dry tropics partnership for healthy waters

Results for Townsville Dry Tropics 2018-2019 Report Card
(released in 2020)

Technical report

Dry Tropics Partnership for Healthy Waters

May 2020

Authorship statement

The technical report of the results of the Townsville Dry Tropics 2018-2019 Report Card (released in 2020) was compiled by the Partnership's Technical Officer, Dr. Tegan Whitehead.

Input was received from the Regional Report Cards Technical Working Group (TWG) members, and experts in litter. Some content was also based on technical reports from the Wet Tropics and Mackay-Whitsunday-Isaac regional Report Cards.

Townsville Dry Tropics TWG members and their respective organisation

Di Tarte	Chair
Tegan Whitehead	Dry Tropics Partnership for Healthy Waters
Richard Hunt	Wet Tropics Partnership
Jessica Gillespie	Mackay Whitsunday-Isaac Partnership
Alysha Lee	Mackay Whitsunday-Partnership
Lyndon Llewellyn	Australian Institute of Marine Science (AIMS)
Angus Thompson	AIMS
Hugh Sweatman	AIMS
Glynis Orr	Department of Natural Resources, Mines and Energy (DNRME)
Carl Mitchell	Department of Environment and Science (DES)
Michael Holmes	DES
Paulina Kaniewska	DES
David Moffatt	DES
Andrew Moss	DES
Rachel D'Arcy	DES
Michael Newham	DES
Paul Groves	Great Barrier Reef Marine Park Authority (GBRMPA)
Stephen Lewis	James Cook University (JCU)
Alexandra Carter	JCU
Chris Manning	Townsville City Council
Melinda Louden	Port of Townsville
Elaine Glen	Port of Townsville

Acknowledgements

In addition to the TWG members, the author also thanks Maria Gomez Cabrera for assistance in calculating the water quality aspects of the document and for proof reading and editing the document. We also thank Bill Venables (CSIRO) for his invaluable assistance and statistical knowledge for greatly helping design the method for analysing and scoring litter data. Members of the Reef Independent Science Panel are also gratefully acknowledged for their advice and review of this document.

We also thank Partners who kindly contributed their data. These Partners include Townsville City Council (Townsville Water & Waste and the Sustainability Team), Port of Townsville, Australian Institute of Marine Science, CSIRO, Queensland Herbarium (through the Department of Environment and Science) and TropWater (JCU). Creative Commons (REMP STP monitoring data) by Townsville City Council is licensed under CC BY 4.0/Adapted Material.

Citation

Whitehead, T (2020). *Results for the Townsville Dry Tropics 2018-2019 Report Card (released in 2020), Technical Report*. Dry Tropics Partnership for Healthy Waters, Townsville.

Executive Summary

The Dry Tropics Partnership for Healthy Waters (referred to as the Partnership) was formed in November 2017 and launched in January 2019. The initial scope of the Partnership is to report on the waterways (freshwater, estuarine and marine) in the Townsville region, from Crystal Creek in the north to Cape Cleveland in the south. The Partnership released its Pilot Report Card in May 2019, reporting on data from the 2017-2018 financial year.

The Townsville Dry Tropics 2018-2019 Report Card (henceforth referred to as the Report Card) will be released in June 2020 and will mainly report on data from the 2018-2019 financial year. The Partnership aims to produce a holistic Report Card that provides information on the ecological condition of waterways (Biodiversity and Water Quality), pressures to the environment (Litter) and the Community (social) and Economic benefits provided by these waterways. Following the release of the Pilot Report Card, some methods were updated, and additional indicators have been scored for the 2018-19 Report Card. To reflect this framework, the results of the Report Card are separated into five reporting components (Biodiversity, Water Quality, Litter, Community and Economy).

The results presented in this document include assessments of the condition of the freshwater, estuarine, inshore marine and offshore marine environments, the pressure of litter (including marine debris) on the environment and the value the community derives from, and their perception of the condition of the Great Barrier Reef (GBR), and the non-monetary economic benefits from waterways, such as the ability to attract tourism to the region. It is acknowledged that litter is not the only pressure on the environment, with other indicators such as artificial barriers and impoundment length, also acting as a pressure on the environment.

The scores and grades for freshwater, estuarine, inshore marine and offshore marine zones are provided for the financial year of July 2018 to June 2019. Results from multiple indicators are aggregated into results for indicator categories, which are aggregated into results for indices. Confidence levels associated with the results are also provided. The indicators selected are affected by a wide range of impacts, including weather (e.g. rainfall), and these influencing impacts are examined within this report.

This document is intended to be read in conjunction with the Townsville Dry Tropics Program Design and the Townsville Dry Tropics Methods document.

The index and overall scores and grades of each waterway environment for the 2018-19 reporting period are presented in the Tables i – iv below for quick reference. Selected key messages are provided and refer to indicators which are presented in detail within the results sections. The below standardised scoring ranges and grades have been applied to the Biodiversity, Water Quality and Litter reporting categories. The first description applies to the Biodiversity and Water Quality reporting categories, whilst the second description applies to the Litter (pressure) reporting category. The scoring ranges and grades are: ■ Very Poor (E)/Very high pressure (VHP) = 0 to <21 | ■ Poor (D)/High pressure (HP) = 21 to <41 | ■ Moderate (C)/Moderate pressure (MP) = 41 to <61 | ■ Good (B)/Low pressure (LP) = 61 to <81 | ■ Very Good (A)/Slight pressure (SP) = 81 to 100 | ■ No score/data gap.

Freshwater basin

Table i. Scores and grades for Biodiversity, Water Quality and Litter for the Ross and Black freshwater basins.

Zone	Score			Grade		
	Biodiversity	Water Quality	Litter	Biodiversity	Water Quality	Litter
Ross freshwater basin	51	69	45	C	B	MP
Black freshwater basin	78	62		B	B	

Freshwater basin key messages:

- Between 2013 and 2017, 187 ha of riparian vegetation was lost, and wetland extent declined by 2 hectares.
- There were no barriers to fish movements within the Black freshwater basin suggesting good connectivity between habitats and fish populations.
- Over 8% of waterways within the Ross freshwater basin are impounded, with more than 10 barriers to fish movement.
- Overall, water quality of most rivers and creeks was graded as being very good or good. The exceptions were the Bohle and Black rivers, which had excessive total phosphorus levels.
- Litter posed a moderate pressure on the Ross freshwater basin compared to 2013-2017.

Estuarine zone

Table ii. Scores and grades for Biodiversity, Water Quality and Litter for the Ross and Black estuarine zones.

Zone	Score			Grade		
	Biodiversity	Water Quality	Litter	Biodiversity	Water Quality	Litter
Ross estuarine zone	77	54	64	B	C	LP
Black estuarine zone	71	64		B	B	

Estuarine zone key messages:

- Between 2013 and 2017, there was good progress towards achieving saltmarsh and mangrove habitat management targets, with less than 7 hectares cleared.
- Most estuaries had moderate or good water quality, except for Louisa Creek/Town Common estuary which had very poor water quality due to excessive nutrients and low dissolved oxygen levels.
- There was less litter within the Ross estuarine zone compared to 2013-2017.

Inshore marine zone

Table iii. Scores and grades for Biodiversity, Water Quality and Litter for Cleveland Bay and Halifax Bay.

Zone	Score			Grade		
	Biodiversity	Water Quality	Litter	Biodiversity	Water Quality	Litter
Cleveland Bay	45	55	70	C	C	LP
Halifax Bay	52	43	35	C	C	HP

Inshore marine zone key messages:

- High levels of macroalgae and low recruitment of coral larvae led to poor to moderate coral reef conditions in Cleveland and Halifax bay, respectively.
- Cleveland and Halifax bays had moderate water quality, however there was excessive nutrients within both bays.
- There was less litter within Cleveland Bay compared for the four previous years, but litter posed a high pressure on Halifax Bay.

Offshore marine zone

Table iv. Scores and grades for Biodiversity and Water Quality for the offshore marine zone.

Zone	Score		Grade	
	Biodiversity	Water Quality	Biodiversity	Water Quality
Offshore	59	97	C	A

Offshore marine zone key messages:

- Offshore water quality (measured by nutrients and suspended solids) was in a very good condition.
- Offshore coral reefs were in a moderate condition. Coral cover was poor, but there was very good recruitment of juvenile corals, which is crucial for the long-term survival of coral reefs.

Table of Contents

Terms and Acronyms

AIMS	Australian Institute of Marine Science
Artificial barriers (as an indicator)	Artificial barriers are any barriers which prevent or delay connectivity between key habitats and potentially impacting migratory fish populations, reducing diversity of aquatic species and communities and the condition of aquatic ecosystems (Moore, 2016).
Basin	Area of land where surface water runs into smaller channels, creeks or rivers discharging into a common point and may include many sub-basins or sub-catchments.
BOM	Bureau of Meteorology
Catchment area	Area of land from which rainfall flows into a river, lake or reservoir and discharges into a common point.
Chlorophyll-*a*	Chlorophyll-*a* is an indicator of phytoplankton biomass and is widely considered a useful proxy of nutrient availability and system productivity.
Climate	In this Report Card, means both natural climate variability and climate change.
CVA	Conservation Volunteers Australia
DES	Department of Environment and Science of the Queensland Government
DIN	Dissolved Inorganic Nitrogen
DO	Dissolved Oxygen
DTPHW	Dry Tropics Partnership for Healthy Waters
Ecosystem	A dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit.
Enclosed Coastal (EC)	An enclosed coastal (EC) water is a partially smooth, semi protected water body including shallow, enclosed waters near an estuary mouth and generally considered the interface between coastal and inland waters. Its boundaries depend on the local or regional authorities.
Environmental values (EV)	Characteristics or qualities of a natural system that supports viable natural communities and human uses.
eReefs	Integrated modelling system to visualise, communicate and report reef information for the GBR
Flow (as an indicator)	Is the degree that the natural river currents or stream flows have been modified, influencing waterways and ecosystem health.
FRP	Filterable Reactive Phosphorus
GBR	Great Barrier Reef
GBR Report Card	GBR Report Card under the Reef Water Quality Protection Plan (2013).

GBRMPA	Great Barrier Reef Marine Park Authority
GBRMP	Great Barrier Reef Marine Park
Impoundment length	An indicator used in the 'in-stream habitat modification' indicator for freshwater basins in the region. The proportion (%) of the linear length of the main river channel when at the full capacity of artificial in-stream structures, such as dams and weirs.
Index	Integration of one or more indicator categories (e.g. coral, seagrass and riparian extent are indicator categories of the habitat index).
Indicator	A measure of one component of an indicator category (e.g. coral composition (indicator) is a measure of coral (indicator category).
Indicator category	Integration of one or more indicators (e.g. the coral category comprises coral composition, change in coral cover, juvenile density, macroalgae cover and coral cover).
Inshore marine environment	Includes enclosed coastal (EC), open coastal (OC) and midshelf (MS) waters, extending east to the boundary with the offshore waters (Department of Environment and Science, 2018). The boundary is based on the delineation guidelines for the Burdekin (which includes the Townsville Dry Tropics region) and the Wet Tropics region. Waters north of Pelorus Island are based on the guidelines for the inshore boundary for the Wet Tropics region.
Inshore marine zone	Inshore marine zone is a reporting zone in the Townsville Dry Tropics Report Card that includes inshore marine environments.
ISP	Independent Science Panel
JCU	James Cook University
LTMP	Long Term Monitoring Program of GBR midshelf and offshore reef communities
Macroalgae (cover)	Indicator used to assess coral health. Macroalgae includes seaweed and other visible benthic (attached to the bottom) marine algae.
MD	Moderate disturbed waters
Midshelf waters	Midshelf waters are from 12 to 48 km offshore in the Burdekin region (waters south of approximately Pelorus Island) and 6 to 24 km offshore in the Wet Tropics region (waters north of Pelorus Island) (GBR, 2010).
MMP	Marine Monitoring Program of the inshore reef communities along Wet Tropics, Burdekin, Mackay, Whitsunday and Fitzroy regions of the GBR
NOx	Generic term for nitrogen oxides such as mixtures of nitrites and nitrates
NRM	Natural resource management
OGBR	Office of the Great Barrier Reef of the Queensland Government

Offshore waters	Offshore waters extend 48 to 180 km in the Burdekin region (waters south of approximately Pelorus Island) and 24 to 170 km offshore in the Wet Tropics region (waters north of Pelorus Island) (GBR, 2010).
Offshore zone	Offshore is a reporting zone in the Townsville Dry Tropics Report Card that includes offshore waters.
Open coastal (OC)	Open coastal waterbodies being at the seaward limit and extends 12 km offshore in the Burdekin region (waters south of approximately Pelorus Island) and 6 km offshore in the Wet Tropics region (waters north of Pelorus Island) (GBR, 2010).
Overall Score	The overall scores for each reporting zone used in the Report Card are generated by an index or an aggregation of indices.
Physical-chemical properties (phy-chem)	Indicator category that includes dissolved oxygen and turbidity.
PN	Particulate Nitrogen
PP	Particulate Phosphorus
QA/QC	Quality Assurance / Quality Control
QPSMP	Queensland Ports Seagrass Monitoring Program
RE	Regional Ecosystem
Reef 2050 Plan	The overarching framework of the Australian and Queensland governments for protecting and managing the reef until 2050
RIMReP	Reef 2050 Integrated Monitoring and Reporting Program

List of Tables

List of Figures

1 Introduction

1.1 Overview

The Dry Tropics Partnership for Healthy Waterways (referred to as the Partnership) was founded in November 2017, with technical work beginning in late May 2018 and the Partnership launched in January 2019. A focus of the Partnership is to produce an annual Report Card on the condition of waterways and their dependent biodiversity within the Townsville Dry Tropics region. The health of waters and their ecosystems are the two main ecological components of waterways (Cork, et al., 2007). The Report Card also presents information on the state of the social and economic benefits that the community derives from waterways. Pressures on the environment are also included, with litter currently the only pressure scored. The report is divided into five main sections to report on each of these components (or reporting categories), which are:

1. Water Quality
2. Biodiversity
3. Community (social)
4. Economy
5. Litter (pressure on all above categories)

'Water Quality' comprises indicators of water quality, whilst 'Biodiversity' refers to all ecological components that are directly associated with or supported by waterways (e.g. wetlands, riparian habitat, coral etc.). Community benefits are the social and cultural benefits derived from waterways, excluding economic benefits. Economic benefits are the monetary benefits industries derive from healthy waterways and the non-monetary economic benefits, such as the ability to attract tourists to the region. Litter is man made products that are released into the environment (either intentionally or non-intentionally). Litter is a pressure on the environment and therefore is presented separately to the other reporting categories, which are reporting on the state of the environment. Different indicators are measured and reported on to provide the overall scores for Water, Biodiversity, Community, Economy and Litter. It is noted that not all indicators are scored in the Report Card due to data gaps or no method for scoring an indicator.

1.2 Report Card reporting zones

The results presented in the 2018-19 Report Card are divided into four environments (freshwater, estuarine, inshore marine and offshore marine) and collectively cover seven zones. The zones are:

- two freshwater zones, called Ross freshwater basin and Black freshwater basin.
- two estuarine zones, called Ross estuarine zone and Black estuarine zone.
- two inshore marine zones, called Cleveland Bay/Ross inshore marine zone (referred to as Cleveland Bay) and Halifax Bay/Black inshore marine zone (referred to as Halifax Bay).
- one offshore marine zone.

The reporting area for the Townsville Dry Tropics is shown in Figure 1.

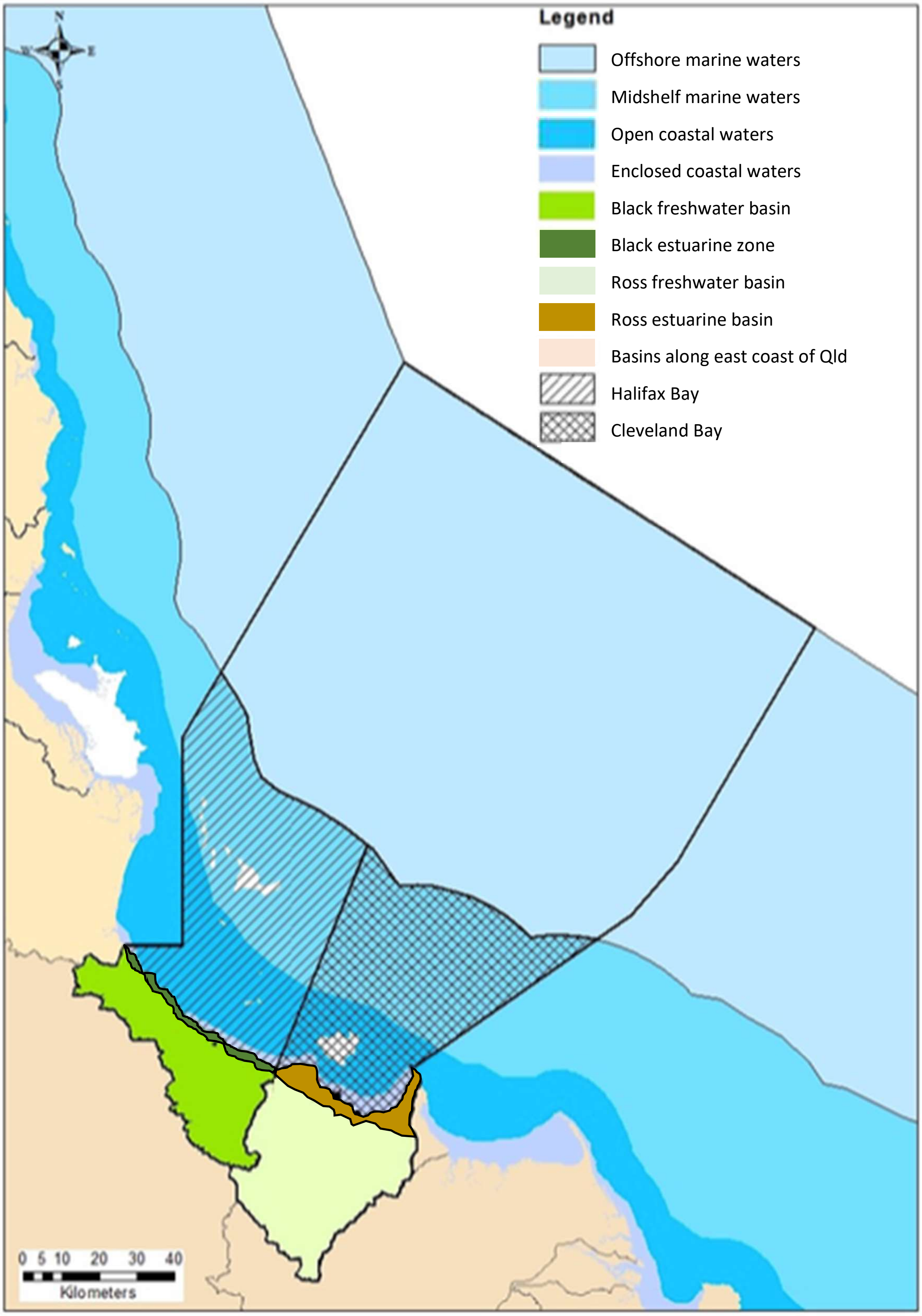


Figure 1. Geographic boundary reported upon by the Dry Tropics Partnership, comprising the Ross and Black freshwater basins and estuarine zones, Cleveland Bay and Halifax Bay and the offshore marine zone. The inshore marine zones comprise midshelf, open coastal and enclosed coastal waters. The right angle in the offshore marine zone is the boundary of the Hinchinbrook Planning area.

1.3 Purpose of this document

The purpose of this document is to provide detailed results on the condition of freshwater basins, estuarine, inshore marine and offshore marine environments within the Townsville Dry Tropics region. This document presents scores and grades for indicators, indicator categories, indices, and overall scores for Water, Biodiversity, Community, Economy and Litter within each zone. Indicators of Water and Biodiversity are scored for each of the seven reporting zones, whilst an overall score for the entire Townsville Dry Tropics region is provided for the indicators of Community and Economy. Litter is currently scored for four reporting zones, as data is not available for the other three zones. The aim is to score Litter for all seven reporting zones as data becomes available.

This document supports the 2018-19 Report Card, which will be released in July 2020 and will provide a summary of the results. For further details on the design of the Report Card program, including reporting zones and reasoning for selecting the indicators, refer to the Townsville Dry Tropics Program Design (Whitehead, 2019a).

2 Methods

Unless otherwise specified, the methods used are the same as those detailed in the 'Methods for the Townsville Dry Tropics annual Report Cards' document (Whitehead, 2019b).

2.1 Terminology

Different indicators are measured to assess (1) water quality, (2) the condition of biodiversity, the state of (3) community and (4) economic benefits and (5) the relative pressure of litter on the environment within the different zones. Indicators that measure a similar aspect of the condition of the environment are grouped together and their scores are aggregated multiple times to produce an overall score for Water Quality, Biodiversity, Community, Economy and Litter.

The levels of aggregation are:

- **Indicator** is a measured variable (e.g. coral cover)
- **Indicator category** is a group of similar indicators (e.g. coral, which is aggregated from indicators of coral such as coral cover and juvenile density). Where an indicator category is represented by a single indicator, the indicator category score is equal to the indicator
- **Index (single) or indices** (plural) is an aggregation of indicator categories (e.g. freshwater habitat is an aggregation of wetland and riparian extent)
- **Reporting categories** is the aggregation of indices. There are five reporting categories (Biodiversity, Water, Community, Economy and Litter) within the Report Card. All indicators scored under a reporting category have similar traits (i.e. all indicators of water quality are scored under the Water reporting category).
- **Overall score** is generated by the aggregation of the scores of the indices (the score generated for each reporting category).

The grades for indices of Biodiversity, Water Quality and Litter will be presented in a coaster for each of the seven zones. An example of a coaster is shown in Figure 2. Litter is a pressure on all other reporting categories (Water Quality, Biodiversity, Community and Economy) but since it is scored for each of the zones (same as the Biodiversity and Water reporting categories) it will be presented with the Water Quality and Biodiversity reporting categories. This decision to include it within the same coaster is for design purposes and to allow simple communication on the Report Card. The wedge for Litter will be smaller than that of the Water Quality and Biodiversity wedge because the results are only based on one indicator, whereas the other are based on multiple indicators. The results for Water Quality, Biodiversity and Litter are not rolled up into one score (three separate scores).

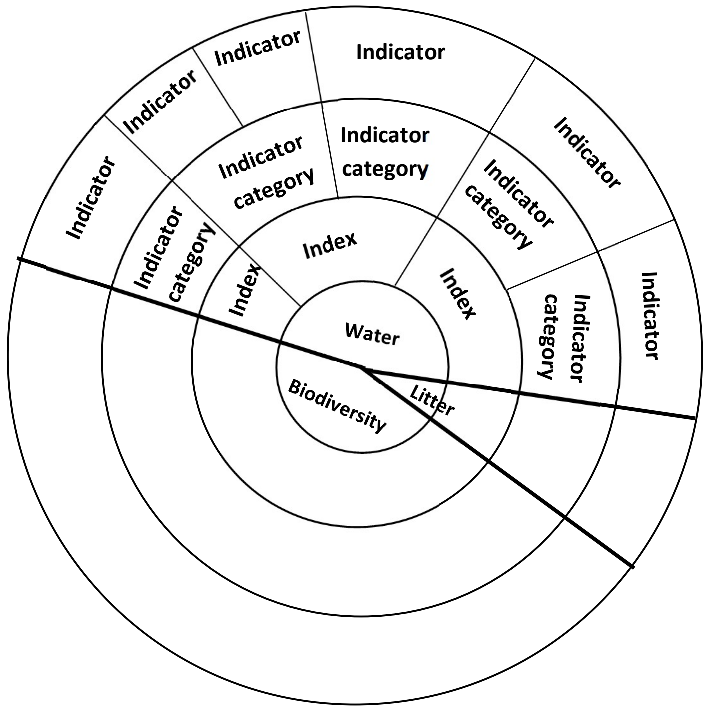


Figure 2. Terminology for defining the levels of aggregation for indicators of Water Quality, Biodiversity and Litter and an example of how they are displayed in the Report Card.

The overall grades (for the entire Townsville region) for Community and Economy will be presented in separate coasters, with an example coaster shown in Figure 3. Presentation of the coasters in the Report Card can be with, or without the two outer rings (indicators and indicator categories).

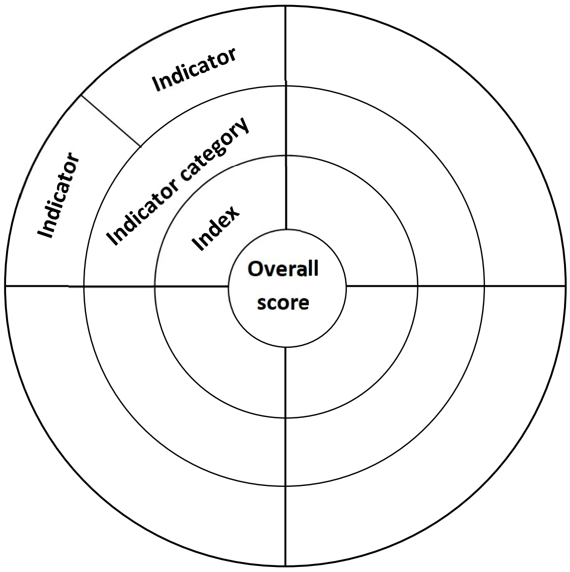


Figure 3. Terminology for defining the levels of aggregation for indicators of Community and Economy and how they are displayed in the Report Card.

2.2 Data used in the Report Card

The Report Card mainly reports on data collected during the 2018-2019 financial year (1 July 2018 to 30 June 2019). However, there are a few exceptions. Within the Biodiversity index, the remote sensing data for the indicators of riparian, wetland, mangrove and saltmarsh extent is only updated every four years, with the latest data from July 1st 2014 to June 30th 2017. Additionally, the results for offshore coral indicators are averaged using a four-year rolling mean (although indicators of coral condition are measured each year).

3 Drivers impacting upon the Townsville Dry Tropics

Climate change and extreme weather, land use, consumerism, urban lifestyles and economic growth are the key drivers that impact upon the condition of the waterways within the Townsville Dry Tropics region. Climatic and extreme weather events that occurred between 1st July 2018 and 30th June 2019 are outlined below.

3.1 Climate

3.1.1 Rainfall

The amount of rainfall within a catchment can influence the amount of nutrients and sediments washed into waterways (Department of Environment and Science, 2018). This is especially applicable to the urban environment, where stormwater drains channel water straight into the waterways (Department of Environment and Science, 2018). As depicted in Figure 4, both the Ross and Black freshwater basins received substantially higher rainfall than the mean. As shown in Table 1 and Figure 5, in the Ross freshwater basin, during the 2018-19 year a total of 2,144 mm of rain was recorded (average across the catchment), which was 1,113 mm above the long-term mean (1,031 mm) or 208% of the long-term mean (Bureau of Meteorology (BOM), 2019a). In the Black freshwater basin, during the 2018-19 financial year, an average of 2,674 mm of rain was recorded across the basin, which was 1,314 mm above or 197% of the long term mean of 1,360 mm (2019a).

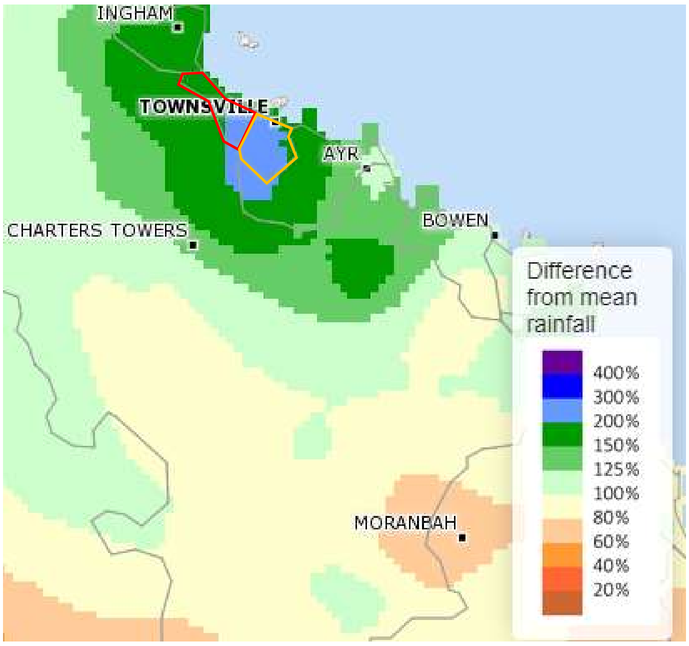


Figure 4. Percentage difference in 2018-19 rainfall from then long term mean rainfall within Black freshwater basin (red outline) and the Ross freshwater basin (orange outline).
The long-term mean is represented as a "difference from mean rainfall" of 100% and was based upon historical rainfall records from 1912 to 2019 supplied by the Bureau of Meteorology (2019a).

Table 1. Annual rainfall statistics for basin areas of the Dry Tropics.

Basin	Total (mm)	Long-term mean (mm)	Decile*	Anomaly (+/- long term mean)	Percentage long term mean (%)
Ross	2144	1031	Highest on record	1113	208
Black	2674	1360	10	1314	197

*Decile ranking category descriptions are shown in Figure 5 legend.
Source: BOM Regional Water Information (http://www.bom.gov.au/water/rwi/#ra_dc/157/2019)

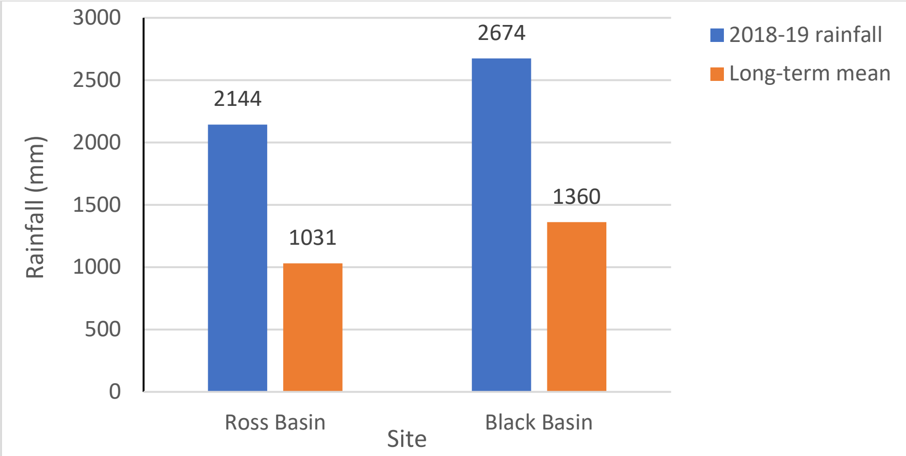


Figure 5. Rainfall for 2018-19 in the Ross and Black basins compared to the long-term mean.
Source of data: (Bureau of Meteorology (BOM), 2019a).

The Ross Basin received most of its rainfall between December and April, whilst in the Black Basin, most rain fell between December and March. The rest of the year received rainfall similar to the long-term average, except for during August when both basins received substantially lower rainfall and during July when the Ross Basin received above average rainfall. The monthly rainfall declines for the Ross and Black basins are presented in Figure 6.

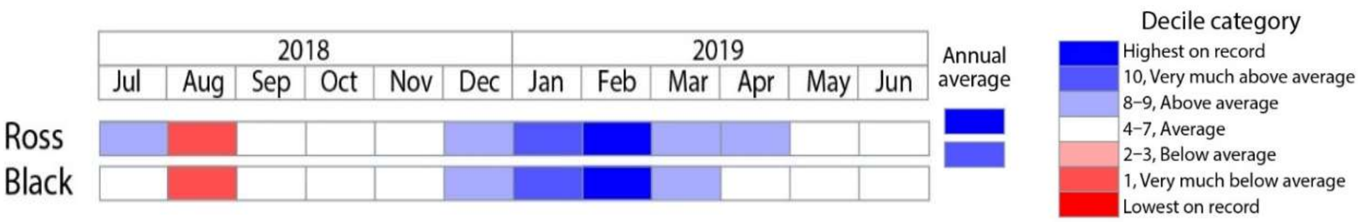


Figure 6. Monthly rainfall deciles and annual average deciles for the Dry Tropics. Source BOM Regional Water Information (http://www.bom.gov.au/water/rwi/#ra_dc/157/2019).

3.1.2 Temperature

Mean temperatures throughout Australia are increasing, with the Townsville Dry Tropics region experiencing a 0.20 to 0.30 degree temperature increase per decade since 1970 (Bureau of Meteorology (BOM), 2020). The degree temperature change per decade since 1970 is shown in Figure 7.

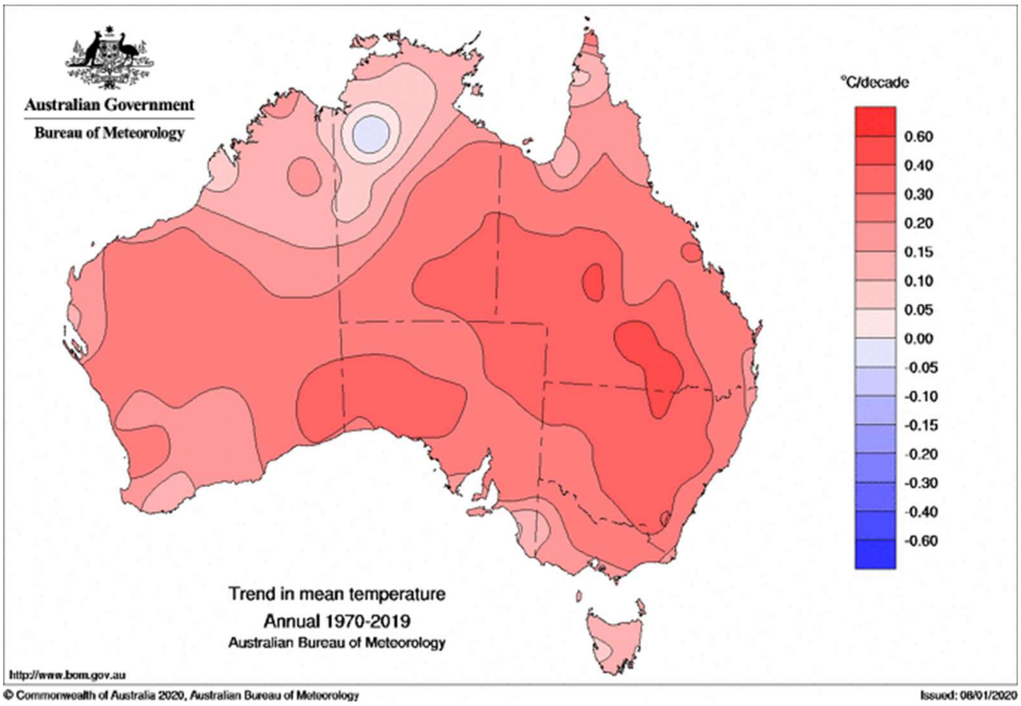


Figure 7. Mean temperature change per decade throughout Australia.
Source: BOM (2020)

3.1.3 Climate change

Climate change is one of the major factors driving the current condition of the environment (Jackson & Rankin, 2016). Climate change is increasing the likelihood and intensity of environmental events, such as cyclones, floods and fires (BOM, 2020). Within the Townsville region, after a very dry start to the year (of below average rainfall), a monsoonal trough impacted upon the region in late January to early February (Bureau of Meteorology (BOM), 2019c). The impacts of the floods on the Townsville region are discussed below.

3.2 Flooding event (February 2019)

3.2.1 Rainfall

3.2.1.1 *Rainfall in the Townsville region*

After a period of intense rain that started in late January 2019, Townsville experienced a major flooding event in early February 2019. The flood was triggered by an active monsoon trough and a slow-moving low pressure system over the northern tropics (BOM, 2019c). By early February, the region had received its average annual rainfall, as shown in Figure 8, and "in and around Townsville, the accumulated totals from consecutive days of heavy rainfall were the city's highest on record since records began in 1888." (BOM, 2019a). Almost twice as much rain fell during the February 2019 event than in previous notable heavy rainfall events (BOM, 2019a).

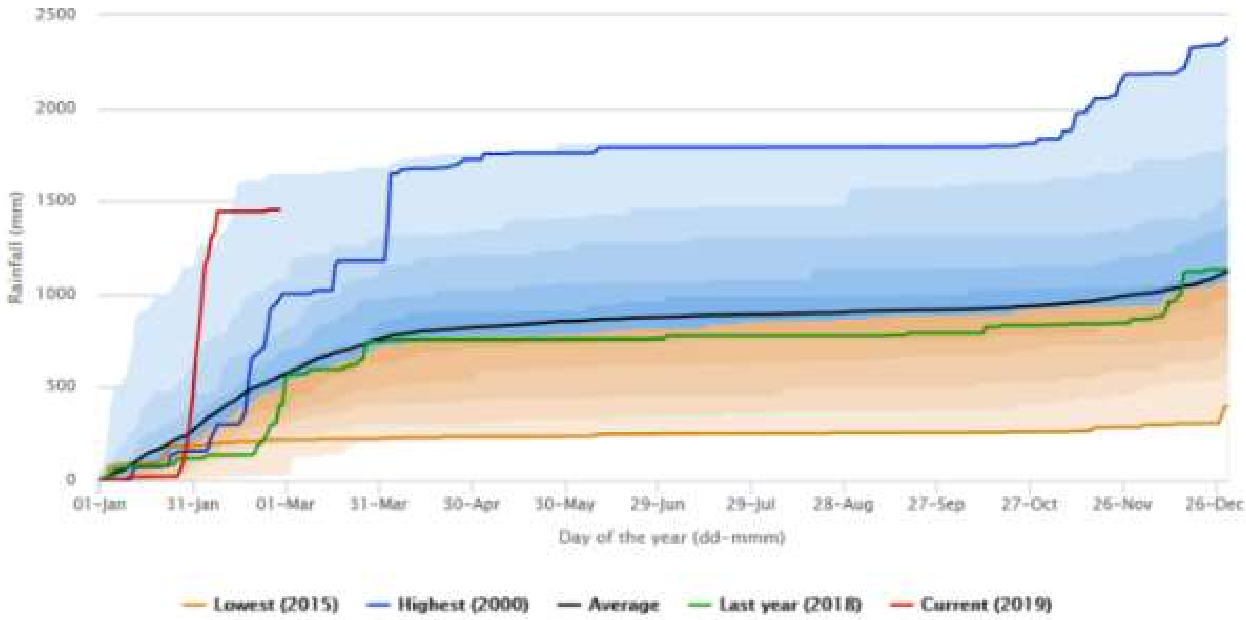


Figure 8. Cumulative daily rainfall at the Townsville Aero site from January to March 2019 (red line) compared against the average rainfall (black line), the lowest rainfall record (2015) (orange line), the previous highest rainfall year (2000) (blue line) and the previous year (2018) (green line).

3.2.1.1.1 Rainfall totals

Heavy rainfall occurred in the Townsville region from the 27th January until the 8th February, with a total of 1420 mm of rain recorded at Mt Stuart weather station and 1392 mm at the Townsville Aero weather station (Bureau of Meteorology (BOM), 2019b). Daily rainfall between the 23rd January and the 10th February are shown in Figure 9. Rain fell most intensely between 29th January and 4th February (inclusive), with Mt Stuart receiving 1196 mm (84% of rainfall) and 1017 mm (73% of rainfall) at the Townsville Aero station (BOM, 2019b). This was the highest rainfall recorded over an eight day period within the Townsville region, breaking the previous record (886 mm in January 1998) by over 200 mm (BOM, 2019b). Additionally, “there were numerous sites in elevated areas that reported 12-day accumulations of more than 2000 mm, including at Paluma, Woolshed, and Upper Bluewater.” (BOM, 2019a).

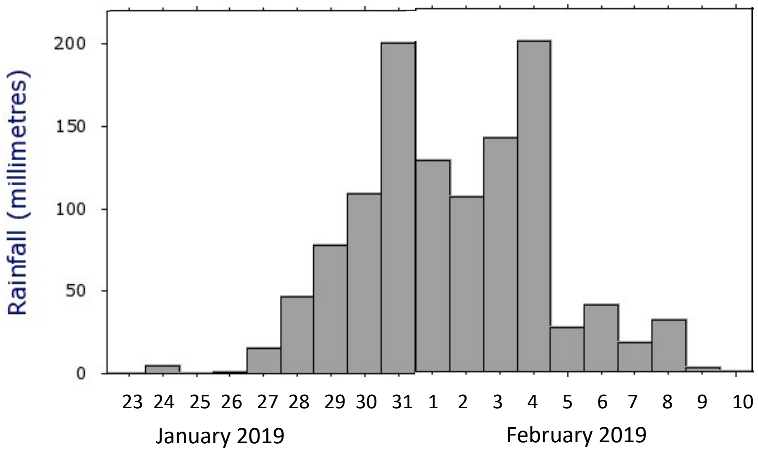


Figure 9. Daily rainfall totals at Mount Stuart (Defence based) from the 23rd January until the 10th February.
Modified from Climate Data Online, Bureau of Meteorology, Commonwealth of Australia, 2019.

3.2.1.1.2 Rainfall since the February 2019 flood

Since the heavy rains in February, Townsville received lower than average rainfall for the rest of the year, except for March (BOM, 2019b). Total rainfall for the year is shown in Figure 10. Approximately four months following the floods, many ephemeral creeks and rivers within Townsville had largely dried with the occasional pool of water, or there were only low flows.

