dry tropics partnership for healthy waters

Dry Tropics Partnership for Healthy Waters
Waterways Report Card 2023

TECHNICAL REPORT

PART 5: Inshore Marine Results

Reporting on data collected 2021 - 2022

JULY 2023 | Dry Tropics Partnership for Healthy Waters (DTPHW)

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12 Inshore Marine Environment

The Inshore Marine Environment in the Dry Tropics region is comprised of two zones: Cleveland Bay and Halifax Bay. In each zone the water quality, and habitat and hydrology indices are reported. Zones are divided into sub zones based on their water types and water quality objectives. The extent of each zone and sub zone is shown in Figure 11, and results are presented below.

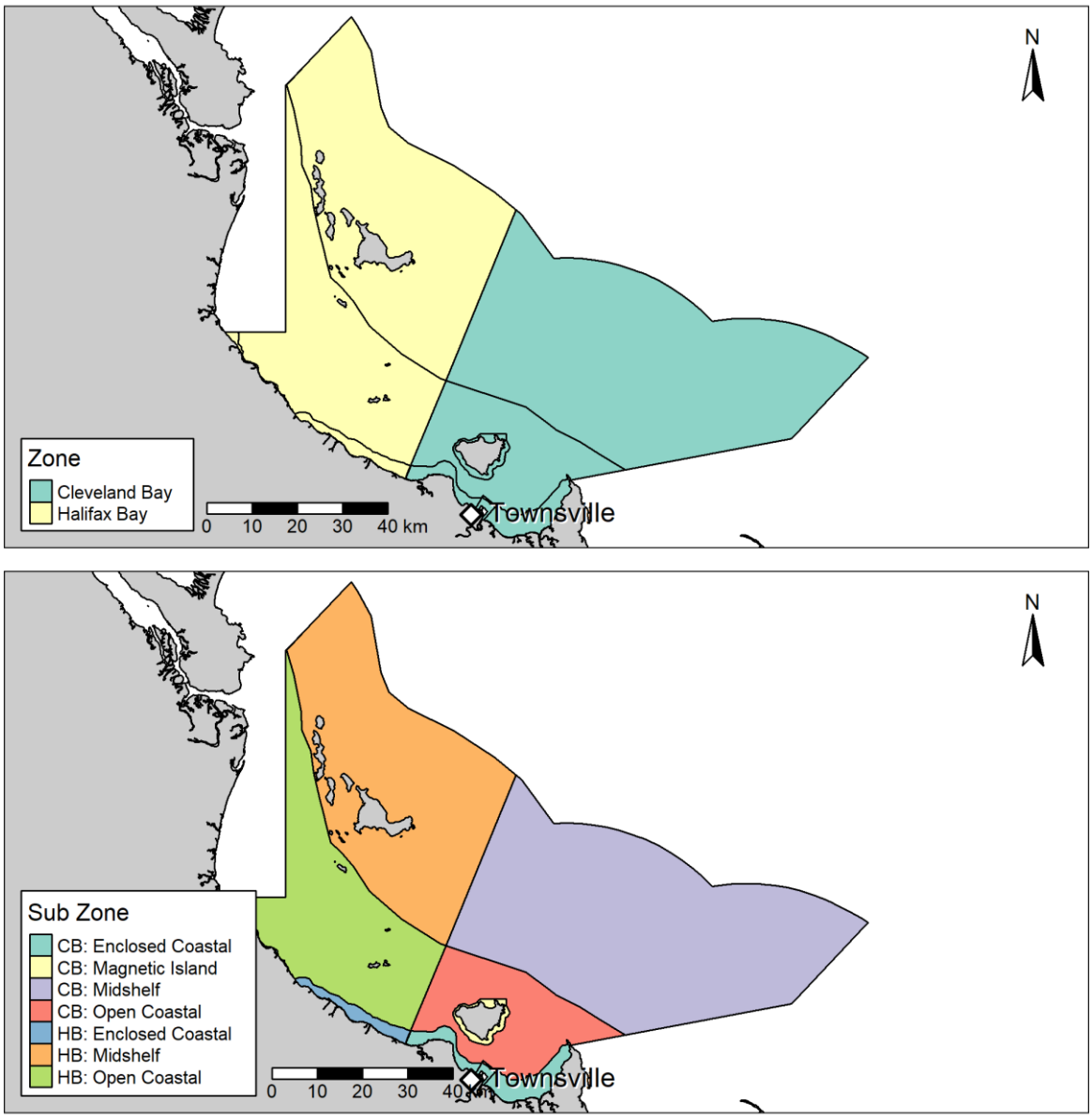

Figure 11. Dry Tropics inshore marine zones and sub zones.

12.1 Water Quality

The water quality index for the Inshore Marine Environment of the Dry Tropics regions consists of three indicator categories: Nutrients, Physical-Chemical Properties, and Chlorophyll *a*. All indicator categories use data provided by multiple partners of the DTPHW team. The water quality index is updated annually, with the most recent updated including data from the 2021–2022 financial year.

12.1.1 Monitoring Sites

In the 2021–2022 technical report, all water quality data was collected from 21 sites. Sites were grouped into eight geographic areas, six sub zones, and two zones as detailed in Table 53. Geographic areas each have unique water quality objectives and are grouped into a sub zone if they share the same water type. Site locations are presented in Appendix PP, and water quality objectives are presented in Appendix QQ, and Appendix TT.

Table 53. Dry Tropics Inshore Marine water quality site summary.

