METHODS

Townsville Dry Tropics Partnership for Healthy Waters annual Waterways Report Card

Updated May 2023 for the 2021-2022 Technical Report

Acknowledgements

The methods document was prepared by the Technical Officers of the Dry Tropics Partnership for Healthy Waters. 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 Waters. 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.

2020-2021 Report Card

For the 2020-2021 report card the water quality, habitat and hydrology, and fish indices were reported upon at a zone level. The litter index was report upon at a regional level, and the urban water stewardship and community indices were not reported upon as the data was yet to be updated.

2021-2022 Report Card

For the 2021-2022 report card the water quality, habitat and hydrology, and fish indices were reported upon at a zone/basin level. The litter index was report upon at a regional level, and the urban water stewardship and community indices were not reported upon as the data is yet to be updated.

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).

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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.

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 Basin and Black Estuarine Basin.
- two inshore marine zones, called Cleveland Bay and Halifax Bay
- one offshore marine zone.

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

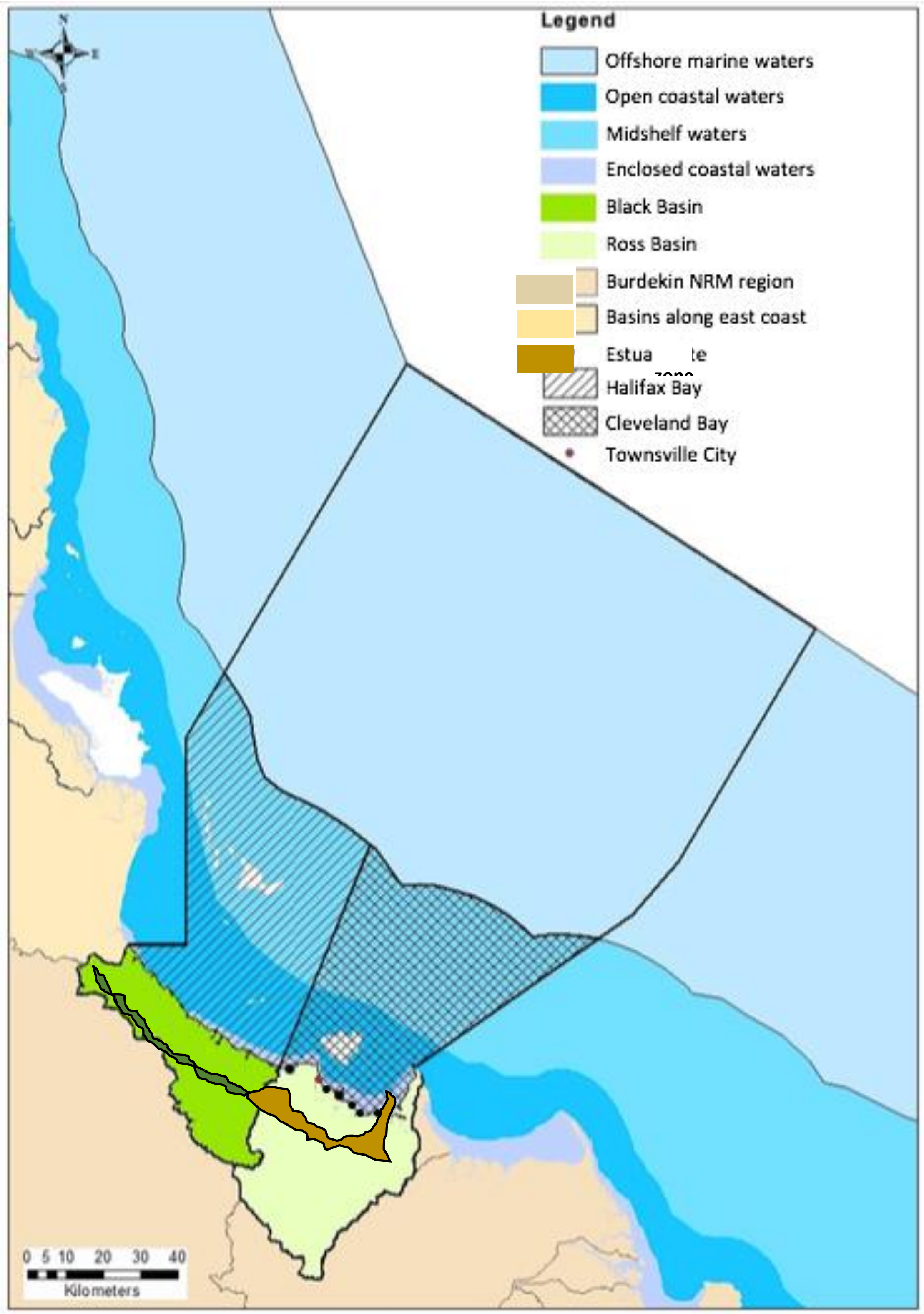


Figure 1. Geographic boundary reported upon by the Dry Tropics Partnership, comprising the Ross and Black Freshwater Basins and estuarine zones, Cleveland Bay and Halifax Bay and the offshore marine zone.

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.

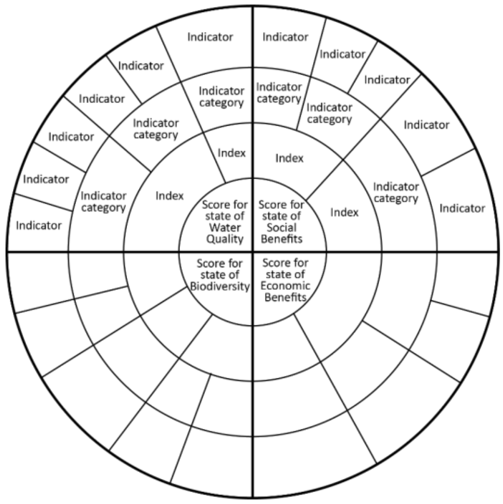
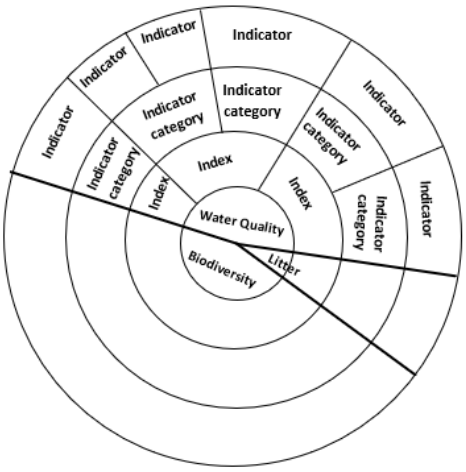
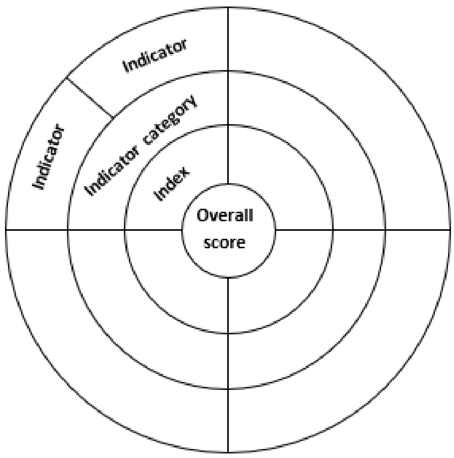
The levels of aggregation are:

- **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 2020-2021 2021-2022	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. 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.

Zone	Index	Indicator categories	Baseline that data was compared against 2019-2020, 2020-2021, 2021-2022 Report Cards	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
	Contaminants	Pesticides	TBC	Annually	TBC
		Metals	TBC	Annually	TBC

Zone	Indicator category	Indicator	Sampling frequency	Frequency of reporting	Baseline that indicator is compared to
		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, 2019-2020, and 2020-2021 Report Cards, the litter metric contained the indicator category, total litter. This is the method that has been approved by the ISP and is continuing to be used.

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)

For freshwater, estuarine, and inshore environments, the water quality indicator categories scored are nutrients and physical-chemical (phys-chem) properties. Additionally, inshore marine zones are scored on their chlorophyll *a* level. Due to no available data, no water quality indicator categories were used for the offshore marine environment in 2020-2021 and 2021-2022. 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

The Black-Ross Freshwater Basins are subdivided into sub basins as per the Water Quality Improvement Plan, 2010 and shown in Figure 2 below. Data is not available for the Stuart Creek and Alligator Creek sub basins. Sample sites within a sub basin are averaged to produce a score for the sub basin. Scores for sub-basins that were historically allocated to the Black or Ross are then averaged to produce a score for these. This does not change the method historically used for calculating the scores for the Black and Ross Basins.

Figure 2: Freshwater Sub Basins

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 *Ross Freshwater Basin*

The Ross Freshwater Basin is divided into the Upper Ross River, Lower Ross River, Bohle River, Stuart Creek, and Alligator Creek sub basins. Monitoring occurs within three sub basins within the Ross Freshwater Basin, comprising 12 sample sites. Sample sites within the Upper Ross River, Lower Ross River, and Bohle River sub basins are shown in Figure 3. These are:

- Bohle River sub basin comprising two sites on the Bohle River.
- Lower Ross River, comprising three sites, which are Aplin's, Gleeson's and Black School (Black) weirs, with Aplin's weir sampled by both TCC and the GBR CLMP.

- Upper Ross River, comprising seven sites within Lake Ross.

Along the Bohle River, there are two sites, which are the mid and far-field locations that comprise part of the receiving environment monitoring program (REMP) for the Condon Sewage Treatment Plant (STP). These sites are recorded as BOH18.1 for mid-field and BOH22.3 for far-field by the data collectors (Townsville City Council).

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 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. The mid-field and far-field sites are approximately 4 km apart, as shown in Figure 3. Between these sites there is the Little Bohle River tributary, and some additional smaller tributaries that join the Bohle River.

Along the Ross River there are three monitoring sites, all situated at the impounded weirs (Black weir, Gleeson weir and Aplin's weir) and several monitoring sites within Lake Ross, as shown in Figure 3. The dam and weirs contain water throughout the year. Lake Ross 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 and the scores are averaged to form a single score for the Lower Ross River sub basin. Water from Lake Ross only flows downstream on occasions where the Ross River Dam gates are opened or following heavy rainfall when the spillway height is exceeded.

Figure 3. Sites within the Ross Freshwater Basin.

These includes (1) the mid and far-field sites for the Condon Sewage Treatment Plant (STP), (2) the monitoring along Lower Ross River and (3) monitoring within the Upper Ross River (Ross Lake). The orange outline in the central image delineates the Ross Freshwater Basin, with the yellow outline delineating the Ross Estuarine Basin. Satellite images from 04/05/2020.

5.1.1.2 *Black Freshwater Basin*

The Black Basin is divided into the Black River, Bluewater Creek, Rollingstone Creek, and Crystal Creek sub basins. Whilst Paluma Lake lies within the Burdekin Basin, it is included as any overflow discharges to the Crystal Creek sub basin.

Since the 2018-19 Report Card, monitoring has occurred at 10 sites (Figure 4) within the Black Freshwater Basin. These sites are:

- Black River sub basin:
- Black RiverBluewater Creek sub basin:
  - Althaus Creek
  - Bluewater Creek
  - Sleeper Log Creek
- Rollingstone Creek sub basin:
  - Leichardt Creek
  - Saltwater Creek
  - Rollingstone Creek
- Crystal Creek sub basin:
  - Ollera Creek
  - Crystal Creek
- Paluma Lake

Figure 4. Freshwater sites (blue dots) within Black Basin.

The red line delineates the Black basin, whilst the blue line delineates the Black Estuarine Basin. Satellite image taken on the 14/12/2020.

For the Pilot 2017-18 Report Card, Paluma Lake was the only site scored within the Black Basin. While the Paluma Lake site is outside of the Black Freshwater Basin, water from it overflows into the Crystal Creek sub 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 Lake are included. The report card process highlighted that Paluma Lake was the only sites sampled within the Black Basin. As a result, in April 2019, monthly sampling commenced by the Department of Environment and Science (DES). The Black River is also sampled by the GBR CLMP and this data is included for the 2021-2022 year.

Many creeks within the Townsville Dry Tropics are seasonal and dry for most of the year (with occasional small pools of still water). Following heavy rain, seasonal creeks will run for up to a few months (depending on event severity). The seasonal 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 lakes and upstream of weirs, where water is monitored all year as there is consistently water present. 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 are measured by different monitoring programs, as shown in **Error! Reference source not found.**.

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 site with the Ross and Black Freshwater Basins.

The indicators measured at each site are shaded in dark grey. Parameters measured are turbidity, filterable reactive phosphorus (FRP), total phosphorus (TP), dissolved inorganic nitrogen (DIN), and dissolved oxygen (DO), and pH. Program operators are Townsville City Council (TCC), the Department of Environment and Science (DES), and the Great Barrier Reef Catchment Loads Monitoring Program (GBR CLMP).

Zone	Site	Monitoring program	Nutrients			Physical-chemical properties		
			FRP	TP	DIN	Turbidity	DO	pH
Ross Freshwater Basin	Ross River Lake	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 Lake	TCC						

5.1.2.1 *Ross Freshwater Basin*

Within the Ross Basin, samples were collected monthly during July 2021 – June 2022 by TCC at the surface or 20 cm to 30 cm below the surface (AECOM, 2016). Samples were collected at Aplin's Weir by the GBR CLMP based on flow during the period July 2021 – June 2022.

5.1.2.2 *Black Freshwater Basin*

From 2018-19 onwards, all sites within the Black freshwater, except Paluma Lake, 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 (restricted sampling due to Covid-19). Between five and eleven months of sampling was conducted in 2020-2021. Between eight and 11 months of sampling was conducted in 2021-2022, with August being the predominant month when sampling did not occur. Sampling was limited during the dry season as some sites were dry or had no flow.

Black River was sampled based on flow by the GBR CLMP throughout the 2021-2022 year.

Paluma Lake continued to be sampled every month by Townsville City Council (TCC), as the lake is a drinking water supply for the Paluma Township and the northern beaches area of Townsville.

Dissolved oxygen, pH, and turbidity were measured by placing the probe approximately 10cm to 30cm 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 Basin, and five within the Black Estuarine Basin. Monthly grab samples were taken at one to four sites per estuary. The estuary names and number of sites sampled per estuary for each year (since 2017-18) are shown in

Table 7. The estuaries and number of sites sampled per estuary within the Ross and Black Estuarine Basins are shown in Figure 5. Some estuaries (e.g., Stuart Creek), no longer have data available for the 2021-2022 report card, results for previous report cards presented as comparison in the 2021-2022 report have been back calculated to only include data from sites still available in 2021-2022.

Table 7. Estuaries and number of sites per estuary within the Ross and Black Estuarine Basins.

Zone	Estuary name	Number of sites within estuary				
		2017-18 Pilot Report	2018-19 Report Card	2019-2020 Report Card	2020-2021 Report Card	2021-2022 Report Card
Ross Estuarine Basin	Bohle River estuary	1	1	1	1	1
	Louisa Creek estuary	3	3	3	3	3
	Ross Creek estuary	3	3	3	2	2
	Ross River estuary	1	1	1	1	1
	Stuart Creek estuary	1	1	1	0	0
	Sandfly Creek estuary	2	2	2	2	2
	Alligator Creek estuary	2	2	1	1	1
Black Estuarine Basin	Bluewater Creek estuary	0	1	1	1	1
	Althaus/Deep Creek estuary	0	1	1	1	1
	Saltwater Creek estuary	0	1	1	3	3
	Rollingstone Creek estuary	0	1	1	1	1
	Crystal Creek estuary	0	1	1	1	1

Figure 5. Monitoring sites within the Ross and Black Estuarine Basins.

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 Basin and labelled. The blue and yellow outline delineates the Black and Ross Estuarine Basin 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. Sites and indicators measured within the Ross and Black Estuarine Basins.

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.

Zone	Site	Monitoring program	Nutrients		Physical-chemical properties		
			TP	DIN	Turbidity	Lower DO	Upper DO
Ross Estuarine Basin	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 Basin	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 Basin*

All sites within the Ross Estuarine Basin 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 Basin 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 Basin*

All sites within the Black Estuarine Basin 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 Basin, 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 sites within each bay. The sites and the descriptions of each site are presented in Table 9. The location of the 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. Sites within Cleveland Bay and Halifax Bay and description of the sites.

Zone	Site	Number of sample sites	
		2017-18 Pilot Report and 2018-19 Report Card	2019-2020, 2020-2021, 2021-2022 Report Card
Cleveland Bay	Enclosed coastal waters	Seven sites. Three sites are part of the receiving environment monitoring program (REMP) that is associated with the Cleveland Bay sewage treatment plant and four sites are monitored by the Port of Townsville.	Five sites. One site is part of the receiving environment monitoring program (REMP) that is associated with the Cleveland Bay sewage treatment plant and four sites are monitored by the Port of Townsville.
	Open coastal waters	Four sites Three sites are monitored by the Port of Townsville, with the other site monitored by the AIMS Marine Monitoring Program (MMP).	
	Magnetic Island	Three sites. Nutrients are monitored at one site by the AIMS Marine Monitoring Program (MMP), whilst the other two are water quality equipment loggers on buoys owned by Port of Townsville.	
Halifax Bay	Enclosed coastal	One site.	
	Open Coastal	One site. Pandora Reef. This site is monitored by the MMP.	
	Midshelf waters	One site. Pelorus Island. This site is monitored by the MMP.	

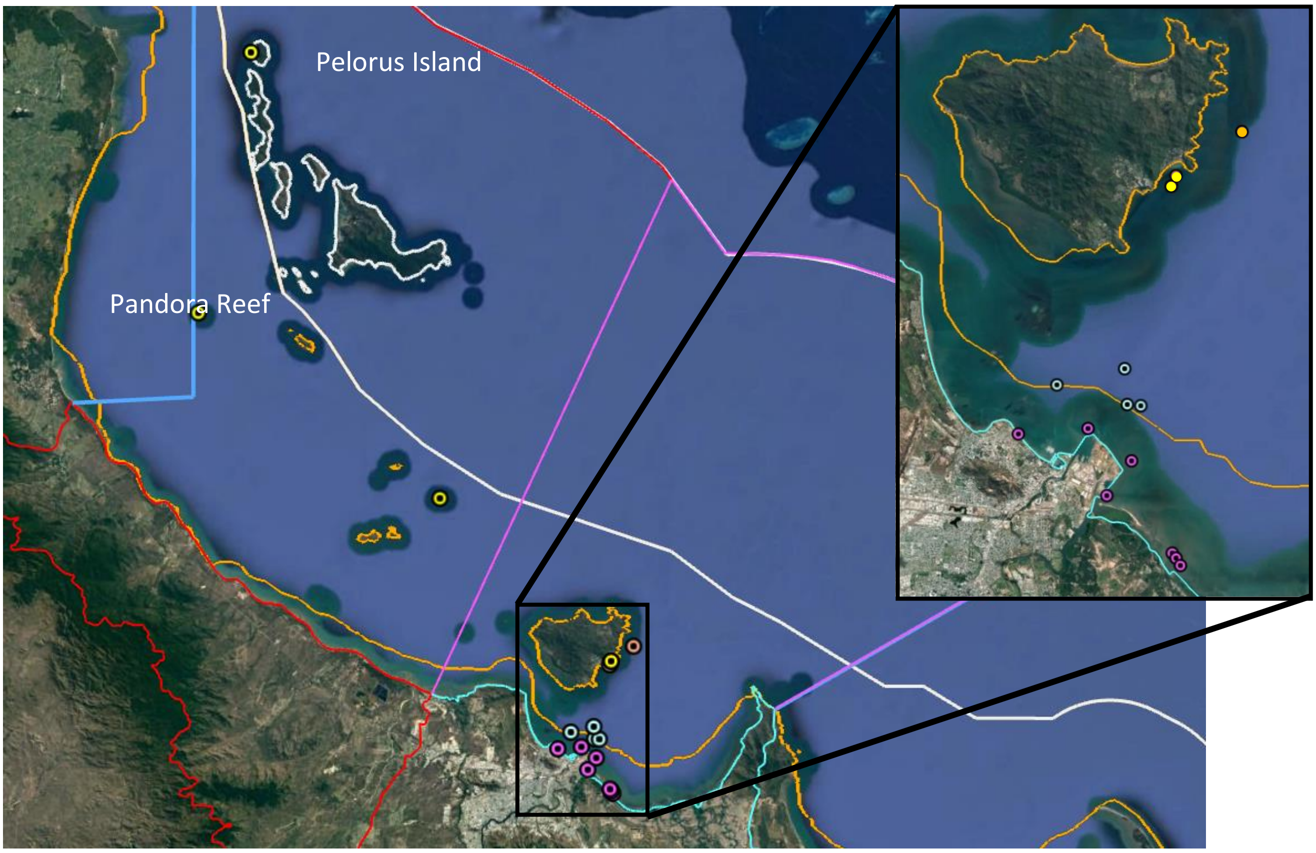


Figure 6 Sites within Cleveland Bay and Halifax Bay.

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 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	Sites	Monitoring program	Type of sample	Frequency	TP	NOx	Turbidity	Chl-*a*	Secchi depth	TSS	PP	PN
Cleveland Bay	Enclosed coastal Cleveland Bay	TCC REMP	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	Ornatas	Grab	Monthly	■	■	■	■		■		
	Open Coastal	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 7). 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 8). Similarly, concentrations of chlorophyll-*a* also appear similar between the two offshore marine zones (see Figure 9). Therefore, the Burdekin zone was considered equivalent to the Townsville Dry Tropics region.

