Results for Townsville Dry Tropics 2019-2020 Report Card

Technical report *(released in 2021)*

June 2021

dry tropics partnership for healthy waters

Authorship statement

The technical report of the results of the Townsville Dry Tropics 2019-2020 Report Card (released in 2021) was compiled by the Partnership's Senior Technical Officer, Dr Tegan Whitehead.

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

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Acknowledgements

We thank Partners who kindly contributed their data and members of the Townsville Dry Tropics Management Committee who provided feedback on the document. 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. Members of the Reef Independent Science Panel are also gratefully acknowledged for their advice and review of this document.

Citation

Whitehead, T (2021). *Results for the Townsville Dry Tropics 2019-2020 Report Card (released in 2021), Technical Report*. Dry Tropics Partnership for Healthy Waters, Townsville.

Executive Summary

This executive summary includes five summary sections covering:

- The Dry Tropics Partnership,
- The region's climate during 2019-2020,
- The state and condition of the environment, including scores and grades for each index for each environment (freshwater, estuarine, inshore marine and offshore marine),
- Site specific scores for litter, and
- Whole-of-Townsville (local government area) scores for the urban water stewardship framework.

The Dry Tropics Partnership

The Dry Tropics Partnership for Healthy Waters (referred to as the Partnership) was formed in November 2017 and launched in January 2019. The current geographic scope of the Partnership covers the waterways (freshwater, estuarine and marine) in the Townsville region, from Crystal Creek in the north to Cape Cleveland in the south and east to the outer Great Barrier Reef (GBR) Marine Park. The Partnership released its Pilot Report Card in May 2019, reporting on data from the 2017-18 financial year and its first full Report Card in June 2020. The Partnerships' second full Report Card (data from 2019-2020) will be released in June 2021. This document is intended to be read in conjunction with the Townsville Dry Tropics Program Design and the Townsville Dry Tropics Methods document.

Climate

Between July 2019 and June 2020, both the Ross and Black freshwater basins experienced lower than average rainfall, recording 72-73% of the annual mean rainfall for both basins. The region also recorded very high air temperatures, with 2019-2020 being in the top 10% of years with the hottest mean temperature. In addition to high air temperatures, sea surface temperatures on the Great Barrier Reef during February 2020 were the hottest of any month ever recorded (since 1900), with sea surface temperatures 1.2°C warmer than the long-term February average. For the northern tropic region, every month during 2020, except December, was amongst the five warmest on record, and each month from January to April 2020 was the second-warmest on record for their respective month. The hot sea surface temperatures resulted in a third extensive marine heatwave in five years, resulting in widespread coral bleaching along the GBR.

State and condition of the environment

The results presented in this document describe the state and condition for freshwater, estuarine, inshore marine and offshore marine environments. The freshwater and estuarine environments are divided into the Ross and Black zones, whilst the inshore marine environment is divided into

Cleveland Bay and Halifax Bay. The offshore marine environment is one zone that encompasses all offshore waters from Palm Island to Cape Cleveland. The Townsville Dry Tropics 2019-2020 Report Card (henceforth referred to as the Report Card) will be released in June 2021 and will mainly report on data from the 2019-2020 financial year.

Within each of these environments (and zones), standardised scores and grades are produced for indicators, indicator categories and indices. Results from multiple indicators are aggregated into results for indicator categories, which are aggregated into results for indices. Within the four environments, there are different indices that are reported upon. Within the freshwater environment there are three indices that are reported upon, namely water quality, habitat and hydrology and fish. This is the first year that freshwater fish are reported upon within the report card. Within the estuarine environment, there are two indices, namely water quality and habitat and hydrology. The habitat and hydrology index was referred to as biodiversity or habitat in the previous two report cards (data from 2017-18 and 2018-19). The index was changed to habitat and hydrology to align with the other regional report cards. Within the inshore marine and offshore marine environment, water quality and habitat are the two indices scored. Habitat was previously referred to as biodiversity within the previous report cards. Confidence levels associated with the results are also reported and are based on how data were collected and analysed.

The index and overall standardised scores and grades of each waterway environment for the 2019-2020 reporting period are presented in the Tables i - iv below for quick reference. Selected key messages are also provided.

Freshwater basins

Table i. Scores and grades for the water quality, habitat and hydrology and fish indices for the Ross and Black freshwater basins.

Zone	Score			Grade		
	Water Quality	Habitat and hydrology	Fish	Water Quality	Habitat and hydrology	Fish
Ross freshwater basin	70	51	57	B	C	C
Black freshwater basin	67	78	78	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 to 100

Freshwater basin key messages:

- Water quality was good or very good for 12 of the 13 rivers/creeks sampled. Bohle River was the exception, with the river having very high nutrient concentrations in relation to the water quality objective.
- Fish communities were in a moderate and good condition within the Ross and Black basins, respectively. Fish communities improved in waterways furthest from urban areas. A high biomass of tilapia occurred within both the Ross and Black freshwater basins.

Estuarine zones

Table ii. Scores and grades for the water quality and habitat and hydrology indices for the Ross and Black estuarine zones.

Zone	Score		Grade	
	Water Quality	Habitat and hydrology	Water Quality	Habitat and hydrology
Ross estuarine zone	90	71	A	B
Black estuarine zone	64	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 (A) = 81 to 100

<u>Estuarine zone key messages:</u>

- Most estuaries were in a good or very good condition with respect to water quality.
- The scores for mangrove and saltmarsh extent (habitat and hydrology index) were good in relation to management targets of no loss. (Note: These results are the same as the 2018-19 Report Card and are based on changes in habitat extent from 2013-2017 in relation to the target of no net loss of habitat).

Inshore marine zones

Table iii. Scores and grades for the water quality and habitat indices for Cleveland Bay and Halifax Bay.

Zone	Score		Grade	
	Water Quality	Habitat	Water Quality	Habitat
Cleveland Bay	80	48	B	C
Halifax Bay	70	52	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 to 100

<u>Inshore marine zone key messages:</u>

- Most sites sampled had good or very good water quality, although nitrogen concentrations were higher than the water quality objectives at most sites.
- Coral reefs were in a moderate condition in both Cleveland Bay and Halifax Bay.
- Seagrass condition was in a moderate condition within Cleveland Bay, with species composition being in a very good condition. Biomass was the lowest scoring indicator, with this score used as the overall score for seagrass condition.

Offshore marine zone

Table iv. Scores and grades for the water quality and habitat indices for the offshore marine zone.

Zone	Score		Grade	
	Water Quality	Habitat	Water Quality	Habitat
Offshore	100	56	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 to 100

<u>Offshore marine zone key messages:</u>

- Offshore water quality 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.
- Crown-of-thorns starfish had a major impact upon the offshore corals, with coral bleaching also having a minor impact.

Litter

Section 9 includes the results for litter using the method first developed in 2018-19. Volunteer based litter clean ups only occurred at five locations and therefore the scores for litter are site specific scores, with no overall zonal score derived. The site-specific scores for litter are provided in Table v below for quick reference.

Table v. Scores and grades for Litter at specific sites within the Townsville Dry Tropics.

Zone	Site	Standardised scores	Grades
Ross estuarine zone	Rowes Bay	83	SP
Ross estuarine zone	Shelly Beach	97	SP
Black estuarine zone	Ollera Beach	20	VHP
Cleveland Bay	Nelly Bay Beach	53	MP
Halifax Bay	Big Rock Bay, Orpheus Island	50	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 data (ND)

<u>Litter key messages:</u>

- Five sites were scored during 2019-2020, with insufficient data available to produce an overall score for a zone.
- Litter posed a slight pressure on Rowes Bay and Shelly Cove Beach at the time the clean-up events occurred. This score was based on comparing the amount of rubbish collected against the average amount of rubbish within the area between 2014-2018.
- At Ollera Beach, litter posed a very high pressure upon the environment compared to 2014-2018 levels.
- At both Nelly Bay Beach on Magnetic Island and Big Rock Bay on Orpheus Island, litter posed a moderate pressure to the environment compared to 2014-2018 levels.

Urban Water Stewardship Framework

Section 10 provides the results for the urban water stewardship framework (UWSF) are presented for the first time. These results were for the whole of Townsville, rather than specific zones/environments. The scores for the UWSF are provided in Table vi for quick reference.

Table vi. Scores and grades for the three reporting components (diffuse source, established urban and developing urban) of the urban water stewardship framework.

Reporting components	Score	Grade
Developing urban	9	C
Established urban	10	C
Point source	12	C

Scoring range: ■ Performing to outdated standards (D) = 0 to <5 | ■ Performing to current minimum standard (C) = 5 to 12.4 | ■ Performing to current best practice performance (B) = 12.5 to 17.4 | ■ Performing to above best practice performance (A) = >17.4

Urban Water Stewardship Framework key messages:

- Management practices associated with Developing Urban, Established Urban and Point Source all received an overall rating of C (current minimum standard). A 'C' rating equates to a moderate level of risk to water quality, which implies either maintenance of the status quo or a chance of slight deterioration in water quality.
- Thirteen of the 16 management activity groups (MAGs) were assessed as being at minimum standard. This suggests that most management activities have room for improvement.
- Townsville City Council was rated at or above best practice for two MAGs relating to social approaches, including collaboration, partnerships, capacity building and learning.
- Infrastructure, management and maintenance MAGs had the lowest or second lowest scores, with a lack of resources cited as an issue when following up on maintenance or compliance issues.

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Terms and Acronyms

AIMS	Australian Institute of Marine Science
Alien species	Alien species are those species that are not native to Australia.
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.
Independent site	An independent site is if there is more than one sampling site along the same watercourse and there is a substantial input into the waterway between the two sites, such as a tributary, storm water input or a sewage treatment plant. Independent sites are score separately.
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
Invasive species (same as non-indigenous species)	Invasive species (same as non-indigenous species) include both alien and translocated species. Alien species are those species that are not native to Australia, whilst translocated species are species that are native to Australia but not native to the waterway.
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
Non-independent site (or monitoring location)	Non-independent site (or monitoring location) is if there is more than one sampling site along the same watercourse and there is a no substantial input into the waterway between the two sites, such as a tributary, storm water input or a sewage treatment plant. Data from the non-independent sites were combined into one independent site and one score is produced for each site.
Non-indigenous species	Non-indigenous species (same as invasive species) are species that include both alien and translocated species. Alien species are those species that are not native to Australia, whilst translocated species are species that are native to Australia but not native to the waterway.
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).
Palustrine wetlands	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).
Physical-chemical properties (phys-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
Riparian extent	Vegetation with a 50 m buffer from a watercourse
RIMReP	Reef 2050 Integrated Monitoring and Reporting Program
Translocated species	Translocated species are species that are native to Australia but not native to the waterway.

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1 Introduction

1.1 Overview

The Dry Tropics Partnership for Healthy Waterways (referred to as the Partnership) was launched in January 2019, with a focus of the Partnership being to produce an annual Report Card. The 'Pilot Report Card' was released in May 2019 and reported on data mainly from the 2017-18 financial year. Each year an annual report card is produced, with the current Report Card reporting on data mainly from the 2019-2020 financial year. In some cases where a seasonal monitoring program extends outside of the financial year period, such as inshore coral, data from the whole monitoring period are included. For monitoring programs that collect data less frequently than annually (e.g. wetland and riparian extent) then the most recent data set is included.

The Report Card includes an assessment of the state of the water quality, habitat and hydrology (or habitat) and fish that is directly dependent on waterways. Indices are scored for the freshwater, estuarine, inshore marine and offshore marine environments within the Townsville Dry Tropics region, however not all indices are scored for each environment (for example, fish is only scored within the freshwater environment). The site-specific results for litter and the ratings for the urban water stewardship framework for the Townsville urban region are also included.

To allow comparisons between the report cards, where appropriate the summary results for each index from 2017-18 and 2018-19 are presented alongside the detailed results for the 2019-2020 results. It is noted that for some indicators, the method for calculating the score changed between the 2017-18 and the 2018-19 Report Card and thus only the 2018-19 and 2019-2020 results were compared.

1.2 Report Card zones

The results presented in the 2019-2020 Report Card 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.

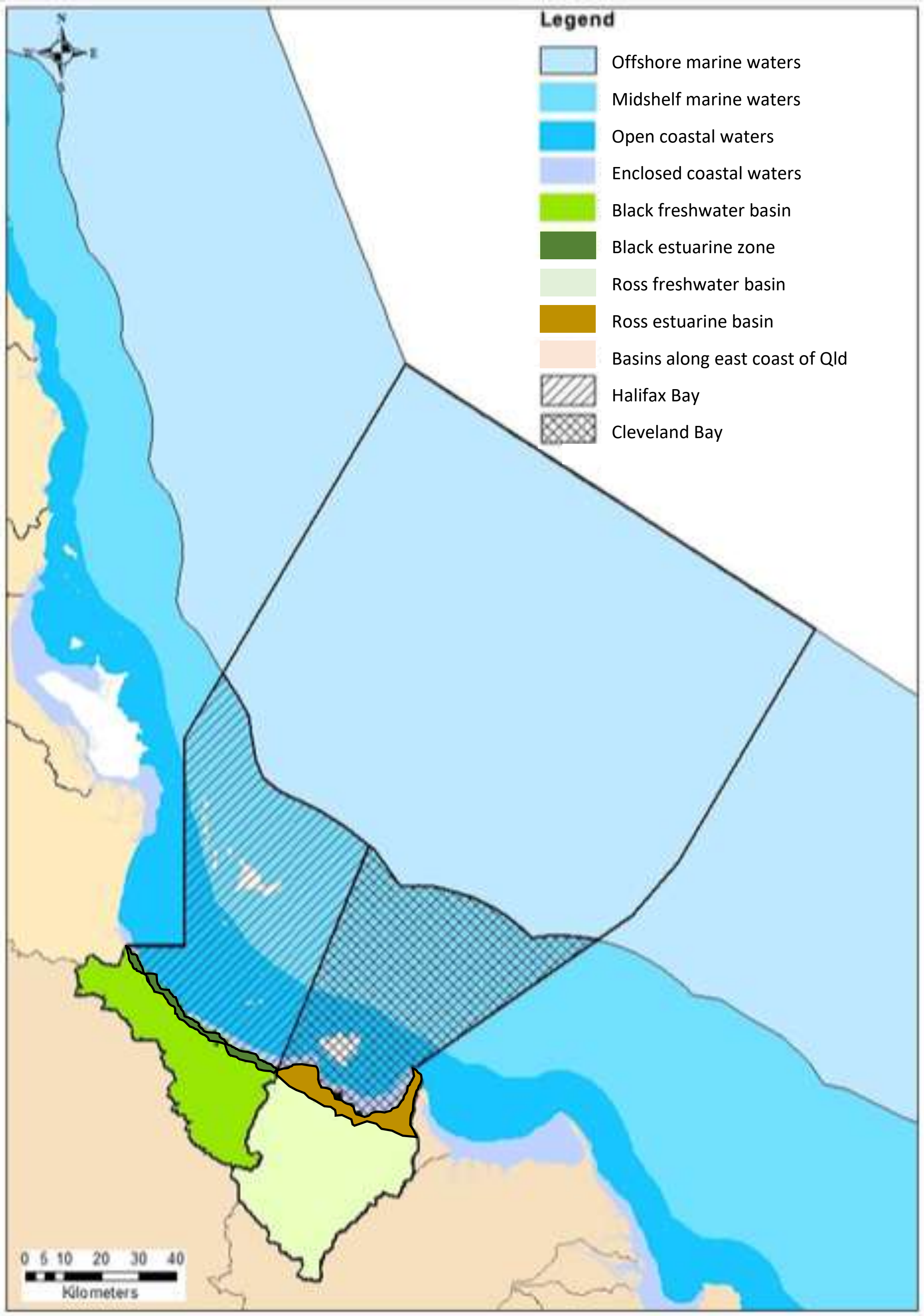


Figure 1. Geographic boundary reported upon by the Dry Tropics Partnership, comprising the Ross and Black freshwater basins and estuarine zones, Cleveland Bay, Halifax Bay and the offshore marine zone.
The inshore marine zones comprise midshelf, open coastal and enclosed coastal waters. The right angle 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, estuaries and the inshore and offshore marine environments within the Townsville Dry Tropics region. This document presents scores and grades for indicators, indicator categories and indices for each of the seven zones. Key messages about each index are presented within the main result section of this document, with the summarised key messages for each environment and zone presented in the executive summary. Confidence scores are also presented within the main results.

This document supports the 2019-20 Report Card 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 and terminology

The methods used are the same as those detailed in the 'Methods for the Townsville Dry Tropics annual Report Cards' document (Whitehead, 2021).

2.1 Terminology

Different indicators are measured to assess water quality, the state of habitat and hydrology and fish within the seven 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 average (overall) score for each the three indices (water quality, habitat and hydrology/habitat and fish) for each environment and zone. The index habitat and hydrology/habitat is referred to as habitat and hydrology within the freshwater and estuarine environment and solely as habitat in the inshore and offshore marine zones. This is because hydrology indicators are not included or planned to be included within the marine environments in subsequent report cards.

The levels of aggregation are:

- **Indicator** is a measured variable (e.g. turbidity).
- **Indicator category** is a group of similar indicators (e.g. nutrients, which is an aggregation of indicators related to nutrients, such as nitrogen and phosphorus). 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. water quality).

The grades for indices of water quality, habitat and hydrology/habitat and fish will be presented in a coaster for each of the seven zones. An example of a coaster is shown in Figure 2. The results for water quality, habitat and hydrology/habitat and fish are not rolled up into one score for the Townsville region (three separate scores).

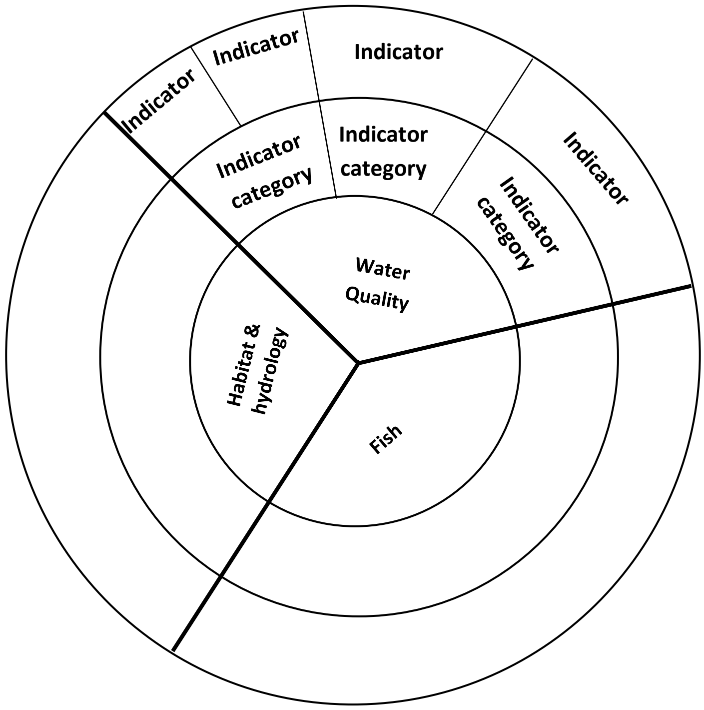


Figure 2. Terminology for defining the levels of aggregation for indicators of water quality, habitat and hydrology/habitat and fish and an example of how they are displayed in the Report Card.

2.2 Scoring categories

All indicators were scored using five ordinal values commonly used in Report Cards, very good (A) to very poor (E), as shown in Table 1.

Table 1. Standardised scoring range and corresponding grade for water quality, habitat and hydrology/habitat and fish 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 1.

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.

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

2.3 Confidence measure

The results for each index are given a qualitative confidence measure. Confidence scores are based on the accuracy and appropriateness of the data used in the analysis. Confidence scores range from 4.5 (very low, with a rating of 1) to 13.5 (very high, with a rating of 5) and were calculated using five criteria, which are listed in Table 2. The definitions for each criterion and more detailed methods for measuring confidence are presented in the Dry Tropics methods document (Whitehead, 2021).

Table 2. Criteria, the score for each criterion and the weighting used to generate the confidence score for indicator categories.

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

*Each criterion was firstly scored from 1 (lowest) to 3 (highest) following the set of rules discussed in the Dry Tropics methods document (Whitehead, 2021). This score was then weighted using the weightings shown in column three of Table 2. The weightings reflect the importance of each criterion.

2.4 Baselines for scoring data

Indicators were compared against either progress towards management targets, or earliest available data/earliest baseline.

Comparing against management targets or the earliest baseline was due to monitoring programs comparing against whichever was most appropriate to that program. 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 a ‘natural’ environment. This is important to ensure that the ‘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.

Whether each indicator category was scored against the management target or earliest baseline was shown in Table 3. Water quality indicators and indicators of freshwater and estuarine habitat extent were compared against management targets, whilst indicators of coral were scored against a mixture of management targets and earliest baseline. All other indicators were compared against the earliest available data.

Table 3. Summary of the baseline that indicator categories were scored against in the 2019-2020 Report Card.

Zone	Index	Indicator categories	Baseline that data was compared against
All zones (chlorophyll *a* only scored in the inshore and offshore marine zones)	Water	Nutrients and physical, chemical properties (phys-chem) and chlorophyll *a*	Management targets (water quality objectives for the Ross and Black Basins and Cleveland and Halifax Bay)
Freshwater and estuarine	Habitat and hydrology	Habitat extent	Management targets (change over four years for the Great Barrier Reef region)
Freshwater		Artificial barriers	Earliest data
Inshore marine		Seagrass condition	Earliest data
Inshore and offshore marine		Coral condition	Juvenile density and coral cover indicators were scored against management targets, composition and cover change indicators were scored against earliest data and macroalgae were scored against a hybrid of both.
Freshwater	Fish	Indigenous (native) species expected (POISE) within waterways (excluding translocated species)	Earliest baseline
		The proportion of Indigenous (native) fish	

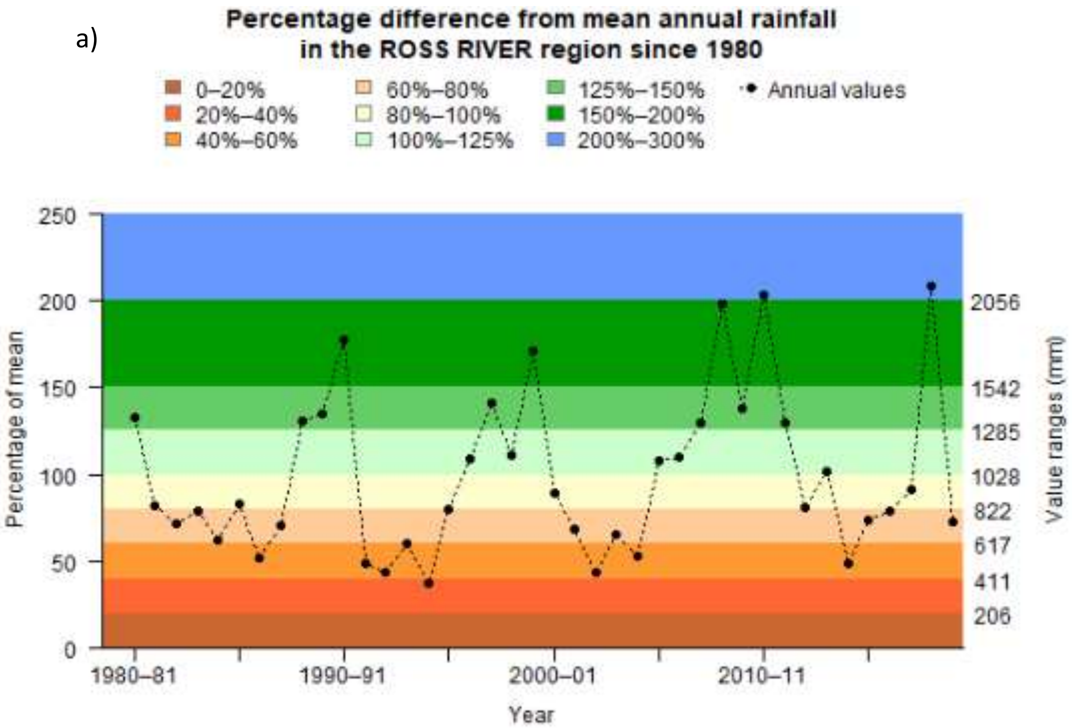
3 Climatic influences on the Townsville Dry Tropics region

Climate change and extreme weather, land use, urban lifestyles and economic growth are the key drivers that impact upon the condition of the waterways within the Townsville Dry Tropics region. A summary of the climatic conditions between 1st July 2019 and 30th June 2020 are outlined below. A description of the Townsville urban environment is also provided.

3.1 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 3a and Figure 3b, in the 2019-2020 financial year, the Ross and Black basins received 72% and 73% of the annual mean rainfall respectively (based on the long-term reference from July 1975) (Bureau of Meteorology, 2021). The lower than average rainfall was not isolated to the Townsville Dry Tropics, with the majority of Queensland receiving lower rainfall than the long-term mean (see Figure 4).

a)



b)

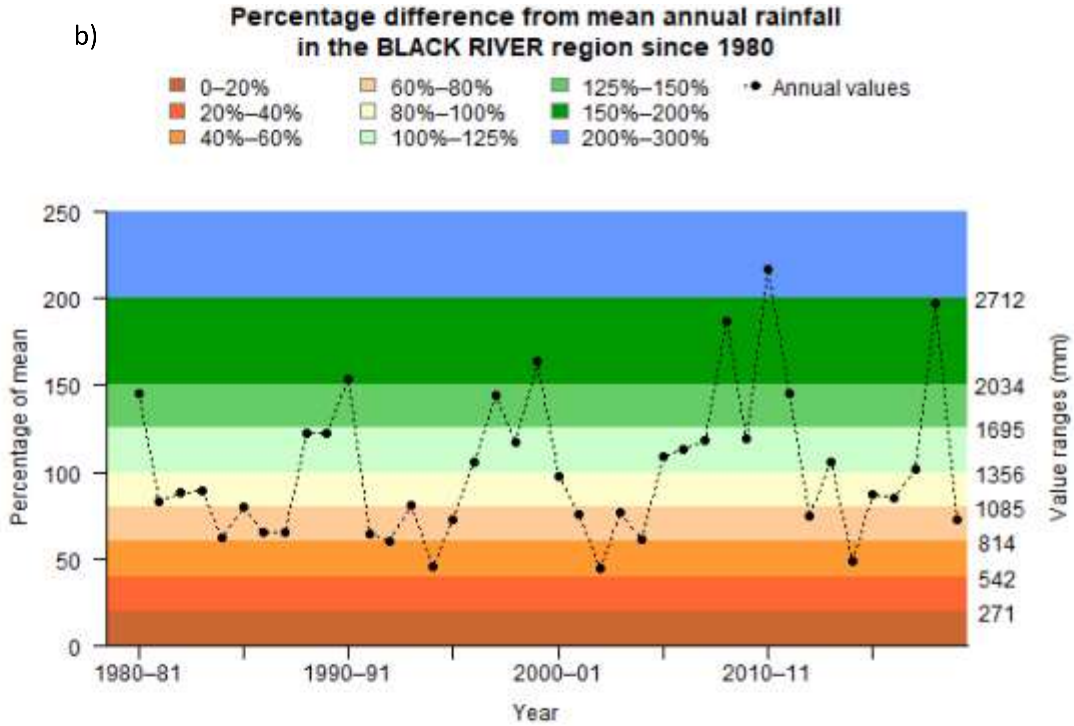


Figure 3. Percentage difference in the annual mean rainfall from 1980-81 until 2019-2020 for the (a) Ross Basin and (b) the Black Basin.

The long-term mean is represented as a "difference from mean rainfall" of 100% and was based upon historical rainfall records from July 1975 to 2021 supplied by the Bureau of Meteorology (2021).

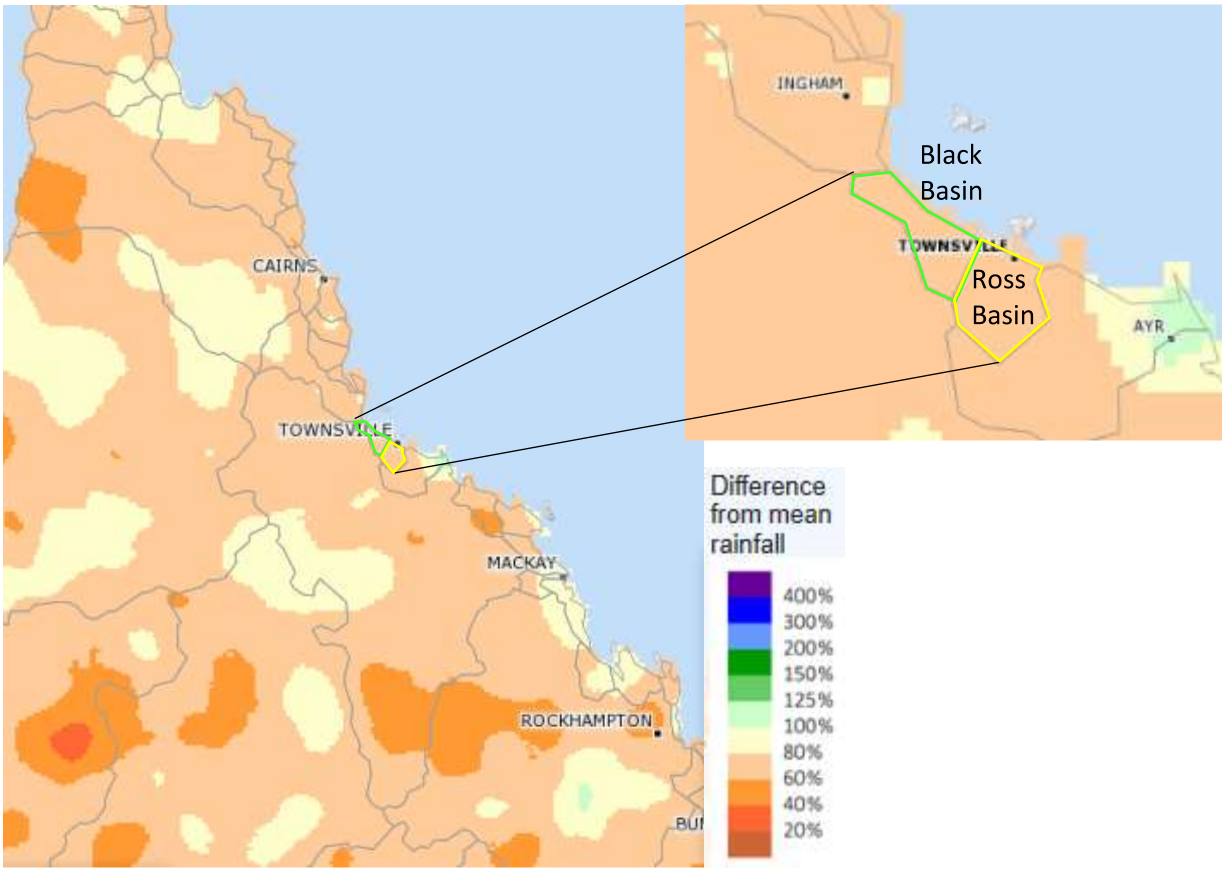


Figure 4. Percentage difference in the annual mean rainfall (1st July 2019 to 30th June 2020) from the long-term mean annual rainfall for the Townsville Dry Tropics, with the Ross and Black basin delineated by the yellow and light green lines, respectively.

The long-term mean is represented as a "difference from mean rainfall" of 100% and was based upon historical rainfall records from July 1975 to 2021 supplied by the Bureau of Meteorology (2021).

As shown in Table 4, in the Ross freshwater basin, a total of 743 mm of rain was recorded across the catchment, which was 285 mm below the long-term mean (1,028 mm) (Bureau of Meteorology, 2021). In the Black freshwater basin, an average of 988 mm of rain was recorded across the basin, which was 368 mm below the long term mean of 1,356 mm (Bureau of Meteorology, 2021).

Table 4. 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	743	1,028	2-3 below average	-285	72
Black	988	1,356	2-3 below average	-368	73

*Decile ranking category descriptions are shown in Figure 5 legend.
Source: BOM Regional Water Information (http://www.bom.gov.au/water/rwi/index.shtml#ra_pa/157/2020)

When assessing rainfall by months, there were only two months (May and July) that recorded above average rainfall for both basins (see Figure 5). The high rainfall in late May was due to a surface trough and moist onshore flow that brought heavy showers onto the north tropical Queensland coast (Bureau of Meterology, 2021). Lower than average rainfall was recorded for five months and notably, within the Black Basin, November and December were the driest ever recorded since 1911 (see Figure 5). For the rest of the year, rainfall was similar to the long-term average.

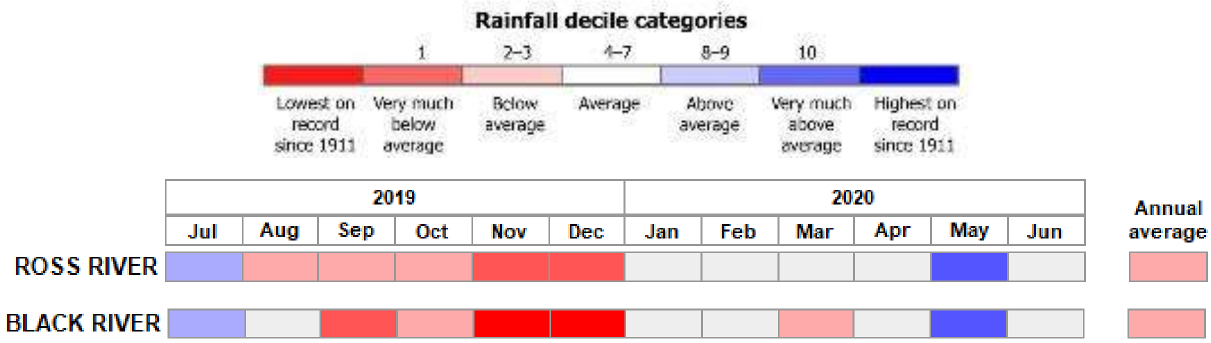


Figure 5. Monthly rainfall deciles and annual average deciles for the Ross and Black Basins from 1st July 2019 until 30th June 2020.

3.2 Air temperature

The 12-month mean temperature from 1st July 2019 until 30th June 2020 was above average throughout Queensland, with the Townsville Dry Tropics region experiencing temperatures that were classified as 'Very much above average' (Bureau of Meteorology, 2021). This classification means the 2019-2020 year was in the top 10% of years with the hottest mean temperature based on 111 years of data (Bureau of Meteorology, 2021).

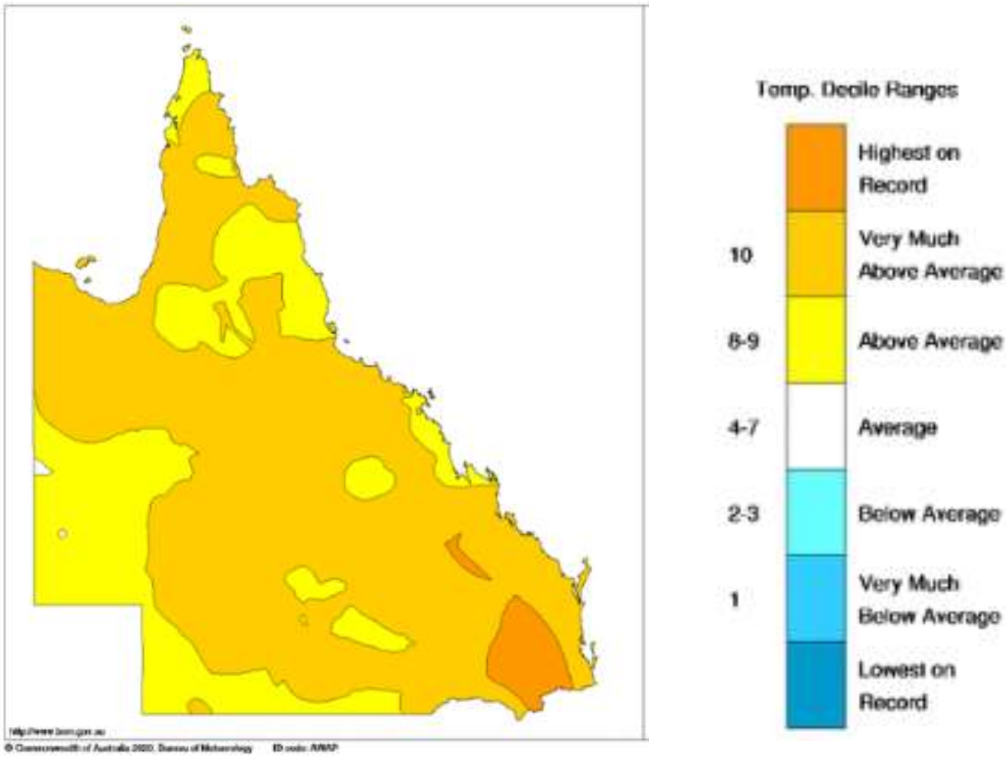


Figure 6. Twelve-monthly (1st July 2019 to 30th June 2020) mean temperature declines for Queensland.
Source: Bureau of Meteorology (2021)

3.3 Sea surface temperature

"Sea temperatures over the 2020 summer were above long-term averages. The highest deviations occurred in inshore areas south of Hinchinbrook Island" and in the northern Cape York , as shown in Figure 7 (Thompson, et al., 2021). The number of Degree Heating Weeks (DHW) weeks experienced along the Great Barrier Reef are shown in Figure 7. Degree Heating Weeks (DHW) are a measure of heat stress estimated as the period, in weeks, where the sea surface temperature was at least 1°C above the mean of the hottest month for that location. Two DHW could be either 2 weeks where sea surface temperatures were 2°C above the maximum monthly mean, or 1 week where temperatures were 3°C higher than the maximum monthly mean. Increased sea surface temperatures impact upon corals and eight DHWs "is a trigger for a level 2 alert under NOAA Coral Reef Watch (2018) and severe bleaching and significant mortality are likely" (Thompson, et al., 2021). The impacts of the heat stress on coral reefs are discussed more in section 7.2.1.2.