Zone	Sub Zone	Geographic Area	Site[18]
Cleveland Bay	Enclosed Coastal	Enclosed Coastal: Inside Port Zone	1, 2, 3
		Enclosed Coastal: Outside Port Zone	4, 5, 6, 7, 8
	Open Coastal	Open Coastal: Inside Port Zone	9
		Open Coastal: Outside Port Zone	10, 11, 12
	Magnetic Island	Magnetic Island	13, 14, 15
Halifax Bay	Enclosed Coastal	Enclosed Coastal	16, 17
	Open Coastal	Open Coastal	18, 19
	Midshelf	Midshelf	20, 21

12.1.2 Overall Summary: Inshore Water Quality

Scores for the water quality index have improved dramatically since the 2018–2019 Technical Report. In Cleveland Bay water quality has increased from a score of 36 (poor) in 2018–2019, to a score of 83 (very good) in 2019–2020 and has remained stable (81) since then. Halifax Bay water quality has increased from a score of 45 (moderate) to a score of 67 (good). However, scores for the water quality index have remained relatively consistent over the last three reporting periods. In Cleveland Bay the index decreased from 83, to 81 but kept a grade of "very good", and in Halifax Bay the index increased from 60 to 70 between 2019–2020 and 2020–2021, before decreasing to 67 in 2021–2022 (Table 54).

Table 54. Current and previous water quality scores and grades for the Dry Tropics Inshore Marine Environment.

Zone	Nutrients	Phys-Chem Properties	Chlorophyll	Water Quality 2021–2022	2020–2021	2019–2020	2018–2019
CB	78	74	92	81	81	83	36
HB	61	65	77	67	70	60	45

Standardised scoring range: ■ = Very Poor: 0 to <21 | ■ = Poor: 21 to <41 | ■ = Moderate: 41 to <61 | ■ = Good: 61 to <81 | ■ = Very Good: 81 to 100.

12.1.2.1 *Key Messages*

- There has been no change in grade since the previous report card (although the score for Halifax Bay decreased from 70 to 67).

[18] Sites have been de-identified.

- All indicator categories have a grade of good or very good.
- The inclusion of additional indicators (TP and FRP) would create a net gain in scores across both zones.

12.1.3 Nutrients

For the 2021–2022 technical report the nutrients indicator category is comprised of four indicators, Nitrogen Oxides (NOx), Particulate Nitrogen (PN), Particulate Phosphorus (PP), and Total Phosphorus (TP). Total Nitrogen (TN), and Filterable Reactive Phosphorus (FRP), have been included as the exploration of a potential new indicators, however, are not included in the aggregation of indicators to the indicator category level.

12.1.3.1 *Results: Inshore Nutrients*

Mean or median values (depending on the indicator) are compared against the relevant water quality objectives. Values are standardised before the comparison and aggregation of indicators (Lonborg 2016). Unstandardised values, sample frequency, and water quality objectives are presented in Appendix QQ, standardised scores are shown in Table 55. Some water quality objectives have been adjusted by local experts where necessary, these values are marked within tables, and unadjusted values can be found in Appendix RR.

12.1.3.1.1 Cleveland Bay

Cleveland Bay received a nutrient indicator category score of 78 (good). Within the zone, two of three sub zones received nutrient indicator category scores of 100 (very good). However, the Magnetic Island Sub Zone received a score of 18 (very poor). All three indicators in this sub zone (NOx, PN, and PP) were graded as “poor” or “very poor” with scores of 0, 15, and 40 respectively (Table 55).

A low nutrients indicator category score in the Magnetic Island Sub Zone relative to other sub zones could be attributed to several factors. Considerations include, the use of different indicators and water quality objectives (WQOs), different sampling times and frequency, or differences in sampling programs and analysis methods (e.g. LORs) (Appendix QQ). Equally, nutrient pollution sources such as septic systems and large infrastructure projects in close proximity may be a core driver of a low grade and score. For three of four indicators, no comparison across all sub zones can be made, however the NOx indicator was collected at all sites and can be used to explore each of these factors.

The WQO for NOx in the Magnetic Island Sub Zone were 2–9x “stricter” than other sub zones and applying WQOs used in other sub zones may influence scores, however the WQOs have been specifically designed to be representative of desired water quality for each area. Further, NOx concentration was 3x higher in the Magnetic Island Sub Zone and signifies a measurable difference, regardless of objective values (Appendix QQ). Although samples were collected more frequently in the Magnetic Island Sub Zone, analysis revealed it was just as likely these additional samples recorded lower concentration values as they were to record higher concentration values (Appendix QQ). However, the specific time of day may have also played a role (e.g., sampling at low tide vs high tide) and further analysis of this variable is required.

Table 55. Standardised scores and grades for the nutrient indicator category and indicators comprising the nutrient indicator category in the Dry Tropics Inshore Marine Environment.

Zone	Sub Zone	Area	NOx	PN	PP	TP	TN[19]	FRP[20]	Nutrients Area	Nutrients Sub Zone	Nutrients Zone
Cleveland Bay	Enclosed Coastal	Inside Port Zone	100	NA	NA	100	100	100	100	100	78
		Outside Port Zone	100	NA	NA	100	100	100	100		
	Open Coastal	Inside Port Zone	100	NA	NA	100	100	100	100	100	
		Outside Port Zone	100	NA	NA	100	81	100	100		
	Magnetic Island	Magnetic Island	0	15	40	NA	NA	100		18 (E)	
Halifax Bay	Enclosed Coastal	Enclosed Coastal	0	NA	NA	100	NA	100		61	61
	Open Coastal	Open Coastal	57	32	75	NA	NA	96		57	
	Midshelf	Midshelf	64	45	83	NA	NA	96		66	

Standardised scoring range: ■ = Very Poor: 0 to <21 | ■ = Poor: 21 to <41 | ■ = Moderate: 41 to <61 | ■ = Good: 61 to <81 | ■ = Very Good: 81 to 100.