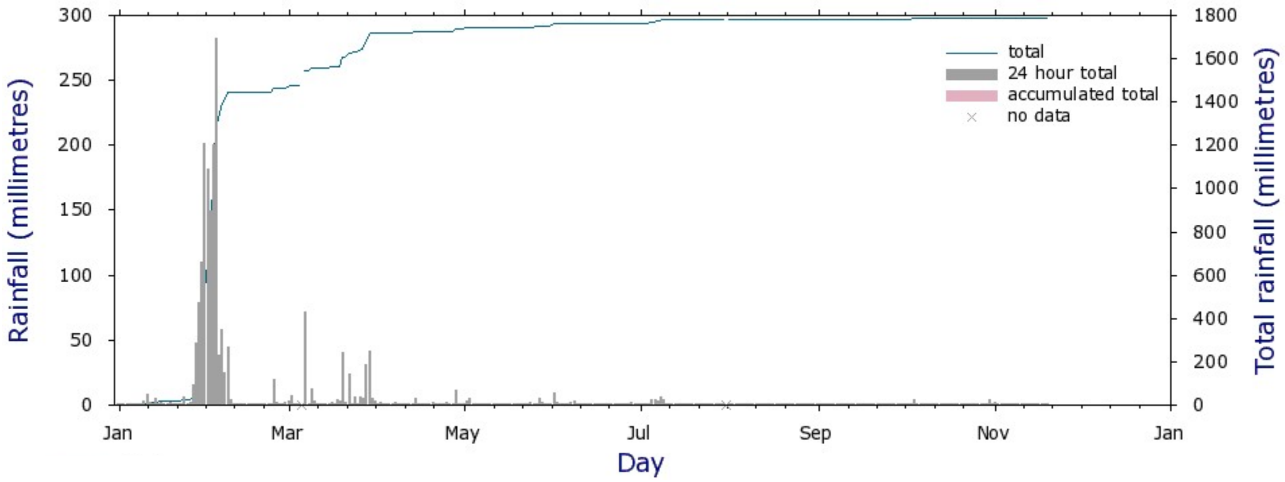


Figure 10. Rainfall totals for a 24 period at Mount Stuart (Defence based) from January 2019 until November 2019.
Source: Climate Data Online, Bureau of Meteorology, Commonwealth of Australia, 2019.

3.2.1.1.3 Percent capacity of Ross River Dam

The persistent, widespread daily rainfalls of more than 100 mm over the region resulted in the Ross River Dam reaching a capacity of 245%, up from around 66% in early January, with this steep increase shown in Figure 11. The change in the Ross River Dam levels from January until November 2019 is shown in Figure 11. On the evening of the 3rd February, the Ross River Dam spillway gates opened, releasing 1,900 cubic metres of water per second into the Ross River.

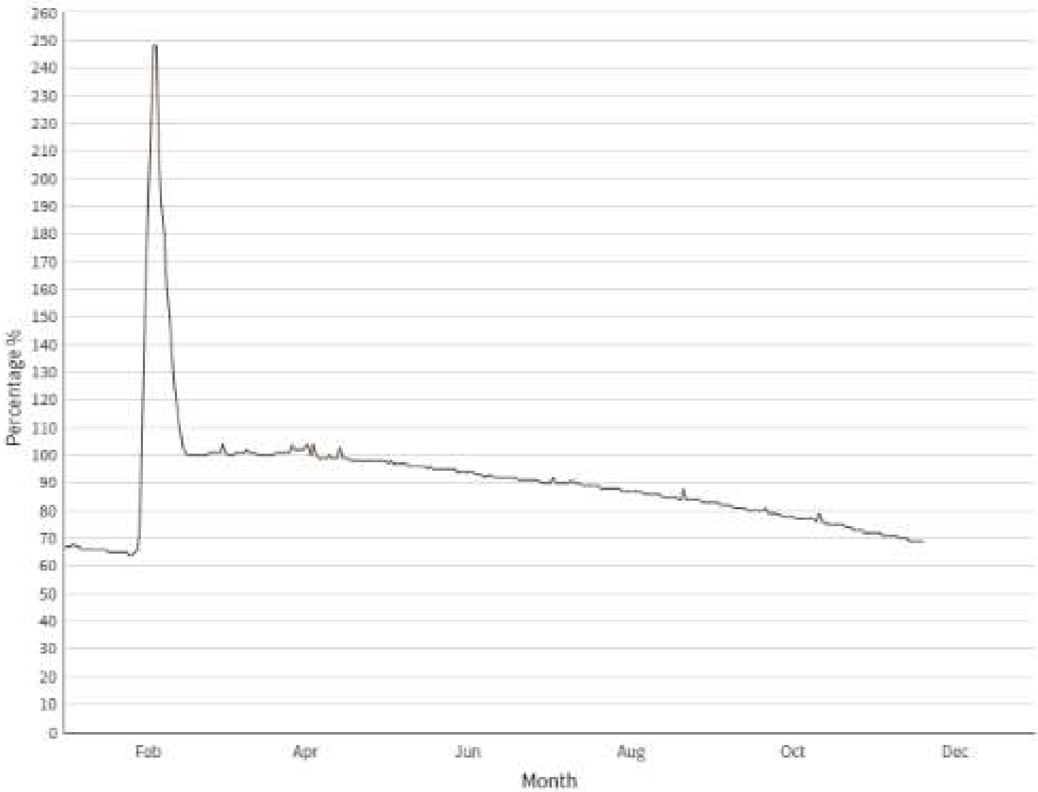


Figure 11. Level (percent capacity) of the Ross River Dam from January until November 2019.

3.2.1.2 *Rainfall in the broader Dry Tropics region*

The broader Dry Tropics region also experienced high rainfall. The amount of rainfall recorded between the 27th January until the 9th February (when most rainfall occurred) at various rainfall stations within the Townsville reporting region and at some stations within the Burdekin region are shown in Table 2. The locations of these rainfall stations are shown in Figure 12. It is noted that some rainfall stations, such as Paluma Dam, received heavy (>100 mm) rain before the 27th January. At all rainfall stations, no or low (<10 mm) rain fell for a week or so after 9th February. Rainfall stations are listed based on the amount of rainfall within the Townsville region and the Broader Dry Tropics/Burdekin Natural Resources Management region.

Table 2. Rainfall from the 27th January until the 9th February 2019 at various weather stations within the Townsville region and the broader Burdekin region.

Reporting region	Gauge station location	Rainfall (mm)
Townsville	Mutarnee Store	1,696
	Rollingstone	1,655
	Yabulu Nickel	1,534
	Mount Stuart (Defence)	1,423
	Townsville Aero Station	1,393
Broader Dry Tropics/ Burdekin Natural Resource Management area	Paluma Ivy Cottage	2,886*
	Woolshed	2,059
	Majors Creek	1,671
	Lansdown CSIRO	1,364
	Townsville Air Weapons Range	1,098
	Horseshoe Bend	1,040
	Mingela Post Office	974

	Powerline TM	970
	Fanning River	757
	Woodhouse	709
	Home Hill Post Office	698
	Clare Alert	666
	Inkerman Bridge	623
	Ayr DPI Research Station	622
	Ravenswood Post Office	487
	Millaroo Alert	481
	Strathbogie Alert	457
	Dalbeg TM	420
	Charters Towers Airport	413
	Burdekin Shire Council	405
	Hillgrove Station	332
	Burdekin Dam Alert	168

*Received over 100 mm in the days prior to the 27th January

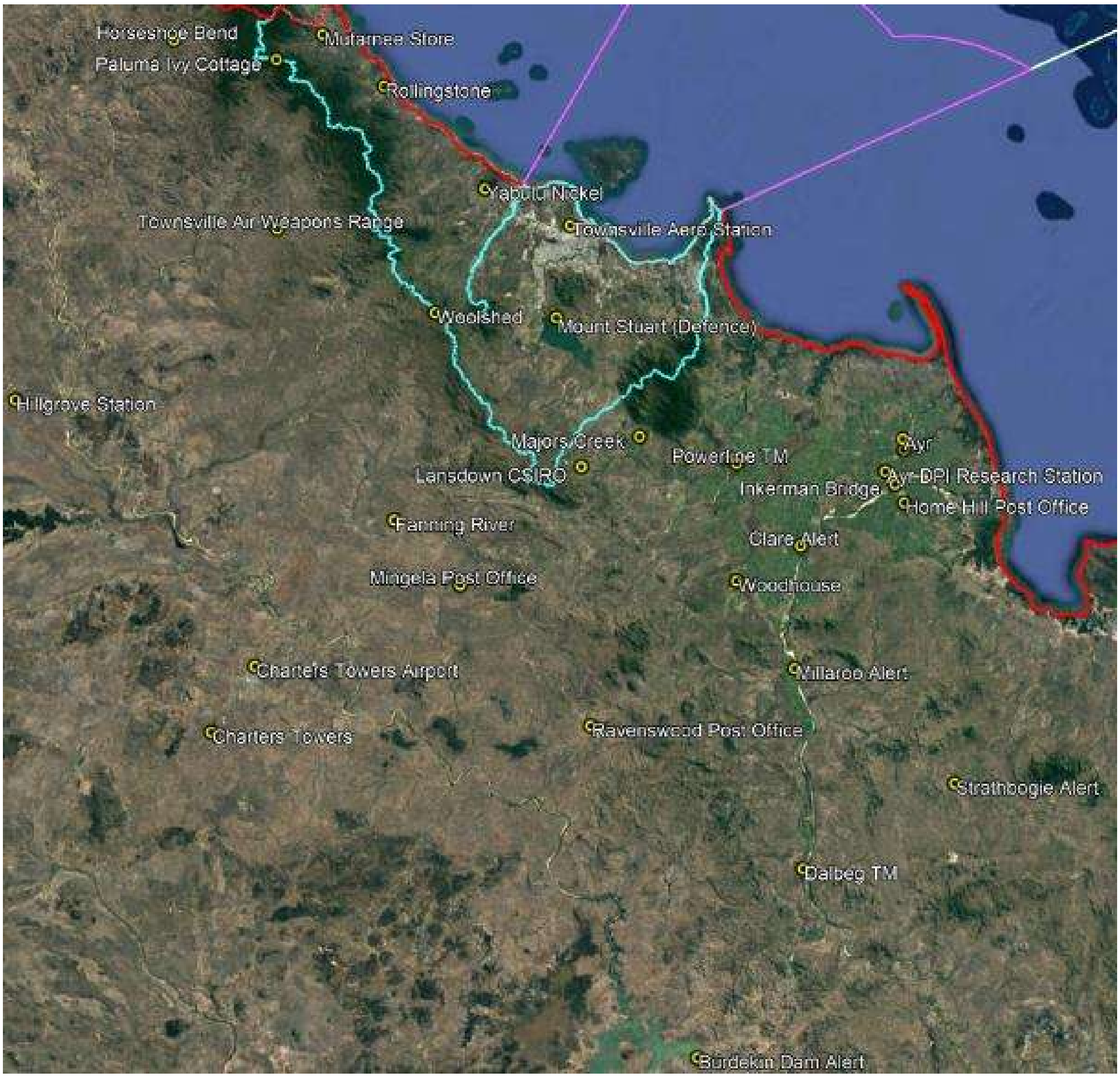


Figure 12. Rainfall stations within the Townsville and the broader Burdekin region.
Only stations in the Burdekin that are near Townsville are shown. The red outline delineates the broader Burdekin area and the blue outline delineates the Black and Ross freshwater basins, which are the two terrestrial Townsville Dry Tropics reporting areas.

On the 10th February, the monsoon moved south westwards and impacted upon north-west regions of Queensland, extending as far west as Mt Isa. The extent of Queensland that experienced higher than average rainfall over the seven-day period is shown in Figure 13. Like Townsville these regions experienced high rainfall and large scale flooding.

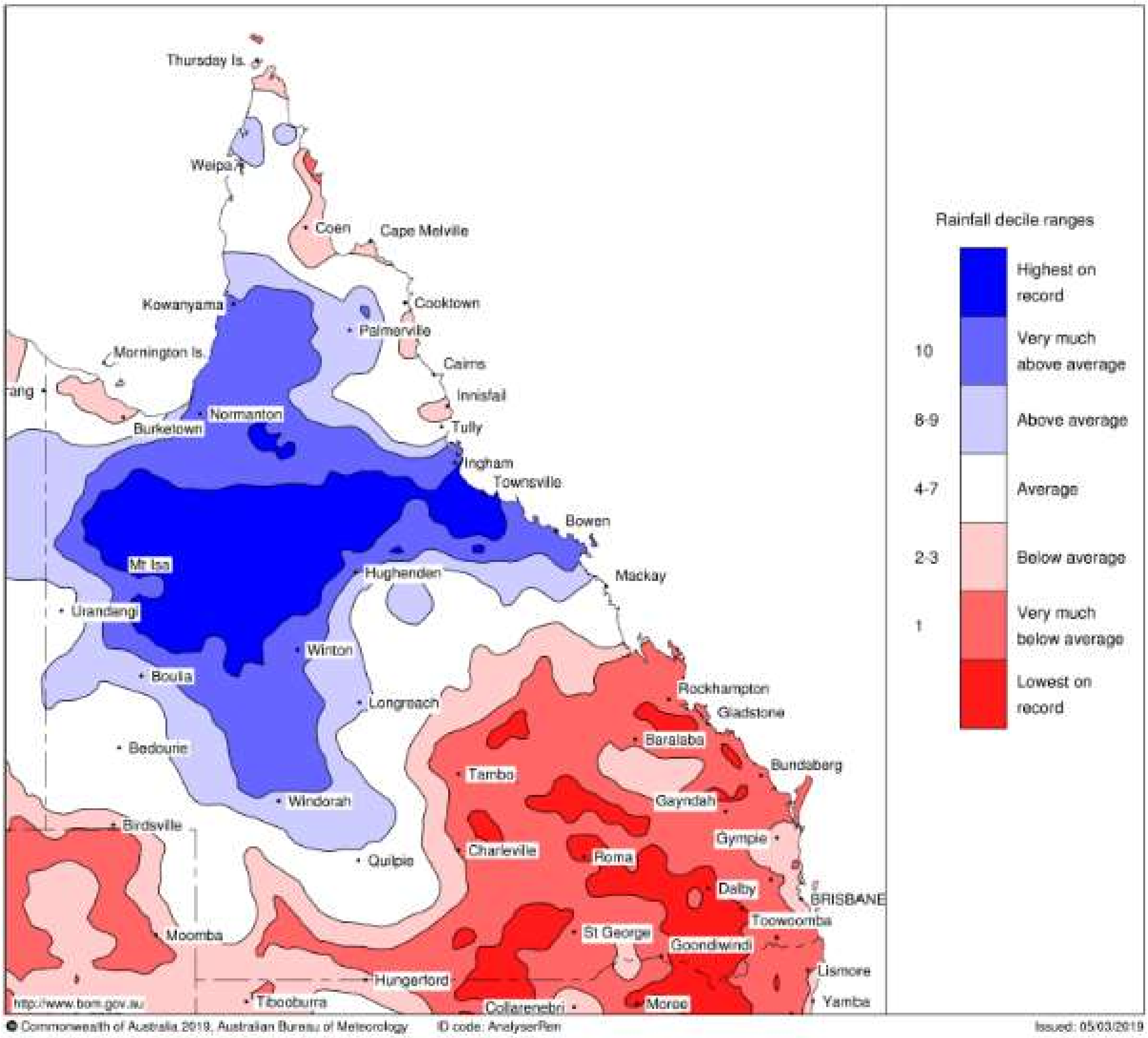


Figure 13. Map of Queensland showing the deciles for the highest 7-day rainfall totals during February 2019.

3.2.2 Runoff rates

Soil saturation and high rainfall meant that runoff during the 2018-19 was the highest on record, with 1,335 mm of runoff recorded in the Ross freshwater basin, which was 1,050 mm above, or 469% of the long-term mean (BOM, 2019b). Within the Black freshwater basin, 1,675 mm of runoff was recorded, which was 1,229 mm above or 375% of the long-term mean (BOM, 2019b). The high rate of runoff meant there was substantial erosion and scouring of riverbanks, resulting in sedimentation of surrounding rivers and creeks. Sedimentation of Ross River and Rollingstone River is shown in Plate 1a and 1b respectively.

Plate 1. Sedimentation of the Ross River and Rollingstone River following the February 2019 flood in Townsville.
Photograph © a) Roslyn Budd and b) Matt Curnock (CSIRO)

3.2.3 Sediment and nutrient discharge into marine water

3.2.3.1 *Discharge from Townsville rivers*

Nutrient and sediment rich waters discharged into the marine area, with discharge from Ross River travelling southwards around Cape Cleveland, as shown in Plate 2a, 2b and 2c. There was a smaller discharge from other rivers that travelled southwards around Cape Pallarenda and into Cleveland Bay, as seen in Plate 2d. In addition to the fine scale sediment and nutrients being washed into the rivers and creeks, large amounts of weeds from the Ross River were washed downstream and deposited into the Port of Townsville (Plate 3).

Plate 2. a, b and c) Discharge from the Ross River travelling southwards around the tip of Cape Cleveland, and d) flood plume travelling southwards into Cleveland Bay following the February 2019 flood in Townsville.
Photograph © Matt Curnock (CSIRO)

Plate 3. Weeds from Ross River deposited within the Port of Townsville following the February 2019 flood in Townsville.
Photograph ©: Port of Townsville.

3.2.3.2 *Discharge from the Burdekin River*

There was substantial erosion of river banks within the Burdekin region, as shown in Plate 4, which resulted in high suspension of the Burdekin River (see Plate 5). The sediment plume from the Burdekin River discharged a thick sediment layer into the marine inshore area (see Plate 6), which extended to and covered some inshore reefs, as shown in Plate 7. Although the Burdekin is not part of the Townsville Dry Tropics reporting region, discharge from the Burdekin River may substantially impacted upon marine waters offshore of Townsville. eReefs modelling has predicted that sediment plumes may travel northward beyond Palm Island as shown in Figure 14.

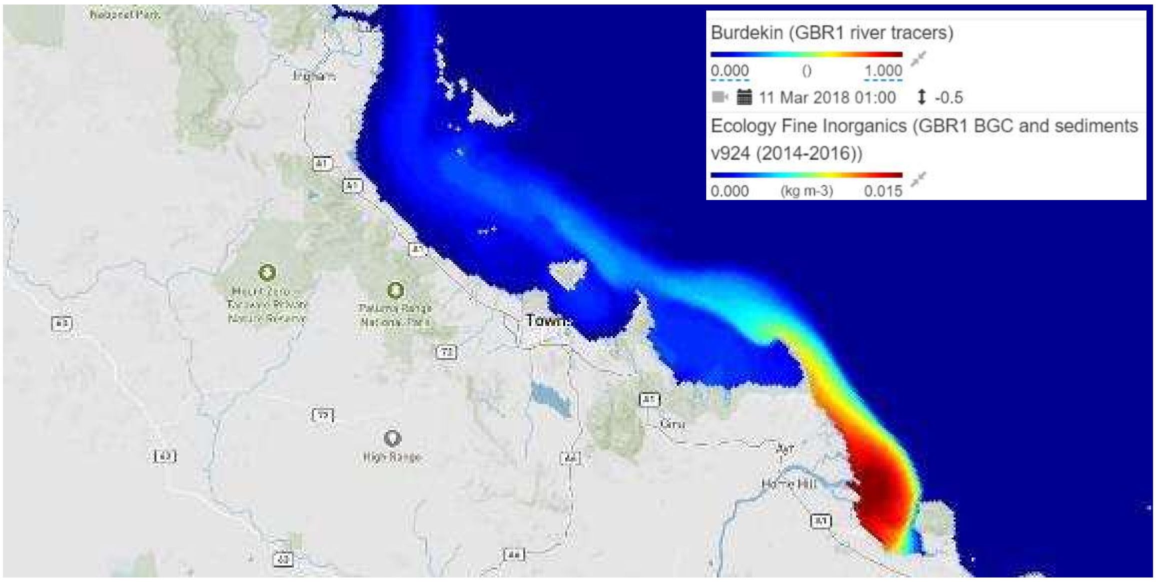


Figure 14. Modelling by eReefs showing a sediment plume on the 9th February 2019 extending from the Burdekin River northwards to Palm Islands.
Source: CSIRO (2019)

Plate 4. Erosion from river and creek gullies within the Burdekin catchment.
Photograph © Matt Curnock (CSIRO)

Plate 5. Sediment suspension of the Burdekin River.
Photograph © Matt Curnock (CSIRO)

Plate 6. Sediment plume from the Burdekin River that discharged into the marine inshore area following the February 2019 flood in Townsville.
Photograph © Matt Curnock (CSIRO)

Plate 7. Sediment plume from the Burdekin River extending to and covering some inshore reefs following the February 2019 flood in Townsville.
Photograph © Matt Curnock (CSIRO)

4 Methods for scoring Water Quality and Biodiversity indicators

4.1 Scoring categories

Indicators of Water Quality and Biodiversity were scored using five ordinal values commonly used in Report Cards, Very good (A) to Very poor €, as shown in Table 3.

Table 3. Standardised scoring range and corresponding grade for Water Quality and Biodiversity indicators and indicator categories.

Scoring range	Grade and colour code
81 to 100	Very Good (A)
61 to <81	Good (B)
41 to <61	Moderate (C)
21 to <41	Poor (D)
0 to <21	Very Poor (E)

Each indicator was scored on a specific scale that was appropriate for the variable being measured and thus some indicators had different scoring ranges. To ensure results for all indicators were comparable, all scores were converted (if required) into a ‘standardised’ score. The standardised score has a scoring range of between 0 and 100, as shown in Table 3. The standardised score includes decimal places to allow grades to be differentiated. For example, 80.9 would be classified as Good, whilst 81 would be classified as Very Good. In the summary tables and in the Report Cards, the scores were presented as integers for simplicity of results.

Scores for each indicator were aggregated into an indicator category, then into an index and then an overall score. Scores can only be aggregated to the next level (i.e. from an indicator category to an index) if they meet the 'minimum information rules for aggregating data'. These rules are:

1. ≥50% of indicators are required to aggregate to an indicator category
2. ≥60% of indicator categories are required to aggregate to an index

The grades for each indicator category and index are presented in a coaster to visually show which components contribute to the overall grade.

The detailed methods to convert the raw habitat data to standardised scores are outlined in the 'Methods for the Townsville Partnership for Healthy Waters (Dry Tropics) annual Report Cards' document (henceforth referred to as the Dry Tropics methods document) (Whitehead, 2019b).

4.2 Confidence measure

The 2018-19 Report Card includes a qualitative confidence measure for each score for the indicator categories within the Water and Biodiversity reporting categories. The confidence scores were based on the accuracy and appropriateness of the data used in the analysis. Confidence scores range from 4.5 to 13.5 and the overall score was allocated a score from very low (1) to very high (5). Confidence scores were calculated using five criteria, which are listed in Table 4. Each criterion was firstly scored from 1 (lowest) to 3 (highest) following the set of rules discussed in the Dry Tropics methods document (Whitehead, 2019b). This score was then weighted using the weightings shown in column three of Table 4. The weightings reflect the importance of each criterion. The definitions for each criterion and more detailed methods for measuring confidence are presented in the Dry Tropics methods document (Whitehead, 2019b).

In future Report Cards, weighting for each criterion may change from the weighting listed in Table 4. A review of the weighting for the representativeness criterion is being undertaken, with the aim of ensuring the confidence measure is less subjective and more transparent.

Table 4. Criteria, score for each criteria and weighting used to generate the confidence score for the indicator categories within Water and Biodiversity.

Criteria	Score	Weighting
Maturity of Methodology	New = 1; Developed = 2; Established = 3	0.36
Validation	Limited = 1; Not comprehensive = 2; Comprehensive = 3	0.71
Representativeness	Low = 1; Moderate = 2; High = 3	2
Directness	Conceptual = 1; Indirect = 2; Direct = 3	0.71
Measured error	>25% = 1; Between 10% and 25% = 2; <10% = 3	0.71

4.3 Baselines that data were compared against

Within current regional Report Cards, indicators were compared to different baselines, with baselines grouped into two categories, which were:

1) progress towards management targets, and

2) earliest available data/earliest baseline.

Ideally the baseline that indicators were compared against would be similar for all indicators (so the scores for indicators were comparable). However, data used in the Report Card was collected from pre-existing monitoring programs, with each program using their own baselines appropriate to that program. As a result, data were compared against two different baselines in this document.

It is important to clearly distinguish between the baselines as they serve different purposes. Comparing against a management target enables managers to assess whether actions are positively or negatively influencing the environment with respect to an agreed target. The agreed target may not be the 'natural' (pre-development) state, but rather a state that is considered acceptable considering environmental, social and economic factors.

Comparing data against the earliest available data is important to show how the environment has changed from 'natural' environments. This is important to ensure that 'natural' baselines used as part of management targets do not shift over time (shifting baseline syndrome). Ideally these baselines would reflect the natural state of the environment pre-European/pre-developed settlement (or pre-land clearing). However, there is no known data available that accurately describes the state of the environment for the Townsville region pre-development. The next best option is to compare present data with the earliest data available. For example, within the Townsville Dry Tropics, the earliest available data for riparian, wetland, saltmarsh and mangrove extent is 1960's aerial surveys (Neldner, et al., 2017), whilst seagrass meadows were first surveyed in 2007 (Bryant, et al., 2019). In the future these baselines could be extended into the past through environmental modelling or advances in palaeoecological reconstructions. In the 2017-18 Pilot Report Card, scoring against the earliest data available was referred to as scoring against pre-European condition. The term 'pre-European condition' or 'pre-development' is not accurate for the Townville Dry Tropics and therefore the term 'earliest baseline' is used in this report instead.

Where data were available, indicators were compared against both targets (progress towards management targets and against the earliest available data). Separate methods were used to analyse data against the different baselines. In the 2018-19 technical report (this document), water quality indicators and indicators of freshwater and estuarine habitat extent were compared against both management targets and earliest baseline. For these indicators, only results of data compared against management targets were presented in the 2018-19 Report Card. All other indicators were only compared against one baseline. Table 5 provides an overview of which baseline/s each index was scored against and which of the scores are shown on the Report Card. Each year the same baselines will be used so that trends in time can be assessed.

Table 5. Summary of the baseline that indicator categories/indices were scored against in the 2018-19 technical reports and in the Report Card.

Index	Indicator categories	Baseline that data was compared against	Baseline that data was compared against for the public summary Report Card
Water	Nutrients and physical and chemical properties (phys-chem)	1. Management targets (water quality objectives), 2. Earliest data (water quality guidelines)	Management targets
Biodiversity	Habitat extent	1. Management targets (change over four years), 2. Earliest data (estimated habitat extent from 1960s)	Management target
	Coral condition	Earliest data	Earliest data
	Seagrass condition	Earliest data	Earliest data
	Artificial barriers	Earliest data	Earliest data
Litter	Litter	Management target	Management target

5 Water Quality results

5.1 Overview of indicator categories and indices

The overall score for Water Quality was based on indicators and indicator categories grouped into the following indices:

- Nutrients and physical and chemical parameters (phys-chem) for the two freshwater and two estuarine zones (Black and Ross)
- Nutrients, phys-chem and chlorophyll *a* for Cleveland Bay and Halifax Bay
- Phys-chem parameters and chlorophyll *a* for the one offshore marine zone.

Only the indicators that were scored in the 2018-19 Report Card are listed above.

The indicator categories and indices aggregated into an overall score for the 2018-19 Report Card are highlighted in Table 6. In the freshwater and estuarine environments, indicators of nutrients and physical-chemical (phys-chem) properties were reported and an overall score generated. In the inshore marine zones (Cleveland Bay and Halifax Bay), indicators of nutrients, phys-chem parameters and chlorophyll *a* were reported and an overall score for water quality generated.

Aspiration indicator categories (categories that the Partnership aims to score in future reports) are indicated by an asterisk in Table 6. There are currently no data and/or scoring method for scoring aspirational indicator categories. In the future, it is aimed that data will become available and methods for scoring indicators will be developed. Aspirational indicator categories were excluded when aggregating scores. This was to allow an overall score for Water Quality to be produced when the minimum information rules for aggregating data were applied. It is important to the Partnership that an overall Water Quality score was produced for the 2018-19 Report Card.

Table 6. Indices and indicator categories that were aggregated to generate an overall score for Water Quality.

The indices and indicator categories aggregated into an overall score for Water for the 2018-19 Report Card are highlighted. Aspirational indicators are shown in white and were not included when aggregating scores.

Zone	Index	Indicator category
Freshwater and estuarine	Hydrology	% catchment impervious/developed
		% native land cover
		Flow
	Nutrients	Total phosphorus (P)
		Dissolved inorganic nitrogen (DIN)
	Phys-chem	Dissolved Oxygen (DO)
		Turbidity
		pH
	Contaminants*	Pesticides
		Metals
		PFAS (freshwater only)
Inshore marine	Nutrients	Total phosphorus
		Oxidised nitrogen (NOx)
		Particulate Nitrogen (PN)
	Phys-chem	Total suspended solids (TSS)
		Turbidity
		Secchi depth
		Temperature
		pH
	Chlorophyll *a*	Chlorophyll *a*
	Contaminants*	Metals
Offshore marine	Phys-chem*	Turbidity/TSS
		Temperature
	Chlorophyll a	Chlorophyll a
Groundwater	Hydrology*	Quantity/recharge rates
	Contaminants*	Salinity/Conductivity

5.2 Comparing water quality data sets against water quality objectives and guideline values

Data were compared against both water quality objectives (WQO) and water quality guidelines (WQG). WQOs are long-term goals for water quality management and define what the water quality should be to protect the ecological value of the system, after consideration of the socio-economic values. In comparison, WQGs are values that are designed to maintain ecosystems in near pre-development condition and are largely based on data from non-impacted waterways (reference sites) or on toxicant concentrations that have negligible impact upon the environment. Water quality objectives act as a proxy for comparing biodiversity indicators against management targets, whilst WQGs act as a proxy for comparisons against a pre-development condition. The WQGs are not regionally specific and instead the values apply to large areas, such as the whole of the central coast of Queensland. The WQOs and especially the WQGs are derived based on wanting to maintain high ecological value within the marine environment (especially of the offshore coral reefs within the Great Barrier Reef) and align with the Australian and New Zealand Environment and Conservation Council water quality guidelines.

It is noted that both the WQOs and the WQGs were derived based on ambient dry weather flows. In Townsville, most rainfall occurs during a 3 month period (Bureau of Meteorology, n.d.). Dry season flows substantially differ to wet season flows, with nutrient and sediment concentrations after the first runoff event is often higher that the ambient dry season flows. There is a need to develop WQOs for both the wet and the dry season to account for this difference in flow regime between the two seasons.

Comparing data against the WQOs was considered more appropriate for the Dry Tropics region given the high level of development within the region. Specific water quality objectives have been derived for the Townsville Ross and Black basins (see section below). Using regionally derived WQOs is more appropriate than using WQGs, as WGOs tend to be derive based on specific waters within the Townsville Dry Tropics (although not always). WQGs were derived for seven different regions, with waterways within the Townsville Dry Tropics being classified based on the WQGs for the Central region (Department of Environment and Heritage Protection, 2009). The Central region extends north from the Burnett River Basin to the Black River Basin (Department of Environment and Heritage Protection, 2009). Reference sites within the freshwater, estuarine and inshore marine waters were chosen to derive the WQGs for these three water types (Department of Environment and Heritage Protection, 2009). However, only a few of these reference sites were within the Townsville Dry Tropics, with Table 7 showing the number of reference sites for the Central region and the number of these that were in the Townsville Dry Tropics region.

Table 7. Number of reference sites used to derive the water quality guideline values (WQGs) for the freshwater, estuarine and inshore waters of the Central region and the number of these reference sites that were within the Townsville Dry Tropics region.

	No. of reference sites for the Central region (incl. the Townsville Dry Tropics)	No. of reference sites within the Townsville Dry Tropics	Location of reference sites within the Townsville Dry Tropics
Freshwater	114	4	Little Crystal creek at Paluma Road, Little Crystal Creek at Moodys, Bluewater Creek at foothills and Alligator Creek at Bowling Green Bay NP
Estuary	15	0	None
Upper Estuary	2	0	None
Inshore marine enclosed coastal	5	0	None
Inshore marine open coastal	1	1	Cleveland Bay Grid Reference 915785 (Mid Bay)

Only scores derived from comparing data against WQOs (management targets) were displayed on the Report Card and are presented in the main text of this document. The results for analysing freshwater, estuarine and inshore marine water quality data against WQGs are shown in Appendix B. For the offshore marine zone, data were only compared against WQGs, as local WQOs have not been defined.

5.2.1 Water quality objectives

Scheduled environmental protection policy WQOs for the freshwater, estuarine, marine inshore and offshore marine zones were sourced from three regionally specific documents. These are:

1. Environmental Protection (Water) Policy 2009: Ross River Basin and Magnetic Island Environmental Values and Water Quality Objectives, Basin No. 118 including all waters of the Ross River Basin, and adjacent coastal waters (including Magnetic Island) (Environmental Policy and Planning Division, 2013). This document was the source for the WQOs for the Ross freshwater basin (freshwater and estuarine waters) and the inshore waters (Cleveland Bay and Magnetic Island).
2. Environmental Protection (Water) Policy 2009: Black River Basin Environmental Values and Water Quality Objectives Basin No. 117, including all waters of the Black River Basin and adjacent coastal waters (Environmental Policy and Planning Division, 2013). This document was the source for the WQOs for the Black freshwater basin (freshwater and estuarine waters) and the inshore waters (Halifax Bay).
3. Environmental Protection (Water) Policy 2009: Tully, Murray and Hinchinbrook Is. River Basins - Environmental Values and Water Quality Objectives - Basins Nos. 113, 114 and 115 and adjacent coastal (Division, Environmental Policy and Planning, 2014). This document was the source for the WQOs for the inshore waters at Pandora Reef and Pelorus Island and, which were the two monitoring sites within Halifax Bay.

When developing the scores and grades for the 2017-18 Pilot Report Card, inconsistencies in the WQOs were determined, with some WQOs based on values from south-eastern creeks and rivers. As a result, some WQOs were adjusted by water quality experts based on more recent sampling undertaken within the Townsville region. Experts decided that all rivers within the same basin, excluding freshwater lakes/reservoirs, would be given the same WQOs, rather than applying different WQOs to specific aquatic ecosystems (as listed under the scheduled policy). These adjustments mean the differences in scores between rivers were driven by differences in water quality, rather than differences in WQOs. The WQOs used for the freshwater and estuaries ecosystems within the Ross freshwater basin and Black freshwater basin are outlined in Table 8, with the adjusted values asterisked. WQOs applicable to Cleveland Bay (offshore of Ross freshwater basin), Halifax Bay (offshore of Black freshwater basin) and the offshore marine zone are presented in Table 9. These values were deemed acceptable by experts and were not adjusted. WQOs have only been listed for the zones where data were available and the zones that were scored in the Report Card.

Table 8. Scheduled and adjusted environmental protection policy water quality objectives for water quality indicators for the Ross and Black freshwater basins and estuarine environments.

NOx indicates oxidised nitrogen and Total P indicates total phosphorus. An asterisk (*) indicates that the value has been adjusted through expert opinion to recognise regional factors. Values for dissolved oxygen (DO) are presented as lower-upper boundary values.

			Ross freshwater basin		Black freshwater basin		Black and Ross freshwater basins
Indicator category	**Indicator**	**Unit**	**Freshwater**	**Estuaries**	**Freshwater**	**Estuaries**	**Freshwater lakes/ reservoirs**
Nutrients	DIN	µg/L	<80	<70*	<20*	<20	<20
	Total P	µg/L	<50	<50	<20*	<25	<30
Physical-chemical	Turbidity	NTU	<22	<20	<5*	<8	<10*
	DO	% sat.	85-110	85-105	90-105*	85-105*	90-110

Table 9. Scheduled environmental protection policy water quality objectives for water quality indicators for Cleveland Bay, Halifax Bay and the offshore marine environment.

NOx indicates oxidised nitrogen and Total P and Particulate indicates total phosphorus and particulate phosphorus. TSS stands for total suspended solids. Where a range of three values are listed, the middle value is used. However, when the middle value is zero, the upper value is used. MD indicates that the guideline values are written for moderately disturbed areas, SD represents the guideline values are for slightly disturbed areas, whilst HEV means the area is of high ecological value.

			Cleveland Bay			Halifax Bay
Indicator category	**Indicator**	**Unit**	**MD2242 Cleveland Bay enclosed coastal/lower estuary waters, & Breakwater Marina (MD)**	**MD2242 Cleveland Bay open coastal waters**	**SD2245 enclosed coastal waters (Geoffrey Bay is within SD2244 but there are no guidelines for that zone).**	**Wet Tropics Open coastal (HEV3121/ SD3121)**
Nutrients	NOx	µg/L	<9	<2	2-4-9	0-0-1
	Particulate N	µg/L	<20 (using MD2242 Cleveland Bay open coastal waters guidelines)	<20	<20 (using MD2242 Cleveland Bay open coastal waters guidelines)	<20
	Total P	µg/L	<30	<30	15-20-30	8-14-22
	Particulate P	µg/L	<2.8 (using MD2242 Cleveland Bay open coastal waters guidelines)	<2.8	<2.8 (using MD2242 Cleveland Bay open coastal waters guidelines)	<2.8
Physical-chemical	Turbidity	NTU	<4.9	<3	0.4-1.0-4.9	0.6-0.9-1.8
	TSS	mg/L	<15	<10	7-10-15	<2
	Secchi depth	m	<1	>3	1.0-1.4-1.9	>10
Chlorophyll *a*	Chlorophyll *a*	µg/L	<2.6	<1	1.0-1.6-2.6	<0.45
Monitoring sites			Enclosed coastal waters	Open coastal waters	Geoffrey Bay	Pelorus Island, Pandora Reef

5.3 Overview of rivers and monitoring sites within the reporting region

There are three major rivers within the reporting extent. These rivers are the Black River, within the Black Basin, and the Ross River and Bohle River, both of which are within the Ross Basin. Across the two catchments there are 13 freshwater sites and 12 estuarine sites. The location of monitoring sites in relation to the main rivers and land use in the Townsville Dry Tropics region is shown in Figure 15.

The Ross River has four major impoundments: Ross River Dam and three weirs, Black School weir (referred to as Black weir), Gleeson's weir, and Aplin's weir. During the wet season, heavy rainfall can result in flow overtopping the impoundments, providing connectivity from the headwaters to the coast. During 2018-19, the flood event in February 2019 resulted in water overtopping the weirs for around four months.

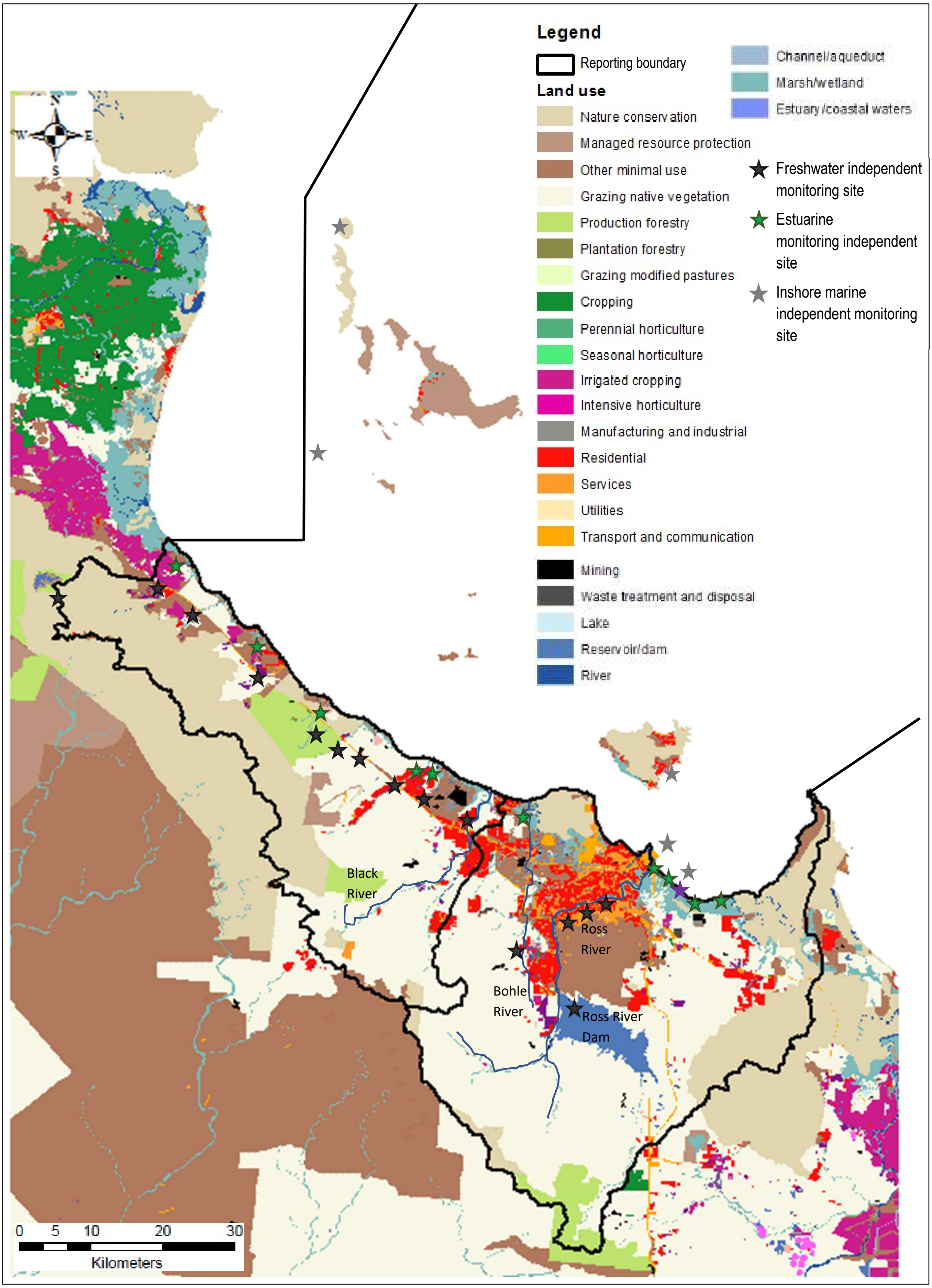


Figure 15. Location of monitoring sites in relation to the main rivers and land use in the Townsville Dry Tropics region.

Source: Adapted from maps from Department of Science, Information Technology and Innovation (DSITI) (2017).

