Methods for the Townsville Partnership for Healthy Waters (Dry Tropics) annual report cards

Updated 2021

Dry Tropics Partnership for Healthy Waters 2021

Acknowledgements

The methods document was prepared by the Technical Officer of the Dry Tropics Partnership for Healthy Rivers. It was reviewed and endorsed by the Regional Report Cards Technical Working Group and the Independent Science Panel and endorsed by the Dry Tropics Partnership for Healthy Rivers. This methods document is updated every year, and is considered a 'living' document.

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Executive Summary

The Townsville Dry Tropics Partnership for Healthy Waters (referred to as the Partnership) was launched in January 2019. The Partnership creates an annual report card that provides a broad-scale overview of the health of the waterways (freshwater, estuarine, inshore marine and offshore marine waters) and their dependent environments. The current scope of the Partnership is to report on the waterways (freshwater, estuarine, inshore marine and offshore marine) in the Townsville region, from Crystal Creek in the north to Cape Cleveland in the south. Multiple organisations collect a suite of scientific data on the health of waterways within this region. Using the information ascertained by producing the report card, the Partnership aims to understand the pressures impacting upon the environment and then undertake projects to improve the health of waterways.

Within the four environments, different indices are reported upon. Within the freshwater environment, water quality, habitat and hydrology and fish are the three indices reported on. 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. Within the estuarine environment, there are two indices, which are water quality, and habitat and hydrology. Within the inshore marine and offshore marine environment, there are two indices, which are water quality and habitat. The results for litter and the urban water stewardship framework are also included in the report cards (from the 2019-2020 Report Card onwards). In the 2018-2019 Report card, litter was scored for each environment, however within the 2019-2020 Report Card, litter was reported as site specific scores. This was because the scores for sites were not representative of the score for the overall zone. The results for the urban water stewardship framework are presented for the first time in the 2019-2020 Report Card, with these scores for the whole of Townsville, rather than specific zones/environments. Social (community) and economic scores were also scored within the 2017-18 and 2018-19 report cards, but not updated for the 2019-2020 Report Card.

In the 2017-18 Pilot Report Card and the 2018-19 Report Card, different terms were used compared to the 2019-2020 Report Card. This document presents the most up-to-date terminology. In the 2017-18 and 2018-19, indicators relating to habitat were classified under an index called biodiversity, but for the 2019-2020 Report Card onwards, the index was changed to habitat and hydrology (within the freshwater and estuarine zones) or habitat (within the inshore and offshore marine zones). There were also changes in the indices and the indicator categories reported upon in the different report cards. The following paragraphs describe the indices that were scored for each of the report cards that have been released so far. This is a living document and will be updated as existing methods are revised, and new methods devised for additional indicators.

Pilot 2017-18 Report Card

The Townsville Dry Tropics Partnership released its Pilot Report Card in May 2019, reporting on data from the 2017-2018 financial year. Indicators on waterway health were grouped into four reporting categories, which were biodiversity, water quality, social (community) and economic. Following the release of the Pilot Report Card, some methods were updated, and additional indicators/indices continue to be added.

2018-19 Report Card

For the 2018-19 Report Card, the following indices were report upon: water quality, biodiversity, socio-economic (community) and litter. A new reporting category of litter was created, which measures the change in the amount of rubbish within the environment based on baseline data from 2014 to 2018. The litter index is a pressure category, with the pressure impacting upon all aspects of the environment (habitat, water quality and socio-economic). The urban water stewardship framework was piloted in Townsville in 2019, with a high level description of the workshop findings published in a standalone document that accompanied the 2018-19 Report Card.

2019-2020 Report Card

For the 2019-2020 Report Card, the following indices were report upon: water quality, habitat, and hydrology/habitat, fish, litter (site-specific results) and the urban water stewardship framework (one score for the Townsville region, not separated into zones). The index habitat and hydrology was used for the freshwater and estuarine environments and habitat was the term used for the inshore marine and offshore marine environment. Freshwater fish was added, in its own index called fish. Socio-economic indicators were removed from the report card, with new survey questions to be developed for the 2020-2021 Report Card. The results from the urban water stewardship framework were included in the technical report and the high level results published in the management report, which accompanied the Report Card.

Format of document

In its present form, this document provides detailed information on the methods used to score the freshwater, estuarine, inshore marine and offshore marine zones. The document provides information on the following:

1. Indicators selected
2. Data collection methods for indicators of water quality, habitat and hydrology/habitat, fish, litter and the urban water stewardship framework
3. Methods to score indicators
4. Method for scoring confidence for each indicator

This document should be read in conjunction with the Program Design for the Townsville Dry Tropics (Whitehead, 2019a) (henceforth referred to as the Program Design).

Table of Contents

Acknowledgements i

Executive Summary ii

Table of Contents iv

List of Tables viii

List of Figures xi

Terms and Acronyms xiii

1 Introduction 1

1.1 General 1

1.2 Report Card zones 1

1.3 Purpose of this document 3

1.4 Document outline 3

1.5 Terminology 3

2 Baselines that data were compared against 5

3 Indicator selection method 7

3.1 Prioritising indicators to include in future report cards 8

3.1.1 Pilot Report Card 8

3.1.2 Post-Pilot Report Card 8

4 Indicators selected 8

4.1 Indicators of water quality 8

4.2 Indicators of habitat and hydrology or habitat 10

4.3 Indicators of fish and biota 11

4.4 Indicators of litter 12

4.5 Community and Economy indicators 12

5 Water quality data collection (sampling sites and sampling methods) 13

5.1 Freshwater 13

5.1.1 Sampling sites 13

5.1.2 Sampling methods 17

5.2 Estuarine sites 18

5.2.1 Sampling sites 18

5.2.2 Sampling methods 20

5.3 Inshore marine sites 21

5.3.1 Sampling sites 21

5.3.2 Sampling methods ... 22
5.4 Offshore marine ... 23
5.4.1 Sampling sites ... 23
5.4.2 Sampling methods ... 26
6 Habitat and hydrology/habitat data collection (sampling sites and sampling methods) ... 26
6.1 Freshwater basins ... 26
6.1.1 Habitat ... 26
6.1.2 Artificial barriers ... 27
6.2 Estuarine waters ... 31
6.2.1 Habitat index ... 31
6.3 Inshore marine ... 32
6.3.1 Habitat ... 32
6.4 Offshore marine ... 37
6.4.1 Coral ... 38
7 Fish ... 38
7.1 Indicator categories ... 39
7.1.1 Proportion of Indigenous (native) Species Expected (POISE) ... 39
7.1.2 Proportion of Non-Indigenous Fish ... 39
7.2 Sampling sites for the fish index ... 39
8 Litter data collection ... 40
8.1 Clean up locations and sampling methods ... 40
8.1.1 Reef Clean standardised sampling ... 41
8.1.2 Non-standardised clean ups ... 42
8.2 Sampling sites to establish earliest/reference baseline ... 42
9 Community and Economic data collection ... 45
10 Indicator scoring methods applicable to the Water quality and Habitat and hydrology/habitat indices 45
11 Water quality scoring methods ... 46
11.1 Water quality objectives ... 47
11.1.1 Freshwater and estuaries ... 47
11.1.2 Cleveland Bay and Halifax Bay ... 50
11.2 Calculating freshwater and estuarine water quality scores ... 53
11.2.1 Calculating the scoring range ... 53

11.2.2 Scaling factor ... 53
11.2.3 Steps to calculate grades ... 54
11.2.4 Weighting sites by catchment area ... 55
11.2.5 Limit of reporting ... 55
11.3 Calculating inshore marine water quality scores ... 56
11.3.1 Steps to calculate grades ... 56
11.3.2 Limit of reporting ... 57
11.4 Offshore marine zone ... 57
12 Habitat and hydrology/Habitat scoring methods ... 58
12.1 Freshwater basins ... 58
12.1.1 Habitat index ... 58
12.1.2 Artificial barriers ... 59
12.2 Estuarine waters ... 60
12.2.1 Habitat index ... 60
12.3 Inshore and offshore marine zones ... 61
12.3.1 Habitat index ... 61
13 Fish scoring methods ... 66
13.1 Fish index ... 66
13.1.1 Proportion of Indigenous (native) Species Expected (POISE) ... 66
13.1.2 Proportion of Non-Indigenous Fish ... 66
13.2 Sampling methods and grades ... 66
14 Litter scoring methods ... 67
14.1 Litter index ... 67
14.1.1 Scoring ranges ... 67
15 Community (social and economic) index ... 69
15.1 Methods used in both the 2017-2018 Pilot Report Card and 2018-2019 Report Card ... 70
15.1.1 Positively working survey questions ... 70
15.1.2 Scoring method ... 70
15.2 Changes in the methods between the 2017-2018 Pilot Report Card and 2018-2019 Report Card 71
15.2.1 Scoring each zone by postcode (used in Pilot Report Card only) ... 71
16 Urban water stewardship framework data collection and scoring methods ... 72
16.1 Reasoning for the urban water stewardship framework ... 72

16.2 Purpose of the urban water stewardship framework 72
16.3 Method 73
17 Confidence scores 76
17.1 Water Quality and Habitat and hydrology/habitat indices.. 76
17.1.1 Method for scoring confidence for Water Quality and Habitat and hydrology/habitat 76
17.1.2 Scoring of confidence for Water quality and Habitat and hydrology/habitat 77
17.1.3 Rules for presenting confidence scores on report cards 78
17.2 Confidence score for Community and Economy 79
18 Limitations and recommendations 79
References 81
Appendix A: Scoring against both water quality objectives and guidelines. 94
18.1.1 Water quality guidelines 94
Appendix B: Scoring methods for calculating riparian, wetland, mangrove, and saltmarsh extent compared to the earliest available baseline. 97
Appendix C: Logic for scoring each grading range within water quality.. 98
18.2 Logic for scoring "Very Good" 98
18.3 Logic for scoring "Good" 98
18.4 Logic for scoring "Moderate, Poor and Very Poor" 98
Appendix D. Community survey questions and indicator categories 99

List of Tables

Table 1. Indices names and the coaster designs for the Pilot 2017-2018 Report Card, the 2018-19 Report Card, and the 2019-2020 Report Card. 4

Table 2. Summary of the baseline that indicator categories/indices were scored against in the 2018-19 and 2019-2020 technical reports and in the Report Card. 6

Table 3. Selection criteria for indicators for the four indices (Water Quality, Habitat and hydrology/Habitat, Community (social) and Economy) of the Townsville Dry Tropics (Townsville Dry Tropics) report cards. 7

Table 4. Indicators measured to determine the score for the water quality index for the freshwater, estuarine and inshore and offshore marine zones. 9

Table 5. Indicators measured to determine the Habitat and hydrology/Habitat index for the freshwater, estuarine and inshore and offshore marine zones. 11

Table 6. Indicators measured to determine the fish and biota indices for the freshwater, estuarine and inshore and offshore marine zones. 12

Table 7. Estuaries and number of non-independent sites per estuary within the Ross and Black estuarine zones. 19

Table 8. Independent sites and indicators measured within the Ross and Black estuarine zones. 20

Table 9. Independent and non-independent sites within Cleveland Bay and Halifax Bay and description of the sites. 21

Table 10. Indicators sampled at each independent site. 23

Table 11. Description of stream risk categories in relation to the Strahler stream order system. 29

Table 12. Description of coral indicators and the environmental zones where each indicator is reported and scored. 34

Table 13. Location of Reef Clean clean-ups within the Townsville Dry Tropics region for 2018 until 2021. 41

Table 14. Location and number of clean ups in the Townsville Dry Tropics region between 1st July 2014 and 30th June 2018. 42

Table 15. Standardised (report card) scoring ranges and corresponding grades for Water Quality and Habitat and hydrology/Habitat indicators and indicator categories. 45

Table 16. Scheduled and adjusted environmental protection policy water quality objectives for water quality indicators for the Ross and Black freshwater basins and estuarine environments. 50

Table 17. Scheduled environmental protection policy water quality objectives for water quality indicators for Cleveland Bay, Halifax Bay, and the offshore marine environment. 51

Table 18. Rules, formulas and scoring ranges for indicators (except lower dissolved oxygen) within the nutrients and phys-chem indicator categories in freshwater basins and estuaries for the Townsville Dry Tropics report card. 54

Table 19. Rules, formulas and scoring ranges for the lower dissolved oxygen (DO) indicator. 55

Table 20. Inshore water quality grades, scoring ranges and scaling for aggregation.......................... 56

Table 21. Great Barrier Reef Marine Park Authority (GBRMPA) water quality guideline values (WQGVs) for total suspended sediments and chlorophyll *a*. 57

Table 22. Scoring ranges, standardisation formulas (to convert raw scores to standardised scores), report card scoring range and report card grades for loss of riparian extent over a four year period. 58

Table 23. Scoring ranges, standardisation formulas (to convert raw scores to standardised scores), report card scoring range and report card grades for loss of wetland, mangrove, and saltmarsh extent over a four year period. 59

Table 24. Scoring ranges, standardisation formulas (to convert raw scores to standardised scores), report card scoring range and report card grades for impoundment length within freshwater and estuarine environments. 59

Table 25. Scoring ranges, formulas to convert raw scores to standardised scores, report card scoring range and report card grades for the fish barriers indicator category. 60

Table 26. Scoring ranges, standardisation formulas, report card scoring range and grades for the fish barrier indicator. 60

Table 27. Description of indicators within the coral cover indicator category.................................. 62

Table 28. Score and threshold for the five indicators of the coral indicator category. 62

Table 29. Sample size (total observations) per survey by the three coral monitoring programs within the Townsville Dry Tropics region. 64

Table 30. Improvement in precision of coral cover estimates with increasing sampling intensity...... 64

Table 31. Weighting for inshore and offshore Reef Check reefs based on precision estimates for one, two and reef sites sampled per reef. 65

Table 32. Coral indicator scoring ranges, formulas to standardise raw scores, report card scoring range and grades. 65

Table 33. Scoring ranges, standardisation formulas (to convert raw scores to standardised scores), report card scoring range and report card grades for Proportion of Indigenous Species Expected (POISE) indicator category within freshwater environments. 66

Table 34. Scoring ranges, standardisation formulas (to convert raw scores to standardised scores), report card scoring range and report card grades for the Proportion of Indigenous Fish indicator category within freshwater environments. 66

Table 35. Mean log (catch per unit effort) per site, per reporting year for Townsville clean up locations for the four years used to establish the baseline (1st July 2014 until 30th June 2018) and for the 2018-2019 financial year. 68

Table 36. Scoring range and corresponding grade for Community and Economic indicator categories and indices and for the Community Stewardship indicator category. 70

Table 37. Changes in the methods used in the 2017-2018 Pilot Report Card compared to the methods used in the 2018-2019 Report Card........ 71

Table 38. 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). 75

Table 39. Score and rating categories for the Urban Water Stewardship Framework. 76

Table 40. Confidence criterion, weighting, and its purpose. 77

Table 41. Scoring rules used for each criterion used to calculate the confidence scores for the Townsville Dry Tropics Report Card. 77

Table 42. Presentation of confidence scores in the report card. 78

Table 43. Percentage of population surveyed within the Townsville region (for the 2018-2019 Report Card) and for each zone (for the 2017-2018 Report Card). 79

Table 44. Current limitations of the data sets within Townsville Dry Tropics report card and improvements being pursued. 79

List of Figures

Figure 1. Geographic boundary reported upon by the Dry Tropics Partnership, comprising the Ross and Black freshwater basins and estuarine zones, Cleveland Bay and Halifax Bay and the offshore marine zone. 2

Figure 2. Independent and non-independent sites within the Ross freshwater basin. 15

Figure 3. Freshwater independent sites (blue dots) within Black Basin. 16

Figure 4. Independent and non-independent sites within the Ross and Black estuarine zones. 19

Figure 5. Independent and non-independent sites within Cleveland Bay and Halifax Bay. 22

Figure 6. The Burdekin inshore (dotted yellow line) and offshore (solid red line) marine zones in relation to the Townsville Dry Tropics region within Queensland. 24

Figure 7 . Concentration of total suspended solid (non-algal particulates) within the Burdekin and Townsville Dry Tropics offshore marine zones. 25

Figure 8. Concentration of chlorophyll-*a* within the Burdekin and Townsville Dry Tropics offshore marine zones. 25

Figure 9. Diagram of the three components of the fish barriers indicator category and how each is calculated. 28

Figure 10. Strahler stream order from headwaters downstream. 30

Figure 11. Classification of a) risk categories for all streams classifications, and b) for major and high impact stream classifications within the Townsville Dry Tropics region (green shading). 30

Figure 12. Seagrass monitoring meadows within the Townsville region. 33

Figure 13. Sampling locations of inshore reefs (pink dots) within Cleveland Bay and Halifax Bay, which comprise the Townsville Dry Tropics inshore marine zone. 35

Figure 14. A Reef Check transect, comprising four 20m replicates along which reef substrate composition is measured. 37

Figure 15. Sampling locations of offshore reefs (red dots) within the Townsville Dry Tropics offshore marine zone (white and purple outline). 38

Figure 16. Location of fish sampling sites within the Ross and Black freshwater basins. 40

Figure 17. Locations where clean ups occurred between 1st July 2014 and 30th June 2019 within 1) Halifax Bay, 2) Cleveland Bay, 3) Ross estuarine zone and 4) Ross freshwater basin. 44

Figure 18. Water types within the Ross Basin. 48

Figure 19. Water types within the Black Basin. 49

Figure 20. Water types within Cleveland and Halifax Bays, showing some WQOs associated with different water types. 52

Figure 21. An example of assigning water quality grades. 53

Figure 22. Theoretical influence of sampling intensity in confidence intervals about mean coral cover. 64

Figure 23. Transformation of standardised collection rates to scores and grades. 69

Figure 24. Score and grade transformation in a near normal distribution curve (same cut off values as Figure 23). 69

Terms and Acronyms

AIMS	Australian Institute of Marine Science
Artificial barriers (as an indicator)	Artificial barriers are any barriers which prevent or delay connectivity between key habitats and potentially impacting migratory fish populations, reducing diversity of aquatic species and communities and the condition of aquatic ecosystems (Moore, 2016).
Basin	Area of land where surface water runs into smaller channels, creeks or rivers discharging into a common point and may include many sub-basins or sub-catchments. For this report card, a basin will refer to only freshwater waterways to differentiate between the freshwater waters and both freshwater and estuarine waters (which are referred to as a catchment).
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.
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 (2017).
GBRMMP	Great Barrier Reef Marine Monitoring Program of the inshore reef communities along Wet Tropics, Burdekin, Mackay, Whitsunday, and Fitzroy regions of the GBR
GBRMPA	Great Barrier Reef Marine Park Authority
GBRMP	Great Barrier Reef Marine Park
Highly disturbed (HD) systems	Measurably degraded ecosystems of lower ecological value. The philosophy applied to degraded aquatic ecosystems is that they still retain - or after rehabilitation may have - ecological or conservation values but for practical reasons it may not be feasible to return them to a slightly to moderately disturbed condition, at least in the short to medium term. (Australian Government Initiative, n.d.).
High ecological value (HEV) systems	For ecosystems highly valued for their unmodified state and outstanding natural and conservation values, there should typically be no change in biodiversity beyond natural variability. Where possible, there should also be no change in water/sediment chemical and physical properties, including toxicants. Effectively unmodified or other highly valued ecosystems, typically (but not always) occurring in national parks and conservation reserves, or in remote and inaccessible locations (Australian Government Initiative, n.d.).
Impoundment length	An indicator used in the 'in-stream habitat modification' indicator for freshwater basins in the region. The proportion (%) of the linear length of the main river channel when at the full capacity of artificial in-stream structures, such as dams and weirs.
Index	Integration of one or more indicator categories (e.g. nutrients and physical-chemical properties are indicator categories of the water quality index).
Indicator	A measure of one component of an indicator category (e.g. turbidity (indicator) is a measure of physical-chemical properties (indicator category).
Indicator category	Integration of one or more indicators (e.g. the physical-chemical properties indicator category is comprised of turbidity, upper dissolved oxygen, and lower dissolved oxygen).
Inshore marine environment	Includes enclosed coastal (EC), open coastal (OC) and midshelf (MS) waters, extending east to the boundary with the offshore waters (Department of Environment and Science, 2018). The boundary is based on the delineation guidelines for the Burdekin (which includes the Townsville Dry Tropics region) and the Wet Tropics region. Waters north of Pelorus Island are based on the guidelines for the inshore boundary for the Wet Tropics region.
Inshore marine zone	Inshore marine zone is a reporting zone in the Townsville Dry Tropics Report Card that includes inshore marine environments.
ISP	Independent Science Panel

JCU	James Cook University
Limit of reporting (LOR)	Limit of reporting means the minimum concentration of a substance in a sample that can be reliably detected by a laboratory (limit of detection).
LTMP	Long Term Monitoring Program of GBR midshelf and offshore reef communities
Macroalgae (cover)	Macroalgae is a collective term used for seaweeds and other benthic (attached to the bottom) marine algae that are generally visible to the naked eye. Larger macroalgae are also referred to as seaweeds, although they are not really "weeds". They are distinguished from microalgae (e.g. diatoms, phytoplankton, and the zooxanthellae that live in coral tissue), which are unicellular (Source: (Diaz-Pulido & McCook, 2008). In this report, macroalgae is an indicator used to assess coral health.
Moderately disturbed (MD) ecosystem	Ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity. The biological communities remain in a healthy condition and ecosystem integrity is largely retained. Freshwater systems would typically have slightly to moderately cleared catchments or reasonably intact riparian vegetation. Marine systems would typically have largely intact habitats and associated biological communities. For slightly to moderately disturbed ecosystems, some relaxation of the stringent management approach used for unmodified ecosystems may be appropriate. An increased level of change might be acceptable, or there might be reduced inferential strength for detecting any change in biological diversity. Source: Australian Government Initiative (n.d.)
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) (Department of Environment and Science, 2018).
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) (Department of Environment and Science, 2018).
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 from the coast to 12 km offshore in the Burdekin region (waters south of approximately Pelorus Island) and from the coast to 6 km offshore in the Wet Tropics region

	(waters north of Pelorus Island) (Department of Environment and Science, 2018).
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
RIMReP	Reef 2050 Integrated Monitoring and Reporting Program
Riparian Extent (as an indicator)	Indicator used in assessing freshwater and estuarine zones derived by mapping the extent of the vegetated interface between land and waterways.
SELTMP	Social and Economic Long-Term Monitoring Program
SF	Scaling Factor
Slightly disturbed (SD) ecosystem	Same definition as moderately disturbed (MD) ecosystem
SMART	Specific, measurable, achievable, relevant, time-bound
Standardised condition score	The transformation of indicator scores into the Dry Tropics Report Card scoring range of 0 to 100.
Sub-indicators	Integration of one or more sub-indicators (e.g. seagrass is comprised of ground biomass, meadow area and species composition).
TCC	Townsville City Council
TDT	Townsville Dry Tropics
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
Water quality guidelines (WQGVs)	Water quality guidelines are values designed to maintain ecosystems in near pre-development condition. They are largely based on data from non-impacted waterways or on toxicant/pollutant concentrations shown to have nil impact. They generally remain consistent across all waterbodies of a similar type (e.g. freshwater, estuary, coastal) and in the same region.
WQIP	Water Quality Improvement Plan

Water quality objectives (WQOs)	WQOs are long-term goals for water quality management. They are measures, levels, or narrative statements of specific water quality indicators (such as salinity or turbidity) that protect EVs after consideration of the socio-economic assessment of protecting the water quality.

1 Introduction

1.1 General

The Townsville Dry Tropics Partnership for Healthy Waterways (referred to as the Partnership) was launched in January 2019, with the Pilot Report Card released in April 2019. A focus of the Partnership is to produce an annual report card that describes the state of the Townsville region waterways. The Report Card is designed to evolve through time, with additional indicators developed and reported upon within the Report Card, as necessary. The Report Card is also designed to highlight gaps in data, with the aim of then fulfilling these gaps.

Currently, the Report Card includes an assessment of three environmental indices, which are the condition of water quality, habitat and hydrology and fish. In the future, if other fauna species are reported upon within the freshwater zone, the index will be named Biota and fish will be included under the Biota index. Indices are scored for the freshwater, estuarine, inshore marine and offshore marine environments within the Townsville Dry Tropics region. Not all indices are scored for each environment, with fish only scored within the freshwater environment. The site-specific results for litter and the ratings for the urban water stewardship framework (UWSF) for the Townsville local government area are also included. Fish were first included in the Report Card in 2019-2020, whilst the results for litter and the UWSF were first included in 2018-19. An assessment of the social and economic benefits the community receives from waterways and the marine environment were included in the Pilot 2017-19 and the 2018-19 Report Card.

1.2 Report Card zones

There are four environments that are reported upon, which are freshwater, estuarine, inshore marine and offshore marine. These environments collectively cover seven zones, which are:

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

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

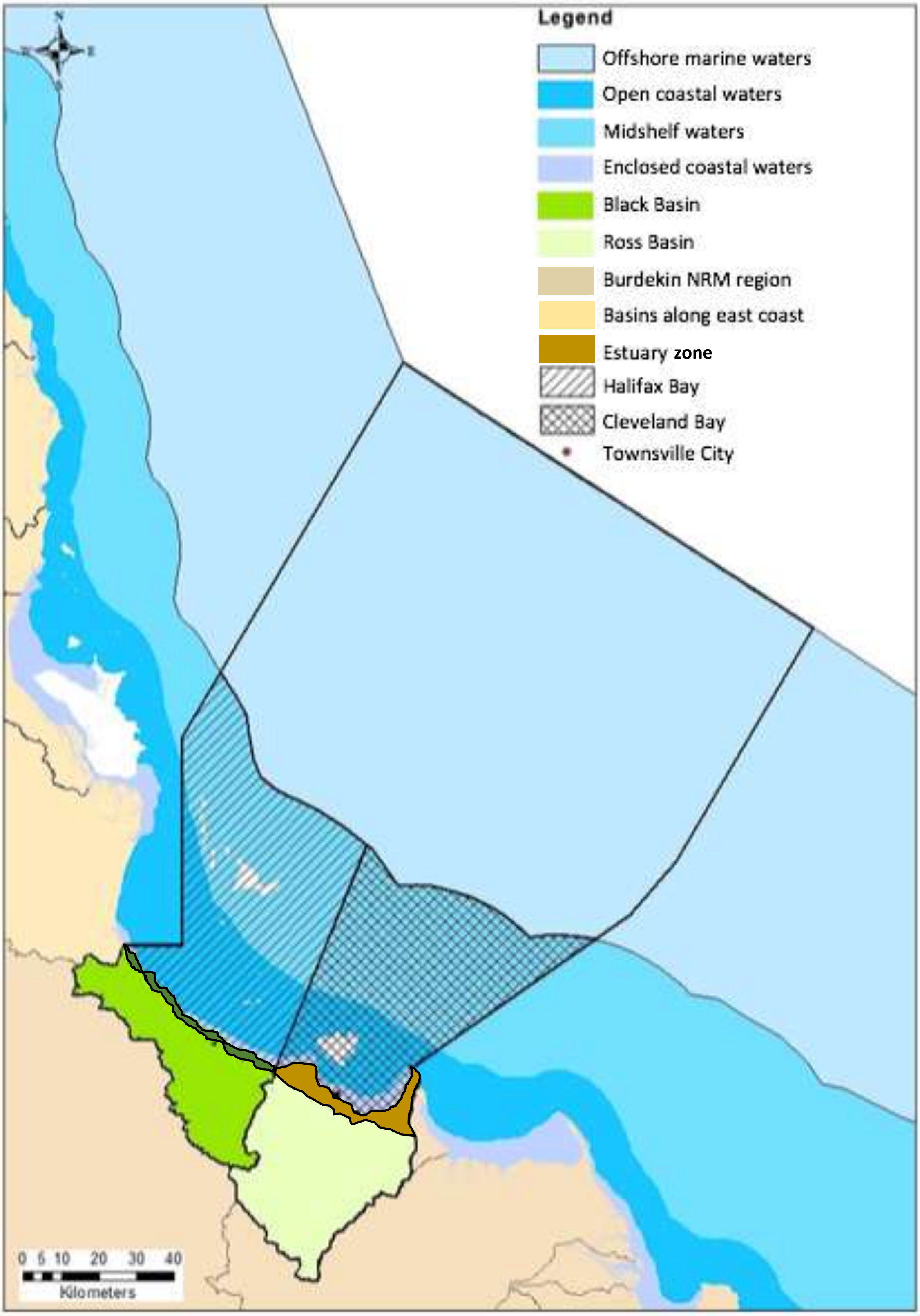


Figure 1. Geographic boundary reported upon by the Dry Tropics Partnership, comprising the Ross and Black freshwater basins and estuarine zones, Cleveland Bay and Halifax Bay and the offshore marine zone.
The inshore marine zones comprise midshelf, open coastal and enclosed coastal waters. The right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

1.3 Purpose of this document

This document describes the methods used to produce the scores for the indices reported upon within the report cards. This is a living document and methods are updated each year as existing methods are revised, and new methods devised for additional indicators. The Townsville Dry Tropics Report Card and Partnership are described in the Program Design (Whitehead, 2019a).