[19] TN is included only as an indicator. TN is not aggregated within the nutrient indicator category.

[20] FRP is included only as an indicator. FRP is not aggregated within the nutrient indicator category.

The unique location and characteristics of the Magnetic Island Sub Zone are likely the main driver of a low NOx score. Although other sub zones are also in close proximity to large-scale infrastructure (e.g., Magnetic Island Marina and Townsville Port), the frequency of smaller infrastructure such as private septic systems is notably higher. Additionally, no other sites sample NOx so far offshore, and the sub zone is likely more exposed to large southern influences such as the Burdekin River (Appendix PP).

Overall, the sub zone frequently receives low scores and grades for the NOx indicator, and consistently records NOx concentrations at or above the water quality guideline levels (Appendix PP). Whereas other sub zones have generally recorded decreasing NOx concentrations over time, with values rarely meeting or exceeding the WQOs (Appendix XX, Figure 74).

12.1.3.1.2 Halifax Bay

Halifax Bay Inshore received a nutrient indicator category score of 61 (good). Within the zone, two sub zones received nutrient indicator category grades of “good” and one sub zone received a grade of “moderate” (Table 55).

There is less contrast in the nutrient indicator category for sub zones in Halifax Bay, and for three of the four indicators, no complete comparison across all sub zones can be made. However, the NOx indicator was collected at all sites and can be used to explore the results. Similar to Cleveland Bay, differences in NOx scores and grades could be attributed to different water quality objectives (WQOs), sampling times, and sampling frequency. Although WQOs did vary, this variation was slight, and the main difference was in mean concentrations (Appendix QQ). Differences in sampling time and frequency were also minimal and showed no clear impact (Appendix ZZ). However, the specific time of day that the sample was collected may also play a role and further analysis is required.

The location of each sub zone may have influenced results and a trend of decreasing NOx concentrations and increasing NOx scores is apparent when moving offshore (Table 55, Appendix PP, Appendix QQ). The trend is visible to a lesser extent in the PN and PP indicators, however both indicators are only measured at two of three sites. Although aspects of the trend are apparent in previous reporting periods, temporal resolution is extremely limited, with results for the Enclosed Coastal Sub Zone only available for the previous reporting period (Appendix PP, Appendix XX).

Overall, this distribution suggests the sources of NOx and other nutrient indicators may be land based in origin with similar factors such as septic systems and runoff as core drivers. However, the mid and outer sub zones of Halifax Bay zone may also be more exposed to large southern influences such as the Burdekin River.

12.1.3.1.3 New Indicators

Two new indicators (FRP and TN) were collected for the 2021–2022 reporting period. Although not included in the aggregation of indicators to produce the nutrients indicator category (Table 55), a secondary analysis has been conducted to review their effect (Appendix EEE). It was found that including these indicators created a net gain in nutrient scores, Cleveland Bay increased from 78 to 83, and Halifax Bay increased from 61 to 72. The FRP indicator had a positive effect at all sub zones, while the TN indicator reduced the nutrient score in one geographic area (Cleveland Bay Open Coastal Outside Port Sub Zone) and had no effect on any other sub zone. The inclusion of the FRP indicator resulted in multiple grade increases, at both the sub zone and zone level, the largest of which was the increase in Magnetic Island from a very poor grade (18) to a moderate grade (44). The

inclusion of the FRP indicator in future reports would allow additional comparison of the same indicator across all sub zones.

12.1.4 Physical Chemical Properties

For the 2021–2022 technical report the physical-chemical properties indicator category is comprised of three indicators, Turbidity (NTU), Total Suspended Solids (TSS), and Secchi Depth (Secchi).

12.1.4.1 *Results: Inshore Physical-Chemical Properties*

Mean or median values (depending on the indicator) are compared against the relevant water quality objectives. Values are standardised before the comparison and aggregation of indicators (Lonborg 2016). Unstandardised values, sample frequency, and water quality objectives are presented in Appendix TT, standardised scores are shown in Table 56. Some values have been adjusted by local experts where necessary, these values are marked within the tables, and unadjusted values can be found in Appendix UU.

Table 56. Standardised scores and grades for the physical-chemical properties indicator category and indicators comprising the physical-chemical properties indicator category in the Dry Tropics Inshore Marine Environment.

Zone	Sub Zone	Area	Turbidity	TSS	Secchi	Physical-Chemical Properties		
						Area	Sub Zone	Zone
Cleveland Bay	Enclosed Coastal	Inside Port Zone	100	100	92	97	70	75
		Outside Port Zone	0	3	83 (A)	34		
	Open Coastal	Inside Port Zone	100	100	100	100	75	
		Outside Port Zone	39	54	39	43		
	Magnetic Island	Magnetic Island	77	85	80		81	
Halifax Bay	Enclosed Coastal	Enclosed Coastal	58	74	NA		66	65
	Open Coastal	Open Coastal	77	72	6		57	
	Midshelf	Midshelf	100	77	30		72	

Standardised scoring range: ■ = Very Poor: 0 to <21 | ■ = Poor: 21 to <41 | ■ = Moderate: 41 to <61 | ■ = Good: 61 to <81 | ■ = Very Good: 81 to 100.