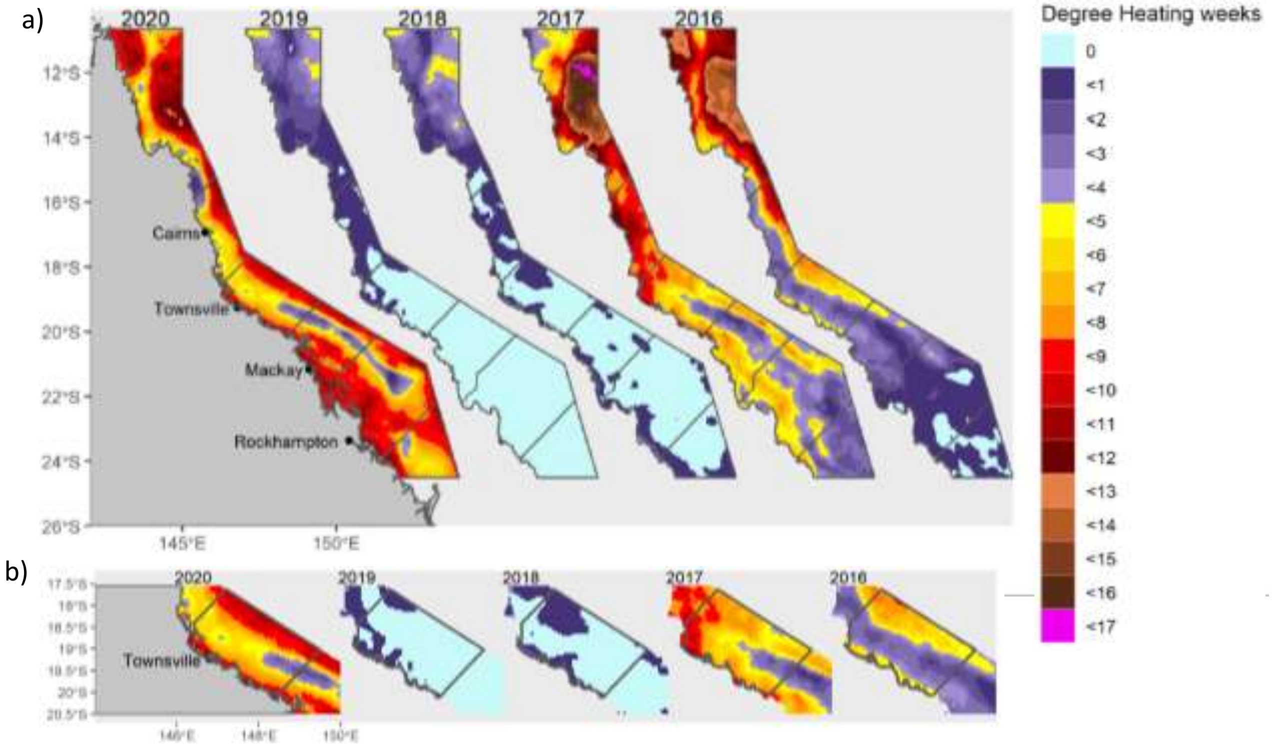


Figure 7. Annual degree heating week estimates for the Reef for a) Cape York to Rockhampton and b) the Townsville region.

Data are the annual maximum degree heating week estimates for each ~25 km2 pixel (Thompson, et al., 2021). Data were sourced from NOAA Coral Reef Watch Satellite and Information Service (2021).

"Sea surface temperatures (SSTs) on the Great Barrier Reef (GBR) during February 2020 were the warmest for any month since instrumental records began in 1900, with temperatures 1.2°C warmer than the long-term February average (1961–1990)" (Bureau of Meteorology (BOM), 2021a). A high-resolution example of above average sea temperatures for one day (18th February 2020) are shown in Figure 8. "For the northern tropics region, every month during 2020, except December, was amongst the five warmest on record and each month from January to April was the second-warmest on record for their respective month (Figure 9). For the Great Barrier Reef region, monthly averaged sea surface temperatures were the warmest on record for February and second-warmest on record for March"

(BOM, 2021b). March and July experienced temperatures between 0.6°C and 1°C warmer than the average (Figure 9) (BOM, 2021). “Temperatures were elevated across the whole reef and there were reports of widespread coral bleaching. This event is the third marine heatwave in five years, coming soon after the consecutive events of 2015–16 and 2016–17. There have now been three mass coral bleaching events on the GBR in the past five years” (BOM, 2021). Three main factors led to the high ocean temperatures on the Reef, which were:

- climate change, resulting in an increase in temperatures.
- a very strong positive Indian Ocean Dipole, which delayed the onset of the Australian monsoon and there was a northward shift in weather systems over Australia in early to mid-summer.
- local weather patterns. There was also less cloud than usual of the GBR during the 2019-2020 summer (BOM, 2021).

“The delayed onset of the Australian monsoon plus reduced cloud cover and weakened winds resulted in clear skies and calm conditions over the reef allowed more hours of sunlight to heat surface waters and less mixing by waves of warmer surface waters with cooler waters beneath” (BOM, 2021).

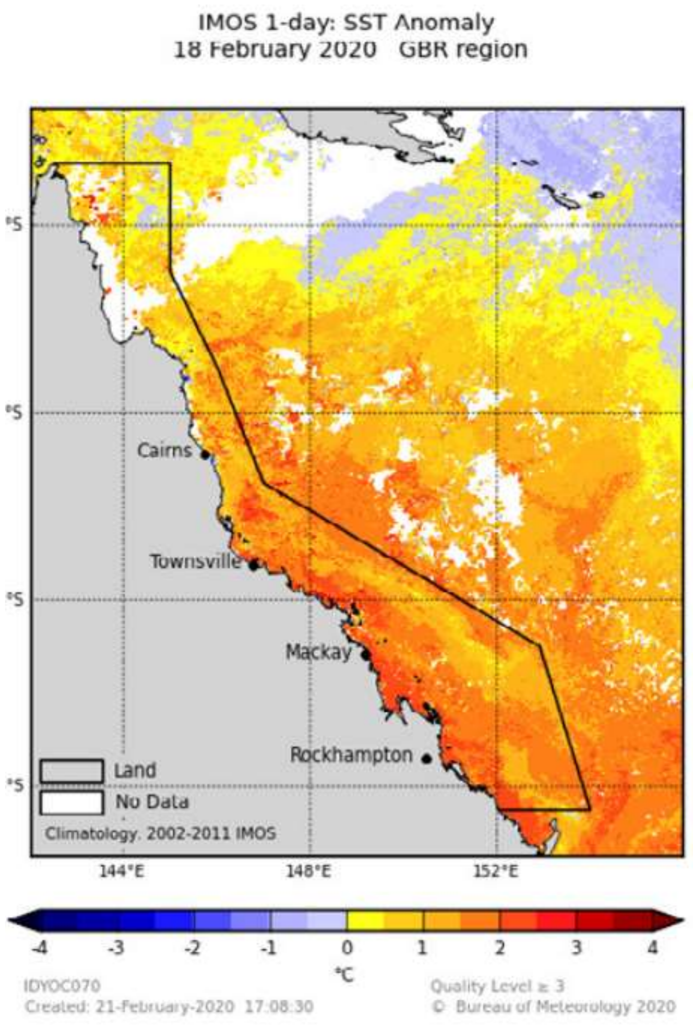


Figure 8. Sea surface temperature anomalies (deviation from the long term mean for the period 2002–2011) for 18 February 2020 showing heat distributed across the whole reef.
The solid black line denotes the boundary of the Great Barrier Reef Marine Park. The map was produced using ReefTemp Next Generation (high resolution mapping products). Source: BOM, 2021a

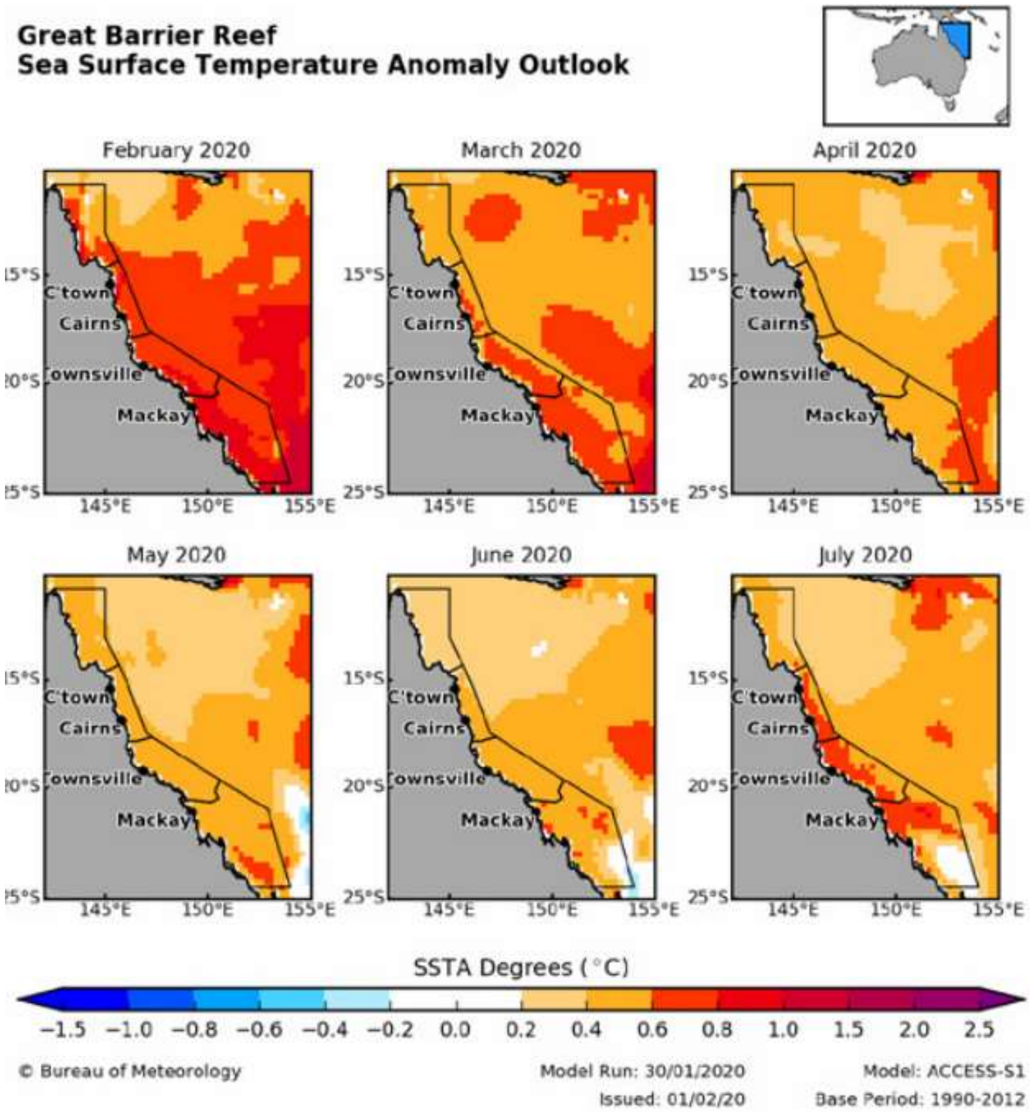


Figure 9. Seasonal sea surface temperature anomaly (deviation from normal) outlook for February-July 2020. Orange-red colours show temperatures warmer than the mean for that month over the period 1990-2012. The outlook was issued on 1 February 2020.
Source: BOM, 2021a

Key messages for climate:

- Both the Ross and Black basins experienced lower than average rainfall.
- The region recorded very high air temperatures and was in the top 10% of years with the hottest mean temperature.
- Sea surface temperatures on the Great Barrier Reef during February 2020 were the hottest of any month ever recorded (since 1900).
- Hot sea surface temperatures resulted in a third marine heatwave in five years, resulting in widespread coral bleaching.

3.4 Urban environment

The Townsville Dry Tropics region is the largest city in regional Queensland, with residential and services being substantial land uses within the region (see Figure 10). Urban development is a major driver of environmental change, with new residential developments occurring in outer suburbs of Townsville and existing developments continuing to expand. The conversion or degradation of natural ecosystems in urban areas has immediate impacts upon biodiversity (Department of Agriculture, Water and the Environment, 2016). Additionally, urban development impacts water quality and changes the flow of water (McGrane, 2016). This often results in a high proportion of the catchment containing impervious surfaces, the construction of artificial barriers and changes to watercourses, all of which can detrimentally impact water quality and the natural flow of water (McGrane, 2016).

Within the Townsville Dry Tropics, the Ross Basin is more developed than the Black Basin, although most developments within the Ross Basin are restricted to the lower half of the catchment. The upper catchment is predominately used for grazing on native vegetation, with nature conservation and production forestry the next largest land uses within the upper catchment. The Ross Basin also contains four major impoundments: Ross River Dam and three weirs, Black School weir (referred to as Black weir), Gleeson weir and Aplin’s weir. These impoundments have a large impact upon the water flow within the Ross River. During the wet season, heavy rainfall can result in flow overtopping the impoundments, providing connectivity from the headwaters to the coast. During most of the dry season, surface waters within the weirs and Ross Dam are generally separate water bodies.

A large proportion of the Black Basin is grazing on native vegetation, especially within the eastern half of the basin. Nature conservation is the second largest land use within the Black Basin, with less amounts of production forestry and a minor amount of intensive horticulture (e.g. pineapple farming). Although residential land use is not currently a major land use within the basin, many new residential developments are occurring within the Black Basin, with developments since 2017 not shown in Figure 10.

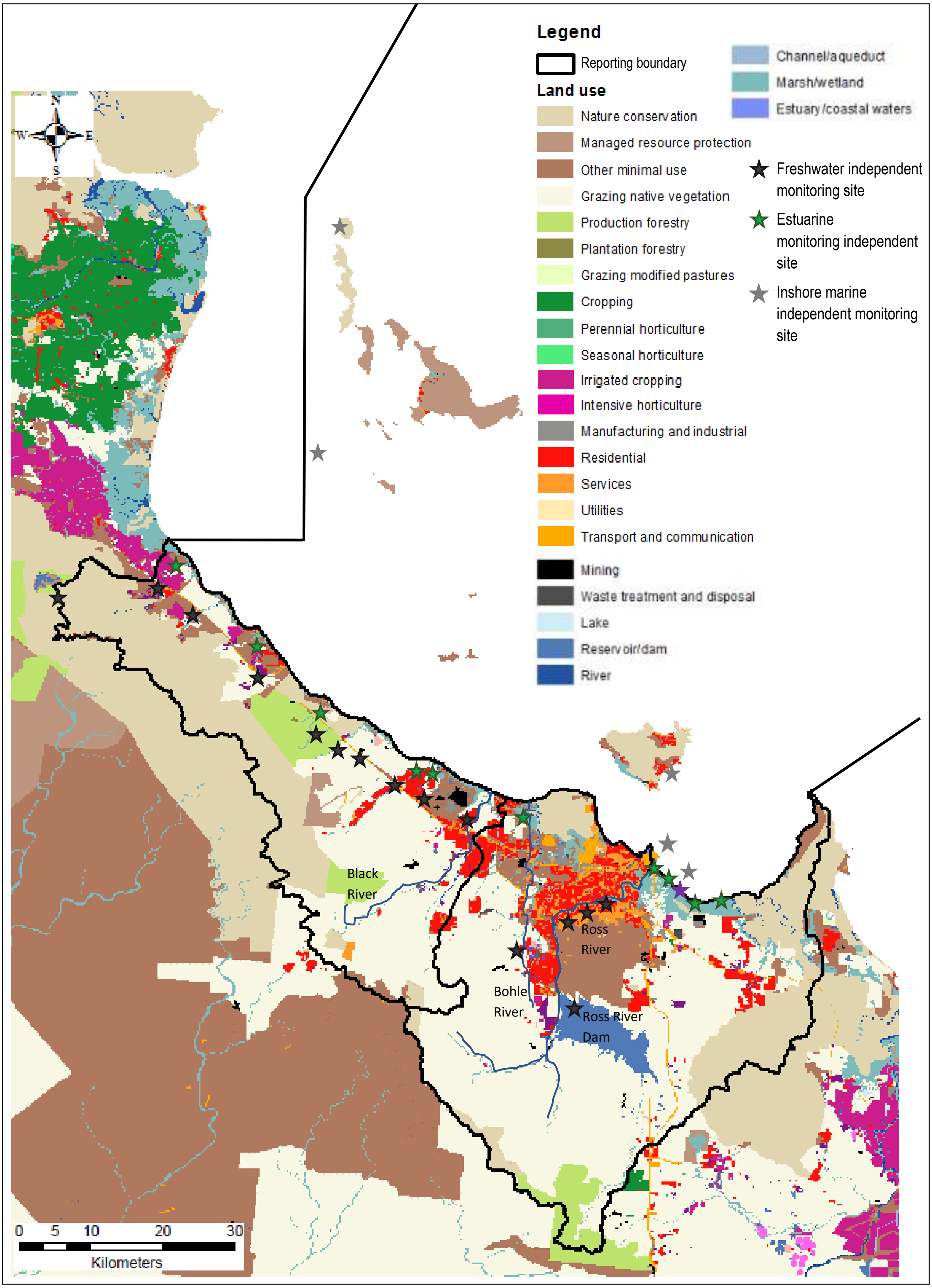


Figure 10. Location of monitoring sites in relation to the main rivers and land use in the Townsville Dry Tropics region.

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

4 Freshwater basins

Within the freshwater basins, water quality, habitat and hydrology and fish are the three indices scored, with the results presented in separate sections below.

4.1 Water quality

4.1.1 Monitoring sites

Monitoring occurred at five independent sites within the Ross freshwater basin and 10 independent sites within the Black freshwater basin.

The freshwater monitoring sites within the Ross freshwater basin are:

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

The position of monitoring sites within the Ross freshwater basin are shown in Figure 11.

Monitoring occurs at 10 independent sites within the Black freshwater basin. These sites are listed below:

- Black River
- Althaus Creek
- Bluewater Creek
- Sleeper Log Creek
- Leichhardt 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 12.

Grab samples were taken once a month at all sites within the Ross Basin. Within the Black Basin, between three and eight monthly samples were taken between 2019 and February 2020. The number of months each site was sampled is shown in Appendix B. No sampling occurred between March and June 2020 due to the travel restrictions associated with Covid-19.

Figure 11. Independent and non-independent sites within the Ross freshwater zone, showing (1) the mid and far-field non-independent sites 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).

These includes (1) the mid and far-field non-independent sites 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 orange outline in the central image delineates the Ross freshwater basin, with the yellow outline delineating the Ross estuarine zone. Satellite images from 04/05/2020

Figure 12. Freshwater independently monitoring sites (blue dots) within Black freshwater basin.
The green line delineates the Black freshwater reporting zone, whilst the blue outline delineates the Black estuarine reporting zone. Satellite image taken on the 14/12/2020.

4.1.2 Results

The overall score for freshwater water quality was based on five indicators and two indicator categories, which are nutrients and physical and chemical (phys-chem) properties. Independent 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). Scores were then aggregated based on the weighted scores. The distributions of data for each indicator are presented as boxplots in Appendix A. The values used to calculate the scores are presented in Appendix B. The parameters used to calculate the scores were the:

- Water quality objectives (WQOs) (which the values that the raw data are compared against),
- Scaling factors (used to scale the scores),
- Annual medians, derived from the monthly medians, and
- 80th percentile of the monthly medians (or 20th percentile for lower dissolved oxygen).

4.1.2.1 *Nutrients*

The scores for nutrients were averaged from the scores for two indicator categories, which are total phosphorus (TP) and dissolved inorganic nitrogen (DIN). The scores for the Ross freshwater basin are shown in Table 5.

Table 5. Scores and grades for total phosphorus (TP), dissolved inorganic nitrogen (DIN) and nutrients for freshwater sites.

The scores for nutrients are the average of the scores for DIN and TP. Non-weighted scores for each site are weighted based on the proportion of measured catchment area. The weighted scores are summed for the overall score for each basin. The significant figures differ where appropriate to show very small numbers.

	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)	68	61	65	B	B	B	458	0.32	21.9	19.5	20.7			
Lower Ross River	66	70	68	B	B	B	786	0.56	37.1	39	38.1			
Black Weir	59	70	64	C	B	B								
Gleeson Weir	74	ND	74	B	ND	B								
Aplin's Weir	66	ND	66	B	ND	B								
Bohle River	15	0	7	E	E	E	169	0.12	1.7	0	0.9			
Bohle far-field	29	0	15	D	E	E								
Bohle mid-field	0	0	0	E	E	E								
Ross freshwater basin	**49**	**33**	**47**	**C**	**D**	**C**	**1413**	**1**	**62**	**60**	**60**	**B**	**C**	**C**
Black River	78	9	44	B	E	C	250	0.37	28.7	25.2	26.9			
Althaus Creek	74	90	82	B	A	A	35	0.05	3.7	4.5	4.1			
Bluewater Creek	90	66	78	A	B	B	86	0.13	11.7	8.6	10.2			
Sleeper Log Creek	62	90	76	B	A	B	41	0.06	3.7	5.4	4.6			
Leichhardt Creek	90	55	72	A	C	B	38	0.06	5.4	3.3	4.3			
Saltwater Creek	90	90	90	A	A	A	36	0.05	4.5	4.5	4.5			
Rollingstone Creek	64	90	77	B	A	B	71	0.10	6.4	9	7.7			
Ollera Creek	63	90	76	B	A	B	39	0.06	3.8	5.4	4.6			
Crystal Creek	90	90	90	A	A	A	77	0.11	9.9	9.9	9.9			
Paluma Dam	90	90	90	A	A	A	2	0.00	0	0	0			
Black freshwater basin	**79**	**76**	**78**	**B**	**B**	**B**	**675**	**1**	**79**	**55**	**67**	**B**	**C**	**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 to 90 (scores are capped at 90) | ■ No data (ND)

The site names for independent sites are written black, whilst non-independent sites are written in brown. Scores for non-independent sites are averaged to create an overall score for an independent site.

The Ross freshwater basin was in a moderate condition with respect to nutrient concentrations, as shown in Table 5. It is noted that the score was on the boundary between moderate and good. Both the Upper Ross River (Ross River Dam) and the Lower Ross River were in a good condition. The Bohle River was in a very poor condition and contained high total phosphorus (TP) and dissolved inorganic nitrogen (DIN) concentrations in relation to the water quality objectives. The Condon Sewage Treatment plant discharges into the Bohle River and this may account for the poor scores for Bohle River. The Bohle River has a low weighting compared to the Upper and Lower Ross River, as the Bohle River only represents 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, with nine of ten rivers sampled in a good or very good condition with respect to nutrients (Table 5). Eight rivers were in a very good or good condition for both DIN and TP, except for the Black River and Leichhardt Creek, which had very poor and moderate results for TP, respectively.

Key messages: Nutrients

- Overall, the Ross freshwater basin was in a moderate condition with respect to nutrients, although condition between individual sites varied considerably.
- Concentrations of nutrients within the Ross River Dam were low compared to the water quality objective (WQO), which equated to a good score for nutrients.
- The Bohle River was in a very poor condition with respect to nutrients, due to high concentrations of both DIN and TP in relation to the WQOs.
- Overall, the Black freshwater basin was in a good condition, with nine of 10 rivers sampled in a good or very good condition with respect to nutrients.
- The Black River had high concentrations of total phosphorus in relation to the WQO.

4.1.2.2 *Physical-chemical properties*

The results for the phys-chem index were derived by averaging the scores of turbidity and dissolved oxygen (DO), with the results presented in Table 6. Both the Ross and Black freshwater basins were in a good condition with respect to phys-chem properties, with all rivers sampled being in a moderate to very good condition overall. Turbidity at all sites (within both basins) received a good or very good grade and all sites, except Black River and Althaus Creek, received very good grades for upper DO concentrations. Lower DO received the lowest score of the three indicators, with the Bohle River, Bluewater and Ollera Creek scoring very poorly for lower DO in relation to the WQO. The low dissolved oxygen levels are likely caused by the ephemeral nature of the watercourses, with many creeks and rivers having very low water levels during the dry season. Very low water levels generally have low dissolved oxygen levels.

Table 6. Scores and grades for turbidity, lower dissolved oxygen (DO), upper DO and the overall physical-chemical (phys-chem) properties for freshwater sites.
The scores for phys-chem properties are the average of turbidity and the lower score of either upper or lower dissolved oxygen. Non-weighted scores for each site are weighted based on the proportion of measured catchment area. The weighted scores are summed for the overall score for each basin. Significant figures differ for ease of presentation.

	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 properties**	Turb-idity	Upper DO	Lower DO	**Phys-chem properties**			Turb-idity	Upper DO	Lower DO	Phys-chem properties	Turb-idity	Upper DO	Lower DO	Phys-chem properties
Upper Ross River (Ross River Dam)	90	90	90	90	A	A	A	A	458	0.32	28.8	28.8	28.8	28.8				
Lower Ross River	90	90	73	82	A	A	B	A	786	0.56	50.4	50.4	40.8	45.6				
Black Weir	90	90	56	73	A	A	C	B										
Gleeson Weir	90	90	73	82	A	A	B	A										
Aplin's Weir	90	90	90	90	A	A	A	A										
Bohle River	90	90	0	45	A	A	E	C	169	0.12	10.8	10.8	0	5.4				
Bohle far-field	90	90	0	45	A	A	E	C										
Bohle mid-field	90	90	0	45	A	A	E	C										
Ross freshwater basin	**90**	**90**	**51**	**72**	**A**	**A**	**C**	**B**	**1413**	**1**	**90**	**90**	**71**	**80**	**A**	**A**	**B**	**B**
Black River	90	62	90	76	A	B	A	B	250	0.37	33.3	22.9	33.3	28.1				
Althaus Creek	90	4	80	47	A	E	B	C	35	0.05	4.5	0.2	4	2.4				
Bluewater Creek	90	90	11	51	A	A	E	C	86	0.13	11.7	11.7	1.5	6.6				
Sleeper Log Creek	70	90	32	51	B	A	D	C	41	0.06	4.2	5.4	1.9	3.1				
Leichhardt Creek	90	90	27	59	A	A	D	C	38	0.06	5.4	5.4	1.6	3.5				
Saltwater Creek	90	90	90	90	A	A	A	A	36	0.05	4.5	4.5	4.5	4.5				
Rollingstone Creek	90	90	51	71	A	A	C	B	71	0.10	9	9	5.1	7.1				
Ollera Creek	90	90	0	45	A	A	E	C	39	0.06	5.4	5.4	0	2.7				
Crystal Creek	90	90	75	83	A	A	B	A	77	0.11	9.9	9.9	8.2	9.1				
Paluma Dam	90	90	69	80	A	A	B	A	2	0.00	0	0	0	0				
Black freshwater basin	**88**	**79**	**53**	**65**	**A**	**B**	**C**	**B**	**675**	**1**	**89**	**75**	**61**	**67**	**A**	**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 to 90 (scores are capped at 90)
The site names for independent sites are written black, whilst non-independent sites are written in brown. Scores for non-independent sites are averaged to create an overall score for an independent site.

Key messages: Physical-chemical properties

- Overall, the Ross and Black freshwater basins were in a good condition with respect to phys-chem properties (average of turbidity and dissolved oxygen (DO)).
- Concentrations of turbidity and upper DO were graded as good or very good for 17 of the 18 rivers sampled.
- Lower DO concentrations were graded as poor or very poor in seven of the 18 sites sampled, with Bohle River, Bluewater Creek and Ollera Creek having very poor lower DO concentrations in relation to the water quality objectives. This is least partly likely due to natural variation and the hydrology of the system, rather than necessarily anthropogenic influence. For example, many rivers and creeks within the Townsville Dry Tropics are ephemeral and as they become shallower during the dry season, the dissolved oxygen within the river declines. The method to score dissolve oxygen does not take into consideration the natural ephemeral nature of watercourses within the Dry Tropics, which causes the indicator to receive a poor or very poor score.

4.1.2.3 *Overall water quality*

As shown in Table 7, water quality was in a good condition for both the Ross and Black freshwater basins. The Bohle River was the only river which had poor water quality overall, with all other rivers having good to very good water quality (Table 7).

Table 7. Overall water quality scores and grades for freshwater sites.

The overall scores for water quality were averaged from the scores for nutrients and physical-chemical (phys-chem) properties. Significant figures differ for ease of presentation.

	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	Nutr-ients	Phys-chem	Water quality
Upper Ross River (Ross River Dam)	65	90	78	B	A	B						
Lower Ross River	68	82	75	B	A	B						
Black Weir	64	73	69	B	B	B						
Gleeson Weir	74	82	78	B	A	B						
Aplin's Weir	66	90	78	B	A	B						
Bohle River	7	45	26	E	C	D						
Bohle far-field	15	45	30	E	C	D						
Bohle mid-field	0	45	23	E	C	D						
Ross freshwater basin	**47**	**72**	**59**	**C**	**B**	**C**	**60**	**80**	**70**	**C**	**B**	**B**
Black River	44	76	60	B	B	B						
Althaus Creek	82	47	65	A	C	C						
Bluewater Creek	78	51	65	B	B	C						
Sleeper Log Creek	76	51	64	B	B	C						
Leichhardt Creek	72	59	66	B	B	C						
Saltwater Creek	90	90	90	A	A	A						
Rollingstone Creek	77	71	74	B	B	B						
Ollera Creek	76	45	61	B	C	B						
Crystal Creek	90	83	87	A	A	A						
Paluma Dam	90	80	85	A	A	A						
Black freshwater basin	**78**	**65**	**71**	**B**	**B**	**B**	**67**	**67**	**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 to 90 (scores are capped at 90)

The site names for independent sites are written black, whilst non-independent sites are written in brown. Scores for non-independent sites are averaged to create an overall score for an independent site.

4.1.2.4 *Confidence scores*

There was low confidence in the water quality scores for the Ross freshwater basin. This was due to limited spatial sampling in the basin, with only three rivers sampled. There was a moderate confidence in the water quality scores for the Black freshwater basins, with most major rivers (10 rivers) monitored. The confidence score within the Black Basin improved from the low confidence in 2018-19 to a moderate confidence. This was because as sampling occurred at each site between three and eight times in 2019-2020, compared to only three times in 2018-19. This increased the representativeness category from a 1 last year to 1.5 this year and thus increased the overall score. The score for each criterion is shown in Table 8.

Table 8. Confidence scores for nutrients, physical-chemical (phys-chem) properties and the overall water quality index (average of nutrients and phys-chem scores) 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).

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 freshwater 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)**
Black freshwater zone	Nutrients	2	3	1.5	3	1	8.6	Moderate (3)
	Phys-chem	2	3	1.5	3	1	8.6	Moderate (3)
	Water quality index						**8.6**	**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.

4.1.2.5 *Comparing scores for water quality between years*

The results for 2019-2020 and 2018-19 are shown in Table 9, with the site specific results for the two years shown in Appendix C. The results from the 2017-18 Pilot Report Card were not included in the comparison because those scores were generated using a different method and fewer sites were sampled, meaning the results were not comparable.

Table 9. Comparison of freshwater water quality scores between 2018-19 and 2019-2020.

	2019-2020 results (current year)			2018-19 results (last year)		
Zone	Nutrients	Physical-chemical properties	Overall water quality	Nutrients	Physical-chemical properties	Overall water quality
Ross freshwater basin	60 B	80 B	70 B	66 B	68 B	66 B
Black freshwater basin	67 B	67 B	67 B	52 C	71 B	62 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 to 100

There is inherent natural variation in river systems due to climatic events, such as changes in rainfall. The natural variation combined with the limited spatial and temporal sampling, especially within the Ross Basin, means that any reliable trends cannot be deduced until there is more data. However, differences in scores are still noted for interest. In 2019-2020, phys-chem properties in the Ross freshwater basin, and nutrients in the Black freshwater basin scored higher than in 2018-19. More data are required before accurate trends and potential reasons for trends can be reported on.

4.2 Habitat and hydrology results

Within the freshwater basin, habitat and artificial barriers were the two indicator categories scored within the habitat and hydrology index. The results for each index are presented in three separate sections. The results for habitat and artificial barriers are the same as presented in the 2018-19 report card, as the results are only updated when new data are available (usually every four years). In previous report cards, this index was referred to as biodiversity, but the name has been changed for the 2019-2020 technical report so the terminology is the same as the other regional report cards.

4.2.1 Habitat

Riparian and palustrine wetland extent were the two indicators measured within the freshwater zone for the habitat index. Data were prepared by the Queensland Herbarium, using data obtained through Google Earth and the Queensland Herbarium's Regional Ecosystem mapping (version 5 for wetland extent and version 11 for riparian) (Neldner, et al., 2017). Scores were based on the four yearly change in habitat extent between 2014 and 2017, with change compared against management targets. The scores for riparian and wetland extent were aggregated to produce an overall score for the habitat index.

4.2.1.1 *Wetland and riparian extent results*

Overall, there was moderate progress towards habitat targets within both the Ross and Black freshwater basins, as shown in Table 10.

Table 10. Scores and grades for riparian extent, wetland extent and the habitat index for the Ross and Black freshwater basins.

The percent (%) of habitat lost and habitat remaining was based on 2013 to 2017 levels and 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 (A) = 81 to 100

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

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. 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 for progressing towards the management target of no loss. However, the method for measuring riparian extent likely underestimates the amount of habitat lost, resulting in better scores than actual (A. Healy, pers. comm., 3rd February 2021). A more accurate method to estimate habitat extent is currently being developed, with updated results to be included in the 2020-21 Report Card.

Key messages: Wetland and riparian extent

- There was a 0.15% and 0.22% loss of wetland extent and a 0.45% and 0.20% loss of riparian habitat from the Ross and Black freshwater basins respectively, equating to moderate progress towards the management target of no loss.
- The method for measuring riparian extent likely underestimates the amount of habitat lost, likely resulting in a better score than actual.

4.2.1.2 *Confidence scores for habitat*

There was a very low confidence in the results for riparian and wetland extent, with the overall rank and the scores for each confidence criterion presented in Table 11. The representativeness was very low, due to the current method to estimate habitat extent likely underestimating the amount of habitat lost. A new, more accurate method has been devised and will be used to assess habitat extent for the 2020-21 Report Card.

Table 11. Confidence scores for riparian extent, wetland extent and the overall habitat extent (average of riparian and wetland extent scores) 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)	Represent-ativeness (2)	Directness (0.71)	Measured error (0.71)	Final score	Rank
Riparian extent	2	2	1	2	1	6.27	Very low (1)
Wetland extent	2	2	1	2	1	6.27	Very low (1)
Habitat extent						**6.27**	**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.

4.2.2 Artificial barriers

The artificial barriers indicator category is comprised of two indicators, which are impoundment length and fish barriers. Both indicators were only scored against the earliest baseline of no barriers. Artificial in-stream barriers, such as weirs and dams, are generally built for flood mitigation and to store water for later use (Department of Environment, Land, Water and Planning, n.d.). However these barriers often have a profound impact upon stream ecology and connectivity (Faulks, et al., 2011).

4.2.2.1 *Impoundment length*

Impoundment length describes how much "natural" channel habitat remains within a waterway. Impoundment length was calculated as the linear length of the stream that is impounded proportional to the total linear length of the watercourse. 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.). Scores were based on 2019 data, as data are only updated every four years. Thus, the scores are the same as the 2018-19 Report Card.

Impoundment length was assessed within watercourses that were classified as major or high importance for fish movement and fish species communities. The Ross freshwater basin received a poor score, with 8.1% of watercourses impounded (see Table 12). This poor score was due to the presence of the Ross River Dam and the three weirs (Black, Gleeson 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 12).

Table 12. Scores and grades associated with impoundment length 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**

Impoundment (% total): ■ Very Poor = ≥10% | ■ Poor = 7 to <10% | ■ Moderate = 4 to <7% | ■ Good = <4 to 1% | ■ Very Good <1%.

Standardised 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 to 100

Key messages: Impoundment length

- Within the Ross freshwater basin, 8.1% of watercourses was impounded due to the presence of three weirs and the Ross River Dam.
- No watercourses within the Black freshwater basin were impounded.

4.2.2.2 *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. Fish barriers were identified based on a 2018-19 desktop analysis of spatial imaging in Google Earth Pro and ArcGIS (Google Earth). Barriers were classified as either passable (a physical barrier that does not prevent fish movement) or impassable (a physical barrier that prevents fish movement from upstream and downstream). The scores, shown in Table 13, are the same as the 2018-19 Report Card, as results are only updated every four years.

Table 13. 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 1) barrier density (average km of watercourse length per barrier), 2) percent (%) of stream length to first barrier, and 3) percent (%) of stream length to first impassable barrier. Numbers are shown to one decimal place for ease of reading, with significant figures differing.

