Gladstone
Healthy Harbour
Partnership

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2024 TECHNICAL REPORT

2024 GLADSTONE HARBOUR REPORT CARD

Authorship statement

This Gladstone Healthy Harbour Partnership (GHHP) Technical Report was written based on material from several separate project reports. Authorship of the GHHP Technical Report is shared by the authors of each of those project reports and the GHHP Research Officer. They summarised the project reports and supplied additional material. The authors of the project reports contributed to the final product. They are listed here by the section/s of the report to which they contributed.

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Executive Summary

Context

The 2024 Gladstone Harbour Report Card evaluates four key aspects of harbour health: Environmental, Social, Cultural, and Economic. Environmental health is assessed across 13 zones within and around Gladstone Harbour. The 2024 report includes data from Environmental and Economic monitoring conducted between 1 July 2023 and 30 June 2024. However, no new assessments were made for the Social and Cultural indicators, so results from previous years have been carried forward. The Economic component is only partially updated, with Economic Value data repeated from the 2022 report. Similarly, the Environmental Fish Health Assessment Index (HAI) scores remain unchanged since 2021. All indicator scores, ranging from 0.00 to 1.00, are converted into grades (see Figure 1).

A **Very good** (0.85 – 1.00)

B **Good** (0.65 – 0.84)

C **Satisfactory** (0.50 – 0.64)

D **Poor** (0.25 – 0.49)

E **Very poor** (0.00 – 0.24)

Figure 1 | Grading scheme used to convert scores to grades in the 2024 Gladstone Harbour Report Card for each component of harbour health.

Overall component grades

In the 2024 Gladstone Harbour Report Card, the Environmental, Social and Economic components received a good (B) grade and Cultural components received a satisfactory (C) grade (Figure 2), with scores for Social and Cultural components carried over from previous assessments.

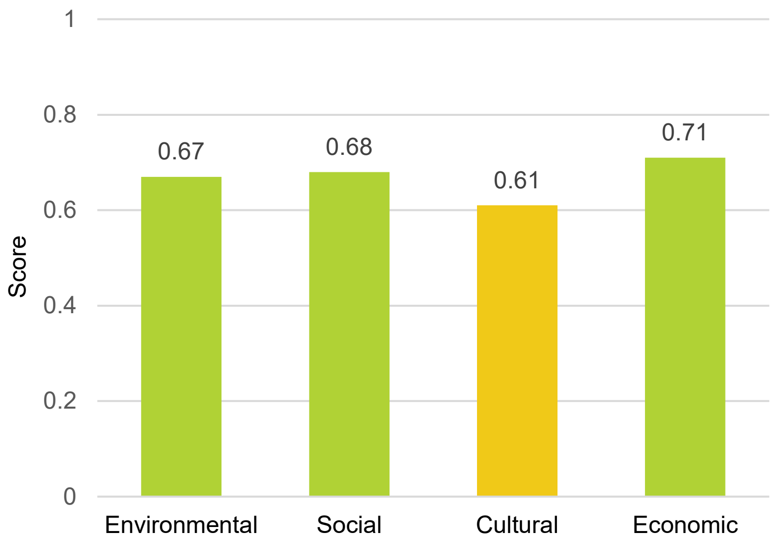

Figure 2 | Overall scores for each of the four components of Gladstone Harbour health in 2024.

Environmental Health

Environmental Health improved from a satisfactory (C) grade in 2023 to a good (B) grade in 2024, with the overall score rising from 0.63 to 0.67.

- Water and Sediment Quality maintained a very good (A) grade with a score of 0.89. Water Quality improved slightly (2023: 0.81, 2024: 0.83), while Sediment Quality remained stable (2023: 0.97, 2024: 0.96).
- Habitats retained a poor (D) grade (0.48), primarily due to low Coral scores (2023 and 2024: 0.14). However, Seagrass scores improved (2023: 0.58, 2024: 0.68), raising its grade from satisfactory (C) to good (B). Mangrove scores also improved (2019: 0.57, 2024: 0.63) but retained a satisfactory (C) grade.
- Fish and Crabs scores increased slightly (2023: 0.57, 2024: 0.62), maintaining a satisfactory (C) grade. Fish health scores remained stable, while Fish recruitment scores improved (2023: 0.47, 2024: 0.57), achieving a satisfactory (C) grade. Mud crab scores declined (2023: 0.51, 2024: 0.46), dropping to a poor (D) grade.

Table 1 | Environmental indicator group scores used in the 2024 Gladstone Harbour Report Card.

Zone	Water and Sediment Quality	Habitats	Fish and Crabs
1. The Narrows	0.84	0.76	0.64
2. Graham Creek	0.93	0.73	0.56
3. Western Basin	0.89	0.67	0.83
4. Boat Creek	0.87	0.65	0.74
5. Inner Harbour	0.86	0.50	0.68
6. Calliope Estuary	0.90	0.73	0.57
7. Auckland Inlet	0.88	0.47	0.52
8. Mid Harbour	0.88	0.39	0.69
9. South Trees Inlet	0.91	0.70	0.61
10. Boyne Estuary	0.87	0.66	0.74
11. Outer Harbour	0.95	0.40	0.84
12. Colosseum Inlet	0.91	0.64	0.76
13. Rodds Bay	0.92	0.73	0.59
Harbour score	0.89	0.48	0.62

Water and Sediment Quality

Since the first report card in 2015, Water quality has consistently achieved good (B) or very good (A) grades, with Sediment quality maintaining very good (A) grades throughout.

Water quality

In the 2024 report card, the Water quality indicator score for Gladstone Harbour was 0.83, earning a good (B) grade (Table 2). Of the 13 zones assessed, three achieved very good (A) grades, while the remaining ten received good (B) grades. Improvements were observed in the nutrient sub-indicator, with Boat Creek improving from poor (D) to satisfactory (C). However, South Trees Inlet and Colosseum Inlet saw declines, both dropping from good (B) to satisfactory (C). Overall, dissolved metals retained very good (A) grades across all zones.

Table 2 | Water quality sub-indicator and zone scores used in the 2024 Gladstone Harbour Report Card. Water quality scores are calculated by aggregation of physiochemical, nutrients and dissolved metals scores. Scores from 2023 and 2022 are shown for comparison.

Water quality	Physico chemical	Nutrients	Dissolved metals	2024	*2023*	*2022*
1. The Narrows	0.78	0.56	1.00	0.78	*0.79*	*0.77*
2. Graham Creek	0.96	0.73	1.00	0.90	*0.85*	*0.85*
3. Western Basin	0.83	0.57	1.00	0.80	*0.78*	*0.77*
4. Boat Creek	0.83	0.64	1.00	0.82	*0.69*	*0.78*
5. Inner Harbour	0.76	0.65	1.00	0.80	*0.78*	*0.84*
6. Calliope Estuary	0.75	0.71	1.00	0.82	*0.81*	*0.81*
7. Auckland Inlet	0.79	0.65	0.97	0.80	*0.77*	*0.78*
8. Mid Harbour	0.80	0.60	1.00	0.80	*0.82*	*0.84*
9. South Trees Inlet	0.87	0.64	1.00	0.84	*0.85*	*0.79*
10. Boyne Estuary	0.79	0.51	1.00	0.76	*0.70*	*0.86*
11. Outer Harbour	0.94	0.82	1.00	0.92	*0.94*	*0.88*
12. Colosseum Inlet	0.87	0.58	0.99	0.81	*0.88*	*0.81*
13. Rodds Bay	0.94	0.68	1.00	0.87	*0.86*	*0.76*
Harbour score	0.84	0.69	1.00	0.83	*0.81*	*0.81*

Sediment quality

For the tenth consecutive year Sediment quality was graded very good (A) in all harbour zones (Table 3). The high scores were due to low concentrations for all measures (arsenic, cadmium, copper, lead, mercury, nickel and zinc).

Table 3 | Sediment quality scores used in the 2024 Gladstone Harbour Report Card. Scores from 2022 and 2023 are shown for comparison.

Zone	2024	*2023*	*2022*
1. The Narrows	0.91	*0.95*	*0.94*
2. Graham Creek	0.96	*1.00*	*0.97*
3. Western Basin	0.98	*0.99*	*0.98*
4. Boat Creek	0.91	*0.94*	*0.89*
5. Inner Harbour	0.93	*0.93*	*0.94*
6. Calliope Estuary	0.99	*0.97*	*0.97*
7. Auckland Inlet	0.95	*0.97*	*0.95*
8. Mid Harbour	0.96	*0.97*	*0.98*
9. South Trees Inlet	0.97	*0.96*	*0.97*
10. Boyne Estuary	0.97	*0.99*	*0.99*
11. Outer Harbour	0.98	*0.99*	*1.00*
12. Colosseum Inlet	1.00	*1.00*	*0.96*
13. Rodds Bay	0.97	*1.00*	*1.00*
Harbour score	0.96	*0.97*	*0.96*

Habitats

Habitats retained a poor (D) grade although the scores improved slightly (2023: 0.43, 2024: 0.48). The three indicators from the Habitats group, Seagrass, Coal and Mangroves, were all assessed in 2024.

Seagrass

Gladstone Harbour seagrass condition was assessed across 14 representative meadows in six monitoring zones. Three sub-indicators were used: biomass (above-ground biomass of a meadow), area (total area of a meadow) and species composition (relative proportions of different species within a meadow).

Seagrass monitoring showed a significant improvement, with the overall score increasing from 0.58 in 2023 to 0.68 in 2024, and the grade increasing from satisfactory (C) to good (B) (Table 4). The Narrows zone achieved a very good (A) grade for the third consecutive year while the Western Basin zone maintained a good (B) grade for the sixth year, with improvements in composition scores for some meadows, though Meadow 6 saw a decline. The Inner Harbour zone showed significant improvements in biomass and area scores, but the overall condition remained poor due to the absence of *Zostera muelleri*. The score in the Mid Harbour zone declined, dropping from satisfactory (C) to poor (D), driven by reductions in seagrass biomass and species composition in Meadow 48, despite gains in Meadow 43. In South Trees Inlet, conditions remained stable, while Rodds Bay showed a significant recovery, with increases in biomass and area scores leading to improved seagrass health after previous years of decline.

Table 4 | Seagrass sub-indicator, overall meadow and zone scores used in the 2024 Gladstone Harbour Report Card. Scores from 2022 and 2023 are shown for comparison.

Zone	Meadow	Biomass	Area	Species comp.	Overall meadow	2024	*2023*	*2022*
1. The Narrows	21	0.89	0.96	0.97	0.89	0.89	*0.93*	*0.94*
3. Western Basin	4	0.88	0.97	0.86	0.87	0.70	*0.72*	*0.82*
	5	0.84	0.91	0.87	0.84			
	6	0.74	0.94	0.32	0.53			
	7	0.85	0.58	1.00	0.58			
	8	0.69	0.84	0.54	0.61			
	52–57*	0.73	0.87	1.00	0.73			
5. Inner Harbour	58	0.87	0.87	0.00	0.43	0.43	*0.10*	*0.39*
8. Mid Harbour	43	0.45	0.86	0.83	0.45	0.49	*0.57*	*0.67*
	48	0.54	0.79	0.65	0.54			
9. South Trees Inlet	60	0.81	1.00	0.99	0.81	0.81	*0.81*	*1.00*
13. Rodds Bay	94	0.85	0.74	0.98	0.74	0.74	*0.38*	*0.42*
	96	0.78	1.00	0.85	0.78			
	104	0.71	0.93	0.84	0.71			
Harbour score						0.68	*0.58*	*0.70*

Note, the 2024 scores may differ slightly to those reported by Reason et al. (2024) due to bootstrapping.

Coral

Coral health was assessed at six representative reefs located in the Mid Harbour and the Outer Harbour. Four sub-indicators were used to assess coral health: coral cover, macroalgal cover, juvenile density and change in hard coral cover. Coral cover and macroalgal cover measure the percent cover of living, adult corals and macroalgae respectively; juvenile density is the number of coral recruits (<5 cm); and change in hard coral cover was averaged over a three-year period to give the rate at which hard coral cover increases or decreases. Coral cover is used to assess the state of a reef while the other sub-indicators measure a reef's potential to recover.

Coral received an overall very poor (E) grade and a very low score of 0.14, for the seventh consecutive year (Table 5). This was a result of a low cover of living coral, high macroalgal cover, low abundance of juvenile corals, and a poor overall score for change in hard coral cover. Score changes at the sub-indicator level were minor between 2023 and 2024 with all sub-indicators receiving similar scores to the previous year. Ongoing pressures such as high macroalgal cover and the widespread presence of the bio-eroding sponge *Cliona orientalis* appear to be hindering the recovery of the coral communities in Gladstone Harbour.

Table 5 | Coral sub-indicator and zone scores used in the 2024 Gladstone Harbour Report Card. Scores from 2023 and 2022 are shown for comparison.

Zone	Coral cover	Macroalgal cover	Juvenile density	Change in hard coral cover	2024	*2023*	*2022*
8. Mid Harbour	0.07	0.23	0.14	0.23	0.17	*0.15*	*0.13*
11. Outer Harbour	0.09	0.00	0.07	0.32	0.12	*0.14*	*0.18*
Harbour score	0.08	0.12	0.11	0.27	0.14	*0.14*	*0.15*

Mangroves

Three sub-indicators were used to assess Mangrove health: Extent, Canopy Condition and Shoreline Condition. Mangrove Extent – the proportion of mangroves in a tidal wetland, and Canopy Condition, were determined from satellite imagery. Shoreline Condition, which assesses the proportion of dead mangroves within the shoreline trees, was determined from aerial photography.

In 2024, the overall Mangroves score for Gladstone Harbour was 0.63, reflecting a satisfactory (C) grade (Table 6). This marks an improvement from a score of 0.49 in 2019. Notably, six of the 13 environmental reporting zones showed grade improvements, while four zones declined, and three remained unchanged. The positive changes were primarily attributed to enhanced Canopy Condition scores across eight zones, significantly contributing to the overall harbour score.

Table 6 | Overall Mangrove sub-indicator and zone scores used in the 2024 Gladstone Harbour Report Card. Scores from 2019 are shown for comparison.

Zone	Mangrove extent	Mangrove canopy condition	Shoreline condition	2024	*2019*
1. The Narrows	0.73	0.76	0.39	0.63	*0.65*
2. Graham Creek	0.83	0.63	ND	0.73	*0.64*
3. Western Basin	0.64	0.71	0.40	0.65	*0.51*
4. Boat Creek	0.72	0.70	0.54	0.65	*0.46*
5. Inner Harbour	0.40	0.63	0.55	0.56	*0.55*
6. Calliope Estuary	0.90	0.73	0.57	0.73	*0.58*
7. Auckland Inlet	0.67	0.72	0.03	0.47	*0.65*
8. Mid Harbour	0.19	0.59	0.88	0.49	*0.55*
9. South Trees Inlet	0.84	0.65	0.29	0.59	*0.60*
10. Boyne Estuary	0.62	0.48	0.88	0.66	*0.26*
11. Outer Harbour	0.72	0.66	0.68	0.68	*0.66*
12. Colosseum Inlet	0.88	0.60	0.44	0.64	*0.72*
13. Rodds Bay	0.79	0.62	0.78	0.73	*0.64*
Harbour score	0.69	0.65	0.53	0.63	*0.57*

ND: No data available for this site

Fish and Crabs

The overall score for Fish and Crabs was 0.62, corresponding to a satisfactory grade (C). The Fish Health Indicator received a good (B) grade and a similar score to the previous year (2023: 0.81 and 2024: 0.84). The Fish Recruitment score improved from 0.47 to 0.57 giving a satisfactory (C) grade compared to a poor (D) grade in 2023. Mud crab scores declined (2023: 0.51, 2024: 0.46) to a poor (D) grade.

Fish health

The overall harbour score for Fish Health is calculated by the average of the harbour scores for two sub-indicators:

1. Fish HAI: A thorough assessment of the health of individual fish based on visual condition and the condition of several internal organs and tissues.

2. Fish Condition: An automated visual assessment of images captured by fishers using a mobile phone app. Length and weight data were also recorded at the time of capture. Scores for Fish Condition are based on two separate metrics; a visual assessment of fish health which includes skin, eyes, fins, parasites and deformities (visual fish condition) and an analysis of weight and length measures (fish body condition).

As no new data for the Fish HAI were collected in 2024, data from the 2021 Fish HAI were used to calculate the overall Fish Health score. The overall score for the 2021 Fish HAI was 0.90 (Table 7).

A new assessment was completed in 2024 for Fish Condition and scores were similar to the previous year (2023: 0.73, 2024: 0.78). The Fish Condition score is calculated from the mean of the visual fish condition and fish body condition for three species of fish caught in Gladstone Harbour during the 2023–24 reporting year (Table 8). Barred javelin, Dusky flathead and Barramundi data were not included in the Fish Condition score calculation due to low sample size and insufficient data.

Table 7 | Fish HAI sub-indicator scores used in the 2024 Gladstone Harbour Report Card. 2020 and 2019 results are shown for comparison.

Species	2024*	*2020*	*2019*
Bream	0.98	*NC*	*0.78*
Barred javelin	0.90	*0.84*	*0.77*
Barramundi	0.98	*0.55*	*0.58*
Blue catfish	0.81	*0.61*	*0.60*
Mullet	0.81	*NC*	*0.73*
Harbour score	0.90	*0.67*	*0.69*

NC – Scores not calculated due to low sample size. *No HAI assessment was conducted this report card. Results are from the 2021 assessment.

Table 8 | Fish Condition measure and sub-indicator scores used in the 2024 Gladstone Harbour Report Card. 2022 and 2023 results shown for comparison.

Species	Visual fish condition	Fish body condition	2024	*2023*	*2022*
Yellowfin bream	0.94	0.46	0.70	0.73	*0.72*
Pikey bream	0.94	0.68	0.81	0.74	*0.73*
Barred javelin	0.96	NC	NC	0.76	*0.72*
Dusky flathead	NC	NC	NC	0.70	*0.70*
Mangrove jack	0.93	0.75	0.84	0.71	*0.72*
Harbour score			0.78	0.73	*0.72*

NC – Scores not calculated due to low sample size

Fish recruitment

Fish recruitment was assessed for two species: Yellowfin bream *Acanthopagrus australis* and Pikey bream *A. pacificus*. Overall, the Fish recruitment score for 2024 was 0.57 and improved a grade to satisfactory (C) from 2023. Eleven of the 12 assessed zones' scores increased or remained the same, and only one zone Rodd's Bay, declined in score (Table 9).

Table 9 | Fish recruitment indicator scores for each zone used in the 2024 Gladstone Harbour Report Card. Results from 2020 to 2023 are shown for comparison.