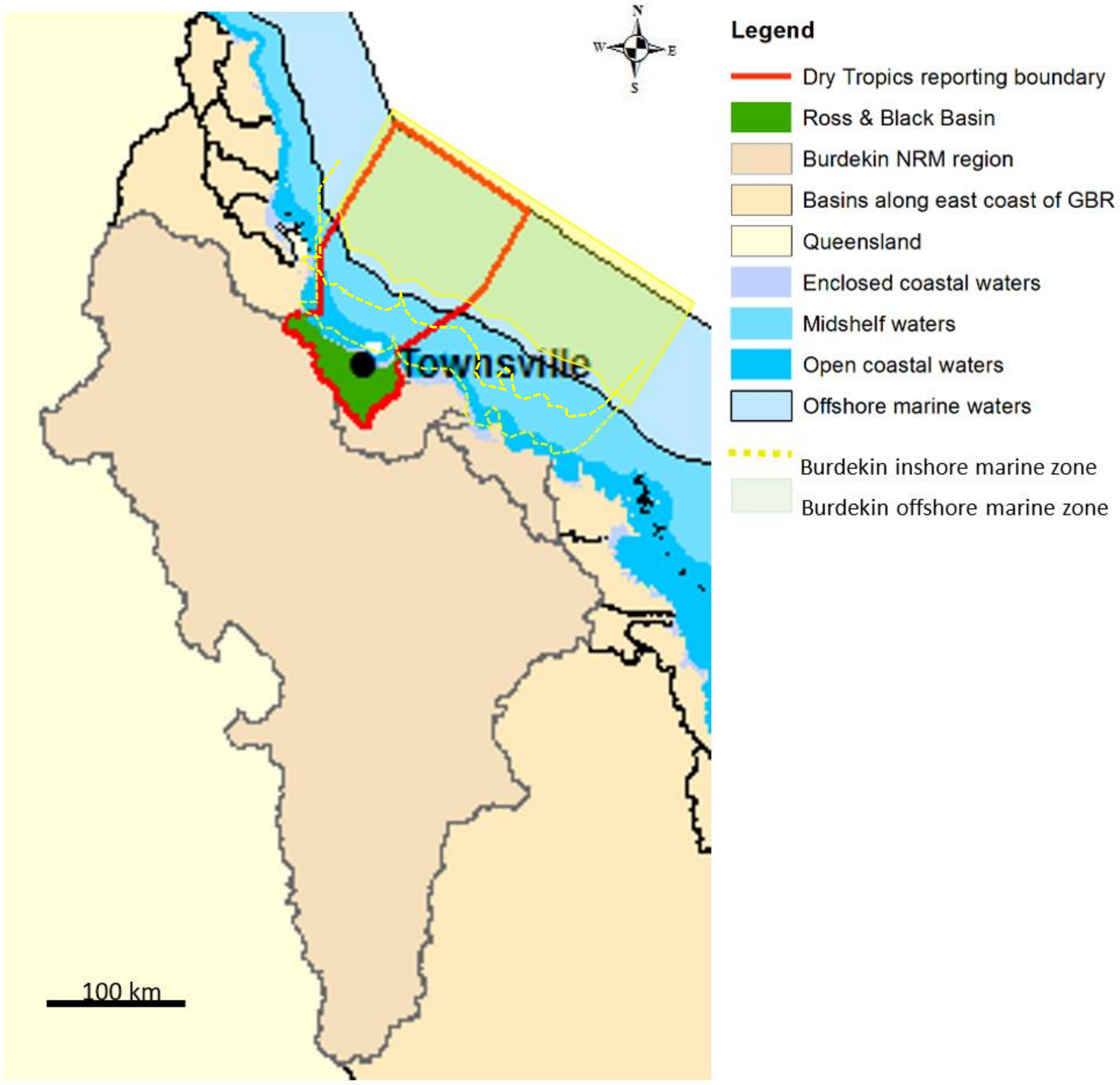


Figure 7. The Burdekin inshore (dotted yellow line) and offshore (solid red line) marine zones in relation to the Townsville Dry Tropics region within Queensland.

The inshore marine zone comprises the enclosed, midshelf and open coastal waters, whilst the offshore marine zone comprises offshore waters.

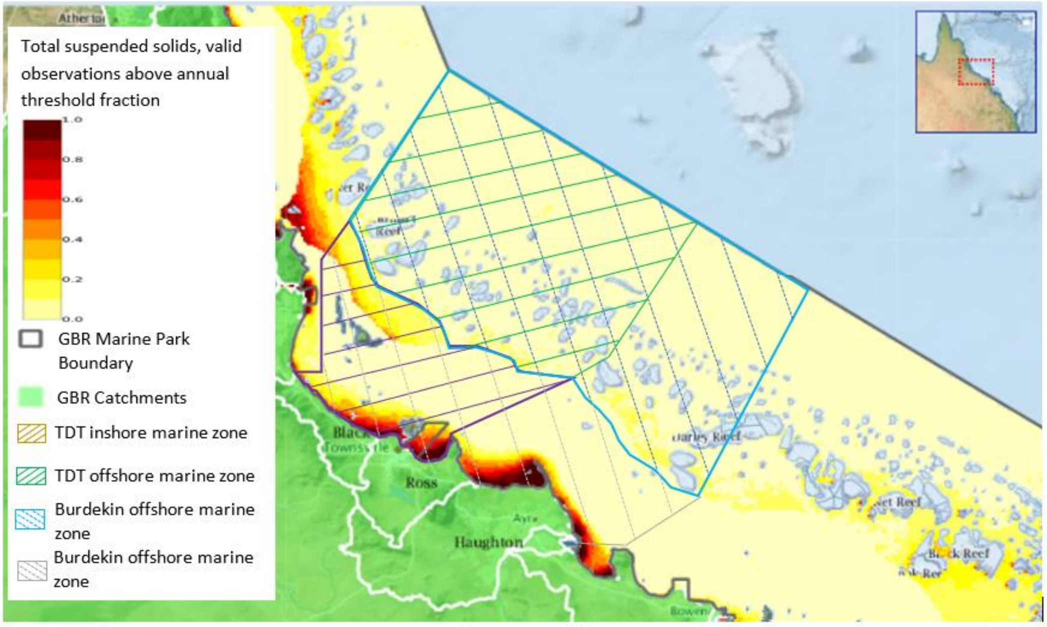


Figure 8 . Concentration of total suspended solid (non-algal particulates) within the Burdekin and Townsville Dry Tropics offshore marine zones.

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

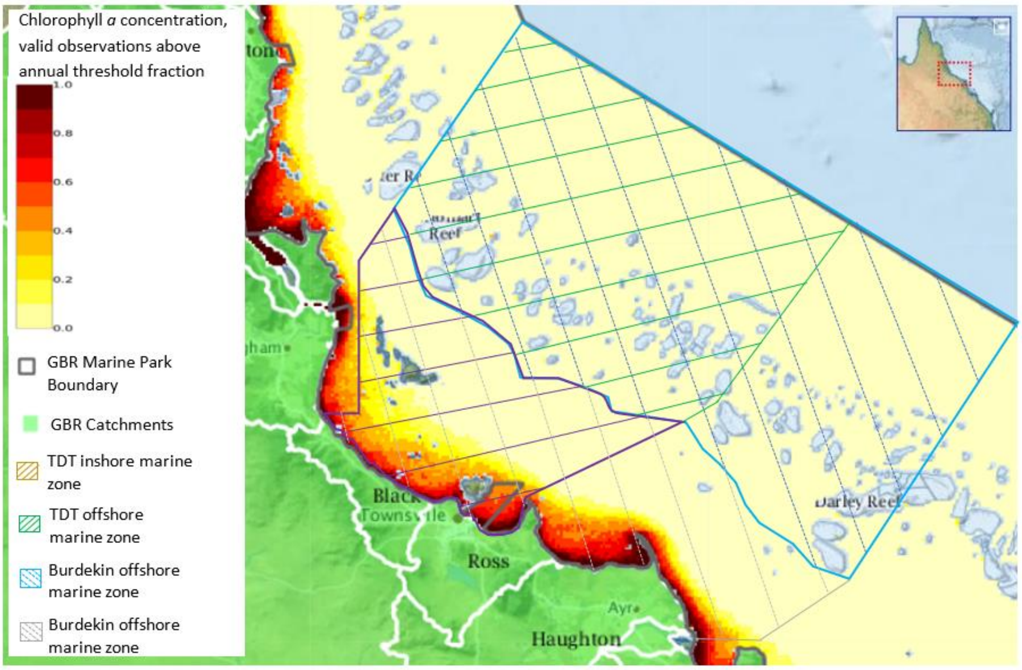


Figure 9. Concentration of chlorophyll-*a* within the Burdekin and Townsville Dry Tropics offshore marine zones.

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

The habitat and hydrology index for the freshwater zone of the Dry Tropic region consists of two habitat specific indicator categories and one hydrology specific indicator category. The habitat indicator categories are Freshwater Riparian Extent, and Freshwater Wetland Extent. Both indicator categories source methodology and preliminary results from the Reef Water Quality Report Card[1]. The data used in the Reef Water Quality Report Card is updated approximately every four years with the next expected updated in 2023. The hydrology specific indicator category is Artificial Barriers and consists of two indicators: Impoundment Length and Fish Barriers. Results for these indicators are provided by a combination of partners of the DTPHW team. This data is updated approximately every four years, the most recent update occurred in 2022 and is included in this technical report.

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

[1] All results are downloaded from the Reef 2050 Water Quality Improvement Plan's [Reef Water Quality Report Card] (Australian Government, 2023).

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 freshwater riparian extent indicator category follows the same methodology used for the Reef Water Quality Report Card (Australian Government, 2023). The methodology defines riparian areas using the base component of the Regulated Vegetation Management Category R data[2], and the Watercourse Lines dataset using 100K features[3]. This boundary is then used to calculate riparian extent using the regional ecosystem vegetation spatial layers[4]. The present riparian extent (2017) is then compared against the previous calculation of extent (2013) to estimate the change in riparian forest extent over time from 2013 to 2017. The change in extent is scored as a "progress to target" where the target is no loss of extent (Healy, 2023). Currently the Dry Tropics Partnership uses the results published by the Reef Plan Great Barrier Reef Report Card with no changes, edits, or updates. The most recently published results are from 2017 and are included in this report.

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).

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[2] The Regulated Vegetation Management Category R data is available for download from QSpatial's [Catalogue] **Invalid source specified.**.

[3] The Watercourse Lines dataset is available for download from QSpatial's [Catalogue] **Invalid source specified.**.

[4] All Regional Ecosystem data was downloaded from QSpatial's [Catalogue] **Invalid source specified.**.

6.1.1.2 *Wetland extent*

The freshwater wetland extent indicator category follows the same methodology used for the Reef Water Quality Report Card (Australian Government, 2023). The methodology uses the entire catchment as the assessment area and calculates wetland extent using the Queensland Wetland Data Version 5 mapping spatial layers[5] **Invalid source specified.**. The data set is filtered to specifically select only unmodified (H1), palustrine vegetation that is the dominant vegetation type (80% or more). The present extent (2017) of the selected wetland vegetation is then compared against the previous calculation of extent (2013) to estimate the change over time from 2013 to 2017. The change in extent is scored as a "progress to target" where the target is no loss of extent **Invalid source specified.**.

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*

Fish barriers in the Dry Tropics region were identified using a combination of regional expert advice, a 2018-2019 desktop analysis of spatial imaging in Google Earth Pro, and the Bulk Water Opportunities Statement Dams weirs and barrages dataset[6].

[5] The latest layer of Queensland Wetland Data is available from QSpatial's [Catalogue] **Invalid source specified.**.

[6] Data is available from the QSpatial [Catalogue]. Note that the dataset is supplemented by regional expert advice and desktop analysis.

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 10. 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.

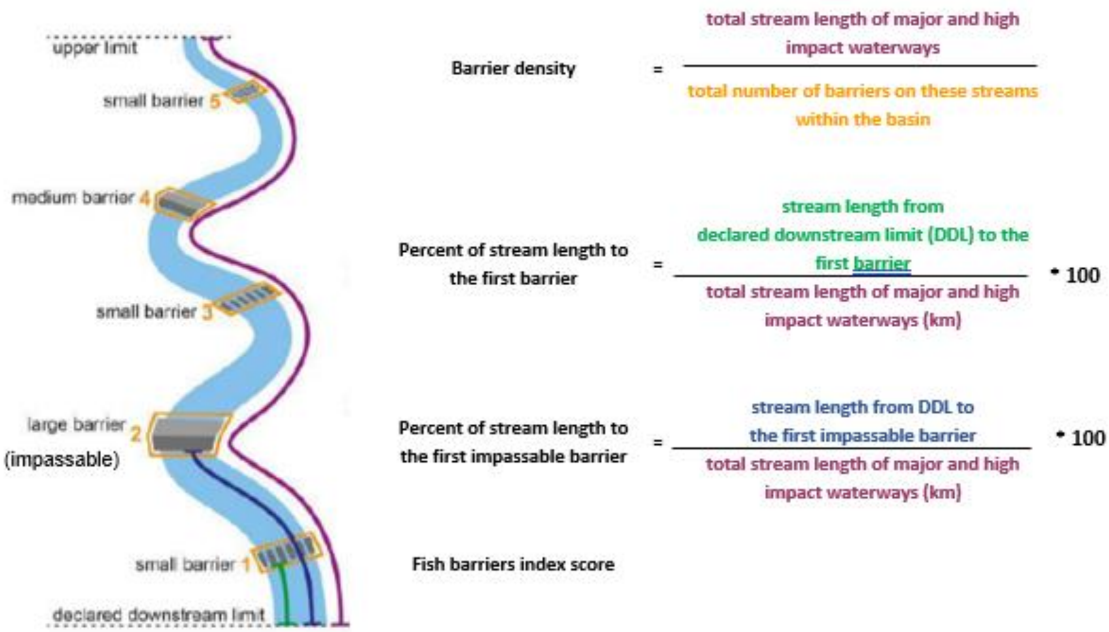

Figure 10. Diagram of the three components of the fish barriers indicator category and how each is calculated.

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 11. 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 12a. Streams that are classified as major or high impact waterways are shown in in Figure 12b.

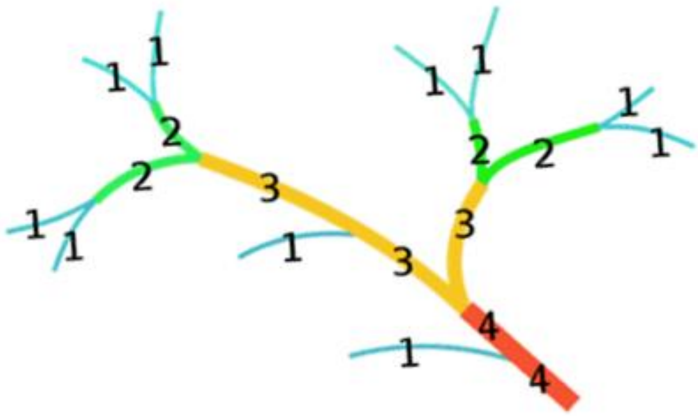

Figure 11. Strahler stream order from headwaters downstream.

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)

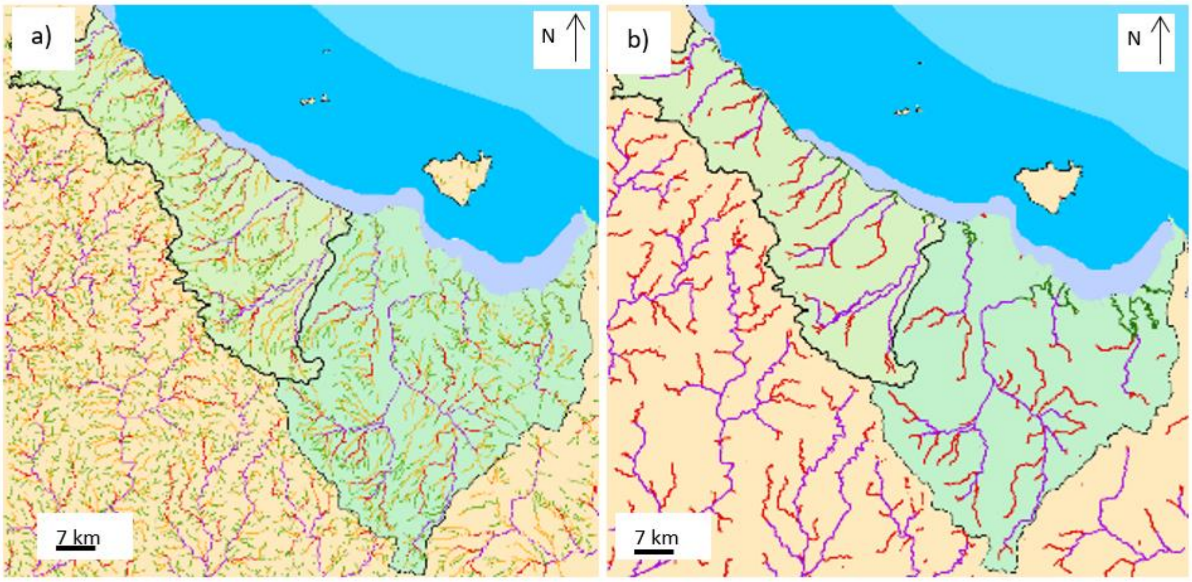

Figure 12. Classification of a) risk categories for all streams classifications, and b) for major and high impact stream classifications within the Townsville Dry Tropics region (green shading).

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 describes how much "natural" channel habitat remains within a waterway. Impoundment length was calculated as the linear length of the waterway that is impounded proportional to the total linear length of the waterway. The length of impounded channel varies according to attributes, such as the height of the constructed in-stream barrier and landscape features, such as gradient of the channel **Invalid source specified.**.

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

6.2.1 Habitat index

Two indicator categories, mangrove and saltmarsh extent and riparian extent, are assessed within the estuarine environment, no hydrology indicator categories are assessed. Thus, the scores for habitat extent are the overall scores for the habitat and hydrology index within the estuarine environment. From the 2021-2022 Report Card onwards estuarine riparian extent was included as an additional indicator category.

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.

6.2.1.2 *Estuarine Riparian Extent*

The estuarine riparian extent indicator category follows the same methodology used for the mangrove and saltmarsh extent indicator category, using data 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). However, all regional ecosystem (RE) habitat types are targeted, and the extent is restricted to the estuarine riparian zone.

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).

6.3 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 13, 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 13. 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

Coral monitoring for the Dry Tropics region is conducted by AIMS through the MMP and the LTMP. The number of coral monitoring sites at surveyed reefs for each inshore zone are provided in Figure 14. The inshore environment includes open coastal and mid-shelf waters, and coral monitoring for inshore zones, therefore, included MMP and some LTMP. The MMP coral surveys typically occurred between May to July 2022. The LTMP coral sampling occurred between September 2021 and May 2022. As from 2021-22 the LTMP coral monitoring program sampling design has been modified and now conducts annual surveys at a reduced number of reefs. Previously the LTMP sampling design surveyed a different set of reefs in alternating years. Prior to 2020-21, the MMP also sampled reefs in alternating years, with additional unscheduled coral surveys (even year scheduled reefs sampled in odd years and vice versa) undertaken to fill gaps when disturbances were suspected. Nine locations are sampled within the Townsville Dry Tropics region, as shown in Figure 14. 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).

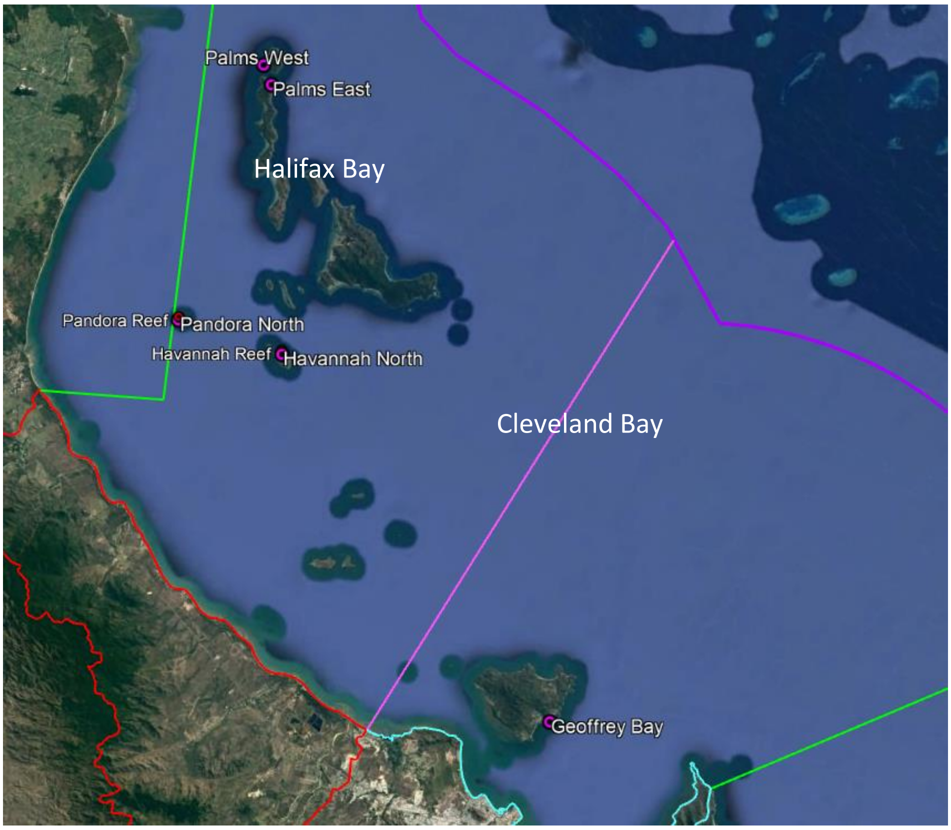

Figure 14. Sampling locations of inshore reefs (pink dots) within Cleveland Bay and Halifax Bay, which comprise the Townsville Dry Tropics inshore marine zone.