5.4 Position of monitoring sites in relation to land use

Water quality in a watercourse is generally influenced by land use activities upstream in the catchment (Huan, et al., 2013). The land use in relation to the monitoring sites within the Townsville Dry Tropics are shown in Figure 15. Rainfall, groundwater inputs and retention in standing water bodies can also affect water quality (DNRME 2019, pers. comm., 25 January 2019). Water quality within the Ross River weirs are influenced by inflow from upstream sources, direct rainfall, localised catchment runoff (including runoff from irrigated areas) and groundwater (DNRME 2019, pers. comm., 25 January 2018). The Ross River is also influenced by stormwater inputs, with stormwater drains collecting water from nearby urban areas and transferring it directly into the Ross River. Water quality within the Ross River Dam is also affected by the occasional supplementation from the Haughton Balancing Storage.

5.5 Classification of independent and non-independent sites

Water quality data were collected from multiple sites throughout the freshwater and estuarine environments within the Ross and Black freshwater basins. In some cases, there was more than one sampling location along the same river, creek or estuary. When this occurred, sites were classified as independent or non-independent sites. To be classified as an independent site, there must be substantial input into the waterway between the two sites. Examples of a substantial input include a tributary, storm water input or a sewage treatment plant.

If sites were not independent, data from the sites were combined into one independent site and one score was produced. An overall score for a reporting zone was then calculated by averaging the scores for all independent sites. For ease of understanding, non-independent sites were referred to as monitoring locations. A monitoring location thus represents the specific location where a sample was taken, whilst a monitoring site refers to the collective of one or more monitoring locations. The methods for scoring independent sites and sites with multiple monitoring locations are outlined in the Methods for the Townsville Partnership document (Whitehead, 2019b).

5.6 Overview of weighting sites by catchment area

Independent freshwater and estuarine sites were weighted by the proportion of the catchment area that each site represents (i.e. the catchment area that drains into where the sampling site was located). The detailed description of how to calculate the catchment area is outlined in the Methods for the Dry Tropics Partnership document (Whitehead, 2019b). It is noted that weighting by catchment area does not provide a precedent for other indicators to be weighted by catchment area. All indicators will be individually assessed as to which was the more suitable method to calculate their scores.

5.7 Freshwater basin results

5.7.1 Overview of monitoring sites

Monitoring occurred at five independent sites within the Ross freshwater basin and 10 independent sites within the Black freshwater basin. At Ross River Dam, Bohle River and Paluma Dam, samples were collected at multiple locations at the site. At all other sites, only one sample was taken from approximately the same location each month.

Within the Ross Bain, all sites were monitored monthly using grab samples. When collating data for the 2017-18 Pilot Report Card, it was found that no estuarine or freshwater monitoring occurred within the Black freshwater basin, except for monthly compliance monitoring at Paluma Dam. To address this knowledge gap, the Department of Environment and Science began monthly monitoring at nine freshwater and five estuarine sites within the Black freshwater basin. Monthly sampling within these sites began in April 2019. For the 2018-19 financial year, there was thus only three data samples collected at each of these sites. These three data samples were used to derive the scores for these sites.

The freshwater monitoring sites within the Ross freshwater basin are:

- Bohle River, comprising two monitoring locations, which are the mid- and far-field receiving end monitoring sites for the Condon Sewage Treatment Plant.
- Lower Ross River, comprising three monitoring locations, which are Aplin's, Gleeson's and Black School (Black) weirs.
- Upper Ross River (Ross River Dam), comprising seven monitoring locations.

The position of monitoring sites within the Ross freshwater basin are shown in Figure 16.

Monitoring occurs at 10 independent monitoring sites within the Black freshwater basin, with one monitoring location at each site. These sites are listed below:

- Black River
- Althaus Creek
- Bluewater Creek
- Sleeper Log Creek
- Leichardt Creek
- Saltwater Creek
- Rollingstone Creek
- Ollera Creek
- Crystal Creek
- Paluma Dam

The position of monitoring sites within the Black freshwater basin are shown in Figure 17.

It is noted that within both basins, dams were scored and included when averaging the overall scores for the basin. Dams were included because they are crucially important to the Townsville community, with the Ross River being the main river through Townsville.

Figure 16. Monitoring locations within the Ross freshwater zone, showing (1) the mid and far-field monitoring locations for the Condon Sewage Treatment Plant (STP), (2) the monitoring along Lower Ross River and (3) monitoring within the Upper Ross River (Ross River Dam).

The blue outline in the middle picture delineates the Ross freshwater zone, with the yellow outline delineating the Ross estuarine zone.

Figure 17. Freshwater monitoring locations (blue dots) within Black freshwater basin.
The red line delineates the Black freshwater reporting zone, whilst the orange outline delineates the Black estuarine reporting zone.

5.7.2 Comparing water quality against water quality objectives

This section presents the results for water quality indicator categories compared against water quality objectives. The results derived from comparing data against water quality guidelines are presented in Appendix B.

5.7.2.1 *Results*

Water quality scores were derived from two indices (nutrients and phys-chem parameters), with the results for freshwater water quality presented in the following sections. The distributions of data for each indicator are presented as boxplots in Appendix C. It is noted that the scores for this year (2018-19) are not comparable to 2017-18 scores because this year additional sites were sampled, and scores were weighted.

The scores and grades presented in Table 10, Table 11 and Table 12 indicate whether water quality within the river or basin met the regionally derived WQO for each indicator. For Table 10 and Table 11, the scores for nutrients were averaged from the scores for TP and DIN (Table 10), whilst the scores for phys-chem parameters were averaged from the scores for turbidity and the numerically lower DO score (Table 11). Scores for water quality were averaged from the scores for nutrients and physical-chemical parameters (Table 12). Scores for water quality were averaged from the scores for nutrients and physical-chemical parameters. Scores for the Lower Ross River were the averages of scores for the Black, Gleeson's and Aplin's weirs (shown in brown writing). The scores for the Bohle River were calculated from the far and mid field sites (shown in brown writing). Scores for Ross freshwater basin were averaged from the scores for Upper Ross River, Lower Ross River and Bohle River. The scores for Black freshwater basin were calculated by averaging the scores for all the sites within that zone. Weighted and non-weighted scores are shown in the tables, with weightings based on the proportion of the catchment area that each independent site represents. For all independent sites, weighted and non-weighted scores are presented, whilst only non-weighted scores are shown for non-independent sites. The overall scores and grades for each indicator and indicator category for the Ross and Black freshwater basins were calculated by summing the weighted scores of all independent sites.

5.7.2.1.1 Nutrients

The scores for nutrients were derived from averaging the scores for the two indicator categories, total phosphorus (TP) and dissolved inorganic nitrogen (DIN). The results for TP and DIN are presented in Table 10. To calculate the overall score for the nutrients index, the scores for each site were weighted based on the proportion of the catchment that each site represented. The measured catchment area and the proportion of the catchment represented by each site is also displayed in Table 10. For each site, unweighted scores were also calculated for each indicator category and index (see Table 10). This allows the condition of each site to be directly comparable and these scores provide an insight into water quality at each site.

The Ross freshwater basin was in a good condition with respect to nutrient concentrations. The Upper Ross River (Ross River Dam) and the Lower Ross River were in a very good and good condition respectively, as shown in Table 10. The Bohle River was in a poor condition and contained high TP concentrations, resulting in very poor scores for TP (Table 10). The Condon Sewage Treatment plant discharges into the Bohle River and this may account for the poor scores for Bohle River. However, the Bohle River has a low weighting compared to the Upper and Lower Ross River, with the Bohle River only representing 12% of the catchment area. This means that these very poor scores had minimal impact upon the overall score for the Ross freshwater basin.

Overall, the Black freshwater basin was in a good condition (Table 10). Most rivers (seven of the ten sites) were in a good or very good condition (Table 10). However, these seven rivers each contributed 10% or less to the overall score for the Black freshwater basin (Table 10). The Black River and Bluewater Creek had two of the worst scores of the 10 sampled rivers, receiving a poor and moderate grade respectively (Table 10). Black River contributed 37% (highest percentage contribution) to the overall score, and Bluewater Creek contributed 13% (the second highest percentage) (Table 10). The scores for these tow waterways lowered the overall score for the Black freshwater basin. There is a greater amount of industrial and urban development surrounding the Black and Bluewater River compared to the other rivers within the Black Basin and this is a possible explanation for the lower water quality scores of these rivers.

Table 10. Integer scores and grades for total phosphorus (TP), dissolved inorganic nitrogen (DIN) and nutrients for freshwater sites.

	Non-weighted scores and grades						Catchment area							
Site	Score			Grade			Catchment area draining into site (km^2)	Proportion of measured catchment area	Weighted score/contribution to final score			Overall Grade		
	DIN	TP	Nutrients	DIN	TP	Nutrients			DIN	TP	Nutrients	DIN	TP	Nutrients
Upper Ross River (Ross River Dam)	90	90	90	A	A	A	458	0.32	29	29	29			
Lower Ross River	67	61	67	B	B	B	786	0.56	37	34	37			
Black Weir	63	61	62	B	B	B								
Gleeson's Weir	68	ND	68	B	ND	B								
Aplin's Weir	71	ND	71	B	ND	B								
Bohle River	68	0	34	B	E	D	169	0.12	8	0	4			
Bohle far-field	72	0	36	B	E	D								
Bohle mid-field	64	0	32	B	E	D								
Ross freshwater basin	**75**	**50**	**64**	**B**	**C**	**B**	**1413**	**1**	**75**	**63**	**70**	**B**	**B**	**B**
Black River	49	0	24	C	E	D	250	0.37	18	0	9			
Althaus Creek	90	43	66	A	C	B	35	0.05	5	2	3			
Bluewater Creek	20	90	55	E	A	C	86	0.13	3	11	7			
Sleeper Log Creek	41*	90	65	D	A	B	41	0.06	2	5	4			
Leichardt Creek	71	90	81*	B	A	B	38	0.06	4	5	5			
Saltwater Creek	74	90	82	B	A	A	36	0.05	4	5	4			
Rollingstone Creek	0	90	45	E	A	C	71	0.10	0	9	5			
Ollera Creek	90	90	90	A	A	A	39	0.06	5	5	5			
Crystal Creek	80	90	85	B	A	A	77	0.11	9	10	10			
Paluma Dam	51	90	70	C	A	B	2	0.00	0	0	0			
Black freshwater basin	**57**	**76**	**66**	**C**	**B**	**B**	**675**	**1**	**50**	**52**	**52**	**C**	**C**	**C**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap (ND)

*The score was on the boundary of the scoring range and rounding to whole numbers resulted in the score being rounding up into the scoring range of the next category. Without rounding, the score is in the grade shown in the table (as grades were based on the score prior to rounding).

5.7.2.1.2 Physical-chemical parameters

The results for the phys-chem index were derived from two indicator categories, turbidity and dissolved oxygen (DO). The results for these indicators and the overall phys-chem index are presented in Table 11. Both Ross freshwater basin and Black freshwater basin were in a good condition with respect to phys-chem parameters, with all rivers sampled being in a moderate to very good condition overall. Turbidity concentrations were rated as moderate to very good at all sites, which was surprising given the large flood event that occurred in February. Immediately following the February floods, aerial images showed high sedimentation of many rivers. Sampling at Ross River Dam and Paluma Dam showed that turbidity levels within the dams were substantially higher in March (post-flood) compared to January (pre-flood). By April concentrations were only slightly higher than pre-flood concentrations and by May turbidity concentrations were back to pre-flood concentrations. This trend was not observed within the three weirs along Ross River, with the turbidity concentrations being similar in January (pre-flood), February and March (both post-flood).

Lower DO received the lowest score of the three indicators, especially within the Ross freshwater basin, where the indicator was usually in a poor condition. The poor DO results may be due to long residence time of water within the weirs (with little or no flow of water between the weirs for most of the year). Within the Ross freshwater basin, data was collected in all months except February (due to the floods).

Table 11. Integer scores and grades for turbidity, lower dissolved oxygen (DO), upper DO and the overall physical-chemical (phys-chem) properties for freshwater sites.

	Non-weighted scores and grades								Catchment area									
Site	Score				Grade				Catchment area draining into site (km^2)	Proportion of measured catchment area	Weighted score/contribution to final score				Overall Grade			
	Turb-idity	Upper DO	Lower DO	Phys-chem parameters	Turb-idity	Upper DO	Lower DO	Phys-chem parameters			Turb-idity	Upper DO	Lower DO	Phys-chem parameters	Turb-idity	Upper DO	Lower DO	Phys-chem parameters
Upper Ross River (Ross River Dam)	90	90	90	90	A	A	A	A	458	0.32	29	29	29	29				
Lower Ross River	90	90	31	61*	A	A	D	C	786	0.56	50	50	17	34				
Black Weir	90	90	39	64	A	A	D	B										
Gleeson's Weir	90	90	0	45	A	A	E	C										
Aplin's Weir	90	90	55	73	A	A	C	B										
Bohle River	71	90	18	45	B	A	E	C	169	0.12	9	11	2	5				
Bohle far-field	68	90	36	52	B	A	D	C										
Bohle mid-field	74	90	0	37	B	A	E	D										
Ross freshwater basin	**84**	**90**	**47**	**65**	**A**	**A**	**C**	**B**	**1413**	**1**	**88**	**90**	**48**	**68**	**A**	**A**	**C**	**B**
Black River	90	47	90	68	A	C	A	B	250	0.37	33	17	33	25				
Althaus Creek	61	29	90	45	B	D	A	C	35	0.05	3	2	5	2				
Bluewater Creek	61	54	90	57	B	C	A	C	86	0.13	8	7	11	7				
Sleeper Log Creek	61	90	90	76	B	A	A	B	41	0.06	4	5	5	5				
Leichardt Creek	66	90	90	78	B	A	A	B	38	0.06	4	5	5	4				
Saltwater Creek	90	90	90	90	A	A	A	A	36	0.05	5	5	5	5				
Rollingstone Creek	90	90	90	90	A	A	A	A	71	0.10	9	9	9	9				
Ollera Creek	90	90	35	63	A	A	D	B	39	0.06	5	5	2	4				
Crystal Creek	90	90	90	90	A	A	A	A	77	0.11	10	10	10	10				
Paluma Dam	90	90	52	71	A	A	C	B	2	0.00	0.2	0.2	0.1	0.2				
Black freshwater basin	**79**	**76**	**81***	**73**	**B**	**B**	**B**	**B**	**675**	**1**	**81**	**65**	**85**	**71**	**A**	**B**	**A**	**B**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap

*The score was on the boundary of the scoring range and rounding to whole numbers resulted in the score being rounding up into the scoring range of the next category. Without rounding, the score was in the grade shown by the colour in the table (as grades were based on the score prior to rounding).

5.7.2.1.3 Overall water quality

As shown in Table 12, water quality was in a good condition for both the Ross and Black freshwater basins. Bohle River was the only river with poor water quality overall, with all other rivers having moderate to very good water quality (Table 12).

Table 12. Water quality scores and grades for freshwater sites.

The overall scores for water quality were averaged from the scores for nutrients and phy-chem properties.

	Non-weighted scores and grades						Weighted scores/contribution to grade and grades					
	Score			Grade			Score			Grade		
Site	Nutr-ients	Phys-chem	Water quality	Nutr-ients	Phys-chem	Water quality	Nutr-ients	Phys-chem	Water quality	Nutri-ents	Phys-chem	Water quality
Upper Ross River (Ross River Dam)	90	90	90	A	A	A						
Lower Ross River	67	61*	64	B	C	B						
Black Weir	62	64	63	B	B	B						
Gleeson's Weir	68	45	56	B	C	C						
Aplin's Weir	71	73	72	B	B	B						
Bohle River	0	45	22	E	C	D						
Bohle far-field	36	52	44	D	C	C						
Bohle mid-field	32	37	34	D	D	D						
Ross freshwater basin	**52**	**65**	**59**	C	B	C	**66**	**68**	**69**	**B**	**B**	**B**
Black River	24	68	46	D	B	C						
Althaus Creek	66	45	56	B	C	C						
Bluewater Creek	55	57	56	C	C	C						
Sleeper Log Creek	65	76	70	B	B	B						
Leichardt Creek	81*	78	79	B	B	B						
Saltwater Creek	82	90	86	A	A	A						
Rollingstone Creek	45	90	68	C	A	B						
Ollera Creek	90	63	76	A	B	B						
Crystal Creek	85	90	88	A	A	A						
Paluma Dam	70	71	71	B	B	B						
Black freshwater basin	66	**73**	70	B	B	B	**52**	**71**	**62**	**C**	**B**	**B**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap

*The score was on the boundary of the scoring range and rounding to whole numbers resulted in the score being rounding up into the scoring range of the next category. Without rounding, the score was in the grade shown by the colour in the table (as grades were based on the score prior to rounding).

5.7.2.2 Confidence scores

There was low confidence in the scores for water quality for the Ross and Black freshwater basins. The score for each criterion is shown in Table 13. The low confidence was due to limited spatial sampling within the Ross freshwater basin, with only three rivers being sampled within this basin. There was also low temporal sampling with the Black freshwater basin, with all results (except for Paluma Dam) based on only three months' worth of data. The methods for sampling nutrients and phys-chem parameters are standard methods. However, the method of weighting sites based on catchment area is a new method. Taking into consideration these two factors, the maturity of method was scored two (out of three).

Table 13. Confidence scores for nutrients, physical-chemical parameters and water quality for the Ross freshwater basin and Black freshwater basin.

Confidence criterion were scored 1-3 and weighted by the value identified in parenthesis. Weighted scores were summed to produce a final score (4.5 – 13.5). Final scores were ranked from 1 to 5 (very low to very high).

Indicator category	Maturity of method (x0.36)	Validation (x0.71)	Represe-ntativeness (x2)	Directness (x0.71)	Measured error (x0.71)	Final score	Rank
Nutrients	2	3	1	3	1	7.6	Low (2)
Phys-chem	2	3	1	3	1	7.6	Low (2)
Water quality index						**7.6**	**Low (2)**

Rank based on final score: Very low (1): 4.5 – 6.3; Low (2): >6.3 – 8.1; Moderate (3): >8.1 – 9.9; High (4): >9.9 – 11.7; Very high (5): >11.7 – 13.5.

5.8 Estuarine zone results

5.8.1 Overview of estuarine monitoring sites

Water quality scores for estuarine zones were derived from two indices, nutrients and phys-chem parameters. There are seven independent monitoring sites in the estuaries within the Ross estuarine zone, and five within the Black estuarine zone. Sites were classified as independent or dependent using the same protocol as used for the freshwater sites. Water samples were collected using grab samples, with samples taken monthly at one to three locations per estuary. In the Black freshwater basin, monthly monitoring started in April 2019 within five estuaries, meaning results were derived based on only three samples at each site.

The independent monitoring sites within the Ross estuary are:

- Bohle River estuary, comprising one monitoring location
- Louisa Creek estuary, comprising three monitoring locations
- Ross Creek estuary, comprising three monitoring locations
- Ross River estuary, comprising one monitoring location
- Stuart Creek estuary, comprising one monitoring location
- Sandfly Creek estuary, comprising two monitoring locations
- Alligator Creek estuary, comprising one monitoring location

The sites and the monitoring locations within each site are shown in Figure 18.

Figure 18. Monitoring locations within the Ross estuary zone.
Monitoring locations include the Bohle River estuary (green dot), Louisa Creek estuary (purple dots), Ross Creek estuary (red dots), Ross River estuary (pink dot), Stuart Creek estuary (yellow dot), Sandfly Creek estuary (orange dots) and Alligator Creek estuary (blue dot). The yellow outline delineates the Ross estuarine zone. The blue lines show the creeks and rivers.

There are five independent monitoring sites within the Black estuary reporting zone, which are:

- Bluewater Creek estuary, comprising one monitoring location
- Deep Creek estuary, comprising one monitoring location
- Saltwater Creek estuary, comprising one monitoring location
- Rollingstone Creek estuary, comprising one monitoring location
- Crystal Creek estuary, comprising one monitoring location

Locations of monitoring sites are shown in Figure 19.

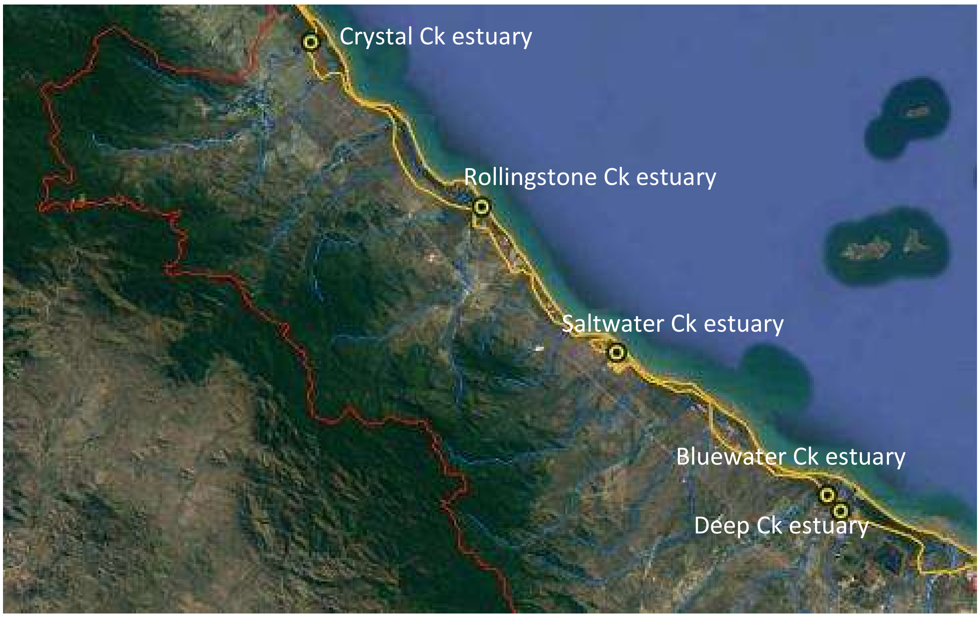


Figure 19. Estuarine (yellow dots) monitoring locations within Black freshwater basin.
The red and orange lines delineate the Black freshwater and estuarine reporting zones respectively

5.8.2 Comparing water quality against water quality objectives

This section presents the results for water quality indicator categories compared against water quality objectives.

5.8.2.1 *Results*

The results for the indicator categories are presented in the following sections. The distributions of scores for each indicator are presented as boxplots in Appendix C. It is noted that the scores for this year (2018-19) are not comparable to 2017-18 scores because additional sites were sampled this year (2018-19) and 2018-19 scores were weighted.

In Table 14, Table 15 and Table 16 scores and grades indicate whether water quality within each estuary met the regionally derived water quality objectives for each indicator. The scores for nutrients were averaged from the scores for TP and DIN (Table 14), the scores for phys-chem parameters were averaged from the scores for turbidity and the numerically lower DO score (Table 15) and the scores for overall water quality were averaged from scores for nutrients and phys-chem parameters (Table 16). Scores for Louisa Creek Estuary were calculated by averaging the scores from three monitoring locations (shown in brown writing) and scores for Ross Creek Estuary and Sandfly Creek Estuary were calculated by averaging the scores from two monitoring locations (shown in brown writing). Scores for Ross freshwater basin were averaged from the scores for Alligator Creek Estuary, Bohle River Estuary, Louisa Creek Estuary, Ross Creek Estuary, Ross River Estuary and Sandfly Creek Estuary. The scores for Black freshwater basin were calculated by averaging the scores for all the sites within that zone. Weighted and non-weighted scores are shown in the tables, with weightings based on the proportion of the catchment area that each independent site represents. For all independent sites, weighted and non-weighted scores are presented, whilst only non-weighted scores are shown for non-independent sites. The overall scores and grades for each indicator and indicator category for the Ross and Black freshwater basins were calculated by summing the weighted scores of all independent sites.

5.8.2.1.1 Nutrients

The scores for nutrients were derived from two indicator categories, total phosphorus (TP) and dissolved inorganic nitrogen (DIN). DIN was calculated by summing oxidised nitrogen (NOx) and Ammonium (i.e. NOx-N + Ammonia-N). The results for total phosphorus, DIN and nutrients are presented in Table 14.

Overall, the Ross estuarine zone was in a moderate condition, whilst the Black estuarine zone was in a good condition with respect to nutrient concentrations. Louisa Creek Estuary (within the Ross estuarine zone) was in a poor condition, with high concentrations of TP and DIN. This may be attributed to waters from the Mt. St Johns Sewage Treatment Plant being discharged into the Louisa Creek Estuary. Ross Creek Estuary (within the Ross estuarine zone), Crystal Creek Estuary and Rollingstone Creek Estuary (both within the Black estuarine zone) also had high concentrations of TP. However, these three estuaries had low concentrations of DIN, resulting in them receiving a moderate grade for overall nutrient concentrations. A pineapple farm is located just upstream of Rollingstone and there is other agricultural farming around Crystal Creek and this may have attributed to the high TP concentrations.

5.8.2.1.2 Physical-chemical parameters

Overall, the Ross and Black estuarine zones were in a very good and good condition respectively in relation to phys-chem parameters, as shown in Table 15. Within both estuarine zones, all sites were in a moderate, good or very good condition. Louisa Creek Estuary (within the Ross freshwater basin) and Crystal Creek Estuary (within the Black freshwater basin) had very poor scores for lower and upper DO respectively, whilst waters within Rollingstone Creek Estuary were turbid, resulting in a very poor score. Indicators at all other sites were in a moderate to very good condition.

Within the Ross estuarine zone, the Ross River Estuary and Bohle River Estuary contributed the greatest proportions (0.68 and 0.24 respectively) to the overall score for the Ross estuarine zone, resulting in the very good overall score. Each estuary within the Black estuarine zone was similarly weighted (between 0.10 and 0.28).

5.8.2.1.3 Overall water quality

Overall, water quality for the Ross estuarine zone were in a good condition, as shown in Table 16. However, Louisa Creek Estuary was in a very poor condition. The Black estuarine zone on the other hand was in a good condition, with most indicators in a good or very good condition, as shown in Table 16. The exception was Rollingstone Creek Estuary, where all the indicators were graded as moderate.

Table 14. Integer scores and grades for total phosphorus (TP), dissolved inorganic nitrogen (DIN) and nutrients for estuarine sites.

Site	Non-weighted scores and grades						Catchment area							
	Score			Grade			Catchment area draining into site (km^2)	Proportion of measured catchment area	Weighted score/contribution to final score			Grade		
	DIN	TP	Nutrients	DIN	TP	Nutrients			DIN	TP	Nutrients	DIN	TP	Nutrients
Alligator Creek Estuary	90	65	77	A	B	B	4.8	0.00	0	0	0			
Bohle River Estuary	90	75	83	A	B	A	295.6	0.24	22	18	20			
Louisa Creek Estuary	25	20	23	D	E	D	52.5	0.04	1	1	1			
Louisa Estuary Site 0.9	75	61	68	B	B	B								
Louisa Estuary Site 6.0	0	0	0	E	E	E								
Louisa Creek/Town Common Estuary	0	0	0	E	E	E								
Ross Creek Estuary	0	90	45	E	A	C	20.8	0.02	0	2	1			
Ross Creek Estuary Site RC04 and RC07	0	90	45	E	A	C								
Ross Creek Estuary Site SB02	0	90	45	E	A	C								
Ross River Estuary	0	90	45	E	A	C	842.8	0.68	0	61	30			
Sandfly Creek Estuary	83	75	79	A	B	B	27.7	0.02	2	2	2			
Sandfly Creek Estuary Site CB10	76	75	76	B	B	B								
Sandfly Creek Estuary Site CB9	90	75	83	A	B	A								
Ross estuarine zone	**48**	**69**	**59**	**C**	**B**	**C**	**1244**	**1**	**25**	**83**	**54**	**D**	**A**	**C**
Althaus/Deep Creek Estuary	61	90	76	B	A	B	69.1	0.18	11	16	14			
Bluewater Creek Estuary	46	90	68	C	A	B	89.7	0.24	11	21	16			
Crystal Creek Estuary	28	90	59	D	A	C	106.1	0.28	8	25	17			
Rollingstone Creek Estuary	9	90	49	E	A	C	77.4	0.20	2	18	10			
Saltwater Creek Estuary	57	90	74	C	A	B	37.4	0.10	6	9	7			
Black estuarine zone	**40**	**90**	**65**	**D**	**A**	**B**	**379**	**1**	**38**	**89**	**64**	**D**	**A**	**B**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap

dry tropics partnership for healthy waters

Table 15. Integer scores and grades for turbidity, lower dissolved oxygen (DO), upper DO and the overall physical-chemical (phys-chem) properties for estuarine sites.

	Non-weighted scores and grades								Low (2)									
Site	Score				Grade				Catchment area draining into site (km^2)	Proportion of measured catchment area	Weighted score/contribution to final score				Grade			
	Turb-idity	Upper DO	Lower DO	Phys-chem prop-erties	Turb-idity	Upper DO	Lower DO	Phys-chem prop-erties			Turb-idity	Upper DO	Lower DO	Phys-chem prop-erties	Turb-idity	Upper DO	Lower DO	Phys-chem parameters
Alligator Creek Estuary	42	90	90	66	C	A	A	B	4.8	0.00	0	0	0	0				
Bohle River Estuary	90	90	77	84	A	A	B	A	295.6	0.24	21	21	18	20				
Louisa Creek Estuary	77	90	20	48	B	A	E	C	52.5	0.04	3	4	1	2				
Louisa Estuary Site 0.9	81*	90	60	70	B	A	C	B										
Louisa Estuary Site 6.0	78	90	0	39	B	A	E	D										
Louisa Creek/Town Common Estuary	71	90	0	36	B	A	E	D										
Ross Creek Estuary	90	90	90	90	A	A	A	A	20.8	0.02	2	2	2	2				
Ross Creek Estuary Site RC04 and RC07	90	90	90	90	A	A	A	A										
Ross Creek Estuary Site SB02	90	90	90	90	A	A	A	A										
Ross River Estuary	90	90	90	90	A	A	A	A	842.8	0.68	61	61	61	61				
Sandfly Creek Estuary	61	90	90	76	B	A	A	B	27.7	0.02	1	2	2	2				
Sandfly Creek Estuary Site CB10	62	90	90	76	B	A	A	B										
Sandfly Creek Estuary Site CB9	61	90	90	75	C	A	A	B										
Ross estuarine zone	**75**	**90**	**76**	**76**	**B**	**A**	**B**	**B**	**1244**	**1**	**88**	**90**	**84**	**87**	**A**	**A**	**A**	**A**
Althaus/Deep Creek Estuary	61	90	90	76	B	A	A	B	69.1	0.18	11	16	16	14				
Bluewater Creek Estuary	90	90	90	90	A	A	A	A	89.7	0.24	22	22	22	22				
Crystal Creek Estuary	41	35	90	66	C	D	A	B	106.1	0.28	11	10	25	18				
Rollingstone Creek Estuary	10	90	90	50	E	A	A	C	77.4	0.20	2	18	18	10				
Saltwater Creek Estuary	44	90	90	67	C	A	A	B	37.4	0.10	4	9	9	7				
Black estuarine zone	**49**	**79**	**90**	**70**	**C**	**B**	**A**	**B**	**379**	**1**	50	75	**90**	70	**C**	**B**	**A**	**B**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap

*The score was on the boundary of the scoring range and rounding to whole numbers resulted in the score being rounding up into the scoring range of the next category. Without rounding, the score was in the grade shown by the colour in the table (as grades were based on the score prior to rounding).

Table 16. Water quality scores and grades for estuarine sites.

	Non-weighted scores and grades						Weighted scores and grades					
	Scores			Grades			Scores			Grades		
	Nutrients	Phys-chem parameters	Water quality	Nutrients	Phys-chem parameters	Water quality	Nutrients	Phys-chem parameters	Water quality	Nutrients	Phys-chem parameters	Water quality
Alligator Creek Estuary	77	66	72	B	B	B						
Bohle River Estuary	83	84	83	A	A	A						
Louisa Creek Estuary	23	48	36	D	C	D						
Louisa Estuary Site 0.9	68	70	69	B	B	B						
Louisa Estuary Site 6.0	0	39	19	E	D	E						
Louisa Creek/Town Common Estuary	0	36	18	E	D	E						
Ross Creek Estuary	45	90	68	C	A	B						
Ross Creek Estuary Site RC04 and RC07	45	90	68	C	A	B						
Ross Creek Estuary Site SB02	45	90	68	C	A	B						
Ross River Estuary	45	90	68	C	A	B						
Sandfly Creek Estuary	79	76	77	B	B	B						
Sandfly Creek Estuary Site CB10	76	76	76	B	B	B						
Sandfly Creek Estuary Site CB9	83	75	79	A	B	B						
Ross estuarine zone	**59**	**76**	**67**	**C**	**B**	**B**	**54**	**87**	**71**	**C**	**A**	**B**
Althaus/Deep Creek Estuary	76	76	76	B	B	B						
Bluewater Creek Estuary	68	90	79	B	A	B						
Crystal Creek Estuary	59	66	62	C	B	B						
Rollingstone Creek Estuary	49	50	50	C	C	C						
Saltwater Creek Estuary	74	67	70	B	B	B						
Black estuarine zone	**65**	**70**	**67**	**B**	**B**	**B**	**63**	**70**	**67**	**B**	**B**	**B**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap

5.8.2.2 *Confidence scores*

There was a moderate confidence in the water quality scores for the Ross estuarine zone and low confidence for the Black estuarine zone. The score for each criterion is shown in Table 17. Only three months of data (three data points) were used to calculate the scores for the Black estuarine zone. This resulted in the representativeness score for the Black estuarine zone only receiving a rank of one. The maturity of method for both the Ross and the Black estuarine zones was scored two (out of three) because the method for weighting sites based on catchment area is a new method.

Table 17. Confidence score for nutrients, physical-chemical parameters and water quality for the Ross and Black estuarine zones.

Confidence criterion were scored 1-3 and weighted by the value identified in parenthesis. Weighted scores were summed to produce a final score (4.5 – 13.5). Final scores were ranked from 1 to 5 (very low to very high).

Basin	Indicator category	Maturity of method (x0.36)	Validation (x0.71)	Representa-tiveness (x2)	Directness (x0.71)	Measured error (x0.71)	Final score	Rank
Ross estuarine zone	Nutrients	2	3	2	3	1	9.6	Moderate (3)
	Phys-chem	2	3	2	3	1	9.6	Moderate (3)
	Water quality index						**9.6**	**Moderate (3)**
Black estuarine zone	Nutrients	2	3	1	3	1	7.6	Low (2)
	Phys-chem	2	3	1	3	1	7.6	Low (2)
	Water quality index						**7.6**	**Low (2)**

Rank based on final score: Very low (1): 4.5 – 6.3; Low (2): >6.3 – 8.1; Moderate (3): >8.1 – 9.9; High (4): >9.9 – 11.7; Very high (5): >11.7 – 13.5.

5.9 Inshore marine results

5.9.1 Overview of monitoring sites

There are three monitoring sites in Cleveland Bay with a total of 12 monitoring locations. These sites are:

- Enclosed coastal waters, comprising three monitoring locations that are part of the receiving end monitoring program (REMP) that is associated with the Cleveland Bay sewage treatment plant and four locations with water type 2241 moderately disturbed (MD) Townsville Port sub-zone water.
- Open coastal waters, comprising three monitoring locations with water type 2241 moderately disturbed (MD) Townsville Port sub-zone waters and one location monitored by the AIMS Marine Monitoring Program (MMP).
- Geoffrey Bay, comprising one location monitored by the AIMS Marine Monitoring Program (MMP).

The different water types have different WQOs as defined in the water quality improvement plans. The positions of the monitoring locations in Cleveland Bay are shown in Figure 20. The number of locations within each site differed compared to the 2017-18 Pilot Report and thus comparisons cannot be made between the scores in this report and those within the previous report.

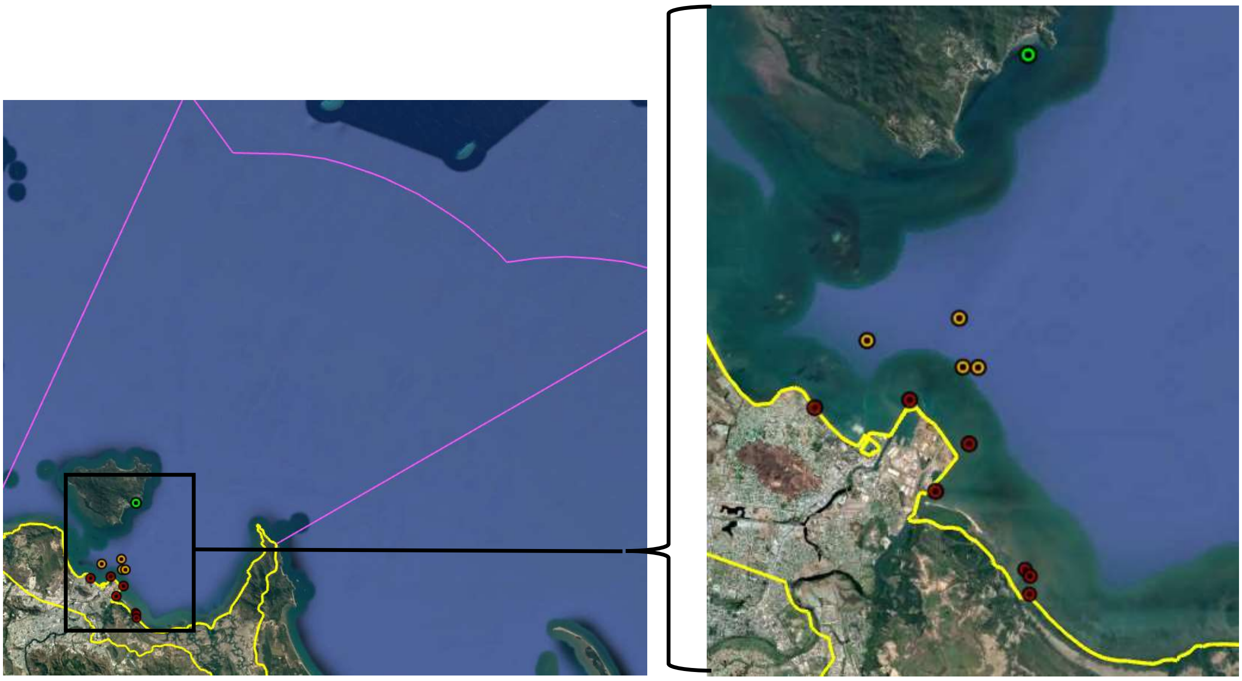


Figure 20. Monitoring locations within Cleveland Bay (delineated by a purple line).
The monitoring locations comprise of enclosed coastal monitoring locations (red dots), open coastal (orange dots) and Geoffrey Bay monitoring location (green dot).

5.9.1.1 *Halifax Bay*

The two monitoring sites within Halifax Bay are:

- Pandora Reef
- Pelorus Island

Sampling at Pandora Reef and Pelorus Island did not occur at the same location each time, although locations were close to each other. Monitoring locations within Halifax Bay are shown in Figure 21.

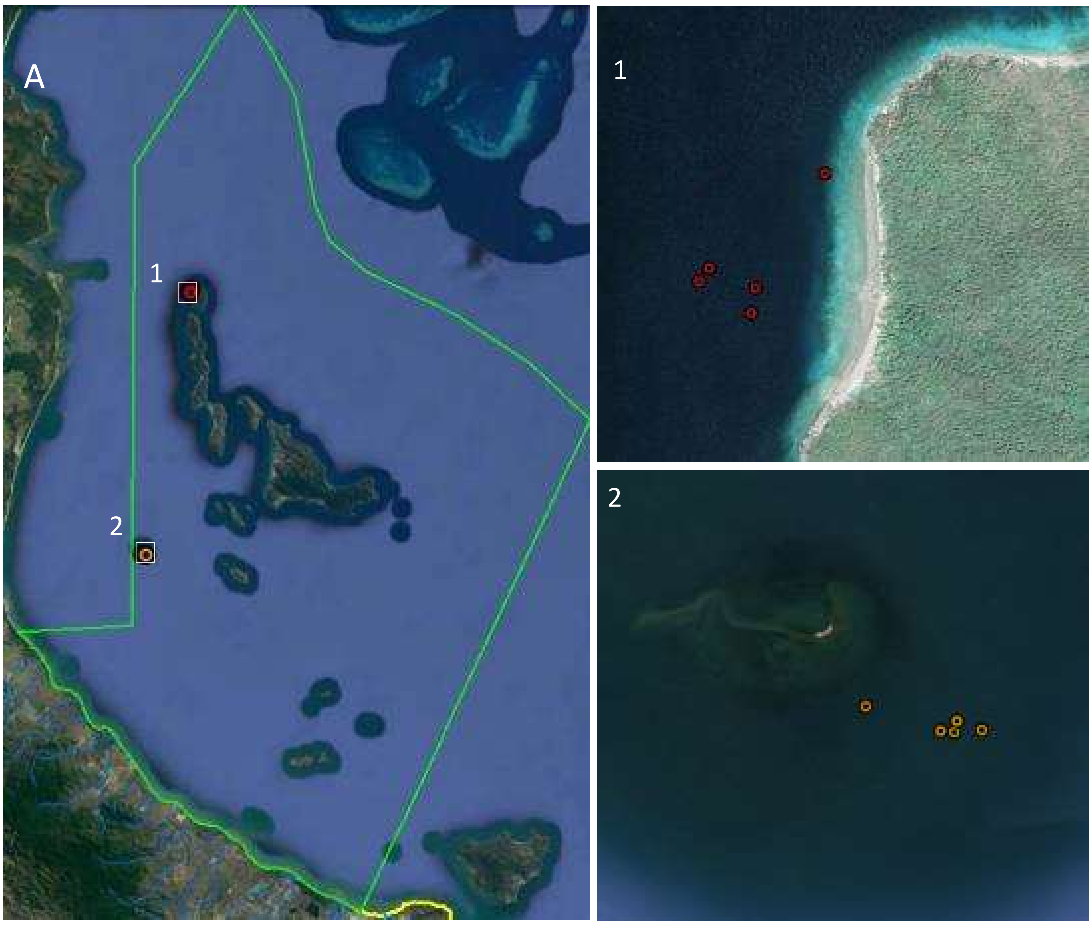


Figure 21. Monitoring locations at (1) Pelorus Island (red dots), (2) Pandora Reef (orange dots), within the Halifax Bay shown in A (green outline).