Zone	2024	*2023*	*2022*	*2021*	*2020*
1. The Narrows	0.44	*0.37*	*0.64*	*0.54*	*0.63*
2. Graham Creek	0.54	*0.53*	*0.80*	*0.84*	*0.92*
3. Western Basin	0.82	*0.77*	*0.98*	*0.94*	*0.98*
4. Boat Creek	0.62	*0.58*	*0.33*	*0.35*	*0.38*
5. Inner Harbour	0.77	*0.58*	*0.51*	*0.61*	*0.63*
6. Calliope Estuary	0.50	*0.28*	*0.47*	*0.68*	*0.66*
7. Auckland Inlet	0.36	*0.36*	*0.60*	*0.63*	*0.80*
8. Mid Harbour	0.54	*0.49*	*0.57*	*0.78*	*0.62*
9. South Trees Inlet	0.39	*0.31*	*0.53*	*0.47*	*0.39*
10. Boyne Estuary	0.64	*0.37*	*0.63*	*0.53*	*0.51*
12. Colosseum Inlet	0.68	*0.41*	*0.29*	*0.56*	*0.63*
13. Rodds Bay	0.60	*0.64*	*0.45*	*0.51*	*0.52*
Harbour score	0.57	*0.47*	*0.57*	*0.62*	*0.64*

Mud crab

Seven zones were sampled to collect data on three Mud crab sub-indicators: abundance, sex ratio and prevalence of rust lesions. Abundance was used to estimate the number of crabs via catch per unit effort (CPUE). Sex ratio quantifies the ratio of legal-sized male crabs (>15 cm spine width) to female crabs of the same size. The prevalence of rust lesions was calculated by comparing the number of crabs with rust lesions to the total number of mud crabs caught at each monitoring zone.

The overall Mud crab score in 2024 declined marginally to 0.46 which resulted in a downgrade to poor (D) from 2023 (satisfactory, C) (Table 10). Of all the zones, abundance scores were highest in The Narrows (0.88) and Boat Creek (1.00), a trend similar to previous years. Sex ratio declined in Boat Creek (0.25) and Calliope Estuary (0.00) compared to 2023 (0.71 and 0.62). There was a low incidence of rust lesions, which led to consistently high scores (0.73–1.00) across all zones.

Table 10 | Mud crab sub-indicator and indicator scores for the 2024 Gladstone Harbour Report Card. Scores from 2023 and 2022 are shown for comparison.

Zone	Abundance (CPUE)	Sex ratio	Prevalence of rust lesions	2024	*2023*	*2022*
1. The Narrows	0.88	0.06	1.00	0.65	0.50	*0.58*
2. Graham Creek	0.00	0.20	0.73	0.31	0.36	*0.33*
4. Boat Creek	1.00	0.25	1.00	0.75	0.67	*0.58*
5. Inner Harbour	0.21	0.09	0.96	0.42	*NC*	*0.14*
6. Calliope Estuary	0.14	0.00	1.00	0.38	0.54	*0.43*
7. Auckland Inlet	0.00	0.05	1.00	0.35	0.33	*NC*
13. Rodds Bay	0.04	0.00	1.00	0.35	0.67	*NC*
Harbour score	0.32	0.09	0.96	0.46	0.51	*0.39*

CPUE – catch per unit effort; NC – Not calculated owing to inadequate sample size (n < 5).

Social Health

There was no new assessment of the Social Health in 2024; the results have carried over from 2022. The overall score for Social Health in 2022 was similar to the previous assessment (2019: 0.67, 2022: 0.68). This score was based on three indicator groups: Harbour Usability 0.62, Harbour Access 0.68 and Liveability and Wellbeing 0.71 (B; Table 11). All indicator grades have been consistent since 2018 (good, B) and the overall Social Health has remained stable since 2015 – suggesting Gladstone residents continue to feel that Gladstone Harbour provides them with a positive living experience and quality of life.

Table 11 | Social Health indicator group and indicator scores used in the 2024 Gladstone Harbour Report Card. Scores from previous assessments are included for comparison.

Indicator group	Social indicators	2024*	2024*	*2019*	*2018*
Harbour Usability	Satisfaction with harbour recreational activities	0.73	0.62	*0.64*	*0.63*
	Perceptions of air and water quality	0.59			
	Perceptions of harbour safety for human use	0.55			
Harbour Access	Satisfaction with access to the harbour	0.75	0.68	*0.67*	*0.67*
	Satisfaction with boat ramps and public spaces	0.67			
	Perceptions of harbour health	0.63			
	Perceptions of barriers to access	0.69			
Liveability and Wellbeing	Liveability and wellbeing	0.71	0.71	*0.70*	*0.70*
Overall score			0.68	*0.67*	*0.67*

*No assessment was undertaken in 2024; results have carried over from the 2022 assessment

Cultural Health

The overall score for the Cultural Health, comprising of the Sense of Place and indigenous Cultural Heritage indicator groups, was 0.61, corresponding to a satisfactory grade (C). No new assessment of Cultural Health was conducted this year. Scores for the Sense of Place indicator group have been carried over from previous years (Table 12). Scores for the Indigenous Cultural Heritage Indicator have also been carried over from previous years (Table 13). From 2025 this part of the Cultural Health Component will be designed to be a stand-alone indicator within the Gladstone Harbour Report Card.

The overall Sense of Place score (0.68) from the 2022 assessment suggests that the community expectations of the Gladstone Harbour area are being met. The scores for the Indigenous Cultural Heritage indicator group have been stable since it was included in the report card in 2016 (Table 13).

Table 12 | Sense of Place indicator and indicator group scores used in the 2024 Gladstone Harbour Report Card. Scores from previous assessments are shown for comparison.

Indicator group	Indicator	2024*	2024*	*2022*	*2019*
Sense of Place	Place attachment	0.61	0.68	*0.68*	*0.65*
	Continuity	0.65			
	Pride in the region	0.76			
	Wellbeing	0.62			
	Appreciation of the harbour	0.84			
	Values	0.68			

*No assessment was undertaken in 2024; results have carried over from the 2022 assessment.

Table 13 | Indigenous Cultural Heritage indicator and indicator group scores used in the 2024 Gladstone Harbour Report Card.

Indicator	Measure	The Narrows	Facing Island	Wild Cattle Creek	Gladstone Central
Physical condition	Intactness of site features	0.82	0.95	0.67	0.85
	Extent of current disturbance	0.63	0.64	0.59	0.44
	Management of threats	0.28	0.11	0.24	0.50
Management strategies	Recording	0.80	0.90	0.80	1.00
	Cultural management	0.10	0.10	0.10	0.10
	Stakeholders	0.50	0.40	0.60	0.40
	Monitoring	0.80	0.90	0.70	1.00
	Access	0.60	0.90	0.60	0.60
	Cultural resources	0.20	0.10	0.10	0.10
Zone score		0.54	0.56	0.49	0.57

Note: No assessment was undertaken in 2024; results have carried over from the 2018 assessment.

Economic Health

In 2024, the overall score for Economic Health was 0.71 corresponding to a good grade (B). Three indicator groups form the Economic Health score: Economic Performance (0.90), Economic Stimulus (0.50) and Economic Value (0.77). The 2024 scores were similar to the 2023 report card, apart from a large decline in the Employment indicator (Table 14). New assessment was conducted in 2024 for all three Economic Performance indicators: Shipping activity, Tourism and Commercial fishing and the Economic Stimulus Employment and Socio-economic status indicators. The Economic Value scores have carried over from the 2022 report card.

Table 14 | Economic Health indicator and indicator group scores used in the 2024 Gladstone Harbour Report Card. Scores from previous assessments are shown for comparison.

Indicator group	Indicators	2024	2024	*2023*	*2022*
Economic Performance	Shipping activity	0.90	0.90	*0.87*	*0.90*
	Tourism	0.90			
	Commercial fishing	0.34			
Economic Stimulus	Employment	0.19	0.50	*0.63*	*0.64*
	Socio-economic status	0.74			
Economic Value (recreation)	Land-based recreation^	0.79	0.77	*0.77*	*0.77*
	Recreational fishing^	0.73			
	Beach recreation^	0.77			
	Water-based recreation^	0.77			
Overall score			0.71	*0.74*	*0.76*

^No assessment was undertaken in 2024 or 2023; results have carried over from 2022.

1 Introduction

1.1 The Gladstone Healthy Harbour Partnership

The Gladstone Healthy Harbour Partnership (GHHP) is a forum that brings together community, research, First Nations people, industry and all levels of Government to monitor the health of Gladstone Harbour. GHHP was formally launched in 2013 and released its first pilot Report Card in 2014. The GHHP vision is that 'Gladstone has a healthy, accessible, working harbour'. The guiding principles of the partnership are open, honest and accountable management and annual reporting of the health of Gladstone Harbour. Actions are based on rigorous science and strong stakeholder engagement to ensure the ongoing and continuous improvement of the health of Gladstone Harbour.

The GHHP Management Committee is a sub-set of the broader Partnership with an operational role. It guides the management of the Partnership to meet its objectives on behalf of the Partners. The GHHP Independent Science Panel provides independent scientific advice, review and direction. Its role is to ensure that the environmental, social, cultural and economic challenges of policy, planning and actions, as they relate to achieving the GHHP vision, are supported by credible science.

The Gladstone Harbour Report Card reports on the Environmental, Social, Cultural and Economic health of the harbour (Figure 1.1). Stakeholder and community consultation identified these four components as important to the community during workshops conducted by GHHP in 2013.

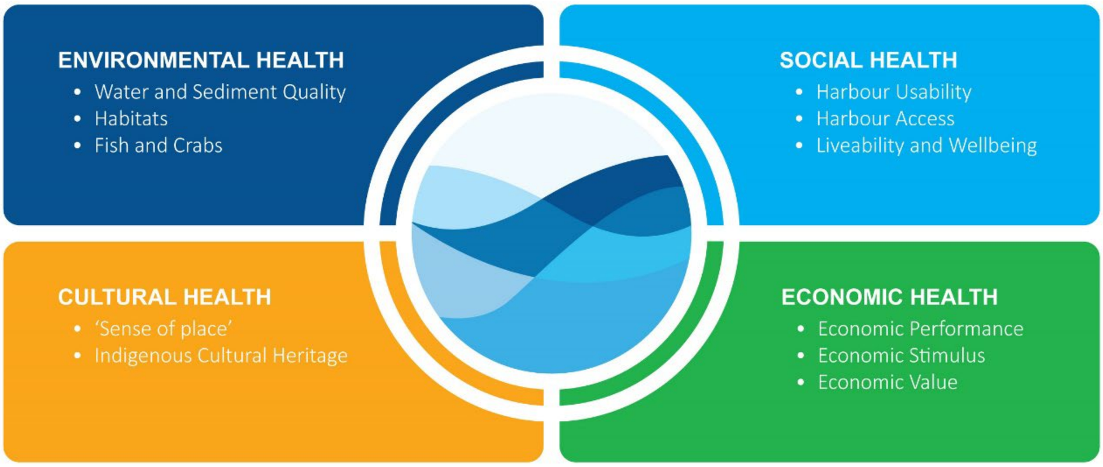

Figure 1.1 | The four components of assessment for Gladstone Harbour health.

1.2 Report Card Monitoring

The 2024 report card showcases new monitoring data collected between 1 July 2023 and 30 June 2024. Ten years of reporting has shown some indicators are stable each year, therefore no new assessments of the Social and Cultural indicators were conducted in 2024; results are carried over from previous report cards. The 2024 report card presents a partial assessment of the Economic indicators, with new assessment of Economic Performance and Economic Stimulus. The Economic Value results are repeated from the 2022 report card. Results from the Environment Fish Health sub-indicator fish Health Assessment Index (HAI) have carried over from 2021.

Environmental monitoring is conducted across 13 geographical zones in and around Gladstone Harbour: The Narrows, Graham Creek, Western Basin, Boat Creek, Inner Harbour, Calliope Estuary, Auckland Inlet, Mid Harbour, South Trees Inlet, Boyne Estuary, Outer Harbour, Colosseum Inlet and Rodds Bay. More information on each of these zones is available in Section 10 of this report.

2 From Indicators to Report Card Grades

2.1 Structure and Indicators

The hierarchy of score aggregation used to calculate the final grade for each component of harbour health can include up to five levels of aggregation: components, indicator groups, indicators, sub-indicators and measures (Table 2.1). This structure derives the final scores from raw data collected through field sampling, community surveys and publicly available sources.

Table 2.1 | The five levels of aggregation employed to determine the grades and scores in the 2024 Gladstone Harbour Report Card.

Name	Explanation
Level 1: Component	The report card reports on the condition of four components of harbour health: Environmental, Social, Cultural and Economic.
Level 2: Indicator group	Group of several related indicators – for instance, the indicator group 'Habitats' comprises the indicators Seagrass and Corals; the indicator group 'Economic Performance' comprises the indicators Shipping activity, Tourism and Commercial fishing.
Level 3: Indicator	An aspect of a system that may be used to indicate the state or condition of that system – for instance, 'Water quality and Seagrass' may be used to indicate the environmental condition of Gladstone Harbour; 'Shipping activity' may be used to indicate the economic state of Gladstone Harbour.
Level 4: Sub-indicator	Group of several related measures – for instance, the 'nutrients sub-indicator' (within water quality) comprises the measures total nitrogen, total phosphorus and chlorophyll-*a*.
Level 5: Measure	A numerical value assigned to an individual parameter used to assess harbour health. It may be based on a single measurement or combination of measurements for each parameter (e.g. an annual average).

Each indicator has a baseline and five ranges (A to E) that are used to calculate the grade for each measurement type. The methods used to determine baselines for each indicator are described in detail in the relevant sections of this report. Each threshold is a decimal value between 0.00 and 1.00 (Figure 2.1). Scores are assigned to measurements that are then aggregated upwards to the component level.

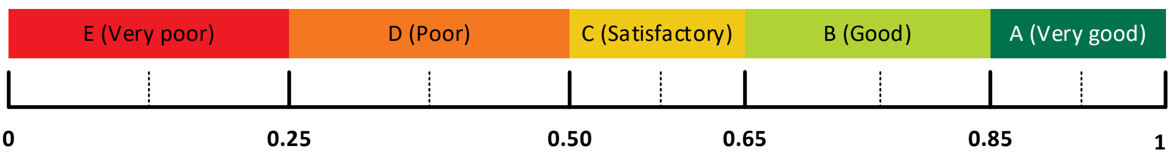

Figure 2.1 | Grade ranges used in the 2024 Gladstone Harbour Report Card.

2.2 Aggregation of report card grades and scores

A number of methods have been used to calculate an index value for the smallest geographic unit of reporting (e.g., 'site' for Water and Sediment Quality, 'reef' for Coral indicators and 'meadow' for Seagrass indicators) in the 2023–24 reporting period.

For example, the starting point for the Water Quality index calculation was the annual mean value for a measure per site. This was calculated by averaging the field data collected on four occasions in the 2023–24 reporting year. The annual site means were used to develop indexed scores between 0.00 and 1.00 compared with relevant guidelines (Figure 2.2) (Department of Environment and Heritage Protection (DEHP) Water Quality Objectives or Australia and New Zealand Guidelines default guideline values as appropriate - ANZG, 2018; DEHP, 2009). This yielded final indexed scores at site level which could be aggregated to higher levels of reporting (Figures 2.3–2.6). References have been provided on the methods used to calculate the indexed values for Coral, Seagrass, Mangroves and Fish and Crabs indicators in their respective sections in this report.

Aggregation used a hierarchical approach so that scores for a range of reporting levels (e.g. indicator, indicator group and component) could be generated for individual zones and for the whole harbour for reporting. The lowest level of reporting (e.g. measures such as aluminium, copper, lead, manganese, nickel and zinc for a site) was aggregated to the next level (e.g. metals in water) using bootstrapped distributions rather than direct means of each measure. The bootstrapping method resamples the original data many times to yield multiple means which are used to develop a series of distributions for measures, sub-indicators, indicators and indicator groups. By aggregating distributions (rather than individual means), the rich distributional properties could be preserved, sample bias could be avoided, and means (the report card score) and variances could be calculated for reporting (Figure 2.7).

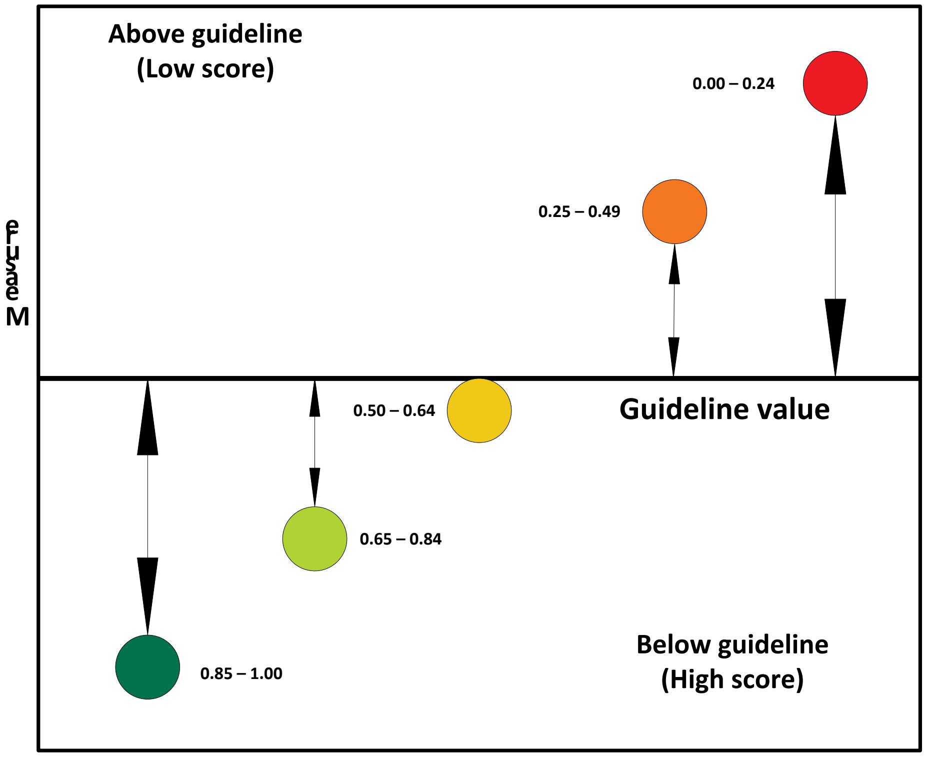

Figure 2.2 | Water and Sediment Quality measures are scored relative to zone and measure specific guideline values.

