longitudinal pattern of decreasing richness and abundance with distance downstream. The lack of a consistent pattern among all other systems indicates that site-specific issues may be the largest influence on macroinvertebrates.
- SIGNAL2 scores ranged from a maximum of 5.8 in the Timbarra River (TIMB3) to 3.8 in the Marylands River (MARY2). The Nymboida catchment displayed a consistently large range of SIGNAL2 scores, with 3 SIGNAL score 10 taxa only occurring in this system.
- The low variability in these scores throughout the 59 freshwater sites indicates low to moderate long-term degradation of water quality and instream habitat. The dominance of Chironomidae (midges), Atyidae shrimps and Notonectidae/Corixidae (waterbugs) (SIGNAL scores of 1-3) at the majority of other sites contributed to lower scores.
- There was a clear pattern of increased abundance and richness of macroinvertebrates in Autumn when compared to Spring, the reverse of the pattern observed in all other Ecohealth projects.

Recommendation

- Macroinvertebrate scores were generally low throughout the catchment, with the exception of the upper Nymboida sub-catchment. This reflects the altered water quality and habitat conditions. The potential for localized increases in macroinvertebrate condition suggest habitat (e.g., woody and organic debris, macrophytes) and therefore food availability, and disturbances such as sediment smothering (e.g., mid-Orara) are drivers of condition.
- The prolonged period of low flows up to Spring 2012 led to a poor condition score in macroinvertebrates, with the macroinvertebrates responding positively to the post-flood conditions with substantial increases in abundance and richness. This suggests that the macroinvertebrate assemblages in the freshwater reaches of the Clarence are resilient to flooding, and appear more impacted by prolonged low flows. Seasonal sampling in Autumn and Spring can detect seasonal shifts in composition, but including pre-and post-flood sampling may be more informative for long -term trends.

5.1.3 Riparian Condition

The riparian land is an intermediary semi-terrestrial zone with boundaries that extend outward from the waters edges to the limits of flooding and upward into the canopy of the riverside vegetation. The area within a riparian zone contains valuable water resources, highly fertile soil and supports high levels of biodiversity as well as many social and economic functions. An assessment of the riparian condition was undertaken on the 60 freshwater sites in 2013.

- Riparian condition scores were generally poor throughout all regions of the Clarence, with the tablelands and estuary sites recording the poorest condition scores as they were often devoid of any extant overstorey streambank vegetation.
- High vegetation scores were linked to high habitat scores. Similarly, high disturbance scores were linked to poor bank condition.
- Bank condition was poor in the majority of freshwater and estuarine sites with evidence of high bank slopes, bank slumping and exposed tree roots. The exception was the Nymboida River and its tributaries that had the highest vegetation and habitat scores and low disturbances in sites within conservation reserves.
- Coastal rivers such as the Orara and tributaries of the Clarence River were often dominated by overstorey weed species such as the invasive Camphor Laurel and *Lantana camara* as a dominant plant in the upper, mid- and understory layers. The presence of weed species, dominance of the organic litter layer by weed species, and reduced habitat and connectivity to remnant vegetation also reduced scores in coastal reaches.
- Northern tributaries generally had poor condition, with Duck Creek and the Cataract and Timbarra River particularly poor. In contrast, there were rivers with good condition riparian zones and channels, with Bookookoorara Creek scoring the highest of the region.

Recommandations

- Riparian revegatation in tablelands and coastal reaches must be a priority. The lack of streambank vegetation is linked to poor bank condition and localized erosion, sediment deposition and benthic habitat smothering throughout rivers, reduced habitat for biota, and poor water quality (evidenced by high nitrogen and tubidity in flood periods from streams with poor riparian condition).

5.2 Future Monitoring

The 2012-13 Clarence Ecohealth program was spatially intensive with 88 sites, but less temporally intensive with 6 sample dates over the 18 month period. The program also incorporated field sampling from teams from the Clarence Valley Council, Office of Environment and Heritage, National Parks and Wildlife Service, Kyogle Shire Council and Richmond Laboratories, and the Northern Rivers CMA. Suggested major outcomes from these analyses are:

5.2.1 Spatial Resolution

There is limited evidence for reducing the number of sampling sites in freshwater reaches as the majority of systems with multiple sites did not show a consistent longitudinal pattern in indicators. Estuarine sites could be optimized to remove the number of sites on the main stem. Combining sites CR8/9/10 into a single site at Grafton (CR9) would not reduce the capacity to detect longitudinal patterns in estuarine reaches.