1.4 Document outline

This document is divided into the following sections:

1. Introduction
2. Reporting against earliest/reference baseline and progress towards management targets
3. Method for selecting indicators
4. Indicators selected
5. Water data collection for the freshwater, estuarine, inshore marine and offshore marine environments (sampling sites and sampling methods)
6. Habitat and hydrology/Habitat data collection for the freshwater, estuarine, inshore marine and offshore marine environments (sampling sites and sampling methods)
7. Community and Economic data collection
8. Litter data collection
9. Indicator scoring methods
10. Water Quality scoring methods
11. Habitat and hydrology/Habitat scoring methods
12. Community and Economic methods
13. Litter scoring methods
14. Urban water stewardship framework data collection and scoring methods
15. Confidence scores

1.5 Terminology

Different indicators are measured to assess each index within the seven zones. Indicators that measure a similar aspect of the condition of the environment are grouped together. Their scores are then aggregated multiple times to produce an average (overall) score for each index for each environment and zone. For the seagrass and coral indicators, there are sub-indicators that are averaged into a score and grade for the indicator. The index habitat and hydrology/habitat is referred to as the habitat and hydrology index within the freshwater and estuarine environments and solely as the habitat index in the inshore and offshore marine zones. This is because hydrology indicators are not included or planned to be reported upon within the marine environments.

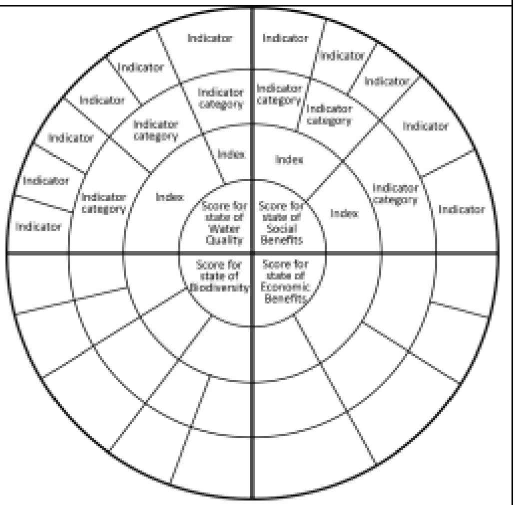
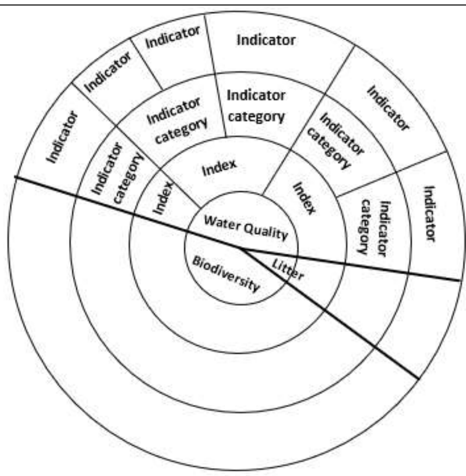
The levels of aggregation are:

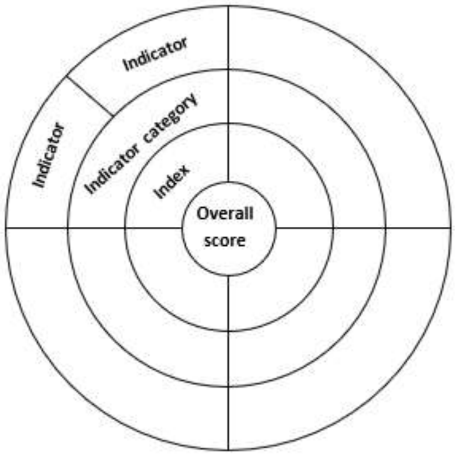
- **Indicator** is a measured variable (e.g. nitrogen).
- **Indicator category** is a group of similar indicators (e.g. nutrients, which is an aggregation of indicators related to nutrients, such as nitrogen and phosphorus). Where an indicator category is represented by a single indicator, the indicator category score is equal to the indicator.
- **Index (single) or indices** (plural) is an aggregation of indicator categories (e.g. water quality).

Index grades are presented in a coaster involving a series of concentric rings, with the overall grade for the index (most aggregated level) in the inner ring and indicator categories and indicators (least aggregated level) in the outer rings. For clarity, generally only the grades for the indices and indicator categories are shown. For the first few iterations of the Report Card, the terminology of the indices and the design of the coasters in the report card changed. The indices names and coaster designs for each report card produced so far are shown in Table 1.

Table 1. Indices names and the coaster designs for the Pilot 2017-2018 Report Card, the 2018-19 Report Card, and the 2019-2020 Report Card.

In the public Report Cards, the grades for the individual indicators were not presented.

Report Card	Indices	Coaster design	
Pilot 2017-2018 Report Card	Water, biodiversity, social (community), and economy	All indices were scored within one wedge for each zone, with all indices comprising a quarter of the coaster, as shown in the next column.	
2018-2019 Report Card	Water quality, habitat, litter and socio-economic (community)	Water quality, habitat and litter were scored in one coaster, although litter was only an 8th of the size of the coaster. Community was scored for the entire Townsville region and results presented in a separate coaster.	

2019-2020	Water quality, habitat and hydrology/habitat, fish, litter and the urban water stewardship framework (UWSF)	Water quality, habitat and hydrology/habitat and fish were scored in one coaster, although fish is only in the two freshwater zones. Litter and the results of the UWSF are reported separately and not within the environmental coaster. Litter was site-specific results only and the results of the QWSF was for the Townsville local government area.	

2 Baselines that data were compared against

Indicators were compared against either progress towards management targets, or earliest available/baseline data. Ideally indicators would be compared against the same targets/baselines so scores are comparable between indicators. However, data used in the Report Card was collected from pre-existing monitoring programs, with each program using their own target or baseline appropriate to that program.

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

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

In the 2017-18 Report Card, water quality were compared against a mixture Where data were available, indicators were compared against both progress towards management targets and against the earliest available data. Separate methods were used to analyse data against the two different levels (targets/baseline).

In the 2018-19 document, water quality indicators and indicators of freshwater and estuarine habitat extent were compared against both management targets and earliest baseline. For these indicators, only results of data compared against management targets were presented in the 2018-2019 Report Card. All other indicators were only compared against one baseline. Table 2 provides an overview of which baseline/s each index was scored against and which of the scores are shown on the Report Card. Each year the same baselines will be used so that trends in time can be assessed.

Table 2. Summary of the baseline that indicator categories/indices were scored against in the 2018-19 and 2019-2020 technical reports and in the Report Card.

			Baseline that data was compared against		
Zone	Index	Indicator categories	2019-2020 Report Card	2018-2019 Report Card	2017-2018 Report Card
Freshwater, estuarine and inshore marine (chlorophyll *a* only scored in the inshore marine)	Water quality	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)	Management targets	Management targets
				Guideline values (earliest baseline)	
Freshwater and estuarine	Habitat and hydrology	Habitat extent	Management targets (change over four years for the Great Barrier Reef region)	Management targets	Pre-European habitat extent (earliest baseline)
				Guideline values (earliest baseline)	
Freshwater		Artificial barriers	Earliest data	Earliest data	Not scored
Inshore marine	Habitat	Seagrass condition	Earliest data	Earliest data	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.		
Offshore marine	Water quality	TSS and Chlorophyll *a*	Guideline value (earliest baseline)		
Freshwater	Fish	Proportion of Indigenous (native) species	Earliest baseline	Not scored	Not scored
		Proportion of non-indigenous species		Not scored	Not scored

3 Indicator selection method

Mostly indicators serve as proxies for ecosystem attributes of interest, although in some instances, indicators simply track the abundance of a single species of ecological, social, or economic importance (Levin, et al., 2009). Indicator selection is detailed in section 5 of the Program Design (Whitehead, 2019a), but is summarised below.

To ensure indicators chosen are scientific and relevant to the community, three steps were undertaken to identify indicators:

1. A workshop was undertaken in September 2018, where 34 science experts and community members listed relevant indicators for each index (Water Quality, Habitat and hydrology/Habitat, Community and Economy). From the 81 potential indicators proposed, 31 were for selected for Habitat and hydrology/Habitat, 22 for Water, seven for Economy and 17 for Community.
2. A subsequent literature search identified indicators commonly used in other report cards, government reports or scientific research papers (both in Australia and overseas) to ensure that all possible indicators relevant to the Townsville Dry Tropics were considered. To provide alignment with the other Queensland regional report cards, it is beneficial to use the same or similar indicators as other programs. A total of 210 potential indicators of the four indices were identified from the literature.
3. Selection criteria (Table 3) were designed to assess each potential indicator from both steps 1 and 2. Indicators that met the criteria were prioritised for inclusion in the Report Card.

Table 3. Selection criteria for indicators for the four indices (Water Quality, Habitat and hydrology/Habitat, Community (social) and Economy) of the Townsville Dry Tropics (Townsville Dry Tropics) report cards.

A yes/no assessment was undertaken to see whether indicators complied within the selection criteria. Those that met all criteria were prioritised for inclusion in the report cards.

	Selection criterion
Scientific value	Indicator scientifically proven to reflect the health of a specific environmental or socioeconomic process.
	Sensitive to change
	Follows the SMART criteria (specific, measurable, attainable (cost-effective), relevant to our catchment and time-bound (sensitive to short term changes)).
	Signals can be measured in a simple, repeated, and cost-efficient way, and subsequent analyses are scientifically robust, clear unambiguous and easily repeatable.
	Links with management objectives and actions (i.e. indicator can be influenced by management practices).
	Aligns with the WQIP
	Aligns with the Reef 2050 Plan
Community value	Representative of the community values in the region
	Easily communicated and understood by stakeholders, management, and the community
	Clearly linked to an objective of the report card
	Can be used to provide a report card score
Data and method availability	Availability of ongoing data (or whether it would be available within the next few years)
	Established scoring method used by other Queensland regional report cards or a method could be developed within short time constraints.
	Guideline values exist (or can be developed) so a score can be produced for the report card.

3.1 Prioritising indicators to include in future report cards

3.1.1 Pilot Report Card

For the Pilot Report Card, indicators that were identified as a priority to the partnership but could not be scored, were classified as either 'future' or 'aspirational' based on the time frame for them to be scored. This was done to ensure these indicators were not forgotten about. Future indicators were those where data or a scoring method were available (but not both), making them more likely to be developed in the short term. Aspirational indicators were defined as those important to the region, but no data were available and unlikely to become available within the next three years.

3.1.2 Post-Pilot Report Card

After the Pilot Report Card, it was decided that aspirational indicators were unlikely to be scored within the next three years. Future indicators were redefined as "indicators where there are data or a scoring method available (but not both), or neither data nor a scoring method were available, but both could be developed within the next five years". Aspirational indicators were redefined as "indicators that are important to the region, but no data were available, and it is unlikely data will become available within the next five years". Aspirational indicators are still included in the methods document to acknowledge that the Partnership aims to eventually report on these.

This change in timeframe was agreed because large field-based monitoring programs would need to be developed and implemented for the aspirational indicators to be scored within the report card. Monitoring would also need to be at a sufficiently fine scale to ensure the data were accurate at a regional scale (so it can be included in the reporting zones of the report card). These types of monitoring programs are currently outside the scope of the Partnership and are unlikely to be developed by other organisations within the next five years. Classifying indicators based on their achievability within the next five years aligns with both the Wet Tropics and Mackay-Whitsunday Partnerships, which operate on a five-year work program design. The Dry Tropics Partnership aims to design a five-year program plan for 2020-2021.

4 Indicators selected

The following sections provide a list of the indicators selected for each index and environmental zones. Reasons for indicators being selected and the link between the indicator and the waterway health are outlined in the Program Design (Whitehead, 2019a).

4.1 Indicators of water quality

The score for the water quality index is based on indicator categories and indicators that are grouped into the following indices:

- Nutrients and physical and chemical (phys-chem) properties for the two freshwater and two estuarine zones.

- Nutrients, physical and chemical properties, and chlorophyll-*a* for the two inshore marine zones.
- Physical and chemical properties and chlorophyll-*a* for the one offshore marine zone.

Groundwater is an aspirational and would be a separate environment zone, with the score for this zone being derived from indicators within the hydrology and contaminants indices.

The indicator categories and indicators of the water quality index and future and aspirational indicators are shown in Table 4. Indicators scored in all report cards are highlighted in green, whilst those scored post-Pilot Report Card are highlighted in cream in Table 4. Future and aspiration indicators are not differentiated by colour and are not highlighted.

Table 4. Indicators measured to determine the score for the water quality index for the freshwater, estuarine and inshore and offshore marine zones.

Frequency of sampling and whether the indicator is compared to the earliest baseline or progress towards management target (referred to as management targets) is shown. Indicators scored in all report cards are highlighted in green, whilst those scored post-Pilot Report Card are highlighted in cream. Future and aspirational indicators are not highlighted. TBC stands for to be confirmed.

Zone	Indicator category	Indicator	Sampling frequency	Frequency of reporting	Baseline that indicator is compared to
Freshwater	Nutrients	Phosphorus (P)	Monthly	Annually	Management target Earliest baseline
		Dissolved inorganic nitrogen (DIN)	Monthly	Annually	Management target Earliest baseline
	Phys-chem	Dissolved Oxygen (DO)	Monthly	Annually	Management target Earliest baseline
		Turbidity	Monthly	Annually	Management target Earliest baseline
		pH	Monthly	Annually	Management target Earliest baseline
	Hydrology	% catchment impervious/developed	TBC	Annually	TBC
		% native land cover	TBC	Annually	TBC
		Flow	TBC	Annually	TBC
	Contaminants	Pesticides	TBC	Annually	TBC
		Metals	TBC	Annually	TBC
		PFAS (Per- and poly-fluoroalkyl substances)	TBC	Annually	TBC
Estuary	Nutrients	Phosphorus	Monthly	Annually	Management target Earliest baseline
		DIN	Monthly	Annually	Management target Earliest baseline
	Phys-chem	Dissolved Oxygen (DO)	Monthly	Annually	Management target Earliest baseline
		Turbidity	Monthly	Annually	Management target Earliest baseline
		pH	Monthly	Annually	Management target Earliest baseline
	Hydrology	% catchment impervious	TBC	Annually	TBC
		% native land cover	TBC	Annually	TBC
		Flow	TBC	Annually	TBC

Zone	Indicator category	Indicator	Sampling frequency	Frequency of reporting	Baseline that indicator is compared to
	Contaminants	Pesticides	TBC	Annually	TBC
		Metals	TBC	Annually	TBC
		PFAS (Per- and poly-fluoroalkyl substances)	TBC	Annually	TBC
Inshore marine	Nutrients	Phosphorus	Monthly	Annually	Management target Earliest baseline
		NOx	Varies, Usually around 6 times	Annually	Management target Earliest baseline
		Nitrogen	Varies, Usually around 6 times	Annually	Management target Earliest baseline
	Phys-chem	Total suspended solids (TSS)	Varies, Usually around 6 times	Annually	Management target Earliest baseline
		Turbidity	Continuous, hourly reads	Annually	Management target Earliest baseline
		Secchi depth	Varies, Usually around 6 times	Annually	Management target Earliest baseline
		Temperature	TBC	Annually	TBC
		pH	TBC	Annually	TBC
	Chlorophyll-*a*	Chlorophyll *a*	Continuous, hourly reads	Annually	Management target Earliest baseline
	Contaminants	Metals	TBC	Annually	TBC
Offshore marine	Phys-chem	Temperature	TBC	Annually	TBC
		Total suspended solids (TSS)	Daily (based on satellite images)	Annually	Management target Earliest baseline
	Chlorophyll-*a*	Chlorophyll *a*	Daily (based on satellite images)	Annually	Management target Earliest baseline
Groundwater	Hydrology	Quantity/recharge rates	TBC	Annually	TBC
	Contaminants	Salinity/Conductivity	TBC	Annually	TBC

4.2 Indicators of habitat and hydrology or habitat

The score for the habitat and hydrology/habitat index is based on indicators and indicator categories grouped into the following indicator categories:

- Habitat (riparian and wetland extent) and artificial barriers (impoundment length and fish barriers) for the two freshwater zones.
- Habitat (saltmarsh and mangrove extent) for the two estuarine zones.
- Habitat (seagrass and coral) for the two inshore marine zones.
- Habitat (coral) for the offshore marine zone.

The indicators and indicator categories for the habitat and hydrology/habitat index that have been included in the various report cards are shown in Table 5. Indicators scored in all report cards are highlighted in green, whilst those scored post-Pilot Report Card are highlighted in cream (Table 5).

Indicators to be reported upon in the future and aspirational indicators are shown in Table 5, but are not highlighted nor differentiated by colour.

Table 5. Indicators measured to determine the Habitat and hydrology/Habitat index for the freshwater, estuarine and inshore and offshore marine zones.

Frequency of sampling and reporting and the baseline the indicator is compared to is shown. Indicators scored in both the Pilot Report Card and the 2018-2019 Report Card are highlighted in green, whilst those scored post-Pilot Report Card are highlighted in cream. Indicators measured in the 2019-2020 Report Card are highlighted in blue. Future and aspirational indicators are not highlighted. TBC stands for to be confirmed.

Zone	Index	Indicator category	Indicator	Sampling and reporting frequency	Baseline that indicator is compared to
Freshwater	Habitat and hydrology	Riparian vegetation	Change in riparian extent	4-yearly	Earliest baseline
			Change in riparian extent	4-yearly	Management target
			Change in riparian condition	TBC	Earliest baseline
			Change in riparian condition	TBC	Management target
		Wetlands	Change in wetland extent	4-yearly	Earliest baseline
			Change in wetland extent	4-yearly	Management target
			Change in wetland condition	TBC	Earliest baseline
			Change in wetland condition	TBC	Management target
		Artificial barriers	Fish barriers	4-yearly	Earliest baseline
			Impoundment length	4-yearly	Earliest baseline
Estuarine	Habitat and hydrology	Saltmarsh	Change in mangrove extent	4-yearly	Earliest baseline
			Change in mangrove extent	4-yearly	Management target
		Mangroves	Change in mangrove extent	4-yearly	Earliest baseline
			Change in mangrove extent	4-yearly	Management target
Inshore marine	Habitat	Coral	Composition	Annually*	Earliest baseline
			Change in cover	Annually*	Earliest baseline
			Juvenile density	Annually*	Earliest baseline
			Macroalgae cover	Annually*	Earliest baseline
			Cover	Annually*	Earliest baseline
		Seagrass	Area/Abundance (% cover/biomass)	Annually	Earliest baseline
			Meadow area	Annually	Earliest baseline
			Species composition	Annually	Earliest baseline
Offshore marine	Habitat	Coral	Change in cover	Annually*	Earliest baseline
			Juvenile density	Annually*	Earliest baseline
			Cover	Annually*	Earliest baseline

*Each AIMS coral survey site is monitored every two years, with monitoring of sites alternating between the years. Coral condition is reported as a two-year rolling mean based on the most recent data for all sites.

4.3 Indicators of fish and biota

Within the fish index, fish is the only category scored. In the future, if additional fauna species are scored within the report card, this index will be renamed as biota and fish will be an indicator category within the biota index. The indicator categories and indicators currently included in the fish index, as well as the future and aspirational indicators in the biota index, are shown in Table 6. Fish was first scored in the 2019-2020 Report Card, with the indicators scored in 2019-2020 shown in blue. Future and aspiration indicators are not differentiated by colour and are not highlighted.

Table 6. Indicators measured to determine the fish and biota indices for the freshwater, estuarine and inshore and offshore marine zones.

Indicators scored in 2019-2020 are highlighted in blue. Future and aspirational indicators are not highlighted. TBC stands for to be confirmed.

Zone	Index	Indicator category	Indicator	Sampling and reporting frequency	Baseline that indicator is compared to
Freshwater	Fish	Fish	Proportion of Indigenous (native) Species Expected (POISE)	Yearly*	Earliest baseline
			Proportion of non-Indigenous Fish indicator	Yearly*	Earliest baseline
Freshwater	Biota	Birds	TBC	TBC	TBC
Estuarine	Biota	Birds	TBC	TBC	TBC
Inshore marine	Biota	Dolphins	TBC	TBC	TBC
		Dugongs	TBC	TBC	TBC
		Turtles	TBC	TBC	TBC
		Fish	TBC	TBC	TBC
Offshore marine	Biota	Fish	TBC	TBC	TBC

*Subject to funding

4.4 Indicators of litter

For the 2018-2019 and 2019-2020 Report Card, there was only one indicator category within the litter index, which was total litter.

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

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

4.5 Community and Economy indicators

For the Pilot Report Card, the Community score was based on indicators grouped into three indicator categories:

- Value and wellbeing from waterways
- Perception of waterways
- Community stewardship

For the 2018-2019 Report Card, the Community score was based on indicators grouped into five indicator categories:

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

- Community stewardship

For both the 2017-2018 and 2018-19 Report Card, Economy score was based on indicators grouped into two indicator categories:

- Non-monetary economic values
- Economic values

At the strategic workshop for the regional report cards, it was decided that the east Queensland regional Partnerships (Dry Tropics, Wet Tropics, Mackay-Whitsunday-Isaac, Fitzroy, and Gladstone regional Partnerships) will progress the social (human dimensions) aspects of the report card using the same approach (survey questions) across the Partnerships. These survey questions will be broad scale questions, with the information allowing comparisons between the Partnerships. The Dry Tropics Partnership will also devise additional questions that are specific to the region. Future work will be undertaken with the Human Dimension Technical Working Group to develop more suitable indicators. The timeframe for developing socio-economic questions is currently unknown.

5 Water quality data collection (sampling sites and sampling methods)

The indicator categories scored within the water quality index are nutrients and physical-chemical (phys-chem) properties for the freshwater and estuarine environments and nutrients, phys-chem properties and chlorophyll *a* for the inshore and offshore marine zones. The sections below provide an overview of the data collection methods for the indicators of water quality, with the methods described separately for each environment. Water indicators are scored against water quality objectives.

5.1 Freshwater

Two indicator categories of water quality are reported upon within the freshwater zone. These are the nutrients indicator category, comprising of the indicators total phosphorus (TP) and dissolved inorganic nitrogen (DIN) indicators, and the phys-chem indicator category, comprising dissolved oxygen (DO) and turbidity indicators. It is noted that these indicators and indicator categories are focused on water quality, with water quantity indicators and objectives not yet developed (and thus not scored within the report cards). The sampling sites and sampling methods for these indicators are described in the following sections (5.1.1 and 5.1.2).

5.1.1 Sampling sites

5.1.1.1 *Classification of independent and non-independent sites*

Water quality data are collected in the field at multiple sites throughout the freshwater and estuarine environments within the Ross and Black basins. In some cases, there are more than one sampling site along the same river, creek, or estuary. When this occurs, sites are classified as independent or non-independent. To be classified as an independent site, there must be a substantial input into the waterway between the site in question and another site. Examples of a substantial input or change in input include a confluence, storm water outlet or significant change in prevailing land use (e.g. a change from National Park to intensive agriculture). If sites are not independent, data from the sites were combined into one independent site and averaged to produce one score for the independent site.

5.1.1.2 *Ross freshwater basin*

Monitoring occurs at three independent sites within the Ross freshwater basin, comprising 12 non-independent sites. These are:

- Bohle River independent site, comprising two non-independent sites.
- Lower Ross River, comprising three non-independent sites, which are Aplin's, Gleeson's and Black School (Black) weirs.
- Upper Ross River (Ross River Dam), comprising seven non-independent sites within the Dam.

Along the Bohle River, there are two non-independent sites, which are the mid and far-field locations that comprise part of the receiving end monitoring for the Condon Sewage Treatment Plant (STP). A proportion of the water treated at Condon STP is discharged into the Bohle River, whilst the remainder is used for irrigation on a nearby golf course and re-used for service on site. Although two near field sites are also monitored as part of the receiving end monitoring program (REMP) for Condon STP, data from these two sites are not included in the Report Card because they do not reflect the ambient condition of the water quality within the Bohle River. These two sites are approximately 4 km apart, as shown in Figure 2. Between these sites there is a minor tributary that joins the Bohle River. However, this tributary rarely flows and therefore is not considered a substantial input. No other substantial inputs have been identified between the two sites. Therefore, they are considered non-independent, and their scores are averaged to produce an overall score for the Bohle River.

Independent and non-independent sites within the Ross freshwater basin are shown in Figure 2. Along the Ross River there are four non-independent sites, all situated within the impounded weirs (Black weir, Gleeson weir and Aplin's weir) or within the dam (Ross River Dam,), as shown in Figure 2. The dam and weirs contain water throughout the year. Ross River Dam is the main water supply for Townsville, whilst Black Weir is a 'back-up' water supply. There is approximately 1.2 km between Black and Gleeson's weir and 2 km between Gleeson's and Aplin's weirs. No substantial inputs have been identified between the three weirs and during the wet season the sites are connected (as water flows between the weirs). The sites are thus classified as non-independent, and the scores averaged to form a single score. The three weirs combined are classified as one independent site, called the 'lower Ross River'. The Ross River Dam site is classified as independent as the Dam gates are rarely opened and thus water from the Ross River Dam rarely flows downstream into the weirs.

Figure 2. Independent and non-independent sites within the Ross freshwater basin.
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.

5.1.1.3 *Black freshwater basin*

Since the 2018-19 Report Card, monitoring has occurred at 10 independent sites (Figure 3) within the Black freshwater basin. These sites are:

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

Figure 3. Freshwater independent sites (blue dots) within Black Basin.
The red line delineates the Black basin, whilst the blue line delineates the Black estuarine zone. Satellite image taken on the 14/12/2020.

For the Pilot 2017-19 Report Card, Paluma Dam was the only site scored within the Black Basin. While the Paluma Dam site is outside of the Black freshwater basin by 150-250 m, water from this dam overflows into the creeks within the Black freshwater basin. The upland water quality within the Black freshwater basin is not directly measured anywhere within the basin due to the difficultly in accessing the area. It is thus important that data from Paluma Dam are included. The report card process highlighted that Paluma Dam was the only sites sampled within the Black Basin. As a result, in April 2019, monthly sampling was undertaken by the Department of Environment and Science (DES).