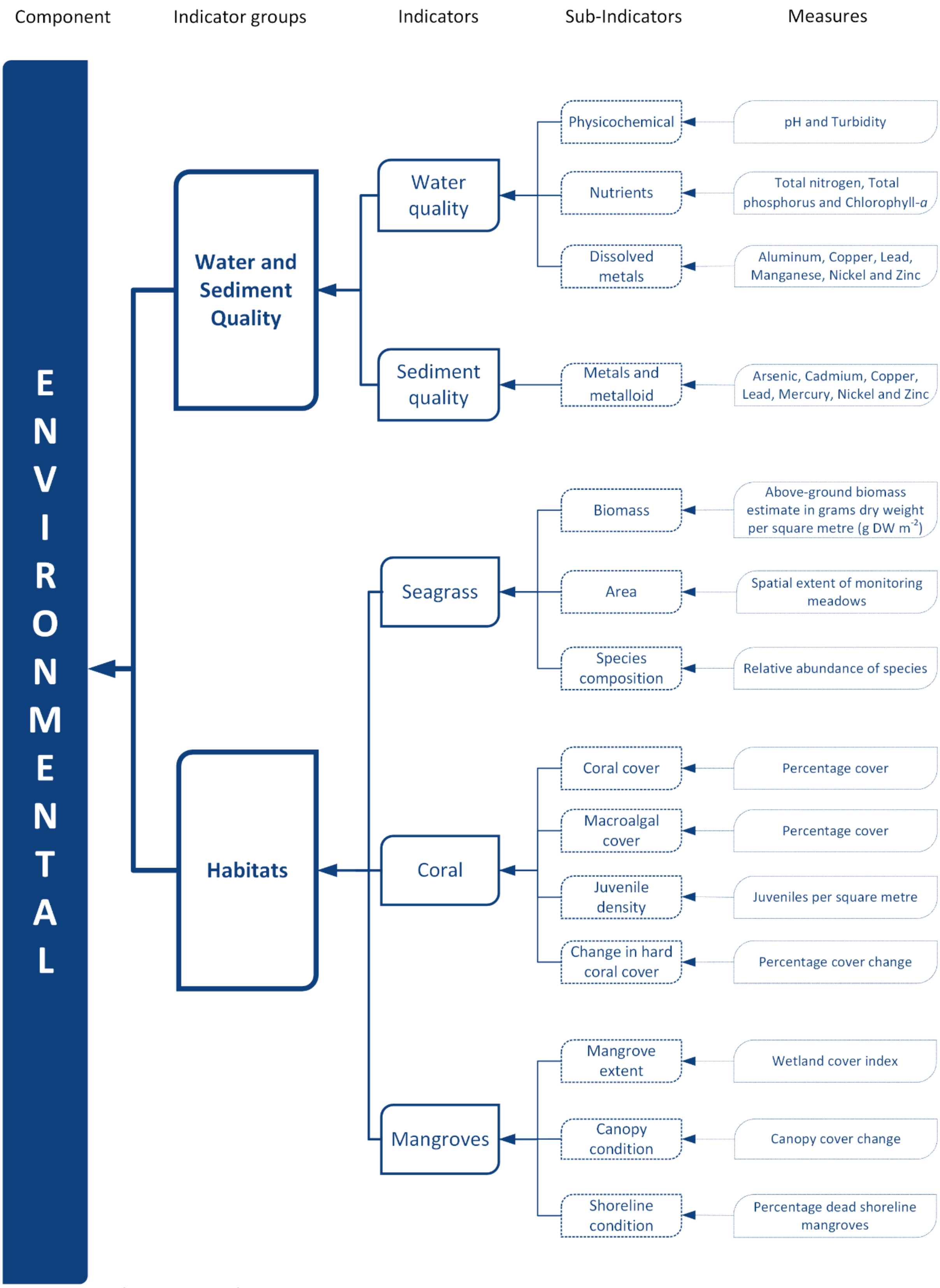

Figure 2.3a | The levels of aggregation used to determine the Environmental scores and grades in the 2024 Gladstone Harbour Report Card. There are three Environmental indicator groups, eight indicators, 19 sub-indicators and 47 measures.

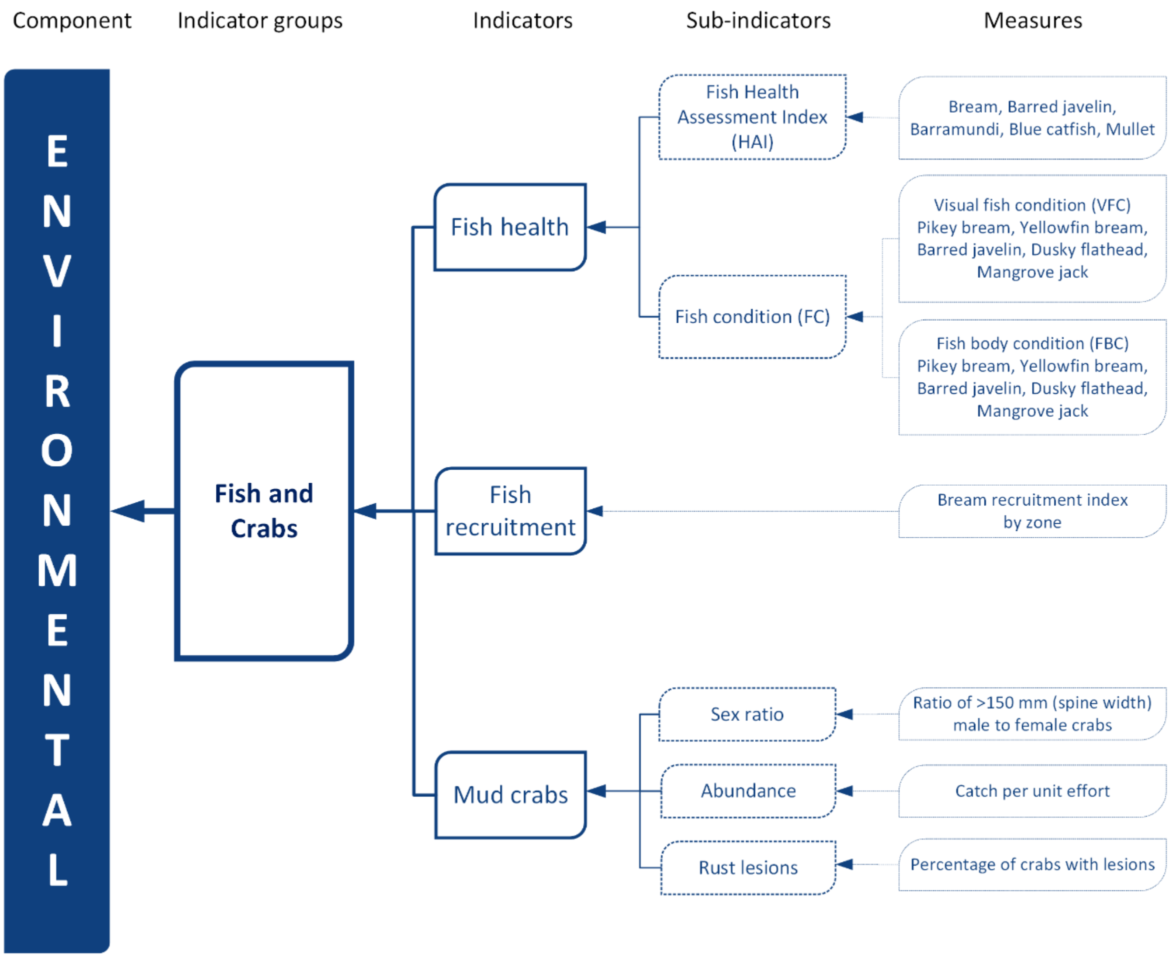

Figure 2.3b | The levels of aggregation used to determine the Environmental scores and grades in the 2024 Gladstone Harbour Report Card. There are three Environmental indicator groups, eight indicators, 19 sub-indicators and 47 measures.

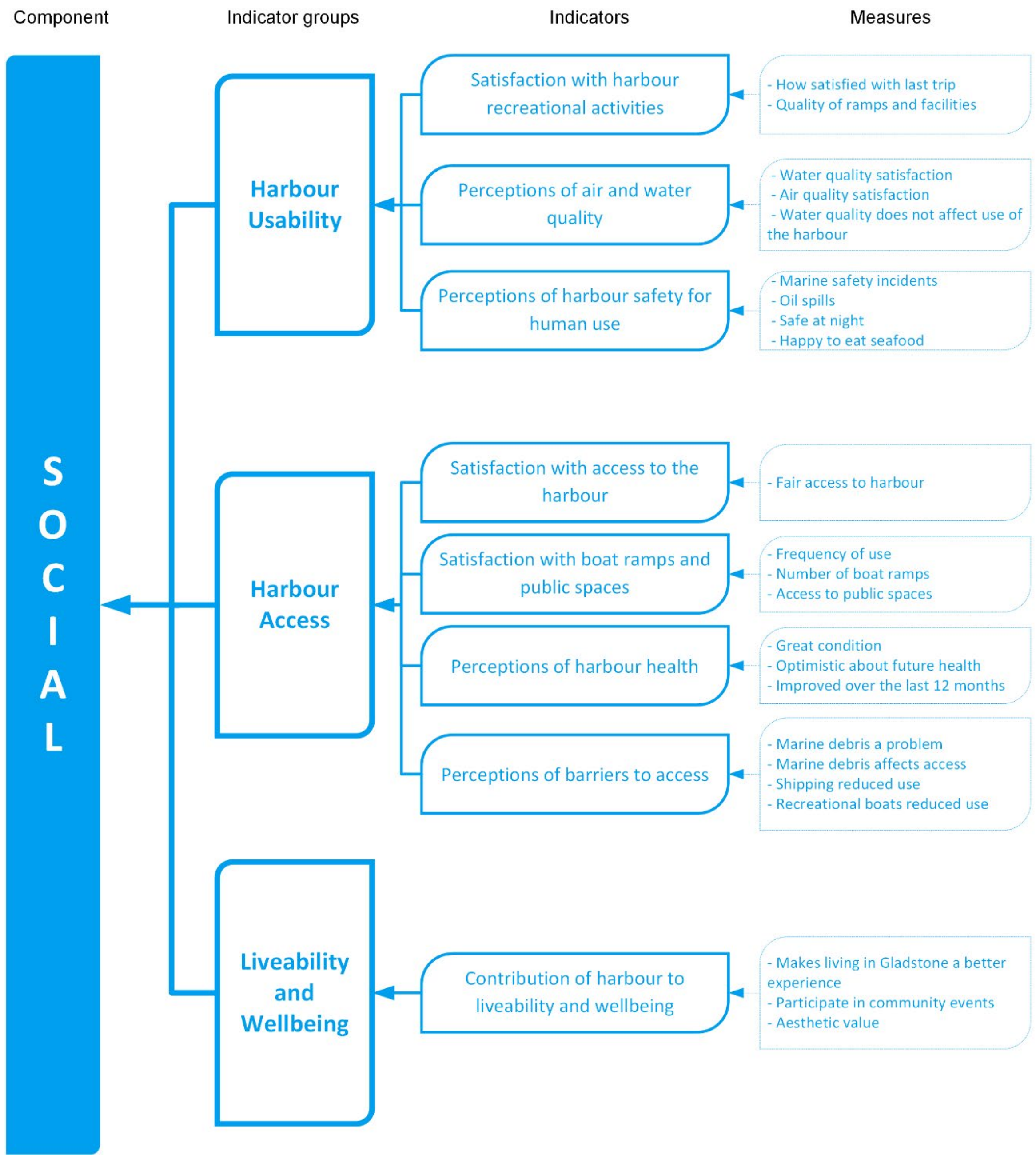

Figure 2.4 | The levels of aggregation used to determine the Social scores and grades in the 2024 Gladstone Harbour Report Card. There are three Social indicator groups, eight indicators and 23 measures.

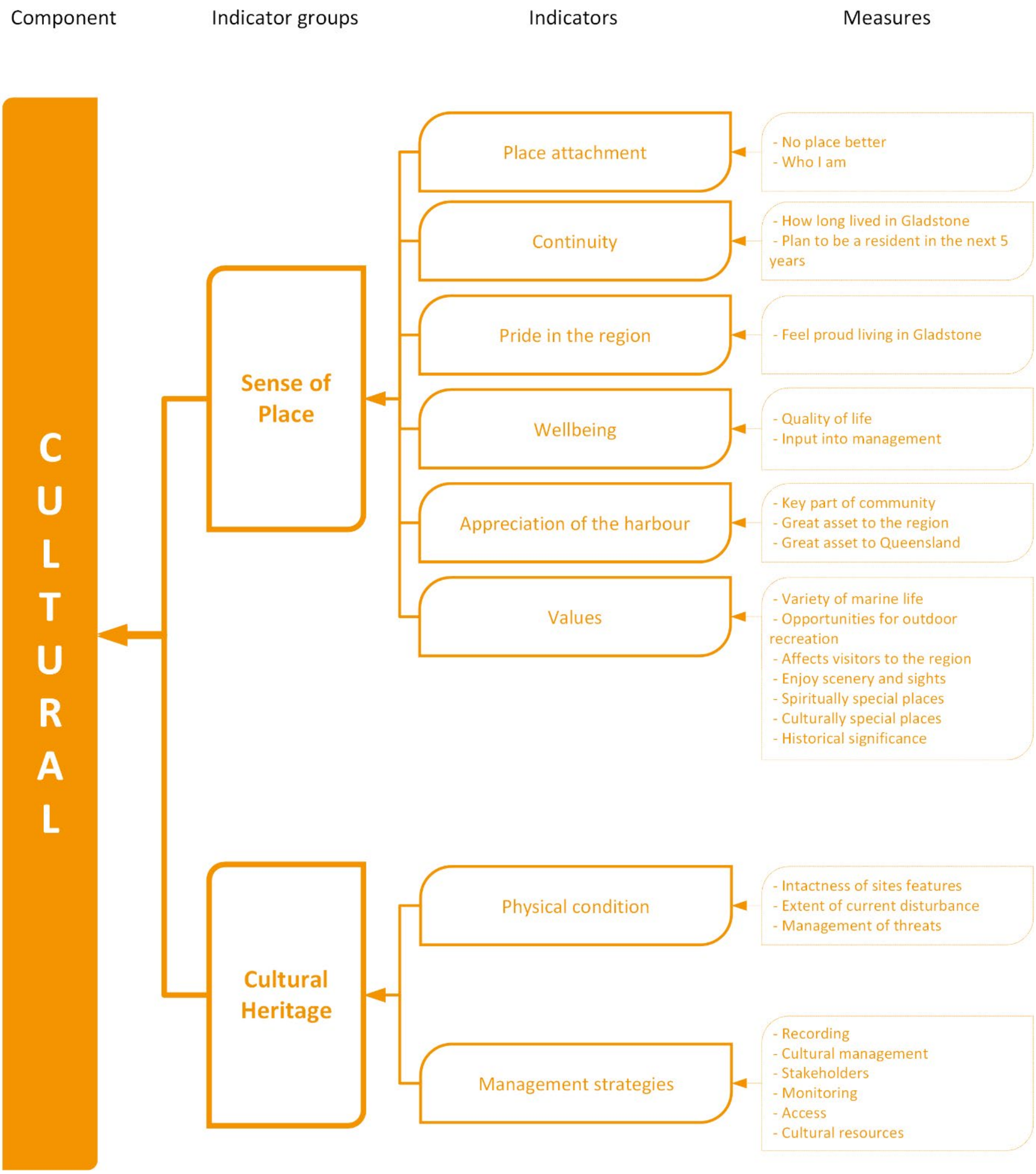

Figure 2.5 | The levels of aggregation used to determine the Cultural grades and scores in the 2024 Gladstone Harbour Report Card. There are two Cultural indicator groups, eight indicators and 26 measures.

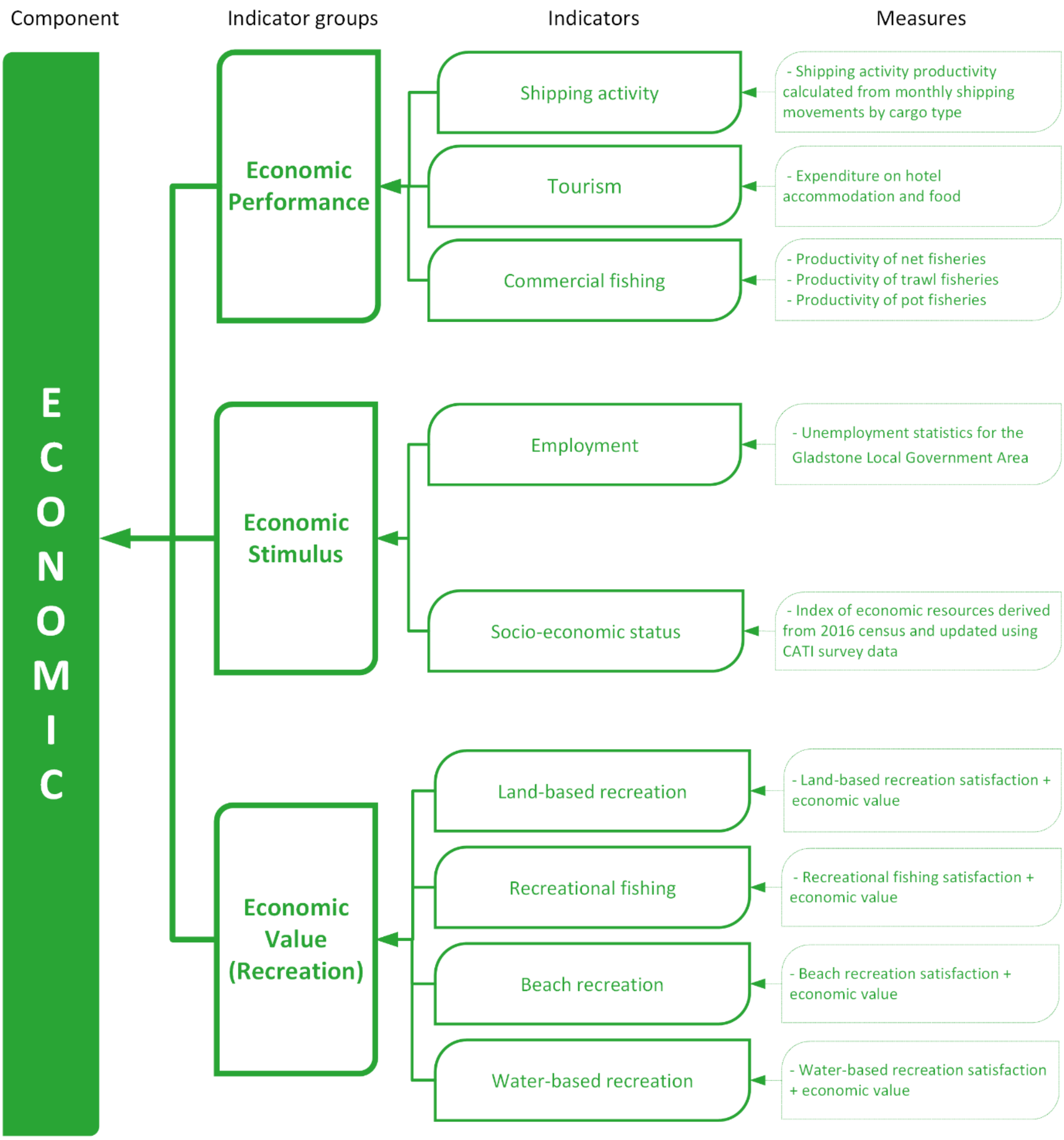

Figure 2.6 | The levels of aggregation used to determine the Economic scores and grades in the 2024 Gladstone Harbour Report Card. CATI: Computer-Assisted Telephone Interviewing. There are three Economic indicator groups, nine indicators and 11 measures.