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 15). 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.

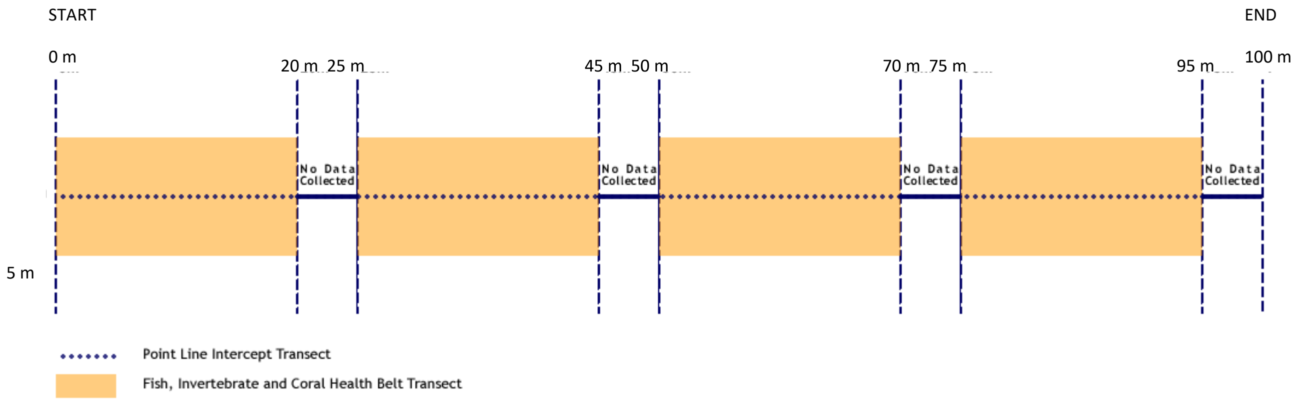

Figure 15. A Reef Check transect, comprising four 20m replicates along which reef substrate composition is measured.

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 16. 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 documented in the technical results report for that year. The LTMP updated the sampling design for 2021-22 onwards. For the Dry Tropics region, the LTMP previously included 16 reefs with a subset monitored in alternating years. The updated sampling design has reduced the number of surveyed reefs to nine and conducts surveys at all reefs every 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.

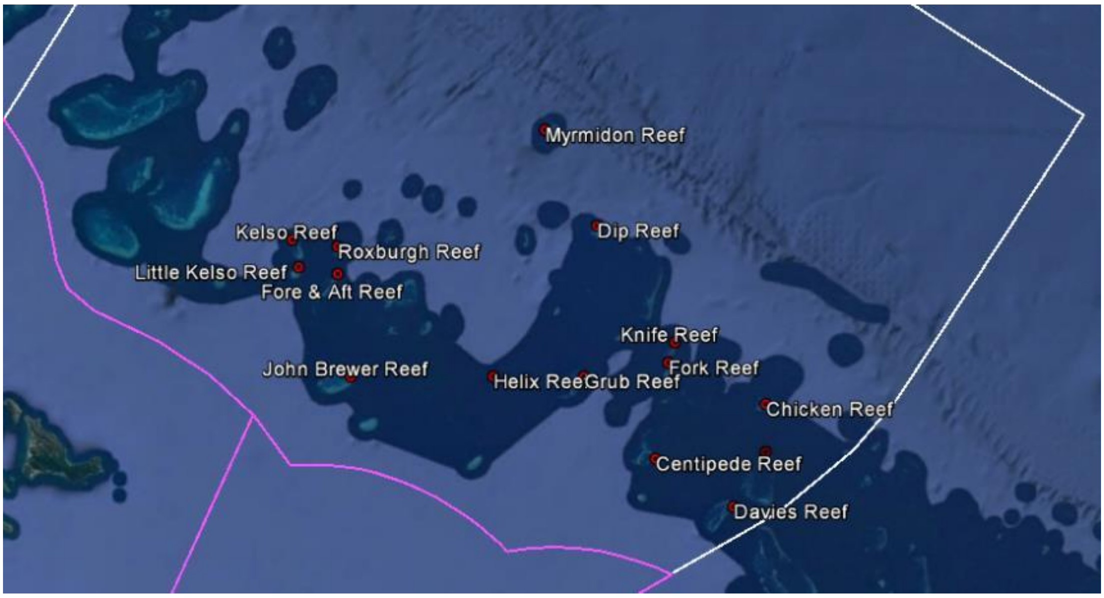

Figure 16. Sampling locations of offshore reefs (red dots) within the Townsville Dry Tropics offshore marine zone (white and purple outline).

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 sites across nine different creeks within the Ross Freshwater Basin. Eleven 11 sites were sampled across 13 different creeks within the Black Freshwater Basin. The sampling sites are shown in Figure 17. 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.

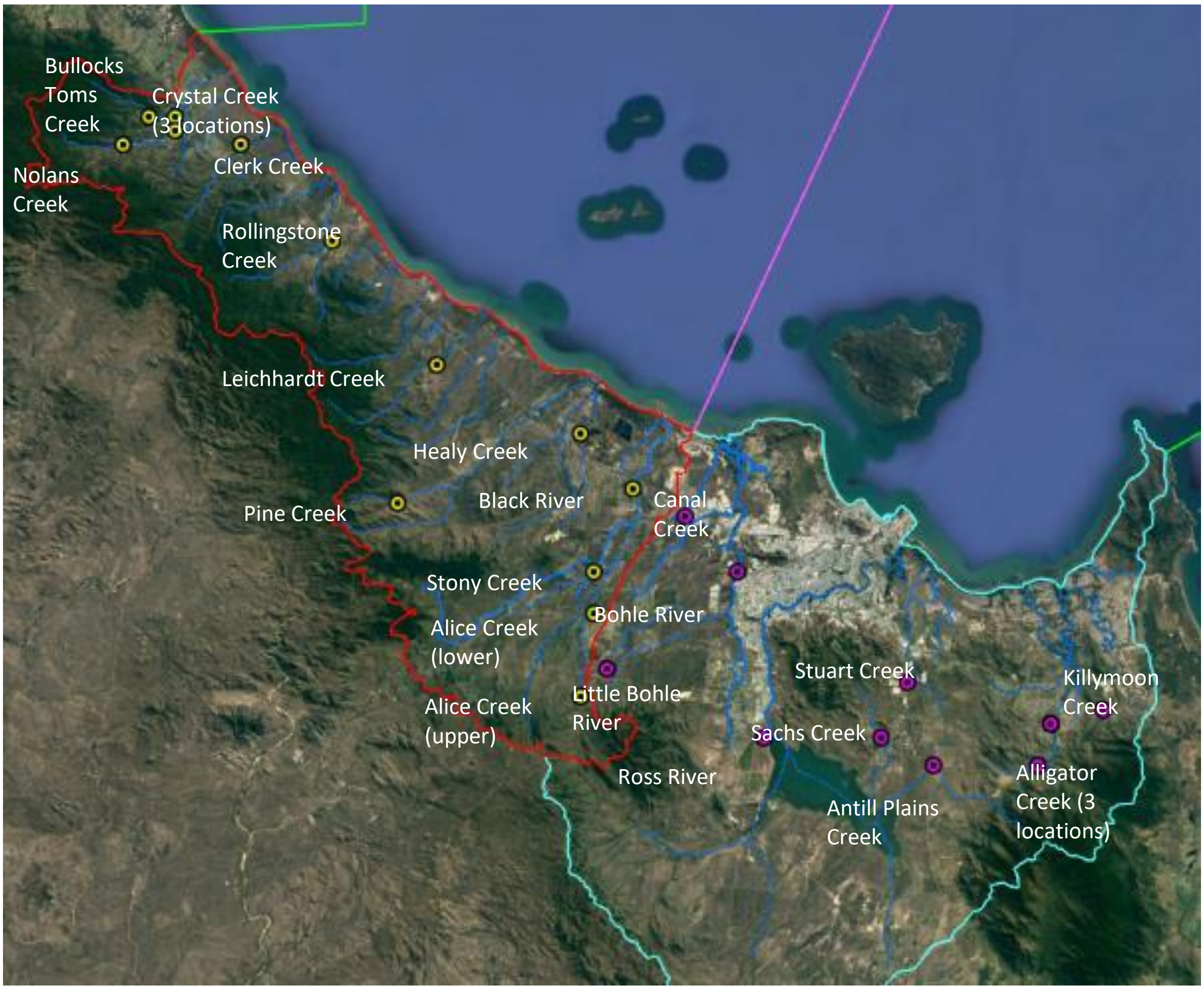

Figure 17. Location of fish sampling sites within the Ross and Black Freshwater Basins.

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

The litter index is comprised of a single indicator to assess the “pressure” that the amount of litter present in a location may be having on that environment. The data used to derive the scores and grades for the litter index is from the Australian Marine Debris Initiative (AMDI) database and is collected in the field by volunteers as part of the Tangaroa Blue Foundation (TBF) clean-up projects. A model has been developed from ‘baseline’ data from the period ~2009 to June 2019 available from the AMDI for each of the partnership regions; Wet Tropics Waterways (WTW), Dry Tropics Partnership for Healthy Waters (DTPHW), Healthy Rivers to Reef (HR2R), and Gladstone Healthy Harbours Partnership (GHHP). The litter collected at sites each year are then compared with this baseline to determine their score and grade.

8.1 Litter Data Collection

The litter collected for the AMDI is classed as macro-litter, that is, it does not include the collection of any micro-litter defined as being less that 5mm long (National Ocean and Atmospheric Administration, 2023).

There are two types of clean ups completed on behalf of the TBF, which are general litter clean ups and Reef Clean standardised clean ups. General litter clean ups are conducted by volunteers from the public at TBF events and those organised by several other community organisations. The area cleaned is not recorded for these events, and as such, area could not be used in the litter index to calculate the “pressure” exerted by the litter quantity collected. The litter collected is sorted into 12 categories, each with subcategories, totalling 145, and the data recorded in the AMDI database (Tangaroa Blue Foundation, 2022). As not all the data from general litter clean ups is sorted, the total litter collected at each event is used for the litter index.

Reef Clean is a government funded project spanning 2018-2023 for TBF and Reef Check to complete standardised clean ups at specified sites on a quarterly basis to provide longitudinal data for these sites. The clean ups are conducted on four transects of specified area at each location and the remaining area around them also cleaned. The total time of collection for the transects and the surrounding area is recorded for each Reef Clean event in the AMDI. The collection time for individual transects is not recorded as instead the area of the transect is, to provide a more consistent measure of the pressure. The Reef Clean sites for each of the partnerships are provided in Table 13 below.

Additional clean up locations were funded for the Reef Clean project; however, these were not part of the transect component of the project. These additional sites have been included in the general litter collections, as the collections are completed using a different method to the standardised methodology.

Table 13: Reef Clean quarterly transect sites for each partnership region

Partnership Region	Site
Wet Tropics	Coconuts Beach
	Dickson Inlet, Port Douglas
	Flying Fish Point Beach
	Four Mile Beach, South End
	Googarra Beach, Tully Heads
	Hull River Estuary, Hull Heads
Dry Tropics	Shelly Cove, Cape Pallarenda Conservation Park
	Aplin's Weir Rotary Park
Mackay-Whitsunday-Isaac	Conway Beach
	Don River Mouth, Bowen
	Half Tide Beach, Hay Point
	Harbour Beach, Mackay
	Louisa Creek Beach, Hay Point
	Pioneer River, Glenella Connection Road, North Mackay
	Queens Beach, Bowen
	Wilsons Beach, Conway
Gladstone Harbour	Auckland Creek, Hanson Road
	Fisherman's Landing
	Barney Point
	Canoe Point, Tannum Sands

8.2 Litter Collection Zones and Sites

The data is extracted from the AMDI by TBF on behalf of the partnerships using spatial files. The litter sites within each region are shown in the Figure 18, Figure 19, Figure 20, and Figure 21 below.