- *Recommendation*: maintaining a minimum of one site within freshwater reaches of each of the major subcatchments is recommended. The intention of multiple sites within each river systems is to detect longitudinal trends in water quality and biotic variables. If only one site remains in each subcatchment the ability to spatially identify reaches of management interest will be reduced.
- *Recommendation*: maintaining sampling at the most downstream freshwater reach in each major subcatchment is recommended as this site represents the cumulative impacts from throughout the upstream catchment, and is generally gauged to allow the calculation of nutrient and sediment loads exported from each catchment.
- *Recommendation:* the optimum combination from the above recommendations is to retain the most downstream site in each subcatchment, one site in the dominant River Style of each subcatchment, and strategic upland sites to establish a local reference condition.

5.2.2 Indicators

- *Recommendation*: Retaining the suite of water quality variables and sampling procedures (water column profiles in sites >1 m depth) is recommended as all variables positively contributed to the understanding of issues at each site and the development of site-based scores for the report card. The inclusion of TP and TN and exclusion of SRP and NOx in future sampling would be the main way to reduce costs. This would have minimum impact on the Ecohealth grades for each site, but impacts on the ability to understand drivers of condition.
- *Recommendation*: Season and site-based characteristics of freshwater reaches both affected the taxonomic composition and abundance of macroinvertebrates. Future macroinvertebrate sampling should include autumn and spring, but should consider further

research into the link between geomorphic characteristics, condition and recovery potential. The present study sampled macroinvertebrates at Pool, Riffle and Edge habitats at each site. Cost-saving with no loss of reporting at the Report Card scale can be achieved by taking a single, integrated sweepnet sample. This will reduce field and lab processing time.

- *Recommendation*: The riparian condition index contributes to the management priorities by identifying biological (weeds) and biophysical (bank erosion) drivers and should be retained for freshwater reaches as an annual survey.
- *Recommendation:* The inclusion of an on-ground riparian assessment for estuarine reaches that includes measures of invasive species and bank condition are recommended to align the data from the riparian assessments in both freshwater and estuary reaches.

5.2.3 Temporal resolution

The frequency of bimonthly sampling over a 12 month period was not feasible in this study due to large flood events. Rainfall in the region during the summer of 2012-13 sampling period was well above the long term mean, with 3 major flood peaks occurring throughout the catchment.

Recommendation: This project has highlighted the importance of sampling within defined hydrologic periods (80th percentile flows), and the potential for both low and high flows to influence site condition. Sampling one out of every four years in the Clarence catchment may not best reflect the long-term condition of the sites as much as the influence of short-term climate conditions. It is recommended to target sampling to specific flow conditions (>80th percentile) in defined time periods (seasonal) over a multi-year timeframe. This will facilitate the capture of data from all sites under similar flow conditions and replicated temporal periods (seasons) within the four year reporting period (e.g., 1 sample/season, 4 seasons/year, for 3 years = 12 sample times). This recommendation removes the potential influence of flow extremes that may be encountered within a shorter 12 month period. Impact of floods on ecological condition and flood-recovery would require a separate sampling program.

5.2.4 Partnerships

This project was a successful partnership among a number of Councils, government agencies and the University of New England. While these partnerships have many benefits well beyond the data collected, a number of issues with data quality and management emerged that could be better managed in future projects.

Recommendation: The inclusion of staff from Councils and Agencies was included with the intention of increasing the number of sites that could be sampled as part of the program, and facilitate education and training where possible. Despite the intent and goodwill of these staff, some Council staff (Guyra, Tenterfield) and Agency (Dorrigo NPWS) were unable to meet their commitments. Similarly, Grafton NPWS staff were often called to perform their core business resulting in sampling delayed or not completed. While this is not the fault of individual staff, it resulted in patchy or missing data, QA issues with sample transport, and substantially increased costs for UNE to pick up the additional sites. Continued partnerships are essential, and these issues must be addressed in future projects if success is to be maximized.

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7 APPENDIX 1 – Water quality field data sheets

Ecohealth Water Quality Data Sheet

Date:___________________________________

Site Name:______________________________ Site ID:___________________________

Location: Easting___________________ Northing_____________ Datum __________

Decimal degrees - Lat __________ Long_____________Elevation ________

Field Personnel ____

Start Time (24 hr) _________________________ End time (24hr) __________________

High Tide Time/Height ______________________ Low Tide Time/Height _____________

Equipment: (Make/Model)_______________________ Serial/ID number_________________

Calibrated by: ___________________________ Calibration Log Complete? Y N

Air Temp ___________________________

Weather Conditions

Water Surface: ☐ flat ☐ choppy ☐ rough

Wind: ☐ nil ☐ light ☐ moderate

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

Sky: ☐ sunny ☐ overcast

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

Ecohealth Water Quality Data Sheet

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

Duplicate TN/TP sample	Yes	No	Sample ID:	
Duplicate SRP/NOx sample	Yes	No	Sample ID:	
Duplicate ICP 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