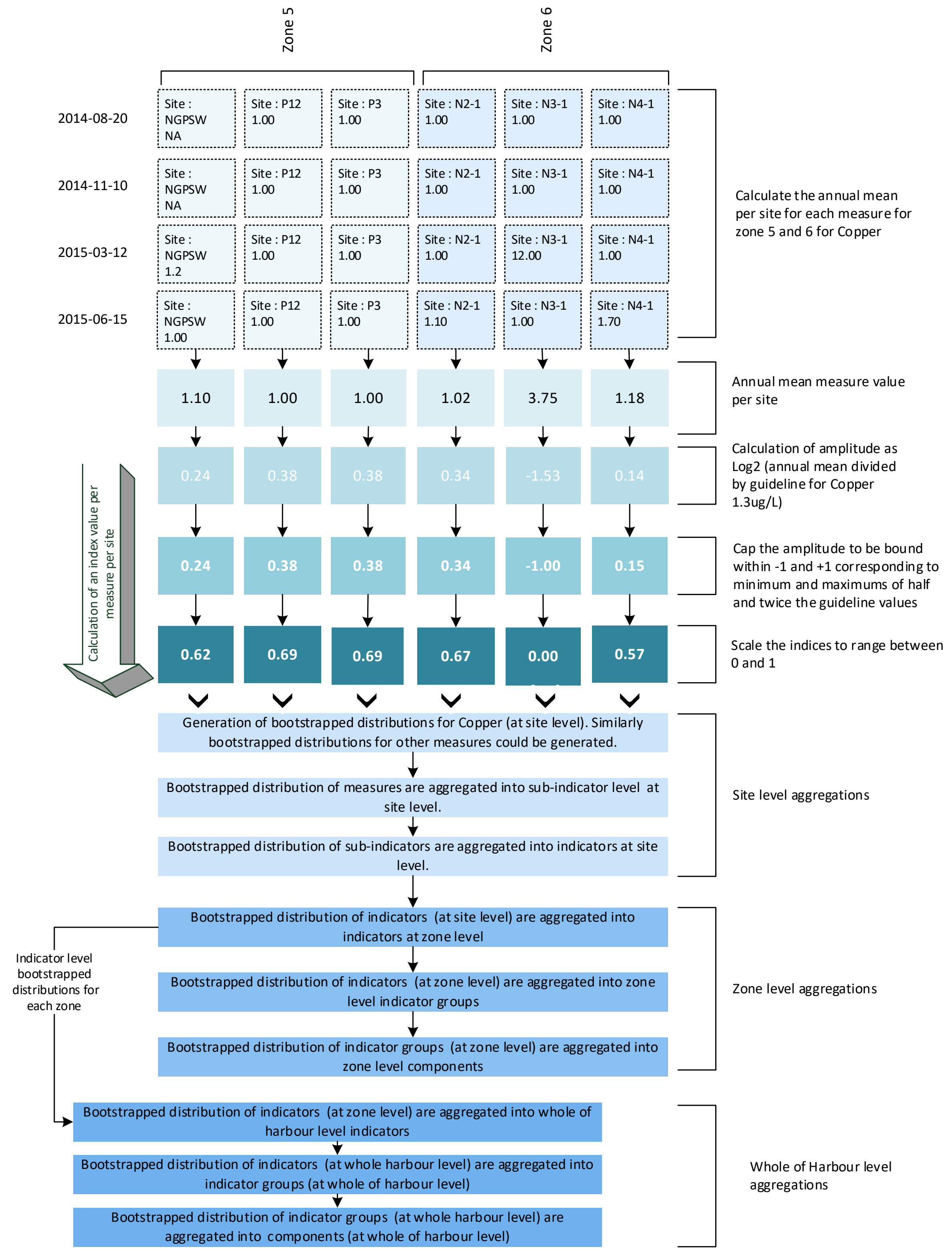

Figure 2.7 | Aggregation of report card scores – a worked example using the Water quality measure for copper in zones 5 and 6.

2.3 Confidence ratings

The GHHP Independent Science Panel have assigned confidence ratings for each indicator within the four components of the report card on a three-point scale (low, moderate and high). These ratings were informed by assessing the appropriateness of the indicators, the number of missing indicators, the adequacy of sampling designs and the availability, completeness and quality of the monitoring data.

The Sediment Quality, Seagrass, Corals, Fish Recruitment, and Mud Crabs indicators within the Environmental component all received high confidence ratings in 2024. This rating reflects that the indicators are appropriate, and additional years of data indicate the robustness of the methods used to determine the grades. Mangroves also received a high confidence rating in 2024, as a new assessment was completed in this reporting year. Water quality and Fish health received moderate ratings (Table 2.2).

Table 2.2 | Confidence ratings for individual Environmental indicators in 2024.

Indicator	Confidence	Reason
Water quality	Moderate	Exclusively, 'far-field' sites were reported on, and these were specifically sampled four times per year.
Sediment quality	High	Appropriate methodology and sampling frequency, minimal laboratory issues since the pilot report card in 2014.
Seagrass	High	Consistent methods used over eight years of monitoring. Minor changes to scoring methods in 2018.
Corals	High	Consistent methods used over eight years of monitoring. Minor changes to scoring methods in 2018.
Mangroves	High	Upgraded to High as new assessment was completed in 2024.
Fish health	Moderate	Seven years of monitoring (2018–24) and the program is based on previous fish health studies. The two fish health projects had similar results. Fish HAI from 2021 was used to calculate 2024 scores.
Fish recruitment	High	Eight years of monitoring with consistent methods and data analysis. Minor change to sampling frequency in 2021.
Mud crabs	High	Seven years of monitoring with an appropriate methodology. The benchmarks are based on local populations. Minor changes to scoring methods in 2020.

The confidence ratings for the Social and Economic components remain unchanged since 2019.

The Social component received a high confidence rating. The methodology was developed specifically for Gladstone Harbour and has been stable since the Pilot Report Card in 2014. The computer-assisted telephone interview (CATI) survey that contributed most of the data was regarded as reliable and repeatable. Data collection was improved with the inclusion of mobile phones in 2017. The 18 to 24-year-old age group were still under-represented while older age participants were over-represented in the survey. The Maritime Safety Queensland data was for the Gladstone Maritime Region which included areas beyond the harbour. Despite these minor issues overall the grade for the Social component was based on a complete set of indicators with no major issues regarding data availability, adequacy or quality.

The confidence rating for the Cultural component consisting of Sense of Place and Indigenous Cultural Heritage indicators was split in 2024 to recognise differences in confidence ratings for the two indicator groups. There were improvements in the Indigenous Cultural Heritage indicator including weighting the scores based on inputs from Traditional Owners and Elders in 2018. However, no survey work has been conducted between 2019 and 2024 and the 2018 scores and grades have been used for this report card. The methodology to assess Indigenous Cultural Heritage in a report card framework is still relatively new and further refinements may be required. The Indigenous Cultural Heritage indicator received a low confidence rating in 2024. In contrast, the methodology to assess *Sense of Place* is well established but based on a single survey only and there is no corroborating data. The *Sense of Place* indicator received a high confidence rating in 2024. The development of ways to corroborate the *Sense of Place* data and continued development of the Indigenous Cultural Heritage indicator will lead to improved confidence for this component.

The Economic component received a high confidence rating because the CATI survey design was reliable, repeatable and developed specifically for the Gladstone Harbour Report Card. Other data that contribute to the Economic results came from a variety of reputable sources. However, there are ongoing issues with the definition of a tourist and separating the effects of Gladstone Harbour from Gladstone City in the Tourism indicator. The grade for the Economic component was based on a complete set of indicators and there were no major issues with data availability, adequacy or quality.

3 The Environmental Health Component

Environmental Health in Gladstone Harbour is assessed through three indicator groups: Water and Sediment Quality, Habitats, and Fish and Crabs. Except for the Fish health sub-indicator Fish HAI, monitoring for all Environmental indicators occurred between 1 July 2023 and 30 June 2024. These results have carried over from previous assessments in 2021.

3.1 Water and Sediment Quality

Water and Sediment Quality are important and interconnected aspects of the harbour ecosystem. A healthy water and sediment system sustains the health of a large number of aquatic species, including fish, turtles, dugongs, seagrass, mangroves and benthic invertebrates. Catchment-related, anthropogenic, climatic and other environmental factors play a major role in determining the Water and Sediment Quality recorded in the harbour. The GHHP Independent Science Panel recommended the measures for Water and Sediment Quality that are used in the report card, all of which have local or national guidelines.

For the Gladstone Harbour Report Card, Water Quality Objectives and guideline values were provided by:

- DEHP Water Quality Objectives for the Capricorn Curtis Coast (DEHP, 2014) for pH, turbidity and nutrients
- ANZG (2018) for metals in water and sediments (except aluminium)
- Golding et al. (2014) for aluminium in marine waters

The Water Quality Objectives used to calculate report card scores differed among geographic zones within Gladstone Harbour for all physicochemical and nutrient measures, but the guideline values were consistent for all metals.

The aluminium guidelines developed by Golding et al. (2014) and applied by DEHP (2014) ranged from 2.1 µg/L in high ecological value zones in Gladstone Harbour (The Narrows, Colosseum Inlet, Rodds Bay) to 24 µg/L in moderately disturbed zones (all other zones). This led to similar actual concentrations of aluminium being scored as very poor in high ecological value zones and very good in moderately disturbed zones. This created the misleading impression that the aluminium concentrations were far worse in high ecological value zones than in moderately disturbed zones. For this reason, the GHHP Independent Science Panel applied the moderately disturbed guideline of 24 µg/L across all zones for aluminium.

Since 2020, the GHHP Independent Science Panel has applied the guideline of 80 µg/L across all zones for manganese in marine waters consistent with ANZECC/ARMCAZ (2000).

The 95% species protection values from the ANZG (2018) water quality guidelines were applied to copper, lead, and zinc, while the 99% species protection value was applied to nickel. Water quality guideline values were selected for moderately disturbed systems.

Water and Sediment Quality data were collected in accordance with the following standards and procedures:

- Australian and New Zealand Standards for water quality and sediment sampling (AS/NZS 5667.1:1998; 5667.4:1998; 5667.6:1998; 5667.12:1998)
- American Public Health Association Standard Methods for the Examination of Water and Wastewater (APHA, 2005)
- Australian and New Zealand Water Quality Guidelines (ANZECC, 1992, 1998; ANZECC/ARMCANZ, 2000; ANZG, 2018)
- Queensland Water Quality Guidelines (DEHP, 2009)
- Department of Environment and Science Monitoring and Sampling Manual (DES, 2018)
- Revision of the ANZECC/ARMCANZ Sediment Quality Guidelines (Simpson et al., 2013)

3.1.1 Water and Sediment Quality data collection

Water quality

Under a data-sharing agreement, the Port Curtis Integrated Monitoring Program (PCIMP) provided GHHP with water quality data to calculate scores for the 2024 report card. The data were collected from 51 sites across 13 harbour zones (Figures 10.1–10.27) during August and November 2023, and March and June 2024. The methods used in this section were provided by PCIMP (PCIMP, 2019).

Eleven water quality parameters were assessed: two physicochemical measures, three nutrient measures and six dissolved metals (Table 3.1). Physicochemical parameters were measured using a multi-parameter water quality sonde (YSI ProDSS), which was calibrated and checked prior to sampling. Measurements were taken at 0.5 m depth intervals through the water column until the seabed was reached. Triplicate sub-surface readings (0.5 m) were recorded at each site.

Water samples for nutrient and dissolved metal analyses were collected from a depth of 0.5 m using a Perspex pole sampler and a pre-acid washed Nalgene bottle (triple rinsed in Milli-Q and site water). Powder free gloves were worn to avoid contamination. Sample water was added directly to laboratory-provided sample bottles for total nitrogen, total phosphorous and chlorophyll-*a*. A sub-sample of water was filtered through a 0.45 µm membrane filter in the field for dissolved metals and dissolved nutrients. All samples were placed immediately on ice and dispatched to arrive at the nominated analysing laboratories within their recommended holding times. Field blanks, travel blanks and duplicate samples (at 20% of sites) were also collected and analysed in accordance with the standard protocols described above for laboratory and field quality assurance and quality control (QA/QC) purposes.

All analysing laboratories have been accredited by the National Association of Testing Authorities, Australia. This is to ensure compliance with relevant international and Australian standards and competency in providing consistently reliable testing, calibration, measurement, and inspection data. Dissolved metal samples were sent to the National Measurement Institute and nutrient samples were sent to the Queensland Health laboratories apart from chlorophyll-*a* samples, which were sent to Australian Laboratory Services. Field blanks, travel blanks and duplicate samples were dispatched to the same respective laboratories based on sample type.

Table 3.1 | Water quality sub-indicators and measures in the 2024 Gladstone Harbour Report Card.

Indicator	Sub-indicator	Measure	Guideline source
Water quality	Physicochemical	pH	DEHP, 2014
		Turbidity	DEHP, 2014
	Nutrients	Total nitrogen (TN)	DEHP, 2014
		Total phosphorus (TP)	DEHP, 2014
		Chlorophyll-*a*	DEHP, 2014
	Dissolved metals	Aluminium (Al)	Golding et al., 2014
		Copper (Cu)	ANZG, 2018
		Lead (Pb)	ANZG, 2018
		Manganese (Mn)	ANZG, 2018
		Nickel (Ni)	ANZG, 2018
		Zinc (Zn)	ANZG, 2018

See Appendix 2 for a full list of Water Quality Objectives and water quality guidelines.

Sediment quality

Six sediment metals and one metalloid (arsenic) were assessed (Table 3.2). Methods in this section were provided by PCIMP (PCIMP, 2019).

Sediment samples were collected from the same 51 harbour monitoring sites used for water quality sampling in May 2024. Grab samples were collected for sediment quality measures using a stainless steel Ponar grab sampler (0.008 m^3 volume). These samples were deposited into a collection tub that had been triple rinsed with seawater and then photographed. All sediment quality measurements used the top 100 mm of the sample, which were deposited into laboratory-provided sample containers using pre-acid-washed polypropylene trowels.

All sample containers were bagged and stored at 4°C and transported to the analysing laboratory, National Measurement Institute, within their recommended holding times. For field QA/QC, separate grabs were made for duplicate samples at 20% of sites.

Sediment nutrients were not included as there are no relevant national or international guidelines. They may be included in future report cards should relevant guidelines become available. Polycyclic aromatic hydrocarbons have not been included since the first report card owing to the extremely low concentrations recorded in 2015.

Table 3.2 | Sediment quality measures in the 2024 Gladstone Harbour Report Card.

Indicator	Sub-indicator	Measure	Guideline source
Sediment quality	Metals and metalloid	Arsenic (As)	ANZG, 2018
		Cadmium (Cd)	ANZG, 2018
		Copper (Cu)	ANZG, 2018
		Lead (Pb)	ANZG, 2018
		Mercury (Hg)	ANZG, 2018
		Nickel (Ni)	ANZG, 2018
		Zinc (Zn)	ANZG, 2018

See Appendix 3 for a full list of Sediment quality guidelines.

In September 2024, the GHHP Independent Science Panel discussed QA/QC issues with the raw dataset for 2024 for the Water and Sediment Quality data collected.

Based on discussions, the GHHP Independent Science Panel recommended not to include NOx and orthophosphate measures in the report card analysis owing to the following issues:

1. Most of the data were below the limit of reporting, meaning that the bulk of the observations were not measured precisely.
2. Scores below the limit of reporting could only be calculated by making an assumption about what the measure might be (e.g. 50% of limit of reporting). This becomes difficult to justify when it involves most of the observations.
3. As Water Quality Objectives differ between zones, the application of the scoring created potentially perverse results (e.g., zones with the lowest Water Quality Objectives tended to have the lowest scores).
4. There would be an element of double counting if NOx and orthophosphate were included, as these are already measured under total nitrogen and total phosphorous respectively.

In 2024, the limit of reporting value for sediment mercury was at an acceptable level (0.01 mg/kg) compared to the guideline value (0.15 mg/kg). As such, the GHHP Independent Science Panel recommended to include sediment mercury in the report card analysis. Sediment mercury was included in previous years when the limit of reporting was at an acceptable level (e.g. 0.01 mg/kg in 2017, 2019 and 2021–24) and excluded in previous years when the limit of reporting was not at an acceptable level (e.g. 0.2 mg/kg in 2018 and 2020).

3.1.2 Water and Sediment Quality measures

A total of 18 Water and Sediment Quality measures were assessed and reported in the 2024 Gladstone Harbour Report Card. These measures were recommended by the GHHP Independent Science Panel as indicative of the factors relevant to the harbour and its condition. The importance of each measure to overall harbour health is described in the sections below.

Physicochemical indicators

pH

The pH of water is a measure of its alkalinity or acidity. By assessing the concentration of free hydrogen and hydroxyl ions in water, pH indicates whether the water is acidic (pH 0–6), neutral (7) or alkaline (pH 8–14). pH is an important property of marine and estuarine water as it determines the solubility and biological availability of many nutrients and metals. As a rule of thumb, the solubility of most metals tends to increase at low pH. Plant and animal species usually tolerate a narrow pH range outside of which their ecology and behaviour are adversely impacted.

Turbidity

Turbidity is a measure of water clarity and is affected by the levels of suspended sediment (sand, silt and clay), organic matter and plankton in the water. Coloured substances such as pigments and tannins from decaying plant matter may also reduce water clarity, but to a lesser extent. High turbidity decreases the light levels reaching the seabed which reduces photosynthesis and the production of dissolved oxygen. This can lead to suppressed growth and reproduction and if exposed to low light for prolonged periods, eventually to mortality of algae, seagrasses and corals.

Nutrients

Nitrogen and phosphorus are essential nutrients for all organisms and occur in the natural environment. However, excess concentrations of these nutrients in the marine environment may lead to increased biomass of phytoplankton, epiphytic algae and macro-algae which can have a range of negative effects. Phytoplankton blooms can be toxic, phytoplankton in the water column increases turbidity, and collapsing algal blooms deplete oxygen concentrations, causing fish kills and undesirable changes in sediment chemistry. Epiphytic algae and macroalgae can also kill or outcompete aquatic organisms such as seagrasses and corals that are important for habitat and foodwebs.

Total nitrogen

Total nitrogen (N) is the sum of all forms of nitrogen in the marine environment, including nitrate, nitrite, ammonia nitrogen and organic nitrogen. Nitrogen is an essential nutrient for all organisms, but at high levels it can lead to the problems described above.

Total phosphorus

In aquatic systems, phosphorus (P) exists in various forms such as dissolved orthophosphate, organic phosphorus and particulate phosphorus. The total phosphorus measure gives an indication of all forms of phosphorus in the water body. Key sources of phosphorus in water include urban run-off, fertiliser run-off, rock weathering, sewage effluent and animal faeces.

Chlorophyll-*a*

Chlorophyll-*a* is a plant pigment used in photosynthesis. Chlorophyll-*a* measured in the water is an indication of concentrations of phytoplankton growth (pelagic microalgae and cyanobacteria) which is related to dissolved nutrient concentrations. High levels of chlorophyll-*a* may indicate presence of elevated nutrient concentrations and potentially, algal or cyanobacterial algal blooms.

Dissolved metals and metalloid

A suite of metals and one metalloid (arsenic) have been selected as indicators of harbour health. General information on the descriptions of metals, factors affecting toxicity and toxicology were retrieved from ANZG (2018).

Aluminium
The element aluminium (Al) is a silvery white metal and the most abundant metal in the Earth's crust (Zumdahl and DeCost, 2010); therefore, it is common to find traces of this element in soil, sediment and water. Aluminium in seawater can be derived from sources that are natural (e.g., weathering of mineral rocks) or anthropogenic (e.g., mining waste, industrial discharges, urban run-off). High levels of dissolved aluminium in aquatic systems are toxic to algae and marine animals.

Arsenic
Arsenic (As) is a naturally occurring element in the environment. It can be introduced into aquatic environments through natural contamination (e.g., by geothermal activity) or anthropogenically, principally through mining-related activities that may disturb arsenic deposits (Garelick et al., 2008). Arsenic may also be mobilised from bauxite residues remaining after aluminium extraction and is typically stored in red mud dams (Lockwood et al., 2014). In sediment, arsenic is available as As (III), As (V) and in methylated forms. It is a highly soluble and mobile element, inorganic forms of which may be toxic to aquatic species. Most biota convert inorganic arsenic to less toxic organic forms (e.g., arsenosugars, arsenobetaine).