5.9.2 Overview of indicators measured at each site

Water quality scores for inshore zones were derived from three indices (nutrients, phys-chem parameters and chlorophyll *a*). The indicators measured varied between sites due to the sites being monitored by different programs. The indicators measured at each inshore site, the type of sampling used (either grab sample or continuous loggers), frequency of sampling and the monitoring program/organisation undertaking the sampling are shown in Table 18.

Table 18. Indicators sampled at each monitoring site.
The indicators measured at each site are shaded in dark grey, with the indicators measured being total phosphorus (TP), oxidised nitrogen (NOx), Chlorophyll *a* (Chl-*a*), total suspended solids (TSS), particulate phosphorus (PP) and particulate nitrogen (PN).

Zone	Site	Monitoring program	Type of sample	Frequency	TP	NOx	Turbidity	Chl-*a*	Secchi depth	TSS	PP	PN
Cleveland Bay	Enclosed coastal Cleveland Bay	TCC	Grab	Monthly	■	■	■	■		■		
		Port of Townsville	Grab	Monthly	■	■	■			■		
	Open coastal Cleveland Bay	Port of Townsville	Grab	Monthly	■	■	■			■		
		MMP	Grab	6 times from Dec 2018 – Apr 2019		■		■	■	■	■	■
	Geoffrey Bay	MMP	Grab	10 times from Sept 2018 – Jun 2019		■		■	■	■	■	■
			Logger	Continuous*			■	■				
Halifax Bay	Pelorus Is.	MMP	Grab	10 times from Sept 2018 – Apr 2019		■		■	■	■	■	■
			Logger	Continuous*			■	■				
	Pandora Reef	MMP	Grab	10 times from Sept 2018 – Jun 2019		■		■	■	■	■	■
			Logger	Continuous*			■	■				

*Hourly reads were produced from continuous logging data. Sampling occurred between 01/07/2018 and 30/06/2019.

5.9.3 Weighting of inshore marine sites

All sites were given equal weighting. It is noted that this method may not be appropriate as monitoring at each site occurred at different spatial and temporal scales. For example, there were seven monitoring locations within the enclosed coastal waters of Cleveland Bay, four within the open coastal waters within Cleveland Bay, while only one at Geoffrey Bay. At Pandora Reef and Orpheus Island, sampling only occurred at one location, with data indicating water quality at that specific monitoring location. The frequency of sampling also differs between sites, as seen in Table 18. A more robust method that accounts for these differences will be explored for future reports.

5.9.4 Results

The results for inshore marine water quality are presented in the following sections. The distributions of scores for each indicator are presented as boxplots in Appendix C.

5.9.4.1 Comparing inshore water against water quality objectives

5.9.4.1.1 Nutrients

The scores for nutrients were derived from the average of total phosphorus (TP), particulate phosphorus (PP), particulate nitrogen (PN) and oxidised nitrogen (NOx). The results for these indicators are presented in Table 19.

Within Cleveland and Halifax bays, there was excessive nutrient levels, with all sites graded as very poor with respect to nutrients.

Table 19. Scores and grades for nutrients within Cleveland Bay and Halifax Bay.
The scores for nutrients were averaged from the scores for total phosphorus (TP), particulate phosphorus (PP), particulate nitrogen (PN) and oxidised nitrogen (NOx). Scores are rounded to whole numbers, except if the score was between 0.01 and 0.99, in which case the data was presented to two decimal places. The number of significant figures differs between numbers for ease of presentation. ND stands for no data.

	Score					Grade				
Site	TP	PP	PN	NOx	Nutrients	TP	PP	PN	NOx	Nutrients
Enclosed coastal	62	ND	ND	ND	ND	B	ND	ND	ND	ND
Open Coastal	ND	0	0	0	0	ND	E	E	E	E
Geoffrey Bay	ND	13	0	0	4	ND	E	E	E	E
Cleveland Bay	ND	**7**	**0**	**0**	**2**	ND	**E**	**E**	**E**	**E**
Pelorus Island	ND	27	0	0	9	ND	D	E	E	E
Pandora Reef	ND	0.30	0	0	0.10	ND	E	E	E	E
Halifax Bay	ND	**14**	**0**	**0**	**5**	ND	**E**	**E**	**E**	**E**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap

5.9.4.1.2 Physical-chemical parameters

As seen in Table 20, Cleveland Bay and Halifax Bay were in a good condition with respect to phys-chem parameters. Enclosed coastal waters were in a poor condition, with the waters being very turbid (very poor score). The poor condition was driven by very poor results for turbidity. The highly turbid waters may be due to the nature of Cleveland Bay, which is a shallow bay and thus subject to high resuspension rates due to wind and wave action. Within Halifax Bay, water clarity (indicated by secchi disk) was very poor, although the overall scores for Halifax Bay was moderate. It is unknown why there is a discrepancy within Halifax Bay between secchi (which received a very poor grade) and turbidity and TSS, which both had good and very good grades.

Based on the raw data alone, sites further offshore had higher water quality than inshore sites. However, it is noted that these scores are driven by the WQOs. The objectives become progressively stricter the further offshore the sites are. As seen from the boxplots in Figure Appendix C 19-21, the further the monitoring sites were offshore, the lower the turbidity and TSS concentrations and the higher the secchi depth WQOs are. Lower turbidity and TSS levels and higher secchi depths indicate better water quality than sites with high turbidity and TSS and low secchi depth.

For all other indicators, the inshore water quality was rated good or very good despite the February 2019 flood. It is important to also consider that sampling in the inshore marine section of the Dry Tropics occurs at different spatial and temporal scales and this may affect the scores.

Table 20. Scores and grades for turbidity, total suspended solids (TSS), secchi depth and the overall physical-chemical (phys-chem) index within Cleveland Bay and Halifax Bay.

The overall phys-chem score was calculated by averaging the scores for Turbidity, TSS and Secchi depth. Scores are rounded, with the number of significant figures differing for ease of presentation. ND stands for no data.

	Scores				Grades			
Site	Turbidity	TSS	Secchi depth	Phys-chem	Turbidity	TSS	Secchi depth	Phys-chem
Enclosed Coastal	0	47	66	38	E	C	B	D
Open Coastal	100	87	66	84	A	A	B	A
Geoffrey Bay	68	86	70	75	B	A	B	B
Cleveland Bay	**56**	**73**	**67**	**65**	**C**	**B**	**B**	**B**
Pelorus Island	87	95	0	87	A	A	E	A
Pandora Reef	75	82	0	52	B	A	E	C
Halifax Bay	**81**	**89**	**0**	**70**	**A**	**A**	**E**	**B**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap

5.9.4.1.3 Chlorophyll *a*

The concentrations of chlorophyll *a* were good overall within both bays. Enclosed coastal waters were in a moderate condition, which was the lowest grade for Cleveland Bay (see Table 21). Chlorophyll *a* concentration was also moderate for Pelorus Island. Interestingly, chlorophyll *a* concentration at Pelorus Island were three times higher during February and early March 2019 than for the rest of the year. If scores were calculated omitting data points for February, Pelorus Island would receive a score of 62 (good grade), which is 18 points higher than the current score of 44. Chlorophyll *a* concentration was recorded continuously throughout the year (logger data) and this increase in concentrations in February and early March indicates that the February 2019 flood had an impact upon the inshore water quality for the following month.

Table 21. Integer scores and grades for Chlorophyll *a* within Cleveland Bay and Halifax Bay.

Scores are rounded, with the number of significant figures differing for ease of presentation.

	Score	Grade
Site	Chlorophyll *a*	Chlorophyll *a*
Enclosed coastal Cleveland Bay	58	C
Open Coastal Cleveland Bay	100	A
Geoffrey Bay	81*	B
Cleveland Bay	**80**	**B**
Pelorus Island	44	C
Pandora Reef	78	B
Halifax Bay	**61**	**B**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap

*The score was on the boundary of the scoring range and rounding to whole numbers resulted in the score being rounding up into the scoring range of the next category. Without rounding, the score was in the grade shown by the colour in the table (as grades were based on the score prior to rounding).

5.9.4.1.4 Overall water quality

Overall, Cleveland Bay and Halifax Bay both had moderate water quality. Summary scores and grades for water quality are presented in Table 22. These scores were driven by very poor scores for nutrient indicators. It is important to note that the lack of homogeneous temporal and spatial sampling regime played a role in these results.

Table 22. Water quality scores and grades for Cleveland Bay and Halifax Bay.

Scores for water quality are averaged from the scores for nutrients, physical-chemical parameters and chlorophyll *a*. Scores are rounded, with the number of significant figures differing for ease of presentation. Scores between 0.01 and 0.99 were not rounded. ND stands for no data.

	Score				Grade			
Site	Nutrients	Phys-chem	Chloro-phyll *a*	Water quality	Nutrients	Phys-chem	Chloro-phyll *a*	Water quality
Enclosed coastal Cleveland Bay	ND	39	58	49	ND	D	C	C
Open Coastal Cleveland Bay	0	84	100	62	E	A	A	B
Geoffrey Bay	4	75	81*	53	E	B	B	C
Cleveland Bay	**2**	**66**	**80**	**55**	**E**	**B**	**B**	**C**
Pelorus Island	9	68	44	40	E	B	C	C
Pandora Reef	0.10	60	78	46	E	C	B	C
Halifax Bay	**6**	**64**	**61**	**43**	**E**	**B**	**B**	**C**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap

*The score was on the boundary of the scoring range and rounding to whole numbers resulted in the score being rounding up into the scoring range of the next category. Without rounding, the score was in the grade shown by the colour in the table (as grades were based on the score prior to rounding).

5.9.4.2 *Confidence scores*

There was low confidence in the results due to limited spatial sampling within the both bays. The scores for each confidence criterion are shown in Table 24.

Table 23. Confidence score for nutrients, physical-chemical parameters and water quality Cleveland Bay and Halifax Bay.

Confidence criterion were scored 1-3 and weighted by the value identified in parenthesis. Weighted scores were summed to produce a final score (4.5 – 13.5). Final scores were ranked from 1 to 5 (very low to very high).

Indicator category	Maturity of method (x0.36)	Validation (x0.71)	Representa-tiveness (x2)	Directness (x0.71)	Measured error (x0.71)	Final score	Rank
Nutrients	2	3	1	3	1	7.6	Low (2)
Phys-chem	2	3	1	3	1	7.6	Low (2)
Water quality index						**7.6**	**Low (2)**

Rank based on final score: Very low (1): 4.5 – 6.3; Low (2): >6.3 – 8.1; Moderate (3): >8.1 – 9.9; High (4): >9.9 – 11.7; Very high (5): >11.7 – 13.5.

5.10 Offshore marine results

5.10.1 Results

Two indices, chlorophyll *a* and phys-chem parameters, comprise the Water Quality reporting category for the offshore marine zone. The indicators for these indices (Chl-a and TSS respectively) were not directly sampled, but instead derived from remotely sensed data. This zone was not broken down into smaller areas, meaning that a single score per each indicator and indicator category was reported.

No results were presented for this zone in the Pilot Report Card so no comparisons can be made with previous years.

5.10.1.1 *Chlorophyll a*

The score for chlorophyll *a* was derived from remote sensing data processed through the BoM's eReefs dashboard. The score was calculated based on relative area (%) of the water body where the annual mean value met the WQG value. Chlorophyll *a* score was graded as being very good, despite the February 2019 flooding event (Table 24).

Table 24. Results for water quality indicators and Water quality index for the offshore marine zone in 2018-2019.

Indicator category	Indicator	Score	Grade	Overall Score for Water Quality	Grade
Chlorophyll *a*	Chl-*a*	99	A	97	A
Phys-chem parameters	TSS	95	A		

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap

5.10.1.2 *Physical-chemical parameters*

The score for total suspended solids (TSS) was derived from remote sensing data processed through the BOM's eReefs dashboard and based on relative area (%) of the water body where the annual mean value meets the WQG value. TSS score was graded as very good despite the February 2019 flooding event (Table 24).

5.10.1.3 *Overall water quality*

Scores for the two indices (chlorophyll *a* and phys-chem) were weighted equally and averaged to provide an overall score for the Water Quality reporting category in the offshore marine zone. The two indices and the overall score for Water Quality were graded as very good.

5.10.2 Confidence scores

There was low confidence in the scores for the offshore zone (see Table 25). This was due to only one indicator being used to score each index and both indicators being indirect measures of water quality characteristics. The data was also derived from remote sensing data, with the data not ground-truthed (no field sampling taken to verify the results).

Table 25. Confidence scores for water quality index for the offshore marine zone.
Confidence criterion were scored 1-3 and weighted by the value identified in parenthesis. Weighted scores were summed to produce a final score (4.5 – 13.5). Final scores were ranked from 1 to 5 (very low to very high).

Indicator	Maturity of method (x0.36)	Validation (x0.71)	Representat-iveness (x2)	Directness (x0.71)	Measured error (x0.71)	Final score	Rank
Chlorophyll *a*	3	2	2	1	1	7.9	Low (2)
Phys-chem	3	2	2	1	1	7.9	Low (2)
Water Quality index						**7.9**	**Low (2)**

Rank based on final score: Very low (1): 4.5 – 6.3; Low (2): >6.3 – 8.1; Moderate (3): >8.1 – 9.9; High (4): >9.9 – 11.7; Very high (5): >11.7 – 13.5.

6 Biodiversity results

The score for Biodiversity was derived from the scores for indicators that were grouped into the following indicator categories:

- Habitat and artificial barriers for the two freshwater basins (Ross and Black freshwater basin)
- Habitat for the Ross and Black estuarine zones, Cleveland Bay and Halifax Bay (inshore marine zones) and one marine offshore zone.

The habitat index was previously referred to as the flora and fauna index (in the Pilot Report Card). The terminology was changed to better reflect the indicators that comprise the index. The term habitat is also more easily understood by the community.

The baselines that each of the indicator categories were scored against in the 2018-19 Report Card are highlighted in Table 26. Artificial barriers were not scored in the 2017-18 Pilot Report Card. This means that the overall scores and grades for each reporting zone are not comparable between the 2017-18 and the 2018-19 Report Card. There was no data to report on the fauna indicator category. In future, it is aimed that this data gap will be filled.

Table 26. Indices and indicator categories aggregated to generate an overall score for Biodiversity and the baseline that the indicators are compared against.

The indices and indicator categories that are scored in the 2018-19 Report Card are highlighted in green.

Zone	Index	Indicator category	Baseline data compared against
Freshwater	Habitat	Riparian vegetation	Management targets and earliest data
		Wetlands	Management targets and earliest data
		Fauna	To be decided
	Artificial barriers	Fish barriers	Earliest data
		Impoundment length	Earliest data
Estuarine zone	Habitat	Estuarine habitat (saltmarsh and mangroves)	Management targets and earliest data
		Fauna	To be decided
	Artificial barriers	Fish barriers	Earliest data
Inshore marine	Habitat	Coral	Earliest data
		Seagrass	Earliest data
		Fauna	To be decided
Offshore marine	Habitat	Coral	Earliest data
		Fish	To be decided

6.1 Freshwater basins

Within the freshwater basin, habitat and artificial barriers were the two indices scored within the Biodiversity category. The results for each index are presented in two separate sections. The indicators of habitat were compared against both baselines, with the results for data compared against progress towards management targets shown in the sections below. The results comparing habitat extent to pre-development habitat extent are shown in Appendix A. These results are presented in an appendix to avoid confusion and so that all the scores shown in the 2018-19 Report Card are in the main document, whilst the other results are presented in the appendices.

6.1.1 Habitat index (scoring against management targets)

Riparian and wetland extent were the two indicators measured within the freshwater zone for the habitat index. Riparian extent was defined as vegetation with a 50 m buffer from a watercourse. Palustrine wetlands are vegetated, non-riverine or non-channel systems that include billabongs, swamps, bogs, springs, soaks etc and have more than 30% emergent vegetation (Department of Environment and Science, 2013).

6.1.1.1 *Data source*

Data on riparian and wetland extent were prepared by the Queensland Herbarium, using data obtained through Google Earth and the Queensland Herbarium's Regional Ecosystem (version 5 for wetland extent and version 11 for riparian) mapping (Neldner, et al., 2017). These data are updated every four years (Neldner, et al., 2017), with the latest available data assessing the change in habitat extent between 2013 and 2017. The method for calculating habitat extent has changed since the Pilot Report Card was released and thus the 2018-19 results are not comparable with the results in the Pilot Report Card. Habitat extent was calculated on a finer scale and using more accurate spatial analysis techniques for the 2018-19 Report Card compared to the data used in the Pilot Report Card.

6.1.1.2 *Scoring ranges for comparing habitat extent against progress towards targets*

The scoring range associated with changes in habitat extent over a four-year period compared to management targets are presented in Table 27. Detailed information on how the scores were derived are presented in the Dry Tropics methods document (Whitehead, 2019b).

Table 27. Scoring ranges, Report Card (standardised) scores and Report Card grades for reporting changes in riparian and wetland extent

Scoring ranges are based on change in habitat extent from over a four-year period from 2013 to 2017 in relation to progress towards management targets.

Change in habitat extent from 2013 to 2017 (progress towards targets)			
Scoring range for riparian habitat	Scoring range for wetland	Report Card scoring range	Grade
0% or increase	0% or increase	81-100	Very good (A)
0-0.10% loss	0-0.10% loss	61-<81	Good (B)
0.11-0.50% loss	0.11-0.50% loss	41-<61	Moderate (C)
0.51-1.0% loss	0.51-3.0% loss	21-<41	Poor (D)
>1.0% loss	>3.0% loss	<21	Very Poor (E)

6.1.1.3 *Results*

The scores for riparian and wetland extent were aggregated to produce an overall score for the habitat index. Scores were based on the four yearly change in habitat extent between 2014 and 2017 compared against management targets. The results and confidence scores are presented below.

Overall, there was moderate progress towards targets within both the Ross and Black freshwater basins, as shown in Table 28**Error! Reference source not found.**. Wetland extent received a moderate score in both basins, with less than one hectare lost from both basins. However, this equated to a 0.15% and 0. 22% loss of wetlands from the Ross and Black freshwater basins respectively. However, riparian vegetation was lost from both the Ross and Black freshwater basins (0.45% and 0.20% loss respectively), resulting in both zones receiving moderate grades. Although the impacts of clearing riparian vegetation within the Ross freshwater basin has not been studied, many other studies from other regions have shown that clearing of riparian vegetation can result in a range of detrimental environmental and ecological impacts (Bennett, et al., 2014). For example, riparian clearing can result in various impacts including a:

- decline in habitat for fauna species, such as birds (Bennett, et al., 2014),
- increase in water temperature, especially maximum temperatures, which can result in a loss of habitat for certain aquatic species, including fish and invertebrates (Bowler, et al., 2012),
- decrease in habitat for aquatic species, as tree roots and debris provide habitat and shelter for aquatic species (Richardson, et al., 2010),
- increase in streambank erosion (Zaimes, et al., 2019), and
- increase in runoff rates and the amount of sediment and nutrients entering waterways. Vegetations acts as a buffer, slowing runoff rates and trapping nutrients and sediments before they enter the watercourse (Swanson, et al., 2017).

Table 28. Scores and grades for the indicator categories of riparian vegetation and wetlands and the index Habitat for the Ross and Black freshwater basins.

The percent (%) of habitat lost and habitat remaining was based on 2013 to 2017 levels compared to management targets. The amount of habitat extent loss is shown in parenthesis. Habitat scores were calculated by averaging the scores for riparian and wetland extent.

Freshwater zone	Raw data (change from 2013-2017)		Standardised score			Grade for indicator categories		
	Riparian extent (percent change from 2013-2017)	Wetland extent (percent change from 2013-2017)	Riparian extent	Wetland extent	**Habitat index**	Riparian vegetation	Wetlands	**Habitat index**
Ross freshwater basin	0.45% lost (135 ha lost)	0.15% lost (< 1 ha lost)	44	59	**51**	C	C	**C**
Black freshwater basin	0.20% lost (52 ha lost)	0.22% lost (<1 ha lost)	56	55	**56**	C	C	**C**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good = 81 to 100 | ■ No score/data gap.

Source: Data sourced from Queensland Government (2019) Reef Water Quality Report Card 2017 and 2018.

6.1.1.3.1 Confidence scores

There was a moderate confidence in the results for riparian and wetland extent, with the overall rank and the scores for each confidence criterion presented in Table 29. Riparian and wetland scores were devised based on GIS mapping, which meant the whole area was mapped. This meant the representativeness score was high.

Table 29. Confidence scores for riparian extent, wetland extent and overall habitat extent for both the Ross and Black freshwater basins.

Confidence criteria were scored 1-3, weighted by the value identified in parenthesis and summed to produce a final (weighted) score (4.5 – 13.5). Final scores rank from 1 to 5 (very low to very high).

	Maturity (0.36)	Validation (0.71)	Representativeness (2)	Directness (0.71)	Measured error (0.71)	Final score	Rank
Riparian extent	2	2	3	2	1	10.3	High (4)
Wetland extent	2	2	3	2	1	10.3	High (4)
Habitat extent						**10.3**	**High (4)**

Rank based on final score: Very low (1): 4.5 – 6.3; Low (2): >6.3 – 8.1; Moderate (3): >8.1 – 9.9; High (4): >9.9 – 11.7; Very high (5): >11.7 – 13.5.

6.1.2 Artificial barriers index

Artificial barriers comprised two indicator categories, which were impoundment length and fish barriers. Both indicator categories were only scored against the earliest baseline (of no barriers). There are no management targets for this indicator.

6.1.2.1 *Impoundment length*

The indicator was selected with the intention to describe how much “natural” channel habitat remained. In-stream barriers are generally built for flood mitigation and to store water for later use (Department of Environment, Land, Water and Planning, n.d.). Impounded areas generally have increased water depth and decreased water velocities (Department of Environment, Land, Water and Planning, n.d.). Artificial in-stream structures, including dams and weirs, have a profound impact upon stream ecology and connectivity (Faulks, et al., 2011). The length of impounded channel varies according to attributes, such as the height of the constructed in-stream barrier, and landscape features, such as gradient of the channel (Department of Environment, Land, Water and Planning, n.d.).

Impoundments can result in high concentrations of nutrients and poor physical chemical composition within waterways (such as decrease in dissolved oxygen) due to the long residence times inherent in these systems during dry conditions (McCully, n.d.). For example, the weirs in Ross River create lake like conditions during dry periods.

6.1.2.1.1 Data source

The 2018-19 Report Card is the first time the impoundment indicator has been reported, with this indicator to be updated every four years. Impoundment locations and estimates of impounded lengths were derived from the Department of Natural Resources and Mines (DNRM) Queensland 1:100,000 ordered drainage network, Google Earth imagery, Queensland Globe spatial layers (Dams, Weirs and Barrages, Referable Dams and Reservoirs), local knowledge and desktop analysis in Google Earth Pro and ArcGIS. Waterways within Queensland were classified into four risk categories (low, moderate, high and major) based on how severely fish movement and fish communities would be impacted if a barrier were constructed within the waterway (Department of Agriculture and Fisheries, 2016). Only streams classified as being of high or major importance within the freshwater basin were included in the assessment (Department of Agriculture and Fisheries, 2016). Impoundment length was calculated as the linear length of the stream that is impounded proportional to the total linear length of the watercourse.

6.1.2.1.2 Results

All watercourses of major or high importance were assessed within the Ross and Black basins. The Ross freshwater basin received a poor score, with 8.1% of watercourses impounded (see Table 30). This poor score was due to the presence of the Ross River Dam and the three weirs (Black, Gleesons and Aplin's weirs) within the lower section of the Ross River. No watercourses within the Black freshwater basin were impounded, resulting in a very good score (see Table 30).

Table 30. Scores and grades for impoundment length indicator category for the Ross and Black freshwater basins.

The scores are based on spatial analysis of imagery from 2019. Only streams of high or major importance in relation to fish movement were included in the assessment.

Freshwater zone	Length of non-impounded watercourse (km)	Length of impounded watercourse (km)	Total watercourse length (km)	Percent (%) of watercourse impounded	Standardised score	Grade
Ross freshwater basin	817	72	888	8.1%	**34**	**D**
Black freshwater basin	659	0	659	0	**100**	**A**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good = 81 to 100 | ■ No score/data gap.

6.1.2.2 *Fish barriers*

Fish barriers are an important indicator to include due to their links to ecosystem health. Additionally, the community places a high level of importance on the presence of freshwater fish species. The ability of commercial species to migrate into freshwaters and spawn is also important for the local economy.

6.1.2.2.1 Data source

Fish barriers were identified using desktop analysis of spatial imaging in Google Earth Pro and ArcGIS (Google Earth). Only streams classified as being of high or major importance within the freshwater basin were included in the assessment (Department of Agriculture and Fisheries, 2016). Fish barriers were classified as either passable or impassable. An impassable barrier was defined as a barrier where there was no chance or a low probability of fish being able to pass across the barrier. The detailed description is described in the Methods document (Whitehead, 2019b). A passable barrier was described as a barrier that does not prevent fish movement and fish can freely move upstream and downstream of the barrier. Fish barriers relate to only the physical barriers present, with other barriers, such as light, dissolved oxygen, chemical and temperature, not considered in this analysis.

It is noted that the catchment area represented by each of the watercourses differs and that the method does not include potential intervention strategies that may be in place to facilitate fish movement. In future reports it may be more appropriate to weight the sites by catchment area and consider the presence of fish and eel ladders in the assessment. Other

6.1.2.2.2 Results

Within the Ross freshwater basin, the five measured watercourses of high or major importance had a total of 12 barriers on them, as shown in Table 31. However only the Ross River had barriers that were classified as impassable, which were the three weirs and the Ross River Dam wall. Overall, the Ross freshwater basin received a good grade for the fish barriers indicator category, with the poor grade for the Ross River offset by the very good grade for Whites Creek (see Table 32). It is noted that Whites Creek is smaller than the Ross River and therefore averaging the two results may not be the best approach, with a more suitable approach to be considered for future Report Cards.

No barriers were present along Black River (see Table 31), with the river receiving a very good score (Table 32). The Black River was the only watercourse assessed within the Black freshwater basin.

Table 31. Raw data for the indicators that comprise the fish barriers indicator category.

The score for the fish barriers indicator category is the average of the three indicators, which are average kilometre of watercourse length per barrier (average km per barrier), percent of stream length to first barrier (% stream length to first barrier), percent of stream length to first impassable barrier (% stream length to impassable barrier). Numbers are shown to one decimal place for ease of reading (significant figures differ between numbers).

		Raw data used to generate scores for indicators						Raw data for each indicator		
Freshwater zone	Watercourse	Total watercourse length	Number of barriers on watercourse	Number of passable barriers	Number of impassable barriers	Length to first barrier (km)	Length to first impassable barrier (km)	Average km per barrier	% stream length to first barrier	% stream length to impassable barrier
Ross freshwater basin	Ross River	263.6	4.0	0.0	4.0	1.0	1.0	65.9	0.4	0.4
	Bohle River	51.1	2.0	2.0	0.0	7.2	51.1	25.5	14.1	100.0
	Stuart Creek	17.5	5.0	5.0	0.0	11.9	17.5	3.5	68.2	100.0
	Alligator Creek	13.7	1.0	1.0	0.0	0.7	13.7	13.7	5.2	100.0
	Whites Creek	11.1	0.0	0.0	0.0	11.1	11.1	No barriers	100.0	100.0
	Average Ross freshwater basin	**71.4**	**2.4**	**1.6**	**0.8**	**6.4**	**18.9**	**27.2**	**37.6**	**80.1**
Black freshwater basin	**Black River**	**92.0**	**0.0**	**0.0**	**0.0**	**0.0**	**92.0**	**No barriers**	**No barriers**	**No barriers**

Table 32. Assigned scores and overall standardised scores and grades for the fish barriers index.

The scores and grades for the fish barriers index are the averages of the scores for the three indicator categories. Assigned scores are on a scale of 1 (lowest score) to 5 (highest score). The assigned scores for the artificial barrier index are the sums of the assigned scores. Overall standardised scores are on a scale of 0 (lowest score) to 100 (highest score). Whole numbers are presented for all numbers, except the average for Ross freshwater basin, which is shown to on decimal place. Significant figures differ between numbers.

		Assigned (raw) scores				Standardised score	Standardised grade
Freshwater zone	Watercourse	Average km per barrier	% stream length to first barrier	% stream length to impassable barrier	Fish barriers index	Fish barriers index	
Ross freshwater basin	Ross River	5	1	1	7	41*	D
	Bohle River	5	1	5	11	61	B
	Stuart Creek	2	3	5	10	61*	C
	Alligator Creek	4	1	5	10	61*	C
	Whites Creek	5	5	5	15	100	A
	Ross freshwater basin	**4.2**	**2.2**	**4.2**	**10.6**	**65**	**B**
Black freshwater basin	**Black River**	**5**	**5**	**5**	**15**	**100**	**A**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good = 81 to 100 | ■ No score/data gap.

*The score was on the boundary of the scoring range and rounding to whole numbers resulted in the score being rounding up into the scoring range of the next category. Without rounding, the score was in the grade shown by the colour in the table (as grades were based on the score prior to rounding).

6.1.2.2.3 Overall results for the artificial barriers index

Overall, the Ross freshwater basin received a moderate grade for artificial barriers, whilst the Black freshwater basin received a very good grade (see Table 33).

Table 33. Overall scores for the artificial barriers index, comprising impoundment length and fish barriers indicator categories, for the Ross and Black freshwater basins.

	Standardised scores for Report Card			Grades for Report Card		
Freshwater zone	Impoundment length indicator category	Fish barrier indicator category	Artificial barriers index	Impoundment length indicator category	Fish barrier indicator category	Artificial barriers index
Ross freshwater basin	34	65	**50**	D	B	**C**
Black freshwater basin	100	100	**100**	A	A	**A**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good = 81 to 100 | ■ No score/data gap.

6.1.2.3 *Confidence scores*

The score for impoundment length, shown in Table 34, was based on all watercourses being assessed and therefore the representativeness score (which has the highest weighting) was a three. This resulted in the overall confidence score being high for impoundment length. For fish barriers, there was low confidence that all potential barriers had been identified (representativeness), ground truthing of barriers was unknown (validation) and that there was no known measured error. Additionally, not all watercourses were assessed for the fish barriers indicator. As a result, there was very low confidence in the scores for fish barriers.

Table 34. Confidence scores for impoundment length, fish barriers and artificial barriers for both the Ross and Black estuarine zone.

Confidence criteria were scored 1-3, weighted by the value identified in parenthesis and summed to produce a final (weighted) score (4.5 – 13.5). Final scores rank from 1 to 5 (very low to very high).

	Maturity (0.36)	Validation (0.71)	Representa-tiveness (2)	Directness (0.71)	Measured error (0.71)	Final score	Rank
Impoundment length	2	2	3	2	1	10.3	High (4)
Fish barriers	2	1	1	2	1	5.6	Very Low (1)
Artificial barriers						**8.0**	**Low (2)**

Rank based on final score: Very low (1): 4.5 – 6.3; Low (2): >6.3 – 8.1; Moderate (3): >8.1 – 9.9; High (4): >9.9 – 11.7; Very high (5): >11.7 – 13.5.

6.1.3 Overall Biodiversity score

The overall score for the Biodiversity reporting category within the freshwater zone is shown in Table 35.

Table 35. Overall score and grades for the Biodiversity reporting component within the freshwater basins.

	Scores			Grades		
Basin	Habitat index	Artificial barriers index	**Biodiversity**	Habitat index	Artificial barriers index	**Biodiversity**
Ross freshwater basin	51	50	**51**	C	C	**C**
Black freshwater basin	56	100	**78**	C	A	**B**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good = 81 to 100 | ■ No score/data gap.

6.1.3.1 *Confidence scores*

There was a moderate confidence in the overall scores for the Biodiversity reporting category (Table 36).

Table 36. Confidence scores for the Biodiversity reporting category for both the Ross and Black freshwater basins. Confidence criteria were scored 1-3, weighted by the value identified in parenthesis and summed to produce a final (weighted) score (4.5 – 13.5). Final scores rank from 1 to 5 (very low to very high).

	Final score	Rank
Artificial barriers	8.0	Low (2)
Habitat extent	10.3	High (4)
Biodiversity	**9.2**	**Moderate (3)**

Rank based on final score: Very low (1): 4.5 – 6.3; Low (2): >6.3 – 8.1; Moderate (3): >8.1 – 9.9; High (4): >9.9 – 11.7; Very high (5): >11.7 – 13.5.

6.2 Estuarine zones

6.2.1 Habitat index (Scoring against management targets)

Habitat extent (mangrove and saltmarsh combined) was the only indicator measured within the habitat indicator category within the estuarine zone. The score for habitat extent is thus also the score for the overall habitat indicator category and for the Biodiversity reporting category. The scoring range associated with changes in habitat extent are presented in Table 37. Detailed information on how the scores were derived are presented in the Dry Tropics methods document (Whitehead, 2019b). Habitat extent was also compared against the earliest baseline, with the results presented in Appendix A.

6.2.1.1 *Data source*

Data was prepared using the same method as outlined in section 6.1.1.1 (for freshwater habitat extent).

6.2.1.2 *Scoring ranges*

The scoring range associated with changes in habitat extent are presented in Table 37. Detailed information on how the scores were derived are presented in the Dry Tropics methods document (Whitehead, 2019b).

Table 37. Scoring ranges, Report Card (standardised) scores and Report Card grades for reporting change in mangrove and saltmarsh extent.

Scoring ranges are based on change in habitat extent from over a four-year period from 2013 to 2017 in relation to progress towards management targets.

Percent change in habitat extent	Report Card scoring range	Grade
0% or increase	81-100	Very good (A)
0-0.10% loss	61-<81	Good (B)
0.11-0.50% loss	41-<61	Moderate (C)
0.51-3.0% loss	21-<41	Poor (D)
>3.0% loss	<21	Very Poor (E)

6.2.1.2.1 Results

Based on spatial sampling, 6 ha (0.05%) and less than one ha (0.02%) of estuarine habitat (mangrove and saltmarsh extent combined) were lost from the Ross and Black estuarine zones respectively (see Table 38). Both zones scored a good grade for progressing towards the management target (Table 38). Although the percentages of habitat lost were relatively small, mangroves and saltmarshes are ecologically important habitats and thus a loss of these habitats may negatively impact the environment (Department of the Environment and Energy, 2016). For example, mangroves and saltmarsh provide critical habitat and breeding grounds for various species, including fish, invertebrates and birds, act as filters for nutrients and sediments, reduce erosion and help to maintain water quality (Department of the Environment and Energy, 2016).

Additionally, sea level rise associated with climate change may also pose a threat to these habitats (Ward, et al., 2016). Changes in the coastline will reduce the area of these habitats and also affect the mangrove-saltmarsh dynamics, promoting mangrove encroachment on saltmarshes and reducing overall biodiversity and productivity of these ecosystems (Ward, et al., 2016). Monitoring the loss of estuarine habitats, as well as the dynamics between mangroves and saltmarshes, is important to understand the source of these changes. It is also important to manage for these changes in order to minimise the loss of the ecosystem services that these habitats provide.

Table 38. Scores and grades for mangroves and saltmarsh combined for the Ross and Black estuarine zone.
Scores and grades were based on the percent (%) loss and percent remaining from 2013 to 2017.

Freshwater zone	Raw data (2013-2017 data)	Standardised score		Grade	
	Mangrove and saltmarsh extent (percent change from 2013-2017)	Mangrove and saltmarsh extent	**Habitat index**	Mangrove and saltmarsh extent	**Habitat index**
Ross estuarine zone	0.05% loss (6 ha lost)	71	71	B	**B**
Black estuarine zone	0.02% loss (<1 ha lost)	77	77	B	**B**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good = 81 to 100 | ■ No score/data gap.
Source: Data sourced from Queensland Government (2019) Reef Water Quality Report Card 2017 and 2018.

6.2.1.2.2 Confidence scores

There was a high confidence in the results for mangrove and saltmarsh extent, with the overall rank and the scores for each confidence criterion presented in Table 39. Mangrove and saltmarsh scores were based on GIS mapping, meaning the whole area was mapped, leading to a high representativeness score. Overall, there was a high confidence in the overall scores for habitat extent, with this confidence score used as the score for the Biodiversity category.

Table 39. Confidence scores for mangrove extent, saltmarsh extent and the overall habitat extent for both the Ross and Black estuarine zones.
The score for habitat extent was also the score for the overall Biodiversity reporting category. Confidence criteria were scored 1-3, weighted by the value identified in parenthesis and summed to produce a final (weighted) score (4.5 – 13.5). Final scores rank from 1 to 5 (very low to very high).

	Maturity (0.36)	Validation (0.71)	Representativeness (2)	Directness (0.71)	Measured error (0.71)	Final score	Rank
Mangrove extent	2	2	3	2	1	10.3	High (4)
Saltmarsh extent	2	2	3	2	1	10.3	High (4)
Habitat extent/Biodiversity reporting category						**10.3**	**High (4)**

Rank based on final score: Very low (1): 4.5 – 6.3; Low (2): >6.3 – 8.1; Moderate (3): >8.1 – 9.9; High (4): >9.9 – 11.7; Very high (5): >11.7 – 13.5.

6.3 Inshore marine zones

6.3.1 Habitat index

Coral and seagrass were the two indicator categories scored within the habitat index for Cleveland Bay and Halifax Bay.

6.3.1.1 *Data source*

6.3.1.1.1 Coral

Most coral data within the Dry Tropics inshore marine zone was collected from eight reefs by the Marine Monitoring Program (MMP). MMP has a biennial sampling design, meaning all reefs are sampled over a two year period (not every monitored reef is sampled every year). More detailed information on the methods used by MMP can be found at http://www.gbrmpa.gov.au/our-work/our-programs-and-projects/reef-2050-marine-monitoring-program and https://www.aims.gov.au/docs/research/monitoring/reef/latest-surveys.html..

Coral community structure and exposure to disturbances differ markedly with depth (Bridge, et al., 2013). This influence of depth is most apparent in inshore areas where the turbidity of waters causes a rapid attenuation of light (Bridge, et al., 2013; Marshall & Baird, 2000). To minimise the differences in depth, the MMP stratifies sampling by depth including transects at both 2 m and 5 m below lower astronomical tide (LAT). MMP conducted surveys at Geoffrey Bay following the February floods, with this data incorporated into the results.

For the first time in regional Report Cards, coral cover data collected by Reef Check was included in the Report Card. Reef Check samples sporadically at inshore reefs around Magnetic Island and during the 2018-19 financial year, two inshore reefs (Middle Reef and Florence Reef) were sampled. Reefs were sampled at a depth of between 1 and 5 m.

6.3.1.1.2 Seagrass

Data on seagrass condition was obtained from the Port of Townsville monitoring program, with monitoring conducted by James Cook University (JCU). Ten monitoring meadows were sampled on the 6-7th and the 14-16th October 2018 (Bryant, et al., 2018) and then in May 2019 after the February 2019 floods (McKenna, et al., 2020). A helicopter was used to survey intertidal areas at low tide and diving to survey shallow sub-tidal areas (Bryant, et al., 2018). The locations of the monitored seagrass meadows are shown in Figure 22. Each indicator for seagrass (biomass, area and species composition) was compared against a baseline to create the score (Bryant, et al., 2018). The baseline was developed in 2007/2008 and updated in 2013 and 2016. Detailed methods for scoring seagrass are explained in Bryant & Rasheed, 2019 and McKenna, et al., 2020. Scores for seagrass condition are shown for pre- and post-floods to provide an indication of whether the floods may have impacted the condition of seagrass.

No data were available on seagrass condition within Halifax Bay and this will be denoted in grey in the Report Card.

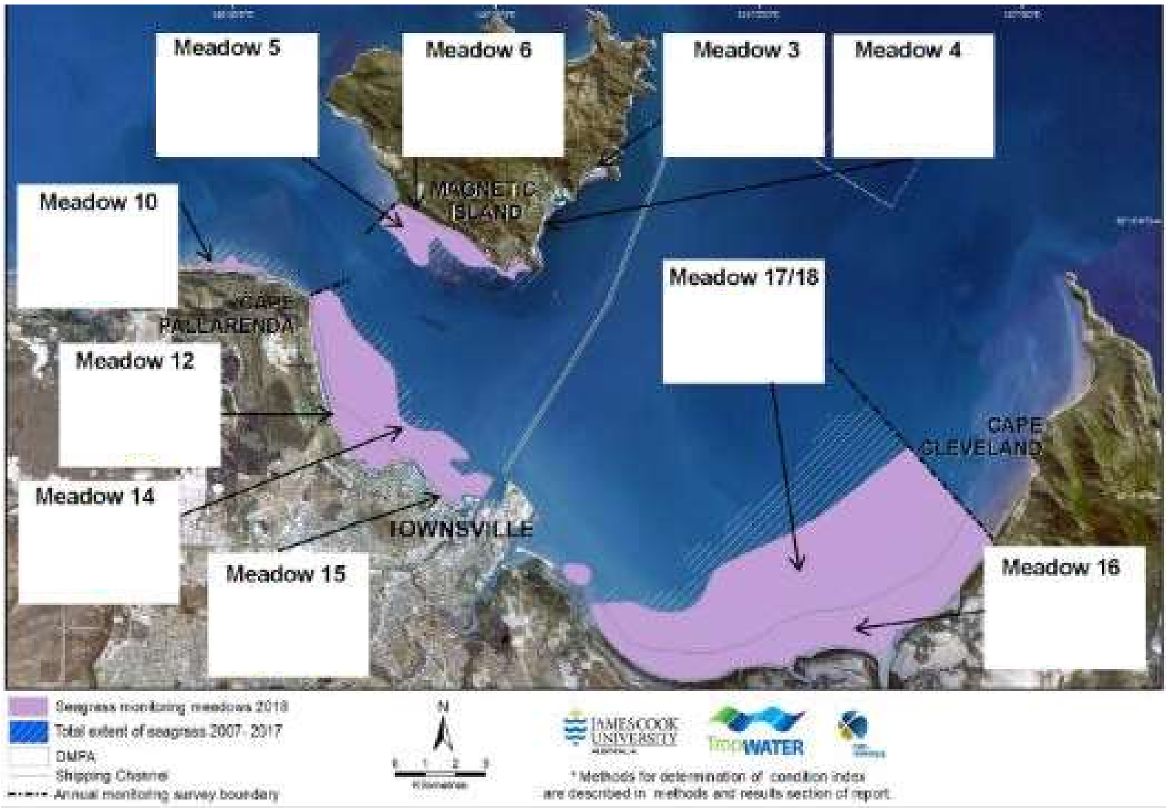


Figure 22. Location of seagrass monitoring meadows within Cleveland Bay.
Source: (Bryant & Rasheed, 2018)

6.3.1.2 *Results*

Both coral and seagrass comprise multiple indicators, with the scores for coral and seagrass presented below.