Many creeks within the Townsville Dry Tropics are highly ephemeral and largely dry for most of the year (with occasional small pools of still water). Following heavy rains, ephemeral creeks will run for up to a few months (depending on event severity). For example, the Black River flowed for around 4.5 months after the February 2019 flood event before largely drying. Some of the streams that are monitored within the Black freshwater basin, such as Black River and Althaus Creek, have no surface flow for most of the dry season. The ephemeral nature of the creeks in the region impacts the sampling frequency and locations of freshwater reaches, as they may not contain flowing water during sampling visits.

5.1.2 Sampling methods

Water quality within creeks/rivers is only monitored if water is flowing, except within the dams and weirs, where water is monitored all year as there is consistently water in the dams/weirs. Thus, sites vary slightly throughout the year to ensure running water is sampled. All indicators are measured at each site using grab samples but vary between sites since they measured by different monitoring programs, as shown in Table 22.

All water quality samples are collected, stored, and transported in accordance with the Environmental Protection (Water) Policy Monitoring and Sampling Manual (Department of Environment and Science, 2018) and then analysed by laboratories accredited by the National Association of Testing Authorities (NATA).

Table 13. Indicators sampled at each independent and non-independent site with the Ross and Black freshwater basins. The indicators measured at each site are shaded in dark grey. Parameters measured are turbidity, total phosphorus (TP), particulate phosphorus (PP), dissolved inorganic nitrogen (DIN), and dissolved oxygen (DO). Program operators are Townsville City Council (TCC) and the Department of Environment and Science (DES).

			Nutrients		Physical-chemical properties		
Zone	**Site**	**Monitoring program**	**TP**	**DIN**	**Turbidity**	**Lower DO**	**Upper DO**
Ross freshwater basin	Ross River Dam	TCC					
	Black Weir	TCC					
	Gleeson's Weir	TCC					
	Aplin's Weir	TCC					
	Bohle River	TCC					
Black freshwater basin	Black River	DES					
	Althaus Creek	DES					
	Bluewater Creek	DES					
	Sleeper Log Creek	DES					
	Leichardt Creek	DES					
	Saltwater Creek	DES					
	Rollingstone Creek	DES					

	Ollera Creek	DES					
	Crystal Creek	DES					
	Paluma Dam	TCC					

5.1.2.1 *Ross freshwater basin*

Within the Ross Basin, all samples are collected monthly at the surface or 20 cm to 30 cm below the surface (AECOM, 2016).

5.1.2.2 *Black freshwater basin*

From 2018-19 onwards, all sites within the Black freshwater, except Paluma Dam, were sampled by the Department of Environment and Science (DES). Monthly sampling occurred. Three months of sampling was undertaken in the 2018-2019 financial year (as sampling only started in April 2018) and between three and eight months of sampling was undertaken in the 2019-2020. Twelve months of data was not collected because Covid-19 resulted in Australia wide travel restrictions (imposed March 2020) which affected the ability of DES staff from Brisbane to travel to the sites. Additionally, there was access issues to some sites and for some of the year, other sites were dry/only pools of water. Paluma Dam was sampled once a month throughout the year by Townsville City Council (TCC), as the Dam is a drinking water supply for the Paluma Township.

Dissolved oxygen and turbidity were measured by placing the probe approximately 10 cm to 30 cm under the stream surface, with readings taken once numbers were stable. Nutrient samples were collected from the centre of shallow creeks by wading into the creek and taking the sample upstream of the disturbance created from the wading to ensure disturbed sediment does not impact samples. In deeper creeks, samples were taken using an extendable sample pole (~ 1.5 m long) with samples collected around 10 cm depth. These protocols were followed because water samples collected at the surface of open stretches of water have significantly higher oxygen levels than samples collected at the edge of creeks, which are more vegetated and have lower water flow (Butler & Burrows, 2007).

5.2 Estuarine sites

Two indicator categories of water quality are reported within the estuarine zones, which are nutrients, comprising of the indicators total phosphorus (TP) and dissolved inorganic nitrogen (DIN) indicators), and physical-chemical (phys-chem) properties, comprising upper and lower dissolved oxygen (DO) and turbidity indicators. Sampling sites and methods are described below (Sections 5.2.1 and 5.2.2).

5.2.1 Sampling 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. The estuary names and number of non-independent sites sampled per estuary for each year (since 2017-19) are shown in

Table 7. The estuaries and number of sites sampled per estuary within the Ross and Black estuarine zones are shown in Figure 4.

Table 7. Estuaries and number of non-independent sites per estuary within the Ross and Black estuarine zones.

Zone	Estuary name	Number of non-independent sites within estuary		
		2017-18 Pilot Report	2018-19 Report Card	2019-2020 Report Card
Ross estuarine zone	Bohle River estuary	1	1	1
	Louisa Creek estuary	3	3	3
	Ross Creek estuary	3	3	3
	Ross River estuary	1	1	1
	Stuart Creek estuary	1	1	1
	Sandfly Creek estuary	2	2	2
	Alligator Creek estuary	2	2	1
Black estuarine zone	Bluewater Creek estuary	0	1	1
	Althaus/Deep Creek estuary	0	1	1
	Saltwater Creek estuary	0	1	1
	Rollingstone Creek estuary	0	1	1
	Crystal Creek estuary	0	1	1

Figure 4. 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.

5.2.2 Sampling methods

Four indicators are measured within the estuarine environment, which are total phosphorus (TP) and dissolved inorganic nitrogen (DIN) for the nutrient indicator category, and dissolved oxygen (DO) and turbidity for the physical-chemical (phys-chem) properties indicator category. These are the same as those measured in the freshwater basin. All indicators are measured monthly throughout the year using grab samples. The indicators measured at each site and the monitoring program/organisation undertaking the sampling are presented in Table 8. All water quality data were collected, stored, transported, and analysed as per freshwater samples (described in Section 5.1.2).

Table 8. Independent sites and indicators measured within the Ross and Black estuarine zones.
Measured indicators are shaded in dark grey and abbreviated as follows: total phosphorus (TP), particulate phosphorus (PP), dissolved inorganic nitrogen (DIN), dissolved oxygen (DO). TCC refers to the Townsville City Council and DES refers to Department of Environment and Science.

			Nutrients		Physical-chemical properties		
Zone	**Site**	**Monitoring program**	**TP**	**DIN**	**Turbidity**	**Lower DO**	**Upper DO**
Ross estuarine zone	Bohle River estuary	TCC					
	Louisa Creek estuary	TCC					
	Ross Creek estuary	TCC					
	Ross River estuary	TCC					
	Stuart Creek estuary	TCC					
	Sandfly Creek estuary	TCC					
	Alligator Creek estuary	TCC					
Black estuarine zone	Bluewater Creek estuary	DES					
	Deep Creek estuary	DES					
	Saltwater Creek estuary	DES					
	Rollingstone Creek estuary	DES					
	Crystal Creek estuary	DES					

5.2.2.1 *Ross estuarine zone*

All sites within the Ross estuarine zone were sampled by the Townsville City Council as part of their sewage treatment receiving environment monitoring plan conditions. Data at each site within the Ross estuarine zone were collected 20 cm to 30 cm below the surface (AECOM, 2016). Data was collected monthly, although in 2019-2020 the Ross Creek Estuary and Ross River Estuary were only sampled four times, and Sandfly Creek estuary was sampled 10 times. All other sites were sampled monthly (12 times).

5.2.2.2 *Black estuarine zone*

All sites within the Black estuarine zone were sampled by the Department of Environment and Science. Sampling occurred monthly starting in April 2018, with three months of sampling undertaken in the 2018-2019 financial year and eight months (July 2019 to February 2020) in the 2019-2020 financial year due to the travel restrictions association with Covid-19.

Samples were collected from approximately the middle of the estuary (in relation to the width of the estuary) using a boat. To minimise the effect of tidal variation, samples were collected on the ebb of neap tides. Depth of a water body can influence water quality results (Butler & Burrows, 2007; Dubuc, et al., 2017). Within the Black estuarine zone, dissolved oxygen and turbidity readings were taken at 20 cm and 80 cm below the surface and averaged into one value, whilst nutrients were collected at approximately 10 cm to 20 cm below the surface.

5.3 Inshore marine sites

5.3.1 Sampling sites

There are two inshore marine zones, which are Cleveland Bay and Halifax Bay, with sampling occurring at three and two independent sites within each bay. The independent and non-independent sites and the descriptions of each site are presented in Table 9. The location of the independent sites within Cleveland and Halifax bays are shown in Table 9. Different sites have different WQOs as defined in the water quality improvement plans.

Table 9. Independent and non-independent sites within Cleveland Bay and Halifax Bay and description of the sites.

Zone	Independent site	No. of non-independent sites within each independent site and description of independent site.	
		2017-18 Pilot Report and 2018-19 Report Card	2019-2020 Report Card
Cleveland Bay	Enclosed coastal waters	Seven non-independent sites. Three non-independent sites are part of the receiving environment monitoring program (REMP) that is associated with the Cleveland Bay sewage treatment plant and four non-independent sites are monitored by the Port of Townsville.	Five non-independent sites. One non-independent site is part of the receiving environment monitoring program (REMP) that is associated with the Cleveland Bay sewage treatment plant and four non-independent sites are monitored by the Port of Townsville.
	Open coastal waters	Four non-independent sites Three non-independent sites are monitored by the Port of Townsville, with the other site monitored by the AIMS Marine Monitoring Program (MMP).	
	Magnetic Island	Three independent sites. Nutrients are monitored at one site by the AIMS Marine Monitoring Program (MMP), whilst the other two others are water quality equipment loggers on buoys owned by Port of Townsville.	
Halifax Bay	Enclosed coastal waters	One independent site. Pandora Reef. This site is monitored by the MMP.	
	Midshelf waters	One independent site. Pelorus Island. This site is monitored by the MMP.	

Figure 5. Independent and non-independent sites within Cleveland Bay and Halifax Bay.
Independent and non-independent sites comprise of Pelorus Island, Pandora Reef, enclosed coastal sites (purple dots), open coastal sites (blue-grey dots) and Magnetic Island sites, which comprised Arthur Bay (orange dot) and Geoffrey Bay sites (yellow dots). The orange line delineates the enclosed coastal to open water boundary whilst the white line is the boundary between open coastal waters and the midshelf. The purple line is the line between Cleveland Bay (right) and Halifax Bay (left). Satellite image taken on the 14/12/2015.

5.3.2 Sampling methods

Water quality scores for inshore zones are derived from three indicator categories, which are nutrients, physical-chemical (phys-chem) properties and chlorophyll-*a*. The indicators measured vary between sites due to the sites being monitored by different programs as shown in Table 10. The indicators measured at each inshore site, the type of sampling used (either grab sample or continuous loggers) and frequency of sampling are also presented in Table 10.

Both the enclosed coastal Cleveland Bay and the open and enclosed coastal Cleveland Bay sites were monitored generally monthly using grab samples. Loggers were also deployed at Geoffrey Bay, Pandora Reef and Palms West Reef as part of the MMP (recording chlorophyll-*a* and turbidity). Loggers were generally deployed between July and January, although the months and duration loggers are deployed for varies throughout the year. In 2019-2020 turbidity loggers were installed at Geoffrey Bay and Arthur Bay at Magnetic Island

Table 10. Indicators sampled at each independent 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 sites	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	Varies between years		■		■	■	■	■	■
	Magnetic Island	MMP (Geoffrey Bay)	Grab	Varies between years		■		■	■	■	■	■
			Logger	Continuous (daily)			■	■				
		Port of Townsville (Geoffrey and Arthur Bay	Logger*	Continuous, every 15 minutes			■	■				
Halifax Bay	Enclosed coastal waters – Pandora Reef	MMP	Grab	Varies between years		■		■	■	■	■	■
			Logger	Continuous (daily)			■	■				
	Midshelf waters (Pelorus Island)	MMP	Grab	Varies between years		■		■	■	■	■	■
			Logger	Continuous (daily)			■	■				

*First time loggers have been deployed at this location

5.4 Offshore marine

Two indicator categories are scored within the water quality index within the offshore marine zone. These indicator categories are chlorophyll *a*, comprising the chlorophyll *a* indicator, and physical-chemical (phys-chem) properties, comprising of the indicator total suspended sediment.

5.4.1 Sampling sites

Water quality is assessed by BOM using eReefs tools for the Burdekin offshore marine zone, which includes the Townsville Dry Tropics offshore marine zone (see Figure 6). Data are only available for the larger Burdekin region (including the Townsville Dry Tropics). Data could not be restricted to only the Townsville Dry Tropics region which is influenced by discharge from the Burdekin River (Wolff, et al., 2018). A visual assessment of the total suspended sediment (non-algal particulates) mapped for the Burdekin and Townsville offshore marine zones for the 2018 calendar year indicated concentrations of suspended sediment were (approximately) similar between the two zones (as shown in Figure 7). Similarly, concentrations of chlorophyll-*a* also appear similar between the two offshore marine zones (see Figure 8). Therefore, the Burdekin zone was considered equivalent to the Townsville Dry Tropics region.

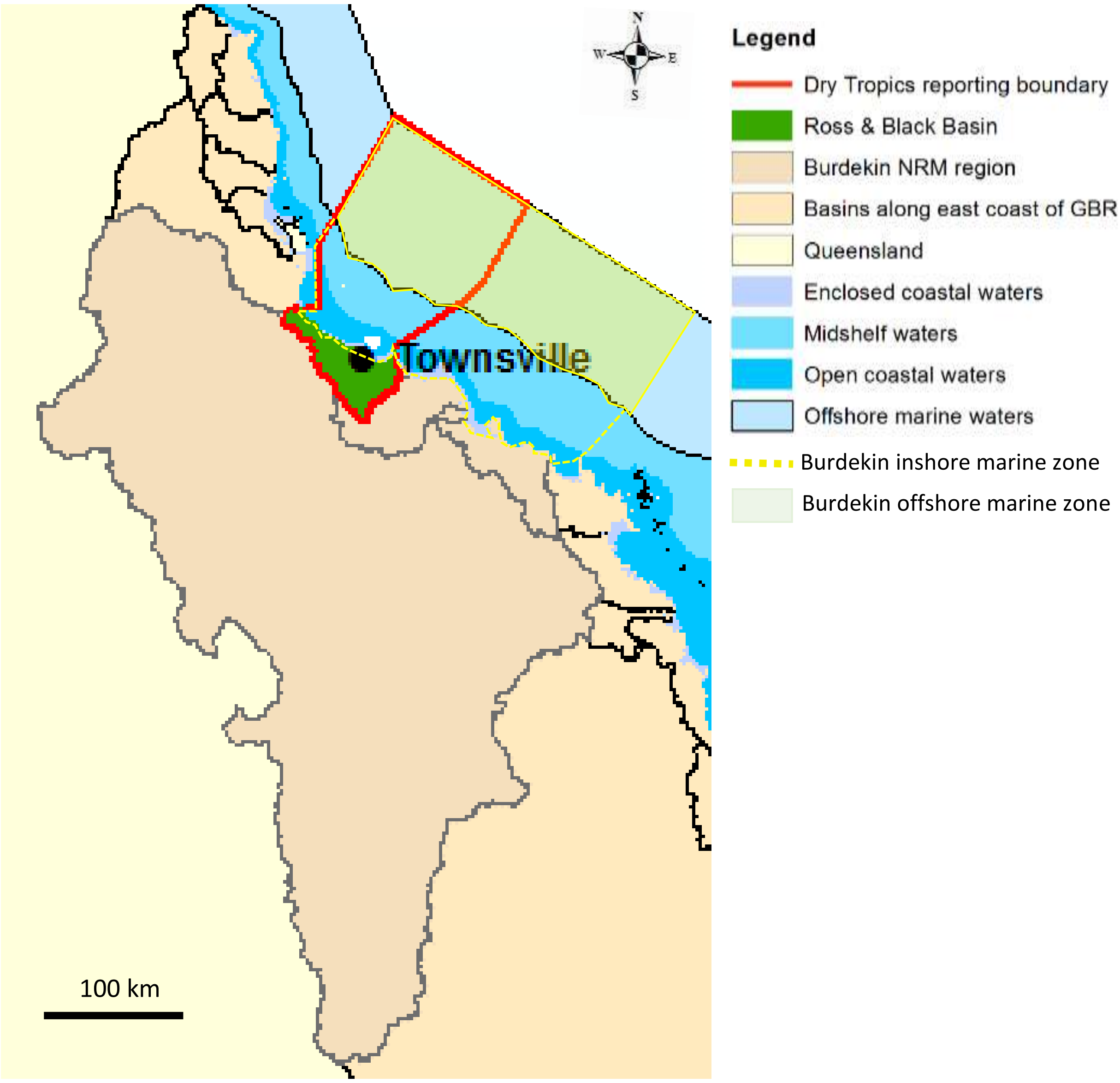


Figure 6. The Burdekin inshore (dotted yellow line) and offshore (solid red line) marine zones in relation to the Townsville Dry Tropics region within Queensland.
The inshore marine zone comprises the enclosed, midshelf and open coastal waters, whilst the offshore marine zone comprises offshore waters.

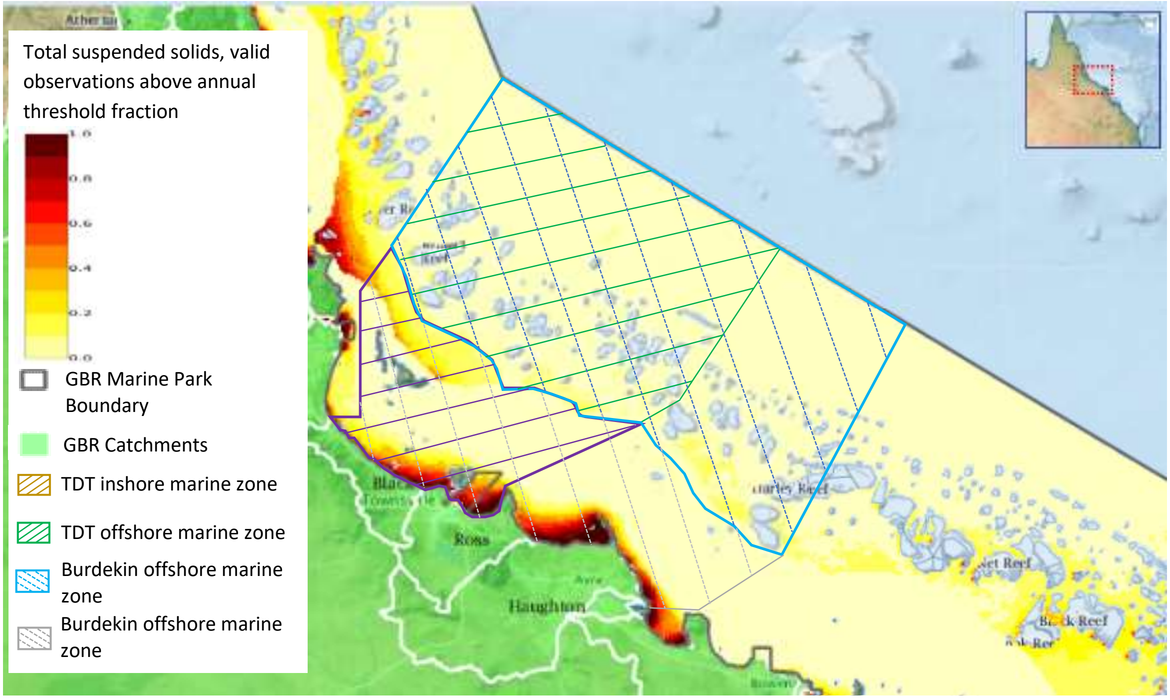


Figure 7 . Concentration of total suspended solid (non-algal particulates) within the Burdekin and Townsville Dry Tropics offshore marine zones.

The shading represents the proportion of observations that were above the annual threshold (or water quality guideline) for the 2018 calendar year.

Source: Wolff, et al., 2018

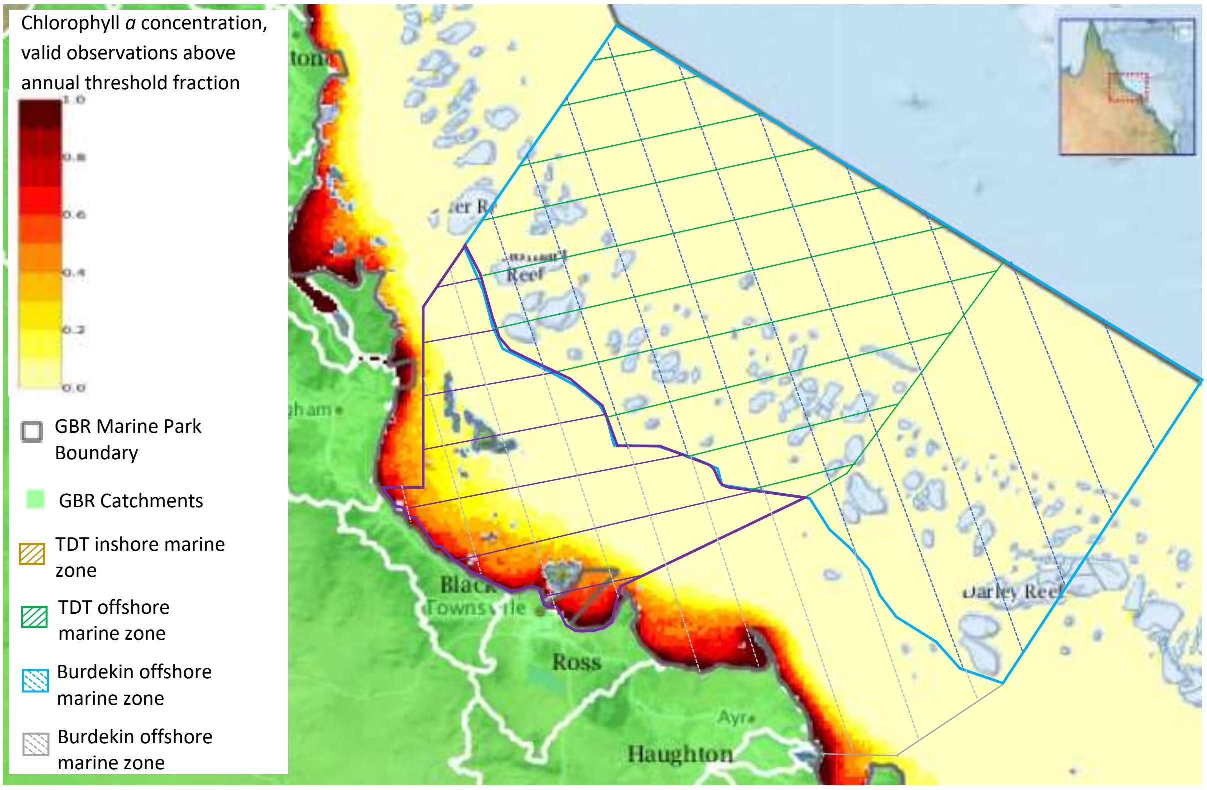


Figure 8. Concentration of chlorophyll-*a* within the Burdekin and Townsville Dry Tropics offshore marine zones.

The shading represents the proportion of observations above the annual threshold (or water quality guideline) for 2018.

Source: Wolff, et al., 2018

5.4.2 Sampling methods

Data for assessing offshore water quality is provided by Bureau of Meteorology (BOM) and is based on satellite data (Bureau of Meteorology, 2019). The data is based on real-time remotely sensed reflectance to determine sea surface temperatures, chlorophyll-*a* levels, suspended sediments, and dissolved organic matter. For each indicator, the proportion of valid pixels above the annual threshold fraction is calculated for each month and the for the year. Data are compared to water quality guidelines rather than objectives (WQOs), as there are no WQOs for the offshore marine zone.

6 Habitat and hydrology/habitat data collection (sampling sites and sampling methods)

The habitat and hydrology/habitat index of the report card comprises of two indicator categories within the freshwater and estuarine environments, which are habitat and artificial barriers. Within the inshore and offshore marine environments, only one indicator category is reported upon, which is habitat. The sections below describe the data collection methods for the indicator categories in the freshwater, estuarine, inshore marine and offshore marine environments.

6.1 Freshwater basins

Data for the indicators of habitat and artificial barriers are collected by desktop analysis.

6.1.1 Habitat

The habitat indicator category is comprised of two indicators, which are wetland and riparian extent. In the Pilot 2017-18 Report Card, habitat extent was scored against the earliest baseline, with the earliest baseline used as a proxy for pre-European/development condition. However inaccuracies in the baseline data (with baselines being based on data from the 1960s) meant that from 2018-19 onwards, habitat extent was compared against progress towards management targets, with a target of zero net habitat loss. For the 2018-19 Report Card, habitat extent was compared against both baselines for a comparison between the methods. Both scores were presented in the technical report, but only the grade derived by comparing data against the management target was presented in the simplified Report Card. The management targets are derived from the targets used for the entire GBR. Over time regional targets will be developed, however in the interim GBR-scale targets will be used. Sections 6.1.1.1 and 6.1.1.2 describe the method for estimating riparian and wetland extent. For the 2019-2020 Report Card onwards, habitat extent was only compared against management targets.

6.1.1.1 *Riparian extent*

The extent of riparian forest regional ecosystems is estimated using topographic drainage data and riverine wetlands derived from data obtained through Google Earth and the Queensland

Herbarium's Regional Ecosystem (version 9) mapping (Neldner, et al., 2017). Riparian extent is defined as areas with a foliage projective cover of at least 11% within a 50 metre buffer of each waterway (Scarth, et al., 2006). Foliage projective cover is the percentage of ground area occupied by the vertical projection of foliage (Armston, et al., 2009; Kitchen, et al., 2010). For scoring the earliest baseline or pre-clearing habitat extent indicator (for the 2017-18 Report Card), the method assumes pre-development riparian forest regional ecosystems were 100% forested (Healthy Rivers to Reef Partnership Mackay-Whitsunday, 2017).

The method used for measuring riparian extent for the 2017-18, 2018-19 and 2019-2020 Report Cards likely underestimated 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. Data for all three report cards has been based on data released in 2017 (habitat change between 2013-2017) (Neldner, et al., 2017).

6.1.1.2 *Wetland extent*

Data were compiled by the Queensland Herbarium, using data obtained through Google Earth and the Queensland Herbarium's Regional Ecosystem (version 9) mapping (Neldner, et al., 2017). Wetland extent is only based on data for palustrine wetlands. Palustrine wetland is vegetated, non-riverine or non-channel systems that have more than 30% emergent vegetation cover (Queensland Government and Department of Environment and Science, n.d.). Palustrine wetlands include, but are not limited to billabongs, swamps, bogs, springs, and soaks (Queensland Government and Department of Environment and Science, n.d.).

For the 2017-18 Pilot Report Card, when wetland extent was compared against the earliest baseline, the earliest baseline was derived from aerial photographs, with most images from the 1960s. However large areas of land were cleared in Queensland (and throughout Australia) pre-1960 (Bradshaw, 2012). Using aerial data from the 1960s is thus unlikely to be representative of true 'pre-European' or pre-development (natural) conditions at a local scale and especially not within highly urbanised areas. For example, in the 1920s, large developments occurred within Townsville, including the construction of major roads, the Hubert's Well Power Station and Aplin's Weir (Townsville City Council, n.d.). The area of pre-European/development habitat extent within the Townsville Dry Tropics is thus likely to be higher (greater extent) than depicted from the 1960s maps (as the 1960s maps already include areas of substantial development and clearing).