Cadmium
Cadmium (Cd) is a non-essential element in plants and animals. The sources of cadmium in oceanic waters may be natural (e.g., volcanic activities, rock weathering) or anthropogenic (e.g. releases from open burning or incineration of municipal waste, mining activities, releases from landfills). In water, cadmium is mostly adsorbed onto sediment and suspended particles. Increased concentrations of cadmium in aquatic systems can lead to a range of toxic effects in fish, invertebrates, amphibians and aquatic plants (UNEP, 2010).

Copper
Copper (Cu) is an essential micro-nutrient for plants and animals. As for other metals, sources of copper in water may be natural (e.g., released from sediments) or anthropogenic (e.g., as a biocide in antifouling marine paint). Increased concentrations of copper in aquatic systems can lead to a range of toxic effects on algae, invertebrates, fish, and other animals.

Lead
Lead (Pb) is a toxic heavy metal that may have anthropogenic (e.g., industrial discharge, mining discharge) or natural origins. Natural waters generally have very low concentrations of lead. In water, lead is mostly adsorbed onto sediment and suspended particles. This metal has no known benefits to aquatic plants or animals. In marine environments, increased lead can disrupt invertebrate growth and therefore affect populations (Botte et al., 2022).

Manganese
Manganese (Mn) is the 11th most abundant element in the Earth's crust and an essential nutrient for the wellbeing of plants and animals. Its origin can be either anthropogenic or natural. The overall toxicity of manganese to marine biota (except corals) is low. Two manganese deposits near Gladstone Harbour have previously been mined and produced over 1,000 tonnes of manganese ore. Those deposits were at Auckland Inlet (mined 1882–1900) and Boat Creek (mined 1901–1902) (Wilson and Anastasi, 2010).

Mercury
Mercury (Hg) is a toxic heavy metal that can have natural (e.g. weathering of rocks over time) or anthropogenic origins (e.g. coal burning power stations). In sediments it can be converted to methylmercury by microorganisms. This highly toxic chemical can build up in shellfish, fish and animals that eat fish. Potential effects of mercury exposure include a reduction in growth rate and development, abnormal behaviour and death.

Nickel

Nickel (Ni) is the 24th most abundant metal in the Earth's crust and is essential for all organisms (Cempel and Nikel, 2006). Nickel in waterways can come from sources that are industrial or natural (e.g., through rock weathering). In water, nickel is mostly adsorbed onto sediment and suspended particles. At high concentrations, nickel becomes toxic to organisms, but it does not tend to bioaccumulate through the food web.

Zinc

Zinc (Zn) is an essential trace element for animals and plants. Anthropogenic sources include zinc from sacrificial anodes in ships, industrial discharges (e.g., mines, galvanic industries, and battery production), sewage effluent, surface run-off and some fungicides and insecticides. At high concentrations zinc is toxic to organisms.

3.1.3 Water and Sediment Quality results and discussion

Water quality

The overall harbour score for Water quality in the 2024 report card was 0.83 resulting in a good (B) grade (Table 3.3). Out of the 13 reporting zones, three received very good (A) grades, while the remaining ten were graded good (B).

Compared to the 2023 report card, physicochemical scores remained stable across most zones, with noticeable improvements in Boyne Estuary, which rose from satisfactory (C) to good (B), and Rodds Bay, which improved from good (B) to very good (A).

Improvement was seen in the nutrients sub-indicator group, where four zones had improved grades. For instance, Boat Creek moved from poor (D) to satisfactory (C), while Graham Creek, Inner Harbour, and Auckland Inlet all improved from satisfactory (C) to good (B). Only two zones, South Trees Inlet and Colosseum Inlet, saw a decline in nutrient grades, both dropping from good (B) to satisfactory (C). All other zones maintained their previous grades for nutrients. Dissolved metals remained consistently very good (A) across all zones.

Table 3.3 | Water quality sub-indicator and zone scores used in the 2024 Gladstone Harbour Report Card. Scores from 2023 and 2022 are shown for comparison.

Water quality	Physico chemical	Nutrients	Dissolved metals	2024	*2023*	*2022*
1. The Narrows	0.78	0.56	1.00	0.78	*0.79*	*0.77*
2. Graham Creek	0.96	0.73	1.00	0.90	*0.85*	*0.85*
3. Western Basin	0.83	0.57	1.00	0.80	*0.78*	*0.77*
4. Boat Creek	0.83	0.64	1.00	0.82	*0.69*	*0.78*
5. Inner Harbour	0.76	0.65	1.00	0.80	*0.78*	*0.84*
6. Calliope Estuary	0.75	0.71	1.00	0.82	*0.81*	*0.81*
7. Auckland Inlet	0.79	0.65	0.97	0.80	*0.77*	*0.78*
8. Mid Harbour	0.80	0.60	1.00	0.80	*0.82*	*0.84*
9. South Trees Inlet	0.87	0.64	1.00	0.84	*0.85*	*0.79*
10. Boyne Estuary	0.79	0.51	1.00	0.76	*0.70*	*0.86*
11. Outer Harbour	0.94	0.82	1.00	0.92	*0.94*	*0.88*
12. Colosseum Inlet	0.87	0.58	0.99	0.81	*0.88*	*0.81*
13. Rodds Bay	0.94	0.68	1.00	0.87	*0.86*	*0.76*
Harbour score	0.84	0.69	1.00	0.83	*0.81*	*0.81*

In the physiochemical sub-indicator group, pH consistently received very good (A) grades across all zones (Table 3.4). However, turbidity grades varied from satisfactory (C) to very good (A). Notably, five zones saw an improvement of one or more grades compared to the 2023 report card: Graham Creek (2023: 0.83, 2024: 0.92), Western Basin (2023: 0.58, 2024: 0.67), Boat Creek (2023: 0.36, 2024: 0.65, Inner Harbour (2023: 0.46, 2024: 0.51) and Boyne Estuary (2023: 0.19, 2024: 0.57). Only Colosseum Inlet declined a grade to good (B). All other zones remained unchanged.

The overall nutrient sub-indicator score increased due to reductions in total phosphorus and chlorophyll-*a* concentrations across the harbour that outweighed some increases in total nitrogen. The latter led to reduced scores for total nitrogen in nine of the 13 zones, including six that scored as poor (D) grades (Western Basin, Boat Creek, Auckland Inlet, Mid Harbour, Boyne Estuary and Colosseum Inlet), and none that scored a good (B) or very good (A).

For total phosphorus, 10 of the 13 zones improved in grades, achieving good (B) or very good (A) grades. Noteworthy improvements were seen in Boat Creek (2023: 0.20, 2024: 0.60), which improved from very poor (E) to satisfactory (C), and Boyne Estuary (2023: 0.60, 2024: 0.78), which improved from satisfactory (C) to good (B). The remaining three zones retained good (B) or very good (A) grades.

Chlorophyll-*a* scores also improved in four zones, including The Narrows (2023: 0.47, 2024: 0.53), Graham Creek (2023: 0.46, 2024: 0.65), Boat Creek (2023: 0.67, 2024: 0.83), and Outer Harbour (2023: 0.62, 2024: 0.90). Five zones experienced declines, while four remained stable. Eight of the 13 zones had moderate or poor scores.

Although nutrient sources are difficult to define, catchment run-off is a major source of nutrients in estuarine waters such as Gladstone Harbour (Hale and Box, 2014). As noted in section 8.2, rainfall and river discharge was generally below average over the report card year. Nutrient loads entering the harbour can also be influenced by land use (agricultural, industrial, urban, etc.), discharge from portside industries, and climatic conditions, with nutrient loads expected to increase with wet season run-off. As nutrients can bind to fine sediments, the resuspension of sediments associated with tidal movements or wave action can also lead to increased nutrient concentrations within Gladstone Harbour.

With the exception of copper concentrations at Auckland Inlet (0.83, B), dissolved metals continued to receive very good (A) grades across all measures and zones, a trend observed since monitoring began.

Table 3.4 | Water quality measure scores used in the 2024 Gladstone Harbour Report Card.

Zone	Physicochemical		Nutrients			Dissolved metals					
	pH	Turbidity	Total N	Total P	Chl-*a*	Al	Cu	Pb	Mn	Ni	Zn
1. The Narrows	1.00	0.57	0.50	0.66	0.53	1.00	1.00	1.00	1.00	1.00	1.00
2. Graham Creek	1.00	0.92	0.56	0.98	0.65	1.00	1.00	1.00	1.00	1.00	1.00
3. Western Basin	1.00	0.67	0.45	0.79	0.46	0.99	1.00	1.00	1.00	1.00	1.00
4. Boat Creek	1.00	0.65	0.49	0.60	0.83	1.00	1.00	1.00	1.00	1.00	1.00
5. Inner Harbour	1.00	0.51	0.53	0.91	0.50	1.00	1.00	1.00	1.00	1.00	1.00
6. Calliope Estuary	1.00	0.50	0.51	0.79	0.81	1.00	1.00	1.00	1.00	1.00	1.00
7. Auckland Inlet	1.00	0.58	0.48	0.70	0.76	1.00	0.83	1.00	1.00	1.00	1.00
8. Mid Harbour	1.00	0.60	0.41	0.88	0.51	1.00	1.00	1.00	1.00	1.00	1.00
9. South Trees Inlet	1.00	0.75	0.55	0.84	0.54	1.00	1.00	1.00	1.00	1.00	1.00
10. Boyne Estuary	1.00	0.57	0.31	0.78	0.44	1.00	1.00	1.00	1.00	1.00	1.00
11. Outer Harbour	1.00	0.88	0.56	1.00	0.90	1.00	1.00	1.00	1.00	1.00	1.00
12. Colosseum Inlet	1.00	0.75	0.44	0.93	0.37	1.00	0.94	1.00	1.00	1.00	1.00
13. Rodds Bay	1.00	0.88	0.58	0.99	0.48	1.00	1.00	1.00	1.00	1.00	1.00
Harbour score	1.00	0.68	0.49	0.83	0.60	1.00	0.98	1.00	1.00	1.00	1.00

Total N – total nitrogen; Total P – total phosphorous; Chl-*a* – chlorophyll-*a*; Al – aluminium; Cu – copper; Pb – lead; Mn – manganese; Ni – nickel; Zn – zinc.

Sediment quality

The overall Sediment quality scores were derived from one sub-indicator – metal and metalloids. Six metals (cadmium, copper, lead, mercury, nickel and zinc) and the metalloid arsenic were assessed. The harbour score for Sediment quality was 0.96 with a very good (A) grade, similar to preceding years (0.95–0.99; very good (A)) (Table 3.5).

Table 3.5 | Sediment quality scores used in the 2024 Gladstone Harbour Report Card. Scores from 2021, 2022 and 2023 are shown for comparison.

Zone	2024	*2023*	*2022*	*2021*
1. The Narrows	0.91	*0.95*	*0.94*	*0.92*
2. Graham Creek	0.96	*1.00*	*0.97*	*0.95*
3. Western Basin	0.98	*0.99*	*0.98*	*0.99*
4. Boat Creek	0.91	*0.94*	*0.89*	*0.92*
5. Inner Harbour	0.93	*0.93*	*0.94*	*0.94*
6. Calliope Estuary	0.99	*0.97*	*0.97*	*0.95*
7. Auckland Inlet	0.95	*0.97*	*0.95*	*0.93*
8. Mid Harbour	0.96	*0.97*	*0.98*	*0.96*
9. South Trees Inlet	0.97	*0.96*	*0.97*	*0.97*
10. Boyne Estuary	0.97	*0.99*	*0.99*	*0.99*
11. Outer Harbour	0.98	*0.99*	*1.00*	*0.98*
12. Colosseum Inlet	1.00	*1.00*	*0.96*	*1.00*
13. Rodds Bay	0.97	*1.00*	*1.00*	*0.98*
Harbour score	0.96	*0.97*	*0.96*	*0.96*

Sediment quality scores have remained stable across all zones since monitoring began, reflecting consistently low concentrations of key measures (arsenic, cadmium, copper, lead, mercury, nickel, and zinc; Table 3.6). Scores for cadmium, copper, lead, mercury, and zinc were uniformly high (1.00), with very good (A) grades across all zones. In contrast, arsenic and nickel scores showed more variation, ranging from 0.60 to 1.00 for arsenic and 0.65 to 1.00 for nickel, consistent with trends observed in previous report cards.

Angel et al. (2012), showed that particulate arsenic concentrations exceeded the ANZECC/ARMCANZ ISQG[1]-low trigger value in two samples from The Narrows and one sample near Quoin Island. They noted that the source of this arsenic was natural (geological formation on the area) and not associated with anthropogenic inputs. Similarly, it has been suggested that The Narrows is a source of dissolved nickel, as dissolved nickel concentrations in water increase with proximity to The Narrows (Angel et al., 2010; Angel et al., 2012). The same general pattern was evident in sediment nickel scores in the current and previous Gladstone Harbour Report Cards, further implying a natural source of nickel.

[1] ISQG refers to the Interim Sediment Quality Guideline. For sediment arsenic and cadmium this guideline is used in the report card.

Table 3.6 | Sediment quality measure scores used in the 2024 Gladstone Harbour Report Card.

	Metals and metalloid						
Zone	As	Cd	Cu	Pb	Hg	Ni	Zn
1. The Narrows	0.69	1.00	1.00	1.00	1.00	0.66	1.00
2. Graham Creek	0.85	1.00	1.00	1.00	1.00	0.85	1.00
3. Western Basin	0.92	1.00	1.00	1.00	1.00	0.96	1.00
4. Boat Creek	0.71	1.00	1.00	1.00	1.00	0.65	1.00
5. Inner Harbour	0.60	1.00	1.00	1.00	1.00	0.89	1.00
6. Calliope Estuary	1.00	1.00	1.00	1.00	1.00	0.91	1.00
7. Auckland Inlet	0.88	1.00	0.97	1.00	1.00	0.79	1.00
8. Mid Harbour	0.69	1.00	1.00	1.00	1.00	1.00	1.00
9. South Trees Inlet	0.87	1.00	1.00	1.00	1.00	0.95	1.00
10. Boyne Estuary	0.81	1.00	1.00	1.00	1.00	1.00	1.00
11. Outer Harbour	0.84	1.00	1.00	1.00	1.00	1.00	1.00
12. Colosseum Inlet	1.00	1.00	1.00	1.00	1.00	1.00	1.00
13. Rodds Bay	0.82	1.00	1.00	1.00	1.00	1.00	1.00
Harbour score	0.82	1.00	1.00	1.00	1.00	0.90	1.00

As – arsenic, Cd – cadmium, Cu – copper, Pb – lead, Hg – mercury, Ni – nickel and Zn – zinc.

3.1.4 Water and Sediment Quality trends

Water and Sediment Quality has consistently received very good (A) grades for the past eight years (Figure 3.1).

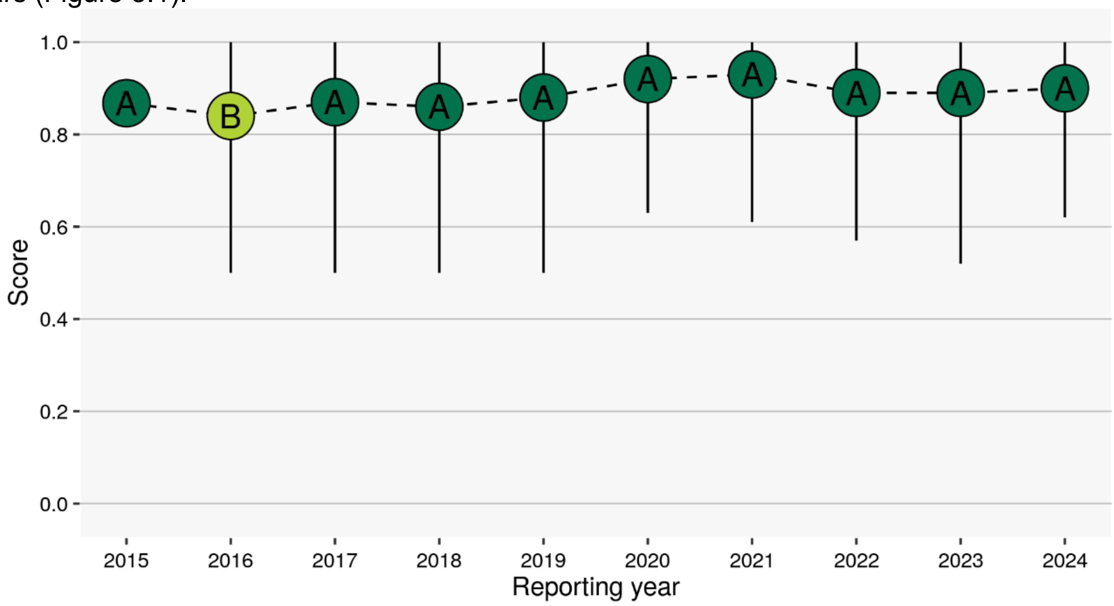

Figure 3.1 | Trends in the overall harbour score for Water and Sediment Quality 2015–2024 (Error bars show 95% bootstrap confidence intervals).

Scores for the Water quality indicator have remained high since the first full report card in 2015 and has been graded good (B) or very good (A; Figure 3.2).

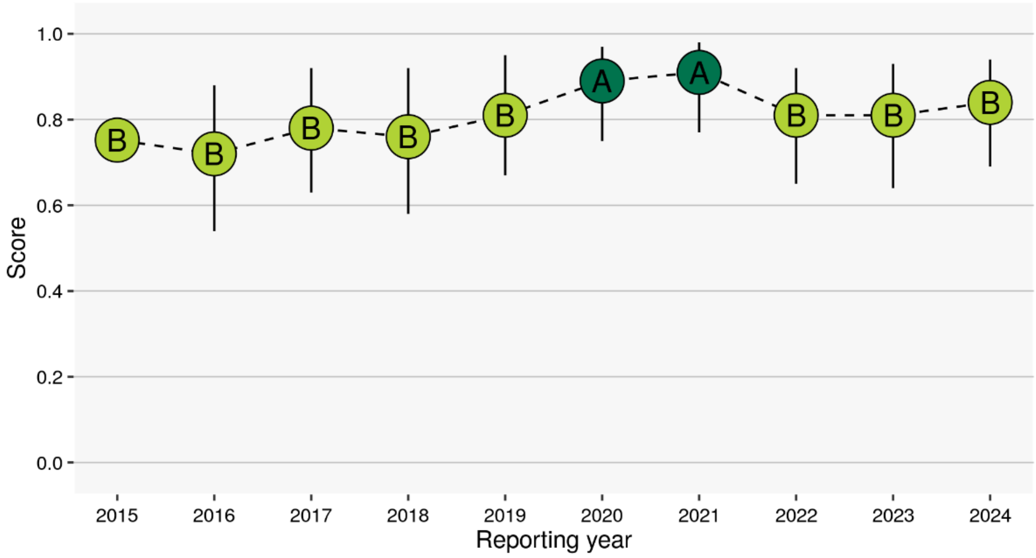

Figure 3.2 | Trends in the overall harbour score for Water quality 2015–2024 (Error bars show 95% bootstrap confidence intervals).

Sediment quality received uniformly very good grades (A) across all Gladstone Harbour reporting zones for the tenth consecutive year (Figure 3.3).