12.1.4.1.1 Cleveland Bay

Cleveland Bay received a physical-chemical properties indicator category score of 75 (good). Within the zone, all sub zones received grades of "good" or "very good" however scores and grades for each indicator varied ranging from 0 to 100 for Turbidity, 3 to 100 for TSS, and 39 to 100 for Secchi (Table 56). The wide range of scores and grades received for all indicators could be attributed to several factors, including the use of different water quality objectives (WQOs), different sampling times and frequency, or differences in sampling programs and analysis methods (Appendix TT). Equally, spatial variations such as proximity to large river outflows, distance offshore, and proximity to the Cleveland Bay shipping channel may be a core driver of a low grade and score.

Some variation in indicators scores between geographic areas can be explained by differences in WQOs. For example, mean values for TSS and Secchi were similar in the Open Coastal Outside Port Zone and Open Coastal Inside Port Zone areas, but differences in WQOs resulted in significantly different standardised scores (Table 56, Appendix TT, Appendix WW). However, WQOs have been specifically designed to be representative of desired water quality for the area, and further, differences are not always responsible for the variation. For example, the "very poor" scores for Turbidity and TSS in the Enclosed Coastal Outside Port Zone area were the result of very high mean values for each indicator, rather than variations in WQOs (Table 56, Appendix TT).

Very poor scores received by the Turbidity and TSS indicators in the Enclosed Coastal Outside Port Zone area are likely driven by a combination of spatial and temporal factors. For both indicators more than 4x as days of grab sampling was conducted, with additional days regularly recording higher Turbidity and TSS values (Appendix AAA, Figure 85, Appendix BBB, Figure 86). These additional sampling days may have picked up on events that were missed in other geographic areas such as dredging that has occurred during the Channel Upgrade program. Interestingly, the secchi indicator in the same geographic area (Enclosed Coastal Outside Port Zone) also did not have the additional sampling and received a notably higher score (Table 56, Appendix CCC). However, while the Turbidity and TSS indicators did receive more days of samples than secchi, the indicators also received samples across more sites. Specifically, Turbidity and TSS were recorded at sites 4, 5, 6, 7, 8, and 9, while secchi was only recorded at site 9 (Appendix PP). These additional sites were in close proximity to the mouth of Sandfly Creek, and downstream of the Cleveland Bay Waste Treatment plant and may have been negatively influenced.

12.1.4.1.2 Halifax Bay

Halifax Bay received a physical-chemical properties indicator category score of 65 (good). Within the zone, two sub zones received nutrient indicator category grades of "good" and one sub zone received a grade of "moderate" (Table 56).

Across Halifax Bay a spatial trend of improved water quality further offshore is apparent, particularly for the Turbidity indicator, with a clear change in grade at each sub zone and similar stepped progression in mean values (Table 56, Appendix TT). Although the standardised grades for TSS in each sub zone do not display this trend, the mean values suggest a similar improvement in concentration between the enclosed and Open Coastal Sub Zones (Appendix TT). The secchi indicator is only measured at two of three sub zones but does show the same trend of improvement further offshore.

Overall, this distribution suggests the sources of decreased water clarity may be predominantly land based in origin, similar to nutrient indicators. Sediment run off and river flow are likely influences.

12.1.5 Chlorophyll *a*

12.1.5.1 *Results: Inshore Chlorophyll a*

Mean chlorophyll *a* values are compared against the relevant water quality objectives. Values are standardised before the comparison and aggregation of indicators (Lonborg 2016). Unstandardised values, sample frequency, and water quality objectives are presented in Appendix TT, standardised scores are shown in Table 57. Some values have been adjusted by local experts where necessary, these values are marked within the tables, and unadjusted values can be found in Appendix TT.

Table 57. Standardised scores and grades for the chlorophyll a indicator in the Dry Tropics Inshore Marine Environment.

Zone	Sub Zone	Area	Chlorophyll *a*		
			Area	Sub Zone	Zone
Cleveland Bay	Enclosed Coastal	Inside Port Zone	NA	100	92
		Outside Port Zone	100		
	Open Coastal	Inside Port Zone	NA	NA	
		Outside Port Zone	NA		
	Magnetic Island	Magnetic Island		83	
Halifax Bay	Enclosed Coastal	Enclosed Coastal		100	77
	Open Coastal	Open Coastal		75	
	Midshelf	Midshelf		54	

Standardised scoring range: ■ = Very Poor: 0 to <21 | ■ = Poor: 21 to <41 | ■ = Moderate: 41 to <61 | ■ = Good: 61 to <81 | ■ = Very Good: 81 to 100.

12.1.5.1.1 Cleveland Bay

Cleveland Bay received a chlorophyll *a* indicator category score of 92 (very good). The Magnetic Island and Enclosed Coastal sub zones received grades of "very good" and the Open Coastal Sub Zone was not graded (Table 57). Mean values were below objectives in all locations (Appendix TT).

12.1.5.1.2 Halifax Bay

Halifax Bay received chlorophyll *a* score of 77 (good). The Enclosed Coastal Water Sub Zone received a score of 100, the Open Coastal Waters Sub Zone received a score of 75, and the Midshelf Sub Zone received a score of 54. Interestingly, across the zone there appears to be a reversal of the spatial trend found in the other indicator categories (improvement further offshore). At each sub zone the grade decreases, from very good in the Enclosed Coastal Sub Zone to moderate in the Midshelf Sub Zone (Table 57).