6.3.1.2.1 Coral

The coral cover indicator was based on data from MMP and Reef Check. The standardised scores for each coral indicator at each reef and for the two depths (2 m and 5 m) are shown Table Appendix D 1. The average scores and grades (averaged by depth) for each reef are shown in Table Appendix D 1. The comparison between the 2017-18 results and the 2018-2019 results are shown in Appendix D.

Both reefs surveyed within Cleveland Bay were in a poor condition, as shown in Table 40. However, the poor score was largely driven by the macroalgae indicator having a very poor grade, as most other indicators were in a moderate condition. Reefs within Halifax Bay were generally in a moderate condition, with four out of the five indicators scoring moderate and the ‘composition of hard coral’ indicator scoring good. Within Halifax Bay, grade for individual reefs ranged from very high to very poor. Pandora Reef and Pandora North Reef were in a poor condition, whilst the other four reefs were in a moderate or good condition. Macroalgae condition was very poor at most reefs, except Palms East and Palms West where the score was very good. Half (3 of the 6) of the monitoring sites within Halifax Bay had a very good composition of hard corals.

Table 40. Average scores and grades for coral indicators and the coral indicator category for Cleveland Bay and Halifax Bay.

The scores for the coral indicator category were calculated by averaging the scores for each indicator. The overall scores for Cleveland Bay and Halifax Bay are shown in bold. No data is abbreviated as ND.

		Standardised scores						Standardised grades					
Site (Reef)	Monitoring Program	Composition of hard corals	% Coral cover	% Change hard corals	Juvenile density	Macro-algae	Coral indicator category	Composition of hard corals	% Coral cover	% Change hard corals	Juvenile density	Macro-algae	Coral indicator category
Florence Bay	Reef Check	ND	42	ND	ND	ND		ND	ND	C	ND	ND	ND
Geoffrey Bay	MMP	50	40	49	44	0	37	C	D	C	C	E	D
Middle Reef	Both	50	44	ND^	54	0	38	C	C	C	ND*	E	D
Cleveland Bay	**Both**	**50**	**46**	**49**	**49**	**0**	**38**	**C**	**C**	**C**	**C**	**E**	**D**
Havannah	MMP	100	47	50	24	77	60	A	C	C	D	B	C
Havannah North	MMP	100	28	77	52	0	52	A	D	B	C	E	C
Palms East	MMP	100	58	91	38	88	75	A	C	A	D	A	B
Palms West	MMP	25	46	55	39	100	53	D	C	C	D	A	C
Pandora	MMP	75	14	47	52	7	39	B	E	C	C	E	D
Pandora North	MMP	0	77	31	52	0	32	E	B	D	C	E	D
Halifax Bay	**MMP**	**67**	**45**	**59**	**43**	**45**	**52**	**B**	**C**	**C**	**C**	**C**	**C**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good = 81 to 100 | ■ No score/data gap.

*The percent change in hard coral cover has not been sampled on Middle Reef since 2014.

6.3.1.2.2 Seagrass

Prior to the floods, overall condition of seagrass meadows within Cleveland Bay was good. All indicators were in a moderate to very good condition, with the results and the associated grades for each indicator and the indicator category presented in Table 41. After the February 2019 floods, there was a decrease in the biomass, especially within meadow 3 and 4, as shown in Table 42. The scores and grades for seagrass condition after the February 2019 floods are shown in Table 42, with these grades presented in the Report Card. While seagrasses appear to have been impacted by the flood, they were still present throughout much of Cleveland Bay.

Table 41. Scores and grades for seagrass indicators and the seagrass indicator category for Cleveland Bay based on data from October 2018 (pre-February 2019 floods).

At each site, the two lowest scores were used to calculate the average for the indicator category. The overall score for Cleveland Bay is averaged from the seagrass indicator category scores for each site. Note that the scoring range for seagrass is different compared to other indicators.

	Standardised score				Grade			
Site (meadow)	Biomass	Area	Species composition	Seagrass indicator category	Biomass	Area	Species composition	Seagrass indicator category
3	85	88	84	85	A	A	B	A
4	67	88	100	67	B	A	A	B
5	78	85	98	78	B	A	A	B
6	70	59	89	59	B	C	A	C
10	91	54	99	54	A	C	A	C
12	92	100	84	88	A	A	B	A
14	68	92	98	68	B	A	A	B
15	93	86	70	78	A	A	B	B
16	90	100	99	90	A	A	A	A
17/18	71	86	95	71	B	A	A	B
Cleveland Bay				**74**				**B**

Scoring range: ■ Very Poor = 0 to <25 | ■ Poor = 25 to <45 | ■ Moderate = 45 to <65 | ■ Good = 65 to <85 | ■ Very Good = 85 to 100 | ■ No score/data gap.

Table 42. Scores and grades for seagrass indicators and the seagrass indicator category for Cleveland Bay based on data from May 2020 (post-February 2019 floods).

At each site, the two lowest scores were used to calculate the average for the indicator category. The overall score for Cleveland Bay is averaged from the seagrass indicator category scores for each site. Note that the scoring range for seagrass is different compared to other indicators.

	Standardised score				Grade			
Site (meadow)	Biomass	Area	Species composition	Seagrass indicator category	Biomass	Area	Species composition	Seagrass indicator category
3	28	73	97	28	D	B	A	D
4	41	85	98	41	C	B	A	C
5	60	89	98	60	C	A	A	C
6	66	50	97	50	C	C	A	C
10	68	51	96	51	C	C	A	C
12	60	100	69	60	C	A	B	C
14	55	74	87	55	C	B	A	C
15	73	74	58	65	B	B	C	B
16	59	100	94	59	C	A	A	C
17/18	55	88	98	55	C	A	A	C
Cleveland Bay				**52**				**C**

Scoring range: ■ Very Poor = 0 to <25 | ■ Poor = 25 to <45 | ■ Moderate = 45 to <65 | ■ Good = 65 to <85 | ■ Very Good = 85 to 100 | ■ No score/data gap.

6.3.1.2.3 Confidence scores

As shown in Table 43, there was a high and moderate confidence in the habitat index results for Cleveland Bay and Halifax Bay, respectively. The score for each confidence criterion is shown in Table 43. Most seagrass beds within Cleveland Bay were monitored, resulting in a good score (3) for representativeness. The representativeness for coral within Cleveland Bay was rated at two because each site was only surveyed once every two years rather than each year.

Table 43. Confidence score for the habitat index (and Biodiversity reporting category) for Cleveland Bay and Halifax Bay.

The same confidence score was used for the Biodiversity reporting category as for the habitat index. Confidence criteria were scored 1-3, weighted by the value identified in parenthesis and summed to produce a final (weighted) score (4.5 – 13.5). Final scores rank from 1 to 5 (very low to very high).

Reporting zone	Indicator category	Maturity of method (x0.36)	Validation (x0.71)	Representativeness (x2)	Directness (x0.71)	Measured error (x0.71)	Final score	Rank
Cleveland Bay	Coral	1.5	3	2	3	2	10.2	High (4)
	Seagrass	2	3	3	3	2	12.4	Very high (5)
	Habitat index/Biodiversity reporting category						**11.3**	**High (4)**
Halifax Bay	Coral	1.5	3	1.5	3	2	9.2	Moderate (3)
	Biodiversity/Biodiversity reporting category						**9.2**	**Moderate (3)**

Rank based on final score: Very low (1): 4.5 – 6.3; Low (2): >6.3 – 8.1; Moderate (3): >8.1 – 9.9; High (4): >9.9 – 11.7; Very high (5): >11.7 – 13.5.

6.3.2 Overall Biodiversity score

Habitat (and the overall Biodiversity score) was moderate for both Cleveland Bay and Halifax Bay, with the overall scores presented in Table 44.

Table 44. Scores and grades for coral, seagrass and overall Habitat for Cleveland Bay and Halifax Bay.

Habitat scores are averages of the scores for coral and seagrass.

	Score			Grade		
Site	Coral	Seagrass	Habitat index	Coral	Seagrass	Habitat index
Cleveland Bay	38	52	45	D	C	C
Halifax Bay	52		52	C		C

Scoring range: ■ Very Poor = 0 to <21 | ■ Poor = 21 to <41 | ■ Moderate = 41 to <61 | ■ Good = 61 to <81 | ■ Very Good = 81 to 100 | ■ No score/data gap.

6.4 Offshore marine results

6.4.1 Habitat index

The habitat index was the only index scored within the offshore marine section and coral was the only indicator category within the habitat index. Habitat was the only index scored within the offshore marine zone. The score for coral is thus also the overall score for the Biodiversity reporting category.

6.4.1.1 *Data source*

Coral was measured as part of the long-term monitoring program (LTMP), with the reefs measured shown in Figure 23**Error! Reference source not found.**. The LTMP has a biennial sampling design, with more detailed information on the methods used by LTMP can be found at https://www.aims.gov.au/docs/research/monitoring/reef/latest-surveys.html.

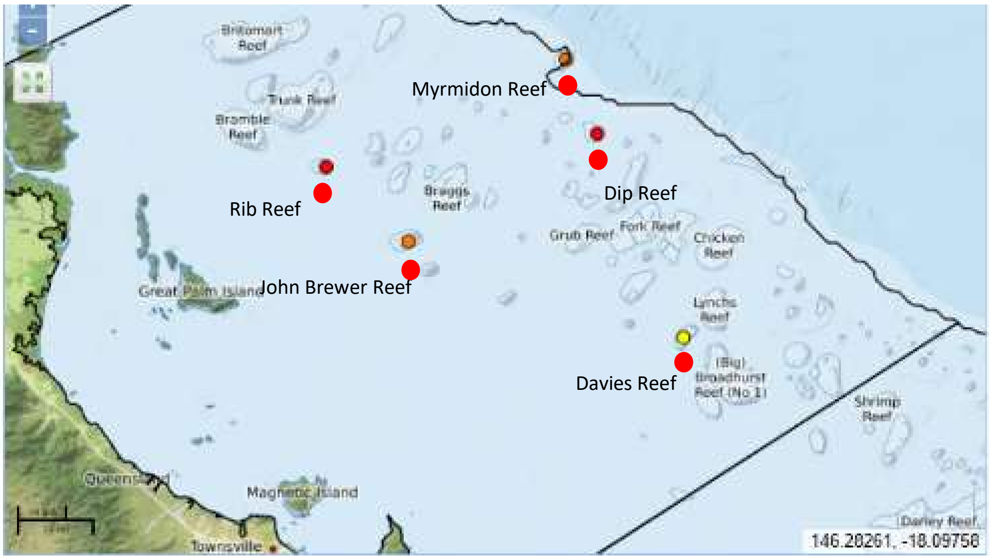


Figure 23. Map showing location of reefs in the Townsville offshore marine zone.
Source: Adapted from AIMS, 2019.

The data included in the 2018-19 Report Card was collected from May 2018 to July 2019. The LTMP samples sites at 6 m to 9 m depth. Surveys were conducted at John Brewer Reef (March 2019) and Davies Reef (June 2019) to assess the impacts of the February 2019 floods and this data were included in the score. Reef Check did not conduct any surveys at offshore reefs during the 2018-19 financial year. It is hoped that in future years, Reef Check will survey offshore reefs, with the data then incorporated into the offshore coral results.

6.4.1.2 *Results*

As seen in Table 45**Error! Reference source not found.**, the overall condition of coral within the offshore marine zone was in a moderate condition. The percentage change in coral cover was moderate, whilst coral cover was poor but juvenile density (recruitment) was very good.

Diseases and pests were present at some reefs (AIMS, 2019). COTS were present at two reefs (out of eight reefs sampled) and one reef (Davies Reef) had elevated signs of white-syndrome disease (AIMS, 2019). "For other reefs in the sector, the incidence of disease and *Drupella* spp. was low and generally below levels seen in previous years. Active removal of COTS has occurred in the Townsville sector over the last few years and may have reduced the number of COTS visible when manta tows were done. No COTS were observed on Rib reef, which had an active outbreak in 2017. No signs of coral bleaching were observed during manta tow surveys (AIMS, 2019)." Scuba surveys indicated low levels of bleaching (0-1%) on Rib Reef and all other reefs had no bleaching (AIMS, 2019).

Table 45. Integer score and grade for coral indicators and the coral indicator category for the offshore marine zone.
The score for the coral indicator category is the average of each indicator score.

Standardised score	Grade

% Change in coral cover	% coral cover	Juvenile density	**Coral indicator category**	% Change in coral cover	% coral cover	Juvenile density	**Coral indicator category**
49	35	94	**59**	C	D	A	**C**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good = 81 to 100 | ■ No score/data gap.

6.4.1.3 *Confidence scores*

As seen in Table 46**Error! Reference source not found.**, there was a low confidence in the overall coral indicator category score. Low confidence was mainly attributed to a low (2) rank in representativeness and measured error criteria. The representativeness was low as only a small proportion of the offshore reefs within the Townsville region were measured.

Table 46. Confidence scoring of offshore coral for the offshore marine zone.
Confidence criteria were scored 1-3, weighted by the value identified in parenthesis and summed to produce a final (weighted) score (4.5 – 13.5). Final scores rank from 1 to 5 (very low to very high).

	Maturity (0.36)	Validation (0.71)	Represent-ativeness (2)	Directness (0.71)	Measured error (0.71)	Final score	Rank
Coral	3	3	1	3	1	8.1	Low (2)

Rank based on final score: Very low (1): 4.5 – 6.3; Low (2): >6.3 – 8.1; Moderate (3): >8.1 – 9.9; High (4): >9.9 – 11.7; Very high (5): >11.7 – 13.5.

7 Community and Economy methods

7.1 Data source

The same data was used as for the Pilot Report Card, as the data has not been updated since 2017. Data were drawn from the Great Barrier Reef (GBR) Social and Economic Long Term Monitoring Program (SELTMP), 2017 (Marshall, et al., 2017). Data were collected between June and August 2017 from coastal population centres between Cooktown and Bundaberg (referred to as the GBR coastal region). This data set is a series of survey questions, with the results designed to be used to describe conditions and trends of the social aspects of waterways and the GBR (Marshall, et al., 2016). The results for community indicators were sourced from questions relating to the perceived health, condition and management of waterways. Questions relating to the non-monetary economic values and industry sustainability were used to score the economic benefits to the community. The survey questions are listed in Appendix E and Appendix F. Respondents listed their postcode and only the answers from Townsville residents were used to derive the scores and grades.

7.2 Methods

Similar methods were used to generate the scores and grades for social and economic indicators as used in the Pilot Report Card. The changes in method between the Pilot Report Card and the 2018-19 Report Card are shown in Table 47.

Table 47. Changes in the methods used in the 2017-18 Pilot Report Card compared to the methods used in the 2018-19 Report Card.

Methods used in 2017-18 Pilot Report Card	Methods used in 2018-19 Report Card
A score for Community was calculated for each zone.	One score for Community was calculated for the entire Townsville region.
Five indicator categories were scored and aggregated into three indices.	Five indicator categories were scored, and each category was also an index.
Survey responses from questions relating to each water type (fresh, estuarine, inshore marine and Great Barrier Reef (GBR) environment) were used to derive the scores and grades for each zone. However, most questions related to the GBR and as a result, only the offshore zone could be scored.	Responses from questions (all water types and for all zones) were used to generate one score for the Townsville region.

8 Community results

8.1 Overview of Community indicator indices

The overall score for Community was averaged from the following indices:

- Value of waterways
- Wellbeing from waterways
- Perception of waterway management
- Perception of environmental condition
- Community stewardship

The scores for each indicator was derived from the average scores from multiple questions, with the survey questions listed in Appendix E.

8.2 Community score for Townsville

In total, 1191 people responded to the survey, which equated to 0.62% of the Townsville population. Townsville received a moderate grade for the overall grade for the Community reporting category, with the scores for each indicator category shown in Table 48. Townsville residents valued their waterways, but thought the waterways were poorly managed and were in a very poor condition.

Table 48. Scores (with standard errors) and grades of the five indicators and the overall score of Community (social rating) for the Townsville region.

Indicator categories	Score	Grade
Value of waterways	7.3 ± 0.39	B
Wellbeing from waterways	6.9 ± 0.044	C
Perceptions of waterway management	5.3 ± 0.039	D
Perceptions of environmental condition	4.7 ± 0.039	E
Community stewardship	7.6 ± 0.39	C
Community score	**6.3 ± 0.40**	**C**

Scoring range (excluding community stewardship): ■ Very Poor (E) = 0 to <5 | ■ Poor (D) = 5 to <6 | ■ Moderate (C) = 6 to <7 | ■ Good (B) = 7 to <8 | ■ Very Good (A) = 8 to 10 | ■ No score/data gap

Scoring range for Community Stewardship: ■ Very Poor (E) = <6 | ■ Poor (D) = 6 to <7 | ■ Moderate (C) = 7 to <8 | ■ Good (B) = 8 to <9 | ■ Very Good (A) = 9 to 10 | ■ No score/data gap

9 Economic results

The score for the Economy reporting category were based on the scores of indicators that were grouped into two indices, which were:

- Non-monetary economic values
- Industry sustainability (ecological and economic)

The scores for each indicator was derived from the average scores from multiple questions, with the survey questions listed in Appendix F.

There were four indicator categories within the non-monetary index, which are shown in Table 49. There was no data on industry sustainability and therefore only the indicators of non-monetary economic values were scored. One score was calculated for the entire Townsville region.

Table 49. Indices and indicator categories which were aggregated to generate an overall score for the Economy reporting category.

The indices and indicator categories that were scored in the 2018-19 Report Card are highlighted in green.

Zone	Index	Indicator category
Entire Townsville region	Non-monetary economic value	Tourism attraction value
		Science and education value
		Fresh local seafood
		Perception of economic value
	Industry Sustainability	Ecological sustainability
		Economic sustainability

9.1 Non-monetary economic Index

In total, 644 people or 0.33% of the Townsville population were surveyed on the non-monetary economic benefits of waterways to the Townsville region. Fewer people responded to questions relating to the economic value of their region and that's why there is fewer respondents than for the Community indicator categories.

Overall, the community perceived very high non-monetary economic benefits from waterways within the Townsville region. The scores for each indicator category are presented in Table 50. All categories received a very good score, except for the benefits of fresh local seafood, which the community scored as being of moderate benefit (Table 50).

Table 50. Scores (with standard errors) and grades for the indicatory categories that comprise the Economy index and overall Economy score for the Townsville region.

Indicator categories	Score	Grade
Tourism attraction value	8.55 ± 0.078	A
Science and education value	8.51 ± 0.072	A
Fresh local seafood	6.72 ± 0.12	C
Perception of economic value	9.28 ± 0.054	A
Non-monetary economic index score	**8.27 ± 0.080**	**A**

Scoring range: ■ Very Poor (E) = 0 to <5 | ■ Poor (D) = 5 to <6 | ■ Moderate (C) = 6 to <7 | ■ Good (B) = 7 to <8 | ■ Very Good (A) = 8 to 10 | ■ No score/data gap

10 Litter

For the first time, Litter was scored in the 2018-19 Report Card. This is a new reporting category and is a pressure category. The Litter category was scored separately because it can detrimentally affect all other reporting categories and therefore does not fit into only one of the other four reporting categories. Litter was scored against a baseline derived from four years of data from the 2014-15 financial year to the 2017-2018 financial year. This was the earliest time that there was data from four reporting zones (Ross freshwater basin, Ross estuarine zone, Cleveland Bay and Halifax Bay). Impacts of litter on the water quality condition, biodiversity health and social and economic condition are described in the sections below.

10.1 Impacts of litter on reporting categories

10.1.1 Impact on Water and Biodiversity reporting categories

"Litter can detrimentally impact water quality through the leaching of additives (chemicals incorporated during production, such as colorants, plasticizers, stabilizers, antioxidants, flame retardants, UV absorbers and antistatic agents (Maximenko, et al., 2019). These additives make some plastics toxic and the leaching of additives to the seawater may also pose ecotoxicological threats to the marine biodiversity (Maximenko, et al., 2019). Litter can also harm the marine wildlife, including birds, mammals and fish (Page, et al., 2004; Boren, et al., 2006; Gregory, 2009). Animals can become entangled in debris (Page, et al., 2004; Boren, et al., 2006; Gregory, 2009) or ingest debris (Gregory, 2009; Verlis, et al., 2013), which can result in death by starvation or result in debilitation, leading to a reduced quality of life and lowered reproductive performance (Gregory, 2009). Most research has focused on the impacts of marine debris on marine species. However, research also shows that freshwater species, such as fish and turtles, can be impacted (Besseling, et al., 2014; Office of Environment and Heritage, 2018)" (Beaumont, et al., 2019).

10.1.2 Impact on Community (social) and Economic reporting categories

The visual presence of litter impacts upon the community, both socially and economically. At a local level, the Social Economic Long Term Monitoring Program found that Townsville residents thought there was too much rubbish on the local beaches (Marshall, et al., 2017). A study of the global impacts of litter found that "litter on the shore is disliked (Hartley et al., 2013), and is often stated as a key reason why visitors will spend less time in these environments or will avoid certain sites if they anticipate it will be littered (Anderson and Brown, 1984; Ballance et al., 2000; Tudor and Williams, 2006; WHO, 2003). This has a range of economic costs, from clean-up expenses to loss of tourism revenue. As well as having economic costs, the presence of litter can also have direct consequences on individuals' physical and mental health. Visitors and maritime workers are susceptible to a range of injuries, such as cutting themselves on sharp debris, getting entangled in nets, and being exposed to unsanitary items (Santos et al., 2005). Spending time at littered coastlines has also been demonstrated to be detrimental to their mood and mental wellbeing (Wyles et al., 2016). In turn, refraining from going to the coast due to these risks, can also have health implications, inhibiting the opportunity to reap the benefits coastlines typically offer, e.g. promoting physical activity, facilitating important social interactions such as strengthening family bonds, and improving physical and mental health (Ashbullby et al., 2013; Papathanasopoulou et al., 2016)" (Beaumont, et al., 2019).

10.2 Method for scoring litter

Litter is a pressure on the environment and is always a negative factor (with any amount of litter being detrimental). This contrasts to most other indicators. For example, indicators of water quality, such as dissolved oxygen, or dissolved inorganic nitrogen, are required at certain levels in the environment, with excessive or insufficient amounts being detrimental, but suitable amounts being a positive. This needs to be reflected in the terminology used to grade the reporting category. Litter was thus graded based on the level of pressure it has on the environment (ecological and socio-economic environment). Rather than using the terms very poor (E), poor (D), moderate (C), good (B) and very good (A) (as is used for all other indicators), litter was graded as very high pressure (VHP), high pressure (HP), moderate pressure (MP), low pressure (LP) and slight pressure (SP). Litter is also displayed as a separate reporting category to reflect this.

It is noted that artificial barriers (both impoundment length and fish barriers) are also always a negative pressure on the environment yet were scored within the Biodiversity reporting category. In the future, the indices and indicators within the various reporting categories may need to be revised for more consistency.

10.3 Data source

Data were collected in the field by volunteers as part of Tangaroa Blue clean-up projects. The location of the clean-ups for the 2018-19 financial year are shown in Figure 24. It is acknowledged that there are limitations with the data source. These limitations include:

- The scores were based on the number of items collected, with the size of an item differing substantially (e.g. a tyre and a cigarette butt were both classified as one item). In the future we anticipate data will be scored by the weight of litter collected. At present, data on total weight was either not recorded at every clean-up or potentially incorrectly recorded (only the heavier items recorded, rather than the weight of all the rubbish).

- At some clean-ups, not all items were counted due to either time constraints or a lack of resources at the clean-up event. This results in false zeros in the data and makes it difficult to differentiate between false zeros and true zeros (where no rubbish was recorded).
- The years before a clean-up event occurred differs at each site. Without clean-ups, rubbish accumulates over years and therefore the number of years before the clean-up occurred likely influenced the amount of rubbish at each site.
- The number of sites measured at each site differs between zones. This may influence the results, especially if frequently cleaned sites were surveyed in one zone and infrequently sites were cleaned at the other zones. It is acknowledged that because of this limitation, the average score for a zone may not be comparable between zones or representative of the amount of rubbish across an entire zone.

For the Report Card (a communication piece), scores were averaged so that the results can be easily communicated with the community. It is noted that all other indicators were averaged to a zone level, even when only data from a few sites were measured. Another limitation is that the area that data were collected from was not standardised and it is unlikely that all rubbish was collected within the area surveyed. However, the statistical method used to score the data overcomes some of these limitations and it is expected that the method will be refined and improved for future Report Cards. For example, for the 2019-2020 Report Card, it is aimed that data from eight standardised clean-ups will be able to be reported on. Using standardised sites will assist in overcoming some of the current limitations with the data.

Additionally, for future clean-ups the aim is to divide litter into four additional categories, as well as having an ‘other rubbish category’ (comprising all litter not within the four categories). The four additional categories that align with current management/litter reduction campaigns are :

- plastic bags, which aligns with the plastic bag ban in Queensland,
- plastic bottles and drink containers, which aligns with the bottle container recycling scheme,
- single use plastic disposable cutlery, which align with the straws no more and plastic free campaigns, and
- cigarette butts, which to align with bans and restrictions on smoking.

Figure 24. Litter clean-up locations for the 2018-19 financial year within 1) Halifax Bay, 2) Cleveland By, 3) Ross estuarine zone and 4) Ross freshwater basin.

10.4 Results

Plastic bags, cigarette butts and filters, plastic drink bottles and tops and plastic containers (no food containers) were the five most littered items in Townsville.

10.4.1 Freshwater basins

Overall, litter was classified as being a moderate pressure on the Ross freshwater basin (see Table 51). However, litter was collected from only two sites and thus the scores may not be representative of the score for the entire zone. There were large variations in scores between the sites, with litter considered a low pressure at Aplin's Weir, but was graded as having a very high pressure at Apex Park (Condon) (see Table 51). No sites were cleaned within the Black freshwater basin, with no score for this zone.

Table 51. Scores and grades for the litter metric for freshwater sites where clean-up events occurred in 2018-19.

Scores were rounded to whole numbers.

Reporting zone	Site	Score	Grade
Ross freshwater basin	Aplin's Weir	70	LP
	Apex Park (Condon)	20	VHP
	Average	**45**	**MP**

Scoring range: ■ Very high pressure (VHP) = 0 to <21 | ■ High pressure (HP) = 21 to <41 | ■ Moderate pressure (MP) = 41 to <61 | ■ Low pressure (LP) = 61 to <81 | ■ Slight pressure (SP) = 81 to 100 | ■ No score/data gap.

10.4.1.1 *Confidence scores*

As presented in Table 52, there was very low confidence in the scores and grades for the litter reporting category. This is because the method is a new method, there was very limited spatial and temporal sampling and there is no measured error.

Table 52. Confidence scores for the litter reporting category for the Ross and Black freshwater basins.

Confidence criteria were scored 1-3, weighted by the value identified in parenthesis and summed to produce a final (weighted) score (4.5 – 13.5). Final scores rank from 1 to 5 (very low to very high).

Maturity (0.36)	Validation (0.71)	Represent-ativeness (2)	Directness (0.71)	Measured error (0.71)	Final score	Rank
1	1	1	3	1	5.9	Very Low (1)

Rank based on final score: Very low (1): 4.5 – 6.3; Low (2): >6.3 – 8.1; Moderate (3): >8.1 – 9.9; High (4): >9.9 – 11.7; Very high (5): >11.7 – 13.5.

10.4.2 Estuarine zones

Overall, litter was classified as having low pressure on Ross estuarine zone (see Table 53), as there was less litter collected from clean-ups in the 2018-19 financial year than the amounts collected between 2014 and 2018. However, data were only collected from three sites in 2018-19 and thus the scores may not be representative of the score for the entire zone. There was more litter at Cape Pallarenda than collected between 2014 and 2018, meaning it had a higher pressure than previously.

This higher pressure is not reflected in the overall score for the zone. No sites were cleaned within the Black estuarine zone, with no score for this zone.

Table 53. Scores and grades for the litter metric for estuarine sites where clean-up events occurred in 2018-19.

Scores were rounded to whole numbers.

Reporting zone	Site	Score	Grade
Ross estuarine zone	Cape Pallarenda	39	HP
	Pallarenda Beach	57	LP
	Rowes Bay	72	LP
	Shelly Cove	86	SP
	Average	**64**	**LP**

Scoring range: ■ Very high pressure (VHP) = 0 to <21 | ■ High pressure (HP) = 21 to <41 | ■ Moderate pressure (MP) = 41 to <61| ■ Low pressure (LP) = 61 to <81 | ■ Slight pressure (SP) = 81 to 100 | ■ No score/data gap.

10.4.2.1 *Confidence scores*

There was very low confidence in the scores and grades for the litter reporting category (see Table 54.

Table 54. Confidence scores for the litter reporting category for the Ross and Black estuarine zones.

Confidence criteria were scored 1-3, weighted by the value identified in parenthesis and summed to produce a final (weighted) score (4.5 – 13.5). Final scores rank from 1 to 5 (very low to very high).

Maturity (0.36)	Validation (0.71)	Represent-ativeness (2)	Directness (0.71)	Measured error (0.71)	Final score	Rank
1	1	1	3	1	5.9	Very Low (1)

Rank based on final score: Very low (1): 4.5 – 6.3; Low (2): >6.3 – 8.1; Moderate (3): >8.1 – 9.9; High (4): >9.9 – 11.7; Very high (5): >11.7 – 13.5.

10.4.3 Inshore marine zones

Overall, litter posed a lower pressure on Cleveland Bay compared to amount of rubbish present from 2014 to 2018. In contrast, there was more litter collected within Halifax Bay than previously, with litter classified as having a high pressure on the zone. The pressure classifications for each site within Cleveland Bay and Halifax Bay are presented in Table 55. There were large variations in pressure scores between the sites within both zones. Within Cleveland Bay, there was more litter at Alma Bay and Geoffrey Bay than collected between 2014 and 2018, with litter classified as having high pressure at both sites. These high pressure scores were not reflected in the low pressure score for Cleveland Bay. Within the Halifax Bay, there was less litter at Yanks Jetty than collected between 2014-18, with this low pressure score not reflected in the overall high pressure score given to Halifax Bay.

Table 55. Scores and grades for the litter metric for Cleveland Bay and Halifax Bay where clean-up events occurred in 2018-19.

Scores were rounded to whole numbers.

Reporting zone	Site	Score	Grade
Cleveland Bay	Alma Bay	23	HP
	Arthur Bay	96	SP
	Florence Bay	100	SP
	Geoffrey Bay	25	HP
	Horseshoe Bay	93	SP
	Nelly Bay	82	SP
	Average	**70**	**LP**
Halifax Bay	Picnic Bay	29	HP
	South Beach	4	VHP
	Yanks Jetty	73	LP
	Average	**35**	**HP**

Scoring range: ■ Very high pressure (VHP) = 0 to <21 | ■ High pressure (HP) = 21 to <41 | ■ Moderate pressure (MP) = 41 to <61| ■ Low pressure (LP) = 61 to <81 | ■ Slight pressure (SP) = 81 to 100 | ■ No score/data gap.

10.4.3.1 *Confidence scores*

There was very low confidence in the scores and grades for the litter reporting category (see Table 56).

Table 56. Confidence scores for the litter reporting category for Cleveland Bay and Halifax Bay.

Confidence criteria were scored 1-3, weighted by the value identified in parenthesis and summed to produce a final (weighted) score (4.5 – 13.5). Final scores rank from 1 to 5 (very low to very high).

Maturity (0.36)	Validation (0.71)	Represent-ativeness (2)	Directness (0.71)	Measured error (0.71)	Final score	Rank
1	1	1	3	1	5.9	Very Low (1)

Rank based on final score: Very low (1): 4.5 – 6.3; Low (2): >6.3 – 8.1; Moderate (3): >8.1 – 9.9; High (4): >9.9 – 11.7; Very high (5): >11.7 – 13.5.

10.4.4 Offshore marine zones

No data was collected for the offshore marine zone, with no scores for this zone.

11 References

AECOM Australia Pty Ltd Receiving Environment Monitoring Program: Design Document, 2014. *Cleveland Bay Purification Plant,* Townsville: Townsville City Council.

AECOM Australia Pty Ltd, 2013. *Wastewater Treatment Plant Upgrade Program Receiving Environment Monitoring Program: Design Document,* Townsville: Townsville City Council.

AECOM Australia Pty Ltd, 2016. *CBPP Upgrade Receiving Environment Monitoring Plan 2016,* Townsville: Townsville City Council.

Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2018. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality,* Artarmon, New South Wales: Australian Water Association.

Australian Bureau of Statistics, 2016. *2016 Census QuickStats.* [Online]
Available at:
http://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat
[Accessed 17 January 2019].

Australian Institue of Marine Science (AIMS), 2019. *Report on surveys of the Townsville sector of the Great Barrier Reef.* [Online]
Available at: https://www.aims.gov.au/reef-monitoring/townsville-sector-2019
[Accessed 7 January 2020].

Australian Institute of Marine Science (AIMS), 2018. *Coral bleaching events.* [Online]
Available at: https://www.aims.gov.au/docs/research/climate-change/coral-bleaching/bleaching-events.html
[Accessed 28th November 2018].

Beaumont, N. et al., 2019. Global ecological, social and economic impacts of marine plastic. *Marine Pollution Bulletin,* Volume 142, pp. 189-195.

Bennett, A., Nimmo, D. & Radford, J., 2014. Riparian vegetation has disproportionate benefits for landscape-scale conservation of woodland birds in highly modified environments. *Journal of Applied Ecology,* 51(2), pp. 514-523.

Bennett, N. et al., 2018. Environmental Stewardship: A Conceptual Review and Analytical Framework. *Environmental Management,* 61(4), pp. 597-614.

Besseling, E., Wang, B., Lürling, M. & Koelmans, A., 2014. Nanoplastic Affects Growth ofS. obliquus and Reproduction of D. magna. *Environmental Science and Technology,* 48(20), pp. 12336-12343.

BOM, 2018c. *Annual climate statement 2017.* [Online]
Available at: http://www.bom.gov.au/climate/current/annual/aus/#tabs=Sea-surface-temperature
[Accessed 28th November 2018].

Boren, J., Morrissey, M., Muller, C. & Gemmell, N., 2006. Entanglement of New Zealand fur seals in man-made debris at Kaikoura, New Zealand. *Marine Pollution Bulletin,* 52(4), p. 442–446.

Bowler, D. et al., 2012. What are the effects of wooded riparian zones on stream temperature?. *Environmental Evidence,* 1(3), pp. 1-9.

Bradshaw, C., 2012. Little left to lose: deforestation and forest degradation in Australia since European colonization. *Journal of Plant Ecology,* 5(1), pp. 109-120.

Bridge, T. et al., 2013. Depth-dependent mortality of reef corals following a severe bleaching event: implications for thermal refuges and population recovery. *F1000Research,* 3(2), p. 187.

Bryant, C. & Rasheed, M., 2018. *Port of Townsville Annual Seagrass Monitoring September 2017,* Townsville: Port of Townsville.

Bryant, C., Wells, J. & Rasheed, M., 2018. *Port of Townsville Annual Seagrass onitoring,* Townsville: TropWater Centre for Tropical Water and Aquatic Ecosystem Research.

Bryant, C., Wells, J. & Rasheed, M., 2019. *Port of Townsville Annual Seagrass Monitoring October 2018,* Cairns: Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER).

Bureau of Meteorology (BOM), 2018b. *Regional Water Information.* [Online]
Available at: http://www.bom.gov.au/water/rwi/#ro_tt/157/2018

Bureau of Meteorology (BOM), 2018. *Climate Data Online.* [Online]
Available at: http://www.bom.gov.au/climate/data/

Bureau of Meteorology (BOM), 2019a. *Regional Water Information,* Canberra: Bureau of Meteorology.

Bureau of Meteorology (BOM), 2019b. *Climate Data Online.* [Online]
Available at: http://www.bom.gov.au/jsp/ncc/cdio/weatherData/
[Accessed 19th November 2019].

Bureau of Meteorology (BOM), 2019c. *Special Climate Statement 69 - an extended period of heavy rainfall and flooding in tropical Queensland,* Canberra: Australian Government.

Bureau of Meteorology (BOM), 2020. *Climate change – trends and extremes,* Canberra: Australian Government.

Bureau of Meteorology, n.d. *Climate of Townsville.* [Online]
Available at: http://www.bom.gov.au/qld/townsville/climate_Townsville.shtml
[Accessed 31st March 2020].

Cay, E., Sivapalan, S. & Chan, K., 2001. *Effect Of Polyacrylamides On Reducing The Dispersive Properties Of Sodic Soils When Flood Irrigated.* Toowoomba, Queensland University of Technology, pp. 28-32.

Cork, S., Stoneham, G. & Lowe, K., 2007. *Ecosystem services and Australian natural resource management (NRM) futures: Paper to the Natural Resource Policies and Programs Committee and the Natural Resource Management Standing Committee,* Canberra: Department of Sustainability, Environment, Water, Population and Communities.

CSIRO, 2019. *eReefs Research Models.* [Online]
Available at: https://research.csiro.au/ereefs/models/
[Accessed 2019].

Department of Agriculture and Fisheries, 2016. *Queensland waterways for waterway barrier works: Queensland Spatial Catalogue - QSpatial.* [Online]
Available at: http://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={77D35E81-

DB9C-45B1-811F-0D2572ADB02A}
[Accessed 16th April 2019].

Department of Environment and Heritage Protection, 2009. *Queensland Water Quality Guidelines 2009, Version 3,* Brisbane: Queensland Government.

Department of Environment and Primary Industries, 2013. *Improving Our Waterways Victorian Waterway Management Strategy,* Melbourne: The State of Victoria Department of Environment and Primary Industries.

Department of Environment and Science, 2013. *Palustrine ecology, WetlandInfo.* [Online]
Available at: https://wetlandinfo.des.qld.gov.au/wetlands/ecology/aquatic-ecosystems-natural/palustrine
[Accessed 18th January 2019].

Department of Environment and Science, 2018. *Catchment care.* [Online]
Available at: https://environment.des.qld.gov.au/water/catchment_care.html
[Accessed 2019 January 2019].

Department of Environment and Science, 2018. *Environmental Protection Policy (Water) 2009 Mapping procedural guide Management intent and water type mapping methodology,* Brisbane: Queensland Government.

Department of Environment, Land, Water and Planning, n.d. *Water and Catchments.* [Online]
Available at: https://www.water.vic.gov.au/
[Accessed 31st March 2020].

Department of Natural Resources and Water, 2009. *Interim Resource Operations Licence for the Ross River Water Supply Scheme,* Brisbane: Queensland Government.

Department of Natural Resources, 2000. *Condamine-Balonne WAMP: environmental flows technical report,* Brisbane: Department of Natural Resources.

Department of Science, Information Technology and Innovation (DSITI), 2017. *Ground cover technical report 2015-16: Great Barrier Reef catchments,* Brisbane: Queensland Department of Science, Information Technology and Innovation.

Department of the Environment and Energy, 2016. *Coastal wetlands—Mangroves and saltmarshes,* Canberra: Commonwealth of Australia.

Division, Environmental Policy and Planning, 2014. *Environmental Protection (Water) Policy 2009 Tully, Murray and Hinchinbrook Is. River Basins Environmental Values and Water Quality Objectives Basins Nos. 113, 114 and 115 and adjacent coastal waters,* Brisbane: Department of Environment and Heritage Protection.

Eakin, C. et al., 2016. Global coral bleaching 2014-2017? Status and an appeal for observations. *Reef Encounter 43,* 31(1), pp. 20-26.

Environmental Policy and Planning Division, 2013. *Environmental Protection (Water) Policy 2009 Black River Basin Environmental Values and Water Quality Objectives Basin No. 117, including all waters of the Black River Basin and adjacent coastal waters,* Brisbane: Department of Environment and Heritage Protection.

Environmental Policy and Planning Division, 2013. *Environmental Protection (Water) Policy 2009: Ross River Basin and Magnetic Island Environmental Values and Water Quality Objectives, Basin 118 including all waters of the Ross River Basin, and adjacent coastal waters (including Magnetic Island),* Brisbane: Department of Environment and Heritage Protection.

Faulks, L., Gilligan, D. & Beheregaray, L., 2011. The role of anthropogenic vs. natural in-stream structures in determining connectivity and genetic diversity in an endangered freshwater fish, Macquarie perch (Macquaria australasica). *Evolutionary Applications,* 4(4), pp. 589-601.

Fisheries Queensland, 2013. *Guide for the determination of waterways using the spatial data layer Queensland waterways for waterway barrier works,* Brisbane: Department of Agriculture, Fisheries and Forestry.

Great Barrier Reef Marine Park Authority (GBRMPA), 2010. *Water Quality Guidelines for the Great Barrier Reef Marine Park. Revised Edition 2010,* Townsville: Great Barrier Reef Marine Park Authority.

Gregory, M., 2009. Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philosophical Transactions of the Royal Society B,* 364(1526), p. 2013–2025.

Gunn, J. M. C., 2010. *Black Ross (Townsville) Water Quality Improvement Plan: Improving Water Quality from Creek to Coral,* Townsville: Townsville City Council - Creek to Coral.