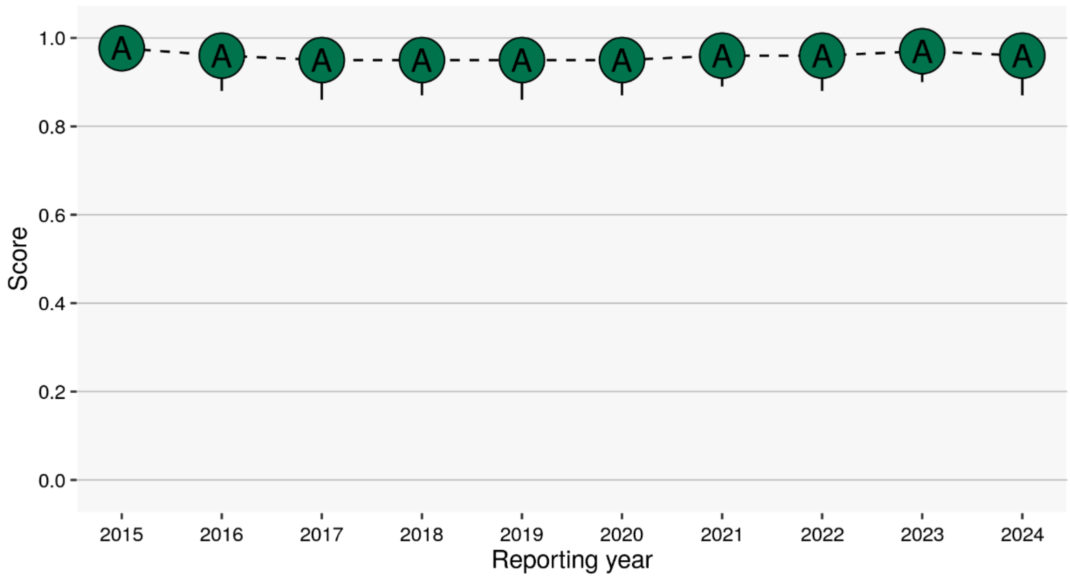

Figure 3.3 | Trends in the overall harbour score for Sediment quality 2015–2024 (Error bars show 95% bootstrap confidence intervals).

3.2 Habitats

3.2.1 Seagrass

What is seagrass?

Seagrasses are the only flowering plants that can live entirely submerged in seawater. These unique, aquatic plants grow in sediment on the seafloor with erect elongate or oval leaves and a buried rhizome and root structure. Seagrasses are widely distributed along the coastlines of the world and provide a range of important functions within the marine ecosystem. There are four families of seagrass worldwide, three of which are commonly found in Gladstone Harbour. The seagrass indicators in the report card are based on five species of seagrass (Figure 3.4):

- *Zostera muelleri ssp. capricorni*
- *Halophila ovalis*
- *Halophila decipiens*
- *Halophila spinulosa*
- *Halodule univervis* (wide and narrow leaf)

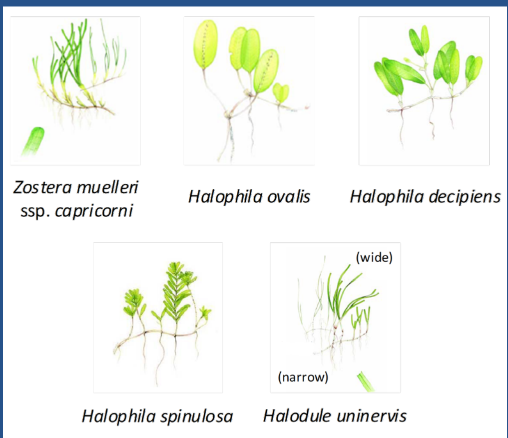

Figure 3.4 | Seagrass species

Seagrass meadows are one of the most important habitat types in Gladstone Harbour. Within the GHHP reporting area, there are 14 monitored seagrass meadows. These are located within six harbour zones: The Narrows, Western Basin, Inner Harbour, Mid Harbour, South Trees Inlet and Rodds Bay. The area and distribution of the seagrass meadows can vary annually, but at peak distribution seagrass meadows in Gladstone Harbour can cover approximately 16,000 ha (Davies et al., 2016). This area includes intertidal, shallow subtidal and deep-water habitats. Seagrasses inhabit various substrata from mud to rock. The most extensive seagrass meadows occur on soft substrata such as sand and mud. Seagrass meadows provide a range of important ecosystem functions, including sediment stabilisation, nutrient cycling and carbon sequestration (Figure 3.5). They also provide nursery areas for juvenile fishes and foraging areas for dugongs, turtles and large fish such as Barramundi.

Seagrasses are highly sensitive to reductions in available light and are susceptible to changes in a range of water quality parameters that affect light penetration. High nutrient levels from agricultural or urban run-off can cause algal blooms that shade seagrass. Increases in water turbidity from suspended sediments can reduce seagrass growth and the size and extent of seagrass meadows. This is due to a decrease in available light and the effects of sediments settling on seagrass leaves. In Gladstone Harbour, increases in turbidity may be associated with flooding, large tidal movements or dredging. At a local scale, dredging can impact seagrasses by increasing turbidity and reducing the amount of available light. While a number of factors can negatively impact seagrass growth, McCormack et al. (2013) indicated environmental conditions are key influences on seagrass meadow condition in Gladstone Harbour.

Information in the following sections is drawn from a seagrass monitoring project that commenced in 2002 (Reason et al. 2024; Smith et al., 2024), funded by the Gladstone Ports Corporation Ltd (GPC). Nearly two decades of monitoring and research have provided insight into potential causes and trends regarding changes in the seagrass meadows of Gladstone Harbour.

3.2.2 Seagrass data collection

The Seagrass Ecology Group from the Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) at James Cook University collected data to estimate the Seagrass scores for the 2024 report card. In 2002, GPC commissioned a fine-scale survey of seagrass within the Gladstone Port Limits (Rasheed et al., 2003). This baseline survey identified large areas of seagrass within the limits of the Port of Gladstone.

The annual seagrass monitoring program started in 2004 and currently assesses 14 representative intertidal and shallow subtidal seagrass meadows in Gladstone Harbour and Rodds Bay (Figures 10.2, 10.6, 10.10, 10.16, 10.18 and 10.26). Meadows were selected to represent the range of seagrass communities within the port considered the most likely to be impacted by port facilities and future developments. Additional out-of-port reference meadows were selected at Rodds Bay. Seagrass monitoring is conducted annually in October or November around the peak of seagrass abundance.

Three sub-indicators of seagrass health were measured to calculate the seagrass scores for the Gladstone Harbour report card:

- **Biomass** – changes in average above-ground biomass within a monitoring meadow
- **Area** – changes in the total area of a monitoring meadow
- **Species composition** – changes in the relative proportions of species within a monitoring meadow

Why is the seagrass species important?

Fisheries habitat: Fish display a distinct preference for particular species of seagrass. A shift in species composition can lead to a change in the abundance and diversity of fishes.

Benthic invertebrate diversity: The abundance and diversity of benthic invertebrates differs between seagrass species. Changes in the benthic invertebrate community can result in the loss of important habitat functions and a decline in the secondary productivity of the meadow.

Coastal protection: Stiffness, biomass, density, leaf length and morphology all influence the coastal protection value of seagrass. Long-lived, slow-growing species provide the greatest protection.

Figure 3.5 | Seagrass at low tide

Carbon sequestration: Species composition is a known variable for carbon sequestration. Larger bodied species are generally associated with higher sedimentary organic carbon stocks.

Resistance to disturbance: Larger bodied, persistent species generally have a higher physiological resistance to disturbance, while small-bodied colonising species can recover more rapidly following disturbances.

Biomass and species composition

Above-ground biomass was estimated using visual estimates. At each site, 0.25 m^2 quadrats were placed in three randomly selected locations. Each quadrat was ranked relative to a series of photographs of quadrats for which the biomass had been previously determined. The percentage of each seagrass species within each quadrat was also recorded. After the quadrats were ranked, the observer also ranked a series of calibration photographs that represented the range of seagrass biomass observed during the survey. The field biomass ranks were then converted into estimates of above-ground biomass in grams dry weight per square metre ($gDWm^{-2}$) for each of the replicate quadrats at a site.

Area

The area of the monitored seagrass meadows was determined with ArcGIS 10.8®. For each meadow, a mapping precision estimate ranging from ≤5 m to 50–200 m was developed based on the mapping methodology (Table 3.7). Spatial data from the survey were entered into the Gladstone Harbour GIS as seagrass meadow layers.

Table 3.7 | Mapping precision and mapping methodology for seagrass meadows for the Gladstone Harbour Report Card seagrass surveys (Adapted from Smith et al., 2022b).

Mapping precision	Mapping method
<5 m	Meadow boundaries mapped by GPS from helicopter Intertidal meadows completely exposed or visible at low tide Relatively high density of mapping and survey sites Recent aerial photography aided in mapping
10–20 m	Meadow boundaries determined from helicopter and boat surveys Intertidal boundaries interpreted from helicopter mapping and survey sites Recent aerial photography aided in mapping Subtidal boundaries interpreted from survey sites Moderately high density of mapping and survey sites
20–50 m	Meadow boundaries determined from helicopter and boat surveys Intertidal boundaries interpreted from helicopter mapping and survey sites Subtidal boundaries interpreted from boat survey sites Lower density of survey sites for some sections of boundary
50–200 m	Meadow boundaries determined from boat surveys Subtidal meadows interpreted from survey sites Lower density of survey sites for meadow boundary

3.2.3 Development of Seagrass indicators and scoring

Seagrass scores for the Gladstone Harbour Report Card were obtained by comparing the results for each seagrass meadow with a predetermined baseline condition for each indicator. Bryant et al. (2014) found that the most appropriate baseline was a fixed 10-year (2002–12) average calculated from previous seagrass surveys.

To estimate seagrass grades, threshold levels for each grade (A–E) were developed based on:

- the historical variability within each meadow
- expert knowledge of meadow types
- tests at a range of thresholds to determine which best fits the historical data

Threshold ranges were developed for the meadow types for the sub-indicator's biomass, area and species composition (Table 3.8). Scores for each sub-indicator were based on these thresholds and a score between 0.00 and 1.00 was calculated to fit the Gladstone Harbour Report Card grade range (Carter et al., 2015).

Between 2015 and 2017, the overall score for each monitoring meadow was defined as the lowest score received for each of the three indicators. The lowest score, rather than the mean of the three indicator scores, was applied because a poor score for any one of the three indicators described a seagrass meadow in poor condition. A review in 2018 of how meadow scores were calculated led to a change in this method. The new method still defines overall meadow condition as the lowest indicator score when this score is either meadow area or biomass; however, where species composition is the lowest score, the overall meadow score is 50% of the species composition score and 50% of the next lowest score (area or biomass). This change was applied to correct an anomaly noted in the 2017 report card where the Inner Harbour received a score of zero owing to a species composition score of zero despite having very good biomass and good area grades. The change acknowledges that the species composition is an important characteristic of a seagrass meadow in terms of defining meadow stability, resilience, and ecosystem services, but is not as fundamental as having seagrass present.

The zone score is the average of the overall meadow scores within that zone, and the overall harbour score is the mean of the zone scores.

Note, the 2024 Gladstone Harbour Report Card scores may differ slightly to those reported by Reason et al. (2024) due to bootstrapping used to calculate Gladstone Harbour Report Card scores. The bootstrapping method resamples the original data many times to yield multiple means which are used to develop a series of distributions for measures, sub-indicators, indicators, and indicator groups. By aggregating distributions (rather than individual means), the rich distributional properties could be preserved, sample bias could be avoided, and means (the report card score) and variances could be calculated for reporting.

Table 3.8 | Threshold values between grades A to E varied for the seagrass meadow types for each of the three seagrass sub-indicators (biomass, area and species composition). Each grade was determined by the percentage difference from a baseline of the 10-year mean (Adapted from Smith et al., 2022b).

Seagrass condition indicators/ Meadow class		**Seagrass grade**				
		Very Good (A)	Good (C)	Satisfactory (C)	Poor (D)	Very Poor (E)
Biomass	Stable	>20% above	20% above–20% below	20–50% below	50–80% below	>80% below
	Variable	>40% above	40% above–40% below	40–70% below	70–90% below	>90% below
Area	Highly stable	>5% above	5% above–10% below	10–20% below	20–40% below	>40% below
	Stable	>10% above	10% above–10% below	10–30% below	30–50% below	>50% below
	Variable	>20% above	20% above–20% below	20–50% below	50–80% below	>80% below
	Highly variable	>40% above	40% above–40% below	40–70% below	70–90% below	>90% below
Species composition	Stable and variable; Single species dominated	>0% above	0–20% below	20–50% below	50–80% below	>80% below
	Stable; Mixed species	>20% above	20% above–20% below	20–50% below	50–80% below	>80% below
	Variable; Mixed species	>20% above	20% above–40% below	40–70% below	70–90% below	>90% below

3.2.4 Seagrass results and discussion

Seagrass monitoring conducted in November 2023 for the 2024 report card revealed an improvement in seagrass condition in Gladstone Harbour, with the grade rising from satisfactory (C) in 2023 to good (B) in 2024. This improvement is linked to an increase in the overall harbour score, which rose from 0.58 in 2023 to 0.68 in 2024 (Table 3.9).

Table 3.9 | Seagrass sub-indicator, overall meadow and zone scores used in the 2024 Gladstone Harbour Report Card. Scores from 2023 and 2022 are shown for comparison.

Zone	Meadow	Biomass	Area	Species comp.	Overall meadow	2024	*2023*	*2022*
1. The Narrows	21	0.89	0.96	0.97	0.89	0.89	*0.93*	*0.94*
3. Western Basin	4	0.88	0.97	0.86	0.87	0.70	*0.72*	*0.82*
	5	0.84	0.91	0.87	0.84			
	6	0.74	0.94	0.32	0.53			
	7	0.85	0.58	1.00	0.58			
	8	0.69	0.84	0.54	0.61			
	52–57*	0.73	0.87	1.00	0.73			
5. Inner Harbour	58	0.87	0.87	0.00	0.43	0.43	*0.10*	*0.39*
8. Mid Harbour	43	0.45	0.86	0.83	0.45	0.49	*0.57*	*0.67*
	48	0.54	0.79	0.65	0.54			
9. South Trees Inlet	60	0.81	1.00	0.99	0.81	0.81	*0.81*	*1.00*
13. Rodds Bay	94	0.85	0.74	0.98	0.74	0.74	*0.38*	*0.42*
	96	0.78	1.00	0.85	0.78			
	104	0.71	0.93	0.84	0.71			
Harbour score						0.68	*0.58*	*0.70*

*Meadow 52-57 consists of a number of small meadows surrounding the Passage Islands in the Western Basin Zone. These meadows are grouped for reporting purposes.

Zone 1 – The Narrows

The Narrows features one monitored meadow at Black Swan Island, an intertidal area with variable biomass. Since monitoring began in 2015, the condition of this meadow has steadily improved, consistently receiving a very good (A) grade for the past three years with scores of 0.94, 0.93, and 0.89, respectively. This year marks the longest consecutive period of high scores for any meadow.

Zone 3 – Western Basin

The Western Basin has six monitored seagrass meadows: five intertidal and one subtidal (Meadow 7). In 2024, this zone earned a good grade (B) for the sixth year in a row.

For Meadows 4, 5, and 6, biomass and area scores were similar to those in 2023. Composition scores improved for Meadows 4 and 5 (from 0.56 to 0.86 and from 0.64 to 0.87, respectively), while Meadow 6 saw a decline (from 0.50 to 0.32).

Meadow 7 showed an improvement in biomass score (from 0.58 in 2023 to 0.85 in 2024), though area and species composition scores remained steady. The overall condition of Meadow 8 was stable.

In Meadows 52–57, biomass scores decreased from 0.88 in 2023 to 0.73 in 2024, leading to a drop in the overall meadow score from 0.88 to 0.73 and a downgrade from very good (A) to good (B).

Zone 5 – Inner Harbour

In the south-east corner of Inner Harbour, near South Trees Inlet, there is one monitored seagrass meadow. This meadow showed significant improvements in both biomass and area scores, rising from 0.21 to 0.87 and from 0.74 to 0.87, respectively, compared to the previous year. Despite these gains, the overall condition of the meadow remains poor due to the continued absence of the key seagrass species *Zostera muelleri*, reflected by a very low species score (0.00).

Zone 8 – Mid Harbour

Mid Harbour has two monitored meadows adjacent to the south-east corner of Curtis Island. Meadow 43, known locally as Pelican Banks, is the largest (baseline = 632 ha) and most productive (baseline = 19 $gDWm^{-2}$) seagrass meadow assessed for the report card. It is also the only meadow where all three indicators are classed as stable or highly stable. Pelican Banks is an intertidal meadow while Meadow 48 is a subtidal meadow neighbouring the eastern side of Quoin Island.

Despite improvements in area and species composition scores for Meadow 43, a significant decline in biomass and species composition in Meadow 48 led to a drop in the zone's overall grade from satisfactory (C) in 2023 to poor (D) in 2024.

In Meadow 43, a shift from the once-abundant seagrass species *Zostera muelleri* to less persistent species like *Halodule uninervis* and *Halophila ovalis* contributed to a low biomass score. Furthermore, high levels of herbivory by dugongs and turtles in Meadow 43 may be altering the species composition and hindering recovery.

Zone 9 – South Trees Inlet

This zone has one monitored meadow which sits off the northern tip of South Trees Island. Meadow 60 is an intertidal meadow and the second smallest of the monitored meadows. The meadow remained in a similar condition to the previous year, with nearly identical scores.

Zone 13 – Rodds Bay

Rodds Bay has three intertidal seagrass monitoring meadows: Meadows 94, 96, and 104. Recent improvements in overall seagrass health in Gladstone Harbour were largely driven by an increase in these meadows' biomass and area scores (2023: 0.30–0.84, 2024: 0.71–1.00).

Between 2009 and 2010, Rodds Bay meadows experienced major declines, culminating in the complete loss of seagrass from 2011 to 2013. However, biomass and area scores peaked between 2019 and 2020, reaching a very good condition after nine to ten years of being rated satisfactory. Although the meadows fell to poor conditions in 2023, their recovery to good condition in 2024 across all indicators suggests that favourable climate conditions have helped improve their resilience and support another season of growth.

Impacts and drivers of seagrass condition

Long-term monitoring of seagrass has previously shown a strong connection between seagrass health and river flow and rainfall in the region (McCormack et al., 2013). In 2024, the Calliope River's outflow was significantly below average, with no flow in the months before the survey – a situation not seen since 2020 (Figure 8.7). This decrease in river flow led to clearer waters, providing ideal conditions for seagrass growth in Gladstone Harbour. Overall, seagrass meadows along Queensland's east coast, from Cairns to Port Curtis, have been improving since the widespread losses in 2009 and 2010 (Smith et al., 2024). However, the extent of recovery has varied depending on local conditions, climate events, and the severity of the initial losses.

In contrast, during previous years, declines in seagrass health were linked to above-average rainfall and increased river discharge (Smith et al. 2024). The higher turbidity from this runoff reduced the amount of light reaching the seagrass, which is crucial for their growth and can ultimately lead to their death.

Another factor affecting seagrass recovery is the herbivory by turtles and dugongs (Rasheed et al., 2017; Christianen et al., 2014). Research by Scott et al. (2021) used cages to exclude herbivores and study their impact on seagrass across the Great Barrier Reef. They found that Pelican Banks experienced more significant loss in seagrass biomass and canopy height compared to other meadows in Port Curtis and Rodds Bay. It appears that the Pelican Banks meadow (Meadow 43; 2024: 0.45, poor (D) grade) is heavily grazed by dugongs and turtles, which may be affecting the species composition and hindering the recovery of this meadow, resulting in its poorer condition.