6.1.2 Artificial barriers

Two indicators, fish barriers and impoundment length, comprise the artificial barrier indicator category. These indicators are compared against the earliest available data of no artificial barriers.

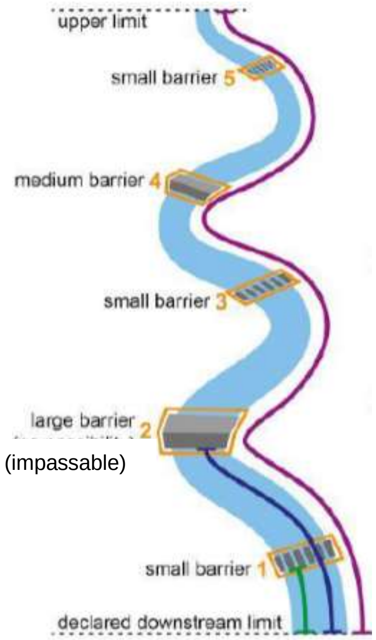
6.1.2.1 *Fish barriers*

A fish barrier is defined as any artificial barrier that prevents or delays water movement and connectivity between key habitats and potentially impacts migratory fish populations (Moore, 2015). A fish barrier also decreases the diversity of freshwater fish communities and/or reduces the condition of aquatic ecosystems (Moore, 2015). Fish barriers is an important indicator to assess because impeding fish movement can detrimentally impact ecosystem health (Department of Water and Environmental Regulation, 2017). For example, "fish barriers can adversely impact upon native species by interrupting spawning or seasonal migrations, restricting access to preferred resources, increasing the change of predation and disease and reducing genetic flow between populations through population fragmentation" (Department of Primary Industries, n.d.).

The score for the fish barriers indicator category is derived from three sub-indicators, which are:

1. barrier density,
2. percent of stream length to the first barrier, and
3. percent of stream length to the first impassable barrier.

Definitions of passable and impassable barriers are given in section 0. with formulas for calculating each component in Figure 9. For the Report Card, only waterways classified as having a major or high impact upon fish movement are included in the data analysis. Townsville region stream classification is described in section 6.1.2.3.



$$\textbf{Barrier density} = \frac{\text{total stream length of major and high impact waterways}}{\text{total number of barriers on these streams within the basin}}$$

$$\textbf{Percent of stream length to the first barrier} = \frac{\text{stream length from declared downstream limit (DDL) to the first barrier}}{\text{total stream length of major and high impact waterways (km)}} * 100$$

$$\textbf{Percent of stream length to the first impassable barrier} = \frac{\text{stream length from DDL to the first impassable barrier}}{\text{total stream length of major and high impact waterways (km)}} * 100$$

Fish barriers index score

Figure 9. Diagram of the three components of the fish barriers indicator category and how each is calculated. For purposes of the diagram the declared downstream limit is equivalent to the upper tidal limit. The fish barriers indicator category comprises of three indicators, barrier density, percent of stream length to the first barrier, and percent of stream length to the first impassable barrier. Each indicator is scored separately and then the scores for these three indicators are summed together to produce the overall score for the fish barriers index.

For the freshwater basins, all measurements are made between the upstream limit and the declared downstream limit (DDL). The DDL is the most downstream location in the waterway where the water is not influenced by estuarine waters therefore is always fresh. This point is selected because any potential barriers downstream of this point still allow tidal movements and thus do not prevent connectivity with this interface. The upper limit is the highest point of major or high impact streams within the catchment. For the estuarine zone, all measurements are made from the DDL downstream to the estuary mouth.

6.1.2.2 *Passable and impassable barriers*

Barriers are classified as passable or impassable. An impassable barrier is a barrier where there is no chance or a low probability of fish movement across the barrier. An impassable barrier is defined as a barrier that never or rarely over tops having either 1) less than 1 flow event per year, 2) is a dam or weir with >2 m head loss, a 3) causeway greater than 2 m high with pipe/culvert configuration less than 10 %, or 4) a bankfull stream width and head loss greater than 1 m (Healthy Rivers to Reef Partnership Mackay-Whitsunday, 2017). Bankfull means the water level at which the stream is at the top of its banks and any further rise will result in spillage (Pen, et al., 2001). A passable barrier is one that does not prevent fish movement allowing free movement between the waterways upstream and downstream of the barrier. Barrier assessments are made at different scales (different stream classifications) depending on which ecosystem are being assessed.

6.1.2.3 *Classification of stream categories*

The degree to which fish communities are impacted by barriers also varies depending on where the barrier occurs. Queensland waterways are classified into four categories based on how severely fish movement and fish communities would be impacted if a barrier were constructed within the waterway. These four categories are major, high, moderate, and low and rely on a combined analysis of stream order, stream slope, flow regime, number of fish present, and fish swimming ability (Department of Agriculture and Fisheries, 2016). The stream risk categories are described in Table 11.

Table 11. Description of stream risk categories in relation to the Strahler stream order system.

Risk category	Description	Strahler stream order system
Major	Generally lower in the catchment, have lower gradient, of higher stream order and categorised by having a high diversity of species with often weak swimming abilities.	4
High		2-3 with low gradient or order 3 with medium gradient
Moderate	Not as influential in determining fish community assemblage within aquatic ecosystems compared to major and high impact streams.	2
Low		1

Stream classifications for the four risk categories are sourced from the data set ‘Queensland waterways for waterway barrier works’ (Department of Agriculture and Fisheries, 2016). Stream risk categories are often defined based on the Strahler stream order system, which is diagrammatically represented in Figure 10. For the regional report cards, only streams where barriers would have a major or high impact upon fish are included in the analysis. The classification of streams into the four risk categories within the Townsville Dry Tropics are shown in Figure 11a. Streams that are classified as major or high impact waterways are shown in in Figure 11b.

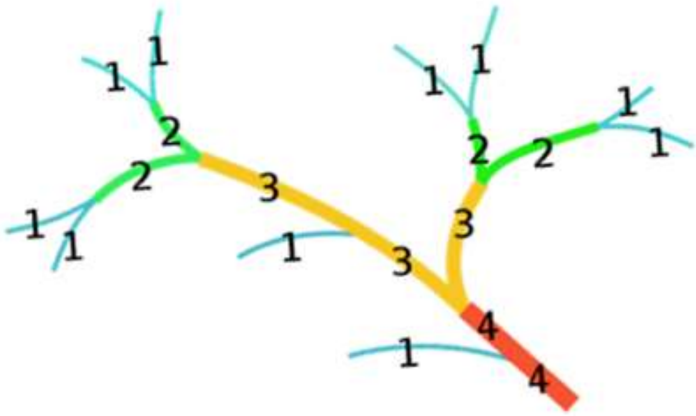


Figure 10. Strahler stream order from headwaters downstream.
Headwaters are the first order and downstream segments are defined at confluences (two streams running into each other). At a confluence, if the two streams are not the same order (i.e. number), the highest order is maintained on the downstream segment. At a confluence of two streams with the same order, the downstream segment receives the next highest order. Divergences such as braided streams maintain the same order all the way through the braid (like a single stream).
Source: (Strahler, 1952)

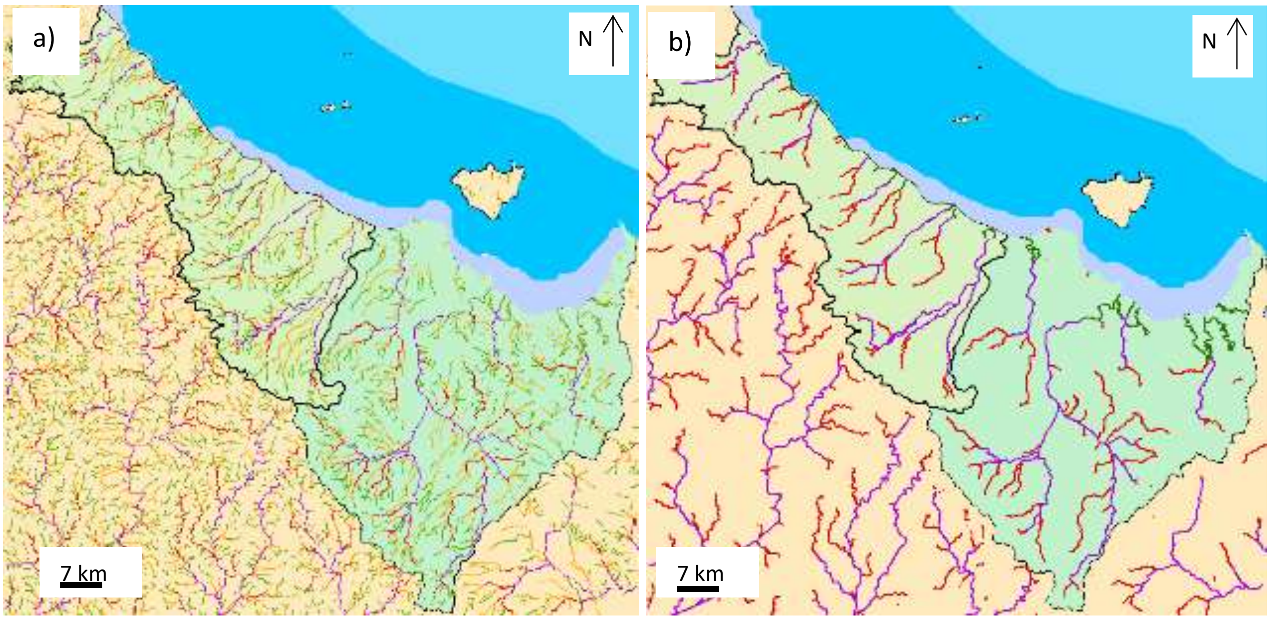


Figure 11. Classification of a) risk categories for all streams classifications, and b) for major and high impact stream classifications within the Townsville Dry Tropics region (green shading).
Major risk streams are delineated in purple, high risk streams are shown in red, moderate risk in orange and low risk in light green. Estuarine waters are shown in dark green.

6.1.2.1 *Impoundment length*

Impoundment length is included as an indicator to highlight loss of natural habitat and ecological processes within waterways. Impoundment length is the percent of total stream length bound by in-stream structures compared to the pre-European/development level of no artificial impoundments (0%). Only non-tidal streams of order three or higher are included in the assessment. This is because stream order three and above are influential in determining fish community assemblages within aquatic ecosystems (Department of Agriculture and Fisheries, 2016). Stream lengths are sourced from the Department of Natural Resources and Mines (DNRM) Queensland 1:100,000 ordered drainage network. The impounded areas are derived primarily from Google Earth imagery, Queensland Globe spatial layers (Dams, Weirs and Barrages, Referable Dams and Reservoirs) and local knowledge. Impoundment data area is updated every four years.

6.2 Estuarine waters

One indicator category, habitat extent, is assessed within the estuarine environment. Thus the scores for habitat extent are the overall scores for the habitat and hydrology index within the estuarine environment.

6.2.1 Habitat index

6.2.1.1 *Mangrove and saltmarsh extent*

Mangroves and saltmarshes are the two indicators within the habitat extent indicator category. For the 2017-2018 Pilot Report Card, mangrove and saltmarsh habitat extent was reported separately and they were reported against the earliest baseline. From the 2018-2019 Report Card onwards, data was compared against progress towards management targets. Data were only available for the combined extent of both mangrove and saltmarsh extent (rather than separate) when comparing against progress towards management targets.

Data are compiled by the Queensland Herbarium, using Google Earth and the Queensland Herbarium's Regional Ecosystem (version 9) maps, with data generally updated every four years (Neldner, et al., 2017). The most recent update occurred in 2019.

Four regional ecosystem (RE) habitat types comprise the mangrove and saltmarsh habitat types within the Townsville region estuarine zone (Queensland Government, n.d.) and are used to determine the habitat extent for mangroves and saltmarshes:

- RE 11.1.1: *Sporobolus virginicus* grassland on marine clay plains (marine couch).
- RE 11.1.2: *Samphire forbland* on marine clay plains, comprising samphire and mudflats with stunted mangroves.
- RE 11.1.3: Sedgelands on marine clay plains, comprising *Melaleuca*, *Eucalyptus* open woodland to woodland and mangroves.
- RE 11.1.4: Mangrove low open forest and/or woodland on marine clay plains.

These regional ecosystems are selected from the Regional Ecosystem dataset (Queensland Government, n.d.), with percentage loss between the latest available data set and the previous data set spatially estimated.

6.3 Inshore marine

Within the inshore marine zone, habitat was the only indicator category assessed within the habitat index. Thus the scores for the habitat indicator category are also the sores for the habitat index.

6.3.1 Habitat

Seagrass and coral are the two indicators that comprise the habitat indicator category. Seagrass is measured annually and compared to a 10-year baseline, whilst the coral indicators are measured every second year at a rotating set of sites.

6.3.1.1 *Seagrass (indicator category)*

The seagrass indicators comprise of three sub-indicators, which are ground biomass, meadow area and species composition.

6.3.1.1.1 Sampling methods

Monitoring data on seagrass are collected by James Cook University (JCU) as part of the Queensland Ports Seagrass Monitoring Program (QPSMP). The QPSMP reports upon seagrass condition in the highest risk areas of Queensland to assist in the planning and management of anthropogenic activities. The QPSMP assesses 50 individual meadows across seven ports along the GBR (Carter, et al., 2016). Ten monitoring meadows, as shown in Figure 12, were sampled annually in the Townsville region using a helicopter to survey intertidal areas at low tide and diving to survey shallow sub-tidal areas (Bryant & Rasheed, 2018). Annual sampling occurs during the peak of the seagrass growing season in late spring/early summer (at the end of the dry season) (Carter, et al., 2016). Meadow selection was based on how representative they are of meadow types found in each location (dominant species, intertidal/subtidal, meadow size and mean biomass). The program and approach have been independently reviewed several times and results published in peer review journals (Carter, et al., 2016). Scoring the seagrass indicators are detailed in Bryant and Rasheed (2018).

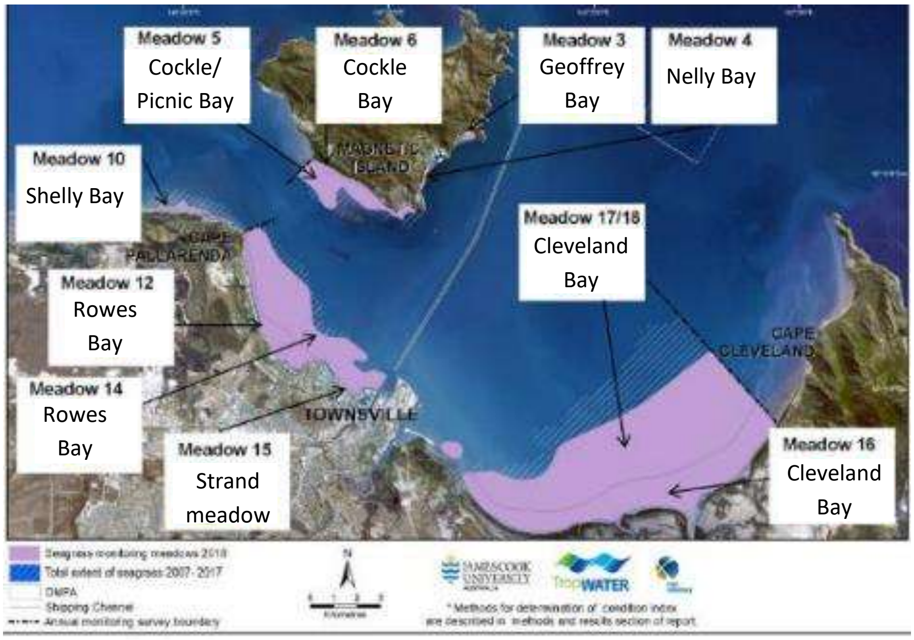


Figure 12. Seagrass monitoring meadows within the Townsville region.
Source: Adapted from Bryant & Rasheed (2018)

6.3.1.2 *Coral*

Coral is measured within the inshore zone by assessing coral cover, macroalgae cover, rate of coral cover change, density of juvenile corals and community composition. The biological importance of each sub-indicator is outlined in Table 12. Data for all five sub-indicators are collected by the Marine Monitoring Program (MMP) and Long-term Monitoring program (LTMP), and coral cover data at a few reefs is also collected by Reef Check, a citizen science program. Coral data from the three programs are weighted and combined where appropriate to produce a final score for coral. Results for these five sub-indicators are averaged to generate a score for coral condition, which is formulated around the concept of community resilience (Thompson, et al. 2016). The underlying assumption is that a 'resilient' community should show clear signs of recovery after inevitable acute disturbances, such as tropical cyclones and coral bleaching (Thompson, et al., 2016). In the absence of disturbance, 'resilient' reefs should maintain high coral cover and coral recruitment should be successful (Thompson, et al., 2016).

Table 12. Description of coral indicators and the environmental zones where each indicator is reported and scored.

Zone/s reported within	Coral sub-indicator	Description
Inshore and offshore marine	Coral cover	A measure of the percent of surface covered by reef-building or hard corals in the reef. High coral cover provides essential ecological goods and services related to habitat complexity, which in turn promotes diversity within reefs (Chong-Seng, et al., 2012). High cover also implies a degree of resilience to chronic pressures influencing the reef, whilst low coral cover may be expected following severe disturbance events (Thompson, et al., 2016). From a purely aesthetic perspective, high coral cover has higher socio-economic value than low coral cover.
Inshore marine	Macroalgae cover	A measure of the proportion (per cent) of cover of large, fleshy algae such as seaweed that is attached to the bottom of the reef. Coral reefs dominated by high macroalgae cover are widely accepted as being in a degraded state (Chong-Seng, et al., 2012). Macroalgae opportunistically colonise areas following physical disturbances since they generally recover faster and out-compete corals (Roth, et al., 2018). Macroalgae have been documented to suppress coral fecundity, reduce recruitment of hard corals, and diminish the capacity of growth among local coral communities (Hoey, et al., 2011; Roth, et al., 2018; Thompson, et al., 2016). Macroalgae is much less evident on offshore reefs (Bauman, et al., 2017). Therefore, this indicator is not calculated for reefs in the offshore zone or included in the offshore reef condition index. A high score for macroalgae suggests that the reef is in a bad condition (degraded).
Inshore and offshore marine	Change in coral cover	A measure of the observed change in hard coral cover compared to modelled predictions derived from the preceding four years of information. The change in coral indicator reveals the rate of gain or loss in coral cover and is a measure of recovery after a disturbance. Coral communities can recover by growing during periods of reduced acute or chronic stress (Ortiz, et al., 2018). Chronic pressures associated with water quality or temperature stress may suppress coral cover increases and indicate a lack of resilience (Carilli, et al., 2009; Thompson, et al., 2016).
Inshore and offshore marine	Juvenile recruitment	A measure of the abundance of hard coral juvenile colonies (up to five centimetres in diameter) per area of available space. Juvenile recruitment is measured by recording the density of juvenile corals that have survived the early stages of life (Thompson, et al., 2016). Enough recruitment of new corals is required for coral communities to recover rapidly following disturbances (Guest, et al., 2016).
Inshore marine	Community composition	The mean and standard error for locations of communities in multivariate space, constrained to lie along a gradient of water quality (combination of Chlorophyll-*a* and TSS). Smaller numbers represent communities typical of poorer water quality. This indicator is used in the inshore zones only and compares the composition of hard coral communities with the expected community composition given each survey site's location along a gradient in water quality (Thompson, et al., 2016). Differences in hard coral communities from the expected composition are interpreted in terms of water quality conditions.

6.3.1.2.1 AIMS Monitoring Program sampling methods

The MMP and LTMP have a nominal biennial sampling design, meaning all reefs are sampled at least once every two years. Nine locations are sampled within the Townsville Dry Tropics region, as shown in Figure 13. At each reef sampled by MMP, two sites are surveyed, with sites located 250 m apart where possible (Australian Institute of Marine Science (AIMS), n.d.). At each site, data are collected along five 20 m transects spaced 5 m apart and at depths of 2 m and 5 m. The MMP stratifies sampling by depth, at 2 m and 5 m below lowest astronomical tide (LAT), because coral community structure and exposure to disturbances substantially differs with depth (Bridge, et al., 2013). The influence of depth is most apparent in inshore areas where the turbidity of waters causes a rapid attenuation of light (Bridge, et al., 2013; Marshall & Baird, 2000). Transects are marked with a star picket at each end, with lengths of reinforcing rod at 10 m intervals.

The only differences between the LTMP and MMP sampling design are:

1) the five transects for offshore surveys are 50 m in length (rather than 20 m for monitoring inshore corals),
2) There are three sites each with five transects at LTMP sites compared to two sites for MMP, and
3) transects for offshore reef surveys are laid along the reef slope parallel to the reef crest at approximately 6 m to 9 m depth (compared to inshore corals which are sampled at 2 m and 5 m depth).

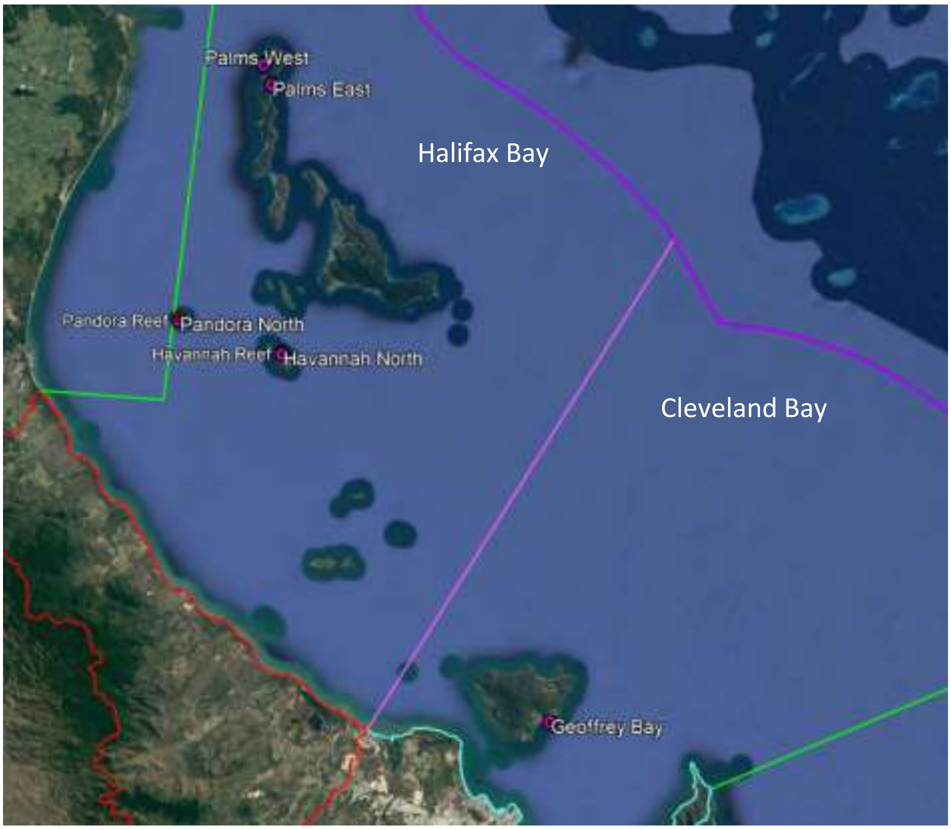


Figure 13. Sampling locations of inshore reefs (pink dots) within Cleveland Bay and Halifax Bay, which comprise the Townsville Dry Tropics inshore marine zone.

At each site, two methods are used to survey coral (Jonker, et al., 2008). These methods are:

- Benthic cover estimated from point intercept transects using underwater digital photography. The LTMP samples 50 photographs at 1 m intervals along each transect, compared to 40 photographs every 0.5 m for the MMP.
- Juvenile corals are counted along belts 0.34cm wide (a dive slate width) along the full 20 m transects (MMP) or first 5 m of each transect (LTMP).

6.3.1.2.1.1 Seafloor photographic intensive surveys

Seafloor photographic intensive surveys are conducted to estimate coral cover and count the number of juveniles. At each transect, 40 digital photographs are taken approximately 40 cm above the substrate at approximately 0.5 m intervals. Coral cover (%) and other benthic categories are then estimated from five points on each image (approximately 200 systematically dispersed points ('observations') per transect). Juvenile density is measured by counting the numbers of coral colonies up to 5 cm in diameter per square metre of unoccupied and suitable space.

6.3.1.2.2 Reef Check sampling methods

Reef Check has also been surveying reefs within the Townsville region for over 15 years to detect broad long-term changes in reef condition. Reef Check predominantly surveys fringing reefs off Magnetic Island and samples at some different reefs to the MMP and LTMP. Including the Reef Check data thus increases the number of reefs sampled (spatial coverage).

6.3.1.2.2.1 Surveying methods

Reef Check has standardised their approach to coral surveys as described in the Reef Check Australia Methods Manual (Hill & Loder, 2013). including volunteer training to increase data accuracy.

6.3.1.2.2.1.1 Variables measured

Reef Check's standard surveys monitor five reef attributes but the only variable that uses a similar method to the MMP and LTMP is their assessment of reef composition (percent cover of 25 different substrate classes) and thus this data can be incorporated with the MMP and LTMP data.

6.3.1.2.2.1.2 Survey protocols

To increase precision and reduce error, Reef Check's standard survey protocol requires:

1. A team scientist/team leader to supervise each survey team, including deploying transects, reviewing data, monitoring volunteers, and answering questions.
2. Standardised site selection and transect deployment procedures.
3. Standardised time requirements for survey completion to ensure consistent survey effort.
4. Minimised redeployment error for the transect tape placement by using a detailed map of the survey area, mean low tide times and GPS coordinates.

5. Grouping species with similar morphological traits to reduce the risk of misidentification.
6. Use of standardised data notation procedures on the underwater data sheets.

6.3.1.2.2.1.3 Survey sites

Survey sites are not permanently marked but GPS locations, maps, tide times and where feasible GPS tows helps teams return to, as close as possible, the same site each year. Sites are selected to be as representative as possible and can be visited year after year.

Within each site, transect depths are grouped into shallow (1-5m), medium (6-9m) and deep (10-12m). Currently, raw data sets combine all transects, not distinguishing between transects completed within shallow, medium, or deep water. Data from all transects will be used in the 2018-2019 report card but in future, the aim is to identify each transect within the shallow and medium depths, which align with the MMP and LTMP sampling depths.

6.3.1.2.2.1.4 Transects

One standard Reef Check survey is undertaken at each dive site visited. A standard survey is conducted along a 100 m transect, of which 80 m is surveyed. The 100 m transect is divided into four 20 m sections (or transect replicates), with each 20 m section separated by 5 m (see Figure 14). This creates independent replicates that can be compared within and between surveys. The transect line is marked by a graduated tape measure that is laid along a constant depth and reef habitat. At every 0.5 m along each 20 m section, the substrate type (directly below the tape measure) is recorded. To determine which part of the reef is directly below the line at each 0.5m interval, a weighted line (called a plumb line) is dropped at each interval and the substrate the weight lands on is recorded. This removes bias to ensure the data is accurate.