12.1.5.2 *Overlap with the Wet Tropics Technical Report*

The Dry Tropics reporting region shares sites 19, 20, 21, and 22 with the Wet Tropics reporting region (Table 53, Appendix PP). Underlying data is identical, however differences in aggregation and reporting style result in minor discrepancies in the final presentation of results (Appendix DDD).

12.1.6 Confidence Scores

Overall, there was low confidence in the results due to limited spatial and temporal sampling for some indicators in both bays (Table 58). For example, within Cleveland Bay almost all sites are within

an 11km section of water near the coastline, despite the Enclosed Coastal Waters stretching more than 58km. It is noted that there is less development in these other areas and thus current monitoring may capture most of the areas impacted by human. More sampling, both along the coast and further offshore, would enable a more accurate understanding of the water quality within the inshore area.

Table 58. Confidence scores for the nutrients, physical-chemical properties, and chlorophyll a indicator categories.

Indicator Category	Maturity (x0.36)	Validation (x0.71)	Representativeness (x2)	Directness (x0.71)	Measured error (x0.71)	Score (Rank)
Nutrients	2	3	1	3	1	7.6 (2)
Phys-Chem	2	3	1	3	1	7.6 (2)
Chlorophyll *a*	2	3	1	3	1	7.6 (2)

Rank based on score: 1 (very low) = 4.5 to 6.3; | 2 (low) = >6.3 to 8.1; | 3 (moderate) = >8.1 to 9.9; | 4 (high) = >9.9 to 11.7; | 5 (very high) = >11.7 to 13.5.

12.2 Habitat

The habitat and hydrology index for the Inshore Marine Environment of the Dry Tropic region consists only of habitat specific indicator categories and is therefore referred to throughout as the habitat index. The habitat index is comprised of two indicator categories: coral, and seagrass, and both indicator categories source their results and discussion from reports published by partner organisations (Mckenna 2022, Thompson 2023).

12.2.1 Overall Summary: Inshore Habitat

Habitat in Cleveland Bay received a score of 57 (good). Scores have improved on all previous years and show a recovery of habitat health to pre-2019 levels. Habitat in Halifax Bay, declined from all previous reporting periods but remained moderate with a score of 45. These results provide insight into the mixed habitat health of the Inshore Marine Environment, and several factors play a role in the grades and scores of this indicator, such as the residual impact of the 2019 flooding event (Table 59).

Table 59. Standardised score for the Inshore Marine Environment habitat index.

Zone	Coral	Seagrass	Habitat Index			
			2021–2022	2020–2021	2019–2020	2018–2019
Cleveland Bay	41	73	57	54	48	56
Halifax Bay	45	ND	45	49	52	52

Coral Standardised scoring range: ■ = Very Poor: 0 to <21 | ■ = Poor: 21 to <41 | ■ = Moderate: 41 to <61 | ■ = Good: 61 to <81 | ■ = Very Good: 81 to 100.

Seagrass Standardised scoring range: ■ = Very Poor: 0 to <25 | ■ = Poor: 25 to <50 | ■ = Moderate: 50 to <65 | ■ = Good: 65 to <85 | ■ = Very Good: 85 to 100.

12.2.1.1 *Key Messages*

- Habitat in Cleveland Bay has received its highest score in the past four years of 57.
- Habitat (coral) in Halifax Bay has received its lowest score in the past four years of 45.
- Seagrass in Cleveland Bay has almost recovered to pre-2019 flood conditions.

- Coral in Cleveland Bay has fluctuated between moderate and poor for the past four years.
- There remains a significant amount of macroalgae recorded at five of seven sites.

12.2.2 Coral

Coral data within the Dry Tropics Inshore Marine Environment was primarily collected by the Great Barrier Reef Marine Monitoring Program (MMP), and the Australian Institute of Marine Science's Long-term Monitoring Program (LTMP). Additional sampling was conducted by the citizen scientist group Reef Check Australia (RCA). Coral was monitored primarily between May 2022 and July 2022 as this allows most influences resulting from summer disturbances such as tropical cyclones and thermal induced coral bleaching to be realised. The coral indicator category is comprised of five indicators that make up the final score for each sample location. These five indicators are hard coral composition, percentage of hard coral cover, percentage change of hard coral, juvenile coral density, and macroalgae density. These five indicators are only measured by the MMP and LTMP while the coral monitoring conducted by RCA only measures the percentage of hard coral cover indicator. This is reflected in the scores shown below (Table 61).

12.2.2.1 *Monitoring Sites*

Cleveland Bay and Halifax Bay were sampled for the Inshore Marine Environment coral assessment. Within Cleveland Bay six sites were sampled, with one site sampled twice by different monitoring programs (Geoffrey Bay). In Halifax Bay six sites were sampled, with two sites sampled twice by different monitoring programs (Pandora Reef and Havannah Reef) (Table 60). Reef locations are shown in Appendix FFF, noting that the Palms West Reef consists of two sites.

Table 60. Inshore Marine coral sampling locations and sampling programs.

Zone	Sampling Program	Sampling Site	ID
Cleveland Bay	MMP & RCA	Geoffrey Bay	1
	RCA	Alma Bay	2
		Florence Bay	3
		Middle Reef	4
		Nelly Bay	5
Halifax Bay	MMP	Palms East	6
		Palms West	7
		Pandora South	8
		Havannah South	9
	LTMP	Pandora North	10
		Havannah North	11

12.2.2.2 *Results: Inshore Coral*

The discussion of these results has been sourced from the Marine Monitoring Program Annual Report for inshore coral reef monitoring 2021–22 report[21].