3.2.5 Seagrass trends

In 2024, the condition of seagrass meadows in Gladstone Harbour was graded good (B), marking a return to the levels observed in the three years preceding 2023 and an improvement from the poor (D) grades reported between 2015 and 2018 (Figure 3.6).

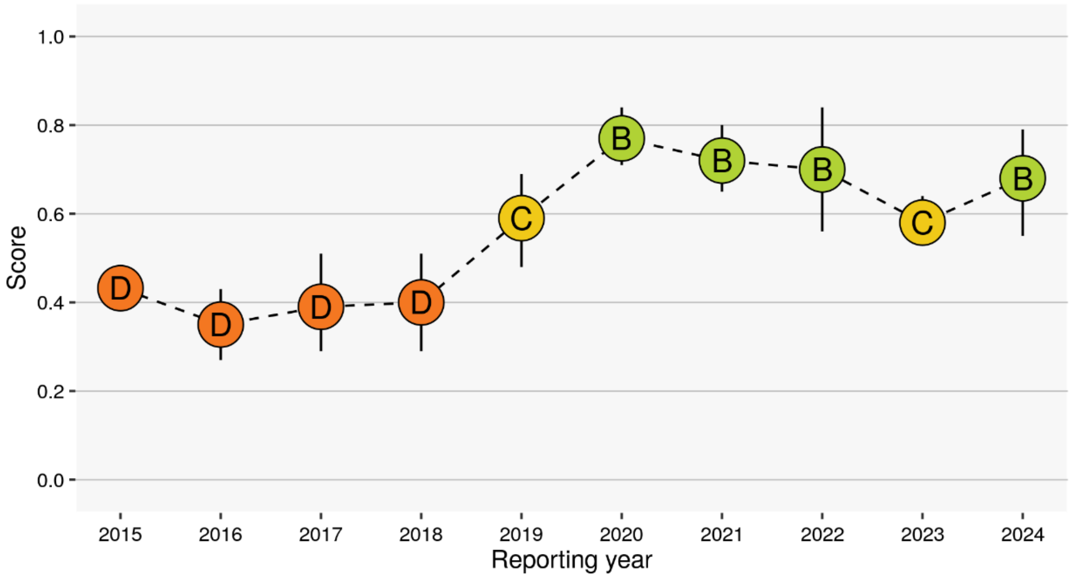

Figure 3.6 | Trends in the overall harbour score for Seagrass 2015–24 (Error bars show 95% bootstrap confidence intervals).

Table 3.10 | Grades for individual seagrass monitoring meadows from annual surveys, 2002–23. Note, report card and monitoring years differ (e.g. 2024 Report Card = Nov. 2023 monitoring). Adapted from Carter et al., 2023 and GHHP Technical reports 2020–23.

Zone	Meadow	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018*	2019	2020	2021	2022	2023
1. The Narrows	21								A	B	B	C	E	D	D	C	D	B	B	B	A	A	A
3. Western Basin	4	B		C	D	B	A	B	A	E	D	B	D	D	C	B	D	C	A	A	A	B	A
	5	C		D	C	B	B	A	C	D	D	C	E	D	D	C	C	C	A	B	A	B	B
	6	B		D	C	B	A	B	A	E	D	D	D	B	B	B	D	C	B	B	B	B	C
	7	B		B	E	A	D	B	D	E	E	E	D	B	B	D	E	A	B	C	C	C	C
	8	A		D	E	B	B	B	B	C	E	D	E	D	D	E	D	D	B	C	B	C	C
	52-57								C	E	E	B	B	C	D	B	B	A	B	B	A	A	B
5. Inner Harbour	58	B		D	B	D	B	B	B	E	D	C	E	D	D	D	E	E	B	C	D	E	D
8. Mid Harbour	43	B		B	B	C	C	A	B	B	C	C	C	C	D	E	D	D	D	D	C	D	D
	48	B		C	B	B	A	B	E	D	D	D	C	D	D	C	C	C	C	C	B	B	D
9. South Trees	60	A		E	E	B	A	A	C	E	E	C	E	C	D	B	A	A	A	A	A	B	B
13. Rodds Bay	94	A		D	A	B	A	A	E	E	E	E	E	D	E	E	E	C	A	B	E	D	B
	96	B		D	C	B	A	A	B	D	E	D	E	D	D	D	E	B	A	B	B	D	B
	104	B		D	B	B	B	A	C	E	E	E	E	C	D	E	E	D	A	C	C	D	B

*Note: 2018 scoring calculation methods changed to acknowledge that species composition is an important characteristic of a seagrass meadow, but not as fundamental as seagrass presence

3.2.6 Coral

Coral communities are iconic components of marine ecosystems in Australia. In addition to their high biodiversity, coral reefs provide spawning, nursery and feeding areas for fish and a variety of other animals. These include sea turtles, crustaceans (such as prawns and crabs) and a large range of benthic organisms such as echinoderms (e.g. sea stars, sea cucumbers, sea urchins), molluscs, sponges and worms. Reefs also provide important ecosystem services such as nutrient recycling, and carbon and nitrogen fixation. In addition to their ecological value, coral reefs have considerable socio-economic importance.

Reefs within the Gladstone Harbour monitoring zones include fringing, platform, headland and rubble fields with hard and soft corals (BMT WBM, 2013). Within the Gladstone Harbour area, reefs have been recorded in the intertidal zones that have suitable substrata and sufficient light penetration around Turtle, Quoin, Rat, Facing and Curtis islands and at Seal Rocks. Coral communities have also been recorded within deeper channels (>5 m) in The Narrows, around Passage Island and the North Passage. Regions of hard and soft coral also occur along the northern edge of Hummock Hill Island and limited coral reef development has also been identified in Rodds Bay (BMT WBM, 2013; DHI, 2013).

Threats to coral reefs include natural and anthropogenic pressures that can operate at global (e.g. climate change, El Niño Southern Oscillation), regional or local scales. These pressures include negative effects from large-scale flooding, sedimentation, urban pollution and agricultural run-off. Coral reef communities within Gladstone Harbour can be exposed to freshwater run-off, elevated turbidity and nutrient levels, and can be vulnerable to the negative impacts of sediments and increases in macroalgal cover (DHI, 2013).

Four sub-indicators of coral health were measured to calculate the coral score for the 2024 Gladstone Harbour Report Card:

1. Coral cover: the combined cover of hard and soft corals observed at the monitored reefs
2. Macroalgal cover: the cover of macroalgae observed at the monitored reefs
3. Juvenile coral density: the density of juvenile corals observed at the monitored reefs
4. Change in hard coral cover: averaged over a three-year period to give the rate at which hard coral cover increases or decreases.

3.2.7 Coral data collection

Establishment of long-term monitoring sites

Coral surveys in July 2015 identified suitable sites for the long-term monitoring program. Prior to starting the surveys, existing reports on coral community locations were used to identify potential sites for long-term coral monitoring (BMT WBM, 2013; DHI, 2013) in the Inner Harbour, Mid Harbour and Outer Harbour zones. The review identified three islands within the Inner Harbour as possible sites for coral monitoring: Quoin, Turtle and Diamantina. However, surveys for areas of hard substrate and subsequent spot checks of the benthic communities were unable to locate suitable monitoring sites. The search for potential Inner Harbour survey sites was hampered by low underwater visibility on both rising and falling tides.

Four permanently marked survey sites (transects) were established in the Mid Harbour at Rat Island, Farmers Reef, Facing Island and Manning Reef and two permanent sites were established in the Outer Harbour at Seal Rocks North and Seal Rocks South (Figures 3.7, 10.16 and 10.22).

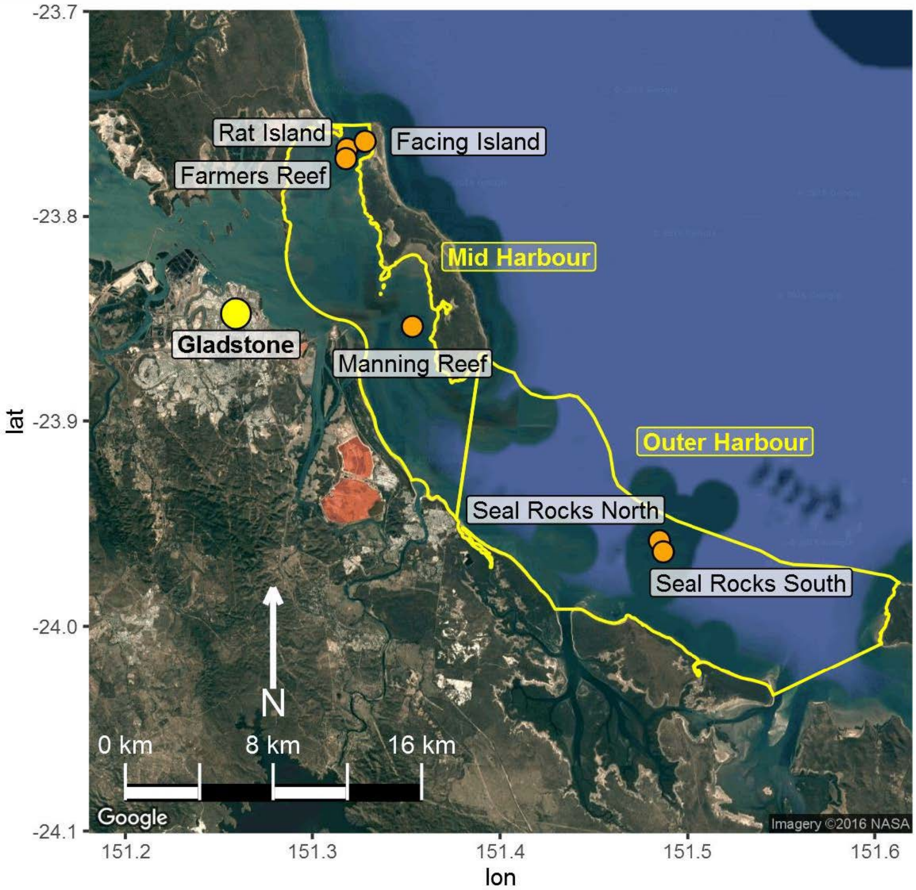

Figure 3.7 | Gladstone Harbour Coral monitoring sites (Thompson et al., 2024).

Coral monitoring

Coral monitoring was conducted in May 2024 and included the following three methodologies:

<u>Photo point intercept transects</u>
The methodology outlined below closely follows that outlined in the Australian Institute of Marine Science Long-term Monitoring Program (Jonker et al., 2008). At each 20 m transect, digital photographs were taken at 50 cm intervals. Estimates of the cover of benthic components, including coral and macroalgae, were made from five fixed points overlayed on each digital image. Most hard and soft corals were identified to genus.

<u>Juvenile corals</u>
Juvenile coral colonies, up to 5 cm in diameter were counted within a 34 cm band along each permanently marked transect. Each colony was identified to genus and assigned to a size class of 0–2 cm or 2–5 cm. The number of juvenile colonies observed along a fixed transect area will be affected by the availability of suitable substrata for settlement. To allow comparisons between reefs and over time, the numbers of recruits along each fixed transect were converted to densities per area available for settlement.

<u>Disturbances</u>
Incidences of coral disease, coral bleaching, coral predation by crown-of-thorns starfish, overgrowth by sponges, and smothering by sediments were counted along a two-metre belt centred on the transect tape. These data are not used in the calculation of report card scores. In the long term, however, they may be valuable for explaining changes in coral condition.

3.2.8 Development of coral sub-indicators and scoring

Each of the four coral sub-indicators was scored against a baseline based on expert opinion and data from the Marine Monitoring Program (MMP) for inshore reefs. The baseline for each of the four sub-indicators represented the threshold between report card grades of satisfactory condition (C) and poor condition (D). The highest possible score of 1.00 was set to represent coral reefs in as good condition as could be expected in the local environment (Table 3.11; Figure 3.8). The lowest score of 0.00 was set to represent the worst condition that could be expected in the local environment (Table 3.11; Figure 3.8). Although it is possible for the observed results to be outside those limits, the scores were capped at 0.00 and 1.00 to allow scaling to the GHHP range of grades.

Combined cover of hard and soft coral

Healthy coral communities have sufficient recruitment and growth of colonies to replace losses resulting from disturbances and environmental limitations. High coral cover suggests that a large brood-stock is available, which increases the potential of other reefs in the vicinity to recover from disturbance. High coral cover also contributes to the structural complexity of a reef and increases its biodiversity by providing habitat for fishes and other marine organisms. Both hard and soft coral cover were included in the assessment.

A detailed description of the development of the critical values and thresholds for coral cover are presented in Thompson et al. (2015). The values and thresholds used for the combined coral cover are based on two prior assessments of coral cover on nearshore reefs. A broad-scale survey of nearshore reefs between Cape Tribulation and the Keppel Islands conducted in 2004 using the same sampling methods as the Gladstone Harbour surveys returned a mean hard coral cover of 33% and 5% cover for soft corals (Sweatman et al., 2007). This 38% mean was observed after severe loss of corals owing to thermal bleaching in 1998 and 2002 and is considered too low for a threshold that would indicate a good condition (Thompson et al., 2015). A summary of coral surveys from over 100 sites between Cape Flattery and the Keppel Islands in 1996 prior to the bleaching events found a mean coral cover of hard corals of approximately 48% when the results were corrected to be consistent with MMP methods (Thompson et al., 2015). Allowing for some soft coral cover and rounding to an even percentage a 50% threshold for coral cover was proposed for the MMP and adopted for use in the Gladstone Harbour report card. Correcting for the differences in the grading schemes between the Reef Report Card and the Gladstone Harbour Report Card a 40% threshold is applied (Table 3.11). This figure is consistent with surveys conducted in Gladstone Harbour (Mid Harbour) prior to 2009 where a mean hard coral cover of 39% was reported (BMT WBM, 2013). Although the BMT WBM (2013) report did not provide a mean estimate for soft coral cover, the report indicates soft coral cover in the middle harbour ranged between ~4% and 40%.

It should be noted that while the thresholds and bounds were originally selected to be consistent with MMP reporting, subsequent changes to the thresholds and bounds for coral cover in the MMP (Thompson et al., 2016) mean that MMP thresholds are no longer consistent with the Gladstone Harbour Report Card.

Macroalgal cover

Macroalgae can suppress coral by increased competition for space and by changing the micro-environment and inhibiting coral colonisation and growth (Foster et al., 2008; Cheal et al., 2010). Once established, macroalgae occupy space that might otherwise be available for coral growth and recruitment. For this sub-indicator, macroalgae belonging to the Rhodophyta (red algae), Phaeophyta (brown algae) and Chlorophyta (green algae) were assessed.

Critical values for macroalgal cover were developed through the MMP and fitted to the Gladstone Harbour Report Card grading scheme (Figure 2.1). A baseline of 14% macroalgal cover was set at the D/C threshold (the point where the grade changes from passing to failing) for coral communities in Gladstone Harbour (Table 3.11).

Owing to changes in the calculation of macroalgae scores in the MMP, including the use of reef-specific water quality conditions (Thompson et al., 2016), a direct comparison of macroalgae scores between the MMP and the Gladstone Harbour Report Card is not possible.

Juvenile coral density

Recovery of coral reefs from disturbances such as flooding, cyclones, thermal bleaching or outbreaks of crown-of-thorns starfish is dependent on the recruitment of new coral colonies and regeneration of existing colonies. The number of juvenile colonies at a reef can be negatively affected by poor water quality particularly where there is elevated concentrations of nutrients and agrichemicals and high turbidity (van Dam et al., 2011; Erftemeijer et al., 2012). High rates of sediment deposition (Rogers, 1990) and a high cover of macroalgae (Foster et al., 2008; Mumby and Steneck, 2008) will also negatively impact the number of juvenile colonies observed. Hence juvenile coral density can provide an indication of a reef's potential for recovery from disturbance given the current conditions.

Prior to 2018, coral in three size classes (0–2 cm, >2–5 cm and >5–10 cm) were identified to the genus level and recorded. In 2018, the >5–10 cm class was discontinued to realign the methodology with that used in the MMP (Thompson et al., 2016). This method was adopted by the MMP because limiting observations to the 0–5 cm range more accurately focuses on juvenile rather than fragmented colonies or small colonies of slow growing corals, which may be mistaken for juvenile colonies and do not reflect recent recruitment and survivorship dynamics.

Thresholds for juvenile coral density were set based on data on the densities of juvenile colonies recorded over four years of the MMP (2005–09). That monitoring determined the mean density of juvenile corals for inshore reefs at sites 2 m below lowest astronomical tide to be about 7.7 juvenile corals per m^2 of available substrate. For this study, the limits were set at 0 and 13 juvenile colonies per m^2 respectively (Table 3.11).

Change in hard coral cover

While low coral cover may occur following acute disturbance such as large floods, it does not necessarily give a good indication of the coral community's ability to recover. This is assessed by measuring the rate at which hard coral cover increases and provides a direct measure of recovery potential. This sub-indicator captures the coral growth performance per reef by comparing observed rate of change (where there is no acute disturbance) to the rate of change observed in the time series of coral cover from 47 near-shore reefs monitored by the AIMS Long-Term Monitoring Program and the MMP from 1987–2007.

The model projections of future coral cover on Great Barrier Reef inshore reefs over the period 1987–02 indicated a long-term decline in coral cover (Thompson and Dolman, 2010). For this reason, the positive score of 1 was reserved for those reefs at which the observed rate of change in cover exceeded the twice the upper 95% confidence interval of the change predicted. Observations falling within the upper and lower confidence intervals of the change in predicted cover were scored as neutral (sub-indicator score 0.5) and those below twice the lower confidence interval of the predicted change received a sub-indicator score of 0. The rate of change is averaged over three years of observations including the most recent. Therefore, it was not possible to have this metric in the Gladstone Harbour Report Card until the third year of surveys in 2017. Years in which disturbance events occurred at particular reefs were not included as there is no logical expectation for an increase in cover in such situations.

While the threshold has been adjusted to suit the grading scheme used in the Gladstone Harbour Report Card (Gladstone Harbour Threshold = 0.5, MMP threshold = 0.4), the thresholds and bounds are broadly consistent with those used in the MMP (see Thompson et al., 2016).

Table 3.11 | Coral sub-indicator thresholds for the Gladstone Harbour Report Cards.

Sub-Indicator	Baseline^	Upper bound (score = 1.00)	Lower bound (score = 0.00)
Combined cover of hard and soft corals	40%	90%†	0%
Macroalgal cover	14%	5%	20%
Juvenile coral density	4.6 m^{-2}	13 m^{-2}	0 m^{-2}
Change in hard coral cover	Lower 95% confidence interval	Twice the upper 95% confidence interval	Twice the lower 95% confidence interval

^aligned with the report card C/D threshold of 0.50. †Reduced from 100% as coral cover rarely attains 100% coverage due to areas of colonisable substrate and variable population dynamics.