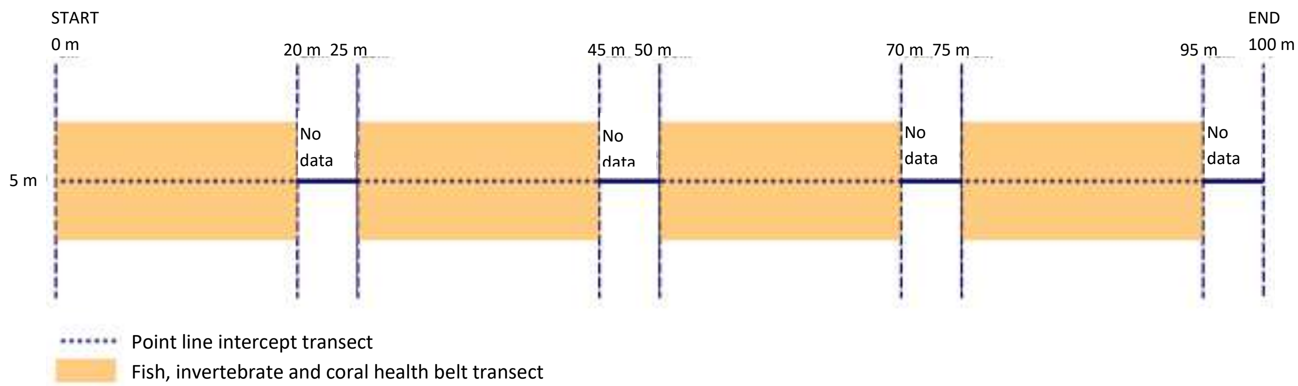


Figure 14. A Reef Check transect, comprising four 20m replicates along which reef substrate composition is measured.

6.4 Offshore marine

Within the offshore marine zone, scores for the habitat index were derived from the coral indicatory category.

6.4.1 Coral

Offshore coral reefs are sampled by the AIMS Long-Term Monitoring Program (LTMP) and by Reef Check. The sites sampled by the LTMP are shown in Figure 15. The reefs sampled by Reef Check varies each year, with between zero and two reefs sampled each year. The reefs sampled by Reef Check each year are document in the technical results report for that year.

Coral condition is assessed by measuring and averaging the scores of three indicators, namely coral cover, change in coral and juvenile recruitment. The LTMP methods are outlined in section 6.3.1.2.1. Surveys occur every two years and some indicator scores are based on a four year rolling mean as the data is derived by modelling from the two years before data was collected.

Figure 15. Sampling locations of offshore reefs (red dots) within the Townsville Dry Tropics offshore marine zone (white and purple outline).

7 Fish

The fish index was first scored in the 2019-2020 Report Card. The assessment of freshwater fish communities is based on two indicator categories, which are the proportion of Indigenous (native) species expected (POISE) within waterways (excluding translocated species) and the proportion of non-Indigenous (native) fish. The proportion of non-indigenous fish indicator category is further divided into two indicators, which are the proportion of translocated fish and the proportion of alien (invasive) fish. The fish index is designed to capture the proportion of native fish (excluding translocated species) compared to the proportion of non-indigenous fish.

7.1 Indicator categories

7.1.1 Proportion of Indigenous (native) Species Expected (POISE)

Native fish is measured by the proportion of observed verse expected species and it compares the species richness of native fish captured during the sampling year against the expected species richness predicted by pre-disturbance models (i.e. the current diversity compared to the modelled expected diversity in the absence of human pressures). The percentage of expected species was converted to a score based on standardised percent ranges, as with other indicators.

7.1.2 Proportion of Non-Indigenous Fish

The proportion of non-indigenous fish is measured as the presence of non-indigenous fish (translocated and alien species) compared to the expected number. Non-indigenous fish affect aquatic plants and animals by competing for food and space, preying on native species, introducing exotic diseases and parasites, and driving habitat changes and therefore it is important to assess them within the environment. The proportion of non-indigenous fish recorded during field surveys was compared with the expected proportion of non-indigenous fish species based on a Queensland-wide model and the percentage was converted to a score using the standardised percent ranges. The presence or absence is documented for seven invasive species.

7.2 Sampling sites for the fish index

Fish were surveyed at 11 independent sites across nine different creeks within the Ross freshwater basin. Eleven 11 independent sites were sampled across 13 different creeks within the Black freshwater basin. The sampling sites are shown in Figure 16. Fish were sampled using backpack electrofishing in the first year (2019-2020 Report Card) during the dry season and will be sampled using electrofishing and boat-based electrofishing during the dry season for the 2020-2021 Report Card.

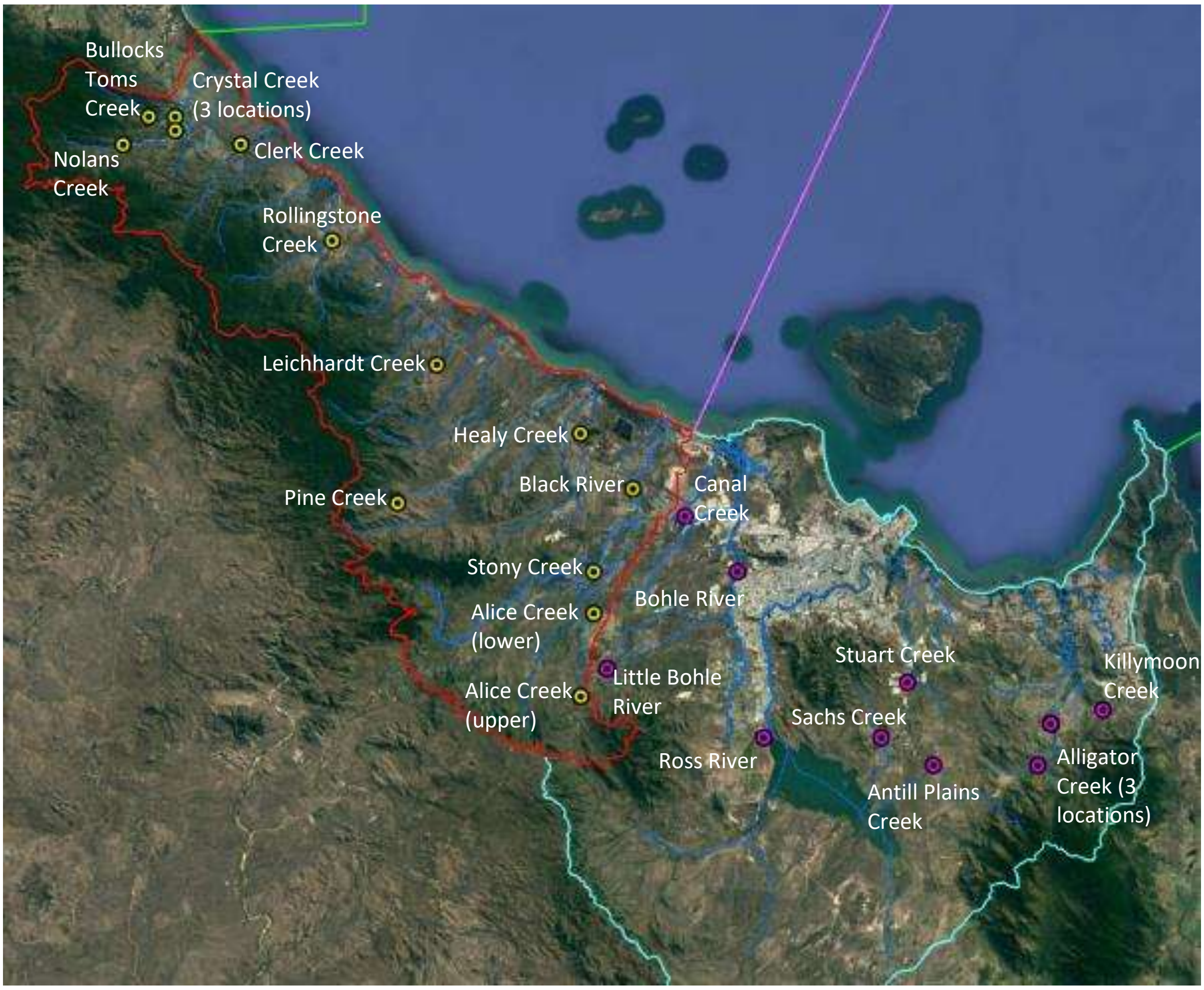


Figure 16. Location of fish sampling sites within the Ross and Black freshwater basins.
The main rivers and creeks are delineated in dark blue, whilst the boundary for the Ross and Black basins are shown in aqua and red, respectively. The purple line is the boundary between Cleveland and Halifax Bays. Satellite image taken on the 14/12/2015.

8 Litter data collection

Total litter is the only one litter indicator category within the litter index. Total litter is compared against a baseline that was derived from four years of data from the 2014-15 financial year to the 2017-2018 financial year. This was the earliest time that there was data from four environmental zones (Ross freshwater basin, Ross estuarine zone, Cleveland Bay and Halifax Bay). The data used to derive the scores and grades for the Litter index is collected in the field by volunteers as part of Tangaroa Blue clean-up projects.

8.1 Clean up locations and sampling methods

There are two types of clean ups that occur within the Townsville region, which are standardised clean ups as part of the Reef Clean project and non-standardised clean ups. Litter data were collected in the field. As of 2019-2020, all data for Tangaroa Blue clean ups are processed through a third party at the request of Tangaroa Blue. This can limit the transparency of the data the

Partnership receives. For the 2018-19 and 2019-2020 Report Card, not all litter clean up data was available to the Partnership and it is hoped that in the future, all data will be available.

All litter collected is sorted into 123 different categories (e.g. straws, plastic bottles, etc.), tallied in the field and then entered into the Australian Marine Database Initiative (AMDI). The AMDI has 127 categories for litter, however it is noted that often multiple different litter items are grouped into the same category and thus it is often difficult to assess the amount of litter for one item only. Additionally, at some clean-up events, items are not separated but are instead included in the "all other" category. For example, within the AMDI the items 'foam cups, food packs and trays' are included as the same category. Sometimes only one or two of these items will be counted, with the others included in the all other rubbish category. This prevented accurate accounting into individual categories, so all rubbish is totalled into a 'total litter' indicator category. Small items and cigarette butts are often missed as they are difficult to see or difficult to pick up.

8.1.1 Reef Clean standardised sampling

In 2018-2019, a government funded project called Reef Clean was implemented. As part of this project, standardised clean ups (starting October 2018 onwards) were undertaken by Tangaroa Blue and Reef Check, whereby volunteers collected litter from along transects for a designated length of time at two sites (Shelly Cove and Apex Park) within the Townsville region. Standardised clean ups occurred biannually from mid-2018 until 2022, although the data was not available to the Partnerships until 2021 (for the 2020-2021 Report Card). It is hoped that the standardised method will enable comparisons between years. There were an additional five sites funded under the Reef Clean scheme, with all the sites listed in Table 13. These additional five sites are not along standardised transects but will enable monitoring at the same sites over a few years, with the aim of assessing trends between the years. It is noted at for the 2019-2020 Report Card, data was only provided for three (Orpheus Island, Nelly Bay and Shelly Cove) out of the six Reef Clean sites that were cleaned during the 2019-2020 financial year (Fantome Island was not cleaned in the 2019-2020 financial year).

Table 13. Location of Reef Clean clean-ups within the Townsville Dry Tropics region for 2018 until 2021. TBF stands for Tangaroa Blue Foundation, whilst RC stands for Reef Check.

Zone	Clean up location	Standardised transect	Organisation responsible for clean ups	Frequency of clean up
Halifax Bay	Orpheus Island	No	TBF/Ocean Crusaders	Annually
Halifax Bay	Fantome Island	No	TBF/Ocean Crusaders	Annually*+
Ross River estuarine zone	Shelly Beach	No	TBF	Annually^+
Cleveland Bay	Alma Bay	No	RC	Biannually^
Cleveland Bay	Nelly Bay	No	RC	Biannually
Ross River estuarine zone	Shelly Cove	Yes	TBF	Quarterly
Ross River freshwater basin	Apex Park, Aplin's Weir	Yes	TBF	Biannually^

*The site was not cleaned in 2019.

+Data was not provided for the 2018-2019 Report Card, although clean up events occurred at the site.

^Data was not provided for the 2019-2020 Report Card, although clean up events occurred at the site.

8.1.2 Non-standardised clean ups

Various organisations, including Coastal Dry Tropics Landcare Inc, Reef Check, Ozfish and Tangaroa Blue, undertakes non-standardised clean ups. The location and frequency of non-standardised clean ups vary between years, although some sites are regularly visited. Generally, easy to access and 'volunteer friendly' sites (such as popular beaches) are cleaned more frequency, with beach clean ups conducted more frequently than clean ups at estuarine and freshwater sites.

For volunteer (non-standardised) clean ups, there is no defined boundary for the area to be cleaned. The number of participants and the total duration of the clean-up event is recorded, however individual effort is not recorded (i.e. if people do not participate for the full time, this is not captured in the data).

8.2 Sampling sites to establish earliest/reference baseline

Between 1st July 2014 and 30th June 2018, clean ups occurred at seven freshwater sites along the Ross River (within the Ross freshwater basin), six sites within the Ross estuarine zone (with most clean ups occurring at four sites along Pallarenda beach), eleven sites within Halifax Bay (Orpheus, Fantome, and Palm Island), and eight sites within Cleveland Bay (all on Magnetic Island). The location of the clean-up sites used to establish the reference baseline are shown in Figure 17. The frequency that each site was cleaned during this four year baseline period varied, with the frequency each site was cleaned shown in Table 14. However, for sites that were revisited, it is noted that not the same location was cleaned each time.

Table 14. Location and number of clean ups in the Townsville Dry Tropics region between 1st July 2014 and 30th June 2018.

No clean ups were undertaken in the Black freshwater basin or Black estuarine zone.

Zone	General location	Site specific location	Number of visits	Years visited
Ross freshwater basin	Ross River	Apex Park (Condon)	1	2018
		Aplin's Weir (Rotary Park)	3	Twice in 2018
		Black Weir	4	2014, twice in 2015, 2016
		Pioneer Park	1	2016
		Ross River (Annandale)	5	2015, twice in 2015 and 2016
		Apex Park (Rasmussen)	1	2016
		Weir Park	2	2016, 2017
Ross estuary/ coast	Pallarenda	Pallarenda Beach	9	3 times in 2013, 2014, 2015
		Cape Pallarenda	1	2018
		Shelley Cover	7	2014, 2015, twice in 2016, 2017
		Rowes Bay	10	2014, twice in 2015, three times in 2017
	Oonoonba	Oonoonba wetlands	1	2017
	Townsville City	Queens Gardens	1	2017
Cleveland Bay	Magnetic Island	Horseshoe Bay	5	2016, 2017, 2018
		Radical Bay	1	2014
		Florence Bay	1	2018
		Arthur Bay	2	2016, 2018
		Alma Bay	4	2014, 2016, 2018

Zone	General location	Site specific location	Number of visits	Years visited
		Geoffrey Bay	3	2015, 2018
		Nelly Beach	5	2015, 2016, 2017, 2018
		Hawkings Point	1	2018
Halifax Bay	Orpheus Island	Horseshoe Bay	4	Twice in 2015, once 2016 and 2017
		Big Rock Bay	1	2018
		Fig Tree Beach	5	2014, 2015, 2016, 2017, 2018
		Yanks Jetty	1	2018
		South Beach	1	2018
		Orpheus Research Station/Pioneer Bay	3	2017, 2018
		Picnic Bay	1	2018
	Fantome Island	North East Beach	1	2018
	Palm Island	Jetty Beach	2	2014, 2015

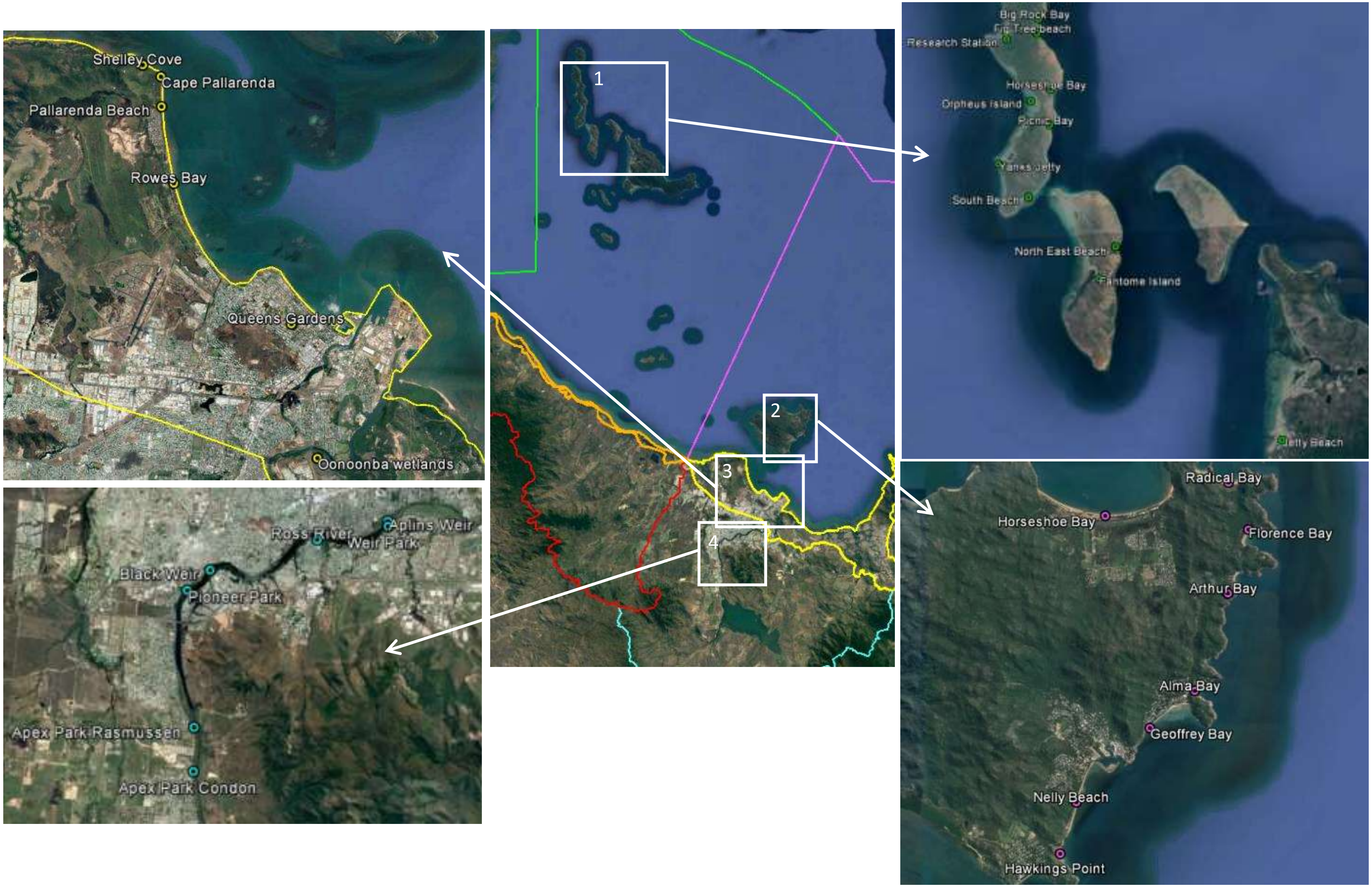


Figure 17. Locations where clean ups occurred between 1st July 2014 and 30th June 2019 within 1) Halifax Bay, 2) Cleveland Bay, 3) Ross estuarine zone and 4) Ross freshwater basin.

There were no sites within the Black estuarine zone, the Black freshwater zone, or the offshore marine zone. The green, pink, orange, yellow, red, and blue outlines delineate Halifax Bay, Cleveland Bay, Black estuarine zone, Ross estuarine zone, Black freshwater basin, and Ross freshwater basin.

9 Community and Economic data collection

Data was drawn from the GBR Social and Economic Long Term Monitoring Program (SELTMP), 2017 (Marshall, et al., 2017). Data was collected between June and August 2017 from coastal population centres between Cooktown and Bundaberg (referred to as the GBR coastal region). This data set is based on a series of survey questions, with the results designed to be used to describe conditions and trends of the social aspects of waterways and the GBR (Marshall, et al., 2016). The results for community indicators were sourced from questions relating to the perceived health, condition, and management of waterways. Questions relating to the non-monetary economic values and industry sustainability were used to score the economic benefits to the community.

10 Indicator scoring methods applicable to the Water quality and Habitat and hydrology/habitat indices

Indicators, indicator categories and indices of water quality and habitat and hydrology are scored using five ordinal values commonly used in report cards (Table 15).

Table 15. Standardised (report card) scoring ranges and corresponding grades for Water Quality and Habitat and hydrology/Habitat indicators and indicator categories.

Standardised (report card) 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 is scored on a specific scale appropriate for the variable being measured and so may have different scoring ranges. To ensure indicator results are comparable, all scores are converted (if required) into a 'standardised' (or 'report card') score by linear interpolation (scaling) within the standardised scoring ranges to between 0 and 100 (see Table 15). Scores are to at least one decimal place to allow grades to be differentiated (e.g. 80.9 is classified as Good, whilst 81 is Very Good). In the summary tables and in the report cards, the scores are presented as integers for simplicity's sake. The standardised scoring range is based on the scoring range used in the Great Barrier Reef Report Card (Department of Environment and Science, 2017). The scores of indicators, indicator categories, indices and the overall scores are represented by colours, as shown in Table 15.

The general formula for converting the raw scores into standardised scores are shown below:

Equation 1. General standardisation equation = a + ABS(b – ((c – d) * (b / e))), where:

a = Lower value of standardised scoring range

ABS = absolute value (positive integer)

b = difference between the lowest and highest value in a standardised scoring range

c = raw score

d = lower value of raw score range

e = difference between the lowest and highest value in a raw scoring range

It is noted that there are exceptions to the general standardisation equation.

Once standardised, scores for each indicator are aggregated into an indicator category, then an index and an overall score. In some cases, an indicator category is derived from a single indicator. Scores can only be aggregated to the next level (i.e. from an indicator to a category, or a category to an index) if they meet the 'minimum information rules for aggregating data':

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

The grades for each indicator category and index are visualised in a coaster to show which components contribute to the grades. Overall scores are presented in the report card, even if not all indicator categories (to derive the grade) are scored.

Subsequent sections detail the scoring of the different indicators of Habitat and hydrology/Habitat in each environmental zone. Similar methods are used to score the indicators in the freshwater and estuarine environments, so these are described together.

11 Water quality scoring methods

Water quality data were compared against regional water quality objectives (WQOs). Water quality objectives act as management targets and allow managers to assess whether their practices and management actions are improving or causing reduced water quality.

WQOs are derived based on ambient dry weather flows and are designed to be assessed against an annual median of test data from a site. The Townsville Dry Tropics are highly seasonal with approximately two to four months of high intensity rainfall and the rest of the year mostly dry. During the wet season and particularly following the first large rainfall event that flushes the system, nutrients and sediment concentrations are likely to be higher than WQO values, as the WQOs are applicable to the entire year. There is a need to develop WQOs for both the wet and the dry season to account for this difference in flow regime between the two seasons.

In 2018-19 a comparison was undertaken whereby water quality data were scored against both water quality objectives (WQOs) and against water quality guidelines (WQGVs). This was done to determine whether there was a substantial difference in using the different values. This was done because some regional report card report against WQOs, whilst others report upon WQGVs and the terms were being used interchangeably. The method for comparing against the WQGVs are detailed in Appendix A. Comparing data against the WQOs was the preferred approach as it is considered more appropriate for the

Townsville Dry Tropics region given that specific water quality objectives have been derived for the region. It is noted that the WQOs are at least 10 years old, with some objectives based on no previous monitoring in the region and instead based on data from south-east Queensland rivers. Updated WQOs are required that are based on water quality monitoring data from the Townsville Dry Tropics region.

11.1 Water quality objectives

Water quality objectives act as a proxy for comparing habitat indicators against management target. "WQOs are long-term goals for water quality management. They are measures, levels, or narrative statements of indicators of water quality (such as salinity or turbidity) that protect environmental values (EVs). They define what the water quality should be to protect the EVs, after considering the socio-economic assessment of protecting the water quality. WQOs are defined for a range of physical indicators (e.g. turbidity, suspended sediment, and temperature), chemical indicators (e.g. phosphorus, nitrogen, and toxicants), biological indicators (e.g. macroinvertebrates and fish), pathogens, and measures of waterway condition (e.g. erosion and riparian vegetation extent and condition). WQOs are derived from site-specific scientific studies, the Queensland Water Quality Guidelines 2009, the Australian and New Zealand Guidelines for Fresh and Marine Waters 2000, and other documents published by recognised entities. WQOs apply to receiving waters (i.e. rivers, estuaries, coastal waters, groundwaters, lakes and wetlands), but they are not end-of-pipe or emission objectives" (Queensland Government, n.d.). WQOs have been developed for a wide range of metrics and include national and state WQGVs, environment protection policies, water quality improvement plans, NRM plans, and the Reef 2050 Plan (Queensland Government, n.d.).

11.1.1 Freshwater and estuaries

There are different WQOs for specific creeks and rivers within the Ross and Black freshwater basins and within the different estuaries within the Ross and Black estuarine zones. Regionally specific WQOs for the freshwater and estuarine zones exist for the Townsville Dry Tropics (see Table 16). The WQOs applicable to the Ross freshwater and estuarine zones are outlined in the 'Environmental Protection (Water) Policy 2009: Ross River Basin and Magnetic Island Environmental Values and Water Quality Objectives, Basin No. 118 including all waters of the Ross River Basin, and adjacent coastal waters' (including Magnetic Island) (Environmental Policy and Planning Division, 2013). The WQOs applicable to the Black Basin and estuarine zone are outlined in the 'Environmental Protection (Water) Policy 2009 Black River Basin Environmental Values and Water Quality Objectives Basin No. 117, including all waters of the Black River Basin and adjacent coastal waters' (Environmental Policy and Planning Division, 2013). Water types within the Ross and Black freshwater and estuarine waters are mapped in
Figure 18 and
Figure 19, respectively.

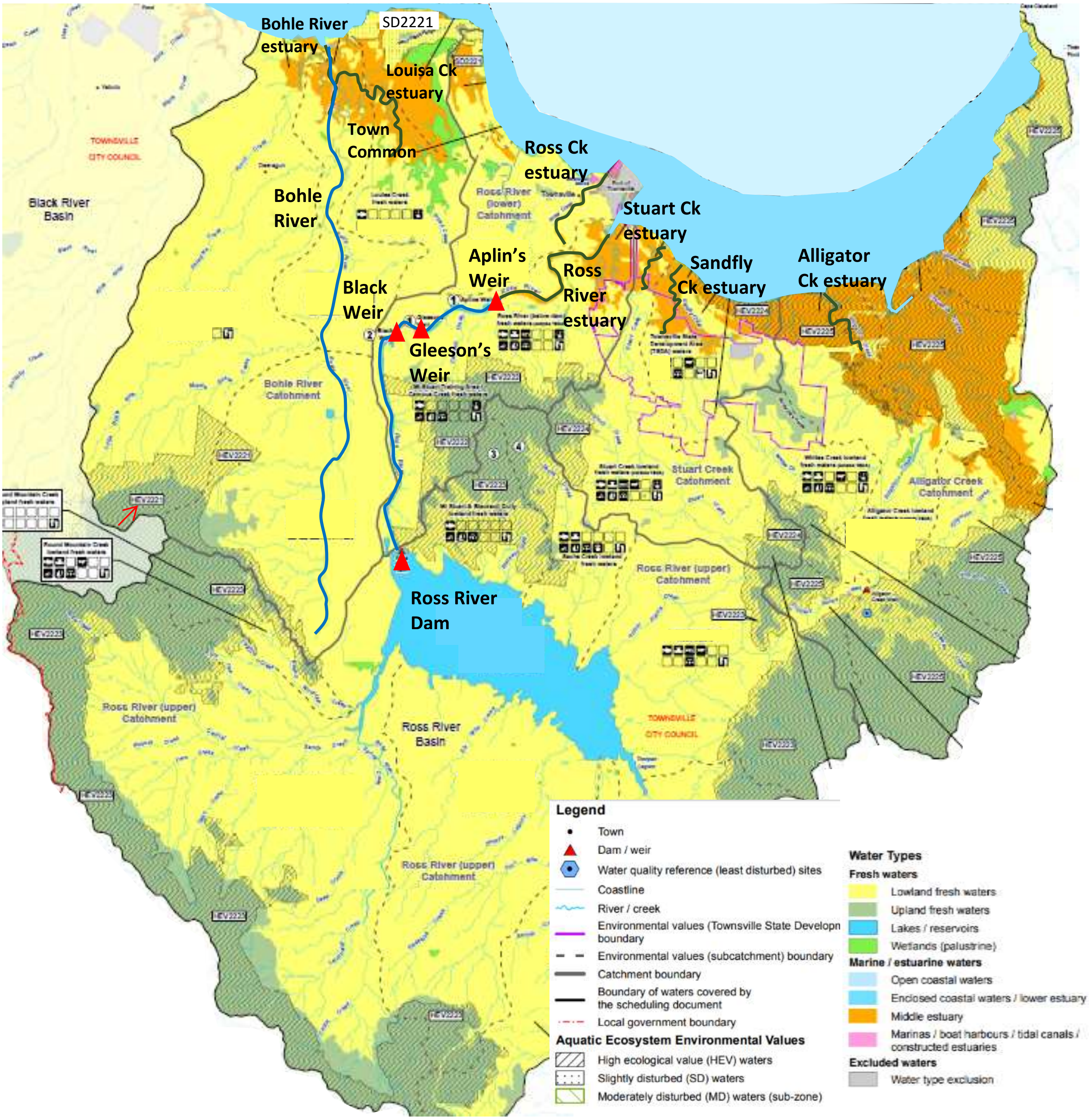


Figure 18. Water types within the Ross Basin.
Creeks (Ck), rivers and estuaries reported in the Townsville Dry Tropics report card are labelled and delineated in dark blue for creeks and rivers and brown for estuaries. Table 16 shows WQOs associated with each water type.