Häder, D., Helbling, E., Williamson, C. & Worrest, R., 2011. Effects of UV radiation on aquatic ecosystems and interactions with climate change. *Photochemical and Photobiological Sciences,* 10(2), pp. 242-260.

Häder, D. et al., 2015. Effects of UV radiation on aquatic ecosystems and interactions with other environmental factors. *Photochemical and Photobiological Sciences,* Volume 14, pp. 108-126.

Healthy Rivers to Reef Partnership Mackay-Whitsunday , 2017. *Methods for the Macyaky-Whitsunday 2016 Report Card,* Mackay: Healthy Rivers to Reef Partnership Mackay-Whitsunday .

Huan, J. et al., 2013. Evaluation of the Impacts of Land Use on Water Quality: A Case Study in The Chaohu Lake Basin. *The Scientific WOrld Journal,* 2013(329187), pp. 1-7.

Industry and Investment NSW, 2009. *Bringing Back the Fish – Improving Fish Passage and Aquatic Habitat in Coastal NSW. Final Report to the Southern Rivers Catchment,* Cronulla: Industry and Investment NSW.

Jackson, W. & Rankin, A., 2016. *Drivers of environmental change.* [Online]
Available at: https://soe.environment.gov.au/theme/overview/topic/drivers-environmental-change
[Accessed 18th January 2019].

Kuchment, L., 2004. The Hydrological Cycle and Human Impact on it. In: A. Hoekstra & H. Savenije, eds. *Water Resources Management.* Oxford: Encyclopedia of Life Support Systems.

Lemon, J. & Hall, D., 2019. *Dispersive (sodic) soils: the science.* [Online]
Available at: https://www.agric.wa.gov.au/dispersive-and-sodic-soils/dispersive-sodic-soils-science
[Accessed 5th March 2019].

Lewis, S. et al., 2015. *Burdekin sediment story. No. 15/report no. 50 for the NQ Dry Tropics NRM, Centre for Tropical Water & Aquatic Ecosystem Research,* Townsville: James Cook University.

Lønborg, C. et al., 2016. *Marine Monitoring Program: Annual Report for inshore water quality monitoring: 2014 to 2015. Report for the Great Barrier Reef Marine Park Authority,* Townsville: Australian Institute of Marine Science and JCU TropWATER.

Lukacs, G., 1996. *Wetlands of the Townsville Area,* Townsville: Australian Centre for Tropical Freshwater Research at James Cook University.

Mackay-Whitsunday Healthy Rivers to Reef Partnership, 2017. *Methods for the Macyaky-Whitsunday 2016 Report Card,* Mackay: Mackay-Whitsunday Healthy Rivers to Reef Partnership.

Marshall, N. et al., 2014. *The Social and Economic Long Term Monitoring Program for the Great Barrier Reef (SELTMP),* Townsville: CSIRO.

Marshall, N. et al., 2016. Advances in monitoring the human dimension of natural resource systems: an example from the Great Barrier Reef. *Environmental Research Letters,* 11(11), pp. 1-17.

Marshall, N., Curnock, M., Pert, P. & Williams, G., 2017. *The Social and Economic Long Term Monitoring Program (SELTMP) for the Great Barrier Reef . Final Report. Report to the Great Barrier Reef Marine Park Authority,* Townsville: Great Barrier Reef Marine Park Authority.

Marshall, P. & Baird, A., 2000. Bleaching of corals on the Great Barrier Reef: differential susceptibilities among taxa. *Coral Reefs,* 19(2), pp. 155-163.

Maximenko, N. et al., 2019. Toward the Integrated Marine Debris Observing System. *Frontiers in Marine Science,* Volume 6, p. 447.

McCully, P., n.d. *Silenced Rivers: The Ecology and Politics of Large Dams.* [Online]
Available at: https://www.internationalrivers.org/dams-and-water-quality
[Accessed 31st March 2020].

McKenna, S. et al., 2020. *Port of Townsville Seagrass Monitoring Program 2019,* Townsville: Centre for Tropical Water & Aquatic Ecosystem Research (TropWater).

Miller, J. et al., 2014. Assessing the impact of urbanization on storm runoff in a peri-urban catchment using historical change in impervious cover. *Journal of Hydrology,* Volume 515, pp. 59-70.

Moore, M., 2016. *HR2R – Freshwater & Estuary Fish Barrier Metrics Report – Final Report for Healthy Rivers to Reef Partnership,* Mackay: Healthy Rivers to Reef Partnership.

National Oceanic and Atmospheric Administration (NOAA), 2018. *Coral Bleaching During & Since the 2014-2017 Global Coral Bleaching Event.* [Online]
Available at:
https://coralreefwatch.noaa.gov/satellite/analyses_guidance/global_coral_bleaching_2014-17_status.php
[Accessed 28th November 2018].

National Oceanic and Atmospheric Administration, 2018. *Coral Bleaching During & Since the 2014-2017 Global Coral Bleaching Event.* [Online]
Available at:
https://coralreefwatch.noaa.gov/satellite/analyses_guidance/global_coral_bleaching_2014-17_status.php
[Accessed 28th November 2018].

Neldner, V. et al., 2017. *Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland. Version 4.0. Updated May 2017,* Brisbane: Queensland Herbarium, Queensland Department of Science, Information Technology and Innovation.

NQ Dry Tropics, n.d. [Online]
Available at: http://nrm.nqdrytropics.com.au/water/
[Accessed 27th November 2018].

Office of Environment and Heritage, 2018. *Freshwater turtles.* [Online]
Available at: https://www.environment.nsw.gov.au/topics/animals-and-plants/native-animals/native-animal-facts/freshwater-turtles
[Accessed 22nd May 2019].

Page, B. et al., 2004. Entanglement of Australian sea lions and New Zealand fur seals in lost fishing gear and other marine debris before and after Government and industry attempts to reduce the problem. *Marine Pollution Bulletin,* 49(1-2), pp. 33-42.

Queensland Government, 2019. *Reef 2050 Water Quality Improvement Plan.* [Online]
Available at: https://reportcard.reefplan.qld.gov.au/
[Accessed 11th February 2020].

Ribaudo, C. et al., 2018. Invasive Aquatic Plants as Ecosystem Engineers in an Oligo-Mesotrophic Shallow Lake. *Frontiers in Plant Science,* 9(1781), pp. 1-14.

Richardson, J. et al., 2010. Do riparian zones qualify as critical habitat for endangered freshwater fishes?. *Canadian Journal of Fisheries and Aquatic Sciences,* 67(7), pp. 1197-1204.

Sheldon, F., Thoms, M., Berry, O. & Puckridge, J., 2000. Using disaster to prevent catastrophe: Referencing the impacts of flow changes in large dryland rivers. *Regulated Rivers: Research and Management,* Volume 16, pp. 403-420.

Strahler, A., 1952. Hypsometric (area-altitude) analysis of erosional topology. *Geological Society of America Bulletin,* 63 (11), pp. 1117-1142.

Swanson, S. et al., 2017. Riparian proper functioning condition assessment to improve watershed management for water quality. *Journal of Soil and Water Conservation,* 72(2), p. 168–182.

The Guardian, 2018. *'Sad surprise': Amazon fish contaminated by plastic particles.* [Online]
Available at: https://www.theguardian.com/environment/2018/nov/16/sad-surprise-amazon-fish-contaminated-by-plastic-particles
[Accessed 15th May 2019].

Thompson, A. et al., 2018. *Marine Monitoring Program. Annual Report for inshore coral reef monitoring: 2016-2017,* Townsville: Great Barrier Reef Marine Park Authority.

Townsville City Council, 2018. *Dam Levels,* Townsville: Townsville City Council.

Townsville City Council, n.d. *Townsville 1901-2003.* [Online]
Available at: https://www.townsville.qld.gov.au/about-townsville/history-and-heritage/townsville-history/townsville-1901-2003
[Accessed 5th March 2019].

Verlis, K., Campbell, M. & Wilson, S., 2013. Ingestion of marine debris plastic by the wedge-tailed shearwater Ardenna pacifica in the Great Barrier Reef. *Australia. Marine Pollution Bulletin,* 72(1), pp. 244-249.

Ward, R., Friess, D., Day, R. & MacKenzie, R., 2016. Impacts of climate change on mangrove ecosystems: a region by region overview. 2(4), p. e01211.

Wet Tropics Healthy Waterways Partnership, 2018. *Wet Tropics Report Card 2018 (reporting on data 2016-17). Waterway Environments: Methods,* Cairns: Wet Tropics Healthy Waterways Partnership and Terrain NRM.

Whitehead, T., 2019a. *Program Design for the Townsville Dry Tropics 2017-2018 Pilot Report Card (released in 2019),* Townsville: Dry Tropics Partnership for Healthy Waters.

Whitehead, T., 2019b. *Methods for the Townsville Partnership for Healthy Waters (Dry Tropics) annual report cards,* Townsville: Dry Tropics Partnership for Healthy Waters.

Zaimes, G., Tufekcioglu, M. & Schultz, R., 2019. Riparian Land-Use Impacts on Stream Bank and Gully Erosion in Agricultural Watersheds: What We Have Learned. *Water,* 11(7), p. 1343.

Zuazo, V. & Pleguezuelo, C., 2008. Soil-erosion and runoff prevention by plant covers. A review. *Agronomy for Sustainable Development,* 28(1), pp. 65-86.

12 Appendix A. Scoring freshwater and estuarine habitat extent against earliest baseline

12.1 Freshwater habitat extent

Freshwater habitat extent was comprised of two indicators, riparian extent and wetland extent.

12.1.1 Data source

Data on riparian extent and wetland extent were prepared by the Queensland Herbarium, using data obtained through Google Earth and the Queensland Herbarium's Regional Ecosystem (version 9) mapping (Neldner, et al., 2017). The earliest available habitat data was from aerial photographs taken in the 1960s (Neldner, et al., 2017), with the amount of loss calculated based on the amount of present vegetation extent compared to the earliest baseline. Data are updated every four years (Neldner, et al., 2017), with the data from 2017 used to produce the scores for the 2018-19 Report Card. The methods for calculating habitat extent changed in 2019 (after the Pilot Report Card was released), with habitat extent now calculated on a finer scale and using more accurate spatial analysis techniques. However, it means that the 2018-19 results are not comparable with the results in the Pilot Report Card. A more detailed description of how the vegetation is mapped is described in Neldner, et al., 2017.

In other regional Report Cards, the earliest baseline is referred to the 'pre-European or pre-development condition'. However, this term is misleading within highly urbanised areas, such as Townsville. This is because pre-development habitat extent is largely based on the estimated amount of habitat from the 1960s (Neldner, et al., 2017). In Townsville substantial areas of vegetation were already cleared in the 1920s (Townsville City Council, n.d.) which means that the estimated pre-development extent is likely to be substantially lower than the true extent. The proportion of current habitat remaining compared to pre-development extent levels are thus likely to be higher than actual. This will result in the scores for habitat extent may appear better than accurate. For the Townsville Dry Tropics Report Card, the term earliest baseline was used instead of pre-development condition.

12.1.2 Scoring ranges for comparing habitat extent against earliest baseline

The scoring range associated with changes in habitat extent compared to the earliest baseline (1960s data) are presented in Appendix A Table 1. Detailed information on how the scores were derived are presented in the Dry Tropics methods document (Whitehead, 2019b).

Appendix A Table 1. Scoring ranges, grades and aggregation formula for scoring riparian and wetland extent (indicators of freshwater habitat extent) and mangrove and saltmarsh extent (indicators of estuarine habitat extent).

Raw scoring range	Formula to convert raw scores into standardised scores	Report Card scoring range	Grade and colour code
≤5%	81+ ABS(19 - ((score-0) *(19/4.9)))	81 to 100	Very Good (A)
>5.0-15%	61+ ABS(19.9 - ((score -5.1) *(19.9/9.9)))	61 to <81	Good (B)
>15-30%	41+ ABS(19.9 -((score -15.1) *(19.9/14.9)))	41 to <61	Moderate (C)
>30-50%	21+ ABS(19.9- ((score -30.1) * (19.9/19.9)))	21 to <41	Poor (D)
>50%	ABS(20.9 - ((score-50.1) *(20.9/49.9)))	0 to <21	Very Poor (E)

12.1.3 Results

Overall, the habitat index for Ross freshwater basin was in a moderate state compared to habitat extent in 1960s, whilst the Black freshwater basin was in good state, as shown in Appendix A Table 2. The riparian extent in the Black freshwater basin was in a good state, however riparian extent scored poorly in the Ross freshwater basin. This is unsurprising given the high level of urban development along waterways within the Ross freshwater basin. Wetland extent was classified as very good within the Ross freshwater basin and moderate within the Black freshwater. However, it is important to note that when comparing data against the earliest baseline, modified wetlands, including bunded estuarine areas, are included in the calculation of wetland extent (although artificial wetlands are not included). This explains why Ross freshwater basin recorded an increase in wetland extent compared to 1960s levels. This result is likely to be misleading as the extent of natural wetlands is likely to have declined in the area. This result will not be displayed on the Report Card as only scores against management targets will be displayed on the Report Card.

Appendix A Table 2. Scores and grades for riparian vegetation, wetlands and Habitat for the Ross and Black freshwater basins.

The percent (%) loss and remaining based on 2013-2017 levels is compared to habitat extent in the 1960s. Scores for the habitat index is the averages of the scores for riparian and wetland extent.

Freshwater zone	Raw data (2013-2017 data)		Standardised score			Grade for indicator categories		
	Riparian extent (2013-2017 data)	Wetland extent (2013-2017 data)	Riparian extent	Wetland extent	**Habitat index**	Riparian vegetation	Wetlands	**Habitat index**
Ross freshwater basin	47% lost 53% remaining	25% increase	22	100	**61**	D	A	**B**
Black freshwater basin	13% lost 87% remaining	25% lost 75% remaining	66	48	**58**	B	C	**C**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good = 81 to 100 | ■ No score/data gap.

12.1.4 Confidence scores

There was a very low confidence in the results for both riparian and wetland extent. The scores used to generate this ranking are presented in Appendix A Table 3. The method for estimating pre-development habitat extent based on GIS mapping is inaccurate at a fine-scale and urban areas (Neldner, et al., 2017), such as Townsville. This resulted in very low scores in 'maturity of the method' and 'representativeness' categories and an overall very low confidence in the results.

Appendix A Table 3. Confidence scores for riparian and wetland extent for both the Ross and Black freshwater basins.

Confidence criteria were scored 1-3, weighted by the value identified in parenthesis and summed to produce a final (weighted) score (4.5 – 13.5). Final scores rank from 1 to 5 (very low to very high).

	Maturity (0.36)	Validation (0.71)	Representa-tiveness (2)	Directness (0.71)	Measured error (0.71)	Final score	Rank
Riparian extent	1	2	1	1.5	2	6.2	Very low (1)
Wetland extent	1	2	1	1.5	2	6.2	Very low (1)

Rank based on final score: Very low (1): 4.5 – 6.3; Low (2): >6.3 – 8.1; Moderate (3): >8.1 – 9.9; High (4): >9.9 – 11.7; Very high (5): >11.7 – 13.5.

12.2 Estuarine habitat extent

12.2.1 Data source

Data was prepared using the same method as outlined in section 12.1.1 (for freshwater habitat extent, with data compared against the earliest baseline).

12.2.2 Results

Estuarine habitat extent (and the overall grade for the habitat indicator category) received a good grade within the Ross estuarine zone and a very good grade within the Black estuarine zone, as shown in Appendix A Table 4.

Appendix A Table 4. Scores and grades for estuarine extent indicator category and the habitat index for the Ross and Black estuarine zones.

The estuarine indicator category is the only indicator category within the habitat index and therefore provides the score for index.

Estuarine/ coastal zone	Raw data	Standardised score		Grade	
	Estuarine extent	Estuarine (Combined mangrove and saltmarsh extent	**Habitat index**	Estuarine (Combined mangrove and saltmarsh extent	**Habitat index**
Ross estuarine zone	8% loss 92% remaining	75	**75**	B	**B**
Black estuarine zone	4% loss 96% remaining	81	**81**	A	**A**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good = 81 to 100 | ■ No score/data gap.

12.2.3 Confidence scores

There was a moderate confidence in the results for mangrove and saltmarsh extent, with the overall rank and the scores for each confidence criterion presented in Appendix A Table 5. Mangrove and saltmarsh scores are based on GIS mapping, resulting in the 'measured error' and 'maturity of method' criteria receiving a low rank (1) Appendix A Table 5.

Appendix A Table 5. Confidence scores for estuarine (mangrove and saltmarsh) extent for both the Ross and Black estuarine zone.

Confidence criteria were scored 1-3, weighted by the value identified in parenthesis and summed to produce a final (weighted) score (4.5 – 13.5). Final scores rank from 1 to 5 (very low to very high).

	Maturity (0.36)	Validation (0.71)	Represent-ativeness (2)	Directness (0.71)	Measured error (0.71)	Final score	Rank
Estuarine extent	1	2	2	2	1	7.9	Low (2)

Rank based on final score: Very low (1): 4.5 – 6.3; Low (2): >6.3 – 8.1; Moderate (3): >8.1 – 9.9; High (4): >9.9 – 11.7; Very high (5): >11.7 – 13.5.

13 Appendix B. Water quality scores for data compared against water quality guideline values

13.1.1 Water quality guideline values

Water quality guideline values (GVs) for freshwater and estuarine waters were sourced from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality document (Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2018). The GVs for the inshore and offshore marine zones were sourced from the Marine Monitoring Program Annual report for inshore water quality monitoring 2014-2015 (Lønborg, et al., 2016). The GVs for the Wet Tropics Partnership are derived from this report. The Wet Tropics Report Card also reports on Pelorus Island (within the Halifax Bay inshore reporting zone) and thus to ensure consistency with the Wet Tropics, the same guideline values will be used. The GVs for the indicators of water quality for freshwater and estuarine waters are presented in Appendix B Table 1, whilst the GVs for indicators of inshore and offshore marine water quality are shown in Appendix B Table 2.

Appendix B Table 1. Water quality guideline values for water quality indicators of the freshwater and estuarine waters.

NOx indicates oxidised nitrogen and Total P indicates total phosphorus. Values for dissolved oxygen (DO) and turbidity are presented as lower-upper boundary values.

Indicator category	Indicator	Unit	Freshwater	Estuaries	Freshwater lakes/ reservoirs
Nutrients	DIN	µg/L	<20	<45	<20
	Total P	µg/L	<10	<20	<10
Physical-chemical	Turbidity	NTU	2-15	1-20	2-200
	DO	% sat.	85-120	80-120	90-120

Source: Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (2018)

Appendix B Table 2. Water quality guideline values for water quality indicators of the inshore marine and offshore marine waters.

NOx indicates oxidised nitrogen and Total P and Particulate indicates total phosphorus and particulate phosphorus. TSS stands for total suspended solids.

			Inshore marine			Offshore marine
			Wet Tropics	Dry Tropics		
Indicator category	Indicator	Unit	Open coastal	Enclosed coastal	Open coastal	
Nutrients	NOx	µg/L	<2	<3	<3	<2
	Particulate N	µg/L	<20	No data	<20	<17
	Total P	µg/L	No data		No data	No data
	Particulate P		<2.8		<2.8	<1.9
Physical-chemical	Turbidity	NTU	<1.5	<6	<1	<1
	TSS	mg/L	<2	No data	<2	<0.7
	Secchi depth	m	>10	>1.5	>10	>17
Chlorophyll *a*	Chlorophyll *a*	µg/L	<0.45	<2	<0.45	<0.4
Monitoring sites			Pandora Reef, Pelorus Island	Enclosed coastal waters	Open coastal waters, Geoffrey Bay	All offshore zone

Source: Lønborg, et al., (2016)

13.2 Freshwater results

13.2.1 Comparing water quality against water quality guidelines

This section presents the results for water quality indicator categories compared against water quality guidelines.

13.2.1.1 *Results*

Water quality scores were derived from scores for nutrients and physical-chemical properties compared against their respective water quality guideline values. It is noted that the scores for this year (2018-19) are not comparable to 2017-18 scores because additional sites were sampled this year (2018-19) and scores were also weighted.

In Appendix B Table 3, Appendix B Table 4 and Appendix B Table 5, scores and grades indicate whether water quality within the river or basin met the water quality guideline values for each indicator. The scores for each indicator category were averaged from the scores for each indicator. Scores for the Lower Ross River were calculated by averaging the scores for the Black, Gleeson's and Aplin's weirs (shown in brown writing). The scores for the Bohle River were calculated from the mid and far field sites (shown in brown). Scores for Ross freshwater basin were averaged from the scores for Upper Ross River, Lower Ross River and Bohle River. The overall score for the Black freshwater basin was calculated from the scores for all sites within that zone. Weighted and non-weighted scores are shown in Appendix B Table 3, Appendix B Table 4 and Appendix B Table 5, with weightings based on the proportion of the catchment area that each independent site represents. For all independent sites, weighted and non-weighted scores are presented, whilst only non-weighted scores are shown for non-independent sites. The overall scores and grades for each indicator and indicator category for the Ross and Black freshwater basins were calculated by summing the weighted scores of all independent sites.

13.2.1.1.1 Nutrients

The scores for nutrients at each site were derived from two indicator categories, total phosphorus (TP) and dissolved inorganic nitrogen (DIN), with the scores shown in Appendix B Table 3. Overall, the Ross and Black freshwater basins were in a good and moderate condition respectively with respect to nutrient concentrations. Overall, the Bohle River, Black River, Bluewater Creek and Rollingstone Creek were in a poor condition. Total phosphorus concentrations were particularly high in the Bohle River, whilst Bluewater Creek and Rollingstone Creek had very high DIN concentrations. Ross River Dam and Crystal Creek were the only two sites where both DIN and TP concentrations were in a good or very good condition.

13.2.1.1.2 Physical-chemical properties

The results for the phys-chem index were derived from two indicator categories, turbidity and dissolved oxygen (DO). The results for these indicators and the phys-chem index are presented in Appendix B Table 4. Ross freshwater basin was in a good condition, although lower dissolved oxygen concentrations often scored poorly or very poorly at most sites. The Black freshwater basin was in a very good condition for all indicators, with all sites being in a good or very good condition (Appendix B Table 4).

Appendix B Table 3. Integer scores and grades for total phosphorus (TP), dissolved inorganic nitrogen (DIN) and nutrients for freshwater sites.

	Non-weighted scores and grades						Catchment area		Weighted scores and grades					
Site	Score			Grade			Catchment area draining into site (km^2)	Proportion of measured catchment area	Weighted score/contribution to final score			Overall Grade		
	DIN	TP	Nutrients	DIN	TP	Nutrients			DIN	TP	Nutrients	DIN	TP	Nutrients
Upper Ross River (Ross River Dam)	90	61	76	A	B	B	458	0.32	29	20	24			
Lower Ross River	67	58	63	B	C	B	786	0.56	37	32	35			
Black Weir	63	58	60	B	C	C								
Gleeson's Weir	68	ND	68	B	ND	B								
Aplin's Weir	71	ND	71	B	ND	B								
Bohle River	58	0	29	C	E	D	169	0.12	7	0	3			
Bohle far-field	60	0	30	C	E	D								
Bohle mid-field	57	0	28	C	E	D								
Overall Ross freshwater basin	**72**	**40**	**56**	**B**	**D**	**C**	**1413**	**1**	**73**	**52**	**63**	**B**	**C**	**B**
Black River	49	0	24	C	E	D	250	0.37	18	0	9			
Althaus Creek	90	21	56	A	D	C	35	0.05	5	1	3			
Bluewater Creek	20	52	36	E	C	D	86	0.13	3	7	5			
Sleeper Log Creek	41	52	46	D	C	C	41	0.06	2	3	3			
Leichardt Creek	71	49	60	B	C	C	38	0.06	4	3	3			
Saltwater Creek	74	58	66	B	C	B	36	0.05	4	3	4			
Rollingstone Creek	0	58	29	E	C	D	71	0.10	0	6	3			
Ollera Creek	90	58	74	A	C	B	39	0.06	5	3	4			
Crystal Creek	80	90	85	B	A	A	77	0.11	9	10	9			
Paluma Dam	51	90	70	C	A	B	2	0.00	0	0	0			
Overall Black freshwater basin	**57**	**53**	**55**	**C**	**C**	**C**	**675**	**1**	**50**	**36**	**43**	**C**	**D**	**C**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap (ND)

*The score was on the boundary of the scoring range and rounding to whole numbers resulted in the score being rounding up into the scoring range of the next category. Without rounding, the score was in the grade shown by the colour in the table (as grades were based on the score prior to rounding).

Appendix B Table 4. Integer scores and grades for turbidity, lower dissolved oxygen (DO), upper DO and the overall physical-chemical (phys-chem) properties for freshwater sites.

	Non-weighted scores and grades								Catchment area								
Site	Score				Grade				Catchment area draining into site (km^2)	Proportion of measured catchment area	Weighted score/contribution to final score				Overall Grade			
	Turb-idity	Upper DO	Lower DO	Phys-chem parameters	Turb-idity	Upper DO	Lower DO	Phys-chem parameters			Turb-idity	Upper DO	Lower DO	Phys-chem parameters	Turb-idity	Upper DO	Lower DO	Phys-chem parameters
Upper Ross River (Ross River Dam)	90	90	90	90	A	A	A	A	458	0.32	29	29	29	29				
Lower Ross River	90	90	31	61*	A	A	D	C	786	0.56	50	50	17	34				
Black Weir	90	90	39	64	A	A	D	B										
Gleeson's Weir	90	90	0	45	A	A	E	C										
Aplin's Weir	90	90	55	73	A	A	C	B										
Bohle River	61*	90	18	39	C	A	E	D	169	0.12	7	11	2	5				
Bohle far-field	60	90	36	48	C	A	D	C										
Bohle mid-field	62	90	0	31	B	A	E	D										
Overall Ross freshwater basin	**80**	**90**	**46**	**63**	**B**	**A**	**C**	**B**	**1413**	**1**	**86**	**90**	**48**	**68**	**A**	**A**	**C**	**B**
Black River	90	90	90	90	A	A	A	A	250	0.37	33	33	33	33				
Althaus Creek	79	90	90	84	B	A	A	A	35	0.05	4	5	5	4				
Bluewater Creek	90	90	90	90	A	A	A	A	86	0.13	12	12	12	12				
Sleeper Log Creek	90	90	90	90	A	A	A	A	41	0.06	5	5	5	5				
Leichardt Creek	90	90	90	90	A	A	A	A	38	0.06	5	5	5	5				
Saltwater Creek	90	90	90	90	A	A	A	A	36	0.05	5	5	5	5				
Rollingstone Creek	90	90	90	90	A	A	A	A	71	0.10	9	9	9	9				
Ollera Creek	90	90	47	68	A	A	C	B	39	0.06	5	5	3	4				
Crystal Creek	90	90	90	90	A	A	A	A	77	0.11	10	10	10	10				
Paluma Dam	90	90	52	71	A	A	C	B	2	0.00	0	0	0	0				
Overall Black freshwater basin	**89**	**90**	**82**	**85**	**A**	**A**	**A**	**A**	**675**	**1**	**89**	**89**	**87**	**87**	**A**	**A**	**A**	**A**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap

*The score was on the boundary of the scoring range and rounding to whole numbers resulted in the score being rounding up into the scoring range of the next category. Without rounding, the score was in the grade shown by the colour in the table (as grades were based on the score prior to rounding).

13.2.1.1.3 Overall water quality

As shown in Appendix B Table 5, water quality was in a moderate condition for the Ross freshwater basin and Black freshwater basin respectively. Bohle River was the only river with poor water quality overall, with all other rivers having moderate to very good water quality (Appendix B Table 5).

Appendix B Table 5. Water quality scores and grades for freshwater sites.

	Non-weighted scores and grades						Weighted scores and grades					
	Score			Grade			Score			Grade		
Site	Nutr-ients	Phys-chem	Water quality	Nutr-ients	Phys-chem	Water quality	Nutr-ients	Phys-chem	Water quality	Nutri-ents	Phys-chem	Water quality
Upper Ross River (Ross River Dam)	76	90	83	B	A	A						
Lower Ross River	63	61*	62	B	C	B						
Black Weir	60	64	62	C	B	B						
Gleeson's Weir	68	45	56	B	C	C						
Aplin's Weir	71	73	72	B	B	B						
Bohle River	29	39	34	D	D	D						
Bohle far-field	30	48	39	D	C	D						
Bohle mid-field	28	31	30	D	D	D						
Ross freshwater basin	56	63	**60**	C	A	B	**36**	**68**	**52**	**D**	**B**	**C**
Black River	36	90	63	D	A	B						
Althaus Creek	46	90	68	C	A	B						
Bluewater Creek	60	90	75	C	A	B						
Sleeper Log Creek	66	90	78	B	A	B						
Leichardt Creek	29	90	59	D	A	C						
Saltwater Creek	74	68	71	B	B	B						
Rollingstone Creek	85	90	88	A	A	A						
Ollera Creek	70	71	71	B	B	B						
Crystal Creek	55	85	70	C	A	B						
Paluma Dam	76	90	83	B	A	A						
Black freshwater basin	55	85	**70**	B	C	B	**35**	**86**	**60**	**D**	**A**	**C**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap

*Rounding to whole numbers resulted in the score of <61 rounding to 61. Since the raw score was less than 61, the number remains in the moderate category (indicated by yellow colour).

13.2.1.2 *Confidence scores*

There was low confidence in the scores for water quality for the Ross and Black freshwater basins. The score for each criterion is shown in Appendix B Table 6. These scores were the same as when the data were compared against water quality objectives. The Ross freshwater basin received a low confidence score due to low spatial sampling within the zone. There was low confidence in the scores for the Black freshwater basin due to the scores for this zone being derived based on only three data points (monthly sampling from April to June).

Appendix B Table 6. Confidence scores for nutrients, physical-chemical parameters and water quality for the Ross and Black freshwater basins.

Confidence criterion were scored 1-3 and weighted by the value identified in parenthesis. Weighted scores were summed to produce a final score (4.5 – 13.5). Final scores were ranked from 1 to 5 (very low to very high).

Indicator category	Maturity of method (x0.36)	Validation (x0.71)	Represe-ntativeness (x2)	Directness (x0.71)	Measured error (x0.71)	Final score	Rank
Nutrients	2	3	1	3	1	7.6	Low (2)
Phys-chem	2	3	1	3	1	7.6	Low (2)
Water quality index						**7.6**	**Low (2)**

Rank based on final score: Very low (1): 4.5 – 6.3; Low (2): >6.3 – 8.1; Moderate (3): >8.1 – 9.9; High (4): >9.9 – 11.7; Very high (5): >11.7 – 13.5.

13.3 Estuarine results

13.3.1 Comparing water quality against water quality guidelines

This section presents the results for water quality indicator categories compared against water quality guidelines.

13.3.1.1 *Results*

The results for the indicator categories are presented in the following sections. The distributions of scores for each indicator are presented as boxplots in Appendix C. It is noted that the scores for this year (2018-19) are not comparable to 2017-18 scores because additional sites were sampled this year (2018-19) and scores were also weighted.

In Appendix B Table 7, Appendix B Table 8 and Appendix B Table 9, the scores and grades indicate whether water quality within each estuary met the water quality guideline values. The scores for nutrients are averaged from the scores for TP and DIN (see Appendix B Table 7), scores for phys-chem parameters were averaged from the scores for turbidity and dissolved oxygen (see Appendix B Table 8) and the overall scores for water quality were averaged from the scores for nutrients and phys-chem parameters (see Appendix B Table 9). Scores for Louisa Creek Estuary are the average of scores from three monitoring locations (shown in brown writing) and scores for Ross Creek Estuary and Sandfly Creek Estuary are the average of scores from two monitoring locations (shown in brown writing). Scores for Ross freshwater basin are averaged from the scores for Alligator Creek Estuary, Bohle River Estuary, Louisa Creek Estuary, Ross Creek Estuary, Ross River Estuary and Sandfly Creek Estuary. The scores for Black freshwater basin were calculated by averaging the scores for all the sites within that zone. Weighted and non-weighted scores are shown in the tables, with weightings based on the proportion of the catchment area that each independent site represents. For all independent sites, weighted and non-weighted scores are presented in the tables, whilst only non-weighted scores are shown for non-independent sites. The overall scores and grades for each indicator and indicator category for the Ross and Black freshwater basins were calculated by summing the weighted scores of all independent sites

13.3.1.1.1 Nutrients

The scores for nutrients were derived from two indicator categories, total phosphorus (TP) and dissolved inorganic nitrogen (DIN). DIN was calculated by summing oxidised nitrogen (NOx) and Ammonium (i.e. NOx-N + Ammonia-N). The results for total phosphorus, DIN and nutrients are presented in .

Overall, the Ross estuarine zone was in a poor condition, whilst Black estuarine zone was in a good condition, as shown in Appendix B Table 7. Within the Ross estuarine zone, Louisa Creek Estuary, was in the very poor condition due to high concentrations of TP and DIN, and Ross Creek was in a poor condition due to high DIN concentrations. Within the Black freshwater basin, four of the five sites were given good or very good grades. Rollingstone Creek received a moderate score but contained very high concentrations of DIN.

13.3.1.1.2 Physical-Chemical

The Ross and Black estuarine zones were both in a good condition, as shown in Appendix B Table 8. Within the Ross estuarine zone, Alligator Creek Estuary and Louisa Creek Estuary were in a moderate condition. Alligator Creek Estuary had turbid waters, resulting in a poor score for turbidity, whilst very poor lower dissolved oxygen levels were recorded at two monitoring sites within Louisa Creek. All sites within Black estuarine zone were in very good condition with respect to phys-chem parameters, except for Rollingstone, which had a moderate score due to having turbid waters.

13.3.1.1.3 Overall water quality

Overall water quality within Ross estuarine zone was in a moderate condition, whilst the Black estuarine zone was in a good condition, as shown in Appendix B Table 9.

Appendix B Table 7. Integer scores and grades for total phosphorus (TP), dissolved inorganic nitrogen (DIN) and nutrients for estuarine sites.

Significant figures between numbers differs for each of reading.

	Non-weighted scores and grades						Catchment area		Weighted score/contribution to final score					
Site	Score			Grade			Catchment area draining into site (km²)	Proportion of measured catchment area	Score			Grade		
	DIN	TP	Nutrients	DIN	TP	Nutrients			DIN	TP	Nutrients	DIN	TP	Nutrients
Alligator Creek Estuary	90	62	76	A	B	B	4.8	0.00	0	0	0			
Bohle River Estuary	90	44	67	A	C	B	295.6	0.24	21	10	16			
Louisa Creek Estuary	21	12	16	D	E	E	52.5	0.04	1	0	1			
Louisa Estuary Site 0.9	63	35	49	B	D	C								
Louisa Estuary Site 6.0	0	0	0	E	E	E								
Louisa Creek/Town Common Estuary	0	0	0	E	E	E								
Ross Creek Estuary	0	57	28	E	C	D	20.8	0.02	0	1	0			
Ross Creek Estuary Site RC04 and RC07	0	57	28	E	C	D								
Ross Creek Estuary Site SB02	0	57	28	E	C	D								
Ross River Estuary	0	57	28	E	C	D	842.8	0.68	0	38	19			
Sandfly Creek Estuary	71	44	57	B	C	C	27.7	0.02	2	1	1			
Sandfly Creek Estuary Site CB10	69	44	56	B	C	C								
Sandfly Creek Estuary Site CB9	73	44	58	B	C	C								
Ross estuarine zone	**45**	**46**	**45**	**C**	**C**	**C**	**1244**	**1**	**24**	**51**	**38**	**D**	**C**	**D**
Althaus/Deep Creek Estuary	90	90	90	A	A	A	69.1	0.18	16	16	16			
Bluewater Creek Estuary	68	90	79	B	A	B	89.7	0.24	16	21	19			
Crystal Creek Estuary	43	90	67	C	A	B	106.1	0.28	12	25	19			
Rollingstone Creek Estuary	14	90	52	E	A	C	77.4	0.20	3	18	11			
Saltwater Creek Estuary	90	90	90	A	A	A	37.4	0.10	9	9	9			
Black estuarine zone	**61***	**90**	**75**	**C**	**A**	**B**	**379**	**1**	**56**	**90**	**73**	**C**	**A**	**B**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap

*The score was on the boundary of the scoring range and rounding to whole numbers resulted in the score being rounding up into the scoring range of the next category. Without rounding, the score was in the grade shown by the colour in the table (as grades were based on the score prior to rounding).

Appendix B Table 8. Integer scores and grades for turbidity, lower dissolved oxygen (DO), upper DO and the overall physical-chemical (phys-chem) properties for estuarine sites.

Significant figures between numbers differs for each of reading.

Site	Non-weighted scores and grades								Low (2)		Weighted scores and grades							
	Score				Grade				Catchment area draining into site (km²)	Proportion of measured catchment area	Score				Grade			
	Turb-idity	Upper DO	Lower DO	Phys-chem prop-erties	Turb-idity	Upper DO	Lower DO	Phys-chem prop-erties			Turb-idity	Upper DO	Lower DO	Phys-chem prop-erties	Turb-idity	Upper DO	Lower DO	Phys-chem prop-erties
Alligator Creek Estuary	31	90	90	60	D	A	A	C	4.8	0.00	0	0	0	0				
Bohle River Estuary	57	90	90	73	C	A	A	B	295.6	0.24	14	21	21	17				
Louisa Creek Estuary	60	90	24	42	C	A	D	C	52.5	0.04	3	4	1	2				
Louisa Estuary Site 0.9	65	90	73	69	B	A	B	B										
Louisa Estuary Site 6.0	58	90	0	29	C	A	E	D										
Louisa Creek/Town Common Estuary	57	90	0	28	C	A	E	D										
Ross Creek Estuary	90	90	90	90	A	A	A	A	20.8	0.02	2	2	2	2				
Ross Creek Estuary Site RC04 and RC07	90	90	90	90	A	A	A	A										
Ross Creek Estuary Site SB02	90	90	90	90	A	A	A	A										
Ross River Estuary	71	90	90	81*	B	A	A	B	842.8	0.68	48	61	61	55				
Sandfly Creek Estuary	46	90	90	68	C	A	A	B	27.7	0.02	1	2	2	2				
Sandfly Creek Estuary Site CB10	47	90	90	69	C	A	A	B										
Sandfly Creek Estuary Site CB9	45	90	90	67	C	A	A	B										
Overall Ross estuarine zone	**59**	**90**	**79**	**69**	**C**	**A**	**B**	**B**	**1244**	**1**	**68**	**90**	**87**	**78**	**B**	**A**	**A**	**B**
Althaus/Deep Creek Estuary	90	90	90	90	A	A	A	A	69.1	0.18	16	16	16	16				
Bluewater Creek Estuary	90	90	90	90	A	A	A	A	89.7	0.24	21	21	21	21				
Crystal Creek Estuary	90	90	90	90	A	A	A	A	106.1	0.28	25	25	25	25				
Rollingstone Creek Estuary	18	90	90	54	E	A	A	C	77.4	0.20	4	18	18	11				
Saltwater Creek Estuary	70	90	90	80	B	A	A	B	37.4	0.10	7	9	9	8				
Overall Black estuarine zone	**71**	**90**	**90**	**81***	**B**	**A**	**A**	**B**	**379**	**1**	**73**	**89**	**89**	**81***	**B**	**A**	**A**	**B**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap

*The score is on the boundary of the scoring range and rounding to whole numbers resulted in the score being rounding up into the scoring range of the next category. Without rounding, the score is in the grade shown in the table (as grades were based on the score prior to rounding).

Appendix B Table 9. Water quality scores and grades for estuarine sites.

	Non-weighted scores and grades						Weighted scores and grades					
	Scores			Grades			Scores			Grades		
	Nutrients	Phys-chem parameters	Water quality	Nutrients	Phys-chem parameters	Water quality	Nutrients	Phys-chem parameters	Water quality	Nutrients	Phys-chem parameters	Water quality
Alligator Creek Estuary	76	60	68	B	C	B						
Bohle River Estuary	67	73	70	B	B	B						
Louisa Creek Estuary	16	42	29	E	C	D						
Louisa Estuary Site 0.9	49	69	59	C	B	C						
Louisa Estuary Site 6.0	0	29	15	E	D	E						
Louisa Creek/Town Common Estuary	0	28	14	E	D	E						
Ross Creek Estuary	28	90	59	D	A	C						
Ross Creek Estuary Site RC04 and RC07	28	90	59	D	A	C						
Ross Creek Estuary Site SB02	28	90	59	D	A	C						
Ross River Estuary	28	81*	54	D	B	C						
Sandfly Creek Estuary	57	68	63	C	B	B						
Sandfly Creek Estuary Site CB10	56	69	62	C	B	B						
Sandfly Creek Estuary Site CB9	58	67	63	C	B	B						
Overall Ross estuarine zone	**45**	**69**	**57**	**C**	**B**	**C**	**38**	**78**	**58**	**D**	**B**	**C**
Althaus/Deep Creek Estuary	90	90	90	A	A	A						
Bluewater Creek Estuary	79	90	84	B	A	A						
Crystal Creek Estuary	67	90	78	B	A	B						
Rollingstone Creek Estuary	52	54	53	C	C	C						
Saltwater Creek Estuary	90	80	85	A	B	A						
Overall Black estuarine zone	**75**	**81***	**78**	**B**	**B**	**B**	**73**	**81***	**77**	**B**	**B**	**B**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap

*The score was on the boundary of the scoring range and rounding to whole numbers resulted in the score being rounding up into the scoring range of the next category. Without rounding, the score was in the grade shown by the colour in the table (as grades were based on the score prior to rounding).

13.3.1.2 *Confidence scores*

There was a moderate confidence in the water quality scores for the Ross estuarine zone and low confidence for the Black estuarine zone. This difference in confidence between zones was due to the scores for the Black estuarine zone being derived based on only three data points (monthly sampling from April to June). The score for each criterion is shown in Appendix B Table 10. These scores are the same as when the data were compared against water quality objectives.

Appendix B Table 10. Confidence score for nutrients, physical-chemical parameters and water quality for the Ross estuarine zone.