		Raw data used to generate scores for indicators						Raw data for each indicator			Standardised score	Standardised grade
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)	Barrier density	% stream length to first barrier	% stream length to impassable barrier	Fish barriers index	
Ross freshwater basin	Ross River	263.6	4.0	0.0	4.0	1.0	1.0	65.9	0.4	0.4	40	D
	Bohle River	51.1	2.0	2.0	0.0	7.2	51.1	25.5	14.1	100	61	B
	Stuart Creek	17.5	5.0	5.0	0.0	11.9	17.5	3.5	68.2	100	60	C
	Alligator Creek	13.7	1.0	1.0	0.0	0.7	13.7	13.7	5.2	100	60	C
	Whites Creek	11.1	0.0	0.0	0.0	11.1	11.1	No barriers	100	100	100	A
	Ross freshwater basin	**71.4**	**2.4**	**1.6**	**0.8**	**6.4**	**18.9**	**27.2**	**37.6**	**80.1**	**65**	**B**
Black freshwater basin	Black River	**92.0**	**0.0**	**0.0**	**0.0**	**0.0**	**92.0**	**No barriers**	**No barriers**	**No barriers**	**100**	**A**

Barrier density (km): ■ Very Poor = 0 to 2km | ■ Poor = >2 to 4km | ■ Moderate = >4 to 8km | ■ Good = >8 to 16km | ■ Very Good >16km.

Percent stream length to first barrier: ■ Very Poor = 0 to <40% | ■ Poor = 40 to <60% | ■ Moderate = 60 to <80% | ■ Good = 80 to <100% | ■ Very Good 100%

Percent stream length to impassable barrier: ■ Very Poor = 0 to 60% | ■ Poor = >60 to 80% | ■ Moderate = >80 to 90% | ■ Good = >90 to <100% | ■ Very Good 100%

Standardised 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 to 100

Within the Ross freshwater basin, there were 12 barriers along the five measured watercourses. The only impassable barriers were the three weirs and the Ross River Dam wall, all of which are along the Ross River. Overall, the Ross freshwater basin received a good grade for the fish barriers indicator category. The poor grade for the Ross River was offset by the very good grade for Whites Creek (see Table 13). It is noted that Whites Creek is smaller than the Ross River and therefore averaging the two results may not be the best approach.

No barriers were present along Black River, with the river receiving a very good score (see Table 13). The Black River was the only watercourse assessed within the Black freshwater basin.

Key messages: Fish barriers

- Overall, the Ross freshwater basin received a good grade with respect to fish barriers.
- There were 12 barriers along the five watercourses within the Ross freshwater basin. Only four of these prevented fish movement, which were the three weirs along the Ross River and the Ross River Dam.
- No barriers were present along Black River, with the site receiving a very good score for fish barriers.

4.2.2.3 *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 14).

Table 14. 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 (A) = 81 to 100

4.2.2.4 *Confidence scores for artificial barriers*

The score for impoundment length, shown in Table 15, 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, as it is unlikely that all potential barriers were identified (representativeness), ground truthing of barriers was unknown (validation) and 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 15. Confidence scores for impoundment length, fish barriers and the overall score for artificial barriers (average of impoundment length and fish barriers scores) 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.

4.2.3 Overall habitat and hydrology score

Overall, the Ross freshwater basin received a moderate grade for the habitat and hydrology index, whilst the Black freshwater basin as rated as good (see Table 16).

Table 16. Overall score and grades for the Habitat and hydrology reporting component within the freshwater basins.

	Scores			Grades		
Basin	Habitat index	Artificial barriers index	**Habitat and hydrology**	Habitat index	Artificial barriers index	**Habitat and hydrology**
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 (A) = 81 to 100

4.2.4 Confidence scores for habitat and hydrology

There was a moderate confidence in the overall scores for the habitat and hydrology index (Table 17).

Table 17. Confidence scores for the habitat and hydrology index (average of artificial barriers and habitat extent scores) for both the Ross and Black freshwater basins.
Scores are rounded to one decimal place. 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	6.3	Very low (1)
Habitat and hydrology	**7.1**	**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.

5 Fish

The fish index is a new index and has not been scored in previous report cards. Within the fish index, fish was the only indicator category measured. In the future, if other fauna species are reported upon, the index will be named Biota and fish will be included under the Biota index.

The assessment of freshwater fish communities is based on two indicator categories, which are the proportion of indigenous (native) species expected within waterways (excluding translocated species) and the proportion of non-indigenous fish. The proportion of non-indigenous fish comprises two indicators, which are the proportion of translocated (native) fish and the proportion of alien (non-native) fish. The fish index is designed to provide a basic description of how similar regional fish communities are to their natural state (before human impacts). Condition ratings are based on the median across a basin, with the median calculated from the multiple sites sampled within each basin. Generally fish were only monitored at one location per site. Whilst the electrofishing methods used are highly effective, not all species present at every site are captured during monitoring. The condition ratings take this into account.

5.1 Monitoring sites

Fish were surveyed at 11 monitoring sites across nine different creeks (one creek was sampled at three locations) within the Ross freshwater basin. Within the Black freshwater basin, 11 monitoring locations were sampled across 13 different sites. Fish were sampled using backpack electrofishing over a five day period in late August 2019. The sampling sites are shown in Figure 13.

Figure 13. Location of fish sampling sites within the Ross (purple dots) and Black freshwater basins (yellow dots).

The main rivers and creeks are delineated in dark blue, whilst the boundary for the Ross and Black basins are shown in aqua and red, respectively. The purple line is the boundary between Cleveland and Halifax Bays. Satellite image taken on the 14/12/2015.

5.2 Results

Thirty-three species were caught during sampling across the Townsville Dry Tropics region, with 26 and 23 species recorded in the Ross and Black freshwater basins, respectively. The species present within the Ross and Black freshwater basins area shown in Table 18 and Table 19, respectively.

Table 18. Fish species present within waterways within the Ross freshwater basin.
The alien species are highlighted in blue, whilst the translocated species are highlighted in pink. The species that were present for each river are highlighted in cream.

Site	Northern perchlet	Barred grunter	Long-finned eel	Roman-nose goby	Fly-specked hardyhead	Gambusia	Mouth almighty	Empire gudgeon	Northern carp gudgeon (undescribed)	Jungle perch	Barramundi	Spangled perch	Indo-Pacific tarpon	Eastern rainbowfish	Southern purple-spotted gudgeon	Bony bream	Butter jew	Hyrtl's tandan	Swamp eel	Mozambique tilapia	Sleepy cod	Greenback mullet	Guppy	Rendahl's tandan	Speckled goby	Seven-spot archerfish
Little Bohle River	1	0	1	0	0	1	0	0	0	0	0	1	0	1	1	0	0	1	0	1	0	0	0	0	0	0
Bohle River	1	0	1	1	1	1	0	1	0	1	1	1	0	1	0	0	0	0	0	1	0	1	0	0	0	0
Sachs Creek	1	0	0	0	1	1	1	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
Killymoon Creek	1	0	1	0	0	0	0	1	0	0	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0
Alligator Creek	1	0	1	0	1	0	1	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0
Stuart Creek	1	0	1	0	1	1	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	0	0	0	0	0
Ross River	1	1	1	0	1	1	1	0	0	0	0	1	0	1	1	1	1	1	1	1	1	0	0	1	1	1
Stony Creek	1	0	0	0	0	1	0	1	1	0	0	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0
Antill Plains Creek	1	0	0	0	1	0	1	0	1	0	0	0	0	1	0	1	1	1	0	0	1	0	0	0	0	0

1 represents present, 0 indicates absence.

Table 19. Fish species present within waterways within the Black freshwater basin.
The invasive species are highlighted in blue. The species that were present for each river are highlighted in cream. No translocated Australian fish species were recorded in catches.

Waterway	Northern perchlet	Giant mottled eel	Long-finned eel	Roman-nose goby	Bunaka	Fly-specked hardyhead	Gambusia	Silver biddy	Snake-head gudgeon	Mouth almighty	False Celebes goby	Empire gudgeon	Jungle perch	Barramundi	Spangled perch	Mangrove jack	Eastern rainbowfish	Southern purple-spotted gudgeon	Hyrtl's tandan	Swamp eel	Mozambique tilapia	Guppy	Scaleless goby
Pine Creek	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0	0
Black River	0	0	1	1	0	0	1	0	0	0	1	1	0	0	1	0	1	0	0	0	1	0	0
Rollingstone Creek	1	0	1	0	0	1	0	0	0	0	1	1	1	0	1	0	1	1	1	0	1	0	0
Healy Creek	1	0	1	0	0	0	1	1	0	0	0	1	0	1	1	0	1	0	0	0	0	0	0
Canal Creek	1	0	1	0	0	0	1	0	0	0	1	1	0	0	1	0	1	1	0	0	1	1	0
Crystal Creek	0	0	1	1	0	1	1	0	0	0	1	1	1	0	0	1	1	1	0	0	0	0	0
Leichhardt Creek	1	0	1	1	1	1	0	0	1	1	0	1	0	0	1	0	1	1	1	0	1	0	0
Crystal Creek	0	1	1	1	0	1	0	1	0	0	1	1	1	1	0	1	1	0	0	1	0	0	1
Bullocky Toms Creek	0	0	1	1	0	1	0	0	0	0	0	1	1	0	0	0	1	1	0	0	0	0	0
Alice River	0	0	1	1	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	0	0
Nolans Gully	0	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	1	1	0	0	0	0	0
Clerk Creek	1	0	1	1	0	0	1	0	0	0	0	1	0	0	1	0	1	1	1	0	0	0	0
Alice River	1	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	1	0	1	1	0

1 represents present, 0 indicates absence.

Twenty-six species (23 native, 3 invasive) were recorded within the Ross freshwater basin, whilst 23 species (20 native, 3 invasive) were recorded within the Black freshwater basin. Invasive species (same as non-indigenous species) include both alien and translocated species. Alien species are those species that are not native to Australia, whilst translocated species are species that are native to Australia but not native to the waterway. A large part of the upper Ross River was not sampled and larger water bodies were also not sampled. Sampling within the upper catchment and larger waterbodies may slightly influence the results, however the current result is still considered reasonable in relation to other basins. This is because the median across sites generally does not rapidly change with the addition of a small number of additional sites.

Median scores were provided for the Ross and Black freshwater basins, with the medians calculated based on the species present at each site. Site results are shown in boxplots for each index and basin in Appendix D (see Figure Appendix D1 and D2).

Overall, fish communities were in a moderate condition within the Ross Basin and a good condition within the Black Basin. The scores for the indicator categories and the overall fish index are shown in Table 20, whilst the raw scores are shown in Table 21. The proportion of non-indigenous species expected within sampled waterways was graded as moderate (62% of expected species present) within the Ross Basin and good (70% of expected species present) within the Black Basin (Table 20 and Table 21). Across all sites within the Ross and Black basins, there was a median of 5.1% and 1.2% of non-indigenous fish within waterways within each basin respectively (Table 21). This translated to a moderate and very good grade for the Ross and Black basins respectively for the proportion of non-indigenous fish indicator category (Table 20).

There was high variability within the creeks and rivers around Townsville, with fish communities generally improving as the creeks were further away from the urban centre. The number of invasive species caught within the Black and Ross basins were similar between the two basins. For example, there were 122 gambusia fish caught in both the Black and Ross basins, whilst there were 319 Mozambique tilapias caught in the Black Basin and 392 Mozambique tilapias in the Ross Basin. In total, there were 8 guppies caught within the basins.

Table 20. Scores and grades for the two indicator categories (proportion of Indigenous species expected and proportion of Indigenous fish), which comprise the overall fish index.

The fish index is the average of the scores for the proportion of Indigenous species expected and the proportion of Indigenous fish. Significant figures differ for ease of presentation.

	Scores			Grades		
Basin	Proportion of Indigenous species expected	Proportion of non-Indigenous Fish index	**Fish index**	Proportion of Indigenous species expected	Proportion of non-Indigenous Fish index	**Fish index**
Ross	54	60	**57**	C	C	**C**
Black	66	91	**78**	B	A	**B**

Scoring range: ■ Very Poor I = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81 to 100

Table 21. Raw scores for the two indicator categories (proportion of Indigenous species expected and proportion of Indigenous fish), which comprise the overall fish index.
The proportion of Indigenous fish indicator category comprises of two indicators, which are the proportion of translocated fish and the proportion of invasive (alien) fish. All proportions are calculated by deriving the median based on all sites monitored. The index is calculated at the site level and the medians reported here are derived from those. Significant figures differ for ease of presentation.

Basin	**Proportion of Indigenous species expected**	Proportion of Indigenous Fish		
		Proportion of translocated fish	Proportion of invasive (alien) fish	**Proportion of non-Indigenous Fish index**
Ross	0.62	0.0	0.037	0.051
Black	0.70	0.0	0.012	0.012

Scoring range for the proportion of Indigenous species expected: ■ Very Poor I = 0 to <0.40| ■ Poor (D) = 0.40 to <0.53| ■ Moderate (C) = 0.53 to <0.67 | ■ Good (B) = 0.67 to <0.80 | ■ Very Good (A) = 0.80 to 1

Scoring range for the proportion of Indigenous species: ■ Very Poor I = >0.20 to 1| ■ Poor (D) = >0.1 to 0.2 | ■ Moderate (C) = >0.05 to 0.1 | ■ Good (B) = >0.03 to 0.05 | ■ Very Good (A) = 0 to 0.3

Key messages:

- Overall, the Ross and Black basins were in a moderate and good condition for fish communities, respectively.
- The Ross and Black basins recorded 62% and 70% of the indigenous species expected within the basins, equating to a moderate and good score.
- Across sampled waterways within the Ross and Black basins, there was a median of 5.1% and 1.2% invasive species present, which equated to a moderate and good grade for the proportion of indigenous species.
- 33 fish species (30 native and three invasive species) were detected across the Townsville Dry Tropics.

5.2.1 Confidence scores for the fish index

There was moderate confidence in the results. Around 1/3 of the major creeks within the Townsville area surveyed. However they were only sampled at one site on one occasion and larger waterbodies were not sampled. Additionally, sites within the upper Ross Basin were not sampled.

Table 22. Confidence scores for the fish index 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
Fish index	2	2	2	3	1	**9**	**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 Estuarine zones

Within the estuarine zone, water quality and habitat and hydrology are the two indices scored, with the results presented in separate sections below.

6.1 Water quality

6.1.1 Monitoring sites

Seven estuaries were monitored within the Ross estuarine zone and five within the Black estuarine zone. Monthly grab samples were taken at one to three sites per estuary. No sampling occurred within the Black estuarine zone from March until June 2020 due to the travel restrictions associated with Covid-19. The estuary names and number of sites sampled per estuary are shown in Table 23. The locations of the sites are shown in Figure 14.

Table 23. Estuaries and number of monitoring sites per estuary within the Ross and Black estuarine zones.

Zone	Estuary name	Number of monitoring sites within each estuary
Ross estuarine zone	Bohle River estuary	1
	Louisa Creek estuary	3
	Ross Creek estuary	3
	Ross River estuary	1
	Stuart Creek estuary	1
	Sandfly Creek estuary	2
	Alligator Creek estuary	1
Black estuarine zone	Bluewater Creek estuary	1
	Althaus/Deep Creek estuary	1
	Saltwater Creek estuary	1
	Rollingstone Creek estuary	1
	Crystal Creek estuary	1

Figure 14. Monitoring sites within the Ross and Black estuarine zones.

Monitoring sites 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 estuaries within the Black estuarine zone and labelled. The blue and yellow outline delineates the Black and Ross estuarine zone respectively, with the red line showing the Black freshwater basin and the orange line delineates the Ross freshwater basin. Satellite image taken on the 04/05/2020.

6.1.2 Results

Water quality scores for estuarine zones were derived from five indicators and two indicator categories, which are nutrients and physical-chemical (phys-chem) properties. The distributions of scores for each indicator are presented as boxplots in Appendix E. The values used to calculate the scores are presented in Appendix F. The parameters used to calculate the scores are:

- Water quality objectives (WQOs), which the raw data were compared against,
- Scaling factors, which are used to scale the scores,
- Annual median, calculated from the monthly medians, and
- 80^{th} percentile, or 20^{th} percentile for lower dissolved oxygen.

6.1.2.1 *Nutrients*

The scores for nutrients were derived by averaging the scores of two indicator categories, which are total phosphorus (TP) and dissolved inorganic nitrogen (DIN). The results for nutrients are presented in Table 24. Concentrations of nutrients were graded as very good and good in the Ross and Black estuarine zone, respectively. All estuaries were in a good or very good condition overall, except for Louisa Creek Estuary within the Ross estuarine zone, where the median concentration of TP was above the water quality objective.

Table 24. Scores and grades for total phosphorus (TP), dissolved inorganic nitrogen (DIN) and nutrients for estuarine sites.

The scores for nutrients are the average of the scores for DIN and TP. Non-weighted scores for each site are weighted based on the proportion of measured catchment area. The weighted scores are summed for the overall score for each basin. Significant figures differ for ease of presentation and to show very small numbers.

	Non-weighted scores and grades						Catchment area							
Site	Score			Grade			Catchment area draining into site (km²)	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	90	90	A	A	A	4.8	0.0039	0.35	0.35	0.35			
Bohle River Estuary	90	90	90	A	A	A	295.6	0.24	21.6	21.6	21.6			
Louisa Creek Estuary	75	30	52	B	D	C	52.5	0.04	2.98	1.2	2.09			
Louisa Estuary Site 0.9	90	90	90	A	A	A								
Louisa Estuary Site 6.0	66	0	33	B	E	D								
Louisa Creek/Town Common Estuary	68	0	34	B	E	D								
Ross Creek Estuary	90	90	90	A	A	A	20.8	0.02	1.8	1.8	1.8			
Ross River Estuary	90	90	90	A	A	A	842.8	0.68	61.2	61.2	61.2			
Sandfly Creek Estuary	90	90	90	A	A	A	27.7	0.02	1.8	1.8	1.8			
Ross estuarine zone	**84**	**68**	**76**	**A**	**B**	**B**	**1244**	**1**	**90**	**88**	**89**	**A**	**A**	**A**
Althaus/Deep Creek Estuary	90	72	80	A	A	B	69.1	0.18	16.2	12.99	14.59			
Bluewater Creek Estuary	71	90	81	B	B	A	89.7	0.24	17.1	21.6	19.35			
Crystal Creek Estuary	58	90	74	C	A	B	106.1	0.28	16.32	25.2	20.76			
Rollingstone Creek Estuary	49	90	70	C	A	B	77.4	0.20	9.83	18	13.92			
Saltwater Creek Estuary	67	90	79	B	A	B	37.4	0.10	6.75	9	7.88			
Black estuarine zone	**67**	**86**	**77**	**B**	**A**	**B**	**379**	**1**	**67**	**87**	**77**	**B**	**A**	**B**

Scoring range: ■ Very Poor I = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81 to 90 (scores are capped at 90)

The site names for independent sites are written black, whilst non-independent sites are written in brown. Scores for non-independent sites are averaged to create an overall score for an independent site.

Key messages: Nutrients

- Overall, nutrients concentrations were graded as very good and good in the Ross and Black estuarine zones.
- Nutrient (total phosphorus and dissolved inorganic nitrogen) concentrations were rated as good or very good in 90% monitored estuaries (10 out of 11 estuaries) in relation to the water quality objectives (WQOs).
- Louisa Creek Estuary was in a moderate condition, due to total phosphorus being higher than the WQO.

6.1.2.2 *Physical-chemical (phys-chem) properties*

The results for the phys-chem index were derived by averaging the scores of turbidity and dissolved oxygen (DO). The scores and grades for the sampled estuaries are presented in Table 25. Overall, the Ross and Black estuarine zones were in a very good and moderate condition respectively in relation to phys-chem properties, with most estuaries sampled in a good or very good condition. All estuaries sampled within the Ross estuary were in a good or very good condition, except for Louisa Creek estuary, which was in a moderate condition. This was due to two monitoring sites within Louisa Creek Estuary receiving very poor grades for lower DO.

Within the Black estuarine zone, Althaus Creek and Bluewater Creek estuaries were in a very poor condition, as they were graded as being turbid and having poor and very poor upper DO scores. These two estuaries are relatively close to each other. In contrast, the other three estuaries within the Black estuarine zone were in a good or very good condition. The differences in scores between estuaries may be at least partly due to internal estuarine processes, with each estuary having different processes that impact upon the turbidity and dissolved oxygen within the system. Since the freshwater creeks that feed into the estuaries had very good turbidity concentrations, this suggests the poor turbidity results are not directly related to the upper catchment. It is possible the turbid waters are due to wave and wind resuspension, as the freshwater section of both creeks were in a very good condition with respect to turbidity.

Table 25. Scores and grades for turbidity, lower dissolved oxygen (DO), upper DO and the overall physical-chemical (phys-chem) properties for estuarine sites. The scores for phys-chem properties are the average of turbidity and the lower score of either upper or lower dissolved oxygen. Non-weighted scores for each site are weighted based on the proportion of measured catchment area. The weighted scores are summed for the overall score for each basin. Significant figures differ for ease of presentation and to show very small numbers.

	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 properties**	Turb-idity	Upper DO	Lower DO	**Phys-chem properties**			Turb-idity	Upper DO	Lower DO	Phys-chem properties	Turb-idity	Upper DO	Lower DO	Phys-chem properties
Alligator Creek Estuary	90	90	90	90	A	A	A	A	4.8	0.004	0.35	0.35	0.35	0.35				
Bohle River Estuary	90	90	90	90	A	A	A	A	295.6	0.24	21.6	21.6	21.6	21.6				
Louisa Creek Estuary	90	90	21	56	A	A	D	C	52.5	0.04	3.6	3.6	0.86	2.7				
Louisa Estuary Site 0.9	90	90	64	77	A	A	B	A										
Louisa Estuary Site 6.0	90	90	0	45	A	A	E	C										
Louisa Creek/Town Common Estuary	90	90	0	45	A	A	E	C										
Ross Creek Estuary	90	90	90	90	A	A	A	A	20.8	0.02	1.8	1.8	1.8	1.8				
Ross River Estuary	90	90	90	90	A	A	A	A	842.8	0.68	61.2	61.2	61.2	61.2				
Sandfly Creek Estuary	52	90	90	71	C	A	A	B	27.7	0.02	1.04	1.8	1.8	1.4				
Ross estuarine zone	**85**	**90**	**64**	**75**	**A**	**A**	**B**	**B**	**1244**	**1**	**90**	**90**	**89**	**90**	**A**	**A**	**A**	**A**
Althaus/Deep Creek Estuary	4	28	90	16	E	D	A	E	69.1	0.18	0.7	5.04	16.2	7.3				
Bluewater Creek Estuary	0	0	90	0	E	E	A	E	89.7	0.24	0	0	21.6	0				
Crystal Creek Estuary	90	69	90	80	A	B	A	B	106.1	0.28	25.2	19.5	25.2	22.4				
Rollingstone Creek Estuary	73	65	90	69	B	B	A	B	77.4	0.20	14.6	12.9	18	13.8				
Saltwater Creek Estuary	90	76	90	83	A	B	A	A	37.4	0.10	9	7.6	9	8.3				
Black estuarine zone	**51**	**48**	**90**	**50**	**C**	**C**	**A**	**C**	**379**	**1**	**51**	**46**	**90**	**49**	**C**	**C**	**A**	**C**

Scoring range: ■ Very Poor I = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81 to 90 (scores are capped at 90)

The site names for independent sites are written black, whilst non-independent sites are written in brown. Scores for non-independent sites are averaged to create an overall score for an independent site.

Key messages: Phys-chem properties

- Ross and Black estuarine zones were in a very good and moderate condition with respect to physical-chemical properties (turbidity and dissolved oxygen).
- 73% of estuaries monitored (eight out of 11 estuaries) were in a good or very good condition.

6.1.2.3 *Overall water quality*

Overall water quality within the Ross estuarine zone was very good, as shown in Table 28. All sites had very good water quality, except for Louisa Creek Estuary, which was in a moderate condition. Overall, the Black estuarine zone was graded as being in a good condition, although Bluewater Creek estuary was only in a moderate condition.

Natural variability, such as geography, vegetation and climate, may cause differences in results between estuaries. Differences in the depth of the site may also affect the results, with shallower sites generally being more turbid. Differences in when sampling was done, in terms of the incoming and outcoming tides, and the distance that the sampling site was from the estuary mouth could also influence the results.

Table 26. Overall water quality scores and grades for estuarine sites.

The overall water quality scores are the average of the scores for the nutrients and physical-chemical (phys-chem) properties.

	Non-weighted scores and grades						Weighted scores and grades					
	Scores			Grades			Scores			Grades		
	Nutrients	Phys-chem properties	Water quality	Nutrients	Phys-chem properties	Water quality	Nutrients	Phys-chem properties	Water quality	Nutrients	Phys-chem properties	Water quality
Alligator Creek Estuary	90	90	90	A	A	A						
Bohle River Estuary	90	90	90	A	A	A						
Louisa Creek Estuary	52	56	54	C	C	C						
Louisa Estuary Site 0.9	90	77	84	A	A	A						
Louisa Estuary Site 6.0	33	45	39	D	C	D						
Louisa Creek/Town Common Estuary	34	45	40	D	C	D						
Ross Creek Estuary	90	90	90	A	A	A						
Ross River Estuary	90	90	90	A	A	A						
Sandfly Creek Estuary	90	71	81	A	B	A						
Ross estuarine zone	**76**	**75**	**76**	**B**	**B**	**B**	**89**	**90**	**90**	**A**	**A**	**A**
Althaus/Deep Creek Estuary	80	16	48	B	E	B						
Bluewater Creek Estuary	81	0	41	A	E	C						
Crystal Creek Estuary	74	80	77	B	B	B						
Rollingstone Creek Estuary	70	69	70	B	B	B						
Saltwater Creek Estuary	79	83	81	B	A	A						
Black estuarine zone	**77**	**50**	**64**	**B**	**C**	**B**	**77**	**49**	**63**	**B**	**C**	**B**

Scoring range: ■ Very Poor I = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81 to 100

The site names for independent sites are written black, whilst non-independent sites are written in brown. Scores for non-independent sites are averaged to create an overall score for an independent site.

6.1.2.4 *Confidence scores for nutrients, physical-chemical properties and overall water quality*

There was a moderate confidence in the water quality scores for the Ross and Black estuarine zone. The score for each criterion is shown in Table 27. The confidence rating for the Black estuarine zone improved from a low confidence in 2018-19 to moderate confidence for 2019-2020. This is because sampling in 2019-2020 occurred once every month for eight months in 2019-2020, compared to only three months for the 2018-19 year.

Table 27. Confidence score for nutrients, physical-chemical (phys-chem) properties and the overall water quality index (average of nutrients and phys-chem scores) 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	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)**

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.

6.1.2.5 *Comparing scores for water quality between years*

Results were compared between 2019-2020 (this year) and 2018-19 (last year), with the scores shown in Table 28.

Table 28. Comparison of estuarine water quality scores between 2018-19 and 2019-2020.
Overall water quality is the average of the scores for nutrient and physical-chemical (phys-chem) properties.

	2019-2020 results (current year)			2018-19 results (last year)		
Zone	Nutrients	Phys-chem properties	Water quality	Nutrients	Phys-chem properties	Water quality
Ross estuarine zone	90 A	90 A	**90 A**	54 C	87 A	**71 B**
Black estuarine zone	78 B	49 C	**64 B**	63 B	70 B	**67 B**

Scoring range: Very Poor I = 0 to <21 | Poor (D) = 21 to <41 | Moderate (C) = 41 to <61 | Good (B) = 61 to <81 | Very Good (A) = 81 to 90 (scores are capped at 90)

A comparison of the results for each site for 2019-2020 and 2018-19 are shown in Appendix G. Results from the 2017-18 Pilot Report Card were not included in the comparison. This is because the method for calculating scores changed between the 2017-18 and the 2018-19 report card, meaning the results are not comparable. Comparing between two years of data (2018-19 and 2019-20) is not sufficient to assess trends over time and more data are required to establish accurate trends and potential reasons for any trends. However it is still interesting to look at the differences between the years. There were higher concentrations of nutrients (equating to poorer scores) within the Ross estuarine zone in 2018-19 than in 2019-2020. This is likely due to the flood event and higher rainfall in 2018-19, which is likely to have washed more nutrients into the waterways compared to the drier 2019-2020 year.

6.2 Habitat and hydrology results

The results are the same as the 2018-19 Report Card, as the data has not been updated since 2017. In previous report cards, this index was referred to as biodiversity, but it has been changed so the term is the same as used by the other regional report cards. It is noted that there are no 'hydrology' indicators are scored within this index.

6.2.1 Habitat extent

Habitat extent (mangrove and saltmarsh extent combined) is the only indicator measured within the habitat indicator category within the estuarine zone. The habitat indicator category is the only category scored within the habitat and hydrology index. The score for habitat extent is thus the score for the overall habitat indicator category and the habitat and hydrology index.

6.2.1.1 *Mangrove and saltmarsh 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 29). Both zones scored a good grade for progressing towards the management target of no loss (Table 29). 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, the method for measuring mangrove and saltmarsh extent likely underestimates the amount of habitat lost, resulting in a better score than accurate (A. Healy, pers. comm., 3rd February 2021). A more accurate method for assessing habitat extent has been devised, with the scores to be updated in the 2020-2021 Report Card.

Table 29. Scores and grades for mangroves and saltmarsh combined for the Ross and Black estuarine zone.
The scores and grades for mangrove and saltmarsh extent is used as the score for the habitat indicator category and the overall habitat and hydrology index. 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 indicator category/Habitat and hydrology index**	Mangrove and saltmarsh extent	**Habitat indicator category/Habitat and hydrology index**
Ross estuarine zone	0.05% loss (6 ha lost out of 120 ha)	71	**71**	B	**B**
Black estuarine zone	0.02% loss (<1 ha lost out of 50 ha)	77	**77**	B	**B**

Scoring range: Very Poor I = 0 to <21 | Poor (D) = 21 to <41 | Moderate (C) = 41 to <61 | Good (B) = 61 to <81 | Very Good (A) = 81 to 100
Source: Data sourced from Queensland Government (2019) Reef Water Quality Report Card 2017 and 2018.

Key messages: mangrove and saltmarsh

- Six ha (0.05%) and less than one ha (0.02%) of mangrove and saltmarsh extent (combined) were lost from the Ross and Black estuarine zones.
- This represents a good grade for progressing towards the management target of zero net loss.
- Mangroves and saltmarshes are ecologically important habitats and thus a loss of these habitats may negatively impact the environment.
- The method for measuring mangrove and saltmarsh extent likely underestimates the amount of habitat lost, resulting in a better score than accurate. A new, more accurate method will be used to assess and score the data in the 2020-21 Report Card.

6.2.1.2 *Confidence scores*

There was very low confidence in the results for mangrove and saltmarsh extent, with the overall rank and the scores for each confidence criterion presented in Table 30. The representativeness was very low due to the method likely underestimating the amount of habitat lost.

Table 30. Confidence scores for mangrove and saltmarsh extent score for both the Ross and Black estuarine zones.
The score for habitat extent was also the score for the habitat extent indicator category and the overall habitat and hydrology 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).

	Maturity (0.36)	Validation (0.71)	Represent-ativeness (2)	Directness (0.71)	Measured error (0.71)	Final score	Rank
Mangrove and saltmarsh extent	2	2	1	2	1	6.27	Very low (1)
Habitat extent/Habitat and hydrology extent						**6.27**	**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.

7 Inshore marine zones

Within the inshore marine zones, water quality and habitat are the two indices scored, with the results presented in separate sections below.

7.1 Water quality

7.1.1 Monitoring sites

There are two inshore marine zones, which are Cleveland Bay and Halifax Bay. The monitoring sites within Cleveland and Halifax bays are shown in Figure 15. Monitoring occurred within three independent sites within Cleveland Bay and two independent sites within Halifax Bay. The number of independent and non-independent sites and the description of the sites are presented in Table 31. Different sites have different WQOs as defined in the water quality improvement plans.

Figure 15. Monitoring sites within Cleveland Bay and Halifax Bay.
The monitoring sites are Pelorus Island, Pandora Reef, enclosed coastal sites (purple dots), open coastal sites (blue dots) and Magnetic Island (orange dots). The pink line is the line between Cleveland Bay (right) and Halifax Bay (left). The purple line is the boundary between open coastal waters and the midshelf. The green lines shown the outer boundary of the inshore marine zone, whilst the red and blue line delineates the boundary for the Black and Ross basins, respectively. Satellite image taken on the 14/12/2015.

Table 31. Monitoring sites within Cleveland Bay and Halifax Bay and description of the sites.

Zone	Independent sites	No. of sites	Description of monitoring sites
Cleveland Bay	Enclosed coastal waters	5	One site is part of the receiving environment monitoring program (REMP) that is associated with the Cleveland Bay sewage treatment plant and four sites were monitored by the Port of Townsville.
	Open coastal waters	4	Three sites were monitored by the Port of Townsville, with the other site monitored by the AIMS Marine Monitoring Program (MMP).
	Magnetic Island (Geoffrey Bay and Arthur Bay)	3	Nutrients were monitored using grab samples and a turbidity logger records continuous data at Geoffrey Bay (north) sampled by the AIMS Marine Monitoring Program (MMP). Turbidity was measured at Geoffrey Bay (south of the MMP site) and Arthur Bay using water quality equipment loggers on buoys owned by Port of Townsville.
Halifax Bay	Enclosed coastal waters	1	Pandora Reef. This site was monitored by the MMP.
	Midshelf waters	1	Pelorus Island. This site was monitored by the MMP.

7.1.2 Indicators measured at each site

Water quality scores for inshore marine zones were derived from three indicator categories, which are nutrients, physical-chemical (phys-chem) properties and chlorophyll *a*. The indicators measured varied between sites due to the sites being monitored by different programs. The indicators measured at each 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 32.

Table 32. Indicators sampled at each 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	Independent site	Monitoring program	Type of sample	Frequency	TP	NOx	Turbidity	Chl *a*	Secchi depth	TSS	PP	PN
Cleveland Bay	Enclosed coastal Cleveland Bay	TCC receiving environmental program	Grab	Monthly	■	■	■	■		■		
		Port of Townsville	Grab	Quarterly	■	■	■			■		
	Open coastal Cleveland Bay	Port of Townsville	Grab	Quarterly	■	■	■			■		
		Marine monitoring program (MMP)	Grab	6 times from Dec 2019 – April 2020		■		■	■	■	■	■
	Magnetic Island (Geoffrey Bay and Arthur Bay)	MMP (Geoffrey Bay north)	Grab	Six times from Sept 2019 – April 2020		■		■	■	■	■	■
			Logger	Continuous (daily)			■	■				
		Port of Townsville (Geoffrey Bay south and Arthur Bay)	Loggers	Continuous, every 15 minutes			■					

Zone	Independent site		Monitoring program	Type of sample	Frequency	TP	NOx	Turbidity	Chl *a*	Secchi depth	TSS	PP	PN
Halifax Bay	Enclosed coastal waters	Pandora Reef	MMP	Grab	Seven times from July 2019 – April 2020		■		■	■	■	■	■
				Logger	Continuous (daily)			■	■				
	Midshelf waters (Pelorus Island)		MMP	Grab	Six times from Sept 2019 – April 2020		■		■	■	■	■	■
				Logger	Continuous (daily)			■	■				

7.1.3 Results

The scores for each site were equally weighted. The distributions of scores for each indicator are presented as boxplots in Appendix H.

7.1.3.1 *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 33, with the detailed description of the results for Cleveland Bay in section 7.1.3.2.1 and for Halifax Bay in section 7.1.3.2.2.

Table 33. 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). The scores for Geoffrey Bay North, Geoffrey Bay South and Arthur Bay were averaged for the overall score for Magnetic Island. The scores for the enclosed coastal, open coastal and Magnetic Island were averaged to produce the overall score for Cleveland Bay. The scores for Pandora Reef and Pelorus Island were averaged to produce an overall score for Halifax Bay. Significant figures differ for ease of presentation.

	Score					Grade				
Site	TP	PP	PN	NOx	**Nutrients**	TP	PP	PN	NOx	**Nutrients**
Enclosed coastal	84	ND	ND	94	89	A	ND	ND	A	A
Open coastal	100	ND	ND	100	100	A	ND	ND	A	A
Magnetic Island	ND	67	9	0	25	ND	B	E	E	D
Geoffrey Bay North	ND	67	9	0	25	ND	B	E	E	D
Geoffrey Bay South	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arthur Bay	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cleveland Bay	**92**	**67**	**9**	**65**	**71**	**A**	**B**	**E**	**B**	**B**
Pandora Reef (Open coastal waters)	ND	75	8	48	44	ND	B	E	C	C
Pelorus Island (Midshelf waters)	ND	70	2	28	33	ND	B	E	D	D
Halifax Bay	**ND**	**73**	**5**	**38**	**39**	**ND**	**B**	**E**	**D**	**D**

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

7.1.3.1.1 Cleveland Bay

Overall, Cleveland Bay was scored as being in a good condition with respect to nutrients. Within Cleveland Bay, enclosed coastal and open coastal waters were in a very good condition, with total phosphorus and oxidised nitrogen concentrations both graded as very good. Geoffrey Bay (northern site) scored poorly with respect to nutrients. This was due to the site having particulate and oxidised nitrogen concentrations that were higher than the water quality objectives (WQOs) against which the data were compared. It is important to note that the nutrient concentrations within the enclosed coastal and open coastal waters within Cleveland Bay were higher than at Geoffrey Bay. However, despite the higher concentrations, these sites received a better score. This was because these sites had lower WQOs, indicating that the WQOs were driving the scores. The annual median concentrations and the WQOs for each indicator for each site are shown in Table 34. The distribution of the raw data for each site are shown in Appendix H. An example of how WQOs are influencing the scores within the inshore marine environment is outlined in section 7.1.3.1.3.