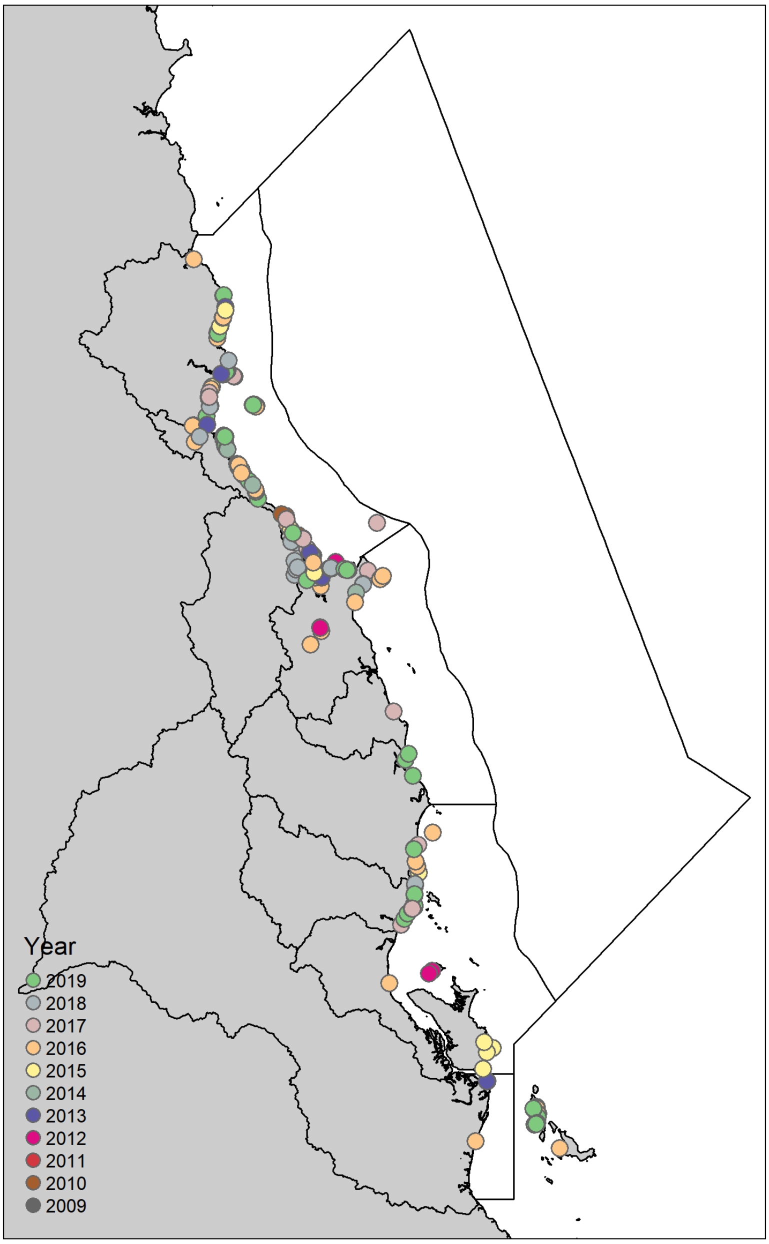

Figure 18: WTW Litter Collection Sites

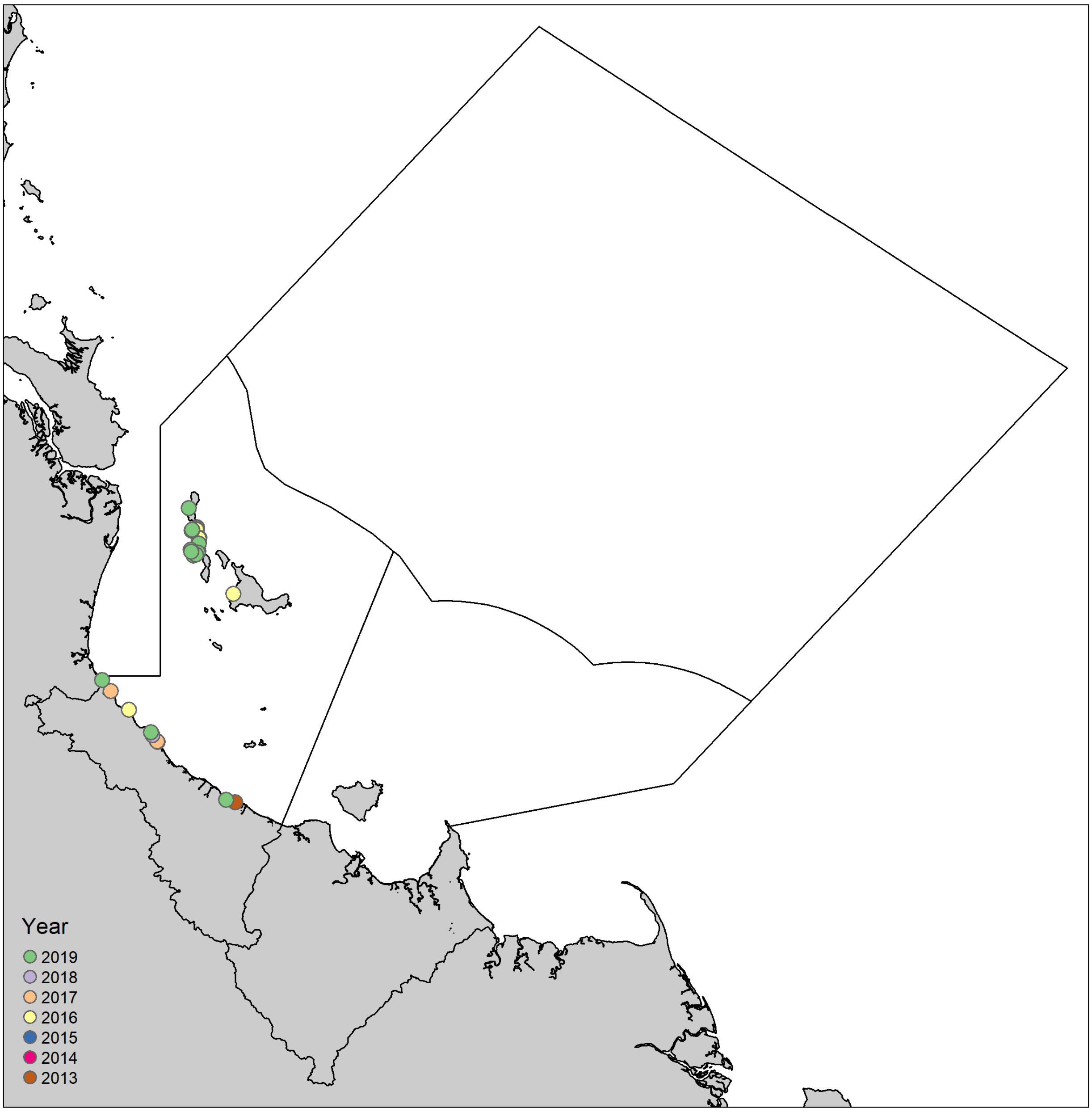

Figure 19: DTPHW Litter Collection Sites

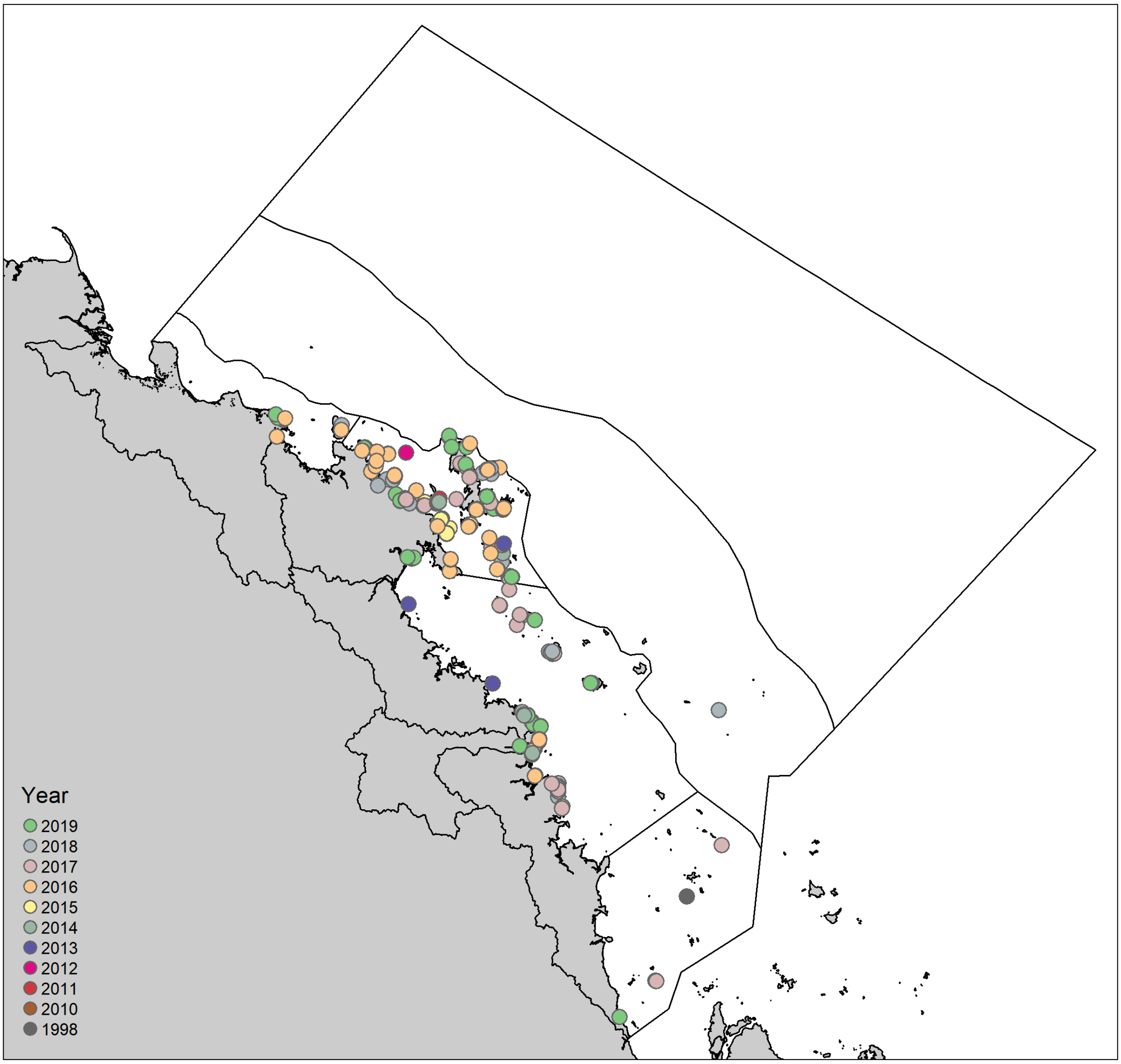

Figure 20: HR2R Litter Collection Sites

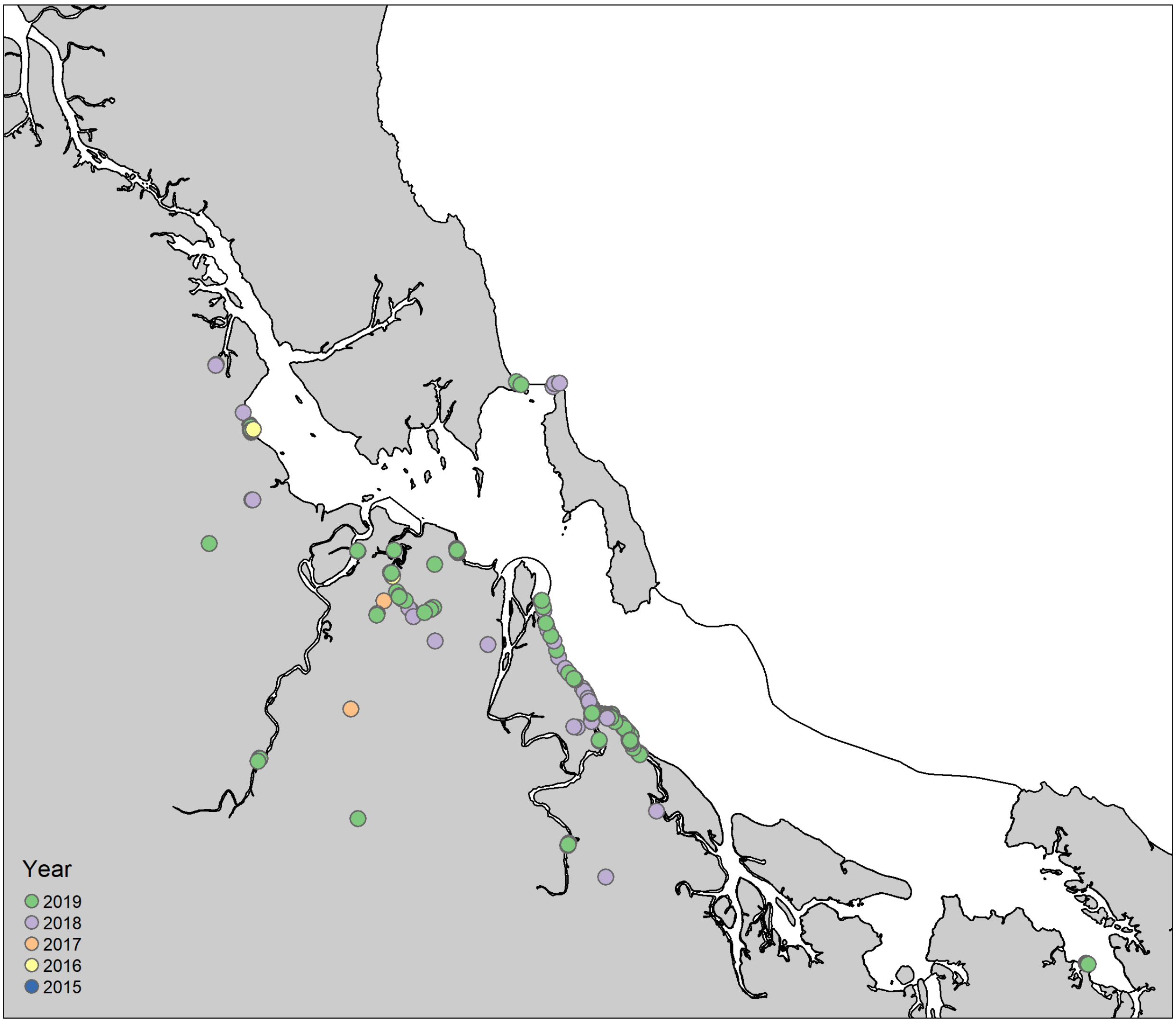

Figure 21: GHHP Litter Collection Sites

The data quality is assessed by TBF prior to provision, and data that is believed to be incorrect is removed. The rules for the removal of data are as follows:

- events with missing data for hours, volunteers, or items (total items is 0); and
- Rig Recycle, Ditch the Flick single item audits, and tackle bins.

The number of excluded entries included in the model fitting process, and for each year of score and grade calculation for each of the partnerships is given in Table 14 below. This is a large reduction on the amount of data previously removed. A large body of work has gone into correcting data that was previously entered incorrectly during the migration from the old AMDI to the newly developed database. The new database provides opportunity for a more detailed assessment of the data available.

Table 14: Number of events excluded by Tangaroa Blue Foundation data cleaning process

Partnership	Model	2019-2020	2020-2021	2021-2022
Wet Tropics Waterways	12	1	2	4
Dry Tropics Partnership for Healthy Waters	2	0	1	2
Healthy Rivers to Reef	50	1	0	1
Gladstone Healthy Harbours Partnership	13	0	0	8

The zones used by the partnerships were used to allocate the litter sites to zones combined with the land use categories that are held within the AMDI. The relevant category is recorded with each litter collection as part of the AMDI Comprehensive Data Sheet and the information used to allocate sites to a category (pers comm TBF). The land use categories used in the AMDI are presented in Table 15 below.

Table 15: AMDI Coastal Codes and Land use Categories

AMDI Coastal Code	Land use
1	Populated coast, sheltered waters
2	Populated coast, open waters
3	Sparsely populated coast, sheltered waters
4	Sparsely populated coast, open waters
5	Island, populated or high tourist numbers
6	Island, unpopulated, low, or no tourist numbers
7	Inland waterway
8	Parks, drains, and structures
9	At sea

Sites that are located along the coastline and thus the border between a land and inshore zone, were allocated based on the AMDI land use category, as this considers the information obtained from the volunteers completing the collection as to the main source of the litter in the location; washed up onto the land from the sea or deposited directly onto the land by visitors. It is recognised that most of the litter sourced in the water may initially have come from the land, however, the intention is to differentiate the mode at which it arrived at the location from which it is has been collected.

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 16).

Table 16. 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 16). 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 16.

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

Equation 1:

$$Standardised\ score = a + \left| b - \left((c - d) * \left(\frac{b}{e} \right) \right) \right|$$

where:

a = Lower value of standardised scoring range

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 Basins. Regionally specific WQOs for the freshwater and estuarine zones exist for the Townsville Dry Tropics (see Table 17). 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

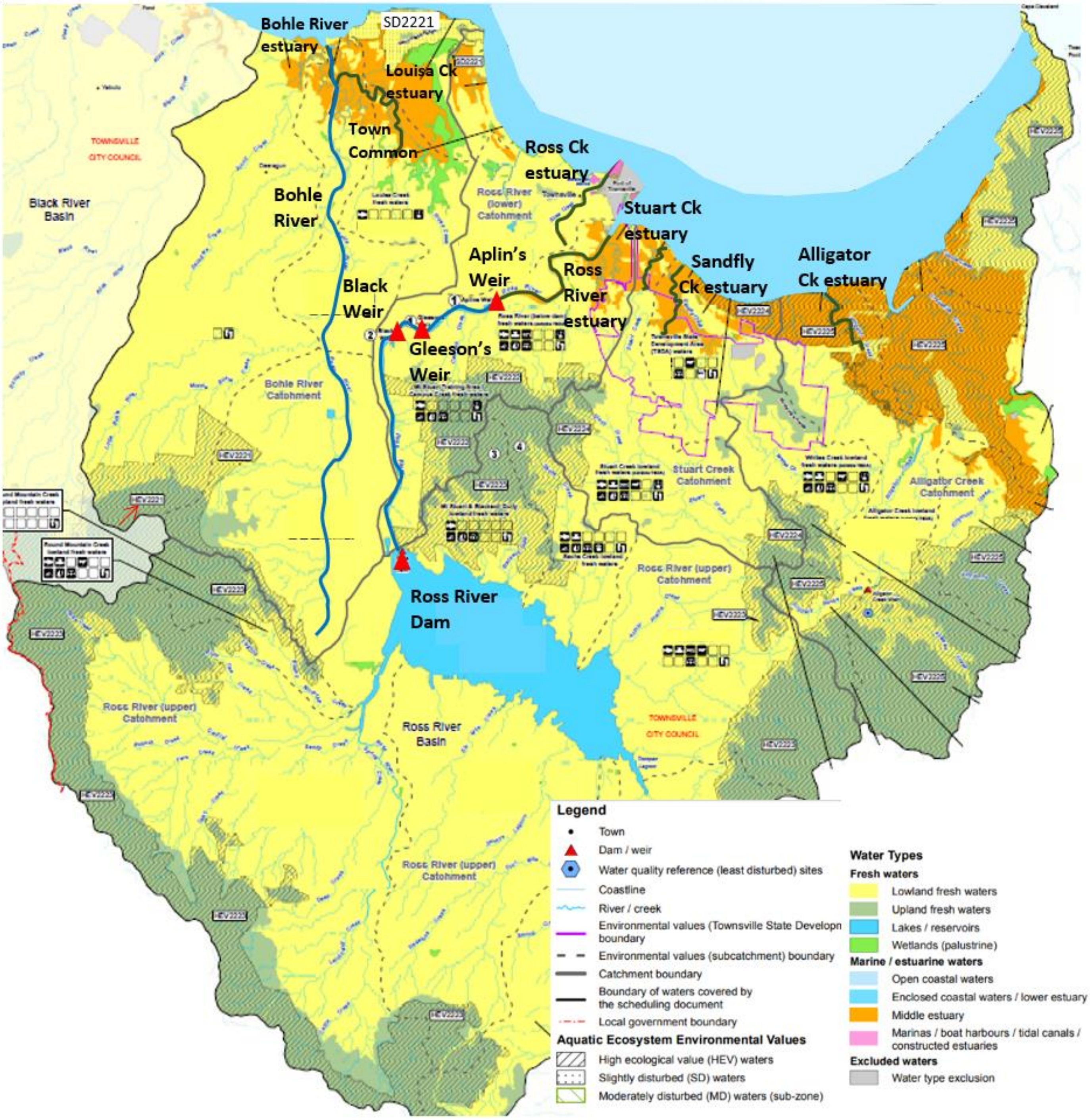

Figure 22 and

Figure 23, respectively.

Figure 22. 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 17 shows WQOs associated with each water type.

Figure 23. 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 17 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 17, with the adjusted values asterisked.

Table 17. 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.

Indicator category	Indicator	Unit	Ross Freshwater Basin		Black Freshwater Basin		Black and Ross Freshwater Basins
			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.

Within Halifax Bay 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 18. 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.

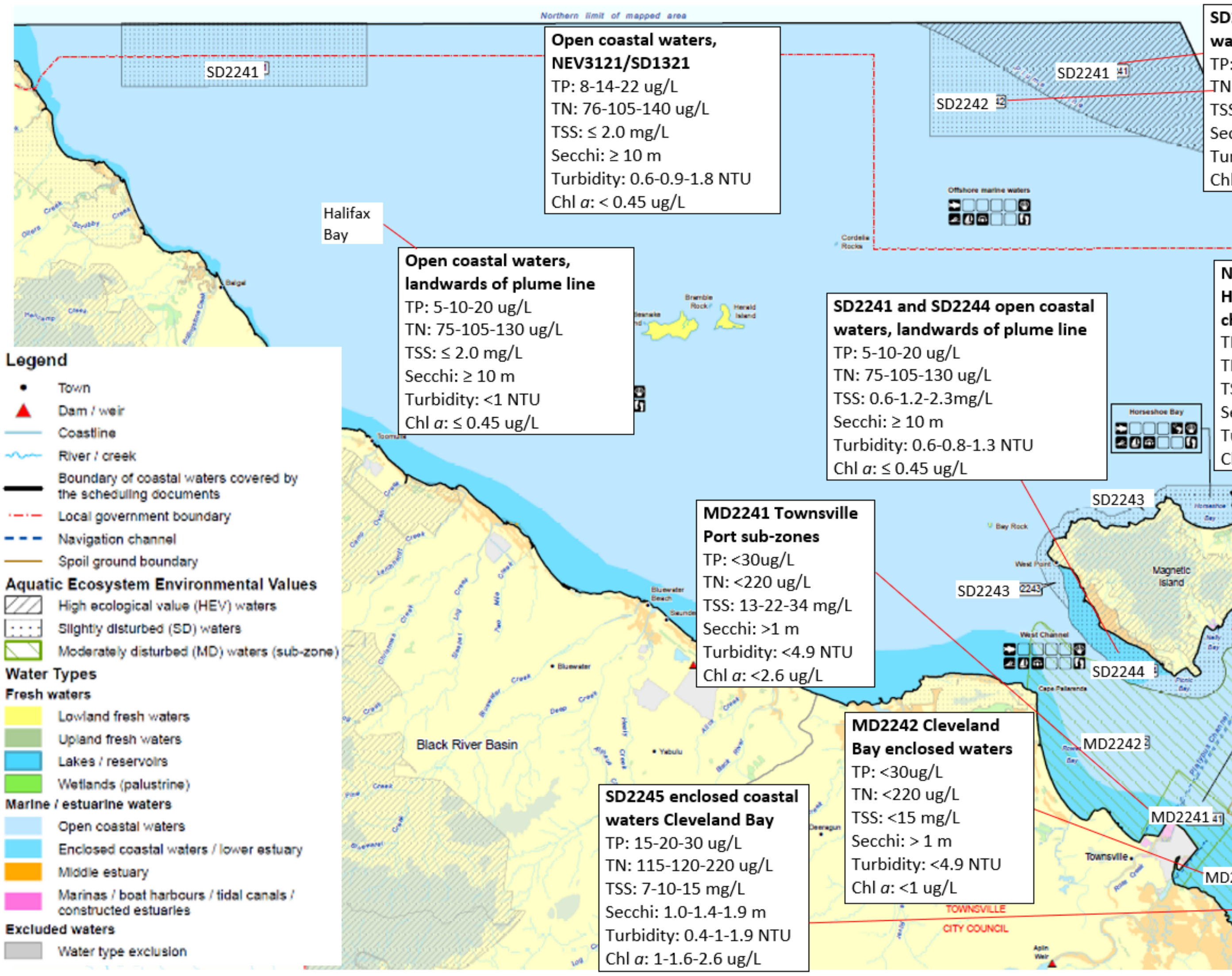

Figure 24 shows where different WQOs apply within Cleveland Bay and Halifax Bay. In the Townsville Dry Tropics, WQOs are stricter in waters further from the coast, representing a natural continuum from coastal to offshore marine waters. As a result, the WQOs for Pandora Reef, Palms West Island and Geoffrey 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 18. 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.

Indicator category	Indicator	Unit	Cleveland Bay			Halifax Bay
			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
Chlorophyll *a*	Chlorophyll *a*	µg/L	<2.6	<1	1.0-1.6-2.6	<0.45
Monitoring sites			Enclosed coastal waters	Open coastal waters	Geoffrey Bay	Pelorus Island, Pandora Reef

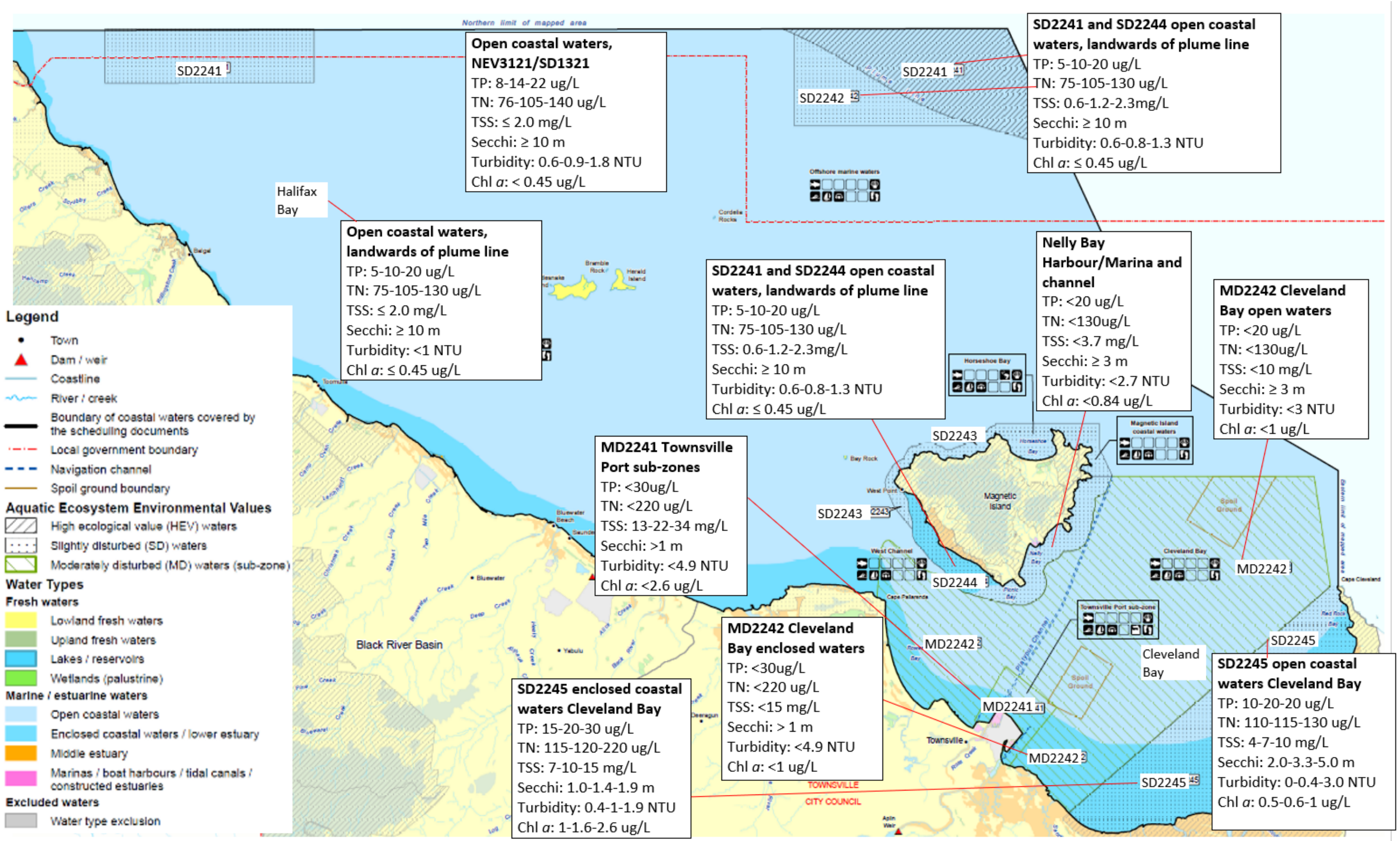

Figure 24. Water types within Cleveland and Halifax Bays, showing some WQOs associated with different water types.

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 25 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 16 of section 9).

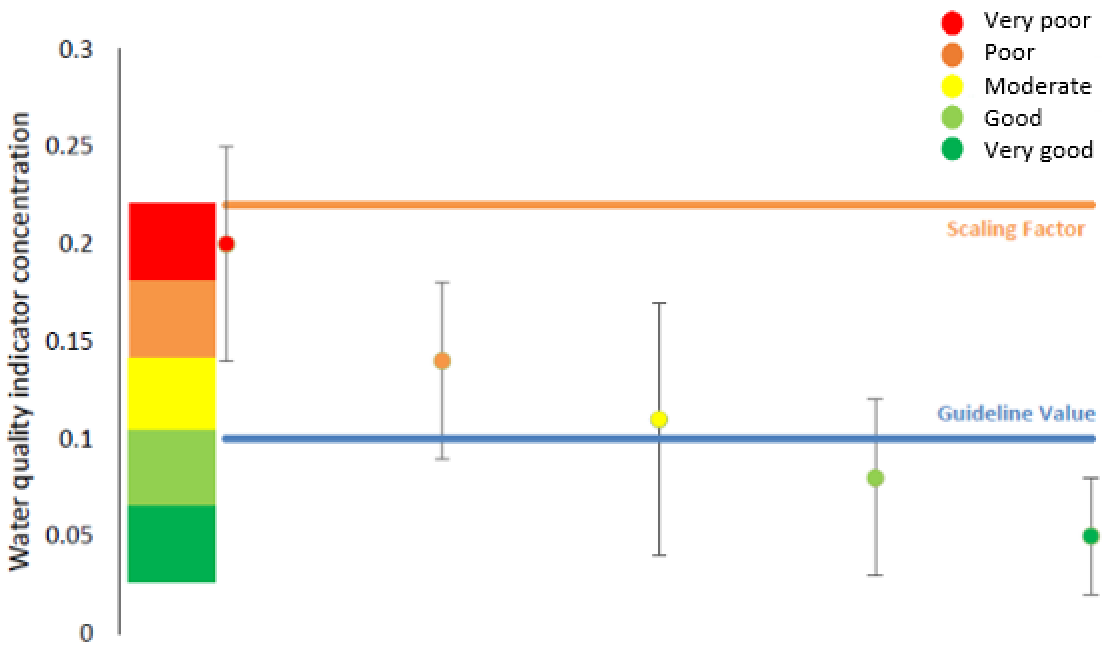

Figure 25. An example of assigning water quality grades.