"The coral indicator category score for the Dry Tropics Inshore Marine Environment has declined from a peak reached in 2020 and remains moderate in 2022. The decline is due primarily to Juvenile coral and Macroalgae scores. In contrast, the mean cover of corals across the region in 2022 reached its highest level since the inception of the MMP in 2005, despite exposure to high water temperatures that led to coral bleaching in 2020 and 2022. While attaining the highest level of coral cover observed during 18 years of monitoring is clearly a positive indication of the resilience of coral reefs in the region, low scores for the Macroalgae indicator suggest ongoing environmental pressures are limiting the condition of some reefs (Table 61)" (Thompson 2023).

Table 61. Inshore Marine coral indicator and indicator category scores for all sites and zones.

Zone	ID	Hard Coral Composition	% Coral Cover	% Change Hard Coral	Juvenile Density	Macroalgae	Indicator Category
Cleveland Bay	1	75	48	56	20	0	40
	2	ND	68	ND	ND	ND	ND
	3	ND	34	ND	ND	ND	ND
	4	ND	83	ND	ND	ND	ND
	5	ND	36	ND	ND	ND	ND
Cleveland Bay		75	51	56	20	0	41
Halifax Bay	6	100	64	46	19	93	64
	7	0	47	60	43	100	50
	8	75	28	51	29	16	40
	9	50	50	51	23	0	35
	10	0	74	26	53	0	3
	11	100	17	50	88	0	51
Halifax Bay		54	47	47	43	35	45

Standardised scoring range: ■ = Very Poor: 0 to <21 | ■ = Poor: 21 to <41 | ■ = Moderate: 41 to <61 | ■ = Good: 61 to <81 | ■ = Very Good: 81 to 100.

12.2.2.2.1 Hard Coral Composition

"The composition indicator declined slightly from a high in 2020 but remains on the boundary between moderate and good in 2022. In general, the steady rise in this indicator through to 2020 tracked the recovery of sensitive corals impacted by TC Yasi and subsequent flood plumes of 2011. Moderate scores for this indicator demonstrate coral community composition remains consistent with the observed in the first years of monitoring.

[21] AIMS MMP data can be found [here].

12.2.2.2.2 Percentage of Hard Coral Cover

There were modest gains in hard coral cover at Havannah, Palms West, and Pandora. Increases were attributed to recovery of *Acropora*, *Montipora*, *Isopora spp*, and a suite of low-abundance genera. The largest decline in coral cover occurred at Palms East, where cover declined from 45.5% in 2021 to 43.1% in 2022. Bleached corals were not observed at this reef and the cause of this decline appears to have been white syndrome disease amongst *Acropora.*

12.2.2.2.3 Percentage Change of Hard Coral

The cover change indicator score for the region has remained moderate with a slight upward trend indicating recovery from the 2020 bleaching event and an ongoing positive balance between losses and gains in cover in recent years.

12.2.2.2.4 Juvenile Density

Juvenile coral density has declined, particularly the Acropora spp., at all reefs measured since 2020. Juvenile density has always been variable among the Dry Tropics reefs but the consistent decline since the 2020 and 2022 bleaching events raise the potential for thermal stress to be impacting early life-history phases of corals. Thermal stress has been shown to lead to reproduction decreasing over subsequent spawning seasons (Ward 2002, Johnston 2020). Furthermore, historic recovery from acute events in the region has been shown to be slow and monitoring of coral settlement during the early years of the MMP indicated sporadic but generally low supply of larvae (Sweatman 2007, Cheal 2013, Davidson 2019). Both low larval supply, and low settlement, may logically contribute to the low density of juveniles on most reefs. Preliminary hydrodynamic modelling (Luick 2007, CSIRO 2023) and differences in population genetics of corals (Mackenzie 2004) indicate limited connectivity between inshore and offshore reefs, meaning local fluctuations are likely to directly influence larval supply.

12.2.2.2.5 Macroalgae

The Macroalgae indicator has continued to decline and remains poor. Very poor scores were recorded at both Havannah and Pandora sites, and Geoffrey Bay where the cover of macroalgae increased or remained at high levels. The macroalgal communities are dominated by large brown species of the genus *Lobophora* and/or *Sargassum*. The high prevalence of macroalgae on many reefs are likely to be suppressing the recovery potential of coral communities. Except for Palms East, and Palms West, macroalgae are common among the reef's algae, as reflected in the poor score for Macroalgae. Although there is substantial variation in the mechanism and strength of interactions between macroalgae and the early life history stages of corals, it can be generally assumed that macroalgae will negatively influence the density of juvenile corals (Viera 2020, Doropoulos 2021). The causes for the recent increase in macroalgae are unknown." (Thompson 2023).

12.2.2.2.6 Overall

In Cleveland Bay, the grade for the coral indicator category was moderate, with a score of 41. This is an improvement on the score and grade from the previous reporting period of 36 (poor), a decline on the 2019–2020 reporting period score of 44, and an improvement in 2018–2019 score of 38. In Halifax Bay, the grade for the coral indicator category was moderate, with a score of 45. This is a decline on the score from all previous reporting periods (48, 50, 52) (Table 62). A key driving factor may be the increased risk of coral bleaching demonstrated by the DHWs risk matrix (Figure 8) due to sea surface temperature increases. These results show a mixed trend of overall coral health as reefs

have been exposed to pressures, such as increased water temperatures that contributed to coral bleaching in 2020 and continues to influence coral bleaching in 2022.