Table 34. Comparison of annual median values and water quality objectives (WQOs) for indicators of nutrients for sites within the inshore marine zone.

Geoffrey Bay and Arthur Bay are Magnetic Island. Significant figures for numbers differ for ease of presentation.

Zone	Site	TP		PP		PN		NOx	
		Median	WQO (mg/L)	Median	WQO (mg/L)	Median	WQO (mg/L)	Median	WQO (mg/L)
Cleveland Bay	Enclosed coastal	0.02	0.03	ND	ND	ND	ND	0.005	0.009
	Open coastal	0.014	0.03	ND	ND	ND	ND	0.003	0.009
	Magnetic Island (Geoffrey Bay and Arthur Bay)	ND	ND	0.0025	0.0028	0.038	0.021	0.0025	0.001
Halifax Bay	Pandora Reef (Open coastal waters)	ND	ND	0.0022	0.0028	0.037	0.021	0.0023	0.001
	Pelorus Island (Midshelf waters)	ND	ND	0.0024	0.0028	0.039	0.02	0.0029	0.002

Colour key: : ■ Annual median is higher (worse) than the WQO | ■ Annual median is lower (better) than the WQO | ■ No data (ND), indicating that the indicator is not scored for that site.

7.1.3.1.2 Halifax Bay

Halifax Bay was scored in a poor condition in relation to the WQOs, with very poor scores for particulate nitrogen at both Pandora Reef and Pelorus Island. Pandora Reef was scored as being in a moderate condition, whilst Pelorus Island was given a poor score, with very poor and poor scores for particulate and oxidised nitrogen, respectively. The annual median concentrations for oxidised nitrogen, particulate phosphorus and particulate nitrogen at Geoffrey Bay (Cleveland Bay), Pandora Reef and Pelorus Island were all very similar (see Table 34), with the differences driven by the WQOs. It is also important to note that the overall scores for Cleveland Bay and Halifax Bay are not comparable due to the enclosed coastal and open coastal sites within Cleveland Bay having substantially different WQOs to the sites sampled within Halifax Bay.

7.1.3.1.3 Influence of water quality objectives on inshore marine results

Oxidised nitrogen was the only indicator that was scored at all sites within both Cleveland Bay and Halifax Bay. Comparing the scores for oxidised nitrogen between the sites provides a good example of how the WQOs are influencing the scores. For this indicator, the water quality objectives (WQOs) for the enclosed coastal and open coastal sites (0.009 mg/L) are nine times higher than the WQOs for Geoffrey Bay (0.001 mg/L) and 4.5 times higher than the WQOs for Pandora Reef and Pelorus Island (0.002 mg/L) (see Table 34). The annual median concentrations for oxidised nitrogen within the enclosed coastal and open coastal waters in Cleveland Bay were twice as high (worse) than the annual median concentrations for Magnetic Island. However the enclosed coastal and open coastal sites received very good scores, whilst Magnetic Island was graded as very poor. The grades for each site thus do not reflect the differences in concentrations. Instead, the differences in WQOs had the greatest influence on the grades. Coastal waters are very dynamic and having substantial differences in WQOs for the different sites makes it difficult to draw meaningful comparisons between the sites sampled.

7.1.3.1.4 Key messages: Nutrients

- Within both Cleveland Bay and Halifax Bay, nitrogen was above the water quality objectives (WQOs) against which data were compared.
- Overall, Cleveland Bay received a good grade. The enclosed coastal and open coastal sites received a very good grade, whilst Geoffrey Bay North received a poor grade. However, the differences in the scores between the sites were driven by the WQOs, with the WQOs being stricter the further offshore. Water quality was in a better condition at Geoffrey Bay, Pandora Reef and Pelorus Island than at the open coastal and enclosed coastal sites.
- Nitrogen was higher than the associated WQOs within Halifax Bay, resulting in the bay receiving a poor score for nutrients.
- The scores for Halifax Bay and Cleveland Bay are not comparable due to the differences in WQOs differing between the sampling sites.

7.1.3.2 *Physical-chemical properties*

The results for phys-chem properties in Cleveland and Halifax bays are presented in Table 35, with the detailed description of the results for Cleveland Bay in section 7.1.3.2.1 and for Halifax Bay in section 7.1.3.2.2.

Table 35. 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. The scores for Geoffrey Bay and Arthur Bay were averaged for the overall score for Magnetic Island. Significant figures differ for ease of presentation.

	Score				Grade			
Site	TSS	Secchi	Turbidity	**Phys-chem**	TSS	Secchi	Turbidity	**Phys-chem**
Enclosed coastal	69	81	40	64	B	A	D	B
Open coastal	100	100	100	100	A	A	A	A
Magnetic Island	100	ND	71	71	A	ND	B	B
Geoffrey Bay North	100	ND	100	100	A	ND	A	A
Geoffrey Bay South	ND	ND	54	54	ND	ND	C	C
Arthur Bay	ND	ND	58	58	ND	ND	C	C
Cleveland Bay	**90**	**91**	**71**	**75**	**A**	**A**	**B**	**B**
Pandora Reef (Open coastal waters)	100	ND	90	95	A	ND	A	A
Pelorus Island (Midshelf waters)	100	ND	100	100	A	ND	A	A
Halifax Bay	**100**	ND	**95**	**98**	**A**	ND	**A**	**A**

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

7.1.3.2.1 Cleveland Bay

Overall, Cleveland Bay was in a good condition with respect to phys-chem properties. Both Magnetic Island and enclosed coastal waters were in a good condition, whilst the open coastal sites were in a very good condition. All sites received a good or very good score for total suspended solids (TSS) in relation to the WQOs. The northern most Geoffrey Bay site received a very good grade for turbidity, whilst the southern Geoffrey Bay site recorded a moderate grade for turbidity. This was surprising since the sites are only approximately 650 m apart and a similar distance to the Geoffrey Bay coastline. The northern site is more protected by the headland from north-easterly winds than the southern site and this might result in better grades.

Turbidity was scored as being in a poor condition within the enclosed coastal waters. A closer examination of the data showed that the poor score for turbidity was driven by high turbidity at one monitoring site (one out of five sites). This site is 600 m from the coast, with wind resuspension, current and natural dynamics of the system resulting in the site being naturally turbid. The site is also influenced by tidal exchange from Sandfly Creek estuary (see Figure 16), although monitoring occurred at high tide. When each monitoring site was examined separately, this site received a very poor score, whilst the other four sites were in a good or very good condition for turbidity. It is noted that the four other sites in a very good or good condition are very spatially close to each other and are likely replicates/sampling a very similar area.

Figure 16. Location of enclosed coastal water monitoring sites (shown by green dots).
The four monitoring sites on the left all recorded good or very good turbidity levels, whilst the location at Sandfly Creek scored very poorly, with high turbidity levels.

It is important to note that the WQOs substantially vary between the sites and this likely impacted the results, although not as substantially as for the scores for nutrients. For example, the enclosed coastal and open coastal sites had between 7.5 and 21 times higher concentrations of TSS than the other sites. The annual median values and the WQOs for each indicator at each site are shown in Table 37 and the raw distribution of phys-chem properties are shown in boxplots in Appendix H. The

WQOs for many indicators vary between the sites, meaning that the overall scores for Cleveland Bay and Halifax Bay are not comparable.

Table 36. Comparison of annual median values and water quality objectives (WQO) for indicators of physical-chemical properties for sites within the inshore marine zone.

Geoffrey Bay and Arthur Bay are Magnetic Island. Significant figures for numbers differ for ease of presentation. ND stands for no data.

Zone	Site	TSS		Secchi		Turbidity	
		Median	WQO (mg/L)	Median	WQO (mg/L)	Median	WQO (NTU)
Cleveland Bay	Enclosed coastal	7.5	22	1.4	1	6.2	4.9
	Open coastal	13	15	2.5	1	1.4	4.9
	Magnetic Island (Geoffrey Bay and Arthur Bay)	1	3.7	ND	ND	1.1	2.7
Halifax Bay	Pandora Reef (Open coastal waters)	0.9	2	ND	ND	0.9	1.5
	Pelorus Island (Midshelf waters)	0.6	2	ND	ND	0.6	1.5

Colour key: ■ Annual median is higher (worse) than the WQO | ■ Annual median is lower (better) than the WQO, except for secchi, where annual medians being higher than the WQO is better | ■ No data (ND), indicating that the indicator is not scored for that site.

7.1.3.2.2 Halifax Bay

Halifax Bay was in a very good condition, with both turbidity and total suspended solids in a very good condition at all sites (see Table 35). Secchi depth was not measured within Halifax Bay. For most indicators, the WQOs for the sites within Halifax Bay were stricter than the WQOs for the sites scored within Cleveland. This means that the good scores for Halifax Bay represent genuine good water quality with respect to phys-chem properties, rather than an artefact of the WQOs.

7.1.3.2.3 Key messages: Physical-chemical properties

- Halifax Bay had good water quality with respect to phys-chem properties.
- Cleveland Bay was scored as very good with respect to phys-chem properties. However the water quality objectives (WQOs) are less strict than the WQOs used within Halifax Bay. Based on the raw data, sites within Cleveland Bay, especially the enclosed coastal waters, had poorer water quality than sites within Halifax Bay.
- Enclosed coastal waters received a poor score for turbidity in relation to the WQOs, however these locations are naturally turbid due to the hydrology of the environment and the high amount of wind resuspension.

7.1.3.3 *Chlorophyll a*

The concentrations of chlorophyll *a* were graded as very good and good within Cleveland Bay and Halifax Bay, respectively. All sites were grades as either good or very good. The results are presented in Table 37, as well as the annual medians and WQOs for chlorophyll *a*. At Geoffrey Bay North, the annual median concentration for chlorophyll *a* was almost 1.5 times higher than all other sites, however received a better score than Pandora Reef and Pelorus Island. This was because the WQO for Geoffrey is almost double that of the other two sites. The enclosed coastal site had a similar annual median compared to Pandora Reef and Pelorus Island. However the WQOs for the enclosed coastal site is 5.5. times higher (less strict) than the other two sites, meaning the enclosed coastal site received a very good grade, whilst Pandora Reef and Pelorus Island received a good grade.

Table 37. Scores and grades for chlorophyll *a* within Cleveland Bay and Halifax Bay, as well as the annual median concentrations and water quality objectives (WQOs) for chlorophyll *a*.

The scores for Geoffrey Bay and Arthur Bay were averaged for the overall score for Magnetic Island. Significant figures differ for ease of presentation. An annual median chlorophyll *a* concentration lower than the WQO indicates better water quality.

Site	Score	Grade	Median (ug/L)	WQO
Enclosed coastal	100	A	0.3	2.6
Open coastal	ND	ND	ND	ND
Magnetic Island	85	A	0.55	0.84
Geoffrey Bay North	85	A	0.55	0.84
Geoffrey Bay South	ND	ND	ND	ND
Arthur Bay	ND	ND	ND	ND
Cleveland Bay	**93**	**A**		
Pandora Reef (Open coastal waters)	70	B	0.38	0.45
Pelorus Island (Midshelf waters)	75	B	0.35	0.45
Halifax Bay	**73**	**B**		

Scoring range for scores and grades: ■ Very Poor I = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81 to 100 | ■ No data (ND).

Colour key for median and WQOs: ■ Annual median is higher (worse) than the WQO | ■ Annual median is lower (better) than the WQO, except for secchi, where annual medians being higher than the WQO is better | ■ No data (ND), indicating that the indicator is not scored for that site.

Key messages: Chlorophyll *a*

- Concentrations of chlorophyll *a* were below the water quality objectives (WOQs) within Cleveland Bay, resulting in all sites receiving very good grades for chlorophyll *a*.
- Halifax Bay received a good grade for chlorophyll *a*.
- Geoffrey Bay had the highest annual median concentration of chlorophyll *a* (0.55ug/L), whilst enclosed coastal sites (within Cleveland Bay), Pandora Reef and Pelorus Island (both within Halifax Bay) all had similar concentrations (around 0.3 to 0.4ug/L). The differences between scores were driven by the differences in the water quality objectives between the sites, rather than the differences in concentrations between the sites.

7.1.3.4 *Overall water quality*

Overall, both Cleveland Bay and Halifax Bay had good water quality. Summary scores and grades for water quality are presented in Table 38.

Table 38. Scores and grades for nutrients, physical-chemical (phys-chem) properties and overall water quality within Cleveland Bay and Halifax Bay.

The overall scores for water quality are the average of the scores for nutrients, phys-chem and chlorophyll a. The scores for Geoffrey Bay and Arthur Bay were averaged for the overall score for Magnetic Island. Significant figures differ for ease of presentation.

	Score				Grade			
Site	Nutrients	Phys-chem	Chloro-phyll *a*	**Water quality**	Nutrients	Phys-chem	Chloro-phyll *a*	**Water quality**
Enclosed coastal	89	64	100	84	A	B	A	A
Open coastal	100	100	ND	100	A	A	ND	A
Magnetic Island	25	70	85	60	D	B	A	C
Geoffrey Bay North	ND	53	ND	54	ND	C	ND	C
Geoffrey Bay South	ND	58	ND	58	ND	C	ND	C
Arthur Bay	25	100	85	70	D	A	A	B
Cleveland Bay	**71**	**75**	**93**	**80**	**B**	**B**	**A**	**B**
Pandora Reef (Open coastal waters)	44	95	70	70	C	A	B	B
Pelorus Island (Midshelf waters)	33	100	75	69	D	A	B	B
Halifax Bay	**39**	**98**	**73**	**70**	**D**	**A**	**B**	**B**

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

7.1.3.5 *Confidence scores*

Overall, there was low confidence in the results due to limited spatial sampling within both bays. The scores for each confidence criterion are shown in Table 39. At each site, there is high confidence in the data, as the sites are frequently monitored. However, across each site and the entire bay there is low confidence. For example, all enclosed coastal monitoring sites within Cleveland Bay are within only an 11 km section of water, near the coastline and immediately offshore of the Townsville CBD area. The coastline within the Cleveland Bay enclosed coastal zone stretches approximately 58 km and thus there is no sampling within a large part of the enclosed coastal waters. It is noted that there is substantially less development in the area not monitored and thus the current monitoring may capture most of the area affected by human impacts. However more sampling, both along the coast and further offshore, would enable a more accurate understanding of the water quality within the inshore area.

Table 39. Confidence score for nutrients, physical-chemical (phys-chem) properties and water quality 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)	Representa-tiveness (x2)	Directness (x0.71)	Measured error (x0.71)	Final score	Rank
Cleveland Bay	Nutrients	2	3	1	3	1	7.6	Low (2)
	Phys-chem	2	3	1	3	1	7.6	Low (2)
	Chlorophyll *a*	2	3	1	3	1	7.6	Low (2)
	Overall water quality						**7.6**	**Low (2)**
Halifax Bay	Nutrients	2	3	1	3	1	7.6	Low (2)
	Phys-chem	2	3	1	3	1	7.6	Low (2)
	Chlorophyll *a*	2	3	1	3	1	7.6	Low (2)
	Overall water quality						**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.

7.1.3.6 *Comparing scores for water quality between years*

The scores differed to the scores from last years, with the scores for 2018-19 and 2019-2020 presented in Table 40. A comparison of the results for each site for 2019-2020 and 2018-19 are shown in Appendix H. Scores were not compared to the 2017-18 scores as the water quality objectives (WQOs) used in 2017-18 differed to those used in the subsequent two report cards.

Table 40. Comparison of inshore marine water quality scores between 2018-19 and 2019-2020.

	2019-2020 results (current year)				2018-19 results (last year)			
Zone	Nutrients	Phys-chem properties	Chlorophyll *a*	Overall water quality	Nutrients	Phys-chem properties	Chlorophyll *a*	Overall water quality
Cleveland Bay	71 B	75 B	93 A	**80 B**	2 E	66 B	80 B	**55 C**
Halifax Bay	39 D	98 A	73 B	**70 B**	6 E	64 B	61 B	**43 C**

Scoring range: ■ Very Poor I = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81 to 100

For 2019-2020, the overall water quality score for both Cleveland Bay and Halifax Bay was higher than in 2018-19. Nutrient concentrations scored better this year compared to last year. This is likely, at least partially, because of the February 2019 floods and the higher rainfall last year (natural variation in the system). Nutrients are rapidly assimilated into the marine environment and therefore the grade for nutrients improved this year, following the flood. Chlorophyll *a* was lower last year, again likely due to the flush of nutrients into the inshore marine environment due to the flood.

The differences between the scores may also be attributed to differences in the number of sites. Within Cleveland Bay, fewer non-independent sites were monitored (within a independent site) this year (2019-2020) compared to last year (2018-19). For example, during the 2018-19 year, data were collected from seven non-independent sites within the enclosed coastal site, whereas only five non-independent sites were sampled at this site during 2019-2020. The two sites that were not sampled in 2019-2020 were close to the one site that scored poorly. Not having these two sites may have at least partially improved the scores in the 2019-2020 year.

Within the open coastal site, nine non-independent sites were sampled in 2018-19, however only three non-independent sites were monitored during 2019-2020. The sites that were removed were very close to sites that continued to be monitored and therefore it likely that the results from the discontinued sites are captured by the other sites. These differences were due to some programs reducing the amount of sampling this year. This year, turbidity data from two loggers were incorporated into the results for Geoffrey Bay, which may also have influenced the results.

7.2 Habitat

Coral and seagrass were the two indicator categories scored within the habitat index.

7.2.1 Coral

7.2.1.1 *Monitoring programs and monitoring sites*

Coral data within the Dry Tropics inshore marine zone was collected by the Great Barrier Reef Marine Monitoring Program (MMP) and the Australian Institute of Marine Science's Long-term Monitoring Program (LTMP), with most sampling occurring from the 3rd to the 6th of April 2020. Reef Check, a citizen science program, also sampled coral cover at a few sites. Coral cover scores from the three programs were weighted and then combined for an overall score. The weightings reflected the differences in the precision and accuracy of the sampling programs. Coral was scored within both Cleveland Bay and Halifax Bay, with the monitoring programs and sites surveyed outlined in sections 7.2.1.1.1 and 7.2.1.1.2 respectively.

7.2.1.1.1 Cleveland Bay

Within Cleveland Bay, Geoffrey Bay reef was sampled by MMP and coral cover was sampled at four reefs by Reef Check. The locations of the reefs monitored within Cleveland Bay are shown in Figure 17.

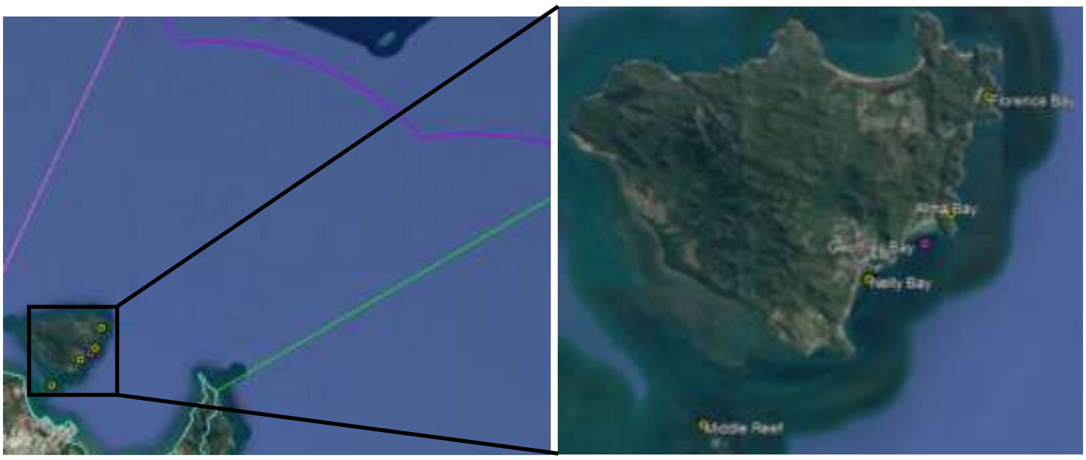


Figure 17. Reefs monitored by Reef Check (shown by yellow dots) and the one reef monitored by both Marine Monitoring Program and Reef Check (shown by the pink dot).

The boundary of the Cleveland Bay inshore zone is delineated by the green and purple lines.

7.2.1.1.2 Halifax Bay

Within Halifax Bay, MMP sampled four reefs, LTMP sampled at two reefs and Reef Check sampled coral cover at four reefs. The locations of the reefs monitored are shown in Figure 18.

Figure 18. Reefs monitored by the Great Barrier Reef Marine Monitoring Program, shown by green dots, the Great Barrier Reef Long-term Monitoring Program, shown in orange dots and by Reef Check, shown by yellow dots.
The boundary of the Halifax Bay inshore zone is delineated by the green, pink and purple lines.

7.2.1.2 *Results*

The results for Cleveland Bay and Halifax Bay are described in sections 7.2.1.2.1 and 7.2.1.2.2.

7.2.1.2.1 Cleveland Bay

Overall, coral condition within Cleveland Bay was in a moderate condition, with the scores for each indicator shown in Table 41. Geoffrey Bay was the only reef where all indicators were scored, and thus these scores represent the scores for all of Cleveland Bay. There was high macroalgae at Geoffrey Bay, with macroalgae generally indicative of poor water quality. The four reefs sampled by Reef Check reported poor or moderate coral cover and resulted in the cover coral score being poor for Cleveland Bay. Florence Bay and Geoffrey Bay had poor coral cover, whilst the other three reefs received a moderate score for coral cover.

Table 41. 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. The overall zone scores for percent (%) coral cover are weighted by monitoring program, but the individual scores for the reefs are not weighted to allow comparison with other indicators. Note that these scores are not a direct reflection of the underlying measured value, but rather just a standardised score. Significant figures differ for ease of presentation.

		Standardised scores						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**
Alma Bay	Reef Check	ND	42	ND	ND	ND	ND	ND	C	ND	ND	ND	ND
Florence Bay	Reef Check	ND	29	ND	ND	ND	ND	ND	D	ND	ND	ND	ND
Geoffrey Bay	Both*	75	48	47	59	0	46	B	C	C	C	E	C
Nelly Bay	Reef Check	ND	25	ND	ND	ND	ND	ND	D	ND	ND	ND	ND
Middle Reef	Reef Check	ND	46						C				
Cleveland Bay	**Both**	**63**	**38**	**47**	**57**	**0**	**44**	**B**	**D**	**C**	**C**	**E**	**C**
Fantome Island	Reef Check	ND	45	ND	ND	ND	ND	ND	C	ND	ND	ND	ND
Cattle Bay, Orpheus Island	Reef Check	ND	73	ND	ND	ND	ND	ND	B	ND	ND	ND	ND
Pioneer Bay, Orpheus Island	Reef Check	ND	55	ND	ND	ND	ND	ND	C	ND	ND	ND	ND
Pelorus Island	Reef Check	ND	58	ND	ND	ND	ND	ND	C	ND	ND	ND	ND
Havannah	LTMP	100	42	50	40	50	56	A	C	C	D	C	C
Havannah North	MMP	100	28	77	52	0	52	A	D	B	C	E	C
Palms East (Orpheus Island)	MMP	100	62	70	34	100	73	A	B	B	D	A	B
Palms West (Pelorus Island)	MMP	0	45	35	41	100	44	E	C	D	C	A	C
Pandora	MMP	75	17	50	71	20	47	B	E	C	B	E	C
Pandora North	LTMP	0	77	31	52	0	32	E	B	D	C	E	D
Halifax Bay	**Both**	**63**	**50**	**52**	**48**	**45**	**52**	**B**	**C**	**C**	**C**	**C**	**C**

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

*Data on percent coral cover is collected by both the MMP program and Reef Check.

7.2.1.2.2 Halifax Bay

Overall, Halifax Bay was in a moderate condition, with three of the five sampled reefs being in a moderate condition (Table 41). However the scores for each indicator substantially varied between reefs, ranging from very good to very poor. For example, macroalgae was also highly variable across reefs, scoring very poorly at the four reefs closest to the coast, but receiving very good scores at Palms East and Palms West. Macroalgae is generally associated with poor water quality. Juvenile density was the most consistent indicator, scoring either poorly or moderately at all sites, except for Pandora where it was in a good condition.

7.2.1.2.3 Coral bleaching

Following the marine heat wave in February 2020, surveys of reefs in the Burdekin region (all Townsville Dry Tropics inshore reefs plus Lady Elliot Reef, which is located offshore of Forrest Beach) were undertaken from 3 to 6 April 2020. There was marked variability in the level of bleaching observed throughout the Great Barrier Reef (GBR) region (Figure 19) (Thompson, et al., 2021).

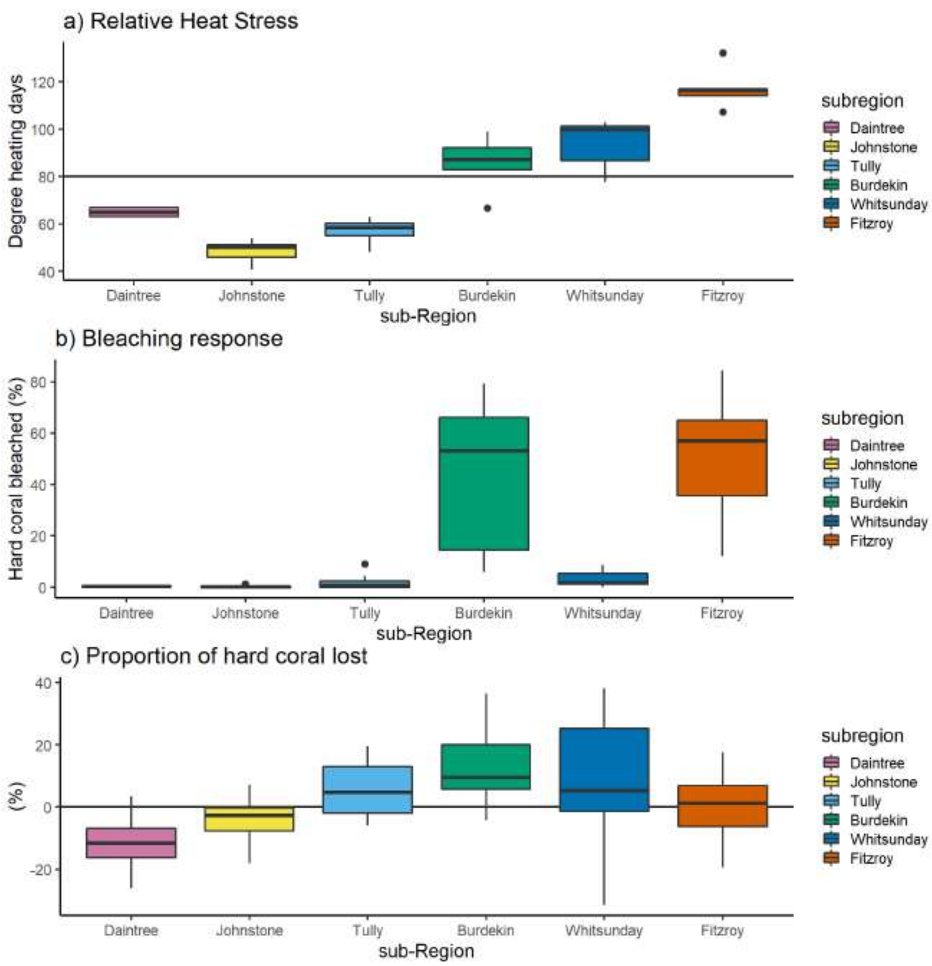


Figure 19. (Sub-)regional distributions of thermal stress and coral community responses in 2020, showing a) degree heating day (DHD) values recorded adjacent to coral monitoring sites (sourced from BoM), b) observed proportion of hard coral cover that was bleached at the time of survey (both partially bleached and bleached white corals are included), and c) the proportion of hard coral cover lost since reefs were last surveyed in either 2019 or 2018. Source: Thompson, et al., 2021

Moderate bleaching is expected when there are between 60 and 100 Degree Heating Days (DHDs) and severe bleaching is expected when greater than 100 DHDs (Garde, et al., 2014).

On average, the proportion of hard coral lost due to the heat wave was the highest for reefs within the Burdekin compared to any other region along the GBR (Figure 19) (Thompson, et al., 2021). The high loss rates were despite the Burdekin having fewer degree heating days (relative heat stress) than the Whitsundays or the Fitzroy region (Figure 19) (Thompson, et al., 2021). On average, around 50% of hard corals were bleached within the Burdekin region, which was the second highest for the GBR region, with Fitzroy having a slightly higher percentage (Figure 19) (Thompson, et al., 2021). Only one reef, Palms East, recorded relatively low levels of bleaching, although the amount of bleaching varied with depth. Palms East had the lowest heat stress metric estimates in the region and only 6% of corals showed signs of bleaching at 2 m depths (Table 42) (Thompson, et al., 2021). However 12% of corals showed signs of bleaching at 5m depth (Table 42) (Thompson, et al., 2021). “At all other reefs at least 50% of corals were bleached at either or both site depths” (Table 42) (Thompson, et al., 2021).

Table 42. Temperature stress metrics observed in 2020 on reefs within the Burdekin region and the percent of hard corals bleached due to the temperature stress.

Degree Heating Days (DHDs) are values derived from satellite observations downloaded from the Bureau of Meteorology (ReefTemp next generation), DHD.obs are degree heating day estimates calculated from in situ temperature loggers, and DHW are degree heating week estimates sourced from (NOAA coral reef watch). Shading indicates values at or above the minimum DHD value at which bleaching was observed during 2020 surveys, or DHW above level 2 alert. The proportion of hard corals bleached at the time of survey at 2 m and 5 m depths are included. Numbers have been rounded.

Region	Reef	DHD	DHD.obs	DHW	% Hard coral bleached	
					2m depth	5 m depth
Dry Tropics region	Palms East	67	48	6	6	12
	Havannah	83	58	9	62	60
	Palms West	84	55	6	71	11
	Pandora	90	82	9	79	75
	Magnetic	99	104	10	19	65
Burdekin region	Lady Elliot	92	85	9	15	46

7.2.1.2.4 Key messages: Coral

- Inshore coral communities were in a moderate condition within both Cleveland and Halifax bays.
- Composition of hard corals were generally in a good condition within both bays, although this was variable across reefs.
- Macroalgae was also highly variable across reefs, scoring very poorly at the four reefs closest to the coast. This contrasted to the very good scores at Palms East and Palms West. Macroalgae is generally associated with poor water quality.
- Low densities of juvenile corals at most shallow sites also continued to limit scores.
- During early 2020, reefs throughout the GBR experienced thermal stress, resulting in widespread coral bleaching. At least 50% of corals were bleached at all sampled inshore reefs within the Dry Tropics region, except for Palms East, and around 10% of hard corals were lost due to the bleaching.

7.2.2 Seagrass

Data on seagrass condition was obtained from the Port of Townsville monitoring program, with monitoring conducted by James Cook University (JCU). Seagrass was monitored in October 2019, with this sampling being the first sampling after the February flood. Sampling was also done in April 2020, but the data was not available when writing this report. Preliminary key messages from the April 2020 surveys were provided and these are incorporated at the end of the results section and noted in the key messages.

Ten monitoring meadows were sampled within the Cleveland Bay inshore marine zone. The locations of the monitored seagrass meadows are shown in Figure 20. No data were available on seagrass condition within Halifax Bay and this will be denoted in grey in the Report Card.

Figure 20. Location of seagrass monitoring meadows within Cleveland Bay.
Source: Adapted from Bryant & Rasheed (2018)

7.2.2.1 *Results*

Overall, Cleveland Bay was in a moderate condition for seagrass condition, with the scores shown in Table 43. The species composition and area indicators were graded as good or very good for eight of the ten meadows. Biomass was the lowest scoring indicator, with Geoffrey Bay and Nelly Bay meadows receiving a poor score for biomass, whilst five meadows were in a moderate condition for biomass. Three meadows were in a good condition in relation to biomass. It is noted that the biomass scores were also the overall scores for seagrass.

Table 43. Scores and grades for seagrass indicators and the seagrass indicator category for Cleveland Bay based on data from October 2019.

The score for the seagrass indicator category is the lowest score of the three indicators. This rule applies except when species composition is the lowest score and then the overall seagrass score is calculated as the average across the two lowest scoring indicators. 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			
Location	Site (meadow)	Biomass	Area	Species composition	**Seagrass indicator category**	Biomass	Area	Species composition	**Seagrass indicator category**
Geoffrey Bay	3	28	73	97	28	D	B	A	D
Nelly Bay	4	41	85	98	41	D	A	A	D
Cockle/Picnic Bay	5	60	89	98	60	C	A	A	C
Cockle Bay	6	66	50	97	50	B	C	A	C
Shelly Beach	10	68	51	96	51	B	C	A	C
Rowes Bay	12	60	100	69	60	C	A	B	C
Rowes Bay	14	55	74	87	55	C	B	A	C
Strand meadow	15	73	74	58	65	B	B	C	B
Cleveland Bay	16	59	100	94	59	C	A	A	C
Cleveland Bay	17/18	55	88	98	55	C	A	A	C
	Cleveland Bay				**52**				**C**

Scoring range: ■ Very Poor I = 0 to <25 | ■ Poor (D) = 25 to <50 | ■ Moderate (C) = 50 to <65 | ■ Good (B) = 65 to <85 | ■ Very Good (A) = 85 to 100

The Dry Tropics report cards have only been reporting on seagrass for three years, with the scores for each meadow presented in Appendix J. Three years of data is insufficient to assess trends, however there is long term data on seagrass data and this information is used below to discuss trends in seagrass condition.

Seagrass experienced a decline from a good condition in 2018 to moderate in 2019. "In most cases, above-ground biomass declines led to a drop in meadow condition with only three out of ten meadows maintaining their 2018 overall condition" (McKenna, et al., 2020). While no scores improved for any meadow metric, species composition shifted very little and meadow area scores dropped in four of the ten meadows (McKenna, et al., 2020). Despite the extreme flooding event in early 2019, seagrasses maintained a good foothold compared to previous major flooding impacts in 2010/2011 (McKenna, et al., 2020). However, average above-ground biomass declined, with the Cleveland Bay meadow (meadow 16) declining by 75% from its peak in 2018. The only meadow to not decline in biomass score was the intertidal *Zostera muelleri* meadow (Meadow 6) at Magnetic Island (McKenna, et al., 2020). Seagrass landscape coverage within most meadows maintained some continuous cover of seagrass, however meadows were patchier than the previous year, with aggregated and isolated patches (McKenna, et al., 2020). The combined area of meadows in Townsville remained similar to the area in 2018 and was the second highest total monitoring area (6,354 ± 758 ha) since monitoring began in 2007 (McKenna, et al., 2020). Dugong feeding trails were observed in six out of ten meadows and across Pallarenda, Magnetic Island and Cleveland Bay. Active dugong feeding was also observed in the Cleveland Bay subtidal meadow (Meadow 17/18) (McKenna, et al., 2020). The October 2019 peak season survey indicated that there may have been a 'lag effect' or legacy of the February floods, with seagrass density at coastal meadows not bouncing back to 'typical' peak season levels.

Preliminary data from April 2020 and September 2020 suggests that the overall condition of seagrasses in Townsville is showing good recovery from the declines following the February 2019 flooding (A. O'Brien, pers. comm., 3rd February 2021). An extensive footprint of seagrass was maintained in the greater port region and the area and biomass of most monitoring meadows were at or above long-term averages. The total footprint of the April 2020 CUSP meadows was ~ 15% larger than recorded during the previous April/May 2019 survey, and average seagrass biomass continued to increase in most meadows from October 2019. The recent April 2020 senescent season survey found that seagrass communities in the Channel Upgrade Seagrass Program (CUSP) meadows have made significant recovery since the February 2019 flood event. Continued persistence and growth of seagrasses in Townsville will be contingent on environmental conditions being favourable during the 2020 seagrass growing season, however results of the April 2020 senescent season survey suggest that they hold a reasonable level of resilience following the February 2019 flood event. Dugongs and their feeding trails in seagrass meadows were observed during both helicopter and boat-based field surveys suggesting ongoing wide use of the habitat as an important food source for megafauna.

Key messages:

- Overall, Cleveland Bay was in a moderate condition for seagrass condition. This score was a decline from the good score from the previous year. It is likely that the decline was attributed to the flood in February 2019. Surveys in 2020 suggest that seagrass is recovering following the floods.
- Both species composition and meadow area were in a good or very good condition for eight of the ten meadows.
- Biomass was the lowest scoring indicator, with Geoffrey Bay and Nelly Bay meadows receiving a poor score for biomass. The overall score for seagrass was based on the lowest scoring indicator, which for each meadow was biomass.

7.2.3 Overall habitat score

Overall, the habitat index received a moderate score 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.