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 site, calculate condition score (0-100) following rules and formula in Table 19 and Table 20.
7. For each 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 19 and Table 20.
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 19. 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 20. 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 19.

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 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:

$$Score = log_2\left(\frac{WQO}{annual\ mean\ of\ measured\ indicator}\right)$$

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

$$Score = log_2\left(\frac{annual\ mean\ of\ measured\ indicator}{WQO}\right)$$

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 21.
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 21. 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 22. 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:

$$(\%\ Water\ body\ \leq WQGV) = 100\% - (\%\ water\ body > WQGV\ within\ reporting\ period)$$

This percentage 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 22. 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 23 for riparian extent and in Table 24 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 23. 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 24. 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 used by the two other 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 25 summarises how impoundment length is converted into a report card grade.

Table 25. 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 26 and then summed (with each component equally weighted) to generate report card scores (Table 27).

Table 26. 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 27. 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 24 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 28) 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 29) following Thompson, et al., (2016). For the report card, thresholds are converted to a scale from 0 (very poor) to 1 (very good).

Table 28. 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 29. 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 26).

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:

$$Sample\ size = Number\ observations\ every\ metre * Number\ transects * transect\ length\ (m) * Number\ sites\ sampled\ within\ the\ same\ reef$$

The sample size for each monitoring program is shown in Table 30 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.

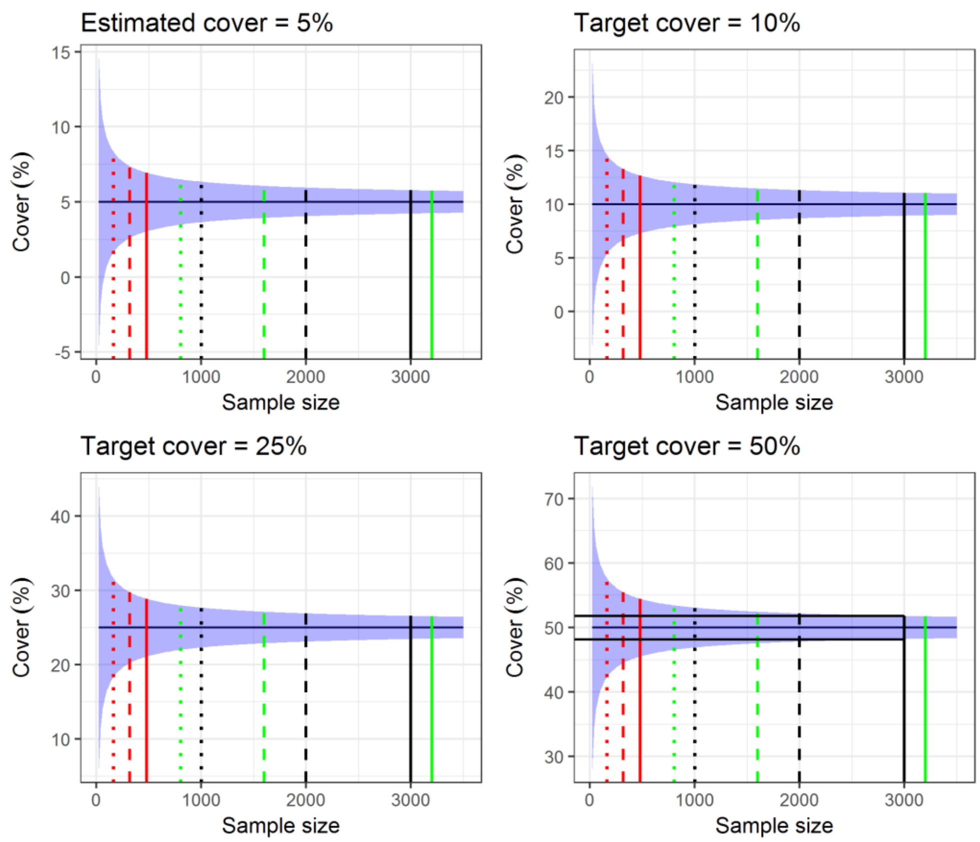

Figure 26. Theoretical influence of sampling intensity in confidence intervals about mean coral cover.

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 30. 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 31. 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 32. 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 32. 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 32. 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 33. All five indicators are equally weighted and averaged to produce an overall score for the coral indicator category.

Table 33. 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 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 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 35. The result is only provided for the whole freshwater basins, with the basin result based on the median across all the sampled sites.

Table 35. 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 Sampling Sites to Establish the Model

The zones, sampling sites, and years of contributing data for each of the partnerships used to establish the model are provided in Table 36 - Table 39.

Table 36: Wet Tropics Waterways Zones, Sites, and Years of Litter Collection used for Model Development

Zone	Site	Years of Collection
North Zone	Banabilla	2016
	Black Rock Reef Beach	2018
	Buchan Point	2010 2016
	Cairns Esplanade Beach	2013 2018
	Cape Kimberley	2011 2012 2013 2014 2015 2016 2017 2018 2019
	Cape Tribulation North	2013
	Clifton Beach	2016
	Coconut Beach	2015 2016 2019
	Cooya Beach	2009 2010 2011 2013 2014 2015 2016 2017 2018 2019
	Daintree Rivermouth	2013
	Dickson Inlet, Port Douglas	2019
	East Trinity Reserve Bund Wall	2012 2013 2015 2016 2017 2018 2019
	Ellis Beach	2010 2016
	Emmagen Beach	2018 2019
	Four Mile Beach, Middle Section	2013 2014 2015 2016 2017 2018 2019
	Four Mile Beach, North End	2013 2014 2015 2016 2017 2018 2019
	Four Mile Beach, South End	2009 2012 2013 2014 2015 2016 2018 2019
	Giangurra Beach, Yarrabah	2012 2013 2015 2018 2019
	Green Island, Cairns	2012 2014 2015 2016 2017
	Holloways Beach	2010 2013 2014 2016 2017
	Kewarra Beach	2010 2014 2015
	Low Isles	2009 2010 2011 2012 2013 2014 2015 2016
	Low Isles UW	2014 2016 2019
	Machans Beach	2010 2013 2017
	Machans Beach South	2018 2019
	Mission Beach, Yarrabah	2018 2019
	Myall Beach, Cape Tribulation	2015 2017
	Newell Beach	2014 2015 2016 2019
	Noah Beach	2013 2014 2015 2016 2018
	Oak Beach	2012 2016 2019
	Oak Beach South	2019
	Palm Cove	2014 2017
	Pebbly Beach, Oak Beach	2016 2019
	Pretty Beach	2013 2014 2015 2016
	Reed Road, Trinity Park	2010
	Rocky Point	2013 2014 2015 2016 2017 2018 2019
	Snapper Island, Queensland	2013 2014 2015 2016 2017 2018
	Thornton Beach	2016 2017 2019
	Turtle Cove Beach	2019
	Wangetti Beach	2009 2010 2014 2015 2016 2019
	Wonga Beach North End	2012 2015 2016 2017 2018
	Wonga Beach South End	2012 2013 2016 2017 2019
	Woody Island, Queensland	2011 2012 2014 2015 2016 2019

Zone	Site	Years of Collection
	Yarrabah Beach	2012 2018 2019
	Yarrabah Browns Beach	2012
	Yorkeys Knob	2010 2016 2017 2018
	Yule Point	2010 2014 2015 2016 2018 2019
Central Zone	Bramston Beach	2017
	Buddabadoo, Yarrabah	2016
	Coconuts Beach	2019
	Etty Bay, Innisfail	2017 2018 2019
	Flying Fish Point Beach	2019
	Jilgi Beach	2013 2014 2016
	Kings Beach, Yarrabah	2017
	Nudey Beach, Fitzroy Island	2015 2016 2018 2019
	Nudey Beach, Fitzroy Island UW	2019
	Welcome Bay, Fitzroy Island	2015 2016 2017 2018 2019
	Welcome Bay, Fitzroy Island UW	2019
	Wungu Beach	2014 2018
South Zone	Bingil Bay Camp Ground	2016
	Djingalynga Beach	2014 2016 2017
	Edmund Kennedy National Park	2012 2013 2014 2016 2017
	Garden Island off Goold Island	2012
	Googarra Beach, Tully Heads	2019
	Goold Island	2012
	Hillock Point, Hinchinbrook Island	2015
	Kennedy Bay, South Mission	2016 2017 2019
	Kurrimine Beach	2013 2014 2017
	Kurrimine Beach Conservation Park	2019
	Lugger Bay, South Mission Beach	2019
	Mission Beach	2015
	Narragon Beach	2016
	Picnic Beach, Hinchinbrook Island	2015
	South Mission Beach	2013 2019
	Stephens Island, Barnard Island Group	2016
	Sunken Reef Beach, Hinchinbrook Island	2015
	Wongaling Beach	2011 2012 2016 2018
	Zoe Bay, Hinchinbrook Island NP	2015
Daintree	Rocky Point Boat Ramp and Park	2019
Mossman	Bruno Rudweig Park, Port Douglas	2019
	Coast Watcher Park, Trinity Beach	2019
	Four Mile Beach North End Carpark	2019
	Mossman River, Mossman	2016
	Port Douglas CBD	2018
	South Mossman Creek	2015 2016 2018
	Town Centre, Trinity Beach	2018
Barron	Commercial Precinct, Smithfield	2018
	Freshwater Creek at Glenoma Park, Cairns	2018
	Freshwater Creek at Goomboora Park, Cairns	2018
	Freshwater Creek near Lower Freshwater Road, Cairns	2018

Zone	Site	Years of Collection
	Freshwater Creek, Jenkins Access Road, Cairns	2016 2018
	James Cook University Campus, Cairns	2018
	Northern Boardwalk, Cairns Airport	2014 2016
Mulgrave-Russell	Admiralty Island, Cairns	2016
	Cairns CBD	2018
	Chinaman Creek Park, Earlville	2019
	Green Patch, Mulgrave River	2016
	Lily Creek, Cairns	2015
	Mick Creek, Giangurru	2019
	Mulgrave River, Goldsborough	2016
	O'Leary's Creek, Gordonvale	2011 2012
Tully	Edmund Kennedy Memorial Walk Track, South Mission Beach	2015
	Hull River Estuary, Hull Heads	2019

14.1.1 Overlap Zone

The Palm Island Zone which forms the southern part of the Wet Tropics Waterways Partnership (WTW) region is not included in Table 36 as it forms part of the overlap zone between the WTW and the Dry Tropics Partnership for Healthy Waters (DTPHW). Geographically, all of the sites within the Palm Island Zone fall within Halifax Bay, and thus for modelling purposes were included within the bay. For reporting, the sites highlighted in green in Table 37 are included in both the WTW Palm Island zone and the DTPHW Halifax Bay zone, the sites highlighted in gold are included only in the WTW Palm Island zone, and the remaining sites are included in only the DTPHW Halifax Bay zone. This is because the boundaries overlap to include the Palm Island group, but otherwise fall part-way through Halifax Bay.

Table 37: Dry Tropics Partnership for Healthy Waters Zones, Sites, and Years of Litter Collection used for Model Development

Zone	Site	Years of Collection
Halifax Bay	Balgal Beach	2013 2016 2017 2019
	Balgal Beach North Section	2018 2019
	Big Rock Bay, Orpheus Island	2018 2019
	Boulder Beach, Orpheus Island	2019
	Cattle Bay, Orpheus Island	2019
	Crystal Beach, Mutarnee	2017 2019
	Fig Tree Beach, Orpheus Island	2015 2016 2018 2019
	Forrest Beach	2016
	Hazard Bay, Orpheus Island	2019
	Horseshoe Bay, Orpheus Island	2016 2018
	Jetty Beach Palm Island	2013 2015 2016
	Lucinda Beach	2013
	Ollera Beach	2014 2016
	Orpheus Island Research Station	2018 2019
	Picnic Bay, Orpheus Island	2019
	Pioneer Bay, Orpheus Island	2016 2019
	South Beach, Orpheus Island	2019
	Toolakea	2013 2019
	Yanks Jetty, Orpheus Island	2019
Cleveland Bay	Alma Bay, Magnetic Island	2016 2018 2019
	Alma Bay, Magnetic Island UW	2019
	Arthur Bay, Magnetic Island	2015 2017 2019
	Florence Bay, Magnetic Island	2019
	Geoffrey Bay, Magnetic Island	2018 2019
	Hawkings Point, Magnetic Island	2018
	Horseshoe Bay, Magnetic Island	2016 2017 2018 2019
	Nelly Bay Beach, Magnetic Island	2015 2016 2018 2019
	Nelly Bay, Magnetic Island UW	2019
	Pallarenda Beach	2012 2013 2014 2015 2018 2019
	Radical Bay, Magnetic Island	2015
	Rowes Bay	2009 2012 2015 2016 2017 2018 2019
	Shelly Beach, Pallarenda	2019
	Shelly Cove, Cape Pallarenda Conservation Park	2014 2015 2016 2017 2018 2019
	Southern Port Road North West Site, South Townsville	2018 2019
Bowling Green Bay	Cape Cleveland, Cungulla	2018 2019
Black	Crystal Creek, Mutarnee	2019
	Rollingstone Creek Bushy Park, Rollingstone	2019
Ross	Apex Park, Condon	2019
	Aplins Weir Rotary Park	2018 2019
	Black Weir, Ross River	2015 2016
	Keyatta Lake	2012
	Loam Island, Ross River, Rasmussen	2016
	Oonoonba Wetlands	2017
	Pioneer Park, Ross River, Townsville	2017
	Queens Gardens, Townsville	2017
	Ross River, Annadale	2015 2016
	Ross River, Thuringowa Central	2019
	Weir Park, Ross River, Townsville	2017

Table 38: Healthy Rivers to Reef Partnership Zones, Sites, and Years of Litter Collection used for Model Development

Zone	Site	Years of Collection
North	Gloucester Island, Eastern Side	2011 2013 2016 2018
	Gordon Beach	2016 2019
	Grays Bay	2013
	Horseshoe Bay Beach, Bowen	2013 2016
	Queens Beach, Bowen	2019
Whitsunday	Airlie Beach	2013 2015 2016 2018
	Armit Island	2016 2018
	Billbob Bay, Shaw Island	2016 2018 2019
	Black Island	2019
	Blue Pearl Bay, Hayman Island UW	2019
	Blue Pearl Bay, Hayman Island, Whitsundays	2019
	Bluff Point	2012 2016
	Border Island Whitsundays	2013 2014 2016 2018
	Bottletop Beach, Hook Island	2016
	Cane Cockies Beach	2011
	Cannonvale Beach	2013 2019
	Coral Beach, Airlie Beach	2015
	Coral Seas Boardwalk, Airlie Beach	2011 2019
	Crayfish Bay North, Hook Island	2019
	Deloraine Island	2016
	Double Bay East (central), Dryander NP	2018
	Double Bay Hut, Dryander NP	2011 2016
	Double Cone Island	2011 2012 2016
	Driftwood Bay, Hamilton Island	2012 2013 2014 2015
	Dryander National Park, Pioneer Bay	2019
	Dumbell Island	2018
	Eagle Bay, Shaw Island	2018
	East Beach, Thomas Island	2017
	Gap Beach, Lindeman Island	2017
	Genesta Bay	2015 2016 2018
	Georges Point	2016 2019
	Goat Island Beach, South Molle Island	2010 2014
	Grassy Island, South Bay	2016 2018
	Grimston Point East	2018
	Grimstone Point Central Beach Western Side	2017 2018
	Grimstone Point Northern Beach Western Side, Airlie Beach	2010 2011 2013 2014 2015 2016 2018 2019
	Grimstone Point, North Coast Eastern Side	2019
	Gumbrell Island	2016 2018
	Haselwood Island, Southern End	2014 2015 2016 2019
	Hill Inlet, Eastern Shore, Whitsunday Island	2019
	Homestead Bay, Cid Island, Whitsundays	2017
	Hook Island, East	2019
	Lindeman Island Resort	2016
	Long Island Sound	2016 2018
	Mackerel Bay Hook Island	2014 2016 2019
	Maher Island	2013 2016
	Maher Island East	2013 2018

Zone	Site	Years of Collection
	Naked Lady Beach, Thomas Island	2017
	Neck Bay East, Shaw Island	2012 2013 2014 2018
	NW Beach, Macona Inlet, Hook Island	2017
	Pandanus Bay Long Island	2013 2015 2019
	Pentecost Island	2016
	Pigs Head Bay, Thomas Island	2017
	Pine Bay East, South Molle Island	2010 2011 2013 2014 2015 2019
	Pine Bay, South Molle Island	2016 2019
	Pine Island	2015
	Shingley Beach, Airlie Beach	2019
	Shute Harbour	2011 2016 2017 2018
	Shute Harbour, Slipway	2019
	Small Island North of Grassy Island	2016
	Solace Bay, Whitsunday Island	2019
	Solway Circuit, Whitsunday Islands National Park	2019
	South Bay, Thomas Island	2017
	South East Bay, Long Island	2011 2013 2014 2015 2016 2019
	South End of Runway, Hamilton Island	2013 2016 2018
	Thomas Island, North East Beach	2019
	Turtle Bay, South Molle Island	2011 2019
	Turtle Bay, Whitsunday Island	2010 2013 2014 2016 2018 2019
	Whitehaven Beach, Whitsunday Island	2017 2019
	Whitsunday Drive barge banks	2011
	Whitsunday Island, South of Hook Pass	2016 2017
	Woodwark Bay Eastern Beach	2018
Central	Blacks Beach	2018 2019
	Blacksmith Island, Whitsundays	2017 2019
	Brampton Island, Multiple Sites	2018
	Bucasia Beach	2014 2018 2019
	Cape Conway	2014 2015 2016
	Cape Hillsborough Beach	2013
	Conway Beach	2012 2019
	Dinghy Bay, Brampton Island	2014 2015 2017
	Eimio Beach	2018 2019
	Far Beach, Mackay	2014 2018
	Goldsmith Island, Whitsundays	2017 2018 2019
	Grass Tree Beach	2017 2019
	Half Tide Beach, Hay Point	2017 2018 2019
	Harbour Beach, Mackay	2016 2017 2018 2019
	Hay Point	2017 2018
	Hay Point Harbour Beach	2018
	Illawong Beach	2018
	Ingot Island, Whitsundays	2017
	Keswick Island, Basil Bay	2019
	Keswick Island, Runway.	2019
	Lamberts Beach, Mackay	2018 2019
	Louisa Creek Beach, Hay Point	2017 2019
	McEwens Beach	2016 2018
	Midge Point	2013
	Oyster Bay, Brampton Island	2014
	Pebbly Bay, Brampton Island	2018

Zone	Site	Years of Collection
	Penrith Island, South Cumberland Islands National Park	2018
	Silversmith Island, Whitsundays	2017
	Solder Reef, Tinsmith Island	2019
	Town Beach, Mackay	2011 2016 2018 2019
	Western Bay, Brampton Island	2017
South	Avoid Island, The Percy Group	2014 2017 2018
	Clairview Beach North	2019
	Douglas Island, The Percy Group	1998
	North Beach, Digby Island	2017
Don	Don River Mouth, Bowen	2019
Proserpine	Urban Surrounds, Airlie Beach	2016 2017 2018 2019
	Urban Surrounds, Jubilee Pocket	2018
	Wilson Beach, Conway	2019
Pioneer	Pioneer River, Glenella Connection Road North Mackay	2019

Sites for the Gladstone Healthy Harbours Partnership (GHHP) include a number of sites that are outside the region covered by the partnership but include waterways that flow into the partnership region. The purpose in including these additional sites is to ensure that the model for the region considers potential litter sources in the same way that is being done in all of the other regions, and thus maintains the ability to compare the outcomes. Not all of the sites will be included in the GHHP reporting as they fall outside the partnership boundary.