Confidence criterion were scored 1-3 and weighted by the value identified in parenthesis. Weighted scores were summed to produce a final score (4.5 – 13.5). Final scores were ranked from 1 to 5 (very low to very high).

Basin	Indicator category	Maturity of method (x0.36)	Validation (x0.71)	Representa-tiveness (x2)	Directness (x0.71)	Measured error (x0.71)	Final score	Rank
Ross estuarine zone	Nutrients	2	3	2	3	1	9.6	Moderate (3)
	Phys-chem	2	3	2	3	1	9.6	Moderate (3)
	Water quality index						**9.6**	**Moderate (3)**
Black estuarine zone	Nutrients	2	3	1	3	1	7.6	Low (2)
	Phys-chem	2	3	1	3	1	7.6	Low (2)
	Water quality index						**7.6**	**Low (2)**

Rank based on final score: Very low (1): 4.5 – 6.3; Low (2): >6.3 – 8.1; Moderate (3): >8.1 – 9.9; High (4): >9.9 – 11.7; Very high (5): >11.7 – 13.5.

13.4 Inshore marine results

13.4.1 Comparing inshore water against water quality guidelines

13.4.1.1 *Results*

13.4.1.1.1 Nutrients

The scores for nutrients are presented in Appendix B Table 11. Nutrients were in a very poor condition in both bays.

Appendix B Table 11. Scores and grades for nutrients within Cleveland Bay and Halifax Bay measured against WQGs.

The scores for nutrients were averaged from the scores for total phosphorus (TP), particulate phosphorus (PP), particulate nitrogen (PN) and oxidised nitrogen (NOx). Scores were rounded, with the number of significant figures differing for ease of presentation. ND stands for no data.

	Score					Grade				
Site	TP	PP	PN	NOx	Nutrients	TP	PP	PN	NOx	Nutrients
Enclosed coastal Cleveland Bay	26	ND	ND	ND	ND	D	ND	ND	ND	ND
Open coastal Cleveland Bay	ND	0	0	0	0	ND	E	E	E	E
Geoffrey Bay	ND	13	0	0	4	ND	E	E	E	E
Cleveland Bay	ND	**7**	**0**	**0**	**2**	ND	**E**	**E**	**E**	**E**
Pelorus Is.	ND	27	0	0	9	ND	D	E	E	E
Pandora Reef	ND	0.30	0	0	0.10	ND	E	E	E	E
Halifax Bay	ND	**14**	**0**	**0**	**5**	ND	**E**	**E**	**E**	**E**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap

13.4.1.1.2 Physical-Chemical parameters

As seen in Appendix B Table 12, Cleveland Bay was in poor condition while Halifax Bay was in moderate condition with respect phys-chem parameters. The Secchi disk indicator rated very poor for most sites, although this was in part due to a strict WQG for this indicator. Within Cleveland Bay, Geoffrey Bay was in a very poor condition, whilst the Midshelf Cleveland Bay was in a moderate condition. Within Halifax Bay, turbidity and TSS at all sites was graded as good and very good respectively.

Appendix B Table 12. Integer scores and grades for turbidity, total suspended solids (TSS), secchi depth and the overall phys-chem index within Cleveland Bay and Halifax Bay measured against WQGs.

Scores were rounded, with the number of significant figures differing for ease of presentation. ND stands for no data.

	Score				Grade			
Site	Turbidity	TSS	Secchi depth	Phys-chem	Turbidity	TSS	Secchi depth	Phys-chem
Enclosed coastal Cleveland Bay	12		79	45	E		B	C
Open coastal Cleveland Bay	100	0	79	60	A	E	B	C
Geoffrey Bay	0	46	0	15	E	C	E	E
Cleveland Bay	**37**	**23**	**53**	**40**	**D**	**E**	**C**	**D**
Pelorus Is.	64	95	0	53	B	A	E	C
Pandora Reef	48	82	0	43	C	A	E	C
Halifax Bay	**56**	**89**	**0**	**48**	**C**	**A**	**E**	**C**

Scoring range: Very Poor (E) = 0 to <21 | Poor (D) = 21 to <41 | Moderate (C) = 41 to <61 | Good (B) = 61 to <81 | Very Good (A) = 81-100 | No score/data gap

*The score was on the boundary of the scoring range and rounding to whole numbers resulted in the score being rounding up into the scoring range of the next category. Without rounding, the score was in the grade shown by the colour in the table (as grades were based on the score prior to rounding).

13.4.1.1.3 Chlorophyll a

Chlorophyll *a* scores were moderate in Cleveland Bay and good in Halifax Bay (see Appendix B Table 13). Concentrations of chlorophyll *a* in Cleveland Bay were poor for two of the sites (enclosed coastal Cleveland Bay and Geoffrey Bay), but the open coastal sites were graded as being very good.

Appendix B Table 13. Integer scores and grades for Chlorophyll *a* within Cleveland Bay and Halifax inshore marine zone measured against WQGs.

Scores are rounded, with the number of significant figures differing for ease of presentation.

	Score	Grade
Site	Chlorophyll *a*	Chlorophyll *a*
Enclosed coastal Cleveland Bay	35	D
Open coastal Cleveland Bay	100	A
Geoffrey Bay	37	D
Cleveland Bay	**57**	**C**
Pelorus Is.	44	C
Pandora Reef	78	B
Halifax Bay	**61**	**B**

Scoring range: Very Poor (E) = 0 to <21 | Poor (D) = 21 to <41 | Moderate (C) = 41 to <61 | Good (B) = 61 to <81 | Very Good (A) = 81-100 | No score/data gap

13.4.1.1.4 Overall water quality against WQGs

Cleveland Bay and Halifax Bay received a poor score for overall water quality. The summary scores and grades for the water quality are presented in Appendix B Table 14. These poor scores for water quality were largely driven by the very poor nutrients scores.

Appendix B Table 14. Water quality scores and grades for Cleveland Bay and Halifax Bay.
Scores for water quality were averaged from the scores for nutrients, physical-chemical parameters and chlorophyll *a* measured against WQGs. Scores are rounded, with the number of significant figures differing for ease of presentation. ND stands for no data.

	Score				Grade			
Site	Nutrients	Phys-chem	Chloro-phyll *a*	Water quality	Nutrients	Phys-chem	Chloro-phyll *a*	Water quality
Enclosed coastal Cleveland Bay	ND	45	35	40	ND	C	D	C
Open coastal Cleveland Bay	0	60	100	53	E	C	A	D
Geoffrey Bay	4	15	37	19	E	E	D	D
Cleveland Bay	**2**	**40**	**57**	**37**	**E**	**D**	**C**	**D**
Orpheus Is.	9	53	44	35	E	C	C	D
Pandora Reef	0.1	43	78	41	E	C	B	C
Halifax Bay	**5**	**48**	**61**	**38**	**E**	**C**	**B**	**D**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81-100 | ■ No score/data gap

*The score was on the boundary of the scoring range and rounding to whole numbers resulted in the score being rounding up into the scoring range of the next category. Without rounding, the score was in the grade shown by the colour in the table (as grades were based on the score prior to rounding).

13.4.1.2 Confidence scores

There was a low confidence in the scores for water quality indices for both Cleveland Bay and Halifax Bay. The score for each criterion is shown in

Appendix B Table 15. The confidence scores were low due to limited spatial sampling, with only three monitoring locations within each inshore zone.

Within Cleveland Bay, monitoring within both the open and enclosed coastal site was within 3 km of the mainland coastline. The monitoring site at Geoffrey Bay was approximately 10 km from the Townsville mainland and approximately 500 m offshore from Magnetic Island. The inshore area extends to approximately 60 km offshore and sampling only close to the coastline is unlikely to accurately represent water quality within the entirety of the area. However, sampling close to the coastline is likely to capture most of the pollutant discharge for terrestrial sources. Within Halifax Bay, all monitoring was conducted farther from the coast than Cleveland Bay sites. Within Halifax Bay, the closest site sampled was Pandora Reef, which is about 16 km from the coast. The difference in the distance sampling sites are from the coast is likely to influence the results between the two bays.

Appendix B Table 15. Confidence scores for water quality indices for Cleveland Bay and Halifax Bay.

Confidence criterion were scored 1-3 and weighted by the value identified in parenthesis. Weighted scores were summed to produce a final score (4.5 – 13.5). Final scores were ranked from 1 to 5 (very low to very high).

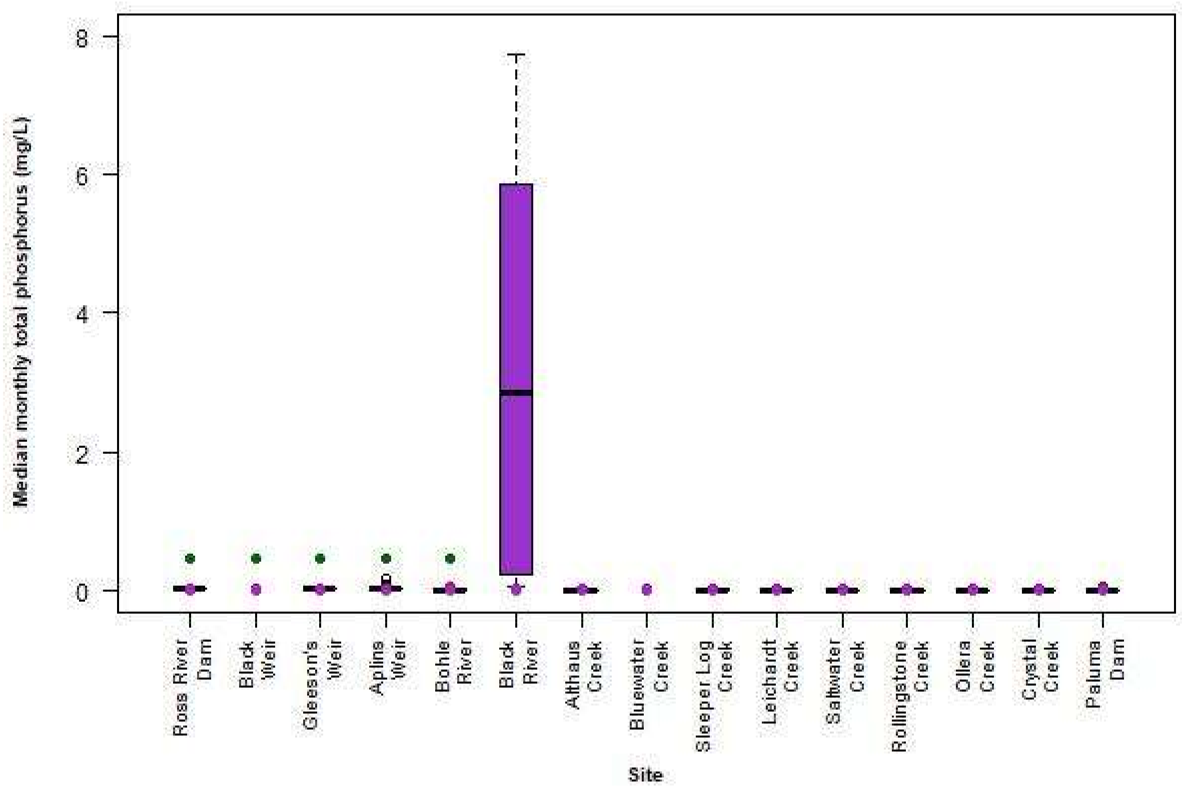
Indicator category	Maturity of method (x0.36)	Validation (x0.71)	Representat-iveness (x2)	Directness (x0.71)	Measured error (x0.71)	Final	Rank
Phys-chem	3	3	1	3	1	8.1	Low (2)
Nutrients	3	3	1	3	1	8.1	Low (2)
Chlorophyll *a*	3	3	1	3	1	8.1	Low (2)
Water quality index						**8.1**	**Low (2)**

Rank based on final score: Very low (1): 4.5 – 6.3; Low (2): >6.3 – 8.1; Moderate (3): >8.1 – 9.9; High (4): >9.9 – 11.7; Very high (5): >11.7 – 13.5.

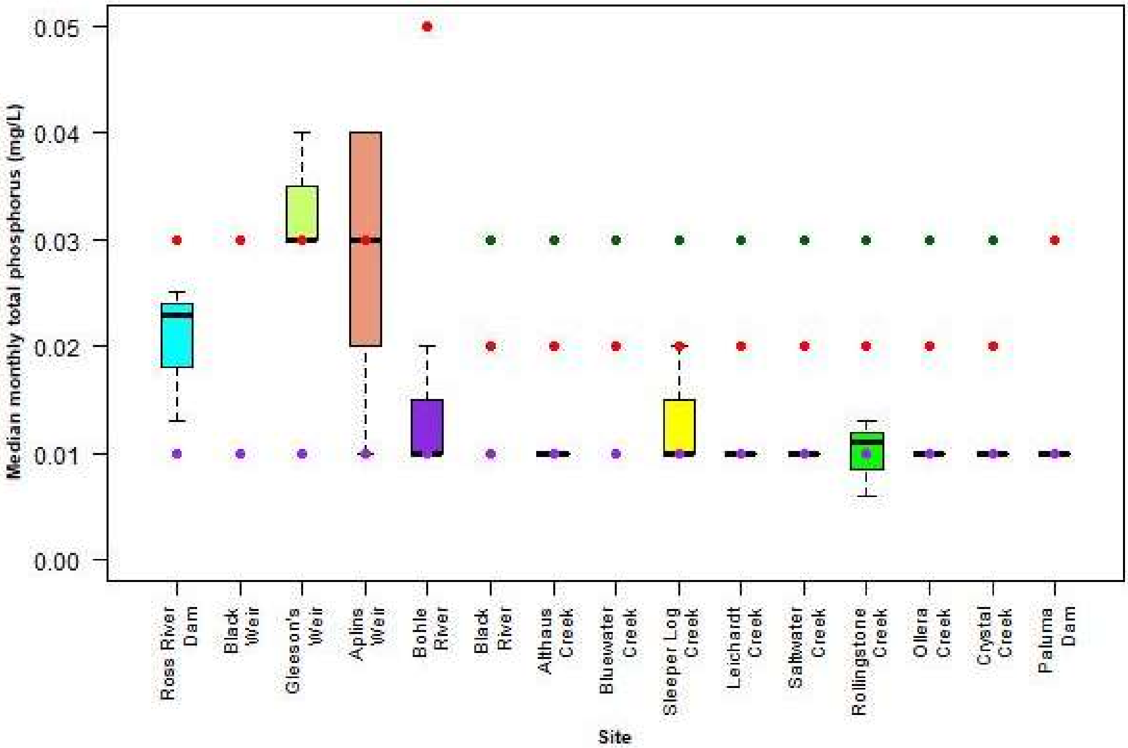
Appendix C. Distribution of water quality data

The following figures are box and whisker plots (boxplots) of water quality indicators at all sites within the freshwater, estuarine and inshore marine zones. The mid-line is the median and the box depicts the upper and lower quartiles. The whiskers are the lowest and highest datum within 1.5 interquartile range (IQR) and outliers are datum above or below 1.5 IQR. Analysis was conducted on all data points collected during the reporting period (not only on the monthly values used for generating scores).

Boxplots for freshwater water quality data

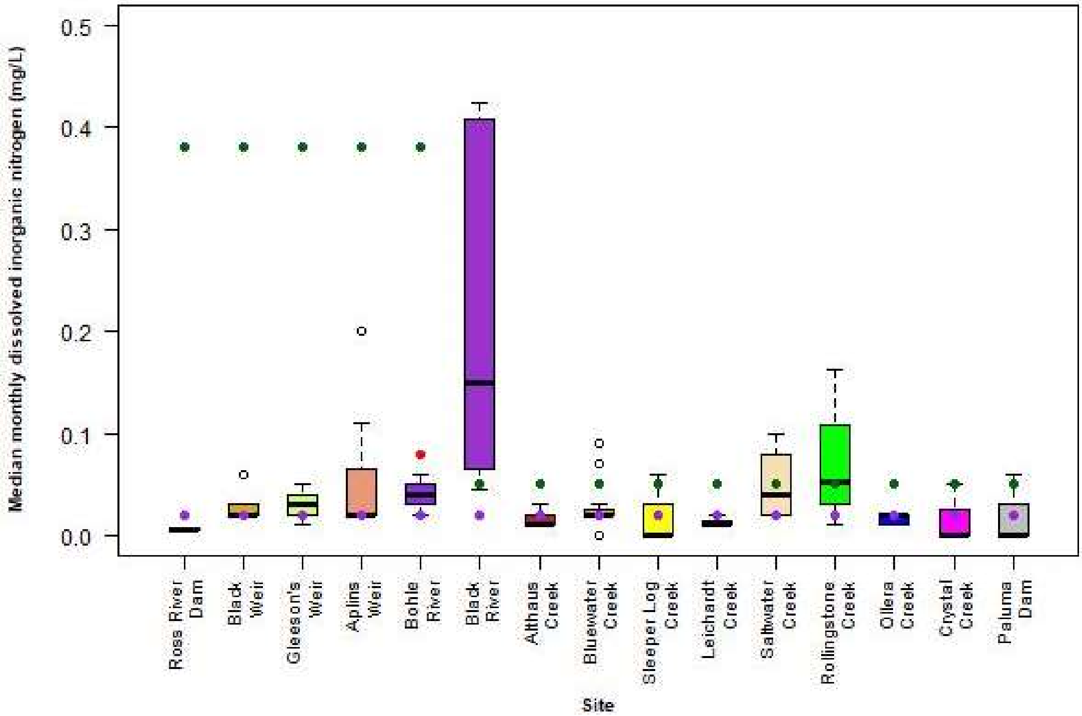


Appendix C Figure 1. Boxplot of total phosphorus concentrations at each freshwater monitoring site.
The red circles indicate the guideline values and the green circles show the scaling factors. Water quality objectives (WQOs) for all sampling sites, except the Bohle River, are the same as the GVs. Outliers are shown as clear circles.



Appendix C Figure 2. Boxplot of total phosphorus concentrations at each freshwater monitoring site, excluding data from the Black River site to allow a closer examination of the boxplots.

The red circles indicate the guideline values and the green circles show the scaling factors. Water quality objectives (WQOs) for all sampling sites, except the Bohle River, are the same as the GVs. Outliers are shown as clear circles.



Appendix C Figure 3. Boxplot of dissolved inorganic nitrogen (DIN) concentrations at each freshwater monitoring site.

The green circles indicate the scaling factors, the red circles shown the water quality objectives (WQOs) and the purple circles show the water quality guideline values (GVs). Water quality objectives (WQOs) for all sampling sites, except the Bohle River, are the same as the GVs. Outliers are shown as clear circles. Note that the WQO for the Bohle River is 4 times higher than the GVs for the other sampling sites.

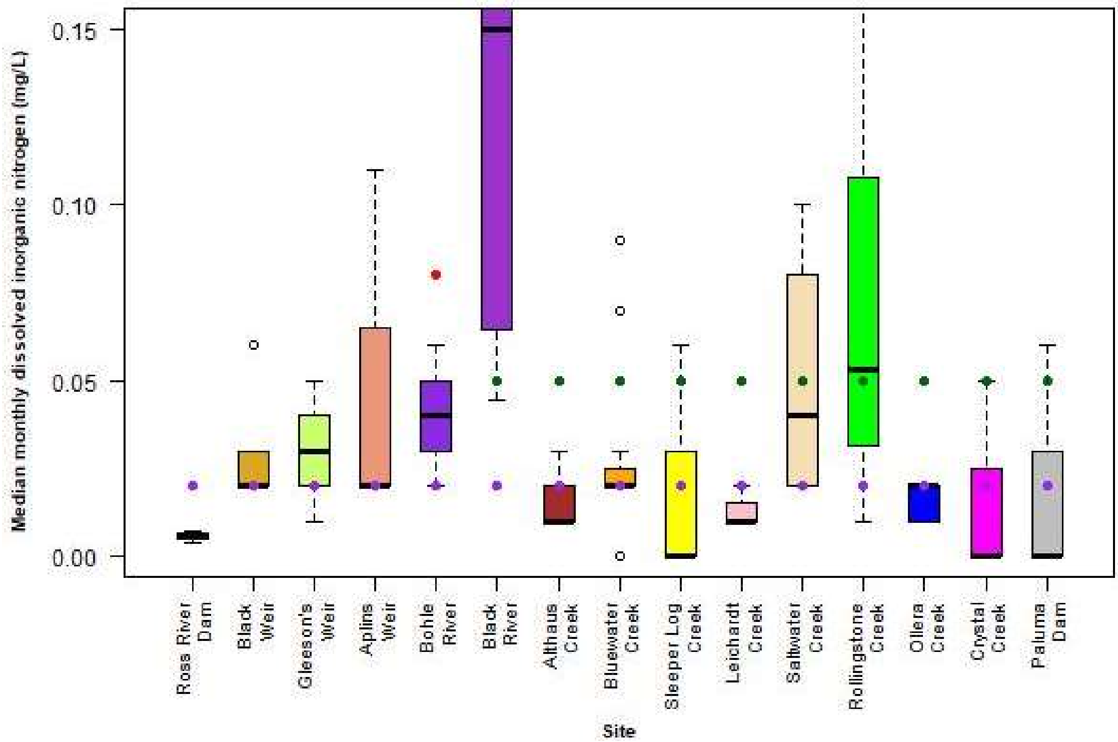


Figure Appendix C 4. Boxplot of dissolved inorganic nitrogen (DIN) concentrations at each freshwater monitoring site, excluding the uppermost data from the Black River site.

The green circles indicate the scaling factors, the red circles shown the water quality objectives (WQOs) and the purple circles show the water quality guideline values (GVs). Water quality objectives (WQOs) for all sampling sites, except the Bohle River, are the same as the GVs. Outliers are shown as clear circles.

Note that the WQO for the Bohle River is 4 times higher than the GVs for the other sampling sites.

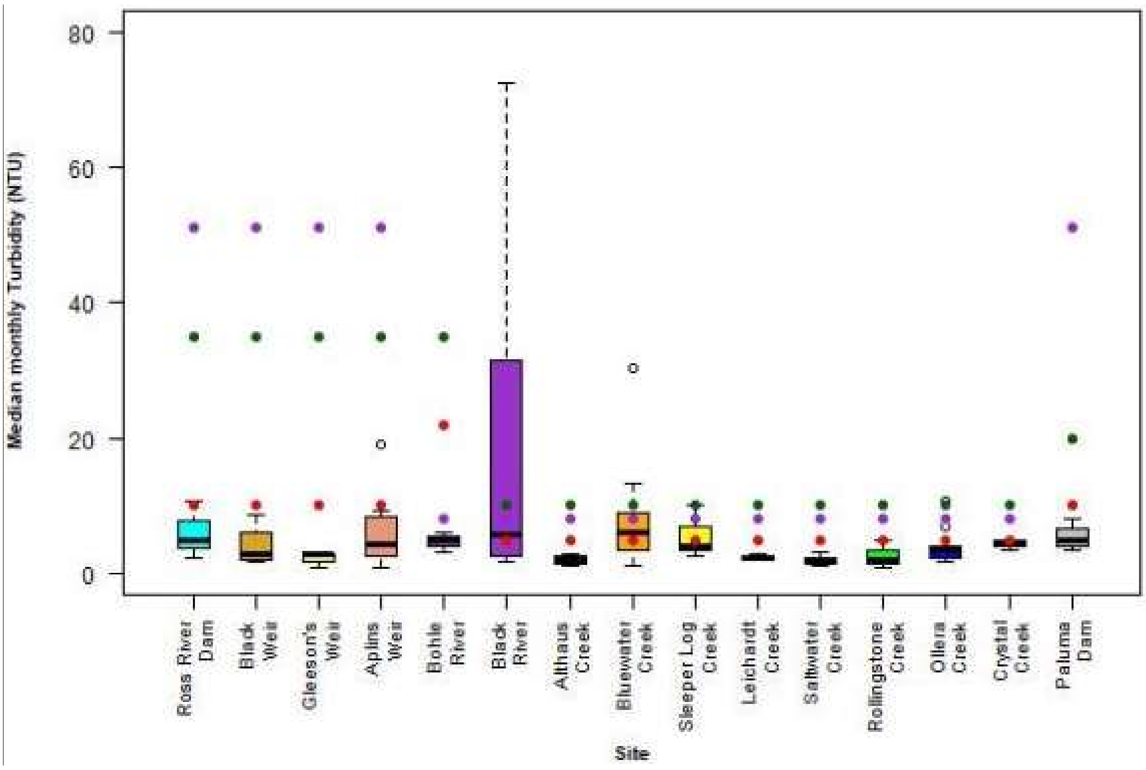


Figure Appendix C 5. Boxplot of turbidity levels at each freshwater monitoring site.

The green circles indicate the scaling factors, the red circles shown the water quality objectives (WQOs) and the purple circles show the water quality guideline values (GVs). Outliers are shown as clear circles.

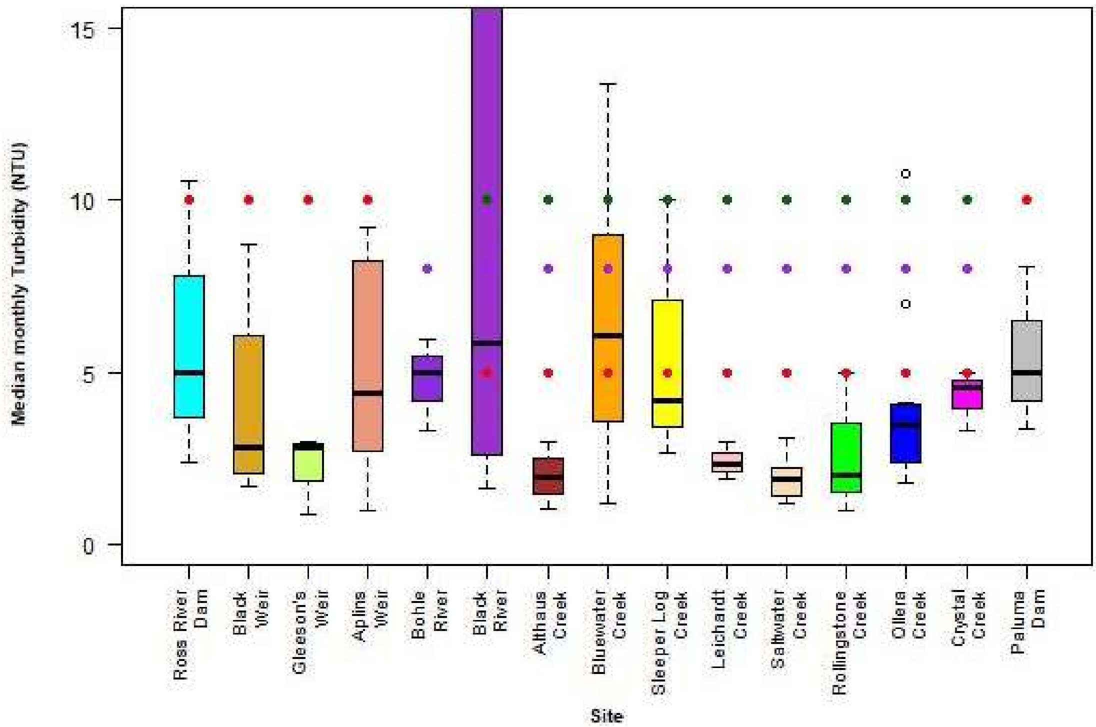


Figure Appendix C 6. Boxplot of turbidity levels at each freshwater monitoring site, excluding the uppermost data from the Black River and the outlier from Bluewater Creek.

The green circles indicate the scaling factors, the red circles shown the water quality objectives (WQOs) and the purple circles show the water quality guideline values (GVs). Outliers are shown as clear circles.

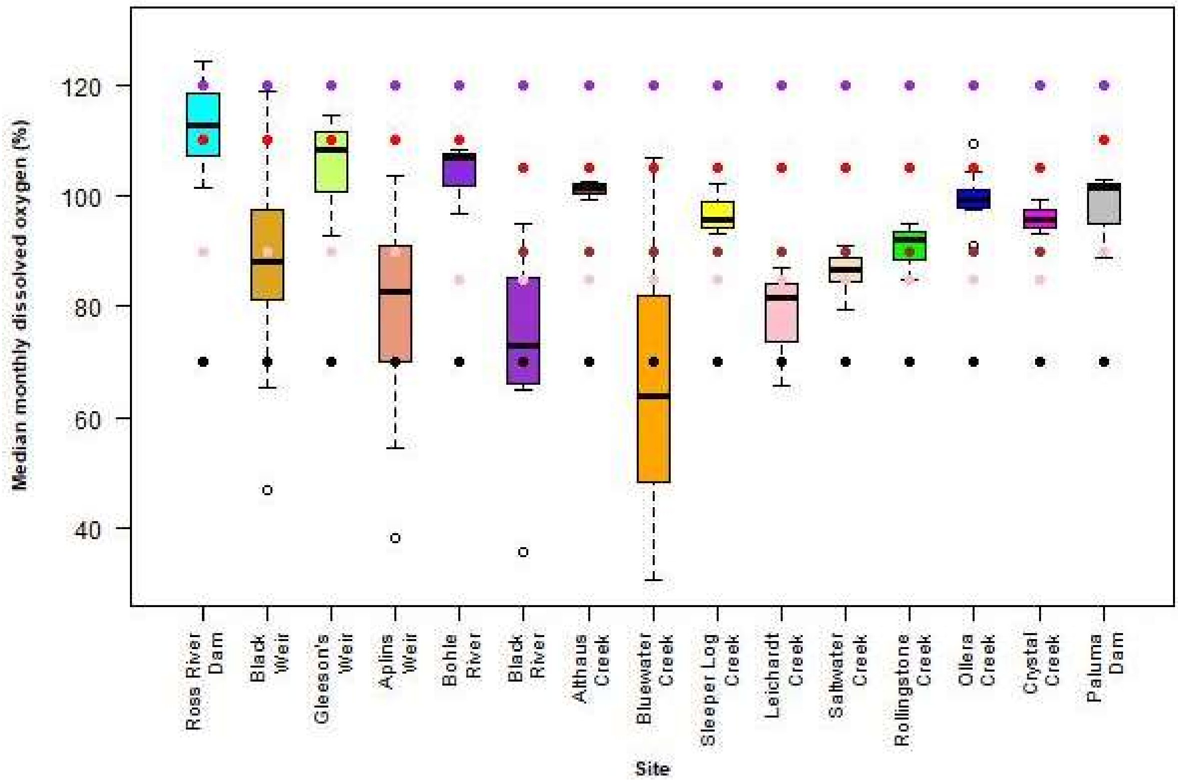


Figure Appendix C 7. Boxplot of dissolved oxygen (DO) concentrations at each freshwater monitoring site.

The green and black circles indicate the scaling factors for the upper and lower DO respectively, the red and brown circles indicate the water quality objectives (WQOs) for the upper and lower DO respectively and the purple and pink circles show the guideline values (GVs) for the upper and lower DO respectively. Outliers are shown as clear circles.

Boxplots for estuarine water quality data

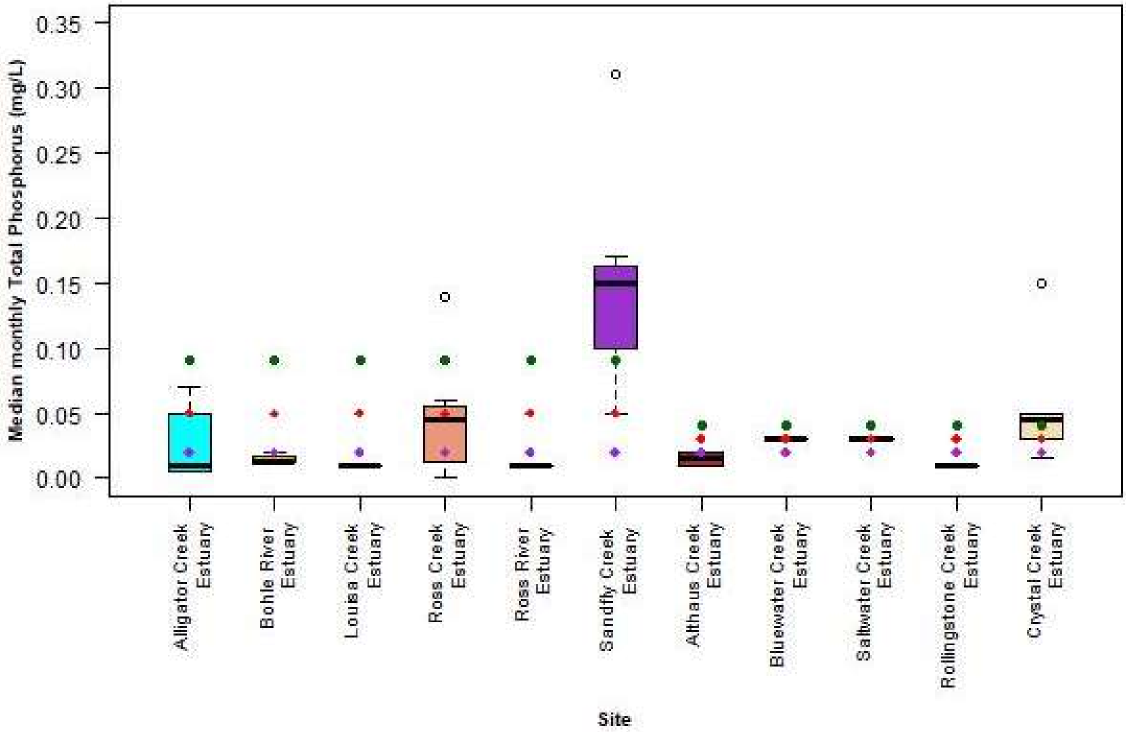


Figure Appendix C 8. Boxplot of total phosphorus concentrations at each estuarine monitoring site.
The green circles indicate the scaling factors, the red circles shown the water quality objectives (WQOs) and the purple circles show the water quality guideline values (GVs). Outliers are shown as clear circles.

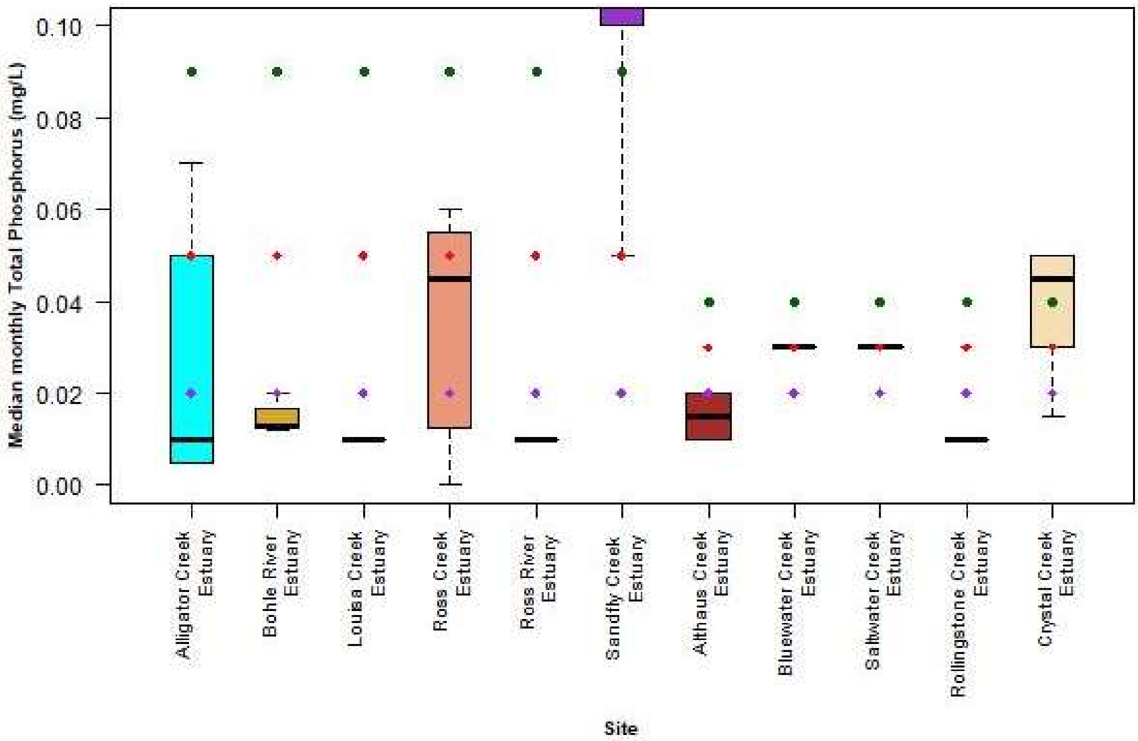


Figure Appendix C 9. Boxplot of total phosphorus concentrations at each estuarine monitoring site, excluding the uppermost data from Sandfly Creek Estuary and the outlier from Crystal Creek Estuary.
The green circles indicate the scaling factors, the red circles shown the water quality objectives (WQOs) and the purple circles show the water quality guideline values (GVs).

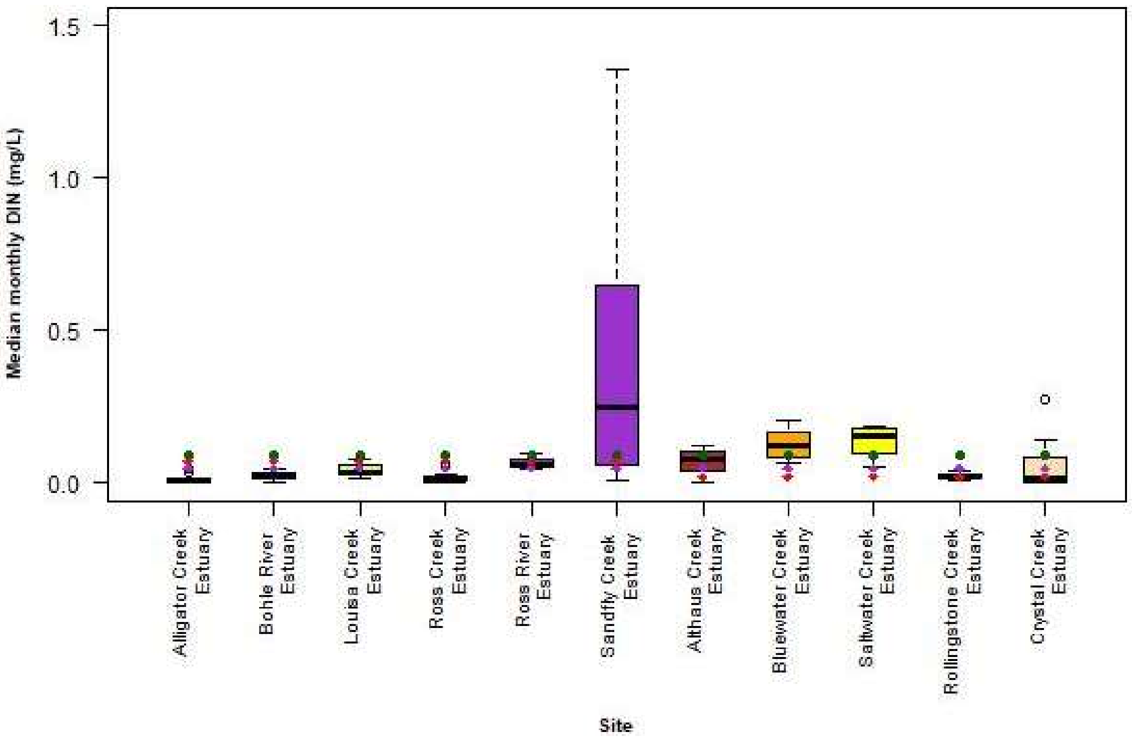


Figure Appendix C 10. Boxplot of dissolved inorganic nitrogen (DIN) concentrations at each estuarine monitoring site.

The green circles indicate the scaling factors, the red circles shown the water quality objectives (WQOs) and the purple circles show the water quality guideline values (GVs). Outliers are shown as clear circles.

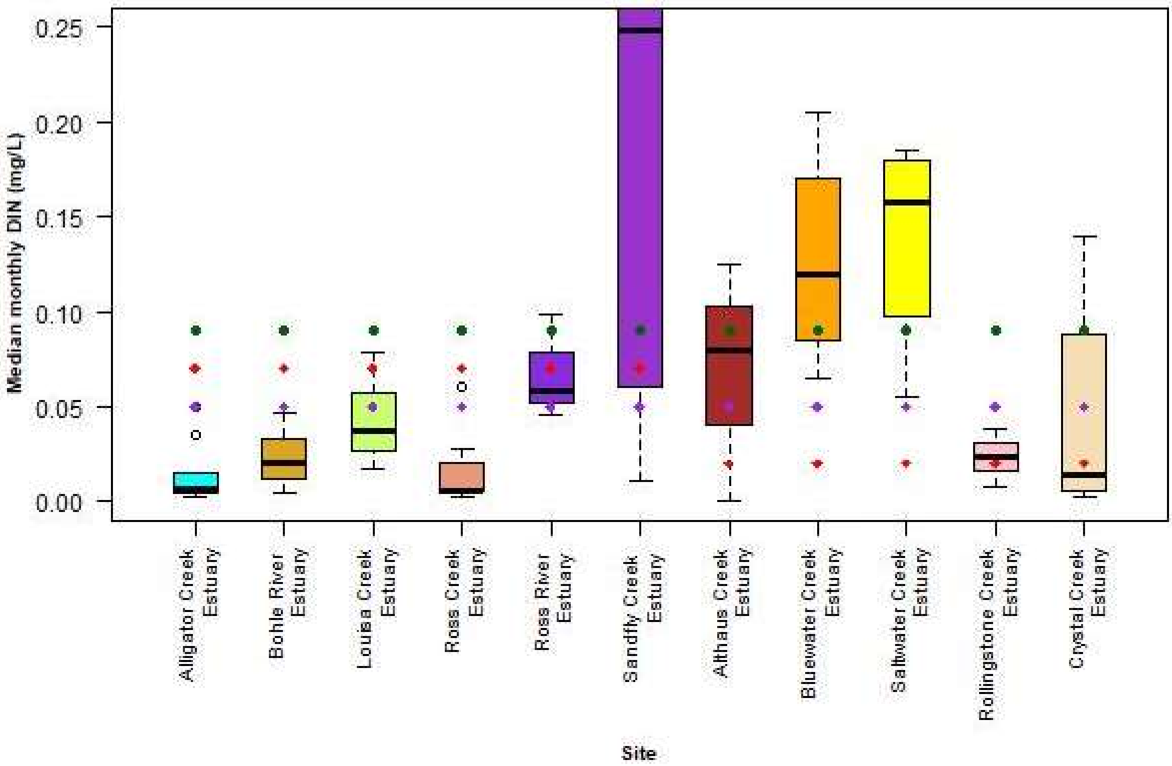


Figure Appendix C 11. Boxplot of dissolved inorganic nitrogen (DIN) concentrations at each estuarine monitoring site, excluding the uppermost data from Sandfly Creek Estuary and the outlier from Crystal Creek Estuary.