Figure 19. Water types within the Black Basin.

Creeks (Ck), rivers and estuaries reported in the Townsville Dry Tropics report card are labelled and delineated in dark blue for creeks and rivers and brown for estuaries. Table 16 shows WQOs associated with each water type.

When developing the scores and grades for the 2017-2018 Pilot Report Card, inconsistencies in the WQOs within the freshwater and estuaries were determined, with some WQOs based on values from south-east Queensland creeks and rivers. As a result, some WQOs were adjusted by water quality experts based on more recent sampling undertaken within the Townsville region. Experts decided that all rivers within the same basin, excluding freshwater lakes/reservoirs, would be given the same WQOs, rather than applying different WQOs to specific aquatic ecosystems (as listed under the scheduled policy). These adjustments mean the differences in scores between rivers were driven by differences in water quality, rather than differences in WQOs. The WQOs used for the freshwater and estuaries ecosystems within the Ross freshwater basin and Black freshwater basin are outlined in Table 16, with the adjusted values asterisked.

Table 16. Scheduled and adjusted environmental protection policy water quality objectives for water quality indicators for the Ross and Black freshwater basins and estuarine environments.

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

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

11.1.2 Cleveland Bay and Halifax Bay

Indicators are scored against regional WQOs using values from 'Environmental Protection (Water) Policy 2009: Ross River Basin and Magnetic Island Environmental Values and Water Quality Objectives, Basin No. 118 including all waters of the Ross River Basin, and adjacent coastal waters' (including Magnetic Island) (Environmental Policy and Planning Division, 2013) for waters within Cleveland Bay (Ross inshore marine zone).

Within Halifax Bay (Black inshore marine zone) monitoring occurs at Palms West Reef (off Pelorus/Orpheus Island) and Pandora Reef. For Palms West Reef sites, WQOs were sourced from 'Environmental Protection (Water) Policy 2009 Black River Basin Environmental Values and Water Quality Objectives Basin No. 117, including all waters of the Black River Basin and adjacent coastal waters' (Environmental Policy and Planning Division, 2013). Pandora Reef is within the waters offshore of Hinchinbrook, so used WQOs from the 'Environmental Protection (Water) Policy 2009 Tully, Murray and Hinchinbrook Is. River Basins - Environmental Values and Water Quality Objectives - Basins Nos. 113, 114 and 115 and adjacent coastal' (Division, Environmental Policy and Planning, 2014).

WQOs applicable to Cleveland Bay (offshore of Ross freshwater basin), Halifax Bay (offshore of Black freshwater basin) and the offshore marine zone are presented in Table 17. These values were deemed acceptable by experts and were not adjusted. WQOs have only been listed for the zones where data were available and the zones that were scored in the Report Card.

There can be multiple WQOs within a reporting zone, which can be substantially different values and resultantly impact water quality scores. Figure 20 shows where different WQOs apply within Cleveland Bay and Halifax Bay. In the Townsville Dry Tropics, WQOs are stricter in waters further from the coast, representing a natural continuum from coastal to offshore marine waters. As a result, the WQOs for Pandora Reef, Palms West Island and Geoffrey Bay are generally stricter than the WQOs for the enclosed coastal/lower estuarine waters. This can generate counterintuitive results, whereby sites with better water quality receive poorer results because the WQOs are more stringent.

Table 17. Scheduled environmental protection policy water quality objectives for water quality indicators for Cleveland Bay, Halifax Bay, and the offshore marine environment.

NOx indicates oxidised nitrogen and TP, PP and PN indicates total phosphorus, particulate phosphorus, and particulate nitrogen. TSS stands for total suspended solids. Where a range of three values are listed, the middle value is used. However, when the middle value is zero, the upper value is used. MD indicates that the guideline values are written for moderately disturbed areas, SD represents the guideline values are for slightly disturbed areas, whilst HEV means the area is of high ecological value. The definition of SD, MD and HEV ecosystems are found in the terms and acronyms.

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

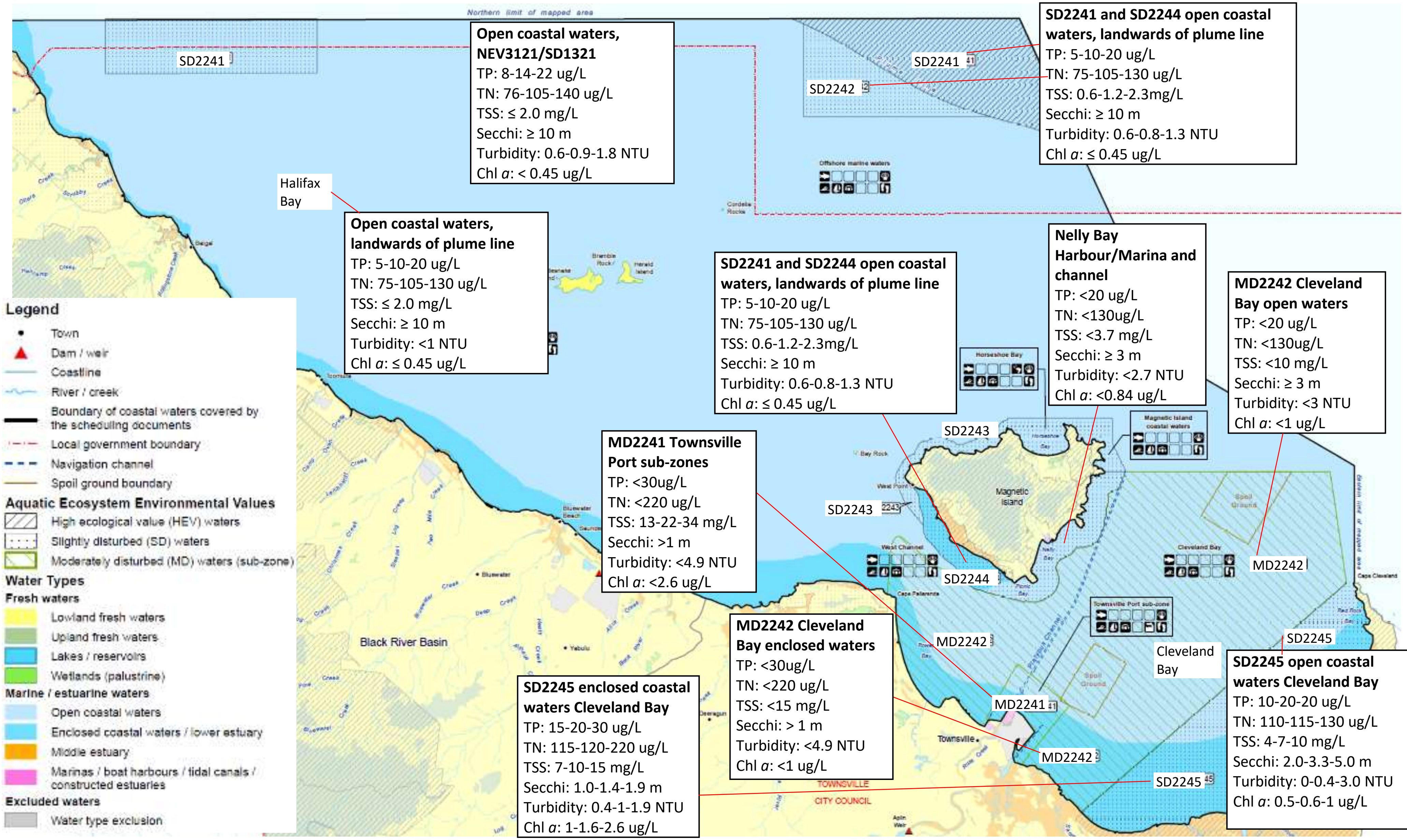


Figure 20. Water types within Cleveland and Halifax Bays, showing some WQOs associated with different water types.

Only water quality variables with objectives for all water types were included to enable comparisons between the water types. While some water types are shown multiple times, the objectives for each water type are only listed once. The indicators scored include total phosphorus (TP), total nitrogen (TN), total suspended solids (TSS), Secchi depth (secchi), turbidity and chlorophyll *a* (Chl *a*).

11.2 Calculating freshwater and estuarine water quality scores

11.2.1 Calculating the scoring range

To calculate a condition score (ranging from 0 - 100) for individual nutrients and phys-chem indicators, annual medians (calculated from monthly medians) are compared to WQOs. If the median complies with WQOs, the score will be within either the "Good" or "Very Good" ranges but be "Moderate", "Poor" or "Very Poor" ranges if non-compliant. An example of how grades are assigned based on annual median compliance with WQOs is shown in Figure 21 and the associated logic in Appendix C. Medians that do not meet the WQOs are scaled between the WQOs using a scaling factor (SF) nominally defined as the 90th (or 10th) percentile of the historic water quality data. The derivation of the SF and its logic is outlined in section 11.2.2. Once indicators are scored and scaled, they are standardised to the GBR report card scoring range (as shown in Table 15 of section 9).

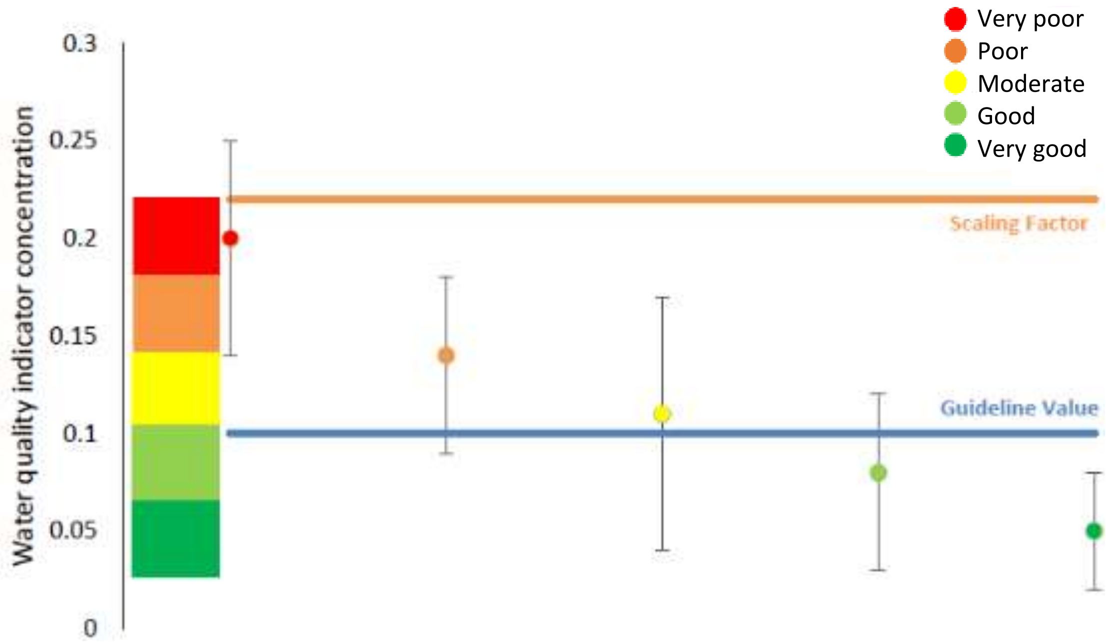


Figure 21. An example of assigning water quality grades.
The middle point represents the annual median, the top whisker the 80th percentile and the bottom whisker the 20th percentile. Values are only scored as good or very good when the annual median meets or betters the guideline value (i.e. the value is at or below the guideline).

11.2.2 Scaling factor

The SF is the 90th (or 10th) percentile of the water quality data, which is ideally calculated from long-term monitoring data from the waterway being assessed. However, long-term monitoring programs do not exist for all waterways, or atypical waterways are monitored (such as waterways where STPs discharge into the waterway). Using data from highly atypical sites can result in anomalously high SF values creating a wide scoring range and reducing the discriminatory power at the lower end of the scoring range.

For the Townsville Dry Tropics, where long-term data sets are unavailable or comprised of atypical sites, the SF is derived from available data and adjusted through expert opinion to a reasonable scoring range (from the WQO to the SF). For example, historical data was not appropriate for setting a SF for upper and lower DO. Expert opinion set the upper DO SF at 120% saturation (M Newham, pers. comm, 27th November 2019). The lower DO SF was set at 50% saturation, which is the value used by the Wet Tropics regional report card. SFs should be higher than the WQOs, as SF represent an undesirable state for the water quality. However, for turbidity, WQOs were often high (up to 50 NTU), whilst the SF (based on the 90th percentile of historic data) was substantially lower. A lower SF than guideline values cause scores to default to 90 (A grade) based on the scoring formula. In this instance, experts decided this was an appropriate score, with the guideline value being too high (M Newham, pers. comm., 27th November 2019). The same or similar SF is used for waterways with the same or similar WQO enabling grade comparison between waterways. SFs are not adjusted annually (as more data is collected) as temporal trends cannot be established. Instead SFs will be reviewed periodically after multiple years of data collection. The same SFs were used for comparing against management targets and guideline values. SF and some WQOs were adjusted by experts within some waterways after the Pilot Report Card determined that they were inaccurate for the region (M Newham, pers. comm, 27th November 2019).

11.2.3 Steps to calculate grades

Steps used to calculate the scores for water quality indicators are:

1. If measurements are less than the level of reporting (LOR, Section 11.2.5), then use 0.5 x LOR.
2. Derive DIN from the freshwater data set (oxidised nitrogen + ammonia nitrogen).
3. Calculate monthly medians.
4. Calculate annual median from monthly medians.
5. Compare annual median to WQOs and WGVs.
6. For each independent site, calculate condition score (0-100) following rules and formula in Table 18 and Table 19.
7. For each independent site, weight the scores by catchment area (see section 0).
8. Weighted scores are converted to report card five-point grades using rules and formula in Table 18 and Table 19.
9. Indicator scores are aggregated into indicator category scores and water quality index scores following the decision rules for minimum information (outlined in section 10).

Table 18. Rules, formulas and scoring ranges for indicators (except lower dissolved oxygen) within the nutrients and phys-chem indicator categories in freshwater basins and estuaries for the Townsville Dry Tropics report card.

Rule	Formula to convert raw scores into standardised scores	Scoring range	Grade and colour code
Median meets WQO and the 80th percentile of monthly medians meet WQO	Assigned 90	81 to 100	Very Good
Median meets WQO, but the 80th percentile of monthly medians do not meet WQO	80.9 - (19.9*ABS((80th-WQO)/(80th-annual median)))	61 to <81	Good
Median does not meet WQO	60.9 - (60.9*ABS((annual median - WQO)/(SF- WQO)))	41 to <61	Moderate
		21 to <41	Poor
		0 to <21	Very Poor

Table 19. Rules, formulas and scoring ranges for the lower dissolved oxygen (DO) indicator.
To meet the lower DO water quality objective (WQO), percent saturation must be higher than the WQO. This is inverse of how the other indicators are calculated and thus the formula is inverse to that shown in Table 18.

Rule	Formula to convert raw scores into standardised scores	Scoring range	Grade and colour code
Median meets WQO and ≥80% of monthly medians meet WQO	Assigned 90	81 to 100	Very Good
Median meets WQO, but 80% of monthly median do not meet WQO	80.9 - (19.9*ABS(((WQO -20th)/(annual median-20th))))	61 to <81	Good
Median does not meet WQO	60.9 - (60.9*(ABS((annual median - WQO)/(SF- WQO))))	41 to <61	Moderate
		21 to <41	Poor
		0 to <21	Very Poor

11.2.4 Weighting sites by catchment area

Catchment area represented by each sampling site differs for each site. To account for this, the proportion that each freshwater and estuarine site represents of the catchment is calculated. The overall score for each indicator category and index is then based on scores from each site weighted by catchment area:

1. Calculate scores for each indicator and index (averaging the two indicator categories scores) for each site.
2. Calculate the catchment area for each site, as being the area that drains into (and thus influences) the site. Catchment areas were approximated in ArcGIS based on the delineation of rivers and their tributaries.
3. Calculate the total catchment area for all sites (within a basin), by summing the site catchment areas.
4. Calculate the proportion of the catchment that each site represents by dividing the catchment area of each site by the total measured catchment area (site catchment area / total measured catchment area).
5. Weight each independent site by catchment area by multiplying the proportion that the site represents by the non-weighted score.
6. Calculate the overall score for each indicator category and index by summing the weighted scores for each site.

Unweighted scores for indicator categories and indices are also presented in the Report Card to allow direct comparison of the condition of each site and give insights into each site's water quality. A more detailed explanation of how sites were weighted is outlined in 'Assessing multiple freshwater and estuarine sites' (Gillespie and Whitehead, 2020 unpublished).

11.2.5 Limit of reporting

"The limit of reporting is defined as the smallest concentration of a chemical that can be reported by a laboratory. If a laboratory is unable to detect a chemical in a sample, it does not necessarily mean that the chemical is absent from the sample altogether. It could be that the chemical concentration in the sample is below the sensitivity of the testing instrument" (Western Environmental Testing Laboratory, n.d.). Consequently, rules have been established for samples where measurements are below the limit of reporting (LOR):

1. Where the LOR is greater than the WQO, data are not used for that indicator because there is no valid interpretation of whether WQOs were met.
2. Where the LOR is less than WQO, a value of 0.5 x LOR is used.

When the LOR is not half of the value for the WQO, using 0.5 x LOR may bias results towards better scores which, along with sample number, is considered when reporting confidence in the results.

11.3 Calculating inshore marine water quality scores

For indicators within the nutrients, physical-chemical (phys-chem) properties and chlorophyll-*a* indicator categories, annual means are calculated at each site with scores calculated using the relevant WQOs.

11.3.1 Steps to calculate grades

Scores are calculated for each indicator (as detailed in Lønborg, et al., (2016) and Waterhouse et al., (2017)). In short:

1. For indicators whereby failing to meet an WQO is defined as values being higher than the WQO, the score is calculated as:

   $$\text{Score} = \log_2 (\text{WQO/annual mean of measured indicator})$$

   For indicators whereby failure to meet an WQO is defined as values being lower than the WQO (e.g. Secchi depth), the score is calculated by:

   $$\text{Score} = \log_2 (\text{annual mean of measured indicator/WQO})$$

2. Scores exceeding -1 or 1 are capped so the water quality index ranged from -1 to 1. This meant that all indicators were on the same scale.
3. The indicators within the nutrients, phys-chem and chlorophyll-*a* indicator categories are converted into report card scores using the standardisation formula shown in Table 20.
4. Scores for indicators are aggregated into indicator category scores and water quality index scores following the decision rules for minimum information (outlined in Section 10).

Table 20. Inshore water quality grades, scoring ranges and scaling for aggregation.

Raw scoring range	Formula to convert raw scores into standardised scores	Standardised Scoring Range	Grade and colour code
>0.5 to 1	100- (19 - ((score-0.51) * (19/0.49)))	81 to 100	Very Good
0 to 0.5	80.9 - (19.9 - (score *(19.9/0.50)))	61 to <81	Good
-0.33 to <0	60.9- (19.9 - ((score -(-0.33)) *(19.9/0.32)))	41 to <61	Moderate
-0.66 to -0.33	40.9- (19.9 - ((score -(-0.66)) * (19.9/0.32)))	21 to <41	Poor
-1 to < -0.66	20.9- (20.9 - ((score -(-1)) *(20.9/0.34)))c	0 to <21	Very Poor

11.3.2 Limit of reporting

The same rules for LOR (Section 11.2.5) applied to the freshwater and estuarine zones are also used for the inshore marine area. Data where the LOR is above WQO values were removed prior to analysis.

11.4 Offshore marine zone

There are no water monitoring programs in place for the Townsville Dry Tropics offshore marine zone. For the 2018-19 and 2019-2020 Report Cards, offshore water quality was assessed using remote sensed data from BOM processed through the eReefs dashboard. For each indicator (chlorophyll-*a* and total suspended solids), the proportion of valid pixels above the annual threshold fraction are calculated each month (Bureau of Meteorology, 2019). The annual threshold fraction is the water quality guideline value (WQGV) used by the Great Barrier Reef Marine Park Authority (Department of Environment and Heritage Protection, 2009) which are shown in Table 21. A WQGV represents the value if waters were in a natural condition (pre-European) and is used to assess how the water quality has changed from 'natural' conditions. Water quality guidelines apply for broad scale regions.

The current method (using satellite data from BOM) compares water quality indicators (TSS and chlorophyll-*a*) against WQGVs only. Monthly values are then averaged over the reporting year prior to calculating scores for both indicators as follows:

Percent area of water body less than or equal to the WQGV = 100% - % water body that exceeded the WQG within the reporting period (financial year)

This percent is directly translated into a score from 0 to 100 for the report card. Scores for total suspended solids and chlorophyll-*a* are weighted equally and averaged to provide an overall score.

Table 21. Great Barrier Reef Marine Park Authority (GBRMPA) water quality guideline values (WQGVs) for total suspended sediments and chlorophyll *a*.
Only the WQGVs for the offshore water quality indicators that are reported on are shown.

Indicator category	Indicator	Units	Guideline value
Phys-chem	Total suspended sediment (TSS)	mg/L	0.7
Chlorophyll-*a*	Chlorophyll *a*	ug/L	0.4

It is noted that for the 2019-20 data, 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.

12 Habitat and hydrology/Habitat scoring methods

In the 2017-18 Report Card, data were compared against the earliest available baseline. The method for scoring habitat extent data against the earliest baseline in described in Appendix B. From the 2018-19 Report Card onwards, habitat and hydrology data were compared against management targets, where management targets have been devised. Otherwise data were compared against the earliest available baseline.

12.1 Freshwater basins

Within the habitat and hydrology index, there are two indicator categories within the freshwater zone, which are habitat extent and artificial barriers.

12.1.1 Habitat index

There are two indicators within the habitat index for the freshwater zone, which are riparian extent and wetland extent. They are equally weighted, with their scores averaged.

12.1.1.1 *Scoring riparian and wetland extent compared to management targets*

The scoring ranges and the method for standardising the raw scores into report card scores and grades (A to E) is shown in Table 22 for riparian extent and in Table 23 for wetland extent. Currently, the management targets to compare habitat extent against are based on targets derived for the whole GBR, in which a Very Good grade is only achieved if there is no loss of natural habitat extent between each mapping period. The scoring ranges and grades are based on the GBR report card, except in the regional report cards habitat extent for wetlands is calculated separately to the scores for mangroves and saltmarshes (latter two combined). In the future, expert opinion will be used to develop regionally specific targets for habitat extent. The maximum score is capped at 81 to promote continual improvement. In future, a method will be devised to score increases in habitat extent (rather than scores based solely on habitat loss). Habitat data are updated at most once every four years.

Table 22. Scoring ranges, standardisation formulas (to convert raw scores to standardised scores), report card scoring range and report card grades for loss of riparian extent over a four year period.

Change in habitat extent (progress towards targets)			
Raw scoring range	**Standardisation formula**	**Report card scoring range**	**Grade**
>0% increase	100- ABS(19 - ((score-0) *(19/99.9)))	81	Very good (A)
0-0.10% loss	61+ ABS(19.9 - ((score -0) *(19.9/0.1)))	61-<81	Good (B)
0.11-0.50% loss	41+ ABS(19.9 -((score -0.11) *(19.9/0.39)))	41-<61	Moderate (C)
0.51-1.0% loss	21+ ABS(19.9- ((score -0.51) * (19.9/0.49)))	21-<41	Poor (D)
>1.0% loss	ABS(20.9 - ((score-1.01) *(20.9/98.99)))	<21	Very Poor (E)

Table 23. Scoring ranges, standardisation formulas (to convert raw scores to standardised scores), report card scoring range and report card grades for loss of wetland, mangrove, and saltmarsh extent over a four year period.

Change in habitat extent (progress towards targets)			
Raw scoring range	**Standardisation formula**	**Report card scoring range**	**Grade**
>0% increase	100- ABS(19 - ((score-0) *(19/99.9)))	81-100	Very good (A)
0-0.10% loss	61+ ABS(19.9 - ((score -0) *(19.9/0.1)))	61-<81	Good (B)
0.11-0.50% loss	41+ ABS(19.9 -((score -0.11) *(19.9/0.39)))	41-<61	Moderate (C)
0.51-3.0% loss	21+ ABS(19.9- ((score -0.51) * (19.9/2.49)))	21-<41	Poor (D)
>3.0% loss	ABS(20.9 - ((score-3.01) *(20.9/96.99)))	<21	Very Poor (E)

12.1.2 Artificial barriers

The artificial barrier indicator category comprises two indicators, which are impoundment length and fish barriers. Both are equally weighted to generate an overall score for artificial barriers. Both indicators are scored against earliest baseline (not management targets).

12.1.2.1 *Impoundment length*

Impoundment length is scored based on the proportion of stream length inundated by artificial impoundment when at maximum volume. Scoring ranges for impoundment length are based on work which benchmarked the ecological condition of multiple rivers within the Murray-Darling Basin in relation to impoundment, which is the method using by the tother regional report card (Healthy Rivers to Reef Partnership Mackay-Whitsunday, 2017). The ecological condition of the Ross River and Black River has not been assessed in this way and thus the ecological condition benchmarking was based on the condition within the Murray-Darling Basin. One of the indicators of impoundments assessed in the Murray-Darling Basin is the proportion of river impounded by dams and weirs, and this is the indicator used here. Benchmarking of ecological condition is based on data from existing studies and expert opinion of a panel of experienced aquatic ecologists (Sheldon, et al., 2000; Department of Natural Resources, 2000). The resulting impact from impoundments is likely to differ between rivers due to factors such as location in the stream network and their construction (e.g. height, material, etc.). However, it is not currently possible to assess the degree of impact, so their impacts are assumed to be equal. Thus, an increase in impoundment number lowers the report card score. Table 24 summarises how impoundment length is converted into a report card grade.