Table 39: Gladstone Healthy Harbours Partnership Zones, Sites, and Years of Litter Collection used for the Model Development

Zone	Site	Years of Collection
The Narrows	Phillipies Landing Rd, Targinnie	2018
Mid Harbour	Canoe Point, Tannum Sands	2016 2017 2018 2019
	Esplanade Beach, Curtis Island	2019
	Facing Island North Point	2018
	North West Shore, Facing Island	2018
	Tannum Sands Main Beach	2017 2018 2019
Western Basin	Fisherman's Landing, Gladstone	2016 2018 2019
Calliope Estuary	Barney Point, Gladstone	2017 2018 2019
South Trees Inlet	Lillys Beach North End, Tannum Sands	2018 2019
Boyne Estuary	Bray Park to Boyne River mouth	2015 2016 2018 2019
	Lilleys Beach	2016 2017 2018 2019
Outer Harbour	Wild Cattle Creek Boat Ramp, Tannum Sands	2018 2019
	Wild Cattle Creek Mouth, Tannum Sands	2015 2016 2017 2018 2019
Rodds Bay	The Esplanade Beach, Turkey Beach	2018 2019
Calliope	Auckland Creek, Gladstone	2018 2019
	Auckland Creek, Golf Course Rd	2018 2019
	Auckland Creek, Hanson Road, Gladstone	2019
	Auckland Creek, Lions Park	2019
	Boat Creek Gladstone	2018
	Briffney Creek, Gladstone	2017 2018 2019
	Calliope River Campgrounds Old Bruce Hwy	2018 2019
	Calliope River, Gladstone Power Station	2019

	Hazelbrook Park, Calliope	2019
	Lake Callemondah	2016 2017 2018 2019
	Tigalee Creek, Sun Valley Park, Gladstone	2017 2018 2019
	Tigalee Creek, Sun Valley Rd	2019
	Tigalee Creek, Toonee Park, Gladstone	2018
	Tigalee Creek, Witney St	2018
	Tondoon Botanic Gardens, Gladstone	2018
	Wild Place, Burua	2017
	Yarwun	2019
Boyne	Boyne Island Conservation Site, Centenary Dr	2018
	Canoe Point Conservation Area, Tannum Sands	2018
	Canoe Point Reserve, Tanyalla	2018 2019
	Eastern Foreshore, Boyne River, Benaraby	2018 2019
	Lions Park, Boyne Island	2019
	Reg Tanna Park, Gladstone	2019
	Truck Bay, Corner Bruce Highway and Tannum Sands Road	2018
	Wapentake Wetlands, South Trees	2018
	Wyndham Park, Boyne Island	2019
Baffle	Canoe Point Reserve, Tanyalla	2018 2019
	The Sands, Tannum Sands	2018
	Wild Cattle Creek Trail, Tannum Sands	2019

14.2 Model Development

The litter collection data provided by TBF contained counts for each of the 12 categories recorded, the length of the area collected, the hours of collection and the number of volunteers who completed the collection. The litter is not always categorised, and as such may have been entered under the "Other" category as a total for general litter. On this basis the model developed by Venables and Whitehead (2019) concluded that the model could only be developed based on total litter, defined as the sum of the categories where sorting had been conducted. Refer to Venables and Whitehead (2019) for details of the method development behind the model.

Standardised Litter pressure as Catch per unit effort (CPUE) is defined by the method as a proportion between the number of items collected and the hours of collection:

$$CPUE \approx \frac{Items\ collected}{(Hours * Volunteers)^x}$$

Venables and Whitehead (2019) noted the benefits of using the log scale "for a variety of both intuitive and technical reasons" including that it converts multiplicative relationships into additive ones, and hence, converts the above equation as follows:

$$\log(CPUE) = \log(Items) - x * \log\,(Hours * Volunteers)$$

It is noted that the variable, *x,* is introduced into the relationship in recognition of the fact that as a site is cleaned, the amount of litter that can be collected each hour is reduced, and thus, over the time of the collection the rate of collection will decrease. For the original model developed for the DTPHW, this was found to be approximately 0.5 (Venables & Whitehead, 2019). Further variations integral in the data are different collection rates for individual volunteers (ability), the density of the litter to be collected (litter that is concentrated in a small area may be collected on a per item basis than litter that is sparsely spread over a large area) and whether litter sorting, as opposed to just collection, has been included in the reported hours (pers. com TBF).

Model development was initially investigated separately for each of the partnership regions: Wet Tropics Waterways Partnership (WTW), Dry Tropics Partnership for Healthy Waters (DTPHW), Healthy Rivers to Reef Partnership (HR2R), and Gladstone Healthy Harbours Partnership (GHHP), however, the existence of the overlap zone between WTW and DTPHW, with scant data in both regions other than the overlap zone, found that the models produced different results. A combined model for all regions, introducing the Region as a variable, was then developed.

The objective of the original model development was to provide a comparison between the partnership Zones in terms of litter pressure. Therefore, the Zones were included as a variable in the analysis. Further, the data shows great variation between the Sites (within the Zones) and at Sites from year to year. As noted from the data in Table 36, Table 37, Table 38, and Table 39 the years of collection at each site are also highly variable, thus the year determines the presence/absence of a site within a year. The data thus forms a hierarchical structure as shown in Figure 27.

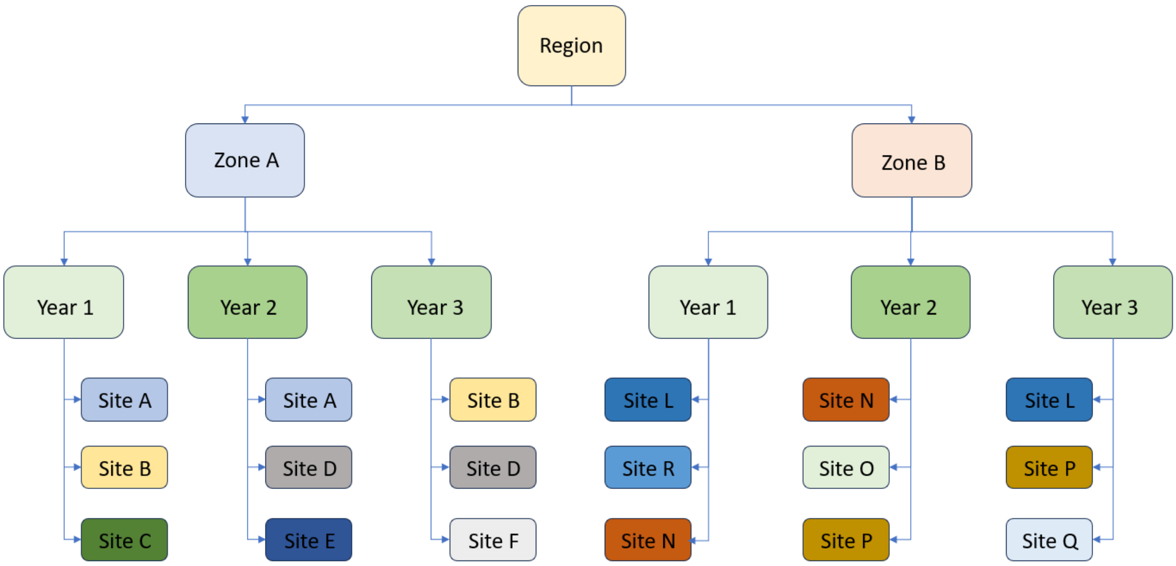

Figure 27: Litter data structure

A generalised linear mixed model (Gaussian) that allows for the inclusion of the random intercepts associated with the Sites within each year of data collection, and the years of data collection was used for the original DTPHW model and is defined by the following equations:

$$\log(Items) = \beta_0 + 0.5 * \log(Hours\ Cleaned) + Zone_{Halifax} + Z_i b_i + \epsilon$$

$$\log(Items) = \beta_0 + 0.5 * \log(Hours\ Cleaned) + Zone_{Cleveland} + Z_i b_i + \epsilon$$

$$\log(Items) = \beta_0 + 0.5 * \log(Hours\ Cleaned) + Zone_{Black} + Z_i b_i + \epsilon$$

$$\log(Items) = \beta_0 + 0.5 * \log(Hours\ Cleaned) + Zone_{Ross} + Z_i b_i + \epsilon$$

where:

*Hours Cleaned = Hours * Volunteers*

Zone is a categorical variable and provides a constant that is relative for each zone recognising the differences between their data.

Site within *Year* and *Year* are random intercept effects (denoted by $Z_i b_i$) accounting for a proportion of the variance within the model, with a proportion assigned to residuals (ϵ). The proportion of variance associated with the residuals indicates that variables contributing to the variation in the data have not been included in the model.

The development of the combined model resulted in Zone as a categorical variable having too many categories to be included as a fixed effect. The Region was instead included as a fixed effect, having only four (4) categories, and the Zone was included as a random intercept.

Count data is typically modelled as having a Poisson distribution, and a larger mean can result in the distribution becoming adequately approximated by a Gaussian, allowing the above linear model to be applied to the data. Whilst this was the case for the original, small DTPHW dataset, the WTW, HR2R, and GHHP data exhibited overdispersion relative to the Poisson distribution (with the variance much greater than the mean), and as such, the combined data was investigated further for its distribution characteristics. Further, implementation of a Gaussian model was found to fail the model assumptions, and thus was not appropriate for the data. The combined data was found to be closest to a negative binomial distribution:

$$Items \sim NB(\mu, \theta) \qquad E[Items] = \mu \qquad Var[Items] = \mu + \frac{\mu^2}{\theta}$$

In this case, the equation estimates the mean of the Items distribution and using the log-link function, provides a linear relationship between the log of the mean (μ) and the fixed and random effects defined as:

$$\log(\mu_{Items}) = \beta_0 + \beta_1 * \log(Hours\ Cleaned) + Region_i + Z_i b_i$$

Where $Z_i b_i$ denotes the random effects. It should be noted, that here, the calculation of $Z_i b_i$ does not function in the same manner as the $\beta_i x_i$ functions for the fixed effects.

It is not appropriate here to go into the details of the estimation methods of the random effects, suffice to say that random effects are characteristics of the data that influence the variance, rather than the mean, of the response variable. They can provide an estimation technique for parameters in a manner that is explanatory, making the estimates robust and stable by allowing Sites (within the hierarchical structure of the data) with only a small amount of data to borrow strength from those with a greater amount of data. The assumption is that these Sites are likely to be similar to those with larger amounts of data because they are drawn from a population. The method results in a shrinkage of extreme values towards the overall mean where the information is the weakest (Venables, 2023). This recognises and accounts for the variability that occurs between Zones, between years for each Zone, and between Sites for each year for each Zone reducing the potential for overfitting of the model. References on generalised linear mixed models for the Negative Binomial distribution are available online for those interested in a greater understanding.

If each of these components were to be included in the model as fixed effects, they would provide a constant value (as they are categorical variables) for each Zone (37 in number), Site (307), and Year (13), and thus the variability of the data would be lost in the calculation of the standardised value for log(μ_{Items}), given that log(*Hours Cleaned = 1*) would revert to a value of zero.

Thus providing

$$\mu_{Items} = e^{\beta_0 + \beta_1 * \log(Hours\ Cleaned) + Region_i + Z_i b_i}$$

With random effects of Site within Year within Zone, Year within Zone, and Zone given in the model design as (1|Zone/year/Site).

From this, the expected value of Items ($E[Items]$) can be calculated for an equivalent "effort" of one (1) hour for each Site in each year, noting that the Zone is constant for each Site, and thus provide a standardised estimate of the effort required for cleaning the litter at each Site.

To test the relationship between Items and Hours Cleaned, the data was plotted removing the random effects of Site within Year within Zone, Year within Zone, and Zone, and compared with the constrained case of

log(μ_{Items}) = 1 * log(*Hours Cleaned*) (red line)

and the alternative case of

log(μ_{Items}) = √log(*Hours*) (green line).

This is presented in Figure 28 with the blue line indicating the derived relationship for each Zone. It is noted that there is data presented for 31 Zones, however, there are a total of 37 Zones across the partnership regions. Six Zones had no data to contribute to the baseline model.

As expected from the data exploration that was completed, the slope of the relationship between log(μ_{Items}) and log(*Hours Cleaned*) for the combined dataset was generally closer to the green line of 0.5 * log(*Hours Cleaned*). The derived coefficient was 0.64 with a dispersion parameter of 1.66. This was found to be very close to the original estimates of 0.5 and 2 respectively.

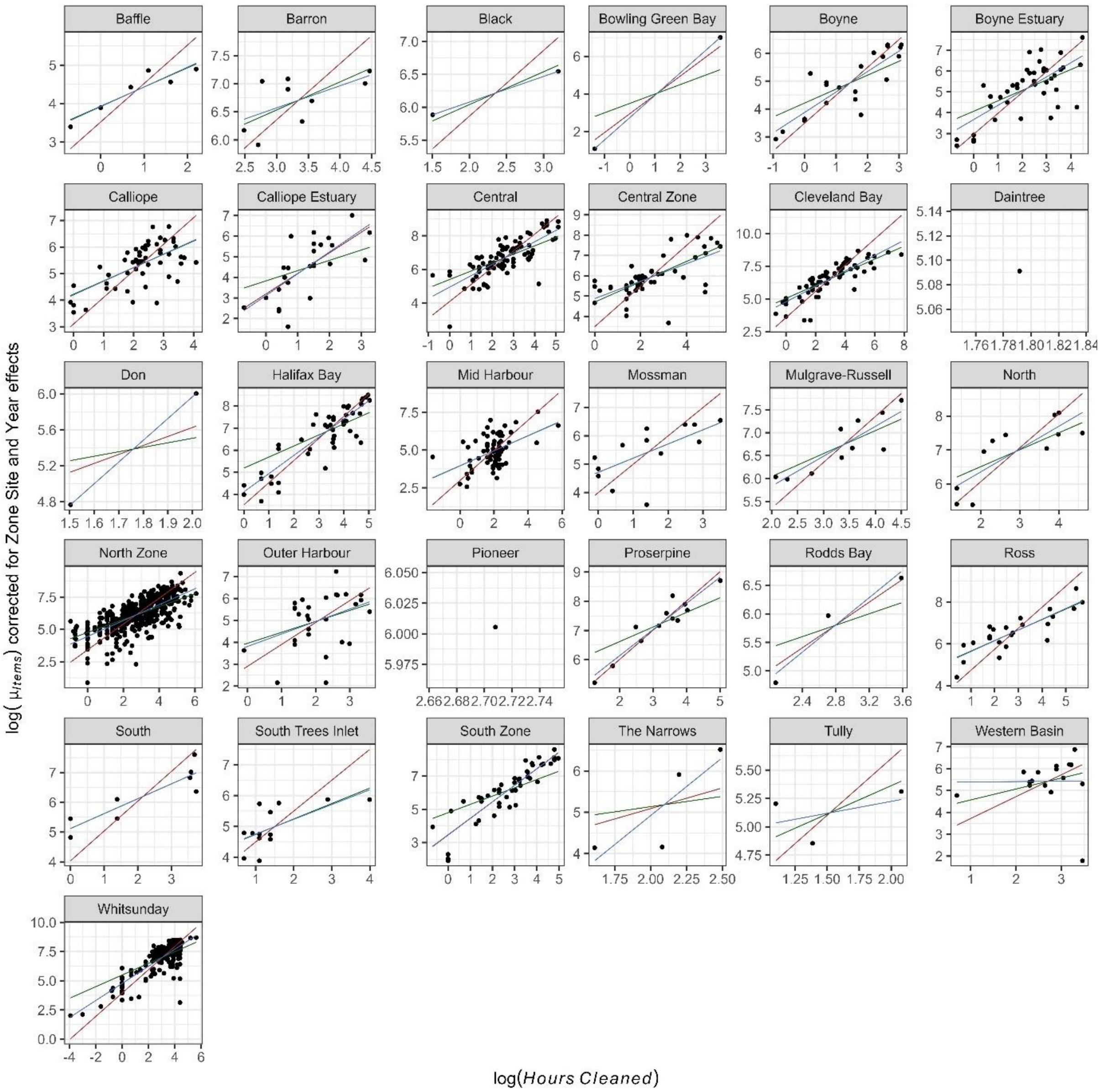

Figure 28: The relationship between the Expected value of log(μ_{Items}) and log(*Hours Cleaned*) with data corrected for the random effects

Generalised linear mixed models for both the Poisson distribution and the Negative Binomial distribution allow for the consideration of a response variable that is a rate, such as the *Catch per unit Effort* described above. In this instance the denominator (*Hours Cleaned*) is included as an "offset", to allow inclusion in the right-hand-side of the model. Thus, the coefficient can be fixed within the model, where there is evidence that the relationship should be maintained. The investigations found that fixing the *Hours Cleaned* as an offset with a coefficient of 0.5[7], and constraining the model to a dispersion parameter of 2 was suitable. The model produces a derived equation for each of the partnership regions to consider the differences between them. It also

[7] The value of 0.5 becomes a coefficient rather than an exponent as the model uses the log link function, thus, log (Hours Cleaned) must be used.

provides a test of whether these differences are statistically significant. The GHHP region was found to be significantly different from the DTPHW (the model baseline), however, WTW and HR2R were found to not be significantly different from DTPHW. The model is described as follows:

$$Items_{ij} \sim NB(\mu_{ij}|b_i)$$

$$E(Items_{ij}|b_i) = var(Items_{ij}|b_i, \theta) \approx \log(\mu|b_i)$$

$$\eta_{ij} = \alpha + \beta_i X_i + Z_i b_i$$

$$\log(\mu_{ij}|b_i) = \eta_{ij}$$

Where:

$b_i = random\ effects \approx N(0, \sigma_i^2)$

$\theta = dispersion\ parameter\ accounting\ for\ the\ difference\ in\ the\ mean\ and\ variance\ of\ the$
$Negative\ Binomial\ distribution\ of\ Items$

$Items_{ij} = Items\ for\ each\ Site\ i\ in\ each\ year\ j$

The model contains the categorical variable, Region, therefore, separate equations are written for each category:

$$\eta_{DTPHW} = 5.1261 + 0.5 * \log(Hours\ Cleaned)$$

$$\eta_{WTW} = 4.86 + 0.5 * \log(Hours\ Cleaned)$$

$$\eta_{HR2R} = 5.4684 + 0.5 * \log(Hours\ Cleaned)$$

$$\eta_{GHHP} = 4.2718 + 0.5 * \log(Hours\ Cleaned)$$

With random effects defined as:

$b_{Zone} = N(0, \sigma^2)\ with\ \hat{\sigma}^2 \approx 0.0697\ with\ 95\%\ confidence\ interval\ (0, 0.243)$

$b_{Year\ within\ Zone} = N(0, \sigma^2)\ with\ \hat{\sigma}^2 \approx 0.166\ with\ 95\%\ confidence\ interval\ (0.0656, 0.328)$

$b_{Site\ within\ Year\ within\ Zone} = N(0, \sigma^2)$

$$with\ \hat{\sigma}^2 \approx 0.728\ with\ 95\%\ confidence\ interval\ (0.602, 0.880)$$

$\theta = 2$

This provides:

$\hat{\mu}_{DTPHW} \approx 168\ with\ 95\%\ confidence\ interval\ (108, 256)$

$\hat{\mu}_{WTW} \approx 72\ with\ 95\%\ confidence\ interval\ (75, 222)$

$\hat{\mu}_{HR2R} \approx 237\ with\ 95\%\ confidence\ interval\ (129, 409)$

$\hat{\mu}_{GHHP} \approx 129\ with\ 95\%\ confidence\ interval\ (42, 126)$

Once the model is fit to the data, estimates of the $\log(\mu_{Items})$ are then obtained for a single hour of collection for each Site. This is to provide a standardised estimate of the data that can then be converted to a score and grade. Given the equations for each region above, this would suggest that the constant for each *Region* will become the value for the estimate of log(μ_{Items}), however, the inclusion of the "random effects" provides for the variation between the Sites for each year for the Zone.

As there is no external benchmark of the amount of litter that is good or bad, the standardised log(μ_{Items}) are ranked and converted to a standardised range of 0-1 (as 1 – cumulative distribution function), and the 20th, 40th, 60th, and 80th percentiles used to establish the baseline cut-offs for the grades of very high pressure (VHP) through to very low pressure (VLP) respectively. The model was fit using a nonlinear least squares "brute force" method due to failure to otherwise converge. The transformation to standardised score and grade model is presented below in Figure 29 and Figure 30, for an alternative view.

The model output for the Zones, Sites, and Years of Collection is provided in Appendix A.