	Standardised score			Grade		
Site	Coral	Seagrass	**Habitat index**	Coral	Seagrass	**Habitat index**
Cleveland Bay	44	52	**48**	C	C	**C**
Halifax Bay	52	ND	**52**	C	ND	**C**

Scoring range for coral: ■ Very Poor I = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81 to 100 | ■ No data (ND)

Scoring range for seagrass: ■ Very Poor I = 0 to <25 | ■ Poor (D) = 25 to <50 | ■ Moderate (C) = 50 to <65 | ■ Good (B) = 65 to <85 | ■ Very Good (A) = 85 to 100 | ■ No data (ND)

7.2.4 Confidence scores

There was a high confidence in the habitat index results for both Cleveland and Halifax bays, with the confidence result presented in Table 45. The score for each confidence criterion is shown in Table 45. Most seagrass beds within Cleveland Bay were monitored, resulting in a high 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. Within Halifax Bay, sampling by the MMP and LTMP occurred at a total of six reefs, with these reefs generally sampled every second year, which was considered moderate (2) for representativeness. The representativeness was higher than in the 2019-2020 Report Card (where it was 1.5) due to coral cover being sampled by Reef Check at an additional four reefs this year. The Reef Check data resulted in a grade change for coral cover within Cleveland Bay and therefore this data was considered sufficient to warrant an increase in the representativeness criterion.

Table 45. Confidence score for the habitat index 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).

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	3	3	3	3	2	12.8	Very high (5)
	Habitat index						**11.5**	**High (4)**
Halifax Bay	Coral	1.5	3	2	3	2	10.2	High (3)
	Habitat index						**10.2**	**High (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.

7.2.5 Comparing scores for the habitat index between years

The scores between the three years were similar, although there was a decline in the seagrass score in 2019-2020, most likely due to the impacts of the February 2019 flood (see Table 46). From 2018-19 to 2019-2020, there was a change in grade for coral (from a D to a C). However this is because 41 is the boundary for the grade change from poor (D) to moderate (C), with the score only changing 3 units between years. Across the three years, coral shows a slight improvement over the three years, however it is noted that only three years of data is insufficient to determine trends.

Table 46. Comparison of inshore coral, seagrass and overall habitat scores between 2019-2020, 2018-19 and 2017-18.
Habitat scores are averages of the scores for coral and seagrass.

	2019-2020 results (current year)			2018-19 results (last year)			2017-18 results (last year)		
Site	Coral	Seagrass	**Habitat index**	Coral	Seagrass	**Habitat index**	Coral	Seagrass	**Habitat index**

Cleveland Bay	44 C	52 C	**48 C**	38 D	74 B	**56 C**	33 D	78 B	**55 C**
Halifax Bay	52 C	ND	**52 C**	52 C	ND	**52 C**	47 C	ND	**47 C**

Scoring range: ■ Very Poor I = 0 to <25 | ■ Poor (D) = 25 to <50 | ■ Moderate (C) = 50 to <65 | ■ Good (B) = 65 to <85 | ■ Very Good (A) = 85 to 100 | ■ No data (ND)

8 Offshore marine

Two indices, water quality and habitat, were scored within the offshore marine scores.

8.1 Water quality results

Two indicator categories, chlorophyll *a* and physical-chemical (phys-chem) properties, were scored for the offshore marine zone. The indicators (chlorophyll *a* (Chl *a*) and total suspended solids (TSS) respectively) for these indicator categories were not directly sampled, but instead derived from remotely sensed data from the Bureau of Meteorology. The offshore zone was not broken down into smaller areas, meaning that a single score per each indicator and indicator category was reported. Additionally, the data is for the entire Burdekin offshore zone (which includes the Townsville offshore zone). Since waters from the Burdekin influence the Townsville region, it is appropriate to report on the scores for the entire Burdekin region.

8.1.1 Chlorophyll *a*, phys-chem properties (total suspended solids) and overall water quality

The scores for chlorophyll *a* and total suspended solids (TSS) were derived from remote sensing data processed through the BoM's eReefs dashboard. Scores were calculated based on relative area (%) of the water body that did not exceed the annual water quality threshold value. Overall water quality, chlorophyll *a* and TSS were in a very good condition for the offshore zone (Table 47).

Table 47. Results for water quality indicators and water quality index for the offshore marine zone in 2018-19.

Chlorophyll *a* is abbreviated as Chl *a*, total suspended solids is abbreviated as TSS and physical-chemical properties is abbreviated as phys-chem properties. The overall water quality score is the average of the scores for the two indicators, chlorophyll a and phys-chem properties.

Indicator category	Indicator	Score	Grade	Overall Score for Water Quality	Grade
Chlorophyll *a*	Chl *a*	100	A	100	A
Phys-chem properties	TSS	100	A		

Scoring range: ■ Very Poor I = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81 to 100

Key messages:

- Chlorophyll *a*, total suspended solids and overall water quality were in a very good condition for the offshore zone.

8.1.2 Confidence scores

There was low confidence in the scores for the offshore zone (see Table 48). This was due to both indicators being indirect measures of water quality characteristics. The data was also derived from remote sensing data, with the data not measured in the field to verify the remote sensing results. During 2019-20 there were limitations in the technical support for maintaining the Marine Water Quality (MWQ) processing scripts and satellite data streams (from which the data are sourced). Consequently, the more recent data for the 2019-20 time series may be of lower quality than earlier time series data, as data may not be calibrated properly. Therefore there is low accuracy (1 out of 3) in the representativeness of the data.

Of note in early 2021, the Bureau of Meteorology advised that the MWQ dashboard had been decommissioned and that the underlying data preparation workflow is likely to be discontinued during the year. Alternative data sources are to be identified for reporting offshore water quality for the 2020-21 reporting year and onwards.

Table 48. 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*	2	1	2	1	1	6.9	Low (2)
Phys-chem (TSS)	2	1	2	1	1	6.9	Low (2)
Water Quality index						**6.9**	**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.

8.1.3 Comparing scores for water quality between years

The scores were very similar to last year, with both 2019-2020 and 2018-19 receiving very good scores (Table 49). Offshore water quality was not scored in 2017-18.

Table 49. Comparison of inshore marine water quality scores between 2018-19 and 2019-2020.

	2019-2020 results (current year)			2018-19 results (last year)		
Site	Chlorophyll *a*	Total suspended solids	Overall water quality	Chlorophyll *a*	Total suspended solids	Overall water quality
Offshore	100 A	100 A	**100 A**	99 A	95 A	**97 A**

Scoring range: ■ Very Poor I = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81 to 100

8.2 Habitat results

Coral was the only indicator measured within the habitat index and thus provides the overall score for this index.

8.2.1 Coral

Coral was measured at 17 reefs by the Australian Institute of Marine Science (AIMS) Long-term Monitoring Program (LTMP). Reef Check also sampled coral cover at John Brewer Reef (which was also sampled by LTMP) and Lodestone Reef. Coral cover scores were weighted to reflect the differences in the precision and accuracy of the sampling programs and then combined into an overall score. The locations of the sampled reefs are shown in Figure 21.

Figure 21. Location of coral reefs (outlined in purple) that were sampled in the Townsville offshore marine zone.

8.2.1.1 *Results*

The overall condition of coral within the offshore marine zone was moderate, with the scores and grades shown in Table 50. Overall, the rate of change in coral cover was poor, with 56% of reefs sampled (nine of 16 reefs) scoring very poorly or poorly for this indicator (Table 50). Only one reef recorded a good score for change in cover (Table 50). The percent coral cover was also poor, with 59% of reefs sampled (10 of 17 reefs) scoring poorly or very poorly (Table 50). However, juvenile recruitment was very good for the offshore zone, with all 16 sampled reefs receiving a good or very good score (Table 50).

Table 50. Scores and grades for coral indicators and the coral indicator category for the offshore marine zone.

LTMP stands for the Great Barrier Reef Long-Term Monitoring Program. The score for the coral indicator category is the average of each indicator score. The overall score for percent (%) coral cover for the zone was weighted by monitoring program, but the individual scores for the reefs were not weighted to allow comparison with other indicators. Note that these scores are not a direct reflection of the underlying measured value, but rather just a standardised score. Significant figures differ between values for ease of reading.

		Standardised scores				Grades			
Site (Reef)	Monitoring program	% Change in coral cover	% Coral cover	Juvenile density	Coral indicator category	% Change in coral cover	% Coral cover	Juvenile density	Coral indicator category
Centipede Reef	LTMP	49	29	97	58	C	D	A	C
Chicken Reef	LTMP	62	60	100	74	B	C	A	B
Davies Reef	LTMP	51	58	100	70	C	C	A	B
Dip Reef	LTMP	37	31	96	54	D	D	A	C
Fore & Aft Reef	LTMP	29	43	100	57	D	C	A	C
Fork Reef	LTMP	48	38	100	62	C	D	A	B
Grub Reef	LTMP	0	11	83	31	E	E	A	D
Helix Reef	LTMP	49	44	100	64	C	C	A	B
John Brewer Reef	Both LTMP and Reef Check	35	35	74	48	D	E	B	C
Kelso Reef	LTMP	0	38	100	46	E	D	A	C
Knife Reef	LTMP	31	59	100	64	D	C	A	B
Little Kelso Reef	LTMP	34	51	80	55	D	C	A	C
Lynch's Reef	LTMP	52	28	92	57	C	D	A	C
Myrmidon Reef	LTMP	31	50	79	53	D	C	B	C
Rib Reef	LTMP	0	13	76	30	E	E	B	D
Roxburgh Reef	LTMP	96	35	67	66	A	D	B	B
Lodestone Reef	Reef Check	ND	23	ND	ND	ND	D	ND	ND
Offshore marine zone		**38**	**39**	**90**	**56**	**D**	**D**	**A**	**C**

Scoring range: ■ Very Poor I = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <80 | ■ Very Good (A) = 80 to 100 | ■ No data (ND)

During the 2019-2020 late summer, a mass coral bleaching event occurred after a prolonged and widespread marine heatwave and affected reefs in this region (Australian Institute of Marine Science, 2020). "The COVID-19 pandemic disrupted fieldwork and as a result, surveys were not conducted at the height of the recent bleaching event" (AIMS, 2020). "Reefs offshore from Townsville were surveyed in June 2020 and, despite being winter, many reefs were still bleached at low to moderate levels" (AIMS, 2020). The full impact of the 2019/2020 mass coral bleaching will be assessed during the next field season (in late August 2020) (AIMS, 2020).

Crown-of-thorns starfish (COTS) have affected reefs within the Townsville region within recent years (AIMS, 2020). During 2019-2020 there were no active outbreaks COTS within the region and only Kelso Reef was classified as being a potential outbreak (AIMS, 2020). However, COTS continue to pose a threat to corals, particularly juvenile corals, and future outbreaks could detrimentally impact upon the ability of coral to recover. Although juvenile density is currently high, this may change if COTS impacts upon these juveniles.

Key messages:

- Overall, coral condition was moderate within the offshore marine zone.
- More than 50% of reefs surveyed scored poorly or very poorly for the rate of change in coral cover and percent of coral cover. Coral cover is in a poor condition due to thermal stress, with three years of coral bleaching within the last five years, and crown-of-thorns starfish (COTS) predating on corals. These factors, and particularly thermal stress, has resulted in substantial loss of coral and has impacted the ability of corals to grow.

- Juvenile density remained high at all 16 reefs surveyed indicating ongoing resilience despite recent disturbances. The scores for juvenile density improved the overall (averaged) scores for coral condition. Without these very good juvenile density scores, the overall score would have been poor. Although juvenile density is high, COTS has the potential to cause large declines of juveniles.
- A mass coral bleaching event occurred in 2019-2020, with low to moderate levels of corals bleached at most reefs surveyed in June 2020. The full impacts of that disturbance may not yet have been captured.

8.2.1.2 *Confidence scores*

There was a high confidence in the overall coral indicator category score based on when sampling occurred (Table 51). This score was mostly driven by the representativeness category being ranked as moderate (2), as 33% of offshore reefs within the Townsville region were measured (Table 51).

Table 51. 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 (x 0.36)	Validation (x 0.71)	Represent-ativeness (x 2)	Directness (x 0.71)	Measured error (x 0.71)	Final score	Rank
Coral	3	3	2	3	1	10.1	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.

8.2.1.3 *Comparing scores for offshore coral between years*

The scores were similar between the three years (from 2017-18 to 2019-2020), although the percent change in coral cover, juvenile density and the overall score for coral has continued to decline from the 2017-18 report. Although three years of data is not sufficient to establish definitive trends, AIMS has been conducting reef surveys for over 30 years on the health of 47 midshore and offshore reefs across the Great Barrier Reef (AIMS, 2020). For the Townsville Dry Tropics region, since 2016, hard coral cover has declined continuously due to repeated mass coral bleaching events in 2016, 2017 and 2020 and due to COTS outbreaks (AIMS, 2019; AIMS, 2020).

Table 52. Comparing offshore coral scores between 2019-2020, 2018-19 and 2017-18.

2019-2020 results (current year)				2018-19 results (last year)				2017-18 results (Pilot report)			
% Change in coral cover	% Coral cover	Juvenile density	**Coral indicator category**	% Change in coral cover	% Coral cover	Juvenile density	**Coral indicator category**	% Change in coral cover	% Coral cover	Juvenile density	**Coral indicator category**
38 D	39 D	90 A	**56 C**	49 C	35 D	94 A	**59 C**	51 C	34 D	97 A	**61 B**

Scoring range: ■ Very Poor I = 0 to <21 | ■ Poor (D) = 21 to <41 | ■ Moderate (C) = 41 to <61 | ■ Good (B) = 61 to <81 | ■ Very Good (A) = 81 to 100

9 Litter

Data were collected in the field by volunteers as part of Tangaroa Blue clean-up events. The locations of the clean-up events are shown in Figure 22.

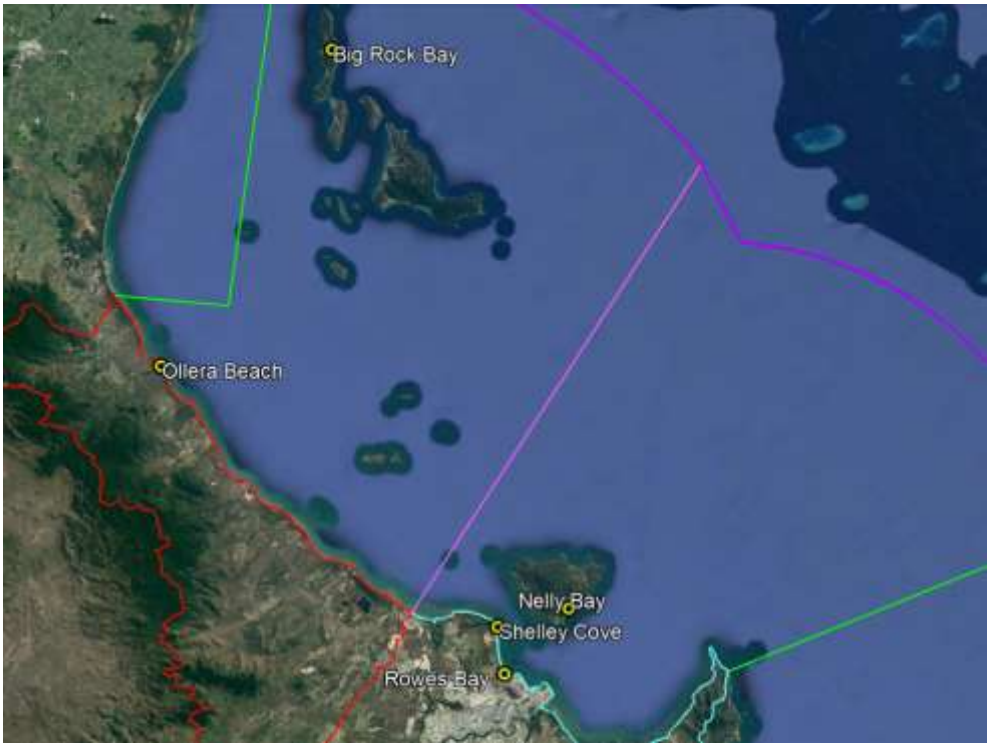


Figure 22. Location of Tangaroa Blue litter clean ups between July 2019 and February 2020 year (yellow dots).

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.

9.1 Results

Site specific results for litter (collected in organised clean up events) are shown in Table 53. Data was only available for five sites. The scores are based on the amount of rubbish collected compared to the annual average amount of rubbish collected between 2014-2018 in clean up events within each zone. At Rowes Bay and Shelly Cove Beach litter only posed a slight pressure to the sites at the time the clean-up events occurred. At Ollera Beach, litter posed a very high pressure upon the environment compared to 2014-2018 levels. At both Nelly Bay Beach and Big Rock Bay on Orpheus Island, litter posed a moderate pressure on the sites.

Table 53. Scores and grades for the litter metric for the Ross freshwater, Ross and Black estuarine zone and Cleveland and Halifax bays between July 2019 and February 2020.

Zone	Site	Standardised scores	Grades
Ross estuarine zone	Rowes Bay	83	SP
Ross estuarine zone	Shelly Cove	97	SP
Black estuarine zone	Ollera Beach	20	VHP
Cleveland Bay	Nelly Bay Beach	53	MP
Halifax Bay	Big Rock Bay, Orpheus Island	50	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

There were substantially fewer public events throughout 2020 due to the social distancing restrictions enforced due to the outbreak of Covid-19. Large-scale public events can generate a high volume of disposable materials (Enviromental Protection Agency, 2020), whilst tourism also can increase the amount of tourist-sourced litter (such as cigarette butts) within a location, especially in areas that are popular for tourists (Wilson & Verlis, 2017). However, during Covid-19 take-out increased (as restaurants closed) and this many have increased the amount of rubbish, especially in more remote areas (S. Duce, pers. comm., 2021). The result for the 2019-2020 year may thus not be representative of the usual amount of litter within the environment.

It is noted that only some clean-ups conducted between July 2019 and February 2020 were included in the results, as only half the data currently available to the Partnership.

Key messages:

- Five sites were scored during 2019-2020, with insufficient data to produce an overall score for a zone.

- Litter posed a slight pressure on Rowes Bay and Shelly Cove Beach at the time the clean-up events occurred. This score was based on comparing the amount of rubbish collected against the average amount of rubbish within the area between 2014-2018.
- At Ollera Beach, litter posed a very high pressure upon the environment compared to 2014-2018 levels.
- At both Nelly Bay Beach and Big Rock Bay on Orpheus Island, litter posed a moderate pressure on the environment.

9.1.1 Confidence scores

As presented in Table 54, there was very low confidence in the scores for the litter reporting category in both 2019 and 2020. This is because there was very limited spatial and temporal sampling and there is no measured error.

Table 54. 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.

9.1.2 Comparing results with last year

The results in the amount of litter within the environment varied substantially between the two years, with the scores shown in Table 55. However the differences in scores were driven by a different number of clean-up events and different locations being cleaned between the two years. Additionally, around 40% of the data was filtered out (‘cleaned up’) prior to being given to the Partnership, which means the scores are likely to be improved compared to last year. It is hoped that next year non-filtered data will be provided to the Partnership to allow for more accurate estimates of litter trends.

The amount of litter at a site can vary substantially between sites depending on the length of time between when clean-up events occurred. The Partnership is currently working with local community groups to develop regular clean up events at specific sites, with the aim of establishing trends in the abundance of litter for specific sites.

In 2019-2020, there is no overall score for a zone. This was because there were too few sites sampled for the data to be extrapolated for an entire zone. In the 2018-19 year, across all of Townsville, litter was collected at 11 sites within four reporting zones, with between one and four clean up events within each zone. The scores for the 2018-19 year are likely to be more accurate due to more data being collected.

Of note, the two sites (Rowes Bay and Nelly Beach Bay) that were sampled in both years recorded similar results both years. For example, Rowes Bay within the Ross estuarine zone, was scored at 79 (classified as a low pressure on the environment) in 2018-19 and then was marginally cleaner, with a score of 83 (classified as a slight pressure) in 2019-2020. Nelly Bay Beach (Cleveland Bay) received a score of 46 (moderate pressure) in 2018-19 and 53 (moderate pressure) in 2019-2020. This suggests at these sites, litter pressure remains similar between the years.

Table 55. Scores and grades for the litter metric for the Ross freshwater, Ross and Black estuarine zone and Cleveland and Halifax bays for the 2018-2019 and 2019-2020 financial years.

		Standardised scores		Grades	
Zone	Site	2018-19	2019-2020	2018-19	2019-2020
Ross freshwater basin	Aplin's Weir Rotary Park*	**7**	ND	**VHP**	ND
Ross estuarine zone	Rowes Bay	79	83	LP	SP
	Pallarenda Beach	56	ND	MP	ND
	Toolakea	47	ND	MP	ND
	Shelly Cove, Cape Pallarenda Conservation Park	51	97*	MP	SP
	Overall	**58**	Insufficient data	**MP**	**SP**
Black estuarine zone	Ollera Beach	ND	20	ND	VHP
	Balgal Beach	81	ND	SP	ND
	Balgal Beach North	52	ND	MP	ND
	Overall	**66**	Insufficient data	**LP**	**VHP**
Cleveland Bay (all sites on Magnetic Island)	Geoffrey Bay	87	ND	SP	ND
	Nelly Bay Beach	46	53	MP	MP
	Alma Bay	80	ND	LP	ND
	Horseshoe Bay	96	ND	SP	ND
	Overall	**77**	Insufficient data	**LP**	**MP**
Halifax Bay	Big Rock Bay, Orpheus Island	ND	50	ND	**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 data (ND)

*Clean-up was conducted as a Reef Clean clean-up site, whereby clean ups are standardised along a transect.

Data from only one Reef Clean event was provided for the 2019-2020 Report Card. Reef Clean events are standardised clean-ups that occur along set transects and are designed to allow more accurate comparisons between years. There are two Reef Clean clean-up sites within the Townsville region and it is hoped that in the future the Dry Tropics Partnership will be able to report upon both Reef Clean sites. It is also recommended that some other sites are regularly cleaned up to allow more accurate comparisons between sites and zones.

10 Urban water stewardship framework

10.1 Reasoning for the urban water stewardship framework

Nutrients, sediments and pesticides are pollutants that affect the resilience of coral reefs and are also key nutrients and sediments derived from urban areas. Understanding and addressing the loads of these nutrients and sediments from urban landscapes to the Great Barrier Reef lagoon may contribute to achieving water quality improvement targets set out in the Reef 2050 Water Quality Improvement Plan.

Environmental stewardship is demonstrated through investment in technology or practices that meet or exceed standards for minimising or avoiding environmental harm, with the intent to enhance the receiving environment.

The framework was developed over approximately two years with input from local Councils. A Pilot workshop was undertaken in Townsville in 2019. The framework has aspects that both councils and the development industry can assess themselves against. However, in 2019-2020 the assessment is focused on assessing Council's urban water management responsibilities.

10.2 Purpose of the urban water stewardship framework

Nutrient and sediment loads can potentially emanate from urban areas under development for residential, commercial, or industrial purposes and are frequently associated with the mobilisation of soils. The main purpose of the Urban Water Stewardship Framework (UWSF) is to assess and report the level of stewardship that urban water managers are undertaking to improve water quality in GBR catchments to address pollutant loads from urban areas (Office of Great Barrier Reef (OGBR), 2021). The framework is used as a tool for assessing and reporting on the level of practice being applied by local governments and by the development and construction sector to manage a) sediment and nutrient loads associated with erosion during the construction phase, b) stormwater runoff during the post-construction phase, and c) sewage wastewater treatment plant releases. The framework also covers water management activities relating to greenfield development, brownfield development and operating and maintaining sewerage networks (OGBR, 2021). These activities contribute to sediment and nutrient loads entering the Great Barrier Reef lagoon. While the amounts of nutrient and sediment entering the GBR from urban areas are relatively small compared to the amounts generated though run-off from agricultural land, they potentially represent a locally significant impact if not managed effectively (OGBR, 2021). Thus, it is important to report upon then. By assessing how well these activities are undertaken, the UWSF provides a metric for measuring management practice change over time and the extent of land under best practice management within the Great Barrier Reef catchment. This can be used to determine whether management practices are helping to improve water quality over time, which is an objective under the Reef 2050 Water Quality Improvement Plan (Reef 2050 WQIP).

Being able to assess the effectiveness of land use management in urban areas within the GBR catchment is an action in the Reef 2050 WQIP (OGBR, 2021). The Reef 2050 WQIP applies to all land-based water pollution that affects water quality in the GBR catchments, including urban and industrial land use, along with agriculture (OGBR, 2021). Thus it is important to assess the urban impacts.

10.3 Method

As per the method outlined in the UWSF Implementation Manual version 2.0 (Department of Environment and Science, 2020), a workshop process was undertaken to collect UWSF assessment data. Apart from data collection, the workshop allowed the sharing of information between participants from different sections of Council. It is expected that this workshop style of data gathering will improve working relationships among stakeholders. This may potentially improve management outcomes for councils, such as furthering total water cycle management outcomes, increasing understanding from the regulator and fewer compliance issues with developers.

Two workshops were undertaken, split up into three reporting components, which are:

1. Activities that may contribute to diffuse pollution associated with **Developing Urban** areas.
2. Activities that may contribute to diffuse pollution associated with **Established Urban** areas.
3. Activities that may contribute to **Point Source** pollution (associated with sewage treatment and management).

Point source pollutants were discussed at one workshop, whilst diffuse source pollution (from both the developing and established environment) was discussed in the second workshop. Key outcomes from the point source workshop were discussed at the beginning of the diffuse workshop, to ensure the information was shared across disciplines. The workshops were held in February 2021, but participants reported on experiences from the 2019-2020 financial year. The workshops were attended by a diverse range of personnel from within council, including staff from the catchment management team, an asset and hydraulic coordinator, a stormwater engineer, a strategic planner/policy personnel, a wastewater engineer, a wastewater operator/wastewater engineer and a assess management staff member.

The point source workshop was attended by six staff from Townsville City Council (TCC). Twelve TCC staff members and one industry representative attended the diffuse workshop. For the point source workshop, one participant had cross-referenced with management plans to verify the answers to some questions. All other questions for the point source and diffuse source workshops were answered based on expert knowledge from people who worked in that field.

Under the framework, urban water management activities are classified into 16 management activity groups (MAGs) across the three reporting components, with each MAG having a similar management objective. Each MAG was then scored to assess how well the objectives were being achieved. In total there were 28 questions relating to developing urban, 21 questions relating to established urban and

17 questions relating to point source pollutants. The MAGs and questions related to four framework elements, which were:

1. Policy, Planning and Governance
2. Infrastructure Management and Maintenance
3. Social Approaches
4. Monitoring, Evaluation, Review and Improvement.

The first, second and fourth element point above are common components in a 'classic' planning and implementation cycle (i.e. Plan – Do –Review). The third dot point, social approaches, is an enabling element that is integrated within and supports the planning and implementation cycle. It incorporates many of the stewardship-related activities and includes community education and involvement programs, as well as collaborative research and development and capacity building. A description of each of the MAGs that were scored for each reporting component (point source, established urban and developing urban) and the framework element to which the MAG relates is shown in Table 56. The framework elements are essentially the general themes of each MAG and are listed to provide an easy-to-understand description of what each MAG relates to.

Table 56. A description of the management activity groups (MAG), the framework elements (general themes) for each MAG and a description of the general theme of the MAG for questions relating to the three reporting components (point source, established urban and developing urban).

Component	Framework elements	Detailed description of the general theme	MAG	Management activity goal (description)
Developing urban (diffuse source pollutants)	Planning and Governance	• Policy, planning and governance	1	Stormwater infrastructure planning and design is continually improving to support more effective total water cycle management.
			2	The development assessment process promotes and supports improved water quality in terms of reducing sediment loads.
			3	Site based stormwater management planning can deliver water quality improvement.
	Infrastructure Management and Maintenance	• Site based stormwater management and erosion prevention and sediment movement control	4	Continuous improvement in stormwater management practices on development and construction sites and reduced sediment loads reaching receiving waters.
	Social Approaches	• Collaboration and partnerships • Capacity building and learning	5	Increased capacity to apply best practice ESC principles to deliver effective ESC measures on site and as part of ESC compliance auditing.
	Monitoring, Evaluation, Reporting and Improvement	• Monitoring, evaluation and improvement • Reporting	6	Risk of severe erosion impacts reduced through site inspections at appropriate times and the monitoring and reporting of stormwater runoff treatment.
Established urban (diffuse source pollutants)	Planning and Governance	• Catchment based and regional planning	1	Continuous improvement in catchment management through integrated total water cycle planning and design.
			2	Continuous improvement in stormwater system management through integrated total water cycle planning.
	Infrastructure Management and Maintenance	• Urban stormwater system (USS) management • USS retrofits and infill development	3	Reduction in water quality pollutants leaving established urban areas.
	Social Approaches	• Collaboration and partnerships • Capacity building and learning	4	Increased capacity to implement catchment based total water cycle management and landscape restoration through collaboration with industry and the community.
	Monitoring, Evaluation, Reporting and Improvement	• Monitoring, evaluation and improvement • Reporting	5	Greater knowledge base to improve the way catchment and water management activities are implemented to achieve the desired outcomes.
Point source	Planning and Governance	• Policy, planning and governance • Catchment based regional planning	1	Fewer license exceedances and reduced nutrient loads released to water because of WSP actively pursuing strategies for reducing discharge, including managing issues associated ageing STP infrastructure before they get critical; and maximising the use of recycling and beneficial reuse options.
	Infrastructure Management and Maintenance	• Sewerage network management and maintenance • Planning for new STP and sewerage network infrastructure or upgrades	2	Potential for failure reduced through effective planning of sewerage network asset management and maintenance activities.
			3	The capacity of wastewater treatment plant assets with respect to expected population increases is managed through effective collaboration between the WSP with other parts of council and State Planning and additional wet weather overflow nutrient loads linked to Infiltration and Illegal Connection (I&I) issues are well understood and mitigated.
	Social Approaches	• Collaboration and partnerships • Capacity building and learning	4	Innovative approaches and whole of catchment total water cycle management solutions to reduce nutrient loads achieved through effective networks and collaborations. Reduced frequency of unplanned releases achieved through effective staff capacity building and training. Further nutrient emission reductions are achieved through customer education and improved influent quality.
	Monitoring, Evaluation, Reporting and Improvement	• Monitoring, evaluation and improvement • Reporting	5	Environmental impacts of releases reduced through effective monitoring, early detection and ongoing reporting, review and improvement.

To align the Urban Water Stewardship Framework with the other sections in this report, the questions within the MAGs represent the indicators, the MAGs represent the indicator categories, whilst the three reporting components (point source, established urban and developing urban) represent the indices.

Each activity within each MAG was assigned a management practice rating of A to D, which was derived through a collaborative and transparent discussion with all participants. The rating scale is shown in Table 57. Mentimeter (an online polling and presentation software) was used to ensure that all participants participated in the workshop and answered the questions. Participants individually entered their answer (rating of A to D) for each question and then the results of the group for each question were displayed. Any differences in scores were discussed and a score for each question was then decided upon by the group. Based on the ratings chosen, the weighted scoring system applied as part of the UWSF assessment process was then used to calculate MAG scores and ratings. MAG ratings were generated to provide council with an understanding of how they were tracking in terms of meeting the operational objectives assigned to each MAG (MAG goals shown in Table 56). These MAG scores were then averaged to produce a score for the relevant framework component. Component scores were then averaged to produce an overall urban water management score for the Townsville urban footprint. Since the TCC is the only Council within the Townsville region, the score for TCC is applied to the regional Townsville Dry Tropics.

Table 57. Score and rating categories for the urban water stewardship framework.

Rating	Rating description	Water Quality Risk Level	Score
A	Innovative/Above best practice performance	Low	>17.5
B	Current best practice performance	Moderately-low	12.5-17.4
C	Performing to current minimum standard	Moderate	5.0-12.4
D	Outdated performance	High	<5.0

10.4 Results

Overall, urban water stewardship for the Townsville Dry Tropics was rated as a C, which equates to minimum industry standard (i.e. general compliance with regulations and applying management practices that, whilst not best practice, are in line with those commonly used in Queensland). Management practices associated with Developing Urban, Established Urban and Point Source all received an overall rating of C (current minimum standard). A ‘C’ rating equates to a moderate level of risk to water quality, which implies either maintenance of the status quo or a chance of slight deterioration in water quality. The scores and grades for each MAG and the overall scores for the three reporting components are shown in Table 58, with the general theme of the MAGs also shown.

Table 58. Scores and grades for each management activity group (MAG) and the overall scores for the three reporting components (diffuse source, establish urban and developing urban) of the Urban Water Stewardship Framework.

Significant figures differ for ease of presentation.

Reporting component	Framework element	Management activity group	Score	Grade
Developing urban	Planning and Governance	1	10	C
		2	7	C
		3	7	C
	Infrastructure, Management and Maintenance	4	8	C
	Social Approaches	5	8	C
	Monitoring, Evaluation, Reporting and Improvement	6	17	B
		Overall	**9**	**C**
Established urban	Planning and Governance	1	10	C
		2	10	C
	Infrastructure Management and Maintenance	3	6	C
	Social Approaches	4	19	A
	Monitoring, Evaluation, Reporting and Improvement	5	8	C
		Overall	**10**	**C**
Point source	Planning and Governance	1	12	C
	Infrastructure Management and Maintenance	2	10	C
		3	13	C
	Social Approaches	4	13	B
	Monitoring, Evaluation, Reporting and Improvement	5	12	C
		Overall	**12**	**C**

Scoring range: ■ Performing to outdated standards (D) = 0 to <5 | ■ Performing to current minimum standard (C) = 5 to 12.4 | ■ Performing to current best practice performance (B) = 12.5 to 17.4 | ■ Performing to above best practice performance (A) = >17.4

Thirteen of the 16 MAGs were assessed as being at minimum standard. This suggests that most management activities have room for improvement and further investigation should be done to determine how this can best be done (including what practice level can realistically be achieved based on the constraints and competing issues that need managing in this region). Infrastructure, management and maintenance MAGs had the lowest or second lowest scores across all three reporting components, as shown in Table 58. At the workshops, it was highlighted that although there are often planning and policy documents in place, there was often a lack of staff or resources (time) to undertake maintenance or follow up on any issues. For example, although site inspections, such as sediment control inspections, were undertaken, there was often limited resources (staff and time) to follow up on any compliance issues.

Three MAGs (MAG 6 in the developing urban component and MAG 4 in the point source and established urban) were rated at or above best practice. MAG 6 related to council undertaking site inspections of soil sediment control measures and monitoring and reporting of stormwater runoff treatment. However, it was noted in the meetings that monitoring the impacts did not necessarily equate to reducing the impacts, as it was difficult to ensure compliance with sediment control measures. Both the MAGs 4 were related to social approaches, including collaboration, partnerships, capacity building and learning. Within TCC, various collaborations and partnerships have been established, including PhD students studying pollutants within the wastewater system and TCC hosting the Dry Tropics Partnership. Additionally, there is a water educator and a wastewater educator, whose roles are to educate mostly school children about topics such as conserving water, recycling and water and waste sustainability. This indicates that management practices associated with social approaches are advanced and indicative of a high level of stewardship.

Key messages:

- Management practices associated with Developing Urban, Established Urban and Point Source all received an overall rating of C (current minimum standard). A 'C' rating equates to a moderate level of risk to water quality, which implies either maintenance of the status quo or a chance of slight deterioration in water quality.
- Thirteen of the 16 MAGs were assessed as being at minimum standard. This suggests that most management activities have room for improvement.
- Townsville City Council was rated at or above best practice for two management activity groups (MAGs) relating to social approaches, including collaboration, partnerships, capacity building and learning.
- Infrastructure, management and maintenance MAGs had the lowest or second lowest scores, with a lack of resources cited as an issue when following up on maintenance or compliance issues.

10.5 Confidence scores

Overall, there was moderate confidence in the scores, with the rank for each criterion and the rational for each rank shown in Table 59. The spatial representativeness has a very high weighting (2.4) compared to the other criterion (between 0.3 and 1.5). Thus, the score for the spatial representativeness strongly influences the results. There is only one council to assess within the Townsville Dry Tropics and therefore Townsville automatically achieves a rank of 3 (high) for this criterion. The high weighting for this criterion is potentially positively biasing the results.

Table 59. Confidence associated with Urban Water Stewardship Results for the 2020-21 monitoring period.
Confidence criteria are scored 1-3 and then weighted by the value identified in parenthesis. Final scores (6 – 18) are additive across weighted confidence criteria. Summary rationales are given below each criterion.

	Maturity (x0.3)	Validation (0.6)	Spatial Represent-ativeness (x2.4)	Temporal Represent-ativeness (x1.5)	Directness (x0.6)	Measured error (x0.6)	Final score	Rank
Scores	2	1	3	1	1	1	**11**	**Moderate (3)**
Rationale	UWSF ratings based on Reef Water Quality Independent Science Panel -endorsed method	Minimal reference to use of primary data for UWSF activity ratings.	All councils (one) in the report card region were included in the assessment.	This is the first year the finalised UWSF assessment method was done in the region (a pilot was done in 2019)	The UWSF assessment process was based on the most common scenario (i.e. not to a particular case).	No measure of error quantified.		

Rank based on final score: 1 (very low): 6 – 8.4; 2 (low): >8.4 – 10.8; 3 (moderate): >10.8 – 13.2; 4 (high): >13.2 – 15.6; 5 (very high): >15.6 – 18.