Table 62. Inshore Marine Environment coral indicator category scores for current and previous technical reports.

Zone	Coral Standardised Score			
	2021–2022	2020–2021	2019–2020	2018–2019
Cleveland Bay	41	36	44	38
Halifax Bay	45	48	50	52

Standardised scoring range: ■ = Very Poor: 0 to <21 | ■ = Poor: 21 to <41 | ■ = Moderate: 41 to <61 | ■ = Good: 61 to <81 | ■ = Very Good: 81 to 100.

12.2.2.3 *Back Calculated Scores*

As the number of coral sites sampled for the 2021–2022 technical report has been updated. Previous results have been back calculated and updated in Table 62, while the original results can still be found in Appendix GGG.

12.2.3 Seagrass

Data for the seagrass indicator category was sourced from the Port of Townsville Long-Term Seagrass Monitoring Program (LTSMP), with monitoring conducted by James Cook University (JCU) (Mckenna 2022)[22]. The LTSMP monitors seagrass annually during the dry season (September – October), when seagrasses are generally at the peak of distribution and abundance. The 2021–2022 technical report uses data collected during September to October in 2021.

12.2.3.1 *Monitoring Sites*

In 2021–2022 seagrass was only monitored in Cleveland Bay. Across Cleveland Bay, ten seagrass meadows are monitored in the LTSMP, and are divided into three spatially distinct groups, Magnetic Island meadows, Cape Pallarenda/Strand meadows, and Cleveland Bay meadows (Table 63). Discussions will focus on these groups. Meadow locations are provided in Appendix HHH.

[22] The [Port of Townsville Seagrass Monitoring Program 2021] report can be found online.

Table 63. Overview of the Long-term Seagrass Monitoring Program (LTSMP) meadows. Adapted from (Mckenna 2022).

Region	Meadow	ID	History
Magnetic Island	Geoffrey Bay	3	Detailed Annual >10 years
	Nelly Bay	4	Detailed Annual >10 years
	Cockle/Picnic Bay	5	Detailed Annual >10 years
	Cockle Bay	6	Detailed Annual >10 years
Cape Pallarenda – Strand	Shelly Beach	10	Detailed Annual >10 years
	Rowes Bay	12	Detailed Annual >10 years
	Pallarenda inc. Virago Shoal	14	Detailed Annual >10 years
	Strand	15	Detailed Annual >10 years
Cleveland Bay	Cleveland Bay	16	Detailed Annual >10 years
	Cleveland Bay	17/18	Detailed Annual >10 years

12.2.3.2 *Results: Inshore Seagrass*

The discussion of these results has been sourced from the Port of Townsville Seagrass Monitoring Program 2021 report.

"The seagrass indicator category is comprised of three indicators that make up the final score for each meadow. These indicators are biomass, area, and species composition. The final score for each meadow is calculated as the lowest individual score of the three indicators, except when species composition is the lowest score. When species composition is the lowest score the final meadow score is calculated as the average of the two lowest indicator scores (e.g., meadow 12 in (Table 64)." (Mckenna 2022).

Table 64. Seagrass indicator scores for all meadows in the Cleveland Bay Inshore Marine Environment.

Region	ID	Biomass	Area	Species Comp.	Meadow Score
Magnetic Island	3	72	86	100	72
	4	79	90	100	79
	5	59	72	99	59
	6	68	79	97	68
Cape Pallarenda – Strand	10	77	58	77	58
	12	96	100	80	88
	14	83	89	99	83
	15	76	83	88	76
Cleveland Bay	16	88	68	97	68
	17/18	79	93	97	79
Overall					73

Standardised scoring range: ■ = Very Poor: 0 to <25 | ■ = Poor: 25 to <50 | ■ = Moderate: 50 to <65 | ■ = Good: 65 to <85 | ■ = Very Good: 85 to 100.

12.2.3.2.1 Magnetic Island seagrass meadows

“There are four monitoring meadows around Magnetic Island (Table 64, Appendix HHH). These meadows range from intertidal to deep-water (>8m below MSL) meadows. The seagrass indicator category score for all meadows in this area was of moderate or better condition for the 2021–2022 report.

The area indicator for all monitoring meadows around Magnetic Island was rated as good or very good compared to their historical baselines. In 2021 all meadows around Magnetic Island maintained a similar footprint to that of 2020 (Table 64).

The meadow biomass (density) indicator was in moderate or better condition for all Magnetic Island monitoring meadows. The intertidal Cockle Bay meadow (Meadow 5) was the only meadow that decreased in condition from good in 2020 to moderate in 2021. This decrease in biomass occurred relatively evenly across the meadow. Individual meadow biomass ranged from 1.69 g DW m^2 to 7.82 g DW m^2 around the island (Table 64).

The species composition indicator at all meadows was also above baseline conditions, with a species mix that reflected a very good condition in all meadows. The only notable change in species composition that occurred around the island was in the Cockle Bay Reef meadow (Meadow 5) where there was a substantial increase in the contribution of *Thalassia hemprichii* to the meadow. There was a corresponding decrease in the presence of *Cymodocea serrulata* in the meadow. These two stable species are very similar in biomass, so it is unlikely that this shift in dominant species was the cause of the biomass decline seen in the meadow (Table 64).