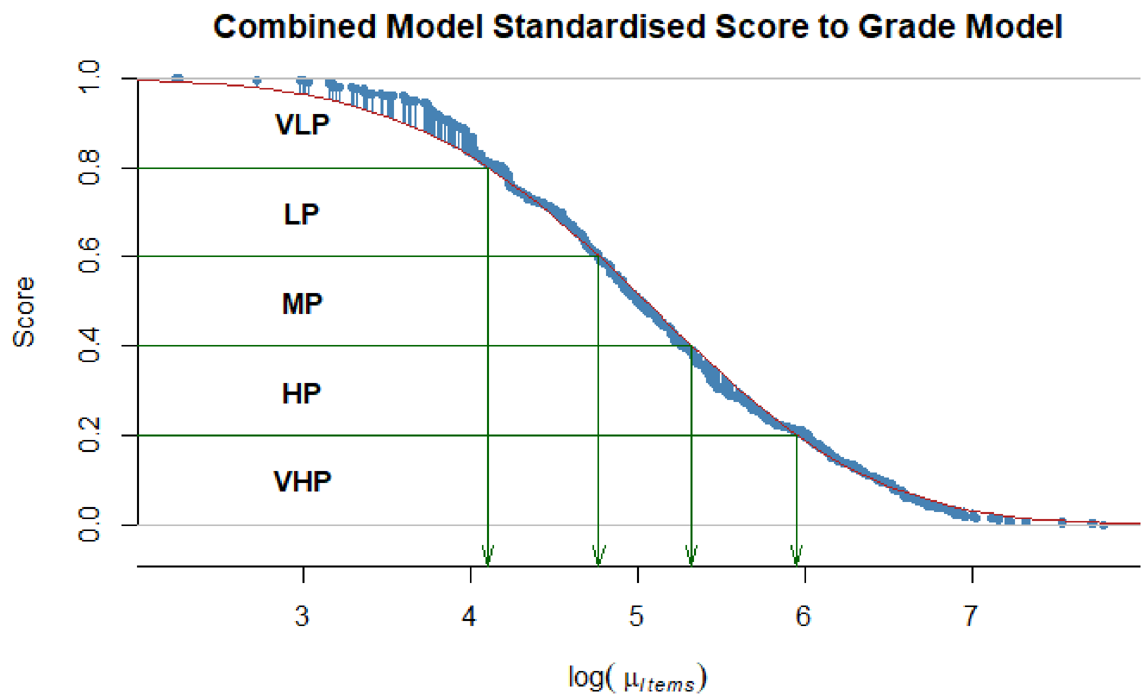

Figure 29: Combined Regions Model Standardised Scores and Grades Transformation

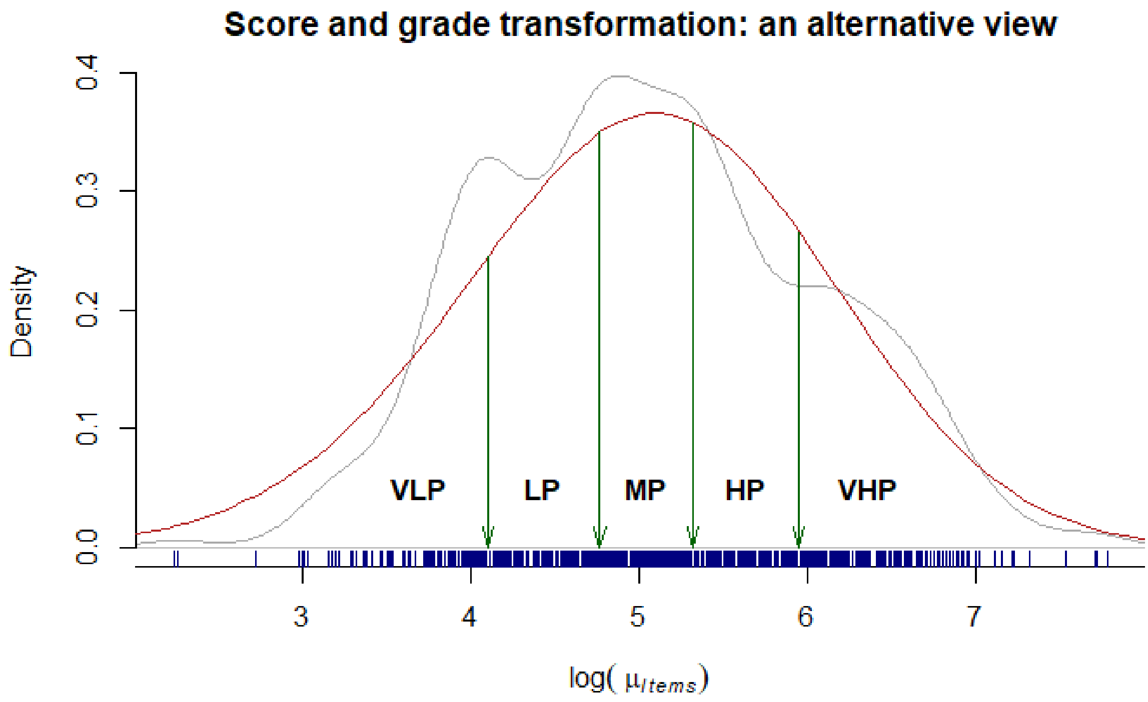

Figure 30: Combined Regions Model Standardised Scores and Grades Transformation: an alternative view

For each year of reporting, the additional data is added to the generalised linear mixed Negative Binomial model, and it is re-fit, to include the new data for *Items* and *Hours Cleaned* at each *Site*. This results in a small variation but has the result of each year providing a more robust model as it is based on more data. Examination of the variation in the results was completed and found only 3.8% of the total dataset (baseline model + additional 3 years of reporting data) had a change in score of 4 or 5 points. Of this, only 2 out of 1140 datapoints were data that were part of the reporting years.

Once the model has been re-fit, the estimates for an effort of 1 hour are obtained as the standardised values to be converted to the score and grade. The model for the calculation of the score and grade is maintained as produced from the baseline model, to ensure that the results from year to year are comparative.

Table 40 presents a comparison of the variance for the random effects across the models and shows that whilst the variance for each effect increases slightly across the models, the confidence intervals for each random effect variance does not change. Similarly, Table 41 presents a comparison of the mean estimates for the intercepts for each of the regions in the Items scale and shows that whilst there is variation in the intercept estimates, the 95% confidence intervals for them does not change.

Table 40: Comparison of the variance of the random effects and associated confidence intervals across the glmm NB models

		Baseline Model	2019-2020 Model	2020-2021 Model	2021-2022 Model
Zone:fyear:Site	**Variance**	0.728	0.739	0.789	0.839
	2.5% CI	0.602	0.602	0.602	0.602
	97.5% CI	0.880	0.880	0.880	0.880
Zone:fyear	**Variance**	0.166	0.152	0.107	0.083
	2.5% CI	0.066	0.066	0.066	0.066
	97.5% CI	0.328	0.328	0.328	0.328
Zone	**Variance**	0.070	0.099	0.111	0.114
	2.5% CI	0.000	0.000	0.000	0.000
	97.5% CI	0.243	0.243	0.243	0.243

Table 41: Comparison of the mean intercept estimate for each region and the 95% confidence intervals

Intercept		Baseline Model	2019-2020 Model	2020-2021 Model	2021-2022 Model
DTPHW	**Mean**	168	157	151	143
	2.5% CI	108	108	108	108
	97.5% CI	256	256	256	256
WTW	**Mean**	129	120	119	113
	2.5% CI	75	75	75	75
	97.5% CI	222	222	222	222
HR2R	**Mean**	237	202	178	178
	2.5% CI	129	129	129	129
	97.5% CI	409	409	409	409
GHHP	**Mean**	72	79	82	77
	2.5% CI	42	42	42	42
	97.5% CI	126	126	126	126

In simplified terms, the process can be summarised as:

Model Development

- Model the linear relationship between the parameters and fit to the model data
- Obtain estimates for each data point for an input of 1 hour of cleaning effort (to standardise the number of items)
- Obtain the model to transform the standardised Items to a standardised score and grade
- Calculate the mean score for each Site for each year (this is because some sites have more than one collection per year or ‘Event’)
- Convert the mean score to the grade based on the transformation model

<u>Each Year of Data for Reporting</u>

- Add the new year of data to the baseline dataset (this will provide the baseline dataset for the next year)
- Re-fit the linear relationship between the parameters for the updated dataset
- Obtain the estimates from the linear model for each datapoint for an input of 1 hour of cleaning effort (standardised number of items)
- Obtain the score for each collection Event using the transformation to score and grade model.
- Calculate the mean score for each Site for each year
- Convert the mean score to the grade using the transformation to score and grade model.

Zone scores and grades are not calculated as to do so would not be representative or comparable from year to year. This is because there is no consistency between the Sites that are included in each Zone each year.

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 E Table 1 and Appendix E 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 42. 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 42. 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 43.

Table 43. 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 44. 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 44. 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.

Component	Framework elements	Detailed description of the general theme	MAG	Management activity goal (description)
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 45. 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 44). 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 45. 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 46 shows the purpose of each criterion and its weighting. In the future, a more robust method will be devised and used.

Table 46. 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 47 and then weighted (weighting shown in Table 46). Overall confidence is then scored by adding all five weighted scores and then ranked against a 1 to 5 qualitative confidence ranking (Table 48).

Table 47. 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 48. 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 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 49. 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 49. 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 Basin	39,730	306	0.77
Black Estuarine Basin	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 50 along with improvements identified and actively being pursued by the Partnership.

Table 50. 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	
	Water quality monitoring sites within Halifax Bay are restricted to near the islands or reefs, whilst within Cleveland Bay 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.

Indicator category	Indicator	Unit	Inshore marine				Offshore marine
			Wet Tropics	Dry Tropics			
			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. Litter Model Output Data

Region	Zone	Site	1997-1998	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
WT	North Zone	Banabilla	NA	NA	NA	NA	NA	NA	NA	NA	35 (HP)	NA	NA	NA
		Black Rock Reef Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	21 (HP)	NA
		Buchan Point	NA	NA	82 (VLP)	NA	NA	NA	NA	NA	89 (VLP)	NA	NA	NA
		Cairns Esplanade Beach	NA	NA	NA	NA	NA	65 (LP)	NA	NA	NA	NA	62 (LP)	NA
		Cape Kimberley	NA	NA	NA	12 (VHP)	10 (VHP)	8 (VHP)	17 (VHP)	15 (VHP)	15 (VHP)	18 (VHP)	9 (VHP)	15 (VHP)
		Cape Tribulation North	NA	NA	NA	NA	NA	73 (LP)	NA	NA	NA	NA	NA	NA
		Clifton Beach	NA	NA	NA	NA	NA	NA	NA	NA	61 (LP)	NA	NA	NA
		Coconut Beach	NA	NA	NA	NA	NA	NA	NA	24 (HP)	54 (MP)	NA	NA	62 (LP)
		Cooya Beach	NA	54 (MP)	33 (HP)	43 (MP)	NA	78 (LP)	87 (VLP)	87 (VLP)	74 (LP)	78 (LP)	78 (LP)	60 (LP)
		Daintree Rivermouth	NA	NA	NA	NA	NA	40 (MP)	NA	NA	NA	NA	NA	NA
		Dickson Inlet, Port Douglas	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	82 (VLP)
		East Trinity Reserve Bund Wall	NA	NA	NA	NA	84 (VLP)	83 (VLP)	NA	35 (HP)	70 (LP)	49 (MP)	42 (MP)	55 (MP)
		Ellis Beach	NA	NA	76 (LP)	NA	NA	NA	NA	NA	77 (LP)	NA	NA	NA
		Emmagen Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	48 (MP)	40 (MP)
		Four Mile Beach, Middle Section	NA	NA	NA	NA	NA	25 (HP)	36 (HP)	37 (HP)	55 (MP)	28 (HP)	44 (MP)	40 (MP)
		Four Mile Beach, North End	NA	NA	NA	NA	NA	63 (LP)	40 (MP)	43 (MP)	55 (MP)	44 (MP)	44 (MP)	39 (HP)
		Four Mile Beach, South End	NA	71 (LP)	NA	NA	60 (LP)	78 (LP)	39 (HP)	64 (LP)	65 (LP)	NA	74 (LP)	86 (VLP)
		Giangurra Beach, Yarrabah	NA	NA	NA	NA	95 (VLP)	7 (VHP)	NA	21 (HP)	NA	NA	68 (LP)	51 (MP)
		Green Island, Cairns	NA	NA	NA	NA	42 (MP)	NA	62 (LP)	51 (MP)	80 (VLP)	36 (HP)	NA	NA
		Holloways Beach	NA	NA	77 (LP)	NA	NA	82 (VLP)	45 (MP)	NA	93 (VLP)	65 (LP)	NA	NA
		Kewarra Beach	NA	NA	74 (LP)	NA	NA	NA	6 (VHP)	30 (HP)	NA	NA	NA	NA
		Low Isles	NA	7 (VHP)	4 (VHP)	63 (LP)	64 (LP)	56 (MP)	77 (LP)	88 (VLP)	83 (VLP)	NA	NA	NA
		Low Isles UW	NA	NA	NA	NA	NA	NA	82 (VLP)	NA	80 (VLP)	NA	NA	91 (VLP)
		Machans Beach	NA	NA	71 (LP)	NA	NA	25 (HP)	NA	NA	NA	67 (LP)	NA	NA
		Machans Beach South	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	80 (VLP)	72 (LP)
		Mission Beach, Yarrabah	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	44 (MP)	67 (LP)
		Myall Beach, Cape Tribulation	NA	NA	NA	NA	NA	NA	NA	18 (VHP)	NA	57 (MP)	NA	NA
		Newell Beach	NA	NA	NA	NA	NA	NA	95 (VLP)	93 (VLP)	85 (VLP)	NA	NA	45 (MP)
		Noah Beach	NA	NA	NA	NA	NA	30 (HP)	9 (VHP)	19 (VHP)	86 (VLP)	NA	29 (HP)	NA
		Oak Beach	NA	NA	NA	NA	90 (VLP)	NA	NA	NA	63 (LP)	NA	NA	56 (MP)
		Oak Beach South	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	77 (LP)
		Palm Cove	NA	NA	NA	NA	NA	NA	52 (MP)	NA	NA	15 (VHP)	NA	NA
		Pebbly Beach, Oak Beach	NA	NA	NA	NA	NA	NA	NA	NA	65 (LP)	NA	NA	57 (MP)
		Pretty Beach	NA	NA	NA	NA	NA	49 (MP)	18 (VHP)	71 (LP)	75 (LP)	NA	NA	NA
		Reed Road, Trinity Park	NA	NA	71 (LP)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Rocky Point	NA	NA	NA	NA	NA	29 (HP)	35 (HP)	35 (HP)	63 (LP)	60 (LP)	77 (LP)	59 (MP)
		Snapper Island, Queensland	NA	NA	NA	NA	NA	14 (VHP)	36 (HP)	18 (VHP)	33 (HP)	28 (HP)	36 (HP)	NA
		Thornton Beach	NA	NA	NA	NA	NA	NA	NA	NA	92 (VLP)	54 (MP)	NA	65 (LP)
		Turtle Cove Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	25 (HP)
		Wangetti Beach	NA	83 (VLP)	60 (LP)	NA	NA	NA	36 (HP)	41 (MP)	64 (LP)	NA	NA	82 (VLP)
		Wonga Beach North End	NA	NA	NA	NA	50 (MP)	NA	NA	64 (LP)	69 (LP)	27 (HP)	64 (LP)	NA
		Wonga Beach South End	NA	NA	NA	NA	63 (LP)	33 (HP)	NA	NA	86 (VLP)	33 (HP)	NA	66 (LP)
		Woody Island, Queensland	NA	NA	NA	52 (MP)	50 (MP)	NA	18 (VHP)	30 (HP)	30 (HP)	NA	NA	50 (MP)
		Yarrabah Beach	NA	NA	NA	NA	73 (LP)	NA	NA	NA	NA	NA	16 (VHP)	52 (MP)
		Yarrabah Browns Beach	NA	NA	NA	NA	87 (VLP)	NA	NA	NA	NA	NA	NA	NA
		Yorkeys Knob	NA	NA	58 (MP)	NA	NA	NA	NA	NA	85 (VLP)	65 (LP)	30 (HP)	NA
		Yule Point	NA	NA	76 (LP)	NA	NA	NA	46 (MP)	88 (VLP)	18 (VHP)	NA	54 (MP)	29 (HP)
WT	Central Zone	Bramston Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	82 (VLP)	NA	NA
		Buddabadoo, Yarrabah	NA	NA	NA	NA	NA	NA	NA	NA	5 (VHP)	NA	NA	NA
		Coconuts Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	80 (VLP)
		Etty Bay, Innisfail	NA	NA	NA	NA	NA	NA	NA	NA	NA	59 (MP)	83 (VLP)	81 (VLP)
		Flying Fish Point Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	77 (LP)

Region	Zone	Site	1997-1998	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
		Jilgi Beach	NA	NA	NA	NA	NA	96 (VLP)	11 (VHP)	NA	32 (HP)	NA	NA	NA
		Kings Beach, Yarrabah	NA	NA	NA	NA	NA	NA	NA	NA	NA	82 (VLP)	NA	NA
		Nudey Beach, Fitzroy Island	NA	NA	NA	NA	NA	NA	NA	83 (VLP)	90 (VLP)	NA	79 (LP)	83 (VLP)
		Nudey Beach, Fitzroy Island UW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	95 (VLP)
		Welcome Bay, Fitzroy Island	NA	NA	NA	NA	NA	NA	NA	74 (LP)	60 (LP)	94 (VLP)	33 (HP)	67 (LP)
		Welcome Bay, Fitzroy Island UW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	95 (VLP)
		Wungu Beach	NA	NA	NA	NA	NA	NA	47 (MP)	NA	NA	NA	58 (MP)	NA
WT	South Zone	Bingil Bay Camp Ground	NA	NA	NA	NA	NA	NA	NA	NA	63 (LP)	NA	NA	NA
		Djingalynga Beach	NA	NA	NA	NA	NA	NA	62 (LP)	NA	67 (LP)	28 (HP)	NA	NA
		Edmund Kennedy National Park	NA	NA	NA	NA	77 (LP)	78 (LP)	62 (LP)	NA	53 (MP)	33 (HP)	NA	NA
		Garden Island off Goold Island	NA	NA	NA	NA	89 (VLP)	NA	NA	NA	NA	NA	NA	NA
		Googarra Beach, Tully Heads	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	82 (VLP)
		Goold Island	NA	NA	NA	NA	89 (VLP)	NA	NA	NA	NA	NA	NA	NA
		Hillock Point, Hinchinbrook Island	NA	NA	NA	NA	NA	NA	NA	23 (HP)	NA	NA	NA	NA
		Kennedy Bay, South Mission	NA	NA	NA	NA	NA	NA	NA	NA	12 (VHP)	11 (VHP)	NA	28 (HP)
		Kurrimine Beach	NA	NA	NA	NA	NA	35 (HP)	17 (VHP)	NA	NA	2 (VHP)	NA	NA
		Kurrimine Beach Conservation Park	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	26 (HP)
		Lugger Bay, South Mission Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	49 (MP)
		Mission Beach	NA	NA	NA	NA	NA	NA	NA	21 (HP)	NA	NA	NA	NA
		Narragon Beach	NA	NA	NA	NA	NA	NA	NA	NA	27 (HP)	NA	NA	NA
		Picnic Beach, Hinchinbrook Island	NA	NA	NA	NA	NA	NA	NA	17 (VHP)	NA	NA	NA	NA
		South Mission Beach	NA	NA	NA	NA	NA	58 (MP)	NA	NA	NA	NA	NA	66 (LP)
		Stephens Island, Barnard Island Group	NA	NA	NA	NA	NA	NA	NA	NA	41 (MP)	NA	NA	NA
		Sunken Reef Beach, Hinchinbrook Island	NA	NA	NA	NA	NA	NA	NA	0 (VHP)	NA	NA	NA	NA
		Wongaling Beach	NA	NA	NA	32 (HP)	66 (LP)	NA	NA	NA	66 (LP)	NA	91 (VLP)	NA
		Zoe Bay, Hinchinbrook Island NP	NA	NA	NA	NA	NA	NA	NA	13 (VHP)	NA	NA	NA	NA
WT	Daintree	Rocky Point Boat Ramp and Park	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	81 (VLP)
WT	Mossman	Bruno Rudweig Park, Port Douglas	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	68 (LP)
		Coast Watcher Park, Trinity Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	47 (MP)
		Four Mile Beach North End Carpark	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	50 (MP)
		Mossman River, Mossman	NA	NA	NA	NA	NA	NA	NA	NA	86 (VLP)	NA	NA	NA
		Port Douglas CBD	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6 (VHP)	NA
		South Mossman Creek	NA	NA	NA	NA	NA	NA	NA	23 (HP)	93 (VLP)	NA	50 (MP)	NA
		Town Centre, Trinity Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	33 (HP)	NA
WT	Barron	Commercial Precinct, Smithfield	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	29 (HP)	NA
		Freshwater Creek at Glenoma Park, Cairns	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	53 (MP)	NA
		Freshwater Creek at Goomboora Park, Cairns	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	65 (LP)	NA
		Freshwater Creek near Lower Freshwater Road, Cairns	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	66 (LP)	NA
		Freshwater Creek, Jenkins Access Road, Cairns	NA	NA	NA	NA	NA	NA	NA	NA	58 (MP)	NA	56 (MP)	NA
		James Cook University Campus, Cairns	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	19 (VHP)	NA
		Northern Boardwalk, Cairns Airport	NA	NA	NA	NA	NA	NA	67 (LP)	NA	41 (MP)	NA	NA	NA
WT	Mulgrave-Russell	Admiralty Island, Cairns	NA	NA	NA	NA	NA	NA	NA	NA	58 (MP)	NA	NA	NA
		Cairns CBD	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	66 (LP)	NA
		Chinaman Creek Park, Earlville	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	42 (MP)
		Green Patch, Mulgrave River	NA	NA	NA	NA	NA	NA	NA	NA	75 (LP)	NA	NA	NA
		Lily Creek, Cairns	NA	NA	NA	NA	NA	NA	NA	34 (HP)	NA	NA	NA	NA
		Mick Creek, Giangurru	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	59 (MP)
		Mulgrave River, Goldsborough	NA	NA	NA	NA	NA	NA	NA	NA	70 (LP)	NA	NA	NA
		O'Leary's Creek, Gordonvale	NA	NA	NA	46 (MP)	38 (HP)	NA	NA	NA	NA	NA	NA	NA