Table 24. Scoring ranges, standardisation formulas (to convert raw scores to standardised scores), report card scoring range and report card grades for impoundment length within freshwater and estuarine environments.

Raw scoring range	Standardisation formula	Report card scoring range	Grade
< 1.0%	81+ ABS(19 - ((score-0) *(19/0.99)))	81-100	Very good (A)
1.0-3.9%	61+ ABS(19.9 - ((score -1) *(19.9/2.99)))	61-<81	Good (B)
4.0-6.9%	41+ ABS(19.9 - ((score -4) *(19.9/2.99)))	41-<61	Moderate (C)
7.0-9.9%	21+ ABS(19.9 - ((score -7) * (19.9/2.99)))	21-<41	Poor (D)
≥ 10.0%	ABS(20.9 - (score-10))	<21	Very Poor (E)

12.1.2.2 *Fish barriers*

The fish barrier indicator is comprised of three sub-indicators, which are barrier density, proportion of stream length to the first barrier, and proportion of stream length to the first impassable barrier. Each indicator was separately scored, as shown in Table 25 and then summed (with each component equally weighted) to generate report card scores (Table 26).

Table 25. Scoring ranges, formulas to convert raw scores to standardised scores, report card scoring range and report card grades for the fish barriers indicator category.
The fish barrier indicator comprises of 1) barrier density (average stream length (kilometre) per barrier), 2) percentage of the stream length to the first barrier (length is proportional to total stream length and multiplied by 100 to calculate percentage), and 3) percent of the stream length to the first impassable barrier (length is proportional to total stream length and multiplied by 100 to calculate percentage). An impassable barrier is one where there was no, or a low, chance of fish movement across the barrier.

Raw scoring range				
Barrier density	**% of stream length to first barrier**	**% of stream length to first impassable barrier**	**Standardisation formula**	**Grade**
≥16.1	No barriers	No impassable barriers	5	Very good (A)
8.1-16	80-99.9%	90.1-99.9%	4	Good (B)
4.1-8	60-79.9%	80.1-90%	3	Moderate (C)
2.1-4	40-59.9%	60.1-80%	2	Poor (D)
0-2	0-39.9%	0-60%	1	Very Poor (E)

Table 26. Scoring ranges, standardisation formulas, report card scoring range and grades for the fish barrier indicator.
The scores are calculated by summing the three components of fish barriers (barrier density, proportion of stream length to the first barrier, and proportion of stream length to the first impassable barrier).

Raw scoring range	Standardisation formula	Report card scoring range	Grade
14-15	81+ ABS(19 + ((score-15) *(19/1)))	81-100	Very good (A)
11-13	61+ ABS(19.9 + ((score -13) *(19.9/2)))	61-<81	Good (B)
8-10	41+ ABS(19.9 + ((score -10) *(19.9/2)))	41-<61	Moderate (C)
5-7	21+ ABS(19.9+ ((score -7) * (19.9/2)))	21-<41	Poor (D)
3-4	ABS(20.9 + ((score-4) *(20.9/1)))	<21	Very Poor (E)

12.2 Estuarine waters

Within the estuarine zone, there are one indicator category, habitat extent, within the habitat and hydrology index.

12.2.1 Habitat index

There is one indicator, combined mangrove and saltmarsh extent, within the habitat extent indicator category.

12.2.1.1 *Scoring mangrove and saltmarsh extent compared to management targets*

The scoring ranges and the method for standardising the raw scores into report card scores and grades (A to E) is shown in Table 23 for mangrove and saltmarsh extent. Currently, the management targets are based on targets derived for the whole GBR, with a Very Good grade only achieved if there is no loss of natural habitat extent between each mapping period. In the future, expert opinion will be used to develop regionally specific targets for habitat extent. The maximum score is capped at 81 to promote continual improvement. In future, a method will be devised to score increases in habitat extent (rather than scores based solely on habitat loss). Habitat data are updated at most once every four years.

12.3 Inshore and offshore marine zones

12.3.1 Habitat index

Seagrass and coral are two indicator categories within the habitat index for the inshore marine zone. Coral and seagrass are equally weighted and are averaged to produce an overall score for the habitat index. Coral is the only indicator category scored within the offshore marine zone.

12.3.1.1 *Seagrass (indicator category within the inshore marine zone)*

There are three indicators within the seagrass indicator category, which are 1) changes in mean above ground biomass, 2) total meadow area and 3) species composition relative to a 10-year baseline (Bryant & Rasheed, 2018). Seagrass meadows within the Townsville Port have been monitored since 2007, with the baseline developed in 2007/2008 and updated in 2013 and 2016 (financial year). The baseline is calculated using a 10-year average.

Details are presented in Carter et al., (2016), but in short, each indicator is scored from 0 to 1, and allocated to A-E grades. Threshold conditions are defined for each indicator (i.e. biological thresholds define very poor to very good). For each meadow, the lowest scoring indicator is the score for the overall score for the site, unless the species composition is the lowest score. If species composition is the lowest score, the two lowest scores are averaged for the meadow. The overall score for seagrass is the average of all the meadows.

12.3.1.2 *Coral (within the inshore and offshore marine zone)*

12.3.1.2.1 Coral indicators

Five indicators of coral indicator category (Table 27) are assessed within the inshore marine zone (Thompson, et al., 2016). All five indicators of coral are determined by the Marine Monitoring Program (MMP), which surveys inshore reefs, and by the Long Term Monitoring Program (LTMP), for offshore reefs. Coral cover indicator is also collected by Reef Check, which is a citizen science program. Observations for each indicator are scored on a continuous scale, with the thresholds within scale based on biological factors and differing for each indicator (Table 28) following Thompson, et al., (2016). For the report card, thresholds are converted to a scale from 0 (very poor) to 1 (very good).

Table 27. Description of indicators within the coral cover indicator category.

Indicator	Description
Coral cover	This indicator scores reef condition based on the proportion of coral cover. Proportional cover includes all genera of hard (order Scleractinia) and soft (subclass Octocorallia) corals. Values are scaled linearly from zero (cover is 0 %) to 1 (cover is at or above 75 %).
Macroalgae cover	This indicator scores proportion of substrate covered by macroalgae. Macroalgae amount varies between reefs, with some having naturally low or high macroalgal cover.
Juvenile density	This indicator was calculated by counting juvenile hard corals (colonies up to 5 cm in diameter) and converting this number to density per m^2 of space available for settlement.
Change in coral cover	Calculated by comparing observed change in coral cover between two visits to predicted change from a Gompertz growth equation (Thompson A, 2010). Models for fast growing acroporid corals were run separate from all other hard coral, which are slower growing.
Community composition	This indicator was calculated by scaling cover for constituent genera (subset to life forms for the abundant genera *Acropora* and *Porites*) by genus weightings which correspond to the distribution of each genus along a gradient of turbidity and chlorophyll-*a* concentration (Thompson, et al., 2016).

Table 28. Score and threshold for the five indicators of the coral indicator category.

Indicator	Brief description	Threshold	Score
Coral cover	Combined hard and soft coral cover	1 at 75% cover or greater	Continuous from 0 to 1
		0 at zero cover	
Macroalgae cover	Proportion of algae cover classified as macroalgae	≤ reef specific lower bound and ≥ reef specific upper bound	Continuous from 0 to 1
Juvenile density	Density of hard coral juveniles (<5 cm diameter)	> 13 juveniles per m^2 available substrate	1
		4.6 – 13 juveniles per m^2 available substrate	Continuous from 0.4 to 1
		< 4.6 juveniles per m^2 available substrate	Continuous from 0 to 0.4
Change in coral cover	Rate of increase in hard coral cover (preceding 4 years)	Change > 2x upper 95% CI of predicted change	1
		Change between 1x and 2x upper 95% CI	Continuous from 0.6 to 0.9
		Change within 95% CI of predicted change	Continuous from 0.4 to 0.6
		Change between 1x and 2x lower 95% CI	Continuous from 0.1 to 0.4
		Change < 2x lower 95% CI predicted change	0
Community composition	Composition of hard coral community	Beyond 95% CI of baseline condition in the direction of improved water quality	1
		Within 95% Confidence intervals of baseline composition	0.5
		Beyond 95% CI of baseline condition in the direction of declined water quality	0

MMP and the LTMP survey different sets of reefs in alternate years. MMP has a biennial sampling design, meaning all reefs are sampled over a two year period (not every monitored reef is sampled every year). Coral community structure and exposure to disturbances differ markedly with depth (Bridge, et al., 2013). This influence of depth is most apparent in inshore areas where the turbidity of waters causes a rapid attenuation of light (Bridge, et al., 2013; Marshall & Baird, 2000). To minimise the differences in depth, the MMP stratifies sampling by depth including transects at both 2 m and 5 m below lower astronomical tide (LAT). More detailed information on the methods used by MMP can be found at http://www.gbrmpa.gov.au/our-work/our-programs-and-projects/reef-2050-marine-monitoring-program and https://www.aims.gov.au/docs/research/monitoring/reef/latest-surveys.html. The LTMP has a biennial sampling design, with more detailed information on the methods used by LTMP can be found at https://www.aims.gov.au/docs/research/monitoring/reef/latest-surveys.html. Reef Check does not have a regular sampling schedule, with different reefs sampled at different frequencies. Typically, some inshore reefs such as Magnetic Island are sampled annually, with offshore reefs sampled sporadically.

12.3.1.2.2 Combining Reef Check and MMP/LTMP scores

The method for calculating the score for each indicator category is detailed in Thompson et al. (2016). Separate scores are calculated for coral cover for Reef Check, MMP and LTMP data using the methods outlined in Thompson et al. (2016). An overall score is determined by combining Reef Check coral cover scores after weighting, with those from the MMP (inshore) or LTMP (offshore).

Reef Check coral cover data is weighted based on the coral cover survey precision relative to that of the MMP and LTMP. Reef Check sometimes surveys several times at the same site each within a year, but only the most recent surveys were included (i.e. multiple same year surveys were not aggregated) because coral cover may have changed between repeat visits.

The precision of sampling for each monitoring program (Reef Check, MMP and LTMP) was calculated as a function of sampling frequency. Precisions was assessed using a simulation of randomly sampling a series of points with known proportions with improved precision expressed as confidence intervals around the mean (Figure 22).

This random simulation showed improvement in precision for each monitoring program could be determined based on sample size (number of observations) which was calculated as:

Sample size = No. observations taken every metre x No. transects x transect length (m) x No. of sites sampled within the same reef

The sample size for each monitoring program is shown in Table 29 with precision estimates calculated for sampling at one, two and three sites (within a reef) (

Table 30, Thompson and Menendez (2018)). Reef Check surveys one site per reef, MMP two sites per reef and LTMP at three sites per reef. Precision estimates were not calculated for more than three sites as it is unlikely Reef Check would survey this intensively even if they increased their current regime.

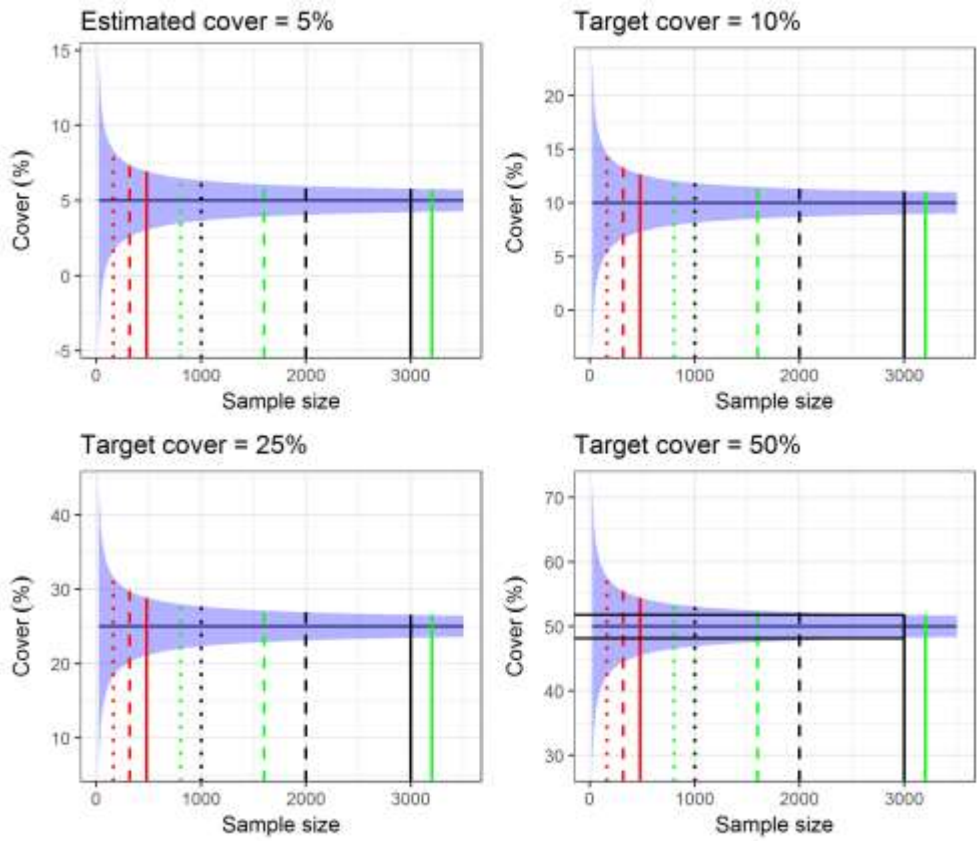


Figure 22. Theoretical influence of sampling intensity in confidence intervals about mean coral cover.
Reference lines indicate sampling intensity used by Reef Check (red), MMP (green) and LTMP (black) for one (dotted), two (dashed) and solid for three (Reef Check, LTMP) or four (MMP) sites within a reef.
Source: Thompson and Menendez (2018)

Table 29. Sample size (total observations) per survey by the three coral monitoring programs within the Townsville Dry Tropics region.

Monitoring program	No. observations taken every metre	No. transects	Transect length (m)	No. of sites sampled within the same reef	Sample size (total observations)
Reef Check	2	4	20	1 (unless otherwise specified)	160 (2 x 4 x 20)
Marine Monitoring Program	80 (8 used)	5	20	2	1,600 (8 x 5 x 20 x 2)
Long Term Monitoring Program	50 (4 used)	5	50	3	3,000 (5 x 5 x 40 x 3)

Table 30. Improvement in precision of coral cover estimates with increasing sampling intensity.
Values represent the span between upper and lower normal approximations of 95 % CI for coral cover estimated at 50%. Additional sites represent multiplicative increases in points sampled at a single site.

Program	Points per site	1 site	2 sites	3 sites
Reef Check	160	15.49	10.96	8.95
MMP	800	6.93	4.90	
LTMP and RAP	1000	6.20	4.28	3.58

Source: Thompson and Menendez (2018).

Reef Check data are individually weighted for each reef against MMP and LTMP data who are each given an equal weight of 1. Reef Check data were weighted depending on whether one, two or three reefs were sampled as shown in Table 31. For inshore reefs, the reef by depth sampling intensity of the MMP (2 sites = 4.9) was used as the standard to scale the Reef Check data. To incorporate Reef Check data, each inshore reef level estimate was weighted by 0.32, based on the calculated weighting from Table 31. For offshore reefs, Reef Check data were compared to offshore LTMP reef, using 3.28 as the standard scale. Reef Check data for offshore reefs were weighted by 0.21. In both inshore and offshore cases, these weightings may be adjusted if Reef Check survey effort increases.

Table 31. Weighting for inshore and offshore Reef Check reefs based on precision estimates for one, two and reef sites sampled per reef.
The weighting is calculated relative to precision of a standard inshore MMP site and depth observation (1,600 observations) and a standard offshore LTMP site (3,000 observations).

Number of sites sampled within the same reef	Number of samples per Reef Check site	Total observations	Inshore reef weighting based on precision	Offshore reef weighting based on precision
1	160	160	1/(15.49/4.9) =0.32	1/(15.49/3.28) = 0.21
2	160	320	1/(10.96/4.9) = 0.45	1/(10.96/3.28) = 0.30
3	160	480	1/(8.95/4.9) = 0.55	1/(8.95/3.28)= 0.37

A lower weighting for the Reef Check data accounts for the lower precision meaning that the citizen science data does not substantially impact upon scores from the MMP and LTMP data. If there are large differences between Reef Check and MMP or LTMP data, it is assumed these are likely to be true differences, rather than sampling error. For example, if sites only monitored by Reef Check have substantially lower or higher coral cover than reefs monitored by MMP or LTMP, it is assumed these differences are real and need to be reflected in the report card score.

12.3.1.2.3 Scoring and grading method

Each coral indicator is scored for each site and averaged across sites to determine the score. These (once Reef Check and MMP data are weighted and combined) are converted into grades for the regional report cards using the standardised formula in Table 32. All five indicators are equally weighted and averaged to produce an overall score for the coral indicator category.

Table 32. Coral indicator scoring ranges, formulas to standardise raw scores, report card scoring range and grades.

Raw scoring range	Standardisation formula	Report card scoring range	Grade
>0.8	Score x 100	81-100	Very good (A)
>0.6 - 0.88	Score x 100	61-<81	Good (B)
>0.4 – 0.6	Score x 100	41-<61	Moderate (C)
>0.2 – 0.4	Score x 100	21-<41	Poor (D)
>0 – 0.02	Score x 100	<21	Very Poor (E)

13 Fish scoring methods

13.1 Fish index

The assessment of freshwater fish communities is based on two indicator categories, which are the proportion of indigenous (native) species expected (POISE) within waterways (excluding translocated species) and the proportion of non-indigenous (native) fish.

13.1.1 Proportion of Indigenous (native) Species Expected (POISE)

The proportion of indigenous (native) species expected (POISE) indicator category is scored using the cut-off values shown in Table 33. The result is only provided for the whole freshwater basins, with the basin result based on the median across all the sampled sites.

Table 33. Scoring ranges, standardisation formulas (to convert raw scores to standardised scores), report card scoring range and report card grades for Proportion of Indigenous Species Expected (POISE) indicator category within freshwater environments.

Raw scoring range	Standardisation formula	Report card scoring range	Grade
0.80 to 1	81+ ABS((19 + ((score-1) *(19/0.2))))	81-100	Very good (A)
0.67 to <0.80	61+ ABS(19.9 + ((score -0.7999) *(19.9/0.1329)))	61-<81	Good (B)
0.53 to <0.67	41+ ABS((19.9 + ((score – 0.6669) *(19.9/0.1339)))	41-<61	Moderate (C)
0.40 to <0.53	21+ ABS((19.9 + ((score -0.5329) * (19.9/0.1329)))	21-<41	Poor (D)
0 to <0.40	ABS((20.9 + ((score - 0.3999)*(20.9/0.3999))))	<21	Very Poor (E)

13.1.2 Proportion of Non-Indigenous Fish

The proportion of non-indigenous fish indicator category is scored using the cut-off values shown in Table 34. The result is only provided for the whole freshwater basins, with the basin result based on the median across all the sampled sites.

Table 34. Scoring ranges, standardisation formulas (to convert raw scores to standardised scores), report card scoring range and report card grades for the Proportion of Indigenous Fish indicator category within freshwater environments.

Raw scoring range	Standardisation formula	Report card scoring range	Grade
0 to 0.3	81+ ABS((19 - ((score-0) *(19/0.025))))	81-100	Very good (A)
>0.03 to 0.05	61+ ABS(19.9 - ((score -0.0251) *(19.9/0.0249)))	61-<81	Good (B)
>0.05 to 0.1	41+ ABS((19.9 - ((score - 0.051) *(19.9/0.049)))	41-<61	Moderate (C)
>0.1 to 0.2	21+ ABS((19.9 - ((score -0.101) *(19.9/0.099)))	21-<41	Poor (D)
>0.20 to 1	ABS((20.9 – ((score—0.201) *(20.9/0.799))))	<21	Very Poor (E)

13.2 Sampling methods and grades

Scores were only provided for the whole of the Ross and Black freshwater basins, with the scores derived from the medians across all the sites (11 and 13 monitoring sites for the Ross and Black basins respectively). Site-specific results were presented, rather than the scores being rolled up for the sites. This is because the sites represent only one location within the waterway at one point in time.

For the 2019-2020 Report Card, 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' as the median across sites generally doesn't change rapidly with the addition of a small number of additional sites.

14 Litter scoring methods

14.1 Litter index

14.1.1 Scoring ranges

The total litter collected at each site within a financial year is compared to the amount of rubbish collected from the four year baseline (data from 1st July 2014 until 30th June 2018). The four years of data (1st July 2014 until 30th June 2018) was used to establish a reference distribution and will be used as the permanent baseline to which data will be compared against. These dates were the earliest period where four years of data were available in more than one zone.

To calculate scores and grades for total rubbish, scores, and grades for the 2018-2019 financial year were determined by relating annual data to the 4-year reference distribution. Data are scaled from 0 to 1 for the report card, with close to zero equating to "near pristine" and close to 1 being a "highly littered" state.

The reference distribution was created by:

1. Calculating number of items collected and the number of hours cleaning.
2. Standardising Catch per unit effort' (CPUE) to an approximately normal distribution:
   Natural log(CPUE) = natural log(Items collected) - ½ log(Hours cleaned)
3. Natural log(CPUE) is considered the index to individual sites within and between years.
4. Where sites were cleaned more than once in a year (of which there were few) natural log(CPUE) over sites within reporting years was averaged. This resulted in only a minor reduction of the calculated index for these zones (Table 35).
5. After ordering the natural log(CPUE) values from smallest to largest, an empirical survivor function (ESF) was derived for the reference distribution (i.e. the probability of survival past time y which is independent of distributional assumptions.
6. The ESF was then created by plotting p (which equals [r + ½]/n), against natural log(CPUE), with r the number of values greater in the sorted list, and n the total number of values.
7. Smoothing the ESF produced the working reference distribution and algorithm easily applied to present and future data.
8. The score corresponding to any natural log(CPUE) value is then obtained using the smoothed ESF constrained to between 0 and 1.

9. From the smoothed ESF, the cut off (A to E) values can be determined (Figure 23 and Figure 24) using the standard report card band widths of 0 to <21 as a E grade, 21 to <41 as a D grade, 41 to <61 as a C grade, 60 to <81 as a B grade and a 81 to 100 as an A grade.

Scoring the litter indicators was designed to show any change (increase or decrease) compared to the four years baseline. For example, if the mean for a financial year is lower than the mean from the four years baseline, the indicator will be graded as a 'A', 'B' or 'C', but would be 'D' or 'E' if there was more rubbish than previous years (or 'the mean from the baseline period'). For more detailed methods on how the scores for the litter index was generated, refer to the 'A Proposal for Litter Scores and Grades' document (Whitehead and Venables, unpublished).

Table 35. Mean log (catch per unit effort) per site, per reporting year for Townsville clean up locations for the four years used to establish the baseline (1st July 2014 until 30th June 2018) and for the 2018-2019 financial year.
Blank cells indicate no clean-up was conducted at that site during that year.

Zone	Site	2014-15	2015-16	2016-17	2017-2018	2018-2019
Halifax Bay	Big Rock Bay		6.83		4.95	
	Fig Tree Beach	7.34	6.77		6.39	
	Jetty Beach	4.74	5.24			
	Orpheus Island		2.04		4.87	
	Picnic Bay					5.55
	South Beach (Orpheus Island)					7.17
	Yanks Jetty					3.95
Ross estuarine zone	Cape Pallarenda					5.16
	Oonoonba			6.06		
	Pallarenda Beach	3.91			4.81	4.54
	Queens Gardens			4.12		
	Rowes Bay	4.70	4.79	4.30	4.06	3.99
	Shelly Cove	5.40	4.64	4.97	3.78	3.30
Ross freshwater basin	Annandale	5.99	6.06			
	Aplin's Weir				4.23	4.06
	Black Weir	5.81	6.27			
	Condon					5.95
	Pioneer Park			4.45		
	Rasmussen		4.63			
	Weir Park			3.61		
Cleveland Bay (Magnetic Island)	Alma Bay		5.73		0.64	5.82
	Arthur Bay	5.46				2.40
	Florence Bay					0.69
	Geoffrey Bay	3.26			5.43	5.71
	Hawkings Point				2.31	
	Horseshoe Bay		3.04	4.70	2.60	2.72
	Nelly Bay	4.18	4.37		3.52	3.53
	Radical Bay	3.61				

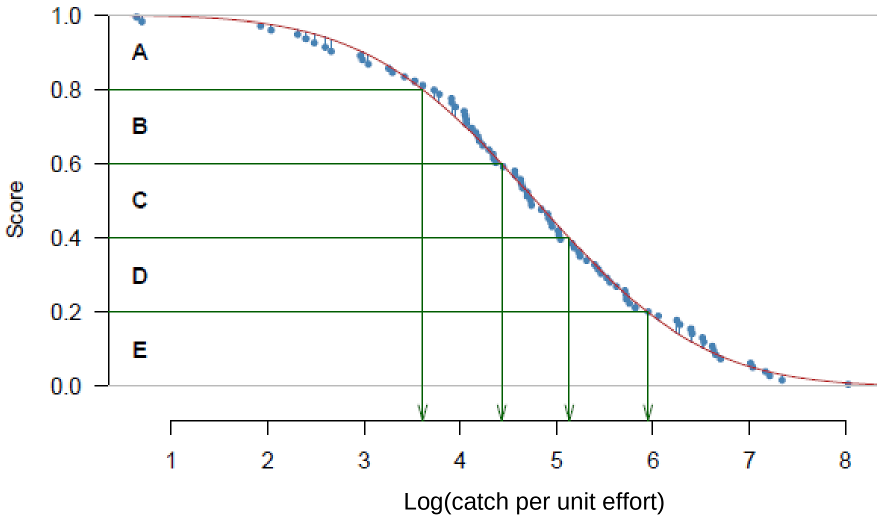


Figure 23. Transformation of standardised collection rates to scores and grades.

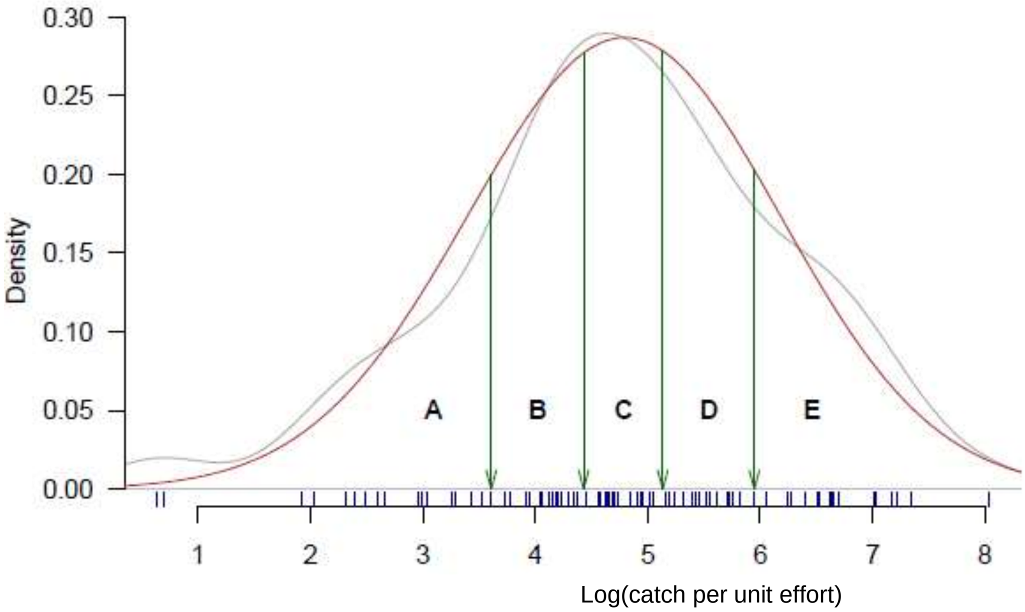


Figure 24. Score and grade transformation in a near normal distribution curve (same cut off values as Figure 23).