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].

Australian Institute of Marine Science, 2020. *Annual Summary Report on coral reef condition for 2019/20. Initial recovery of the Great Barrier Reef threatened by the third mass bleaching event in five years,* Townsville: Australian Institute of Marine Science.

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 (BOM), 2021a. *2020 marine heatwave on the Great Barrier Reef,* Canberra: Bureau of Meterology.

Bureau of Meteorology (BOM), 2021b. *Annual climate statement 2020: Sea surface temperatures equal-fourth-warmest on record for the Australian region as a whole.* [Online]
Available at: http://www.bom.gov.au/climate/current/annual/aus/#tabs=Sea-surface-temperature
[Accessed 21 April 2021].

Bureau of Meteorology, 2021. *Regional Water Information.* [Online]
Available at: http://www.bom.gov.au/water/rwi/index.shtml#ra_pa/152/2020
[Accessed 27th January 2021].

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].

Bureau of Meterology, 2021. *Queensland in 2020: warm across the state; dry in the east.* [Online]
Available at: http://www.bom.gov.au/climate/current/annual/qld/summary.shtml
[Accessed 19 April 2021].

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 Agriculture, W. a. t. E., 2016b. *Urban development Biodiversity 2016 Austraila State of the Environment 2016,* Canberra: Department of Agriculture, Water and the Environment.

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 and Science, 2020. *Urban Water Stewardship Framework Implementation Manual -Version 2.0,* Brisbane: Office of Great Barrier Reef.

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.

Enviromental Protection Agency, 2020. *Recycling and reuse. Waste wise events. What is a waste wise evenet?.* [Online]
Available at: https://www.epa.nsw.gov.au/your-environment/recycling-and-reuse/business-government-recycling/waste-wise-events
[Accessed 24 March 2021].

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.

Garde, L., Spillman, C., Heron, S. & Beeden, R., 2014. ReefTemp Next Generation: A New Operational System for Monitoring Reef Thermal Stress. *Journal of Operational Oceanography,* Issue 7, pp. 21-33.

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].

McGrane, S., 2016. Impacts of urbanisation on hydrological and water quality dynamics, and urban water management: a review. *Hydrological Sciences Journal,* 61(13), pp. 2295-2311.

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

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.

NOAA Satellite and Information Service (National Environmental Satellite, Data, and Information Service (NESDIS)), 2021. *Daily Global 5km Satellite Coral Bleaching Heat Stress Monitoring.* [Online]
Available at: https://coralreefwatch.noaa.gov/product/5km/
[Accessed 30 April 2021].

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].

Office of Great Barrier Reef (OGBR), 2021. *Urban Water Stewardship Framework factsheet,* Brisbane: Office of Great Barrier Reef.

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.

Thompson, A. et al., 2021. *Marine Monitoring Program Annual Report for Inshore Coral Reef Monitoring: 2019–20. Report for the Great Barrier Reef Marine Park Authority,* 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., 2021. *Methods for the Townsville Partnership for Healthy Waters (Dry Tropics) annual report cards,* Townsville: Dry Tropics Partnership for Healthy Waters.

Wilson, S. & Verlis, K., 2017. The ugly face of tourism: Marine debris pollution linked to visitation in the southern Great Barrier Reef, Australia. *Marine Pollution Bulletin,* 117(1-2), pp. 239-246.

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.

Appendix A. Distribution (boxplots) of freshwater water quality data.

The following figures are box and whisker plots (boxplots) of water quality indicators at all freshwater water quality monitoring sites. 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).

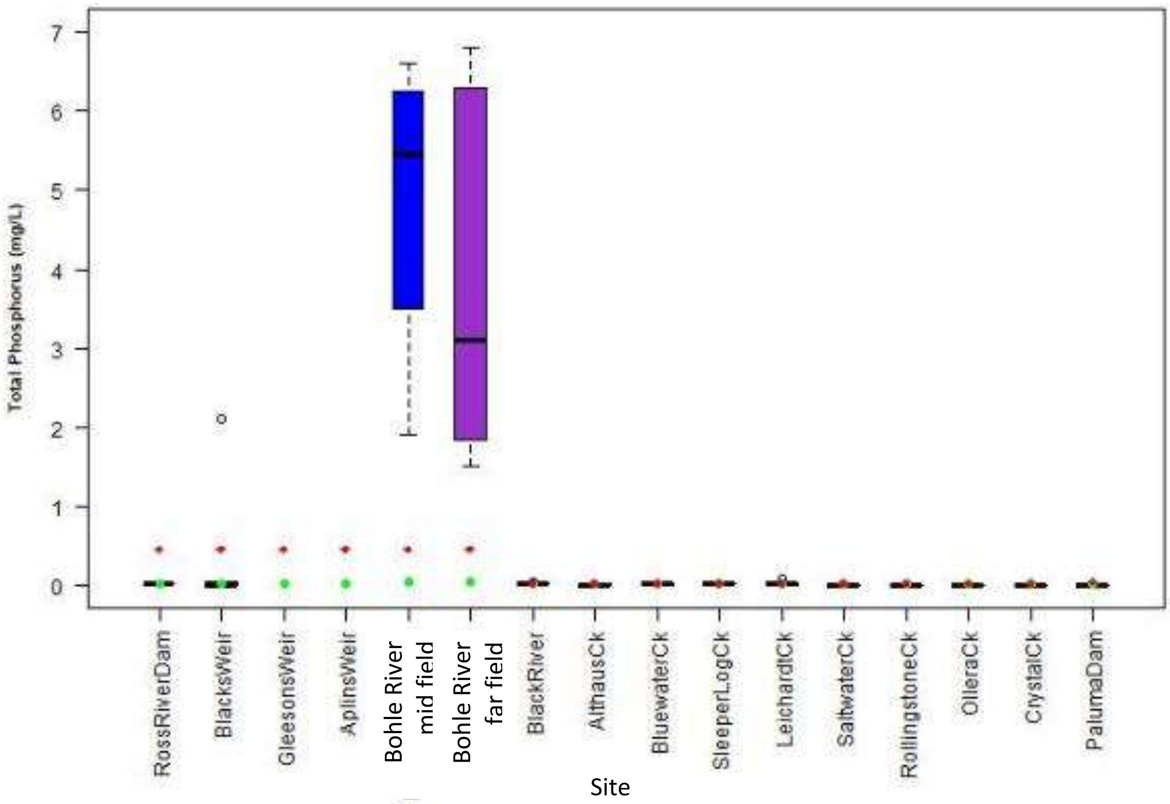


Figure Appendix A1. Boxplot of total phosphorus concentrations at each freshwater monitoring site.
The green circles indicate the water quality objectives (WQOs) and the red circles show the scaling factors. Outliers are shown as clear circles.

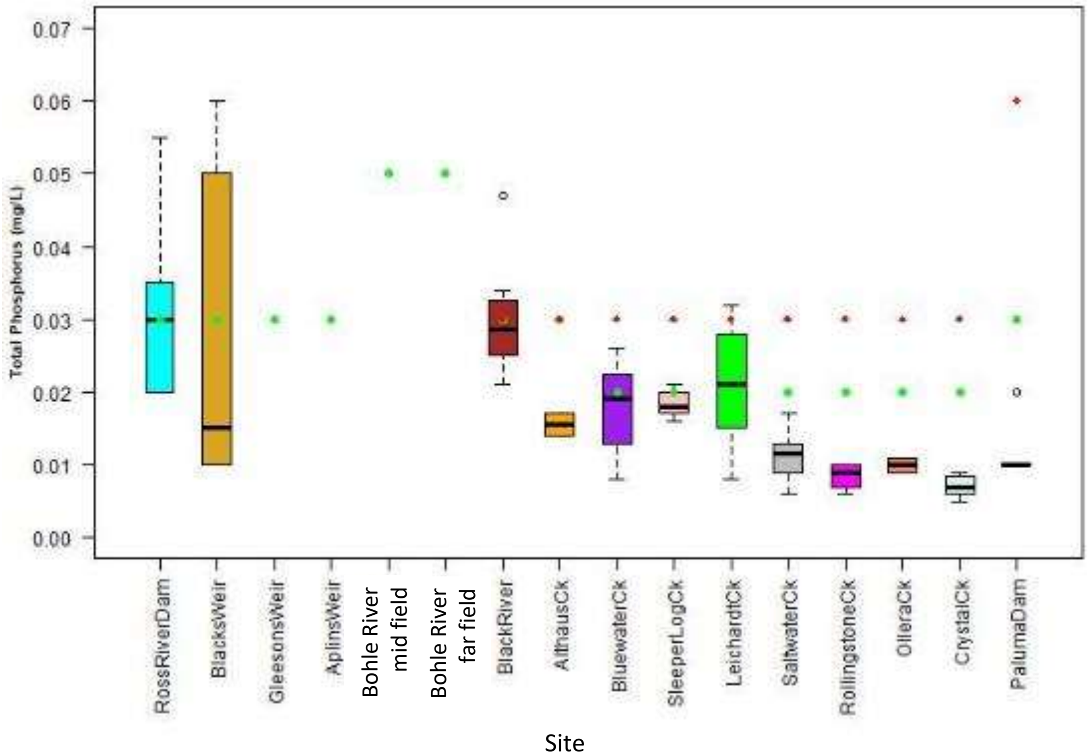


Figure Appendix A2. Boxplot of total phosphorus concentrations at each freshwater monitoring site excluding data from the Bohle River sites, to allow a closer examination of the boxplots.

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

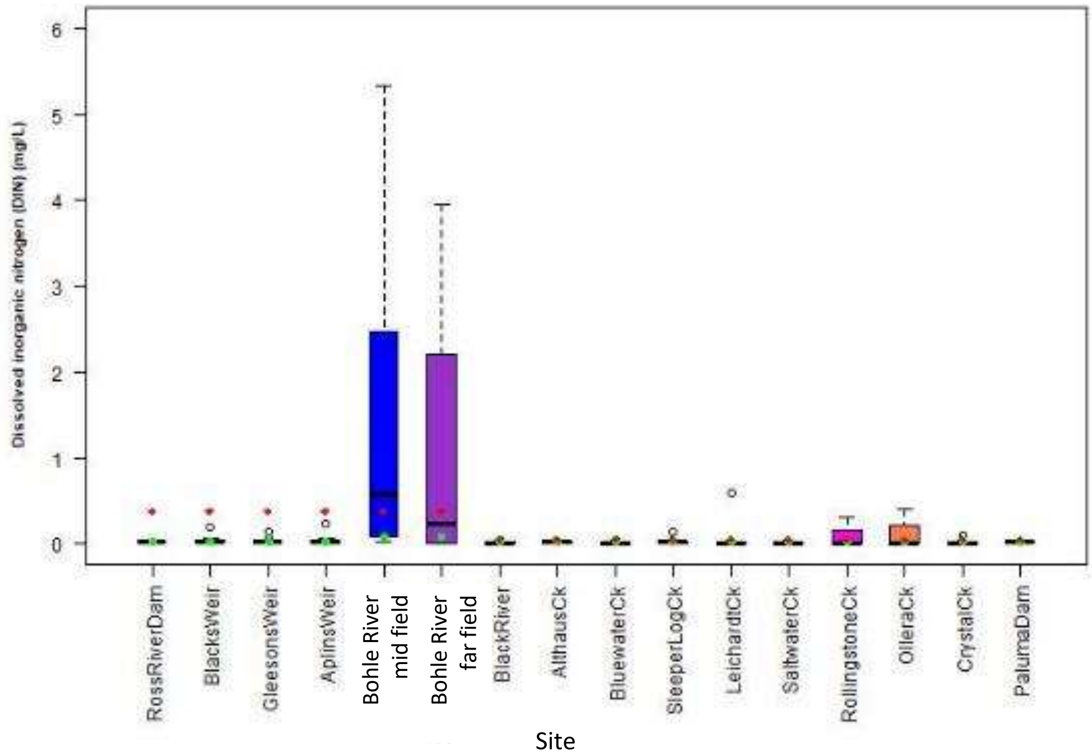


Figure Appendix A3. Boxplot of dissolved inorganic nitrogen (DIN) concentrations at each freshwater monitoring site.

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

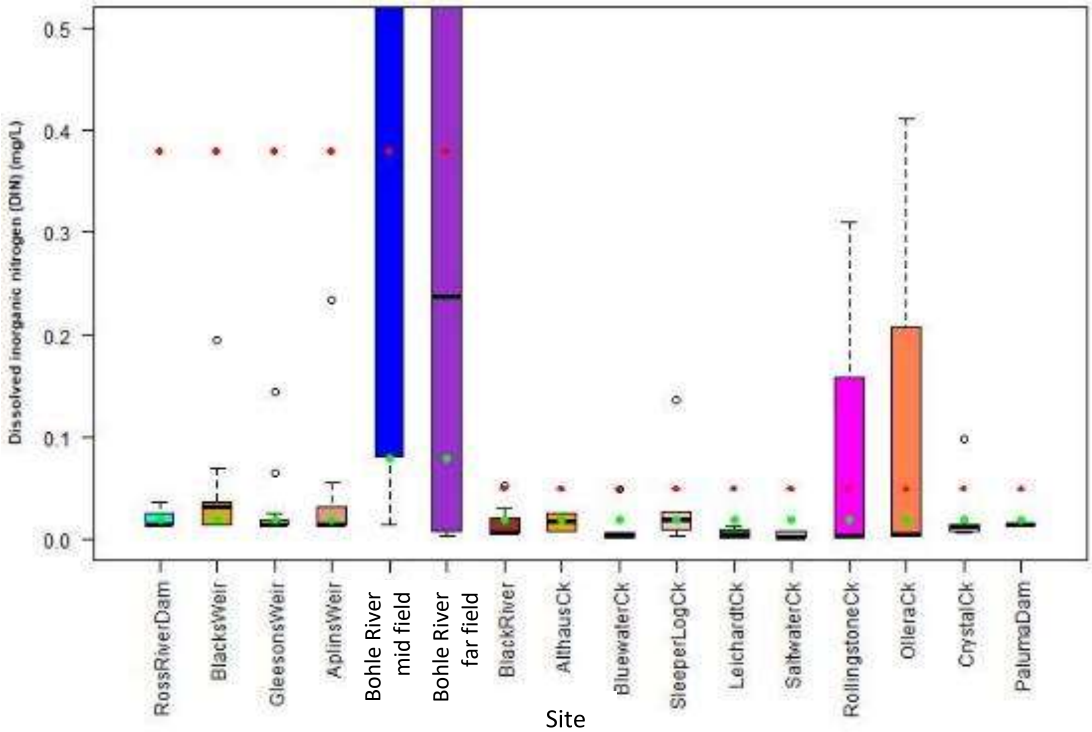


Figure Appendix A4. Boxplot of dissolved inorganic nitrogen (DIN) concentrations at each freshwater monitoring site, excluding the uppermost data from the Bohle River site.

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

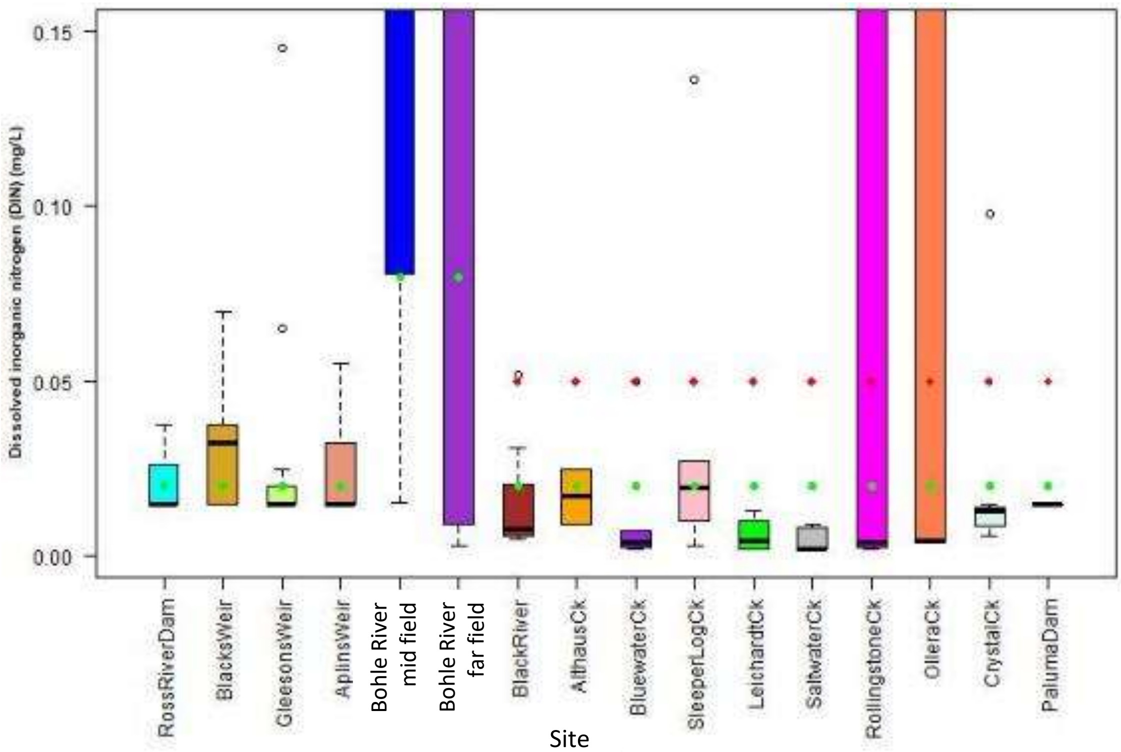


Figure Appendix A5. Boxplot of dissolved inorganic nitrogen (DIN) concentrations at each freshwater monitoring site, excluding the uppermost data from the Bohle River, Rollingstone Creek and Ollera Creek.

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

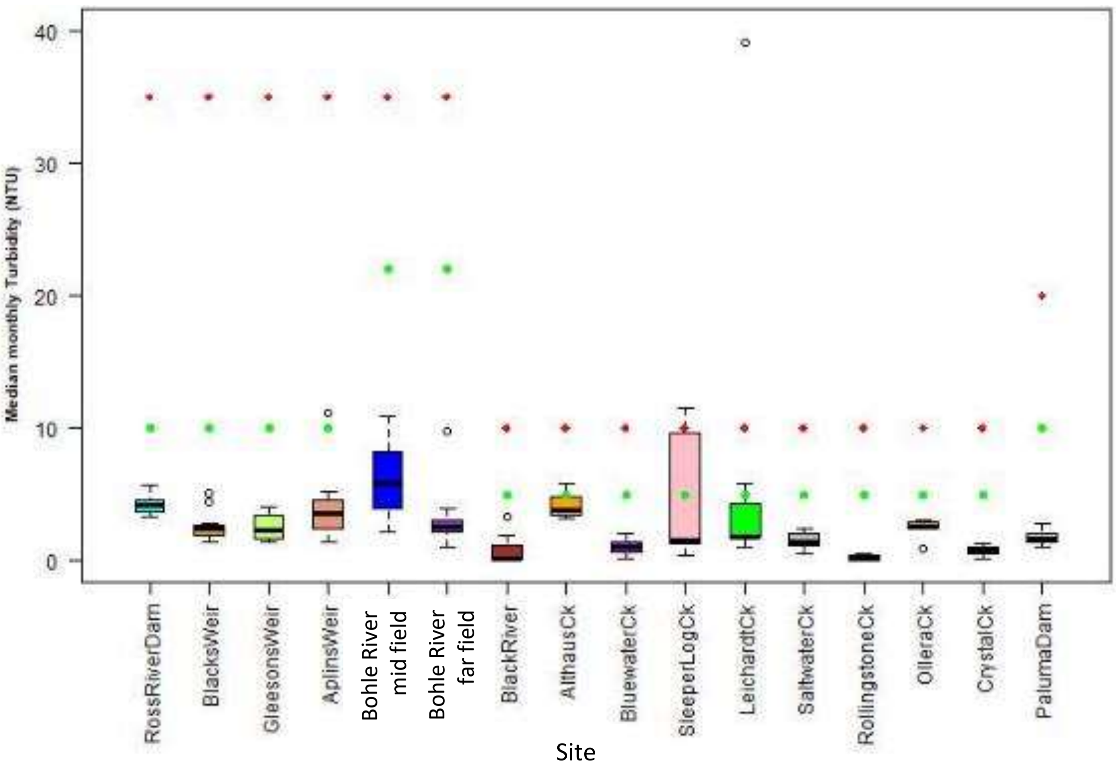


Figure Appendix A6. Boxplot of turbidity levels at each freshwater monitoring site.
The green circles indicate the water quality objectives (WQOs) and the red circles show the scaling factors. Outliers are shown as clear circles.

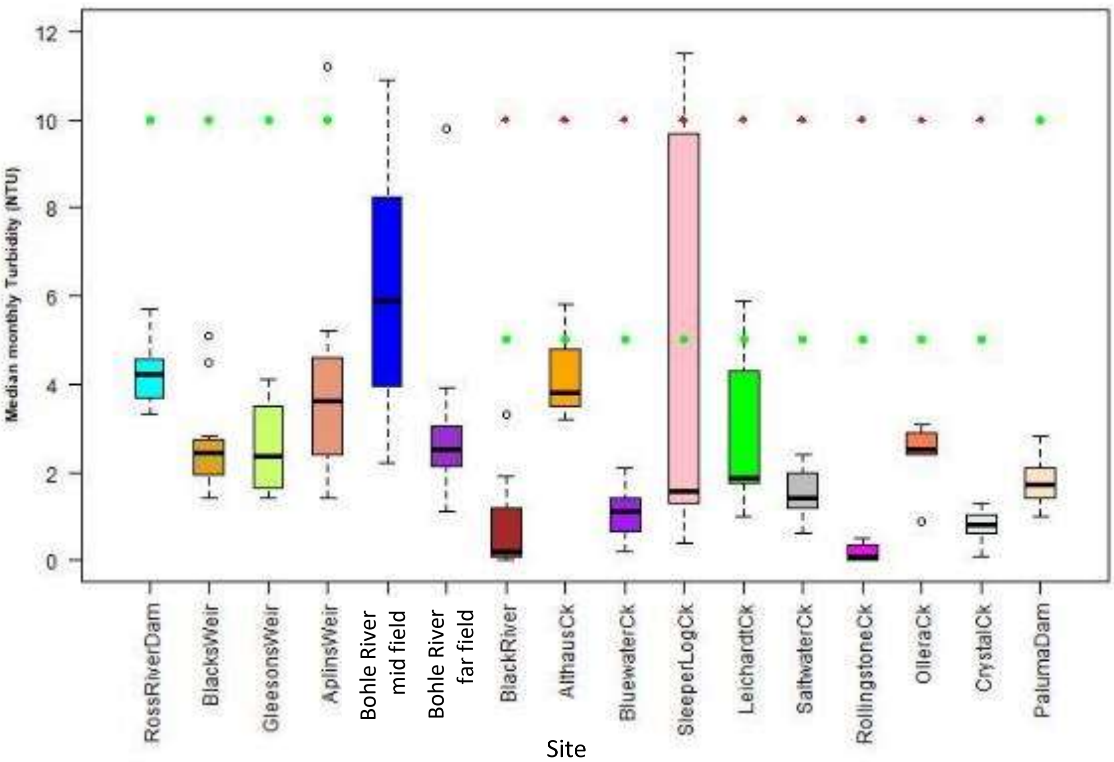


Figure Appendix A7. Boxplot of turbidity levels at each freshwater monitoring site, excluding the scaling factors for the Ross River sites (Dam and weirs) and the Bohle River sites.
The green circles indicate the water quality objectives (WQOs) and the red circles show the scaling factors. Outliers are shown as clear circles.

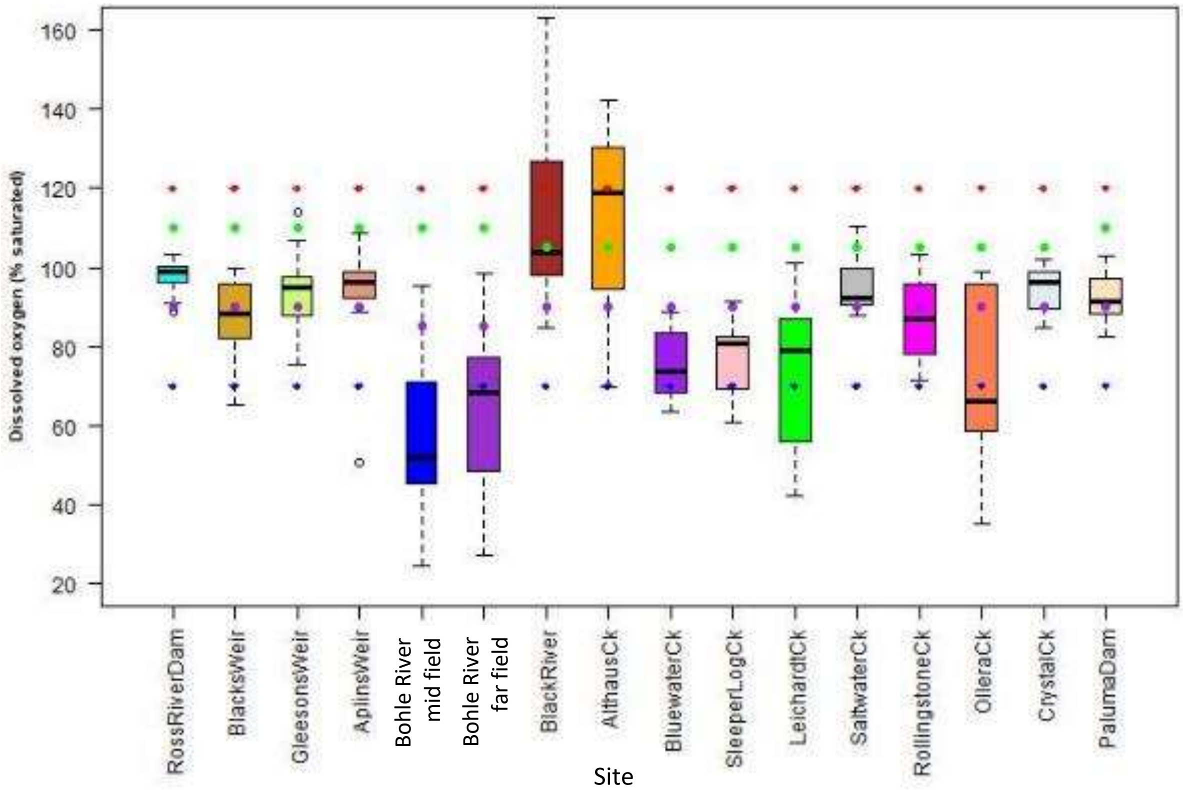


Figure Appendix A8. Boxplot of dissolved oxygen (DO) concentrations at each freshwater monitoring site. The green and purple circles indicate the water quality objectives (WQOs) for the upper and lower DO respectively and the red and blue circles indicate the scaling factors for the upper and lower DO, respectively. Outliers are shown as clear circles.

Appendix B. Comparisons of values used to calculate water quality scores within the freshwater basins.

Table Appendix B1. Annual median values (med), 80th percentiles (perc) (or 20th percentile for lower dissolved oxygen), water quality objectives (WQOs) and scaling factors (SF) for indicators of nutrients and physical-chemical properties for all sites monitored within the Ross and Black freshwater basins.

The thick black line delineates between the sites within the Ross estuarine zone (above line) and sites within the Black estuarine zone (below the line). Significant figures differ and indicators are shaded for ease of presentation. Significant figures differ for ease of presentation. ND stands for no data. Shading is added to easily distinguish between indicators.

	Indicators of nutrients										Indicators of physical-chemical properties															
	Dissolved inorganic nitrogen (DIN), mg/L					Total phosphorus (TP), mg/L					Turbidity (NTU)					Upper dissolved oxygen (% saturated)					Lower dissolved oxygen (% saturated)				
Site	No. of sam-ples	Med	80th or 20th perc*	WQOs	SF	No. of sam-ples	Med	80th or 20th perc*	WQOs	SF	No. of sam-ples	Med	80th or 20th perc*	WQOs	SF	No. of sam-ples	Med	80th or 20th perc*	WQO	SF	No. of sam-ples	Med	80th or 20th perc*	WQOs	SF
Upper Ross River (Ross River Dam)	12	0.015	0.029	0.02	0.38	12	0.03	0.038	0.03	0.46	12	4.2	4.6	10	35	12	99	101	110	120	12	99	96	90	70
Black Weir	12	0.033	0.039	0.02	0.38	12	0.015	0.050	0.03	0.46	12	2.5	2.8	10	35	12	88	97	110	120	12	88	82	90	70
Gleeson Weir	12	0.015	0.023	0.02	0.38	12	ND	ND	0.03	0.46	12	2.4	3.6	10	35	12	95	98	110	120	12	95	86	90	70
Aplin's Weir	12	0.015	0.034	0.02	0.38	12	ND	ND	0.03	0.46	12	3.6	4.6	10	35	12	96	99	110	120	12	96	92	90	70
Bohle far-field	12	0.24	2.4	0.08	0.38	12	3.1	6.4	0.05	0.46	12	2.5	3.1	22	35	12	68	78	110	120	12	68	44	85	70
Bohle mid-field	12	0.57	2.7	0.08	0.38	12	5.5	6.3	0.05	0.46	12	5.9	8.6	22	35	12	52	74	110	120	12	52	43	85	70
Black River	8	0.008	0.023	0.02	0.05	8	0.029	0.033	0.03	0.03	8	0.2	1.3	5	10	8	104	129	105	120	8	104	98	90	70
Althaus Creek	3	0.017	0.022	0.02	0.05	3	0.016	0.016	0.03	0.03	3	3.8	5	5	10	3	119	133	105	120	3	119	90	90	70
Bluewater Creek	8	0.004	0.007	0.02	0.05	8	0.019	0.023	0.02	0.03	8	1.1	1.52	5	10	8	74	86	105	120	8	74	66	90	70
Sleeper Log Creek	6	0.020	0.027	0.02	0.05	6	0.018	0.02	0.02	0.03	6	1.6	9.7	5	10	6	81	83	105	120	6	81	69	90	70
Leichhardt Creek	8	0.0045	0.011	0.02	0.05	8	0.021	0.029	0.02	0.03	8	1.9	4.6	5	10	8	79	87	105	120	8	79	55	90	70
Saltwater Creek	6	0.002	0.008	0.02	0.05	6	0.012	0.013	0.02	0.03	6	1.4	2	5	10	6	92	100	105	120	6	92	91	90	70
Rollingstone Creek	4	0.004	0.13	0.02	0.05	4	0.009	0.01	0.02	0.03	4	0.1	0.32	5	10	4	87	95	105	120	4	87	79	90	70
Ollera Creek	5	0.0045	0.17	0.02	0.05	5	0.01	0.011	0.02	0.03	5	2.5	2.9	5	10	5	66	96	105	120	5	66	54	90	70
Crystal Creek	7	0.013	0.015	0.02	0.05	7	0.007	0.009	0.02	0.03	7	0.8	1.2	5	10	7	96	101	105	120	7	96	87	90	70
Paluma Dam	12	0.015	0.015	0.02	0.05	12	0.01	0.01	0.03	0.06	12	1.7	2.16	10	20	12	91	98	110	120	12	91	88	90	70

*20th percentile is used in the calculations for lower dissolved oxygen, with the 80th percentile used for all other indicators.

Appendix C. Comparison of site specific results for nutrients and physical-chemical properties for freshwater sites for 2018-19 and 2019-2020.

Table Appendix C1. Comparison of scores for indicators of nutrients, physical-chemical (phys-chem) properties and overall water quality for freshwater sites sampled in the 2018-19 and 2019-2020 financial years.

The score for nutrients is the average of the scores for dissolved inorganic nitrogen (DIN) and total phosphorus (TP). The scores for phys-chem properties are the average of turbidity and the lower score of either upper or lower dissolved oxygen (DO). The overall water quality score is the average of the scores for the nutrients and phys-chem properties. Significant figures differ for ease of presentation.

Site	Non-weighted scores for 2019-2020 (current year)								Non-weighted scores for 2018-19 (last year)							
	DIN	TP	**Nutrients**	Turbidity	Upper DO	Lower DO	**Phys-chem properties**	Water quality	DIN	TP	**Nutrients**	Turbidity	Upper DO	Lower DO	**Phys-chem properties**	Water quality
Upper Ross River (Ross River Dam)	68	61	65	90	90	90	90	78	90	90	90	90	90	90	90	90
Lower Ross River	66	70	68	90	90	73	82	75	67	61	67	90	90	31	60	64
Black Weir	59	70	64	90	90	56	73	69	63	61	62	90	90	39	64	63
Gleeson Weir	74	ND	74	90	90	73	82	78	68	ND	68	90	90	0	45	56
Aplin's Weir	66	ND	66	90	90	90	90	78	71	ND	71	90	90	55	73	72
Bohle River	15	0	7	90	90	0	45	26	68	0	34	71	90	18	45	22
Bohle far-field	29	0	15	90	90	0	45	30	72	0	36	68	90	36	52	44
Bohle mid-field	0	0	0	90	90	0	45	23	64	0	32	74	90	0	37	34
Ross freshwater basin	**49**	**33**	**47**	**90**	**90**	**51**	**71**	**59**	**75**	**50**	**64**	**84**	**90**	**47**	**65**	**59**
Black River	78	9	44	90	62	90	76	60	49	0	24	90	47	90	68	46
Althaus Creek	74	90	82	90	4	81	47	65	90	43	66	61	29	90	45	56
Bluewater Creek	90	66	78	90	90	11	51	65	20	90	55	61	54	90	57	56
Sleeper Log Creek	62	90	76	70	90	32	51	64	40	90	65	61	90	90	76	70
Leichhardt Creek	90	55	72	90	90	27	59	66	71	90	80	66	90	90	78	79
Saltwater Creek	90	90	90	90	90	90	90	90	74	90	82	90	90	90	90	86
Rollingstone Creek	64	90	77	90	90	51	71	74	0	90	45	90	90	90	90	68
Ollera Creek	63	90	76	90	90	0	45	61	90	90	90	90	90	35	63	76
Crystal Creek	90	90	90	90	90	75	83	87	80	90	85	90	90	90	90	88
Paluma Dam	90	90	90	90	90	69	80	85	51	90	70	90	90	52	71	71
Black freshwater basin	**79**	**76**	**78**	**88**	**79**	**53**	**71**	**71**	**57**	**76**	**66**	**79**	**76**	**80**	**73**	**70**

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

Appendix D. Distribution (boxplots) of fish data within the Ross and Black freshwater basins.

Figure Appendix D1 Fand D2 are box and whisker plots (boxplots) of fish indicator categories for both freshwater basins, based on sampling at 11 and 13 sites. 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.

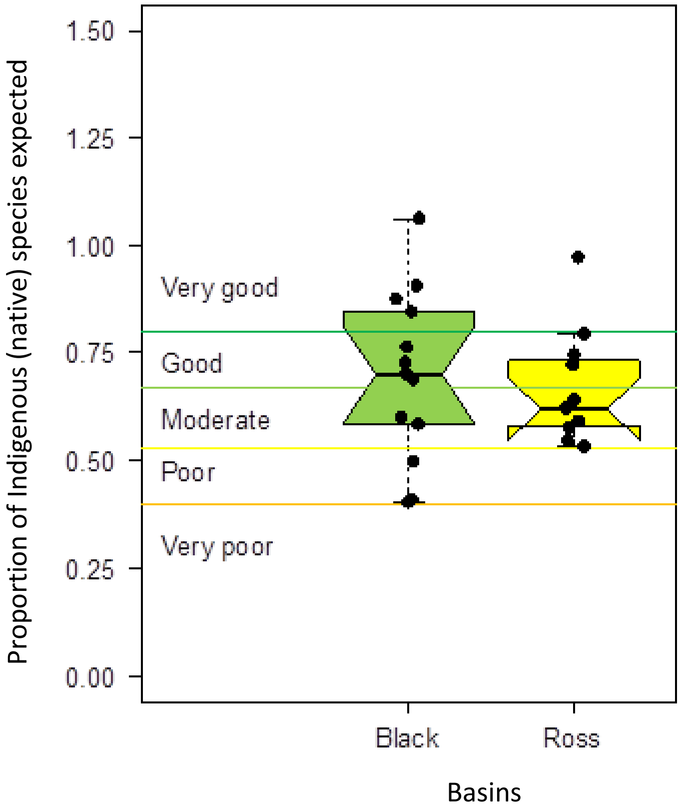


Figure Appendix D3. Boxplot of the proportion of Indigenous (native) species (POISE) expected within waterways within the Ross and Black freshwater basins.

The boxplot is based on sampling from 11 sites within the Ross freshwater basin and 13 sites within the Black freshwater basin. The black dots shown the results for each site. The different coloured lines delineate the cut-offs for the different grades.