Region	Zone	Site	1997-1998	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
WT	Tully	Edmund Kennedy Memorial Walk Track, South Mission Beach	NA	NA	NA	NA	NA	NA	NA	81 (VLP)	NA	NA	NA	NA
		Hull River Estuary, Hull Heads	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	85 (VLP)
DT	Halifax Bay	Balgal Beach	NA	NA	NA	NA	NA	30 (HP)	NA	NA	67 (LP)	67 (LP)	NA	58 (MP)
		Balgal Beach North Section	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	54 (MP)	39 (HP)
		Big Rock Bay, Orpheus Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	17 (VHP)	22 (HP)
		Boulder Beach, Orpheus Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	51 (MP)
		Cattle Bay, Orpheus Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	29 (HP)
		Crystal Beach, Mutarnee	NA	NA	NA	NA	NA	NA	NA	NA	NA	25 (HP)	NA	39 (HP)
		Fig Tree Beach, Orpheus Island	NA	NA	NA	NA	NA	NA	NA	3 (VHP)	6 (VHP)	NA	8 (VHP)	11 (VHP)
		Forrest Beach	NA	NA	NA	NA	NA	NA	NA	NA	47 (MP)	NA	NA	NA
		Hazard Bay, Orpheus Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	13 (VHP)
		Horseshoe Bay, Orpheus Island	NA	NA	NA	NA	NA	NA	NA	NA	5 (VHP)	NA	4 (VHP)	NA
		Jetty Beach Palm Island	NA	NA	NA	NA	NA	33 (HP)	NA	16 (VHP)	3 (VHP)	NA	NA	NA
		Lucinda Beach	NA	NA	NA	NA	NA	50 (MP)	NA	NA	NA	NA	NA	NA
		Ollera Beach	NA	NA	NA	NA	NA	NA	52 (MP)	NA	17 (VHP)	NA	NA	NA
		Orpheus Island Research Station	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	75 (LP)	49 (MP)
		Picnic Bay, Orpheus Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6 (VHP)
		Pioneer Bay, Orpheus Island	NA	NA	NA	NA	NA	NA	NA	NA	61 (LP)	NA	NA	62 (LP)
		South Beach, Orpheus Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4 (VHP)
		Toolakea	NA	NA	NA	NA	NA	71 (LP)	NA	NA	NA	NA	NA	66 (LP)
		Yanks Jetty, Orpheus Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	68 (LP)
DT	Cleveland Bay	Alma Bay, Magnetic Island	NA	NA	NA	NA	NA	NA	NA	NA	64 (LP)	NA	81 (VLP)	41 (MP)
		Alma Bay, Magnetic Island UW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	96 (VLP)
		Arthur Bay, Magnetic Island	NA	NA	NA	NA	NA	NA	NA	45 (MP)	NA	32 (HP)	NA	91 (VLP)
		Florence Bay, Magnetic Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	72 (LP)
		Geoffrey Bay, Magnetic Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	58 (MP)	61 (LP)
		Hawkings Point, Magnetic Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	78 (LP)	NA
		Horseshoe Bay, Magnetic Island	NA	NA	NA	NA	NA	NA	NA	NA	71 (LP)	45 (MP)	73 (LP)	67 (LP)
		Nelly Bay Beach, Magnetic Island	NA	NA	NA	NA	NA	NA	NA	85 (VLP)	51 (MP)	NA	65 (LP)	46 (MP)
		Nelly Bay, Magnetic Island UW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	99 (VLP)
		Pallarenda Beach	NA	NA	NA	NA	75 (LP)	41 (MP)	44 (MP)	74 (LP)	NA	NA	53 (MP)	63 (LP)
		Radical Bay, Magnetic Island	NA	NA	NA	NA	NA	NA	NA	80 (VLP)	NA	NA	NA	NA
		Rowes Bay	NA	58 (MP)	NA	NA	63 (LP)	NA	NA	58 (MP)	47 (MP)	58 (MP)	65 (LP)	69 (LP)
		Shelly Beach, Pallarenda	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	44 (MP)
		Shelly Cove, Cape Pallarenda Conservation Park	NA	NA	NA	NA	NA	NA	48 (MP)	47 (MP)	56 (MP)	48 (MP)	76 (LP)	67 (LP)
		Southern Port Road North West Site, South Townsville	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	62 (LP)	67 (LP)
DT	Bowling Green Bay	Cape Cleveland, Cungulla	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	91 (VLP)	53 (MP)
DT	Black	Crystal Creek, Mutarnee	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	48 (MP)
		Rollingstone Creek Bushy Park, Rollingstone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	59 (MP)
DT	Ross	Apex Park, Condon	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	47 (MP)
		Aplins Weir Rotary Park	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	65 (LP)	45 (MP)
		Black Weir, Ross River	NA	NA	NA	NA	NA	NA	NA	14 (VHP)	15 (VHP)	NA	NA	NA
		Keyatta Lake	NA	NA	NA	NA	19 (VHP)	NA	NA	NA	NA	NA	NA	NA
		Loam Island, Ross River, Rasmussen	NA	NA	NA	NA	NA	NA	NA	NA	44 (MP)	NA	NA	NA
		Oonoonba Wetlands	NA	NA	NA	NA	NA	NA	NA	NA	NA	26 (HP)	NA	NA
		Pioneer Park, Ross River, Townsville	NA	NA	NA	NA	NA	NA	NA	NA	NA	58 (MP)	NA	NA
		Queens Gardens, Townsville	NA	NA	NA	NA	NA	NA	NA	NA	NA	62 (LP)	NA	NA
		Ross River, Annadale	NA	NA	NA	NA	NA	NA	NA	12 (VHP)	18 (VHP)	NA	NA	NA
		Ross River, Thuringowa Central	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	52 (MP)
		Weir Park, Ross River, Townsville	NA	NA	NA	NA	NA	NA	NA	NA	NA	71 (LP)	NA	NA

Region	Zone	Site	1997-1998	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
MWI	North	Gloucester Island, Eastern Side	NA	NA	NA	9 (VHP)	NA	8 (VHP)	NA	NA	42 (MP)	NA	15 (VHP)	NA
		Gordon Beach	NA	NA	NA	NA	NA	NA	NA	NA	19 (VHP)	NA	NA	62 (LP)
		Grays Bay	NA	NA	NA	NA	NA	37 (HP)	NA	NA	NA	NA	NA	NA
		Horseshoe Bay Beach, Bowen	NA	NA	NA	NA	NA	13 (VHP)	NA	NA	50 (MP)	NA	NA	NA
		Queens Beach, Bowen	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	87 (VLP)
MWI	Whitsunday	Airlie Beach	NA	NA	NA	NA	NA	12 (VHP)	NA	14 (VHP)	18 (VHP)	NA	25 (HP)	NA
		Armit Island	NA	NA	NA	NA	NA	NA	NA	NA	88 (VLP)	NA	14 (VHP)	NA
		Billbob Bay, Shaw Island	NA	NA	NA	NA	NA	NA	NA	NA	6 (VHP)	NA	11 (VHP)	32 (HP)
		Black Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	58 (MP)
		Blue Pearl Bay, Hayman Island UW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	66 (LP)
		Blue Pearl Bay, Hayman Island, Whitsundays	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	18 (VHP)
		Bluff Point	NA	NA	NA	NA	16 (VHP)	NA	NA	NA	16 (VHP)	NA	NA	NA
		Border Island Whitsundays	NA	NA	NA	NA	NA	1 (VHP)	9 (VHP)	NA	13 (VHP)	NA	12 (VHP)	NA
		Bottletop Beach, Hook Island	NA	NA	NA	NA	NA	NA	NA	NA	59 (MP)	NA	NA	NA
		Cane Cockies Beach	NA	NA	NA	37 (HP)	NA	NA	NA	NA	NA	NA	NA	NA
		Cannonvale Beach	NA	NA	NA	NA	NA	31 (HP)	NA	NA	NA	NA	NA	63 (LP)
		Coral Beach, Airlie Beach	NA	NA	NA	NA	NA	NA	NA	51 (MP)	NA	NA	NA	NA
		Coral Seas Boardwalk, Airlie Beach	NA	NA	NA	23 (HP)	NA	NA	NA	NA	NA	NA	NA	57 (MP)
		Crayfish Bay North, Hook Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	8 (VHP)
		Deloraine Island	NA	NA	NA	NA	NA	NA	NA	NA	61 (LP)	NA	NA	NA
		Double Bay East (central), Dryander NP	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7 (VHP)	NA
		Double Bay Hut, Dryander NP	NA	NA	NA	25 (HP)	NA	NA	NA	NA	26 (HP)	NA	NA	NA
		Double Cone Island	NA	NA	NA	31 (HP)	21 (HP)	NA	NA	NA	47 (MP)	NA	NA	NA
		Driftwood Bay, Hamilton Island	NA	NA	NA	NA	2 (VHP)	17 (VHP)	11 (VHP)	5 (VHP)	NA	NA	NA	NA
		Dryander National Park, Pioneer Bay	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	11 (VHP)
		Dumbell Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	47 (MP)	NA
		Eagle Bay, Shaw Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6 (VHP)	NA
		East Beach, Thomas Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	67 (LP)	NA	NA
		Gap Beach, Lindeman Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	52 (MP)	NA	NA
		Genesta Bay	NA	NA	NA	NA	NA	NA	NA	4 (VHP)	25 (HP)	NA	5 (VHP)	NA
		Georges Point	NA	NA	NA	NA	NA	NA	NA	NA	10 (VHP)	NA	NA	9 (VHP)
		Goat Island Beach, South Molle Island	NA	NA	42 (MP)	NA	NA	NA	8 (VHP)	NA	NA	NA	NA	NA
		Grassy Island, South Bay	NA	NA	NA	NA	NA	NA	NA	NA	28 (HP)	NA	16 (VHP)	NA
		Grimston Point East	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	17 (VHP)	NA
		Grimstone Point Central Beach Western Side	NA	NA	NA	NA	NA	NA	NA	NA	NA	72 (LP)	10 (VHP)	NA
		Grimstone Point Northern Beach Western Side, Airlie Beach	NA	NA	25 (HP)	29 (HP)	NA	7 (VHP)	8 (VHP)	11 (VHP)	18 (VHP)	NA	10 (VHP)	48 (MP)
		Grimstone Point, North Coast Eastern Side	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	20 (HP)
		Gumbrell Island	NA	NA	NA	NA	NA	NA	NA	NA	47 (MP)	NA	12 (VHP)	NA
		Haselwood Island, Southern End	NA	NA	NA	NA	NA	NA	6 (VHP)	7 (VHP)	15 (VHP)	NA	NA	13 (VHP)
		Hill Inlet, Eastern Shore, Whitsunday Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	84 (VLP)
		Homestead Bay, Cid Island, Whitsundays	NA	NA	NA	NA	NA	NA	NA	NA	NA	80 (VLP)	NA	NA
		Hook Island, East	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6 (VHP)
		Lindeman Island Resort	NA	NA	NA	NA	NA	NA	NA	NA	14 (VHP)	NA	NA	NA
		Long Island Sound	NA	NA	NA	NA	NA	NA	NA	NA	40 (MP)	NA	35 (HP)	NA
		Mackerel Bay Hook Island	NA	NA	NA	NA	NA	NA	13 (VHP)	NA	30 (HP)	NA	NA	6 (VHP)
		Maher Island	NA	NA	NA	NA	NA	2 (VHP)	NA	NA	6 (VHP)	NA	NA	NA
		Maher Island East	NA	NA	NA	NA	NA	1 (VHP)	NA	NA	NA	NA	11 (VHP)	NA
		Naked Lady Beach, Thomas Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	69 (LP)	NA	NA

Region	Zone	Site	1997-1998	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
		Neck Bay East, Shaw Island	NA	NA	NA	NA	11 (VHP)	11 (VHP)	1 (VHP)	NA	NA	NA	12 (VHP)	NA
		NW Beach, Macona Inlet, Hook Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	75 (LP)	NA	NA
		Pandanus Bay Long Island	NA	NA	NA	NA	NA	8 (VHP)	NA	14 (VHP)	NA	NA	NA	19 (VHP)
		Pentecost Island	NA	NA	NA	NA	NA	NA	NA	NA	23 (HP)	NA	NA	NA
		Pigs Head Bay, Thomas Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	79 (LP)	NA	NA
		Pine Bay East, South Molle Island	NA	NA	32 (HP)	24 (HP)	NA	2 (VHP)	2 (VHP)	26 (HP)	NA	NA	NA	11 (VHP)
		Pine Bay, South Molle Island	NA	NA	NA	NA	NA	NA	NA	NA	10 (VHP)	NA	NA	7 (VHP)
		Pine Island	NA	NA	NA	NA	NA	NA	NA	44 (MP)	NA	NA	NA	NA
		Shingley Beach, Airlie Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	44 (MP)
		Shute Harbour	NA	NA	NA	33 (HP)	NA	NA	NA	NA	32 (HP)	29 (HP)	19 (VHP)	NA
		Shute Harbour, Slipway	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	18 (VHP)
		Small Island North of Grassy Island	NA	NA	NA	NA	NA	NA	NA	NA	60 (LP)	NA	NA	NA
		Solace Bay, Whitsunday Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7 (VHP)
		Solway Circuit, Whitsunday Islands National Park	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4 (VHP)
		South Bay, Thomas Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	22 (HP)	NA	NA
		South East Bay, Long Island	NA	NA	NA	9 (VHP)	NA	16 (VHP)	7 (VHP)	13 (VHP)	70 (LP)	NA	NA	8 (VHP)
		South End of Runway, Hamilton Island	NA	NA	NA	NA	NA	8 (VHP)	NA	NA	18 (VHP)	NA	6 (VHP)	NA
		Thomas Island, North East Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	8 (VHP)
		Turtle Bay, South Molle Island	NA	NA	NA	4 (VHP)	NA	NA	NA	NA	NA	NA	NA	10 (VHP)
		Turtle Bay, Whitsunday Island	NA	NA	31 (HP)	NA	NA	2 (VHP)	4 (VHP)	NA	8 (VHP)	NA	4 (VHP)	11 (VHP)
		Whitehaven Beach, Whitsunday Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	85 (VLP)	NA	74 (LP)
		Whitsunday Drive barge banks	NA	NA	NA	32 (HP)	NA	NA	NA	NA	NA	NA	NA	NA
		Whitsunday Island, South of Hook Pass	NA	NA	NA	NA	NA	NA	NA	NA	19 (VHP)	35 (HP)	NA	NA
		Woodwark Bay Eastern Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7 (VHP)	NA
MWI	Central	Blacks Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	48 (MP)	69 (LP)
		Blacksmith Island, Whitsundays	NA	NA	NA	NA	NA	NA	NA	NA	NA	10 (VHP)	NA	14 (VHP)
		Brampton Island, Multiple Sites	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	35 (HP)	NA
		Bucasia Beach	NA	NA	NA	NA	NA	NA	85 (VLP)	NA	NA	NA	70 (LP)	56 (MP)
		Cape Conway	NA	NA	NA	NA	NA	NA	13 (VHP)	20 (HP)	12 (VHP)	NA	NA	NA
		Cape Hillsborough Beach	NA	NA	NA	NA	NA	14 (VHP)	NA	NA	NA	NA	NA	NA
		Conway Beach	NA	NA	NA	NA	37 (HP)	NA	NA	NA	NA	NA	NA	58 (MP)
		Dinghy Bay, Brampton Island	NA	NA	NA	NA	NA	NA	58 (MP)	48 (MP)	NA	18 (VHP)	NA	NA
		Eimio Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	35 (HP)	50 (MP)
		Far Beach, Mackay	NA	NA	NA	NA	NA	NA	65 (LP)	NA	NA	NA	47 (MP)	NA
		Goldsmith Island, Whitsundays	NA	NA	NA	NA	NA	NA	NA	NA	NA	4 (VHP)	21 (HP)	12 (VHP)
		Grass Tree Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	44 (MP)	NA	56 (MP)
		Half Tide Beach, Hay Point	NA	NA	NA	NA	NA	NA	NA	NA	NA	31 (HP)	52 (MP)	26 (HP)
		Harbour Beach, Mackay	NA	NA	NA	NA	NA	NA	NA	NA	24 (HP)	19 (VHP)	62 (LP)	29 (HP)
		Hay Point	NA	NA	NA	NA	NA	NA	NA	NA	NA	29 (HP)	38 (HP)	NA
		Hay Point Harbour Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	50 (MP)	NA
		Illawong Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	59 (MP)	NA
		Ingot Island, Whitsundays	NA	NA	NA	NA	NA	NA	NA	NA	NA	25 (HP)	NA	NA
		Keswick Island, Basil Bay	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	24 (HP)
		Keswick Island, Runway.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	60 (LP)
		Lamberts Beach, Mackay	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	51 (MP)	35 (HP)
		Louisa Creek Beach, Hay Point	NA	NA	NA	NA	NA	NA	NA	NA	NA	49 (MP)	NA	87 (VLP)
		McEwens Beach	NA	NA	NA	NA	NA	NA	NA	NA	50 (MP)	NA	60 (LP)	NA
		Midge Point	NA	NA	NA	NA	NA	42 (MP)	NA	NA	NA	NA	NA	NA
		Oyster Bay, Brampton Island	NA	NA	NA	NA	NA	NA	43 (MP)	NA	NA	NA	NA	NA
		Pebbly Bay, Brampton Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	32 (HP)	NA
		Penrith Island, South Cumberland Islands National Park	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	21 (HP)	NA
		Silversmith Island, Whitsundays	NA	NA	NA	NA	NA	NA	NA	NA	NA	11 (VHP)	NA	NA

Region	Zone	Site	1997-1998	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
		Solder Reef, Tinsmith Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5 (VHP)
		Town Beach, Mackay	NA	NA	NA	61 (LP)	NA	NA	NA	NA	26 (HP)	NA	41 (MP)	34 (HP)
		Western Bay, Brampton Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	54 (MP)	NA	NA
MWI	South	Avoid Island, The Percy Group	NA	NA	NA	NA	NA	NA	77 (LP)	NA	NA	58 (MP)	60 (LP)	NA
		Clairview Beach North	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	65 (LP)
		Douglas Island, The Percy Group	69 (LP)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		North Beach, Digby Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	41 (MP)	NA	NA
MWI	Don	Don River Mouth, Bowen	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	87 (VLP)
MWI	Proserpine	Urban Surrounds, Airlie Beach	NA	NA	NA	NA	NA	NA	NA	NA	14 (VHP)	22 (HP)	25 (HP)	25 (HP)
		Urban Surrounds, Jubilee Pocket	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	22 (HP)	NA
		Wilson Beach, Conway	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	79 (LP)
MWI	Pioneer	Pioneer River, Glenella Connection Road North Mackay	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	68 (LP)
GHHP	The Narrows	Phillipies Landing Rd, Targinnie	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	54 (MP)	NA
GHHP	Mid Harbour	Canoe Point, Tannum Sands	NA	NA	NA	NA	NA	NA	NA	NA	82 (VLP)	83 (VLP)	76 (LP)	82 (VLP)
		Esplanade Beach, Curtis Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	28 (HP)
		Facing Island North Point	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	38 (HP)	NA
		North West Shore, Facing Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	51 (MP)	NA
		Tannum Sands Main Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	90 (VLP)	82 (VLP)	81 (VLP)
GHHP	Western Basin	Fisherman's Landing, Gladstone	NA	NA	NA	NA	NA	NA	NA	NA	94 (VLP)	NA	85 (VLP)	90 (VLP)
GHHP	Calliope Estuary	Barney Point, Gladstone	NA	NA	NA	NA	NA	NA	NA	NA	NA	79 (LP)	77 (LP)	36 (HP)
GHHP	South Trees Inlet	Lillys Beach North End, Tannum Sands	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	63 (LP)	48 (MP)
GHHP	Boyne Estuary	Bray Park to Boyne River mouth	NA	NA	NA	NA	NA	NA	NA	73 (LP)	77 (LP)	NA	99 (VLP)	63 (LP)
		Lilleys Beach	NA	NA	NA	NA	NA	NA	NA	NA	82 (VLP)	84 (VLP)	77 (LP)	60 (LP)
GHHP	Outer Harbour	Wild Cattle Creek Boat Ramp, Tannum Sands	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	71 (LP)	41 (MP)
		Wild Cattle Creek Mouth, Tannum Sands	NA	NA	NA	NA	NA	NA	NA	87 (VLP)	82 (VLP)	63 (LP)	55 (MP)	52 (MP)
GHHP	Rodds Bay	The Esplanade Beach, Turkey Beach	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	78 (LP)	66 (LP)
GHHP	Calliope	Auckland Creek, Gladstone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	86 (VLP)	58 (MP)
		Auckland Creek, Golf Course Rd	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	85 (VLP)	83 (VLP)
		Auckland Creek, Hanson Road, Gladstone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	48 (MP)
		Auckland Creek, Lions Park	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	66 (LP)
		Boat Creek Gladstone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	92 (VLP)	NA
		Briffney Creek, Gladstone	NA	NA	NA	NA	NA	NA	NA	NA	NA	96 (VLP)	44 (MP)	56 (MP)
		Calliope River Campgrounds Old Bruce Hwy	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	54 (MP)	34 (HP)
		Calliope River, Gladstone Power Station	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	75 (LP)
		Hazelbrook Park, Calliope	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	87 (VLP)
		Lake Callemondah	NA	NA	NA	NA	NA	NA	NA	NA	87 (VLP)	92 (VLP)	53 (MP)	50 (MP)
		Tigalee Creek, Sun Valley Park, Gladstone	NA	NA	NA	NA	NA	NA	NA	NA	NA	94 (VLP)	88 (VLP)	75 (LP)
		Tigalee Creek, Sun Valley Rd	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	67 (LP)
		Tigalee Creek, Toonee Park, Gladstone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	86 (VLP)	NA
		Tigalee Creek, Witney St	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	82 (VLP)	NA
		Tondoon Botanic Gardens, Gladstone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	93 (VLP)	NA
		Wild Place, Burua	NA	NA	NA	NA	NA	NA	NA	NA	NA	98 (VLP)	NA	NA
		Yarwun	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	77 (LP)
GHHP	Boyne	Boyne Island Conservation Site, Centenary Dr	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	38 (HP)	NA
		Canoe Point Conservation Area, Tannum Sands	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	85 (VLP)	NA
		Canoe Point Reserve, Tanyalla	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	82 (VLP)	95 (VLP)

Region	Zone	Site	1997-1998	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
		Eastern Foreshore, Boyne River, Benaraby	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	60 (LP)	46 (MP)
		Lions Park, Boyne Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	57 (MP)
		Reg Tanna Park, Gladstone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	55 (MP)
		Truck Bay, Corner Bruce Highway and Tannum Sands Road	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	69 (LP)	NA
		Wapentake Wetlands, South Trees	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	39 (HP)	NA
		Wyndham Park, Boyne Island	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	42 (MP)
GHHP	Baffle	Canoe Point Reserve, Tanyalla	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	87 (VLP)	96 (VLP)
		The Sands, Tannum Sands	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	79 (LP)	NA
		Wild Cattle Creek Trail, Tannum Sands	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	93 (VLP)

Appendix E: Community survey questions and indicator categories

Appendix E 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

Index/indicator category	Indicator (survey questions)
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 E 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