12.2.3.2.2 Cape Pallarenda–Strand seagrass meadows

There are four monitoring meadows that make up the Cape Pallarenda–Strand region (meadows 10, 12, 14, 15) (Table 64, Figure 90). The seagrass indicator category for all meadows in this area was of moderate or better condition for the 2021–2022 report.

The biggest spatial changes between 2020 and 2021 across all monitoring meadows occurred in this region (area indicator). The intertidal/shallow subtidal *H. uninervis* meadow between Cape Pallarenda and Kissing Point (Meadow 12) increased to its largest recorded area in the program; 320ha. Most of the expansion of this meadow occurred at the deeper margins of the meadow and through the middle of the meadow where historically it has been patchy. The meadow adjacent to Meadow 12: the shallow subtidal *H. spinulosa* meadow, between Cape Pallarenda and Breakwater Marina (Meadow 14) also expanded in its distribution by up to 50%, changing in condition from good in 2020 to very good in 2021 for area. Most of the expansion of this meadow also occurred at the deeper margins of the meadow, with the meadow extending out to 5.2m below mean sea level (Table 64).

Meadow biomass across all meadows in this region remained in moderate or better condition, similar to 2020. For Meadow 12, along with the area indicator, there was a corresponding increase in meadow biomass to one of the highest meadow densities recorded for the meadow in the program; 5.36 g DW m^2. Much of the biomass increase occurred in the northern half of the meadow where higher density, continuous cover seagrass occurred. There were no other notable changes in meadow biomass for the other meadows in the region (Table 64).

Species composition for all four meadows in the region was in good or very good condition in 2021. Species composition has been relatively stable in the inshore *H. uninervis* meadow (12). In 2021 there was a higher proportion of *H. uninervis* ‘wide’ morphological form in the meadow which likely

contributed to the increase in meadow biomass. Species composition in the adjacent subtidal *H. spinulosa* meadow has also been stable but the dominant species has switched through the years between *H. spinulosa* and *H. uninervis*. For the intertidal Shelley Beach (meadow 10), *Z. muelleri* species composition has been in good or very good condition since 2017. Similarly, species composition in the 'Strand' meadow (15) has been in very good condition for the last two years, with *H. uninervis* the dominant species over these years (Table 64).

12.2.3.2.3 Cleveland Bay seagrass meadows

There are two monitoring meadows in Cleveland Bay: the intertidal *Z. muelleri* meadow (16) and the shallow subtidal *H. uninervis* meadow (17/18). These meadows are the largest coastal meadows in Townsville. Both meadows were in an overall good condition in 2021 in both programs (Table 64).

At the adjacent subtidal *H. uninervis* meadow (meadow 17/18), meadow biomass rebounded from a low in 2019, to be in good condition in 2020 and has remained in good condition through 2021. The area of this meadow has also been on an upward trajectory over the last several years. Much of this increase has been the result of meadow expansion at the deeper margins of the meadow. The species composition in the meadow has been stable since 2018. *Halodule uninervis* accounts for around 50% of the meadow biomass (Table 64)." (Mckenna 2022).

12.2.3.2.4 Overall

In Cleveland Bay, the grade for seagrass monitoring meadows was good, with a score of 73. This is a slight improvement on the score from the previous reporting period (71) and a large improvement on the 2019–2020 reporting period score (52). These results show an upward trend of growth and recovery over the past three reporting periods for overall seagrass health (Table 65).

Table 65. Standardised score for the seagrass indicator category.

Zone	Seagrass Standardised Score			
	2021–2022	2020–2021	2019–2020	2018–2019
Cleveland Bay Inshore Marine Zone	73	71	52	74

Standardised scoring range: ■ = Very Poor: 0 to <25 | ■ = Poor: 25 to <50 | ■ = Moderate: 50 to <65 | ■ = Good: 65 to <85 | ■ = Very Good: 85 to 100.

12.2.4 Confidence Scores

Confidence in the seagrass and coral indicator categories was high to very high. Seagrass had a rank of 5 out of 5, and the coral indicator had a rank of 3, and 4 (Cleveland Bay was not as well represented as Halifax Bay). Across both zones, the coral indicator received a maturity score of 3 as methods have been peer reviewed and published. Validation and directness both received a 3 as extensive on ground validation and direct measurement of corals occurs, and measured error received a 2 as some components of the indicator do not have their error quantified. Cleveland Bay received a representativeness score of 1.5 as although fives reefs are sampled, at four of these sites only one of the five coral indicators are measured. While Halifax Bay received a representativeness score of 2 as all five indicators are measured at six sites. The seagrass indicator category received a perfect confidence score, with a 3 in every category due to an extensive, and mature monitoring methodology, with more than ten years of monitoring across 10 distinct meadows.

Table 66. Confidence scores for the coral and seagrass indicator categories.

Indicator Category	Maturity (x0.36)	Validation (x0.71)	Representativeness (x2)	Directness (x0.71)	Measured error (x0.71)	Score (Rank)
Coral (CB)	3	3	1.5	3	2	9.8 (3)
Coral (HB)	3	3	2	3	2	10.8 (4)
Seagrass	3	3	3	3	3	13.5 (5)

Rank based on score: 1 (very low) = 4.5 to 6.3; | 2 (low) = >6.3 to 8.1; | 3 (moderate) = >8.1 to 9.9; | 4 (high) = >9.9 to 11.7; | 5 (very high) = >11.7 to 13.5.