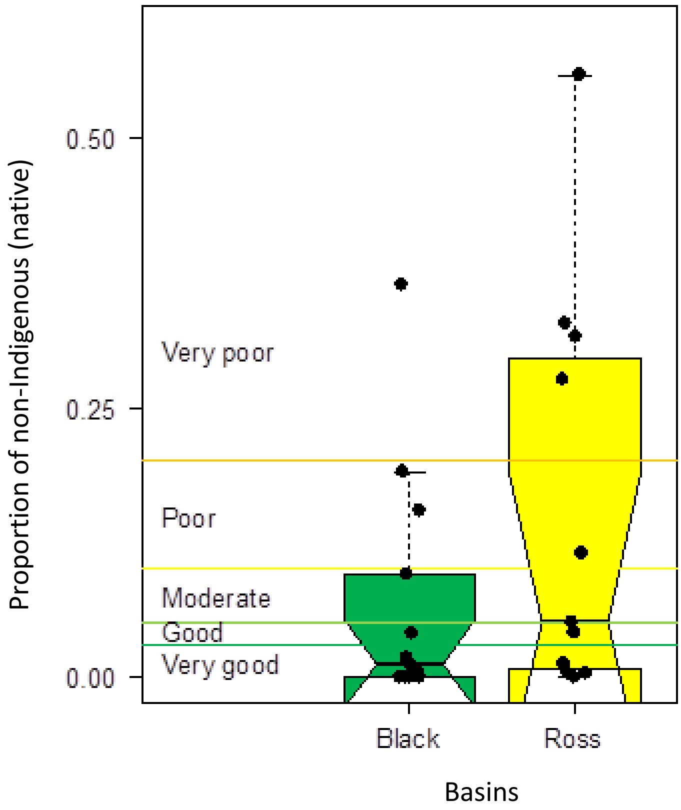


Figure Appendix D2. Boxplot of the proportion of non-Indigenous (native) fish within waterways within the Ross and Black freshwater basins.

The boxplot is based on sampling from 11 sites within the Ross freshwater basin and 13 sites within the Black freshwater basin. The black dots shown the results for each site. The different coloured lines delineate the cut-offs for the different grades.

Appendix E. Distribution (boxplots) of estuarine water quality data.

The following figures are box and whisker plots (boxplots) of water quality indicators at all estuarine water quality monitoring sites. 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.

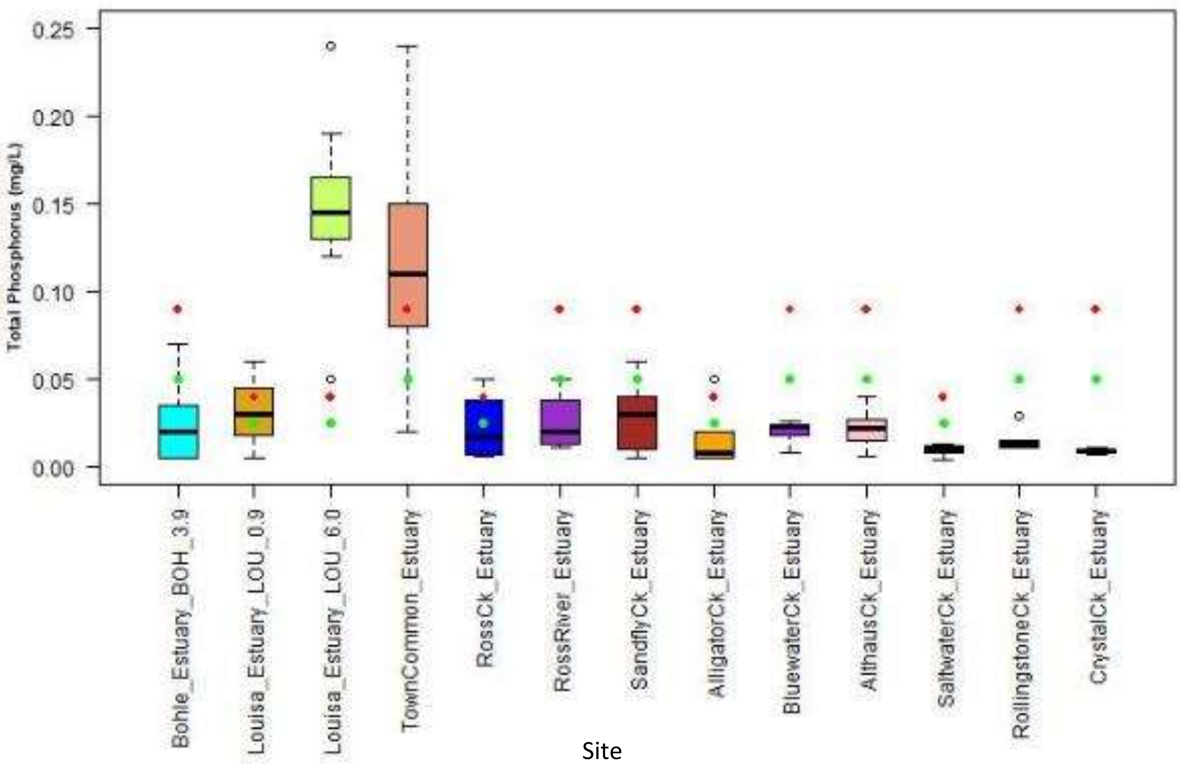


Figure Appendix E1. Boxplot of total phosphorus concentrations at each estuarine monitoring site.
The green circles indicate the water quality objectives (WQOs) and the red circles show the scaling factors. Outliers are shown as clear circles.

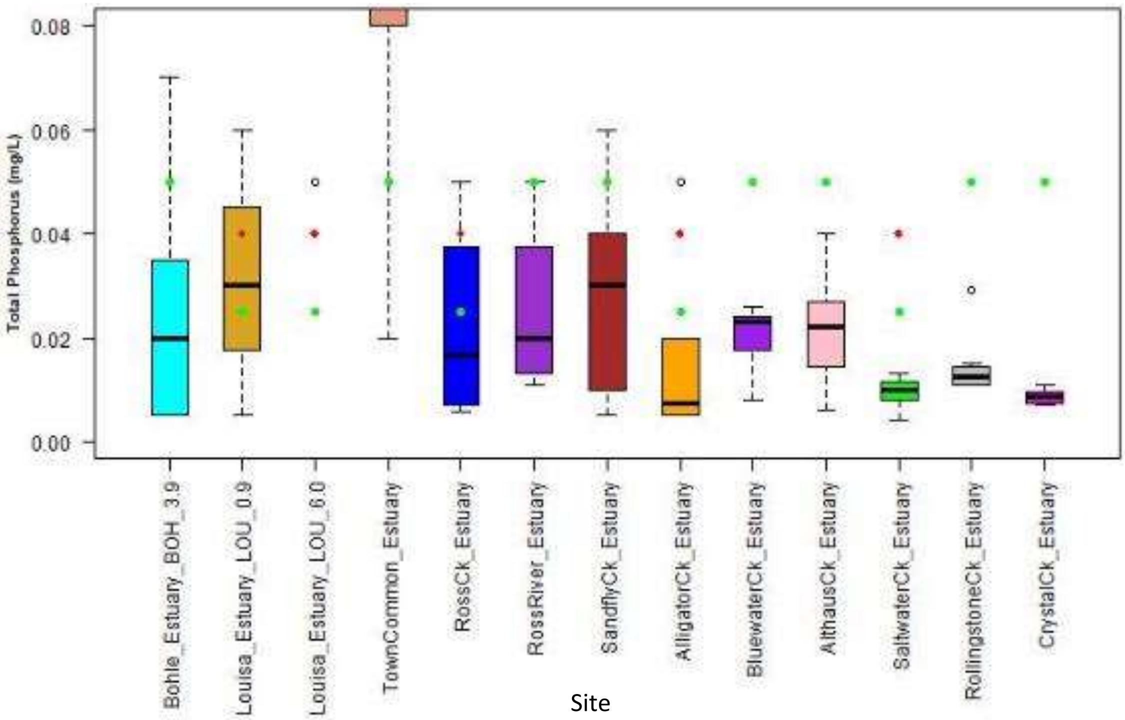


Figure Appendix E2. Boxplot of total phosphorus concentrations at each estuarine monitoring site, excluding the uppermost data from Louisa Creek Estuary (site LOU 0.6) and the Town Common Estuary.

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

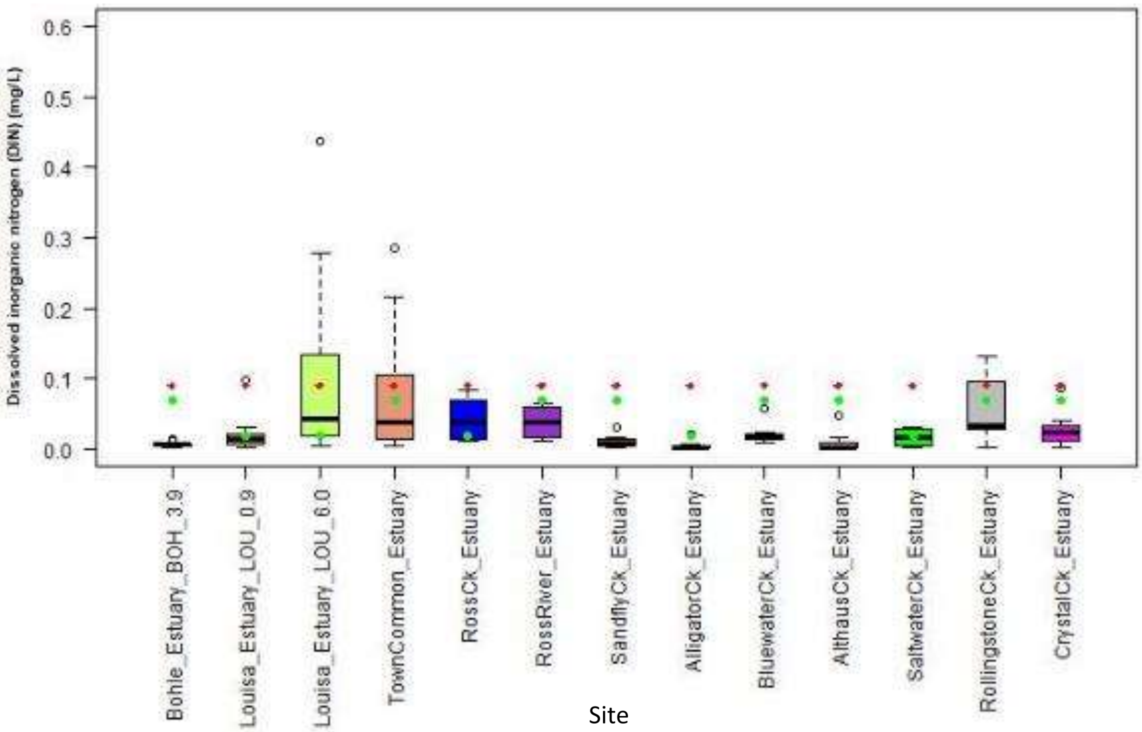


Figure Appendix E3. Boxplot of dissolved inorganic nitrogen (DIN) concentrations at each estuarine monitoring site.

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

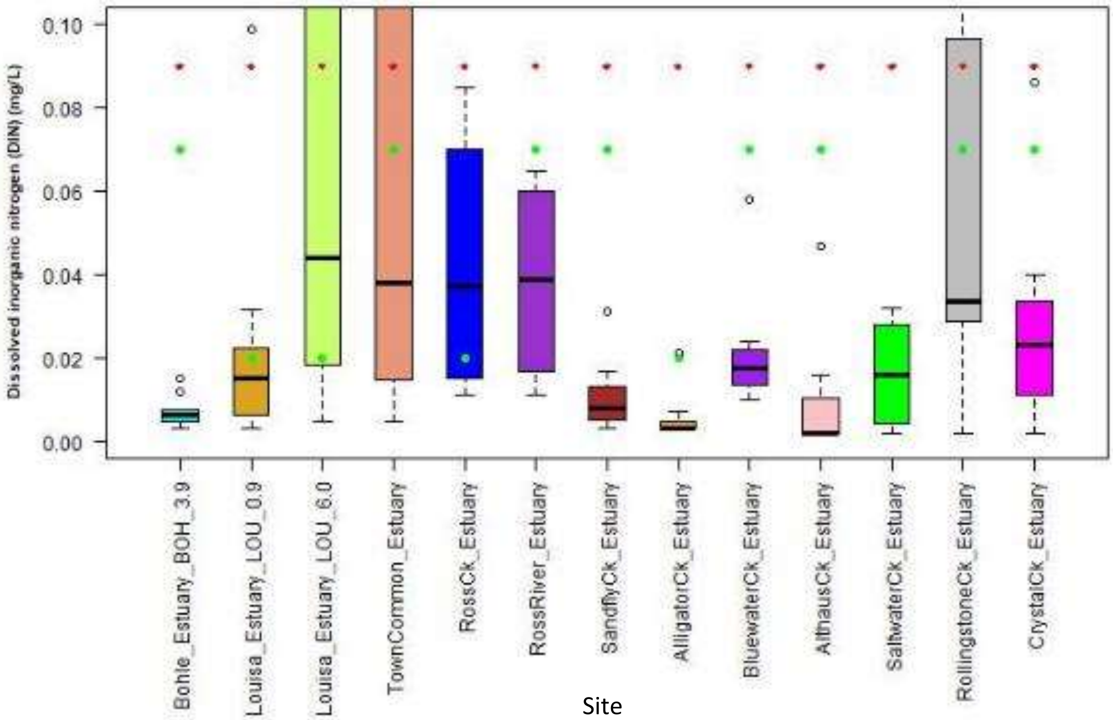


Figure Appendix E4. Boxplot of dissolved inorganic nitrogen (DIN) concentrations at each estuarine monitoring site, excluding the uppermost data from Louisa Creek Estuary (site LOU 0.6), Town Common Estuary and Rollingstone Creek Estuary.

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

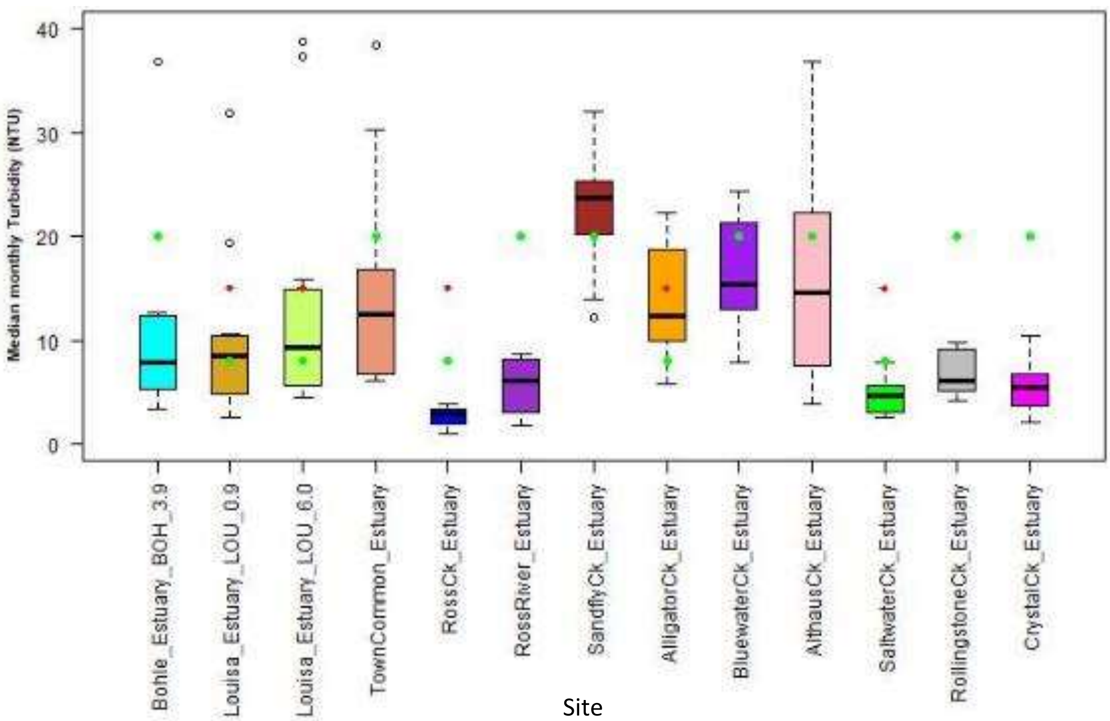


Figure Appendix E5. Boxplot of turbidity levels at each estuarine monitoring site.

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

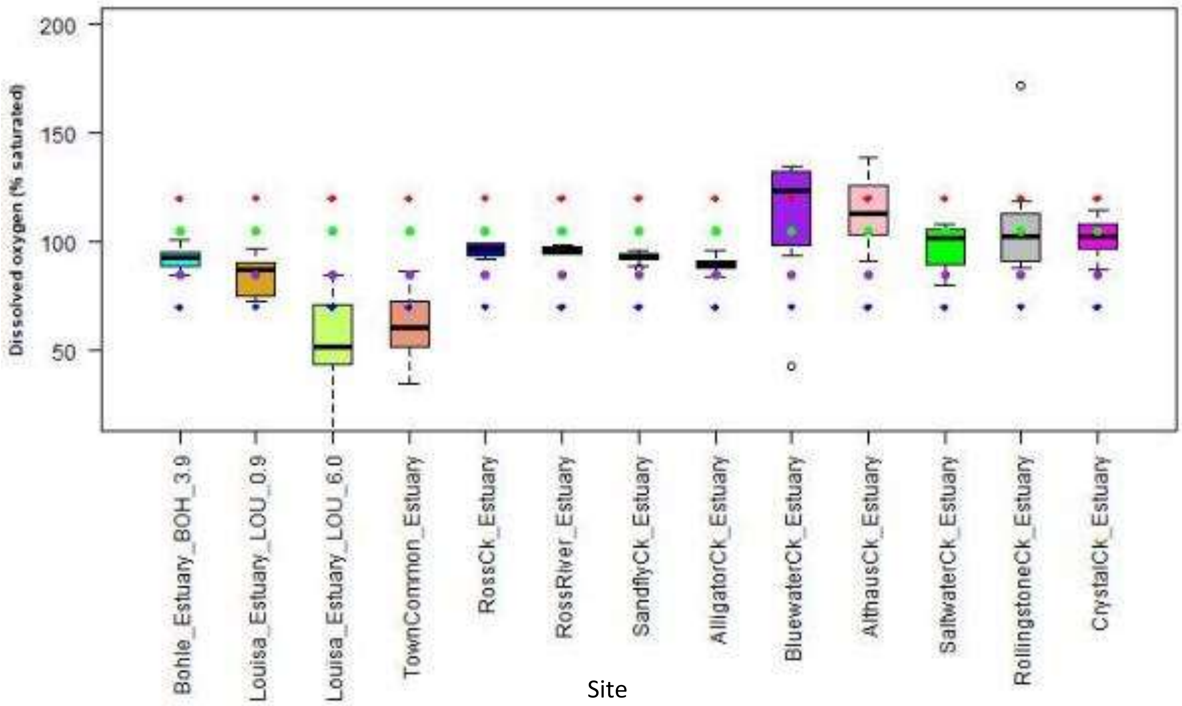


Figure Appendix E6. Boxplot of dissolved oxygen (DO) concentrations at each estuarine monitoring site.
The green and purple circles indicate the water quality objectives (WQOs) for the upper and lower DO respectively and the red and blue circles indicate the scaling factors for the upper and lower DO, respectively. Outliers are shown as clear circles.

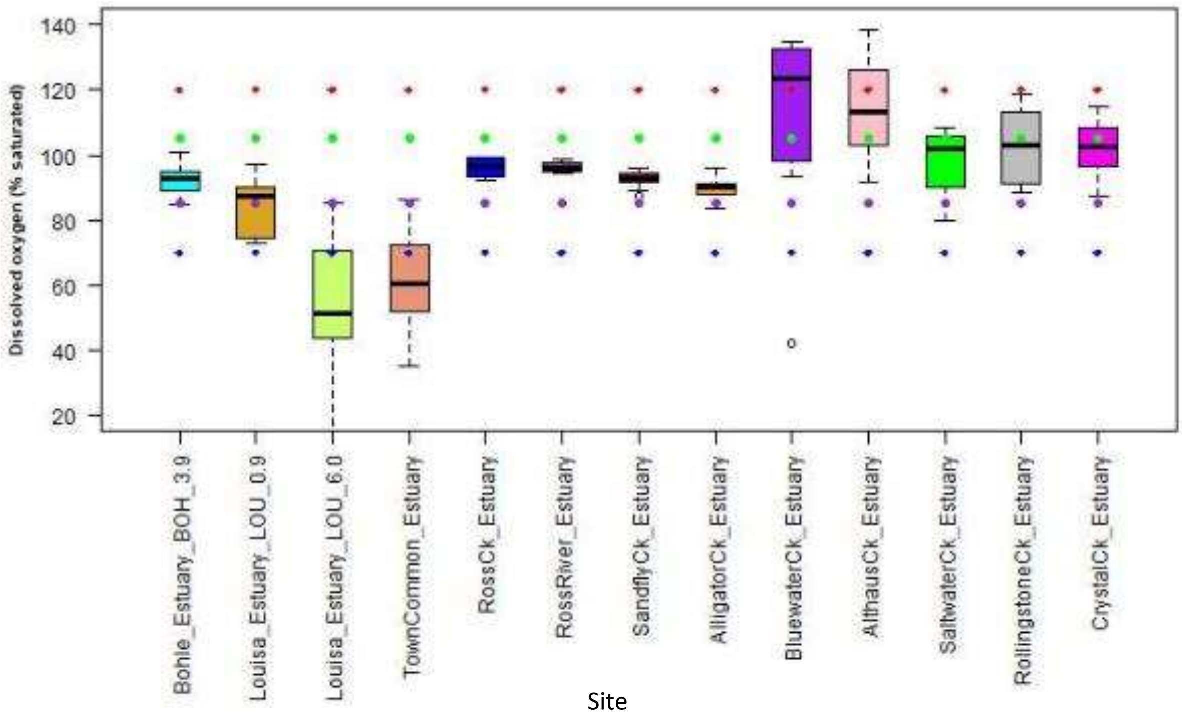


Figure Appendix E7. Boxplot of dissolved oxygen (DO) concentrations at each estuarine monitoring site, excluding the outlier at Rollingstone Estuary.
The green and purple circles indicate the water quality objectives (WQOs) for the upper and lower DO respectively and the red and blue circles indicate the scaling factors for the upper and lower DO, respectively. Outliers are shown as clear circles.

Appendix F. Comparisons of values used to calculate water quality scores within the Ross and Black estuarine zones.

Table Appendix F2. Annual median values (med), 80th percentiles (perc) (or 20th percentile for lower dissolved oxygen), water quality objectives (WQO) and scaling factors (SF) for indicators of nutrients and physical-chemical properties for all sites monitored within the Ross and Black estuarine zone.
The thick black line delineates between the sites within the Ross estuarine zone (above line) and sites within the Black estuarine zone (below the line). Significant figures differ and indicators are shaded for ease of presentation. Significant figures differ for ease of presentation. ND stands for no data. Shading is added to easily distinguish between indicators.

	Indicators of nutrients										Indicators of physical-chemical properties														
	Dissolved inorganic nitrogen (DIN), mg/L					Total phosphorus (TP), mg/L					Turbidity (NTU)					Upper dissolved oxygen (% saturated)					Lower dissolved oxygen (% saturated)				
Site	No. of sam-ples	Med	80th or 20th perc*	WQO	SF	No. of sam-ples	Med	80th or 20th perc*	WQO	SF	No. of sam-ples	Med	80th or 20th perc*	WQO	SF	No. of sam-ples	Med	80th or 20th perc*	WQO	SF	No. of sam-ples	Med	80th or 20th perc*	WQO	SF
Alligator Creek Estuary	10	0.00	0.01	0.07	0.09	10	0.05	0.05	0.05	0.09	10	12.4	18.8	20.0	45	10	89.8	91.8	105	120	10	89.8	87.4	85	70
Bohle River Estuary	12	0.006	0.008	0.07	0.09	12	0.040	0.050	0.05	0.09	12	7.9	12.5	20	45	12	92.7	95.2	105	120	12	92.7	88.5	85	70
Louisa Estuary Site 0.9	12	0.02	0.02	0.07	0.09	12	0.05	0.05	0.05	0.09	12	8.6	10.5	20	45	12	87.2	90.4	105	120	12	87.2	74.0	85	70
Louisa Estuary Site 6.0	12	0.04	0.16	0.07	0.09	12	0.15	0.17	0.05	0.09	12	9.3	15.5	20	45	12	51.3	73.5	105	120	12	51.3	42.9	85	70
Louisa Creek Estuary/Town Common	12	0.04	0.14	0.07	0.09	12	0.11	0.15	0.05	0.09	12	12.5	18.1	20	45	12	60.7	74.6	105	120	12	60.7	49.6	85	70
Ross Creek Estuary	4	0.04	0.07	0.07	0.09	4	0.02	0.04	0.05	0.09	4	2.8	3.2	20	45	4	96.7	99.2	105	120	4	96.7	93.4	85	70
Ross River Estuary	4	0.04	0.06	0.07	0.09	4	0.02	0.04	0.05	0.09	4	6.1	8.1	20	45	4	96.0	97.5	105	120	4	96.0	94.9	85	70
Sandfly Creek Estuary	10	0.008	0.014	0.070	0.09	10	0.045	0.05	0.05	0.09	10	23.7	26.5	20	45	10	92.6	94.4	105	120	10	92.6	91.2	85	70
Althaus/Deep Creek Estuary	8	0.002	0.012	0.02	0.09	8	0.022	0.0274	0.025	0.04	8	14.6	22.78	8	15	8	113	126	105	120	8	113.1	102.68	85	70
Bluewater Creek Estuary	8	0.018	0.022	0.02	0.09	8	0.023	0.024	0.025	0.04	8	15.3	21.48	8	15	8	123	133	105	120	8	123.3	97.1	85	70
Crystal Creek Estuary	8	0.02	0.03	0.02	0.09	8	0.0085	0.0096	0.025	0.04	8	5.5	6.8	8	15	8	102.5	108	105	120	8	102.5	95.8	85	70
Rollingstone Creek Estuary	8	0.03	0.10	0.02	0.09	8	0.01	0.01	0.025	0.04	8	6.10	9.22	8	15	8	102.9	114.4	105	120	8	102.9	90.7	85	70
Saltwater Creek Estuary	8	0.02	0.03	0.02	0.09	8	0.010	0.012	0.025	0.04	8	4.7	5.6	8	15	8	102.1	106.0	105	120	8	102.1	89.3	85	70

*20th percentile is used in the calculations for lower dissolved oxygen, with the 80th percentile used for all other indicators.

Appendix G. Comparison of site specific results for nutrients and physical-chemical properties for estuarine sites for 2018-19 and 2019-2020.

Table Appendix G2. Comparison of scores for indicators of nutrients, physical-chemical (phys-chem) properties and overall water quality for estuarine sites sampled in the 2018-19 and 2019-2020 financial years.

The score for nutrients is the average of the scores for DIN and TP. The scores for phys-chem properties are the average of turbidity and the lower score of either upper or lower dissolved oxygen. The overall water quality score is the average of the scores for the nutrients and phys-chem properties.

Site	Non-weighted scores for 2019-2020 (current year)								Non-weighted scores for 2018-19 (last year)							
	DIN	TP	**Nutrients**	Turb-idity	Upper DO	Lower DO	**Phys-chem properties**	**Water quality**	DIN	TP	**Nutrients**	Turbidity	Upper DO	Lower DO	**Phys-chem properties**	**Water quality**
Alligator Creek Estuary	90	90	90	90	90	90	90	90	90	65	77	42	90	90	66	72
Bohle River Estuary	90	90	90	90	90	90	90	90	90	75	83	90	90	77	84	83
Louisa Creek Estuary	75	30	52	90	90	21	56	54	25	20	23	77	90	20	48	36
Louisa Estuary Site 0.9	90	90	90	90	90	64	77	84	75	61	68	80	90	60	70	69
Louisa Estuary Site 6.0	66	0	33	90	90	0	45	39	0	0	0	78	90	0	39	19
Louisa Creek/Town Common Estuary	68	0	34	90	90	0	45	40	0	0	0	71	90	0	36	18
Ross Creek Estuary	90	90	90	90	90	90	90	90	0	90	45	90	90	90	90	68
Ross River Estuary	90	90	90	90	90	90	90	90	0	90	45	90	90	90	90	68
Sandfly Creek Estuary	90	90	90	52	90	90	71	81	83	75	79	61	90	90	76	77
Ross estuarine zone	**84**	**68**	**76**	**85**	**90**	**64**	**75**	76	**48**	**69**	**59**	**75**	**90**	**76**	**76**	**67**
Althaus/Deep Creek Estuary	90	72	80	4	28	90	16	48	61	90	76	61	90	90	76	76
Bluewater Creek Estuary	71	90	81	0	0	90	0	41	46	90	68	90	90	90	90	79
Crystal Creek Estuary	58	90	74	90	69	90	80	77	28	90	59	41	35	90	66	62
Rollingstone Creek Estuary	49	90	70	73	65	90	69	70	9	90	49	10	90	90	50	50
Saltwater Creek Estuary	67	90	79	90	76	90	83	81	57	90	74	44	90	90	67	70
Black estuarine zone	**67**	**86**	**77**	**51**	**48**	**90**	**50**	64	**40**	**90**	**65**	**49**	**79**	**90**	**70**	**67**

Scoring range: Very Poor I = 0 to <21 | Poor (D) = 21 to <41 | Moderate (C) = 41 to <61 | Good (B) = 61 to <81 | Very Good (A) = 81 to 100

Appendix H. Distribution (boxplots) of inshore marine water quality data.

The following figures are box and whisker plots (boxplots) of water quality indicators at all inshore marine water quality monitoring sites. 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).

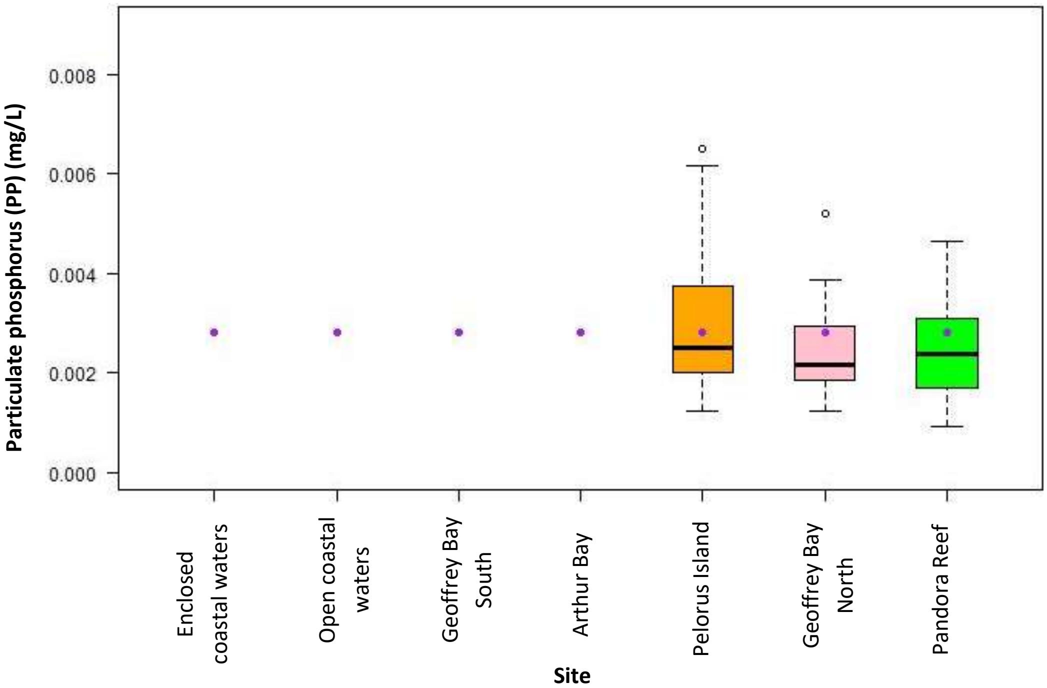


Figure Appendix H1. Boxplot of particulate phosphorus concentrations at each inshore marine monitoring site.
Data were collected using grab samples. The purple circles indicate the water quality objectives.

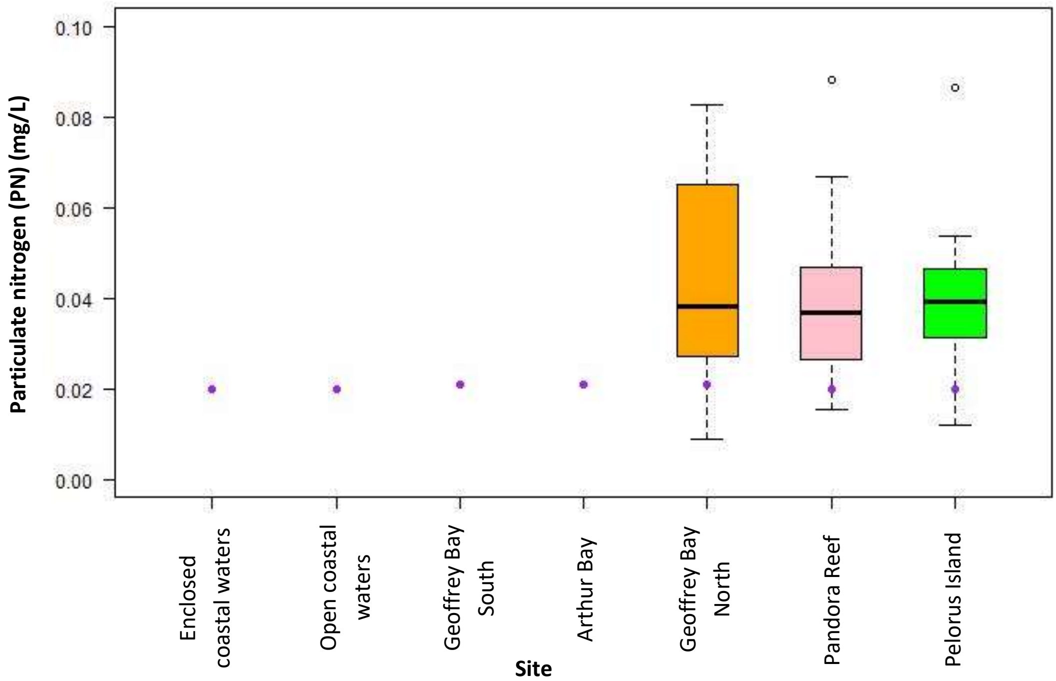


Figure Appendix H2. Boxplot of particulate nitrogen concentrations at each inshore marine monitoring site.
Data were collected using grab samples. The purple circles indicate the water quality objectives.

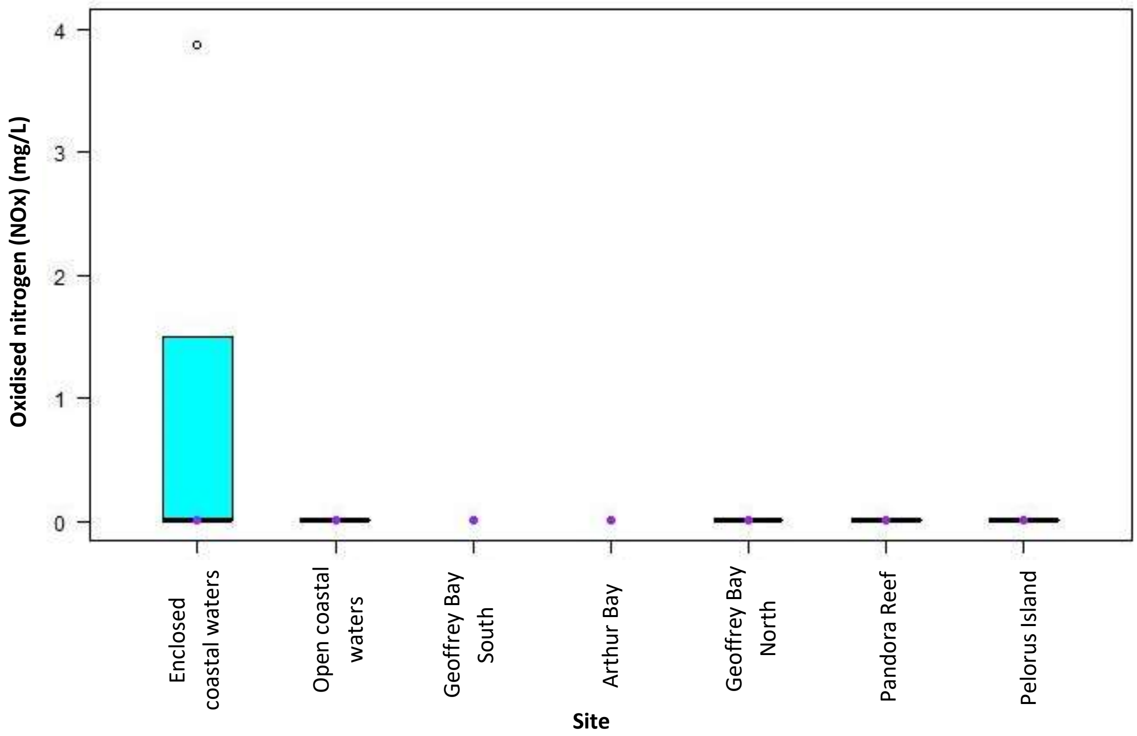


Figure Appendix H3. Boxplot of oxidised nitrogen concentrations at each inshore marine monitoring site. Data were collected using grab samples. The purple circles indicate the water quality objectives.