15 Community (social and economic) index

Community results were scored in the 2017-2018 Pilot Report Card and the 2018-2019 Report Card, but not in the 2019-2020 Report Card. New survey questions, including regional specific questions, will be developed in late 2020 or 2021, with community scores aimed to be scored in the 2021-2022 Report Card. It is aimed that surveys will be undertaken every two to four years after that.

15.1 Methods used in both the 2017-2018 Pilot Report Card and 2018-2019 Report Card

Survey questions acted as the indicators, with similar themed questions forming indicator categories. The survey questions (within their respective indicator categories) that were used to generate the scores for Community and Economy are listed in Appendix D Table 1 and Appendix D Table 2 respectively.

15.1.1 Positively working survey questions

Survey respondents ranked each question from 1 (lowest/strongly disagree) to 10 (highest/strongly agree). The score for each question was averaged into indicator categories, with indicator categories then averaged to generate a score for an index and then the overall score for Community and Economy. Some survey questions were positively worded, whilst others were negatively worded to minimise systematic bias in the survey responses. All negative questions were changed to be written so they were positively worded, and the scores inverted (e.g. a score of 1 for a negatively worded question is inverted to a 10 to represent the equivalent positively worded question). For example, a question such as "Thinking about coral bleaching makes me feel depressed" was changed to "Thinking about coral bleaching does not make me feel depressed". This was done so that all answers were on the same scale (e.g. a 10 meant the highest positive response, whilst 1 was the lowest score).

15.1.2 Scoring method

The Community and Economic benefits were graded using a five-point scale ranging from A (Very Good) to E (Very Poor). The distributions of rating scores from each survey question were assessed for normality. Whilst most questions had normally distributed responses, the responses for the Community Stewardship indicator category were highly skewed (more positive scores). This reflects most of the respondents self-rating their stewardship behaviour at the top end of the scale. To account for this positivity (or virtue) bias, the A-E scoring range has been shifted upwards for this indicator category (so that a higher mean score is required to achieve a Very Good score). The scores and the corresponding grades for the indicator categories and indices for Community and Economic are shown in Table 36. Grades given to the socio-economic data sets does not necessarily indicate passing or failing a guideline. Instead it indicates that the community derives moderate benefits from waterways. This contrasts with the grading system of environmental indicators, where a C grade is a pass, and a D is a failure.

Table 36. Scoring range and corresponding grade for Community and Economic indicator categories and indices and for the Community Stewardship indicator category.

Scoring range for Community and Economic indicator categories and indices*	Scoring range for Community stewardship indicator category	Grade and colour code
8 to 10	9 to 10	Very Good (A)
7 to <8	8 to <9	Good (B)
6 to <7	7 to <8	Moderate (C)
5 to <6	6 to <7	Poor (D)
<5	<6	Very Poor (E)

*Scoring range for all indicator categories and the overall Community and Economic indices except the Community Stewardship indicator category.

15.2 Changes in the methods between the 2017-2018 Pilot Report Card and 2018-2019 Report Card

The same SELTMP data were used to generate the scores for the 2018-2019 Report Card and the 2017-2018 Pilot Report Card. Similar methods were used to generate the scores and grades for social and economic indicators as used in the Pilot Report Card. The changes in method between the Pilot Report Card and the 2018-2019 Report Card are shown in Table 37.

Table 37. Changes in the methods used in the 2017-2018 Pilot Report Card compared to the methods used in the 2018-2019 Report Card.

The same survey data was used in both surveys, with the survey data from 2017.

Methods used in 2017-2018 Pilot Report Card	Methods used in 2018-2019 Report Card
Five indicator categories were scores and aggregated into three indices (as detailed in section 4.4).	Five indicator categories were scored, and each category was also an index (as detailed in section 4.4).
Survey responses were grouped by postcode to enable scores for Community to be calculated for each environmental zone (detailed below in section 15.2.1).	One score for Community was calculated for the entire Townsville region.
Survey responses from questions relating to each water type (fresh, estuarine, inshore marine and Great Barrier Reef (GBR) environment) were used to derive the scores and grades for each zone. However, most questions related to the GBR and as a result, only the offshore zone could be scored (detailed below in section 15.2.1).	Responses from questions (all water types and for all zones) were used to generate the score.

A simple demographic analysis of the SELTMP respondents will also be undertaken in future report cards. Report Card to assist with the interpretation of the results. When the Partnership expands to include reporting on the wider Burdekin NRM region, socio-economic indicators will be scored separately for the Townsville and Burdekin regions in recognition of their differences but noting the economies of the two regions may be linked and difficult to separate.

15.2.1 Scoring each zone by postcode (used in Pilot Report Card only)

For the Pilot Report Card, survey responses could be filtered based on postcodes within the Townsville Dry Tropics zones (as SELTMP survey data contain postcodes and basic demographic details of respondents). A limitation of this approach was that the SELTMP survey was primarily designed to determine the perceived social and economic value of the entire GBR region, rather than specific waterways. This meant that within the freshwater, estuarine or inshore marine zones, scores for each zone could only be derived for the community stewardship index (and not the other two indices). Stewardship scores were generated for each zone by grouping postcode responses to the Townsville Dry Tropics areas. Questions on stewardship related to the activities people undertook within their specific region (homes). This enabled scores to be generated at a finer-scale than for the other indicators.

An additional limitation was that some overlap occurs in postcodes across the Townsville region. For example, the postcodes for Alligator Creek, Palm Island and Balgal Beach are the same (4816). For some postcodes, the sample size was non-representative and inadequate to generate a score for a zone. For example, there were only six survey respondents from Magnetic Island residents (postcode

4819), from a total of 2,335 residents (as of 2016 Census data). Magnetic Island residents are the only residents within the Cleveland Bay inshore marine zone. Therefore, a community stewardship score for the Cleveland Bay zone was not generated.

The offshore zone was the only zone where the scores for each index could be generated, with the questions relating to only the GBR (rather than specific regions). The answers from all survey respondents within the postcodes were averaged to generate the score for each indicator. For these questions, it is acknowledged that the responses are reflective of the entire GBR, rather than parts of the GBR within the offshore marine zone. In future, the intent is to develop specific survey questions to identify values and perceptions for the offshore marine zone (rather than the whole GBR). A total of 1,191 people in Townsville participated in the survey from a total population of approximately 192,988.

16 Urban water stewardship framework data collection and scoring methods

16.1 Reasoning for the urban water stewardship framework

Nutrients, sediments and pesticides are pollutants that affect the resilience of coral reefs and are also key contaminants 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 several 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. The framework is reporting on the stewardship by Councils and it does not necessarily mean that these stewardship grades will result in improvements or changes to Council operating procedures in terms of managing urban water.

16.2 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.

16.3 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 38. 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 38. 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 39. 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 38). 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 39. 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	Current minimum standard	Moderate	5.0-12.4
D	Superseded or out-dated standards	High	<5.0

17 Confidence scores

The report card includes a qualitative confidence score for each score (for each indicator within each reporting zone) providing an estimate of data accuracy. Confidence is assessed by experts, as per the Great Barrier Reef, Wet Tropics and Mackay-Whitsunday Report Cards.

17.1 Water Quality and Habitat and hydrology/habitat indices

17.1.1 Method for scoring confidence for Water Quality and Habitat and hydrology/habitat

Confidence scores for the Water quality and Habitat and hydrology/habitat indices were derived using a criteria matrix which identifies the key components that contribute to method confidence (e.g. method maturity, how direct it measures variables). Each criterion is then scored using a defined set of scoring attributes, based on expert opinion or measured data. Five criteria are used with each criterion weighted according to its importance. Table 40 shows the purpose of each criterion and its weighting. In the future, a more robust method will be devised and used.

Table 40. Confidence criterion, weighting, and its purpose.

Criterion	Weighting	Purpose
Maturity of method	Weighted 0.36 so it does not outweigh the importance of the other criteria	Shows confidence that the method/s being used are broadly accepted by the scientific community. Methods must be repeatable, well documented, robust, and defendable.
Validation	Weighted 0.71 so it does not outweigh the importance of the representativeness criteria.	Shows proximity of the indicator being measured to the indicator reported. Proxy use is scored lower than direct measures. This criterion minimises compounding of errors
Representa-tiveness	This criterion is considered the most important so is weighted 2	Show how well monitoring/data reflects upon a sample. For example, a representative study provides a good indicator of how a whole population behaves. Sample size, spatial and temporal resolution of the data are important considerations.
Directness	Weighted 0.71 to not outweigh representativeness	Assesses the confidence in the relationship between the monitoring and the indicators being reported.
Measured error	Weighted 0.71 to not outweigh representativeness	Incorporates uncertainty into the metric (using any quantitative data if it exists).

17.1.2 Scoring of confidence for Water quality and Habitat and hydrology/habitat

For all indicators, each criterion is scored 1 (lowest) to 3 (highest), following rules in Table 41 and then weighted (weighting shown in Table 40). Overall confidence is then scored by adding all five weighted scores and then ranked against a 1 to 5 qualitative confidence ranking (Table 42).

Table 41. Scoring rules used for each criterion used to calculate the confidence scores for the Townsville Dry Tropics Report Card.

Maturity of methodology (weighting 0.36)	**Validation** (weighting 0.71)	**Representat-iveness** (weighting 2)	**Directness** (weighting 0.71)	**Measured error** (weighting 0.71)
Score = 1 **New** or experimental methodology	**Score = 1** **Limited** Remote sensed data with no or limited ground truthing, or Modelling with no ground truthing, or Survey with no ground truthing	**Score = 1** **Low** 1:1,000,000 or < 10% of population survey data	**Score = 1** **Conceptual** Measurement of data that have conceptual relationship to reported indicator	**Score = 1** > 25% error or limited to no measurement of error or error not able to be quantified
Score = 2 **Developed** peer reviewed method	**Score = 2** **Not comprehensive** Remote sensed data with regular ground truthing (not comprehensive), or Modelling with documented validation (not comprehensive), or Survey with ground-truthing (not comprehensive)	**Score = 2** **Moderate** 1:100,000 or 10%-30% of population survey data	**Score = 2** **Indirect** Measurement of data that have a quantifiable relationship to reported indicators	**Score = 2** < 25% error or some components do not have error quantified
Score = 3 **Established** methodology in published paper	**Score = 3** **Comprehensive** Remote sensed data with comprehensive validation program supporting (statistical error measured), or Modelling with comprehensive validation and supporting documentation, or Survey with extensive on ground validation or directly measured data	**Score = 3** **High** 1:10,000 or 30-50% of population survey data	**Score = 3** **Direct** Direct measurement of reported indicator with error	**Score = 3** 10% error and all components have errors quantified

Table 42. Presentation of confidence scores in the report card.

Final range of confidence score	Rank	Confidence scores	Display on report card
>11.7 to 13.5	Five	Very High (5)	●●●●●
>9.9 to 11.7	Four	High (4)	●●●●○
>8.1 to 9.9	Three	Moderate (3)	●●●○○
>6.3 to 8.1	Two	Low (2)	●●○○○
4.5 to 6.3	One	Very low (1)	●○○○○
		No data	○○○○○

Confidence scores are calculated separately for each indicator within each zone because number of sampling sites and sampling methods differed between zones. The representativeness criterion is considered at both a spatial and temporal scale, with the lowest score for these two aspects adopted for that indicator. For example, if spatial representativeness is moderate (i.e. 2), but temporal representativeness is low (i.e. 1), the representativeness score is low.

Occasionally, data from different programs was used to derive condition scores for an indicator in the same reporting zone. For example, in Cleveland Bay (Ross inshore marine zone) water quality data was sourced from the Townsville City Council, Townsville Port and the MMP. Confidence in the data provided by each organisation/program varied due to different sampling methods, frequency, and sample site number. The following decision rules are applied where two or more data sets contributed to an overall indicator score in the same reporting zone:

1. When the amount of data is equally divided between the two data sets, confidence is scored conservatively (i.e. the lower of two scores is applied).
2. When the amount of data is not equally divided between the data sets, confidence is scored by using the score for the dominant data set (the data set with more data).

17.1.3 Rules for presenting confidence scores on report cards

For presenting the confidence score in the report card, confidence scores are aggregated into a single score for each of the freshwater, estuarine, inshore marine and offshore marine zones. The rules for aggregation are:

- For each indicator, when confidence scores are different across only two reporting zones (e.g. different between freshwater and estuarine zones), confidence is scored conservatively using the lowest score as the final score for that indicator.
- For each indicator, when confidence scores are different across three or more zones, the median is used as the final confidence score for the indicator.
- When confidence scores for an indicator category or index differ between zones, the median score is used as the overall score for the indicator category or index.

17.2 Confidence score for Community and Economy

There is currently no method to score confidence for Community and Economic indices. The standard error associated with each score and the percentage of the population that was sampled was presented with the results. The standard error was calculated for each question and then averaged for each indicator category and the overall Community and Economic index. The standard error represents the variability in survey responses. This variability does not provide a measure of how accurate the data is, only a reflection of the variability of responses.

The percentage of the population was calculated based on the number of survey respondents and the number of people living within the zone. The number of survey respondents, population within each zone and percentage of the population surveyed for each zone is presented in Table 43. The population within each zone was calculated by summing the population for each suburb (and postcode) within that zone. Population data was based on the 2016 Census data (Australian Bureau of Statistics, 2016).

Table 43. Percentage of population surveyed within the Townsville region (for the 2018-2019 Report Card) and for each zone (for the 2017-2018 Report Card).
The same survey data from 2017 was used in both the report cards.

Zone	Population	Population surveyed	Percentage (%) of the population surveyed
Ross Basin (freshwater)	138,538	596	0.43
Black Basin (freshwater)	4,015	112	2.79
Ross estuarine zone	39,730	306	0.77
Black estuarine zone	6,484	58	0.89
Cleveland Bay (inshore marine zone)	2,335	6	0.26
Halifax Bay (inshore marine zone)	2,455	0	0.00
Offshore marine zone	193,557	1,191	0.62
Total Townsville region	**193,557**	**1,191**	**0.62**

18 Limitations and recommendations

There are currently many limitations with the data sets used within the Townsville Dry Tropics report card, with the main issues outlined in Table 44 along with improvements identified and actively being pursued by the Partnership.

Table 44. Current limitations of the data sets within Townsville Dry Tropics report card and improvements being pursued.

Data sets	Limitation	Way to address limitation
Water quality data	Spatial representativeness of data in all the freshwater basins is limited to the lower part of the catchment. Additionally, within the Ross freshwater basin, monitoring only occurs within the Ross River and the Bohle River.	Establish a low cost monitoring program and reduce replication between existing monitoring programs.
	Less than half of the estuaries within both the Ross and Black zone are scored	

Data sets	Limitation	Way to address limitation
	Water quality monitoring sites within Halifax Bay (Black inshore marine zone) are restricted to near the islands or reefs, whilst within Cleveland Bay (Ross inshore marine zone) all sites are within the enclosed coastal or mid-shelf waters (within 3 km of land).	There is the potential to use eReefs data.
Habitat extent (riparian, wetland, mangrove, and saltmarsh)	Habitat extent measurements do not consider habitat condition (e.g. may be high coverage but habitat could be in a poor condition).	The Partnership will work towards developing a method to score habitat condition.
Coral	Coral scores (inshore and offshore) are based on only a limited number of reefs.	Developing a method to include citizen science data on coral cover within the report card. This would mean data from other reefs can be included in the report card.
Litter	Litter is only scored within four of the zones, with limited sampling sites (and low sampling frequency) within these zones.	Work with Partners who conduct clean ups to target different areas. There are limited volunteer resources, which is a limiting factor in increasing the number of surveys that can be done. Beach clean ups with standardised sampling methods will be undertaken from 2018 until 2022 within four of the zones. Twenty-two gross pollutants traps were installed around Townsville in 2020 and the aim is to incorporate the data from the traps into the litter metric.
All social and economic indicators	Social and economic indicators are only scored across the entire region, with most questions focused on the GBR (not regionally specific questions).	Work with Human Dimensions Working Group to derive regionally appropriate indicators.

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Appendix A: Scoring against both water quality objectives and guidelines.

In the 2018-2019 technical report, water quality data were compared against both water quality objectives (WQOs) and water quality guideline values (WQGVs). This was done to determine which was more appropriate and whether there were substantial differences between the scores calculated using the different values. Water quality objectives act as management targets and allow managers to assess whether their practices and management actions are improving or causing reduced water quality. Assessing against WQGVs allows managers to assess how the water quality has changed from 'natural' conditions. Water quality guidelines apply for broad scale regions, whilst WQOs are derived for specific regions.

Comparing data against the WQOs was the preferred approach as it is considered more appropriate for the Townsville Dry Tropics region given that specific water quality objectives have been derived for the region. Only the scores where data were compared against management targets are displayed on the 2018-2019 report card. For report cards produced for 2019-2020 onwards, only the results comparing data against WQOs will be presented (except for offshore water quality, which is only compared against guideline values because no WQOs exist for the offshore zone). There are issues with both the WQGVs and the WQOs, with the WQOs needing to be updated. However, in the absence of updated objectives, the current objectives will be used and adjusted through expert opinion if necessary.

The below sections detail the water quality guidelines that data were compared against within the freshwater, estuarine and inshore marine environments.

18.1.1 Water quality guidelines

Water quality guidelines (WQGVs) act as a proxy for comparisons against an earliest baseline condition. Benchmarking against WQGVs allows assessment of whether current water quality will protect aquatic life and maintain ecosystems. "WQGVs are largely based on data from non-impacted waterways or on toxicant/pollutant concentrations shown to have nil impact. Importantly, WQG for a specific indicator generally remains consistent across all waterbodies of a similar type (e.g. freshwater, estuary, coastal) and in the same region." (A. Moss, pers. Comm., 31st July 2019).

The WQGVs are not regionally specific and instead apply to large areas. Within Queensland, WQGVs are derived for seven different regions, with waterways within the Townsville Dry Tropics being classified based on the WQGVs for the Central region (Department of Environment and Heritage Protection, 2009). The Central region extends north from the Burnett River Basin to the Black River Basin (Department of Environment and Heritage Protection, 2009). Reference sites within the freshwater, estuarine and inshore marine waters were used to derive the WQGVs for these three water types (Department of Environment and Heritage Protection, 2009). However, only a few of these reference sites were within the Townsville Dry Tropics, with the number of reference sites for the Central region and the number of these that were in the Townsville Dry Tropics region shown in Appendix A Table 1.

Appendix A Table 1. Number of reference sites used to derive the water quality guideline values (WQGVs) for the freshwater, estuarine and inshore waters of the Central region and the number of these reference sites that were within the Townsville Dry Tropics region.

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

18.1.1.1 *Freshwater and estuaries*

Water quality guidelines used for freshwater and estuarine waters within the Ross and Black basins are based on the Central region Queensland Water Quality Guidelines (2009) (Department of Environment and Heritage Protection, 2009). The WQGVs for indicators reported upon within the Ross and Black freshwater and estuarine zones within the report card are presented in Appendix A Table 2.

Appendix A Table 2. Water quality guidelines for the Ross and Black freshwater and estuarine waters which are based on the Central Coast Queensland guidelines.

DIN guideline values were calculated by summing the guideline values for ammonia N and oxidised N. Percent saturation is abbreviated to % sat and creek is abbreviated to Ck.

			Freshwater		**Estuarine waters**
Indicator category	**Indicator**	**Unit**	**Lowland streams**	**Freshwater lakes/ reservoirs**	**Mid-estuarine and tidal canals, constructed estuaries, marinas, and boat harbours**
Nutrients	DIN	µg/L	80	20	20
	Total P	µg/L	50	10	25
Physical-chemical	Turbidity	NTU	50	1-20	8
	DO	% sat	85-110	90-110	85-100
Monitoring sites	Within the Ross Basin		Bohle River	Black (School) Weir, Gleeson's Weir, Aplin's Weir, Ross River Dam	Ross River Estuary, Ross Ck Estuary, Alligator Ck Estuary, Louisa Ck, Bohle River Estuary, Sandfly Ck Estuary, Stuart Ck Estuary
	Within the Black Basin		Black River, Bluewater Ck, Leichardt Ck, Sleeper Log Ck, Althaus Ck, Saltwater Ck, Ollera Ck, Crystal Ck	Paluma Dam	Bluewater Ck Estuary, Deep Ck Estuary, Saltwater Ck Estuary, Rollingstone Ck Estuary

Of the 114 freshwater reference sites that were used to derive the WQGVs, there were only four freshwater sites within the Townsville Dry Tropics, as shown in Appendix A Table 2. None of the 17 reference sites for estuaries were within the Townsville Dry Tropics (Appendix A Table 2). Due to the limited reference sites within the Townsville Dry Tropics region, the WQGVs for the freshwater and estuarine sites may not be representative of the guideline water quality for the Townsville Dry Tropics region.

18.1.1.2 *Cleveland Bay and Halifax Bay*

WQGVs for inshore waters within the Townsville Dry Tropics report card are based on the Queensland Water Quality Guidelines (2009) for the Central Coast Queensland region (Department of Environment and Heritage Protection, 2009). Notably, only one reference site (in Cleveland Bay) is used to derive the WQGVs for the entire open coastal marine waters within the Central Coast region (Department of Environment and Heritage Protection, 2009). WQGVs for the enclosed coastal waters are determined from five reference sites, but none are within the Townsville Dry Tropics (Department of Environment and Heritage Protection, 2009). Thus, the WQGVs for enclosed coastal waters may not be representative for the Townsville Dry Tropics region.

Results for Palms West Reef (within Halifax Bay/Black inshore marine zone) are reported in the Wet Tropics Report Card which sources the WQGVs for Pandora Reef from the Marine Monitoring Program Annual report for inshore water quality monitoring 2014-2015 (Lønborg, et al., 2016). To ensure consistency with the Wet Tropics, the same WQGVs are used. It is noted that the Wet Tropics report card compares water quality data against WQGVs, not WQOs. For the Townsville Dry Tropics report, the results displayed in the report card are the water quality scores compared against the WQOs. This means the scores for the Wet Tropics and Townsville Dry Tropics may differ due to differences in the WQOs and the WQGVs vary. WQGVs for indicators reported in the inshore marine zone of the Townsville Dry Tropics report card are presented in Appendix A Table 3, with the monitoring sites corresponding to each water type shown.

Appendix A Table 3. Water quality guidelines for inshore zone waters, with the sites corresponding to each water type shown.

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

Appendix B: Scoring methods for calculating riparian, wetland, mangrove, and saltmarsh extent compared to the earliest available baseline.

Habitat extent is calculated for riparian, wetland (palustrine) and mangrove and saltmarsh (combined) extent for each freshwater basin or estuary. The condition score for the extent of vegetation is determined by calculating the percent loss of habitat extent since estimated earliest baseline (1960s data) compared to the current extent. The score is calculated by subtracting the mapped extent for the current year from the estimated earliest baseline extent. For riparian habitat, the earliest baseline extent is assumed to be 100% of mapped riparian area. Wetland (palustrine), mangrove and saltmarsh have estimated earliest habitat extent based on mapping provided by DES. Based on the percent loss, the report card score is calculated using the standardisation formula shown in Appendix B Table 1.

Appendix B Table 1. Scoring ranges, grades and aggregation formula for scoring riparian, wetland, mangrove, and saltmarsh extent.

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

Appendix C: Logic for scoring each grading range within water quality.

18.2 Logic for scoring "Very Good"

If the median is equal or better than (≥) the water quality objective (WQO) or guideline (WQG) and equal or more than 80% of the data are also ≥WQO, then a score of 90 is assigned (90 is the mid-point of the "Very Good" scoring band (81-100)).

In the past, the TWG considered other options, including a value at the bottom (81) or top (100) of scoring band. However, this would decrease and increase aggregated scores and grades, respectively. The TWG have been unable to develop an alternate practical method to derive scores between 81 and 100. Functioning ecosystems required some level of nutrients and sediment, so a method based simply upon reductions of these metrics to near zero concentrations is inappropriate (otherwise, distilled water could be considered as having ideal water quality). It is noted that a more nuanced scoring system for "Very Good" would likely be supported by the Independent Science Panel (ISP).

18.3 Logic for scoring "Good"

If the median is ≥WQO, but less than (<) 80% of data values are ≥WQO, the condition is considered "Good", and a score is calculated between 61 and <81. The condition score for "Good" is determined by calculating the position (through linear interpolation) of the WQO relative to the 50th and 80th percentiles of the data for that metric. Linear interpolation is used because the scoring bandwidths cover a linear range between 0 and 100 and the TWG has no basis for choosing an alternative method. (It is noted that there is no reason why the interpolation needs to be linear).

18.4 Logic for scoring "Moderate, Poor and Very Poor"

Where the median is worse (non-compliant) with the WQO, a score is calculated between 0 and <61. The score is based on a linear interpolation of the median relative to the WQO and the Scaling Factor (SF). This method was used because the bandwidths for the scores cover a linear range between 0 and 100. Where the median is worse than the SF, a score of 0 is assigned.

Appendix D. Community survey questions and indicator categories

Appendix D Table 1. Indicators used to determine the score of Community for the Townsville Dry Tropics region. An asterisk (*) indicates the question was changed so they were positively worded. Each index only comprised one indicator category.

Index/indicator category	Indicator (survey questions)
Values of waterways	I value the GBR because it supports a desirable and active way of life
	I value the GBR because we can learn about the environment through scientific discoveries
	The aesthetic beauty of the GBR is outstanding
	I value the GBR because it inspires me in artistic or thoughtful ways
	I value the GBR because it is an important part of my culture
Wellbeing from waterways	I love that I live beside the GBR
	Thinking about coral bleaching does not make me feel depressed
	I value the GBR because it makes me feel better physically and/or mentally
	I feel proud that the GBR is a World Heritage Area
	The GBR is part of my identity
	The GBR contributes to my quality of life and well-being
Perception of waterway management	I do have fair access to the GBR compared to other user groups
	I feel confident that the GBR is well managed
	I support the current rules and regulations that affect access and use of the GBR
	I feel like I can contribute to GBR management
	I think enough is being done to effectively manage the GBR
	I feel confident that the freshwater areas in my region are well managed
	I support the current rules and regulations that affect access and use of freshwater areas (rivers and creeks) in my region
Perception of environmental condition	The coral reefs in my region are in good condition
	I am not worried about the status of freshwater fish in my region
	The freshwater areas (e.g. rivers, creeks) in my region are in good condition
	There is not much rubbish (plastics and bottles) on the beaches in my region
	The mangroves in my region are in good health
	The estuarine and marine fish in my region are in good condition
	I like the colour/clarity of the water along the beaches in my region
	The coral reef in my region is in good condition
Stewardship	I have the necessary knowledge and skills to reduce any impact that I might have on the GBR
	I can make a personal difference in improving the health of the great barrier reef
	I make every effort to use energy efficiently in my home and workplace
	I often consider the environmental impact of the production process for goods and services that I purchase
	I usually make any extra effort to reduce the waste I generate
	I re-use or recycle most goods and waste
	I would like to learn more about the condition of the GBR
	I would like to do more to help protect the GBR
	I would like to do more to improve water quality in my waterways (including rivers, creeks)

Appendix D Table 2. Indicator categories and indicators used to determine the score of Economy for the Townsville Dry Tropics region.

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