The green circles indicate the scaling factors, the red circles shown the water quality objectives (WQOs) and the purple circles show the water quality guideline values (GVs). Outliers are shown as clear circles.

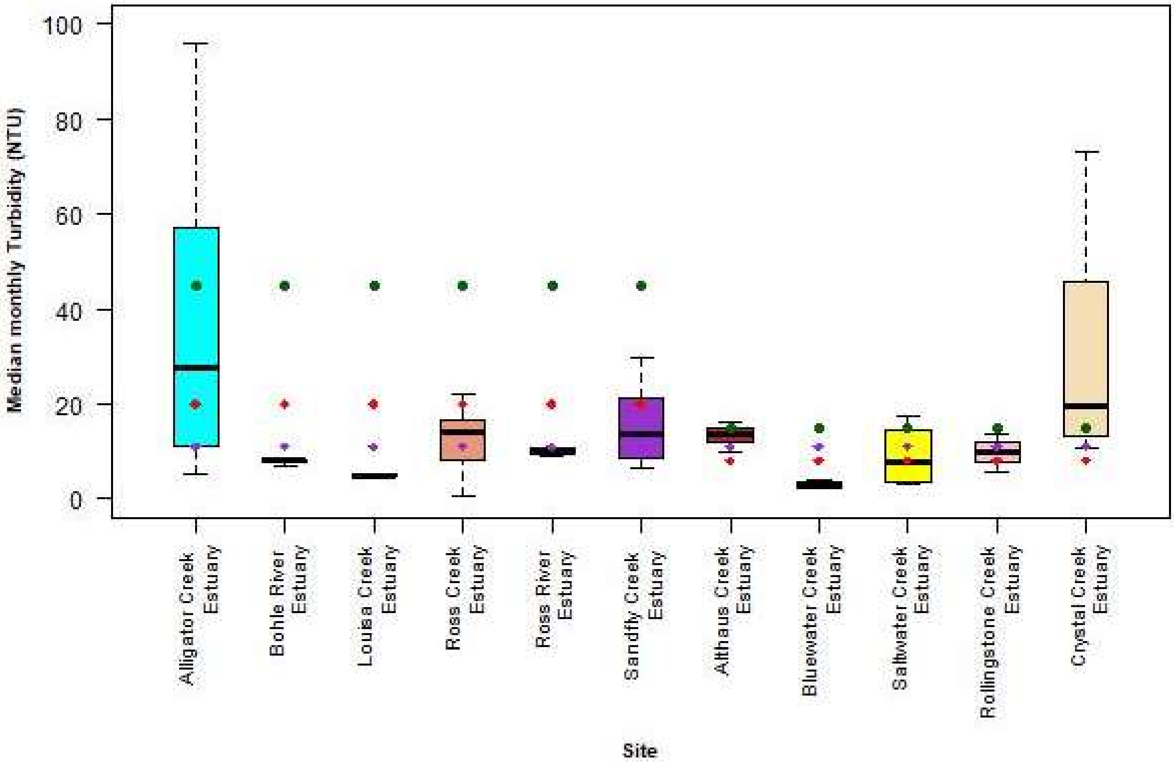


Figure Appendix C 12. Boxplot of turbidity levels at each estuarine monitoring site.
The green circles indicate the scaling factors, the red circles shown the water quality objectives (WQOs) and the purple circles show the water quality guideline values (GVs).

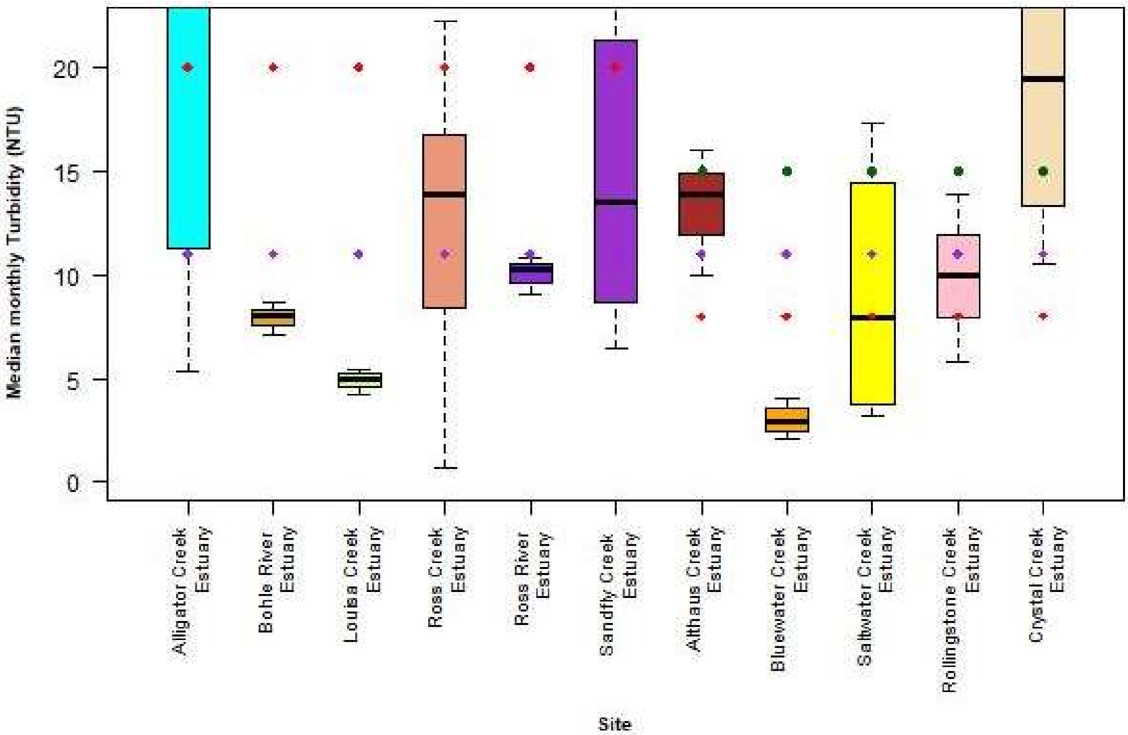


Figure Appendix C 13. Boxplot of turbidity levels at each estuarine monitoring site, excluding the uppermost data from Alligator, Sandfly and Crystal Creek estuaries.
Sampling sites within the Ross freshwater basin have a scaling factor of 45 for turbidity. These values have been excluded to allow a closer examination of the data. The green circles indicate the scaling factors, the red circles shown the water quality objectives (WQOs) and the purple circles show the water quality guideline values (GVs).

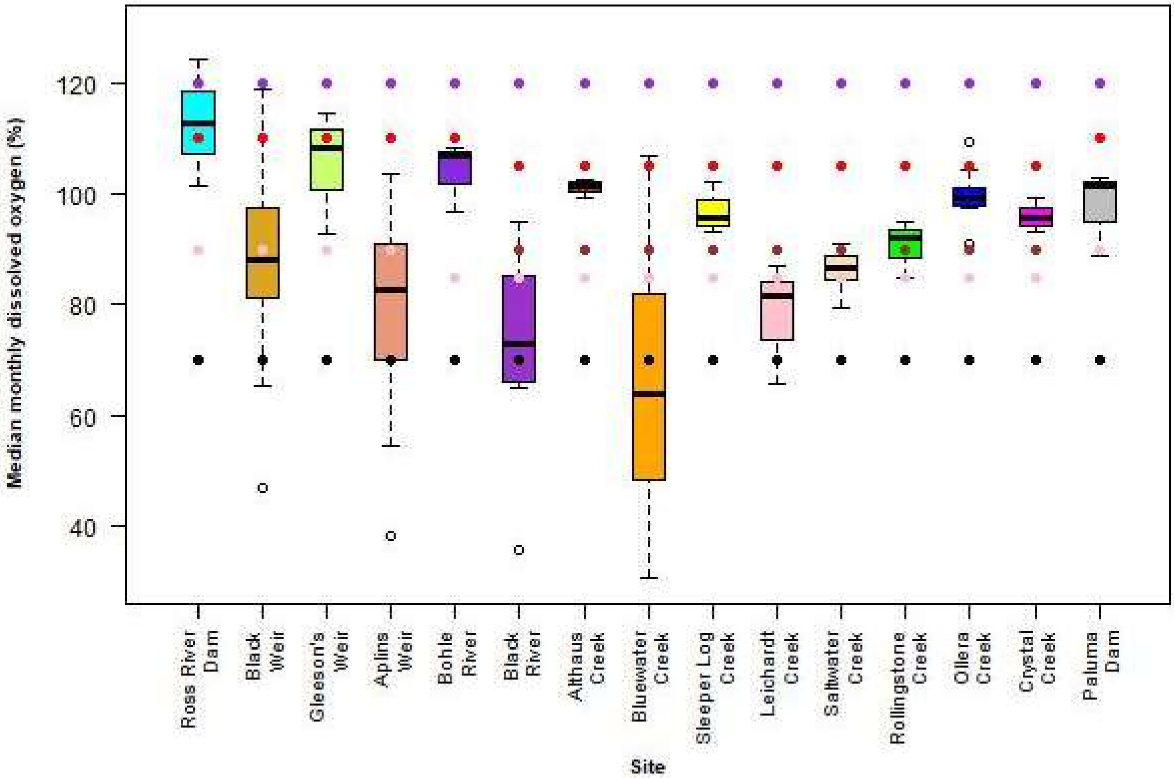


Figure Appendix C 14. Boxplot of dissolved oxygen (DO) concentrations at each estuarine monitoring site. The green and black circles indicate the scaling factors for the upper and lower DO respectively, the red and brown circles indicate the water quality objectives (WQOs) for the upper and lower DO respectively and the purple and pink circles show the guideline values (GVs) for the upper and lower DO respectively. Outliers are shown as clear circles. Outliers are shown as clear circles.

Boxplots for inshore marine water quality data

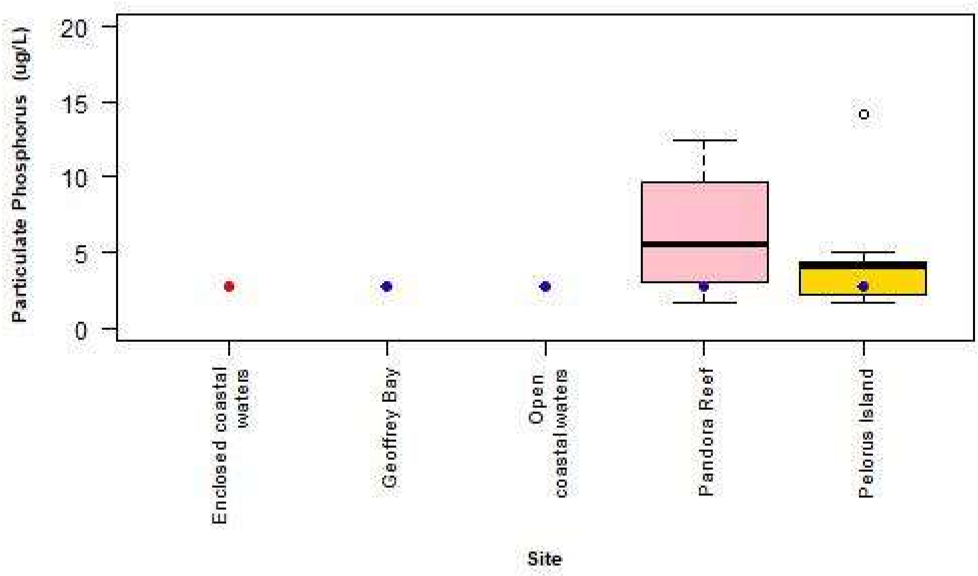


Figure Appendix C 15. Boxplot of particulate phosphorus concentrations at each inshore marine monitoring site, using data collected from grab samples.
The red circles indicate the water quality objectives and the blue circles indicate the water quality guideline values.

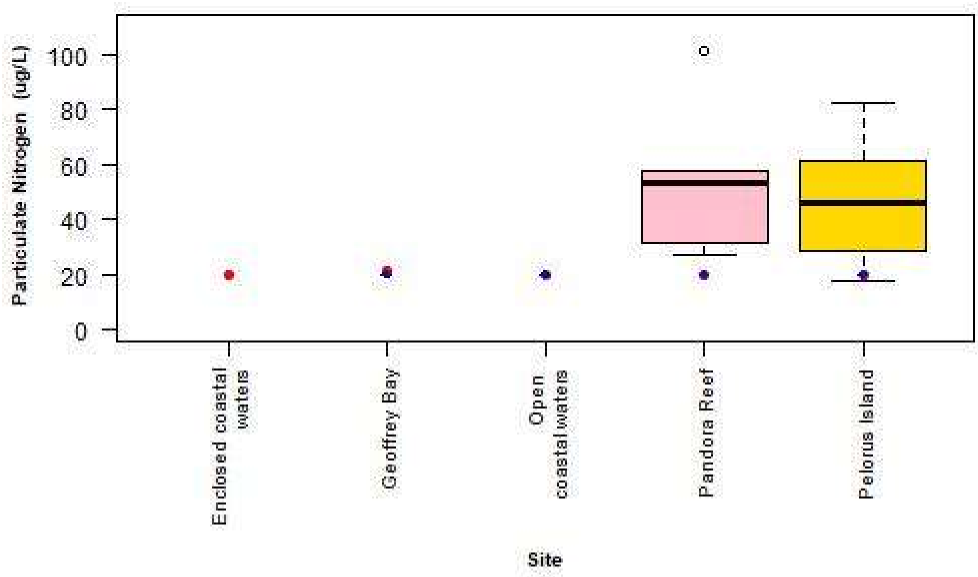


Figure Appendix C 16. Boxplot of particulate nitrogen concentrations at each inshore marine monitoring site, using data collected from grab samples.
The red circles indicate the water quality objectives and the blue circles indicate the water quality guideline values.

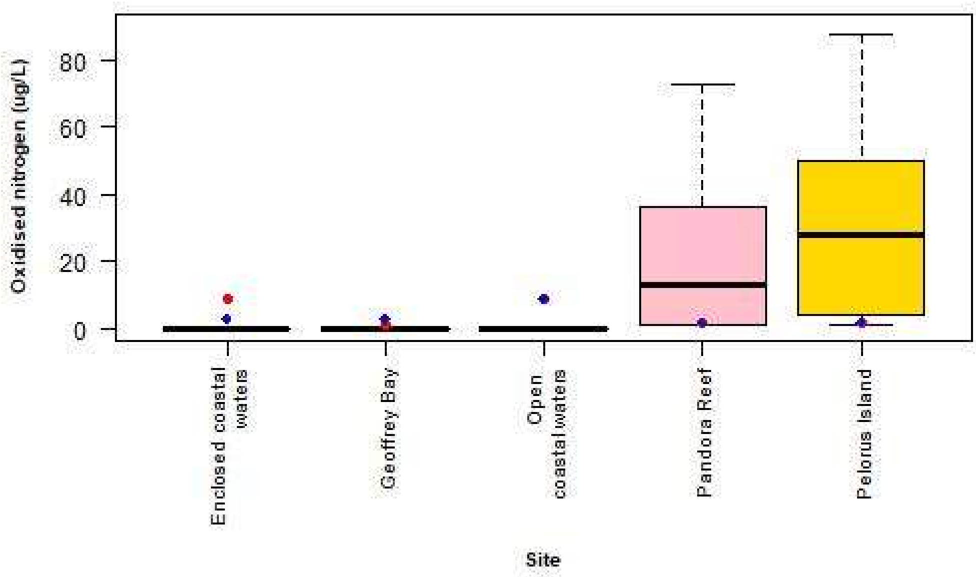


Figure Appendix C 17. Boxplot of oxidised nitrogen concentrations at each inshore marine monitoring site, using data collected from grab samples.

The red circles indicate the water quality objectives and the blue circles indicate the water quality guideline values.

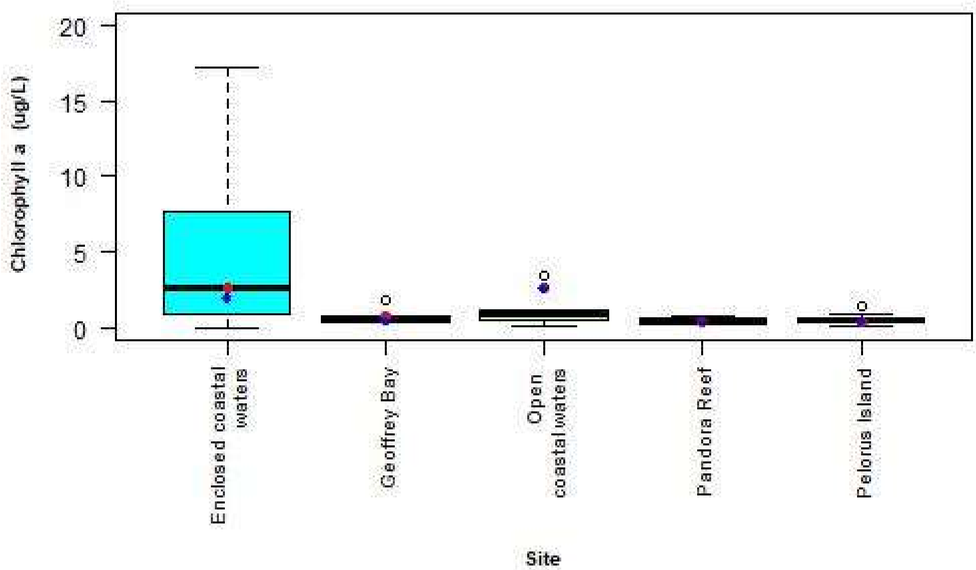


Figure Appendix C 18. Boxplot of chlorophyll *a* concentrations at each inshore marine monitoring site, using data collected from grab samples.

The red circles indicate the water quality objectives and the blue circles indicate the water quality guideline values.

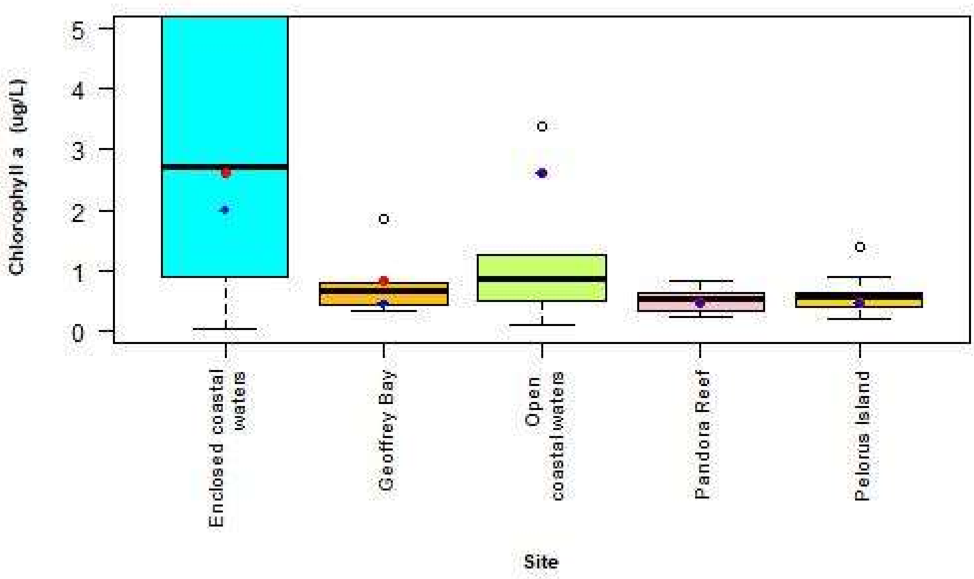


Figure Appendix C 19. Boxplot of chlorophyll *a* concentrations at each inshore marine monitoring site, excluding the uppermost data from the enclosed coastal waters site to allow a closer analysis of the data and using data collected using grab samples.

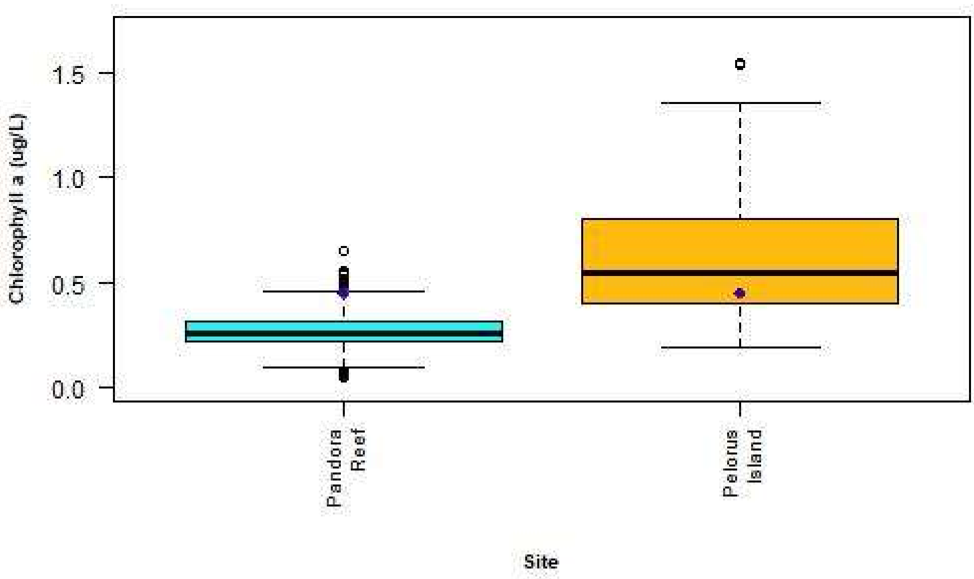


Figure Appendix C 20. Boxplot of chlorophyll *a* concentrations at each inshore marine monitoring site, using data collected from hourly loggers.

The red circles indicate the water quality objectives and the blue circles indicate the water quality guideline values.

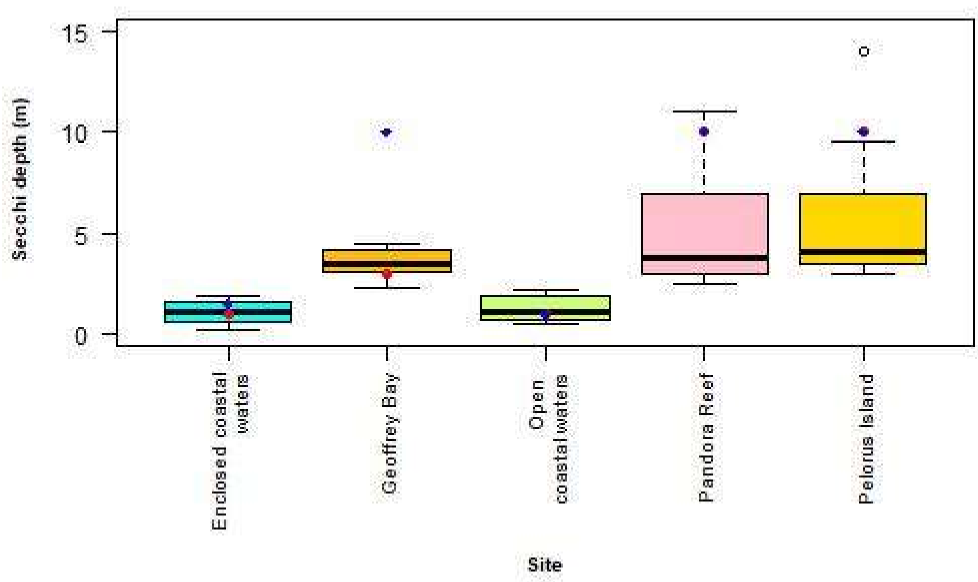


Figure Appendix C 21. Boxplot of secchi depth levels at each inshore marine monitoring site, using data collected from grab samples.

The red circles indicate the water quality objectives and the blue circles indicate the water quality guideline values.

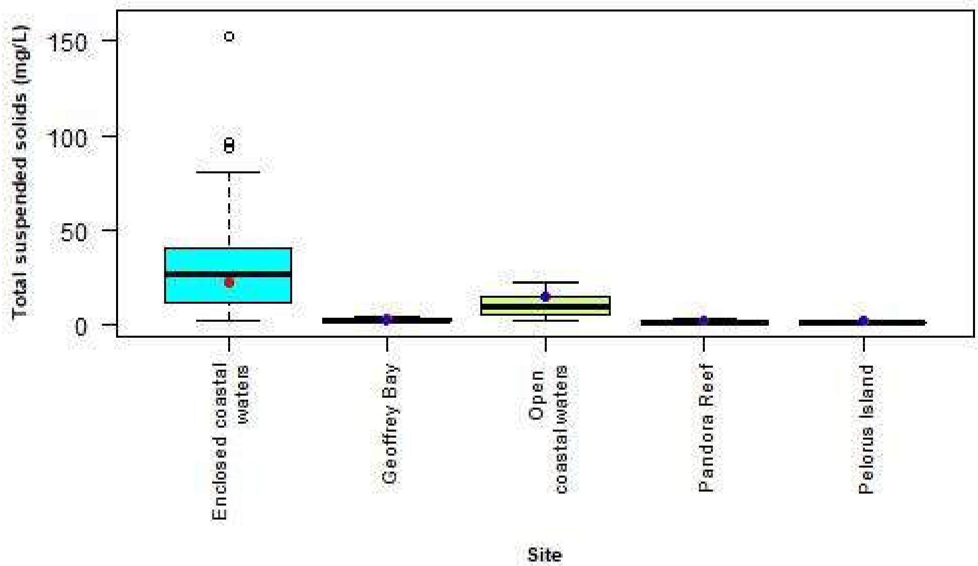


Figure Appendix C 22. Boxplot of total suspended solids levels at each inshore marine monitoring site, using data collected from grab samples.

The red circles indicate the water quality objectives and the blue circles indicate the water quality guideline values.

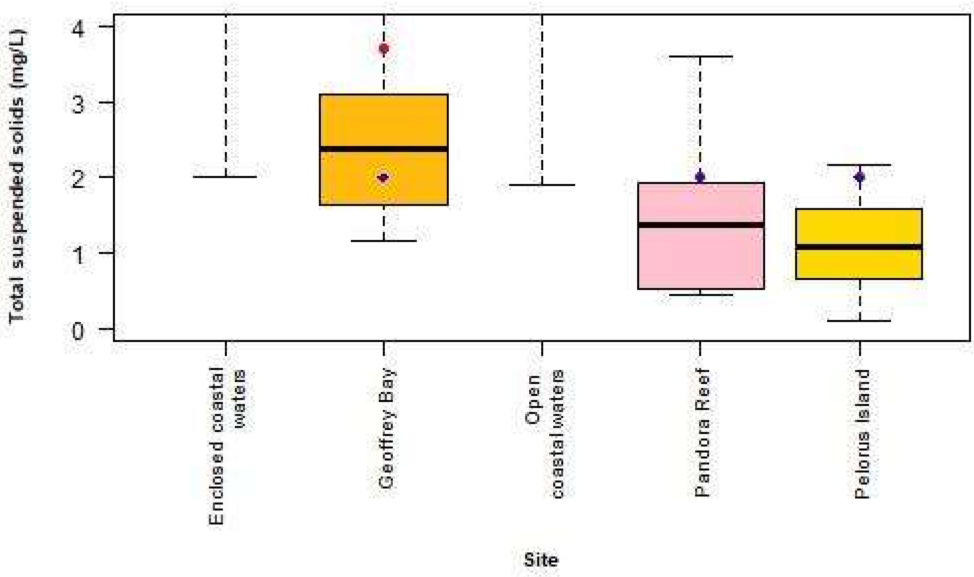


Figure Appendix C 23. Boxplot of total suspended solids levels at each inshore marine monitoring site, excluding the uppermost data from the enclosed and open coastal waters sites and using data collected from grab samples.

The red circles indicate the water quality objectives and the blue circles indicate the water quality guideline values.

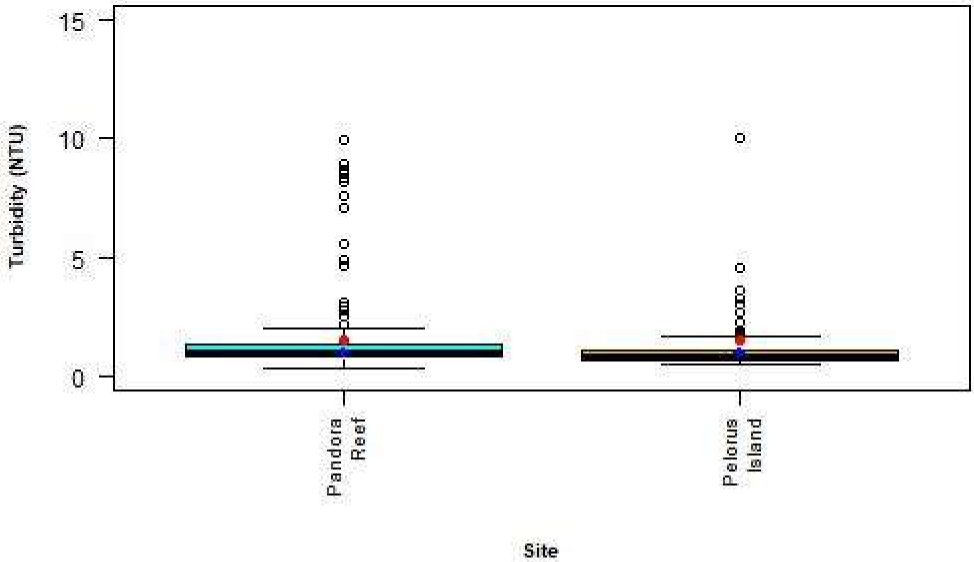


Figure Appendix C 24. Boxplot of turbidity levels at each inshore marine monitoring site, with data collected using hourly loggers.

The red circles indicate the water quality objectives and the blue circles indicate the water quality guideline values.

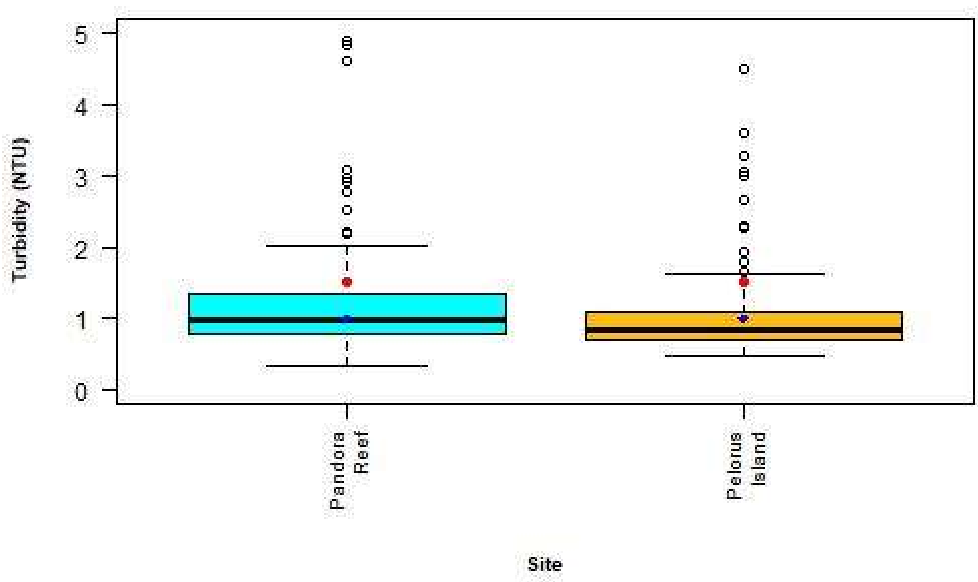


Figure Appendix C 25. Boxplot of turbidity levels at each inshore marine monitoring site, excluding the uppermost outliers and using data collected using hourly loggers.

The red circles indicate the water quality objectives and the blue circles indicate the water quality guideline values.

Appendix D. Coral reef scores and grades

Coral scores and grades for 2 m and 5 m average depth

The scores and grades for 2 m and 5 m average depth are shown in Table Appendix D1.

Comparison with 2017-18 results

The scores and grades comparing between 2017-18 and 2018-19 scores and grades are shown in Table Appendix D 2. The overall grade for Cleveland Bay and Halifax Bay was the same as it was in 2017-18 Report Card. Within Cleveland Bay, composition of hard corals and percentage change in hard cover within the bay improved one grade from 2017-18 to 2018-19. Within Halifax Bay, the grade for macroalgae and percent coral cover also improved between years.

Table Appendix D 1. Standardised scores and grades for indicators of inshore coral condition for all reefs monitored during the 2018-19 financial year.

The overall scores for Cleveland Bay and Halifax Bay are presented as integers to conform to the grading system. In Cleveland Bay, both Reef Check and the Marine Monitoring Program (MMP) conduct surveys of inshore reefs. To produce the overall scores for Cleveland Bay, Reef Check and MMP scores were weighted. However, only the standardised scores are presented for clarity of results. In Halifax Bay, only MMP conducted surveys and therefore sites did not need to be weighted, with the overall scores calculated by averaging for each indicator (down the column). All sites monitored by MMP are sampled at 2 m and 5 m depths, with the scores then averaged to produce an overall score for the site. The overall scores for each site were averaged to produce the overall scores for each reporting zone (Cleveland Bay and Halifax Bay). The overall scores for each site and for each reporting zones (Cleveland Bay and Halifax Bay) are shown in bold, with the overall scores for each zone are highlighted in cream. No data is abbreviated as ND.

			Standardised scores						Standardised grades					
Site (Reef)	Monitoring Program	Depth (m)	Composi-tion of hard corals	% Coral cover	% Change hard corals	Juvenile density	Macro-algae	**Coral indicator category**	Composi-tion of hard corals	% Coral cover (raw score)	% Change hard corals	Juvenile density	Macro-algae	**Coral indicator category**
Florence Bay	Reef Check		ND	**42**	ND	ND	ND		**ND**	**ND**	**C**	**ND**	**ND**	**ND**
Geoffrey Bay	MMP	2	50	31	45	22	0	30	C	D	C	D	E	D
Geoffrey Bay	MMP	5	50	50	53	67	0	44	C	C	C	B	E	C
Geoffrey Bay	MMP	**Average**	**50**	**40**	**49**	**44**	**0**	**37**	**C**	**D**	**C**	**C**	**E**	**D**
Middle Reef	MMP	2	50	52	ND*	54	0	39	C	C	E	C	E	D
Middle Reef Bay	Reef Check		ND	35	ND	ND	ND		ND	ND	C	ND	ND	ND
Middle Reef		**Average**	**50**	**44**	**ND**	**54**	**0**	**38**	**C**	**C**	**C**	**ND**	**E**	**D**
Cleveland Bay		**Average**	**50**	**46**	**49**	**49**	**0**	**38**	**C**	**C**	**C**	**C**	**E**	**D**
Havannah	MMP	2	100	42	0	12	100	51	A	C	E	E	A	C
Havannah	MMP	5	100	52	100	36	53	68	A	C	A	D	C	B
Havannah	MMP	**Average**	**100**	**47**	**50**	**24**	**77**	**60**	**A**	**C**	**C**	**D**	**B**	**C**

Havannah North	MMP	5	100	28	77	52	0	52	A	D	B	C	E	C
Palms East	MMP	2	100	54	82	23	100	72	A	C	A	D	A	B
Palms East	MMP	5	100	62	100	53	75	78	A	B	A	C	B	B
Palms East	MMP	**Average**	**100**	**58**	**91**	**38**	**88**	**75**	**A**	**C**	**A**	**D**	**A**	**B**
Palms West	MMP	2	0	46	67	36	100	50	E	C	B	D	A	C
Palms West	MMP	5	50	45	43	42	100	56	C	C	C	C	A	C
Palms West	MMP	**Average**	**25**	**46**	**55**	**39**	**100**	**53**	**D**	**C**	**C**	**D**	**A**	**C**
Pandora	MMP	2	50	12	57	27	0	29	C	E	C	D	E	D
Pandora	MMP	5	100	15	37	77	15	49	A	E	D	B	E	C
Pandora	MMP	**Average**	**75**	**14**	**47**	**52**	**7**	**39**	**B**	**E**	**C**	**C**	**E**	**D**
Pandora North	MMP	5	0	77	31	52	0	32	E	B	D	C	E	D
Halifax Bay		**Average**	**67**	**45**	**59**	**43**	**45**	**52**	**B**	**C**	**C**	**C**	**C**	**C**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = assigned 90 | ■ No score/data gap

*The percent change in hard coral cover has not been sampled on Middle Reef since 2014.

Table Appendix D 2. Grades for 2017-18 and 2018-19 for each indicator of coral condition for reefs sampled within Cleveland Bay and Halifax Bay. The overall grades for each bay are also presented.

		2017-18 grades						2018-2019 grades					
Site (Reef)	Monitoring Program	Composition of hard corals	% Coral cover (raw score)	% Change hard corals	Juvenile density	Macro-algae	Coral indicator category	Composition of hard corals	% Coral cover (raw score)	% Change hard corals	Juvenile density	Macro-algae	Coral indicator category
Florence Bay	Reef Check	ND	ND	ND	ND	ND	ND	ND	ND	C	ND	ND	ND
Geoffrey Bay	MMP	D	D	D	C	E	D	C	D	C	C	E	D
Middle Reef	Both	C	C	ND^	C	E	D	C	C	C	ND^	E	D
Cleveland Bay	**Both**	**D**	**C**	**D**	**C**	**E**	**D**	**C**	**C**	**C**	**C**	**E**	**D**
Havannah	MMP	A	C	B	D	C	C	A	C	C	D	B	C
Havannah North	MMP	A	E	C	A	E	C	A	D	B	C	E	C
Palms East	MMP	A	E	C	C	E	C	A	C	A	D	A	B
Palms West	MMP	C	D	A	D	A	C	D	C	C	D	A	C
Pandora	MMP	B	E	D	C	E	D	B	E	C	C	E	D
Pandora North	MMP	E	B	E	C	E	D	E	B	D	C	E	D
Halifax Bay	**MMP**	**B**	**D**	**C**	**C**	**D**	**C**	**B**	**C**	**C**	**C**	**C**	**C**

Scoring range: ■ Very Poor (E) = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good = 81 to 100 | ■ No score/data gap.

^The percent change in hard coral cover has not been sampled on Middle Reef since 2014.

Appendix E. Social and economic survey questions and indicator categories

The following two tables provide the list of indicators used to derive the scores and grades for the social and economic component of the Report Card.

Table Appendix E 2. Indicators used to determine the score of Community for the Townsville region.

Index/Indicator category	Indicators (survey questions)
Value from waterways	The aesthetic beauty of the GBR is outstanding
	I value the GBR because it supports a variety of life, such as fish and corals
	I value the GBR because it supports a desirable and active way of life
	I value the GBR because we can learn about the environment through scientific discoveries
	I value the GBR because it is spiritually important to me
	I value the GBR because it inspires me in artistic or thoughtful ways
	I value the GBR simply because it exists, even if I don't use or benefit from it
	I value the GBR because of its rich Traditional Owner Heritage
	I value the GBR because it provides a place where people can continue to pass down wisdom, traditions and a way of life
	I value the GBR because it is an important part of my culture
Wellbeing from waterways	I feel proud that the GBR is a World Heritage Area
	The GBR is part of my identity
	The GBR contributes to my quality of life and well-being
	I would not be personally affected if the health of the GBR declined
	Thinking about coral bleaching makes me feel depressed*
	I love that I live beside the GBR
	I value the GBR because it makes me feel better physically and/or mentally
Perception of waterway management	I do not have fair access to the GBR compared to other user groups*
	I feel confident that the GBR is well managed
	I feel confident that the freshwater areas in my region are well managed
	I support the current rules and regulations that affect access and use of the GBR
	I think enough is being done to effectively manage the GBR
	I am not worried about climate change impacts on the GBR
	I feel that future generations have been adequately considered in the management of the GBR
	I support the current rules and regulations that affect access and use of freshwater areas (rivers and creeks) in my region
Perception of environmental condition	I feel optimistic about the future of the GBR
	There is too much rubbish (plastics and bottles) on the beaches in my region*
	I am worried about the status of freshwater fish in my region
	The coral reefs in my region are in good condition
	The mangroves in my region are in good health
	The estuarine and marine fish in my region are in good condition
	The freshwater areas (e.g. rivers, creeks) in my region are not in good condition*
Stewardship	I would like to do more to help protect the GBR
	I would like to do more to improve water quality in my waterways (including rivers, creeks)
	I would like to learn more about the condition of the GBR
	I make every effort to use energy efficiently in my home and workplace
	I rarely consider the environmental impact of the production process for goods and services that I purchase*
	I don't usually make any extra effort to reduce the waste I generate*
	I re-use or recycle most goods and waste

*Questions are negatively worded, and their associated scores were inverted to reflect if the question was positively worded. This was done to ensure the ranking scale (1-10 from strongly disagree to strongly agree) has the same meaning as it does for positively worded questions.

Appendix F. Economic survey questions, indicators and indicator categories

Table Appendix F 1. Indicator categories and indicators used to determine the score of Economy.

Index	Indicator categories	Indicator
Non-monetary economic value	Tourism attraction value	I value the GBR because it attracts people from all over the world
	Science and education value	I value the GBR because we can learn about the environment through scientific discoveries
	Produce	I value the GBR for the fresh seafood it provides
	Perception of economic value	The GBR is a great asset for the economy of this region