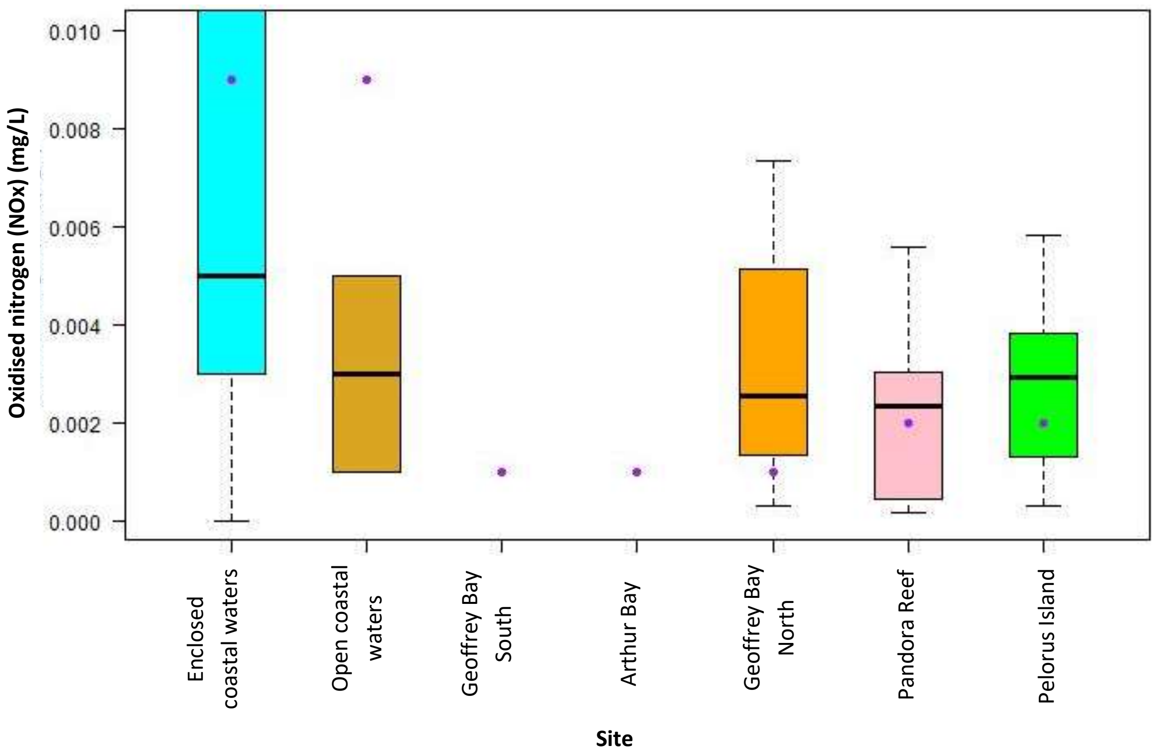


Figure Appendix H4. Boxplot of oxidised nitrogen concentrations at each inshore marine monitoring site. Outliers and the uppermost data of the enclosed coastal waters site was removed to allow a closer examination of the plots. Data were collected using grab samples. The purple circles indicate the water quality objectives.

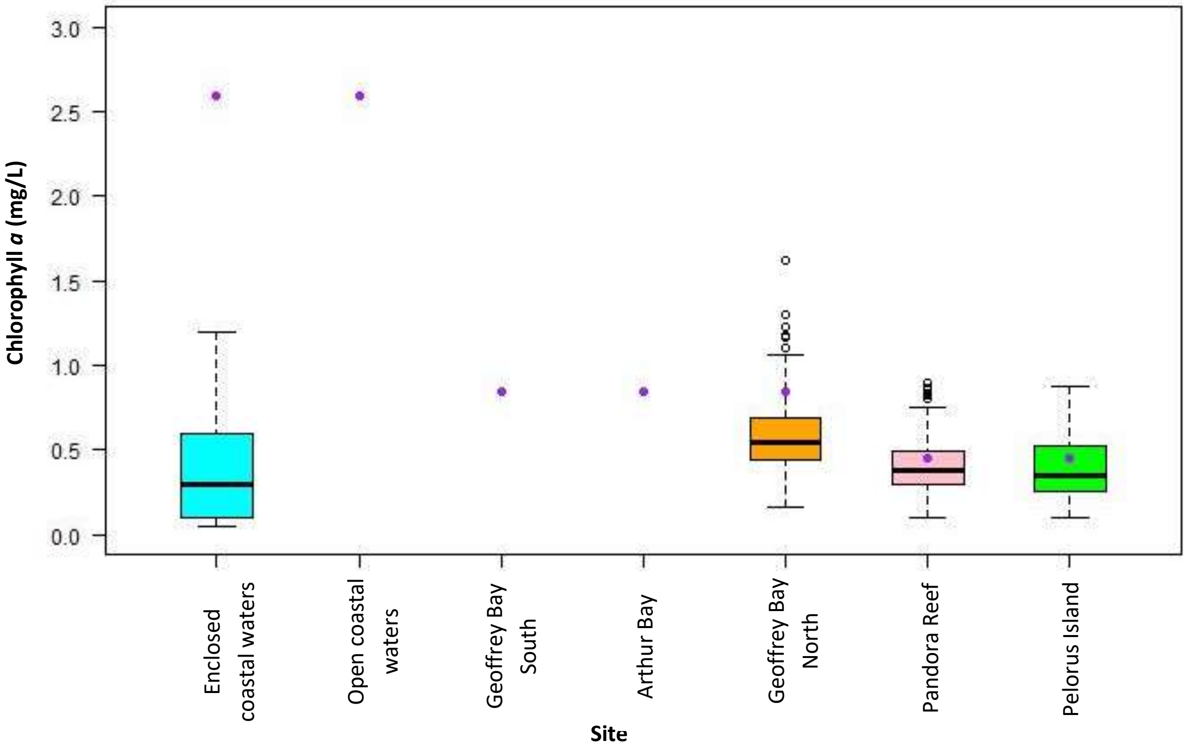


Figure Appendix H5. Boxplot of chlorophyll *a* concentration at each inshore marine monitoring site.
Data were collected using grab samples and at some sites, logger samples. The purple circles indicate the water quality objectives.

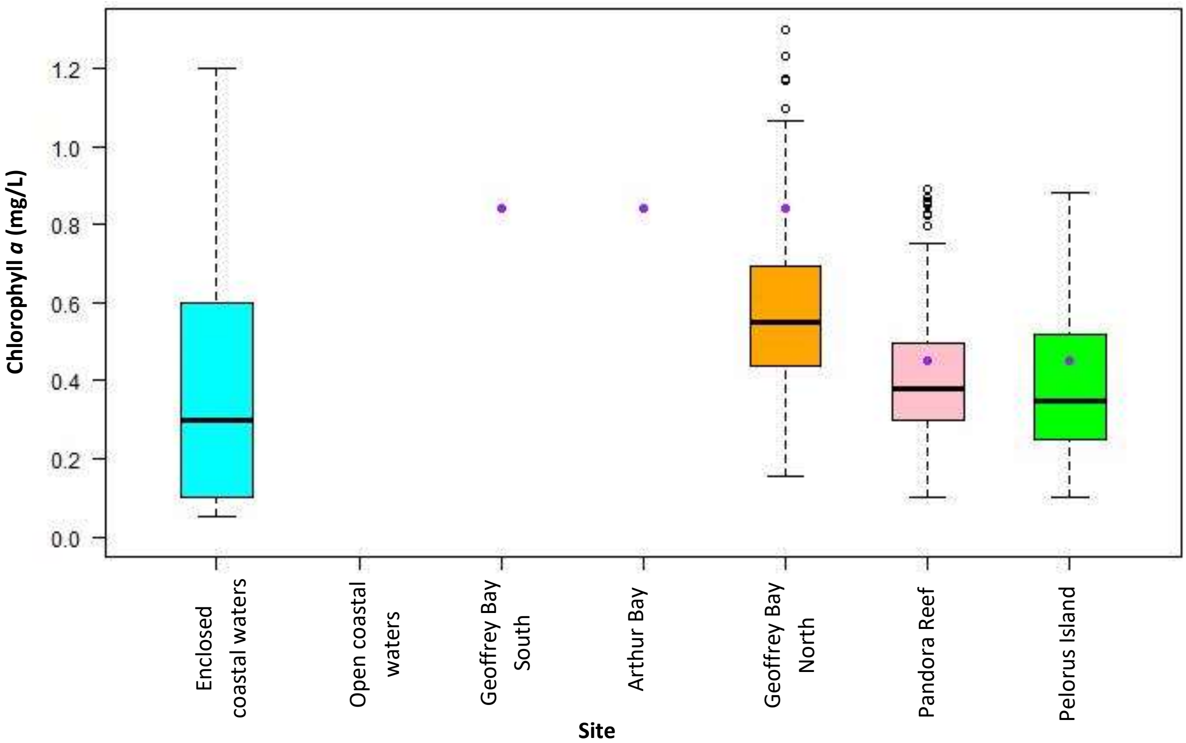


Figure Appendix H6. Boxplot of chlorophyll *a* concentration at each inshore marine monitoring site, excluding the uppermost outlier from Geoffrey Bay and the water quality objective values from the enclosed and open coastal waters sites.
Data were collected using grab samples and at some sites, logger samples. The purple circles indicate the water quality objectives.

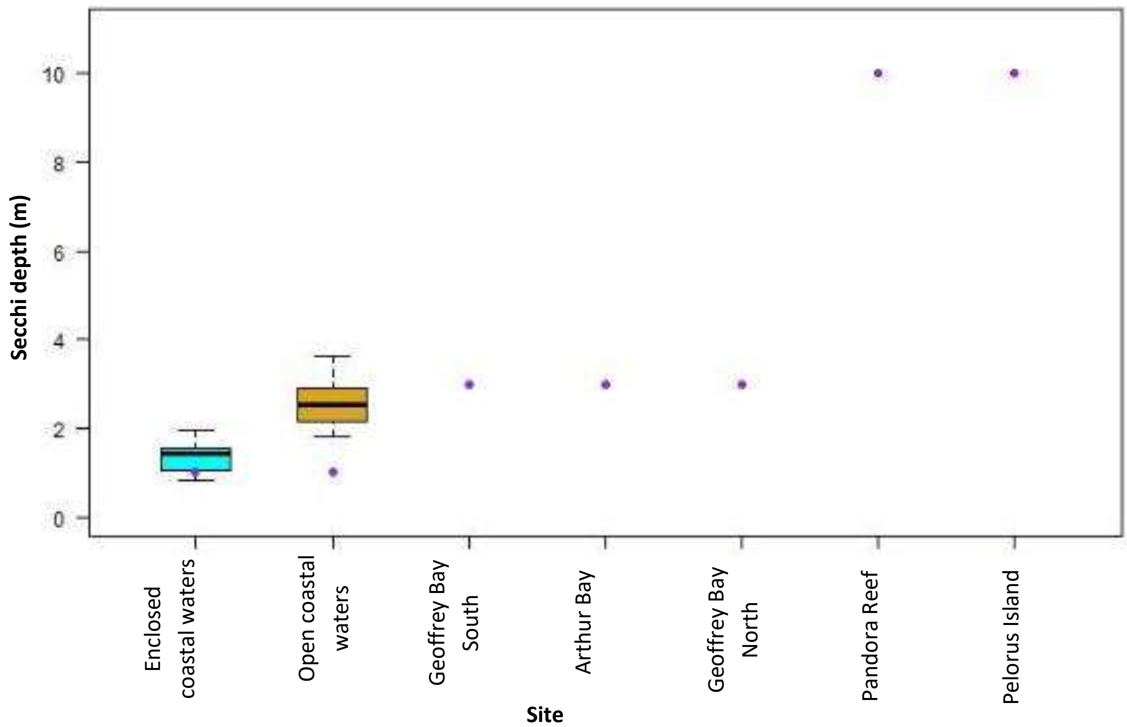


Figure Appendix H7. Boxplot of secchi depth at each inshore marine monitoring site.
Data were collected using grab samples. The purple circles indicate the water quality objectives.

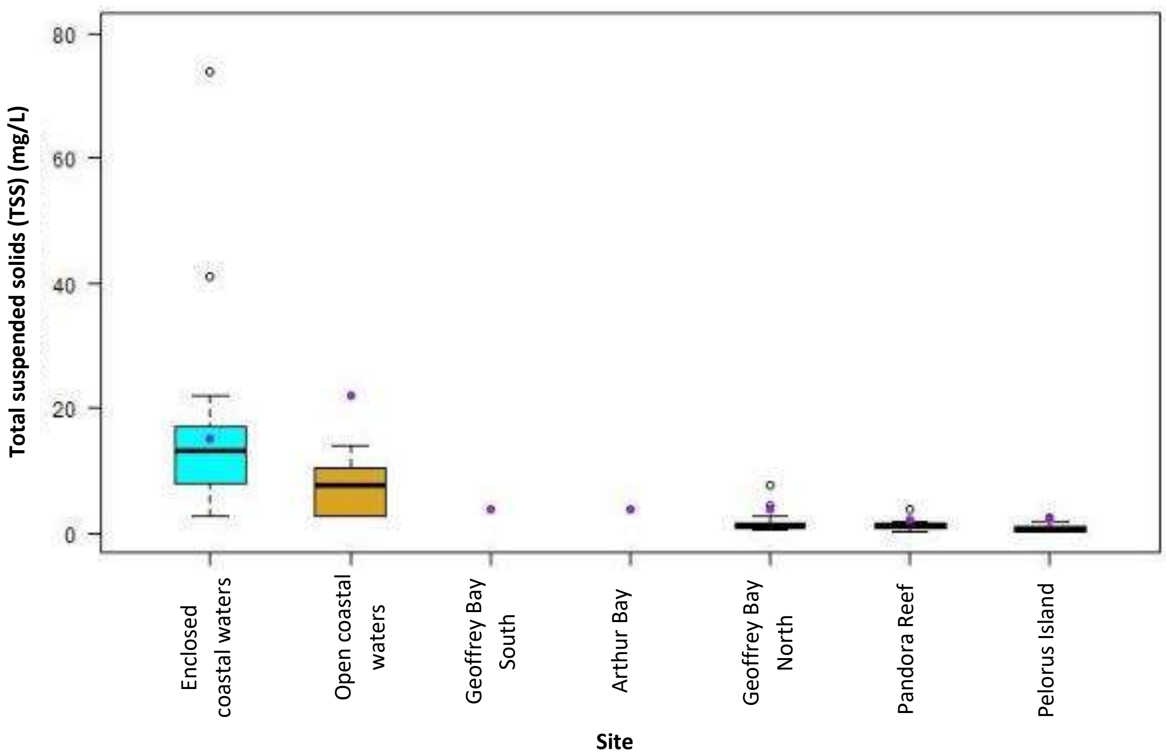


Figure Appendix H8. Boxplot of total suspended solids at each inshore marine monitoring site.
Data were collected using grab samples and at some sites, logger samples. The purple circles indicate the water quality objectives.

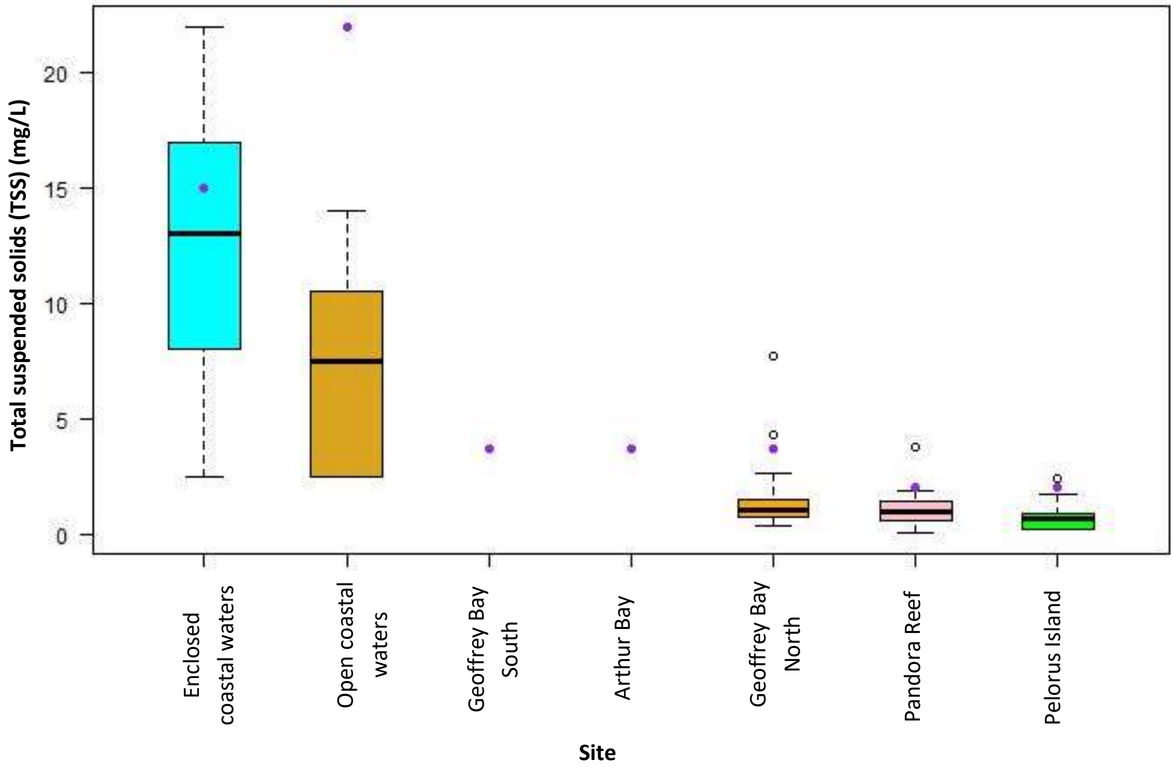


Figure Appendix H9. Boxplot of total suspended solids at each inshore marine monitoring site, excluding the outliers from the enclosed coastal waters site.

Data were collected using grab samples. The purple circles indicate the water quality objectives.

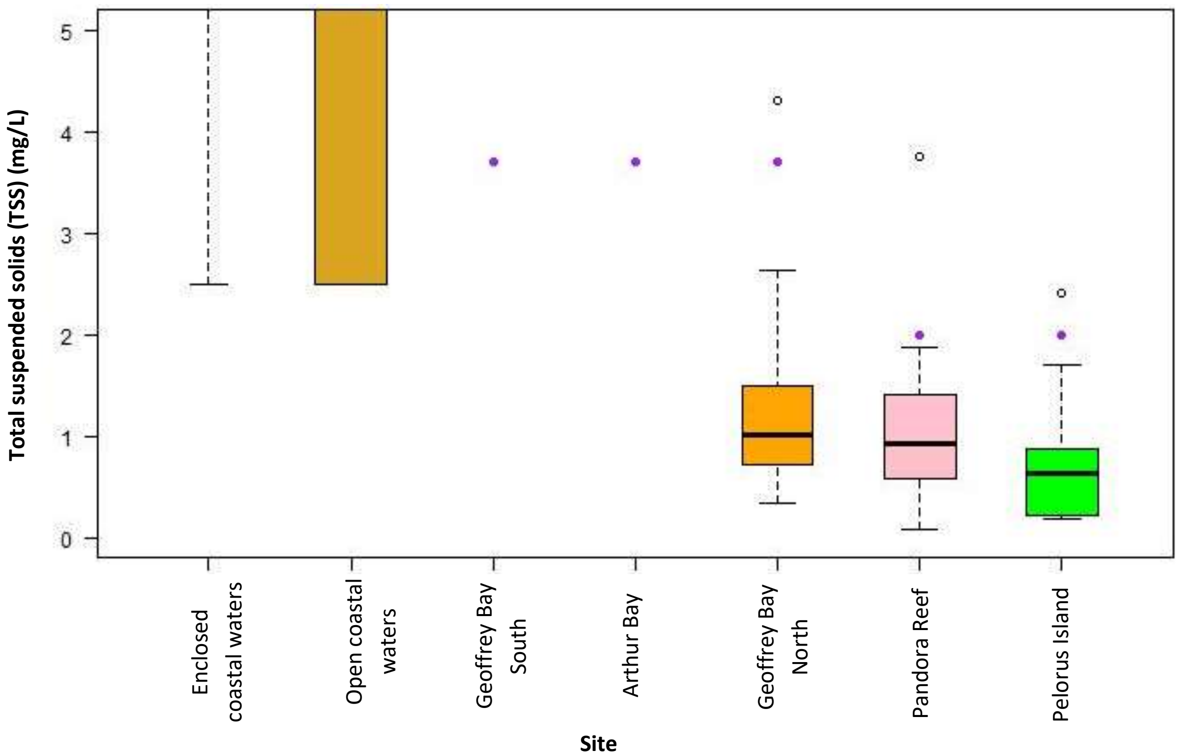


Figure Appendix H10. Boxplot of total suspended solids at each inshore marine monitoring site, excluding the uppermost data from the enclosed and open coastal waters sites.

Data were collected using grab samples. The purple circles indicate the water quality objectives.

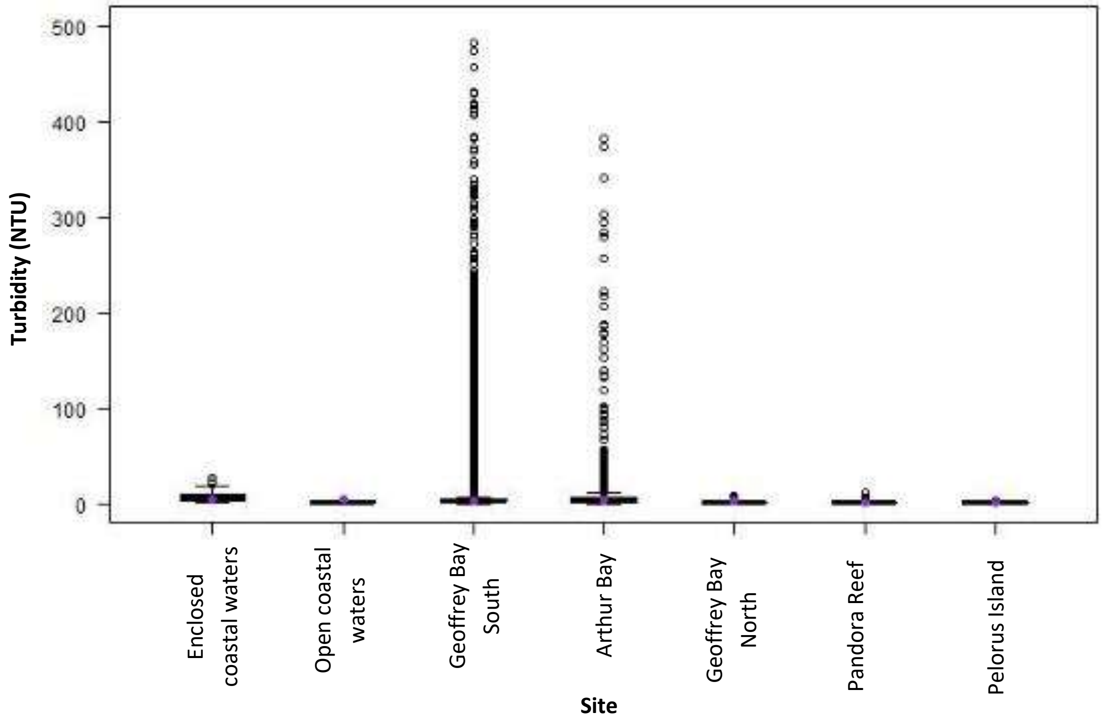


Figure Appendix H11. Boxplot of turbidity levels at each inshore marine monitoring site.

Data was collected using grab samples at most sties, with logger samples used to collect turbidity data at Geoffrey Bay South and Arthur Bay. The purple circles indicate the water quality objectives.

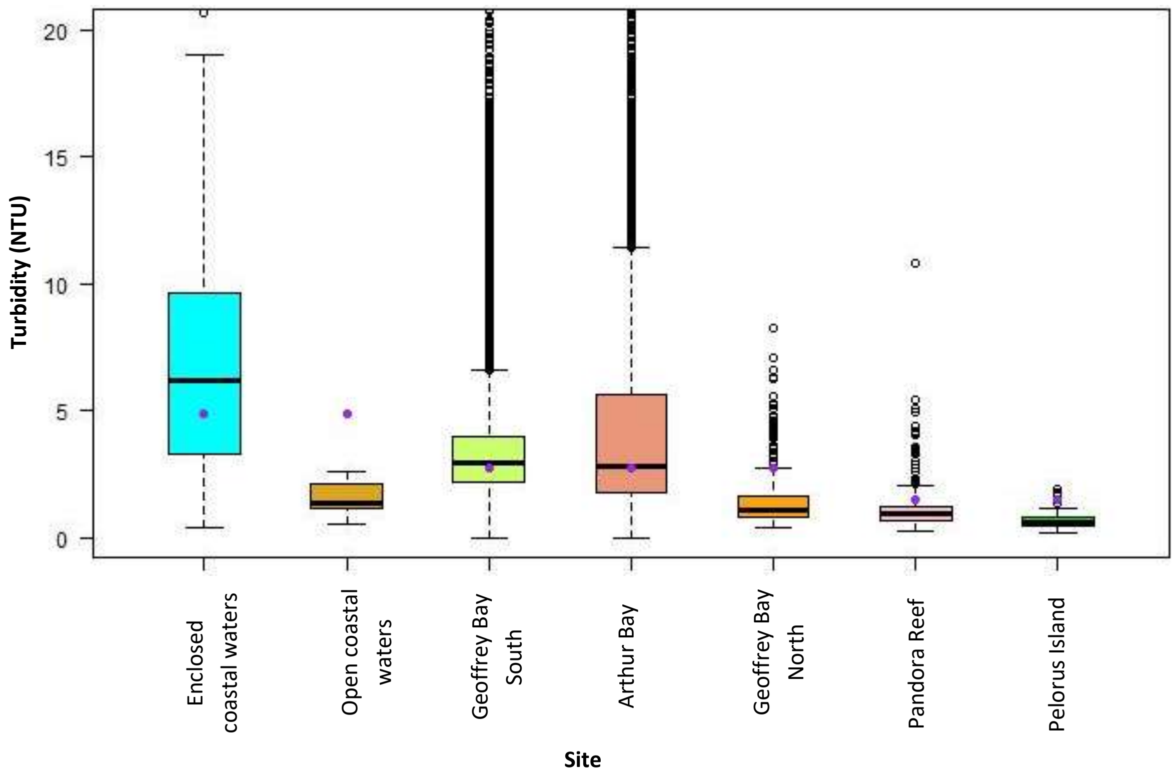


Figure Appendix H12. Boxplot of turbidity levels at each inshore marine monitoring site, excluding the uppermost outliers.

Data was collected using grab samples at most sties, with logger samples used to collect turbidity data at Geoffrey Bay South and Arthur Bay. The purple circles indicate the water quality objectives.

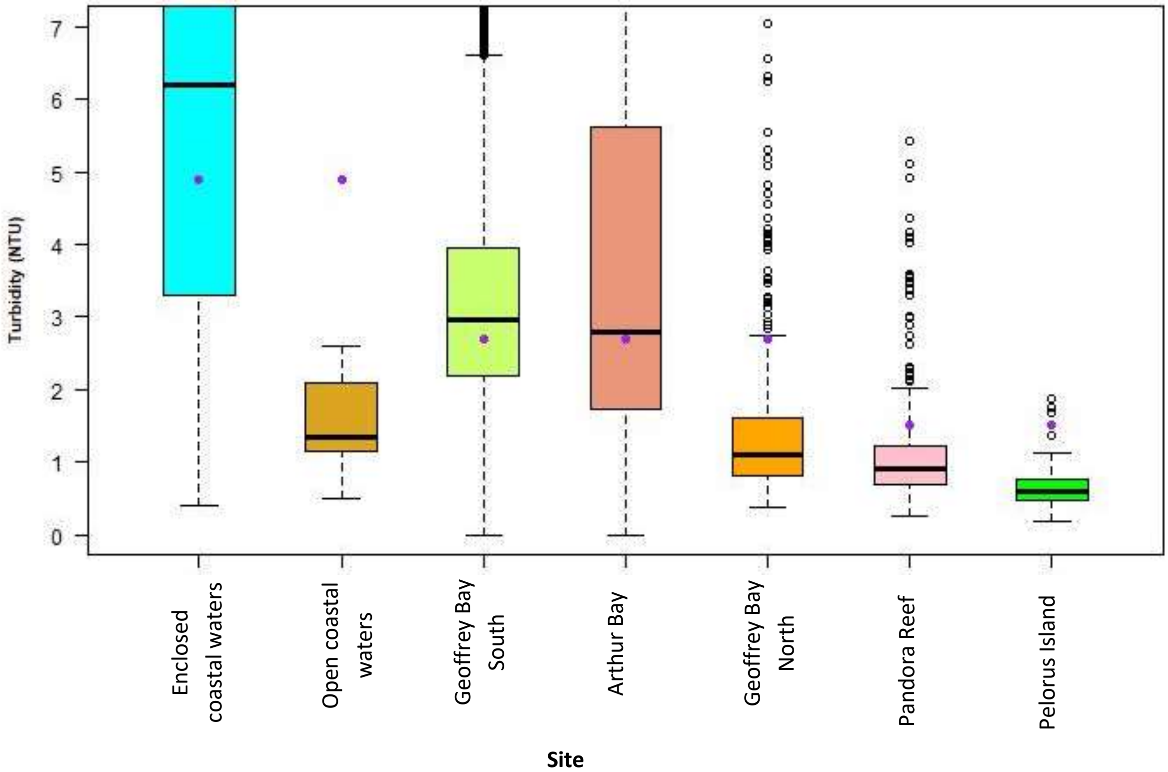


Figure Appendix H13. Boxplot of turbidity levels at each inshore marine monitoring site, excluding most outliers and the uppermost data from the enclosed coastal waters site.

Data was collected using grab samples at most sties, with logger samples used to collect turbidity data at Geoffrey Bay South and Arthur Bay. The purple circles indicate the water quality objectives.

Appendix I. Comparison of site specific results for nutrients and physical-chemical properties for inshore marine sites for 2018-19 and 2019-2020.

Table Appendix I3. Comparison of scores for indicators of nutrients, physical-chemical (phys-chem) properties, chlorophyll *a* and overall water quality for inshore marine sites sampled in the 2018-19 and 2019-2020 financial years.

The scores for nutrients were averaged from the scores for total phosphorus (TP), particulate phosphorus (PP), particulate nitrogen (PN) and oxidised nitrogen (NOx). The overall phys-chem score was calculated by averaging the scores for turbidity, TSS and secchi depth. The overall scores for water quality are the average of the scores for nutrients, phys-chem and chlorophyll a. The scores for Geoffrey Bay and Arthur Bay were averaged for the overall score for Magnetic Island. Significant figures differ for ease of presentation.

	Non-weighted scores for 2019-2020 (current year)											Non-weighted scores for 2018-19 (last year)										
	Nutrients					Phys-chem						Nutrients					Phys-chem					
Site	TP	PP	PN	NOx	**Nutrients**	TSS	Secchi depth	Turb-idity	**Phys-chem**	**Chloro-phyll *a***	**Water quality**	TP	PP	PN	NOx	**Nutrients**	TSS	Secchi depth	Turb-idity	**Phys-chem**	**Chloro-phyll *a***	**Water quality**
Enclosed coastal	84	ND	ND	94	89	69	81	40	64	100	84	62	ND	ND	ND	ND	47	66	0	38	58	49
Open Coastal	100	ND	ND	100	100	100	100	100	100	ND	100	ND	0	0	0	0	87	66	100	84	100	62
Magnetic Island	ND	67	9	0	25	100	ND	71	71	85	60	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Geoffrey Bay North	ND	67	9	0	25	100	ND	100	100	85	54	ND	13	0	0	4	86	70	68	75	80	53
Geoffrey Bay South	ND	ND	ND	ND	ND	ND	ND	54	54	ND	58	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arthur Bay	ND	ND	ND	ND	ND	ND	ND	58	58	ND	70	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cleveland Bay	**92**	**67**	**9**	**65**	**71**	**90**	**91**	**71**	**75**	**93**	**80**	**ND**	**7**	**0**	**0**	**2**	**73**	**67**	**56**	**65**	**80**	**55**
Pandora Reef (Open coastal waters)	ND	75	8	48	44	100	ND	90	95	70	70	ND	0.3	0	0	0.10	82	0	75	52	78	46
Pelorus Island (Midshelf waters)	ND	70	2	28	33	100	ND	100	100	75	69	ND	27	0	0	9	95	0	87	87	44	40
Halifax Bay	**ND**	**73**	**5**	**38**	**39**	**100**	ND	**95**	**98**	**73**	**70**	**ND**	**14**	**0**	**0**	**5**	**89**	**0**	**81**	**70**	**61**	**43**

Scoring range: Very Poor I = 0 to <21 | Poor (D) = 21 to <41 | Moderate (C) = 41 to <61 | Good (B) = 61 to <81 | Very Good (A) = 81 to 100 | No data (ND)

Appendix J. Comparison of site specific results for seagrass meadows within Cleveland Bay for 2019-2020, 2018-19 and 2017-18.

Table Appendix J1. Comparison of scores for indicators of seagrass for meadows within Cleveland Bay sampled during the 2019-2020, 2018-19 and 2017-18 financial years.

		Scores for 2019-2020 (current year)				Scores for 2018-19 (last year)				Scores for 2017-18 (Pilot year)			
Location	Site (meadow)	Biomass	Area	Species composition	**Seagrass indicator category**	Biomass	Area	Species composition	**Seagrass indicator category**	Biomass	Area	Species composition	**Seagrass indicator category**
Geoffrey Bay	3	28	73	97	28	85	88	84	85	82	95	79	80
Nelly Bay	4	41	85	98	41	67	88	100	67	84	87	85	84
Cockle/Picnic Bay	5	60	89	98	60	78	85	98	78	86	84	100	84
Cockle Bay	6	66	50	97	50	70	59	89	59	86	53	96	53
Shelly Beach	10	68	51	96	51	91	54	99	54	93	57	92	57
Rowes Bay	12	60	100	69	60	92	100	84	88	90	100	80	85
Rowes Bay	14	55	74	87	55	68	92	98	68	82	89	98	82
Strand meadow	15	73	74	58	65	93	86	70	78	89	92	89	89
Cleveland Bay	16	59	100	94	59	90	100	99	90	95	79	97	79
Cleveland Bay	17/18	55	88	98	55	71	86	95	71	86	86	96	86
Cleveland Bay					**52**				**74**				**78**

Scoring range: ■ Very Poor (E) = 0 to <25 | ■ Poor (D) = 25 to <50 | ■ Moderate (C) = 50 to <65 | ■ Good (B) = 65 to <85 | ■ Very Good (A) = 85 to 100

Appendix K. Comparison of site specific results for inshore reefs within Cleveland and Halifax bays for 2019-2020, 2018-19 and 2017-18.

Table Appendix K4. Comparison of scores for indicators of inshore coral sampled in the 2019-2020, 2018-19 and 2018-19 financial years.

The score for the coral indicator category is the average of the scores for the five indicators (listed previously). The overall score for Cleveland Bay and Halifax Bay is the average of the scores for the sites listed above bay name. RC stands for Reef Check, a citizen science program that monitors coral cover within the inshore reefs. MMP and LTMP stand for the Great Barrier Reef (GBR) Marine Monitoring Program and the GBR Long-term Monitoring Program. OI stands for Orpheus Island, whilst PI stands for Pelorus Island.

		Standardised scores for 2019-2020						Standardised scores for 2018-19 (last year)						Standardised scores for 2017-18 (Pilot report card)					
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**	Composition of hard corals	% Coral cover	% Change hard corals	Juvenile density	Macro-algae	**Coral indicator category**
Alma Bay	RC	ND	42	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Florence Bay	RC	ND	29	ND	ND	ND	ND	ND	42	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Geoffrey Bay	MMP &RC*	75	48	47	59	0	46	50	40	49	44	0	37	44	0	30	32	25	26
Nelly Bay	RC	ND	25	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Middle Reef	RC	ND	46	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	53^	0^	51^	ND	50^	38^
Cleveland Bay	**Both**	**63**	**38**	**47**	**57**	**0**	**44**	**50**	**41**	**49**	**44**	**0**	**37**	49	0	40	32	38	32
Fantome Island	RC	ND	45	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cattle Bay (OI)	RC	ND	73	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pioneer Bay (OI)	RC	ND	55	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pelorus Island	RC	ND	58	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Havannah	LTMP	100	42	50	40	50	56	100	47	50	24	77	60	21	50	49	75	100	59
Havannah North	MMP	100	28	77	52	0	52	100	28	77	52	0	52	100	0	9	58	100	53
Palms East (OI)	MMP	100	62	70	34	100	73	100	58	91	38	88	75	58	10	20	59	100	49
Palms West (PI)	MMP	0	45	35	41	100	44	25	46	55	39	100	53	29	100	40	83	50	60
Pandora	MMP	75	17	50	71	20	47	75	14	47	52	7	39	45	2	11	39	75	34
Pandora North	LTMP	0	77	31	52	0	32	0	77	31	52	0	32	58	0	72	8	0	27
Halifax Bay	**Both**	**63**	**50**	**52**	**48**	**45**	**52**	**67**	**45**	**59**	**43**	**45**	**52**	**52**	**27**	**33**	**54**	**70**	**47**

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 to 100 | ■ No data (ND)

*Data on percent coral cover is collected by both the MMP program and Reef Check.

^The site has not been sampled since 2014, with the scores carried over from 2014.