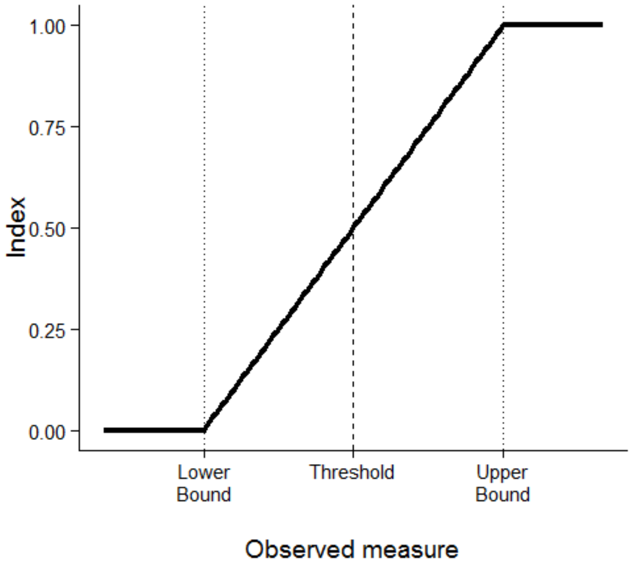

Figure 3.8 | Generic scoring of the coral sub-indicators based on the threshold and bounds outlined in Table 3.11.

Aggregation of sub-indicator scores

Bootstrapping was used to aggregate individual scores for each sub-indicator within a zone to produce the zone score. This involved constructing a bootstrap distribution of 10,000 samples for each sub-indicator in each zone. The mean of those distributions represented the zone score for each sub-indicator. Aggregating the sub-indicator distribution from each zone (sub-indicator score) generated the harbour level scores, and the overall harbour indicator score was calculated as the mean of the harbour sub-indicator scores.

3.2.9 Coral results and discussion

Coral received an overall very poor (E) grade and a very low score of 0.14, for the seventh consecutive year (Table 3.12). This low score reflects the low cover of living coral, high macroalgal cover, low abundance of juvenile corals, and minimal change in hard coral cover across most surveyed reefs. Changes in overall zone scores at the sub-indicator level were minor between 2023 and 2024, with all four sub-indicators remaining within ±0.05 of the previous year's scores.

Table 3.12 | Coral sub-indicator and zone scores used in the 2024 Gladstone Harbour Report Card. Scores from 2023 and 2022 are shown for comparison.

Zone	Coral cover	Macroalgal cover	Juvenile density	Change in hard coral cover	2024	*2023*	*2022*
8. Mid Harbour	0.07	0.23	0.14	0.23	0.17	*0.15*	*0.13*
11. Outer Harbour	0.09	0.00	0.07	0.32	0.12	*0.14*	*0.18*
Harbour score	0.08	0.12	0.11	0.27	0.14	*0.14*	*0.15*

Coral cover scores saw a slight increase at Facing Island (+0.03) but remained unchanged or declined at all other reefs (Table 3.13). Although minor fluctuations in scores have been observed over the past six years, they remain well below the 40% threshold needed for a satisfactory (C) grade. Both harbour zones are currently graded as very poor (E) for coral cover (Table 3.12). Scuba surveys reveal that the bio-eroding sponge *Cliona orientalis* continues to affect coral communities throughout the harbour, especially impacting *Turbinaria* at Seal Rocks South, as well as *Porites* and *Cyphastrea* on reefs in the Mid Harbour zone. This sponge's prevalence is likely hindering coral cover recovery across the harbour. In 2024, its presence was also recorded for the first time at Manning Reef (Table 3.14).

Farmers Reef achieved a very good (A) grade for macroalgae cover, marking an improvement from the previous year's satisfactory (C) grade in 2023. This stands in stark contrast to all other reefs, which received a very poor grade (E) for the ninth consecutive year (Table 3.13). Macroalgae communities are more variable at reefs in the Mid Harbour zone, where cover and composition vary both from year to year. In 2024, communities at the four Mid Harbour reefs were dominated by the red macroalgae *Asparagopsis* or the brown macroalgae *Lobophora*. In contrast, community composition at the two Outer Harbour reefs was stable, with communities consistently dominated by the two brown macroalgae genera, *Sargassum* and *Lobophora*.

Figure 3.9 | Large Dispsataea coral at Farmers Reef. The upper portion is bleached in response to high summer seawater temperatures. Photographer - Cassandra Thompson (AIMS, 2024)

The density of juvenile corals across the harbour has continued to decline, earning a very poor (E) grade for the sixth consecutive year (Table 3.12). While Facing Island, Rat Island, and Seal Rocks North reefs saw slight score increases compared to the previous year (0.01–0.04), their overall grades remained unchanged (Table 3.13). All other reefs experienced score declines, maintaining their very poor (E) grades. In 2009, high coral cover was associated with a strong presence of fast-growing, branching *Acropora* juveniles. However, in 2024, this crucial juvenile family remains notably absent across the harbour, potentially limiting coral recovery until their reappearance and survival.

In Gladstone Harbour, changes in hard coral cover have been consistently graded as poor (D) for the past eight years. In 2024, the Mid Harbour's hard coral cover score remained very poor (E), largely due to very low scores at Manning Reef and Rat Island (Table 3.13). Despite a modest improvement (+0.17) at Seal Rocks North, a large decline at Seal Rocks South (-0.33) kept the

Outer Harbour's overall grade for hard coral cover at poor (D). High water temperatures in early 2020 resulted in coral bleaching at the two Outer Harbour sites, Seal Rocks North and Seal Rocks South. In early 2024, high water temperatures were present again in this region and caused bleaching which was observed during surveys in May. The stress incurred during these bleaching events likely compounded the ongoing pressure imposed by abundant macroalgae and will have contributed to the observed slow recovery of coral cover.

Table 3.13 | Individual Coral sub-indicator values and scores by reef.

Reef	Coral cover		Macroalgal cover		Juvenile density		Change in hard coral cover	
	Value (%)	score	Value (%)	score	Value (m^2)	score	Value (%)	score
8. Mid Harbour								
Facing Island	10.64	0.13	55.95	0.00	0.33	0.04	269	0.47
Farmers Reef	3.13	0.04	6.38	0.92	2.79	0.30	-0.50	0.31
Manning Reef	1.25	0.02	71.06	0.00	0.84	0.09	-1.00	0.15
Rat Island	8.38	0.10	24.63	0.00	1.3 1	0.14	-0.38	0.00
11. Outer Harbour								
Seal Rocks North	2.47	0.03	53.81	0.00	0.78	0.08	0.60	0.50
Seal Rocks South	11.37	0.14	42.67	0.00	0.48	0.05	-0.24	0.14

Coral recovery

Initial Coral monitoring in the Gladstone Harbour Report Card in 2015 highlighted very low coral cover, reflecting the severe impact of the 2013 floods (Thompson et al. 2015). Reduced salinity levels from freshwater run-off in flood plumes are a known cause of coral mortality. In January 2013, heavy rainfall from Tropical Cyclone Oswald caused major flooding in the Boyne and Calliope rivers, temporarily lowering salinity levels within Gladstone Harbour. Data from the Mid Harbour showed that salinity levels stayed below 20 PSU for about three days (27–29 January 2013), with a minimum of 5 PSU recorded on 28 January (Vision Environment Queensland 2013a, b). These sustained low salinities likely caused significant coral mortality in the harbour. Research by Berkelmans et al. (2012) established a salinity threshold of 22 PSU for *Acropora* corals, such as staghorn and elkhorn, over three days; exceeding this threshold can result in coral death. Since the severe flooding in 2013, recovery of coral communities in Gladstone Harbour has been limited.

Although coral cover has remained low since monitoring began in 2015, the recovery potential of these reefs is the key indicator of their overall condition. The scores for macroalgal cover, juvenile density, and changes in hard coral cover are specifically designed to assess this recovery process. Unfortunately, the consistently poor to very poor grades across these three sub-indicators underscore the limited recovery potential of corals in Gladstone Harbour.

The results strongly suggest a continued shift from coral to macroalgal dominance within Gladstone Harbour. The persistently poor to very poor grades across sub-indicators support studies that demonstrate density-dependent feedback mechanisms, which favour macroalgal dominance in conditions that promote its proliferation (Mumby et al., 2007; Mumby et al., 2013). The consistently high macroalgal cover may be hindering coral recruitment by occupying space needed for juvenile settlement. Data from the MMP reveal a general pattern of high macroalgal cover coupled with low juvenile coral densities on several reefs. The poor to very poor grades for changes in hard coral cover are also likely influenced by coral-macroalgae interactions. Macroalgae genera such as *Sargassum*, *Asparagopsis*, and particularly *Lobophora* and *Dictyota* have direct negative impacts on living corals (Lirman, 2001; Vega Thurber et al., 2012; Morrow et al., 2017). Additionally, the widespread presence of the bio-eroding sponge *Cliona orientalis* remains a significant contributor to coral mortality within the harbour (Table 3.14). Coral bleaching due to high water temperatures in early 2020 has likely further contributed to the current condition. Ongoing monitoring since 2015 shows a clear lack of recovery following the severe coral loss noted that year.

In the broader context of inshore reefs on the Great Barrier Reef, coral communities in Gladstone Harbour perform poorly compared to other reefs monitored by the MMP (Thompson et al. 2024). Unsurprisingly, the Gladstone Harbour reefs are regionally most similar to those in the Fitzroy Region, particularly Pelican Island. Located near the mouth of the Fitzroy River, Pelican Island was severely impacted by flooding in 2011. Like the reefs in Gladstone Harbour, coral recovery at Pelican Island has been minimal, with high cover of red and brown macroalgae persisting through 2021. Reefs monitored by GHHP also closely resemble those at Daydream and Double Cone islands in the Whitsundays region, which were severely impacted by TC Debbie in 2017. The coral communities at Pelican Island, Daydream Island, Double Cone Island, and Gladstone Harbour share common characteristics, including low coral cover, high macroalgae cover, or a combination of both.

Table 3.14 | Causes of coral mortality at time of survey in 2024. Survey area of 200 m^2 at each reef. Data from 2020–23 included for comparison. Bio-eroding sponge is primarily *Cliona orientalis*.

Reef	Damage	Genus	Colonies affected				
			2020	2021	2022	2023	2024
Facing Island	Bio-eroding sponge	*Porites*	22	8	10	17	14
		Turbinaria	-	1	-	-	-
	Atramentous necrosis	*Psammocora*	-	-	-	1	1
	Bleaching		0–5%	-	-	-	1–5%
Farmers Reef	Atramentous necrosis	*Cyphastrea*	-	2	-	-	1
	Bio-eroding sponge	*Cyphastrea*	7	4	7	8	-
		Porites	-	-	1	-	1
	Bleaching		0–1%	-	-	-	1–5%
	Unknown	*Porites*	-	-	1	-	
Manning Reef	Bio-eroding sponge	*Psammocora*	-	-	-	-	1
Rat Island	Atramentous necrosis	*Cyphastrea*	-	1	7	1	-
	Bio-eroding sponge	*Cyphastrea*	8	9	5	10	3
		Plesiastrea	1	-	-	-	-
		Porites	-	-	1	-	-
		Turbinaria	4	3	2	41	3
		Favites	1	1	-	-	1
	Black band disease	*Turbinaria*	1	-	-	-	-
	Bleaching		0–10%	-	-		-
Seal Rocks North	Bio-eroding sponge	*Favites*	-	-	-	1	-
		Goniopora	-	-	-	1	-
		Turbinaria	-	-	-	3	-
	Bleaching		1–50%	-	-	<1%	11-30%
Seal Rocks South	Atramentous necrosis	*Turbinaria*	-	1	-	-	-
	Bio-eroding sponge	*Turbinaria*	9	7	6	3	4
		Goniopora	-	-	-	1	-
		Favites	-	1	1	1	-
	Bleaching		20–40%	-	-	<1%	6–30%
	Physical		0-1%	-	-	-	-

Unknown	*Acropora*	-	-	1	-	-

3.2.10 Coral trends

The overall grade for Coral in the 2024 Gladstone Harbour Report Card was very poor (E) for the seventh consecutive year (Figure 3.10). Ongoing monitoring since 2015 further reinforces a lack of recovery since the severe loss of coral evidenced pre-GHHP monitoring (Table 3.15).

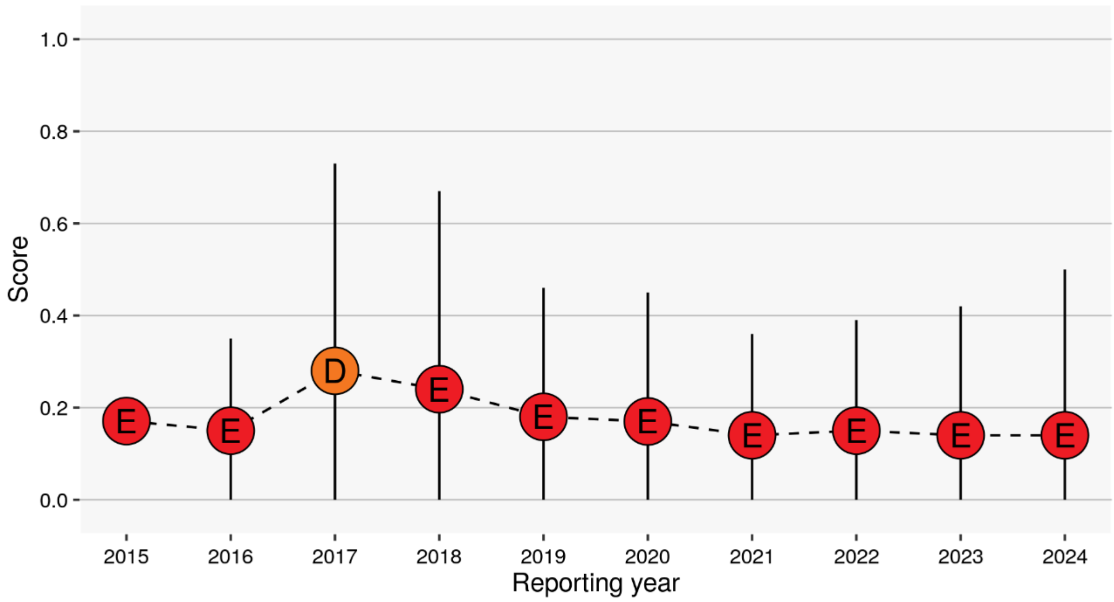

Figure 3.10 | Trends in the overall harbour score for Coral 2015–24 (Error bars show 95% bootstrap confidence intervals). Note, the 2020 score was corrected for an error in change in hard cord cover calculation and differs from the score previously reported on. Refer to 2020 Coral Report or 2020 Technical Report for further detail.

Table 3.15 | A comparison of coral sub-indicator scores for the Mid Harbour and Outer Harbour for surveys conducted from 2015–22.

Zone	2015	2016	2017	2018	2019	2020*	2021	2022	2023	2024
8. Mid Harbour										
Coral cover	0.08	0.05	0.08	0.06	0.09	0.09	0.07	0.06	0.07	0.07
Macroalgae cover	0.37	0.10	0.50	0.41	0.02	0.15	0.00	0.07	0.14	0.23
Juvenile density	0.23	0.33	0.33	0.34	0.24	0.15	0.15	0.13	0.14	0.14
Change in hard coral cover	-	-	0.44	0.30	0.42	0.44	0.43	0.26	0.22	0.23
Zone Score	0.23	0.16	0.33	0.27	0.19	0.2	0.16	0.13	0.15	0.13
11. Outer Harbour										
Coral cover	0.05	0.09	0.06	0.05	0.07	0.08	0.07	0.12	0.08	0.09
Macroalgae cover	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Juvenile density	0.33	0.33	0.44	0.45	0.22	0.08	0.15	0.11	0.00	0.07
Change in hard coral cover	-	-	0.37	0.33	0.40	0.39	0.26	0.48	0.40	0.32
Zone Score	0.13	0.14	0.21	0.2	0.17	0.14	0.12	0.18	0.14	0.12

*Note, 2020 scores shown were corrected for an error in change in hard coral cover calculation and differ from the scores previously reported on. Refer to 2020 Coral Report or 2020 Technical Report for further detail.

3.2.11 Mangroves

Mangroves thrive in tidal wetlands across all 13 GHHP environmental reporting zones. These coastal ecosystems consist of flowering trees and shrubs uniquely adapted to marine and estuarine tidal conditions. Their adaptations include exposed above-ground breathing roots, salt-excreting leaves, and live water-dispersed propagules (Duke, 2006). Mangroves provide critical habitat and nursery areas for aquatic species like barramundi, mud crabs, and prawns, while the canopy offers diverse niches for bird species. They also perform essential ecosystem services, such as protecting seagrass and coral communities by filtering runoff and reducing shoreline erosion through wave energy absorption. Highly productive mangroves have a significant capacity for carbon storage and export (UNEP, 2023).

Since the 1940s, mangroves and tidal saltmarsh vegetation have significantly changed across the Port Curtis region, particularly around the central port area due to substantial urban and port development, which has led to the loss of tidal wetland areas. Between 1941 and 1999, the region lost 38% of its mangroves, equivalent to 1,470 hectares, and a 34% loss of tidal wetlands, totalling 1,342 hectares (Duke et al., 2003). These losses are primarily attributed to land reclamation, especially near the mouths of the Calliope and Boyne Rivers and Auckland Inlet. However, natural fluctuations in climate can also impact tidal wetlands, leading to changes due to depositional gain or loss and shifts in ecotones (Duke et al., 2003). While these historical changes are significant, using a 1940s mangrove distribution as a baseline for the Gladstone Harbour Report Card is impractical due to data limitations and the challenge of restoring past distributions. Therefore, the baseline for two of the three mangrove indicators (extent and canopy condition) is determined from the previous assessment (~five-year period) The third indicator, shoreline condition, is based on current conditions.

3.2.12 Mangroves data collection

Mangroves assessment area

Unlike other environmental indicators, which focus on aquatic habitats, mangroves thrive in tidal wetlands that were initially outside the 13 GHHP environmental reporting zones. To include mangroves in the reporting, the existing zones have been expanded to cover tidal wetland areas. Since mangrove health can be affected by the surrounding catchment, the expanded zones are divided as needed to align with sub-catchments based on Queensland Government drainage sub-basin areas. This division results in a total of 23 sub-zones (Table 3.16, Figure 3.11). For all mangrove indicators, the zone score is calculated as the average of the sub-zone scores.

Table 3.16 | GHHP environmental reporting zones and Mangrove monitoring sub-zones.

GHHP Environmental monitoring zone	Mangrove monitoring zones
1. The Narrows	1a The Narrows 1b The Narrows
2. Graham Creek	2 Graham Creek
3. Western Basin	3a Western Basin 3b Western Basin
4. Boat Creek	4 Boat Creek
5. Inner Harbour	5a Inner Harbour, Enfield Creek 5b Inner Harbor Barney Point
6. Calliope Estuary	6 Calliope Estuary
7. Auckland Inlet	7 Auckland Inlet
8. Mid Harbour	8a Mid Harbour, Curtis Island 8b Mid Harbour, Facing Island 8c Mid Harbour, West
9. South Trees Inlet	9 South Trees Inlet
10. Boyne Estuary	10 Boyne Estuary
11. Outer Harbour	11a Outer Harbour, Wild Cattle Creek 11b Outer Harbour, Split End
12. Colosseum Inlet	12a Colosseum Inlet, Main 12b Colosseum Inlet, Hummock Hill
13. Rodds Bay	13a Rodds Bay, East 13b Rodds Bay, West 13c Rodds Bay, Pancake Creek 13d Rodds Bay, Hummock Hill

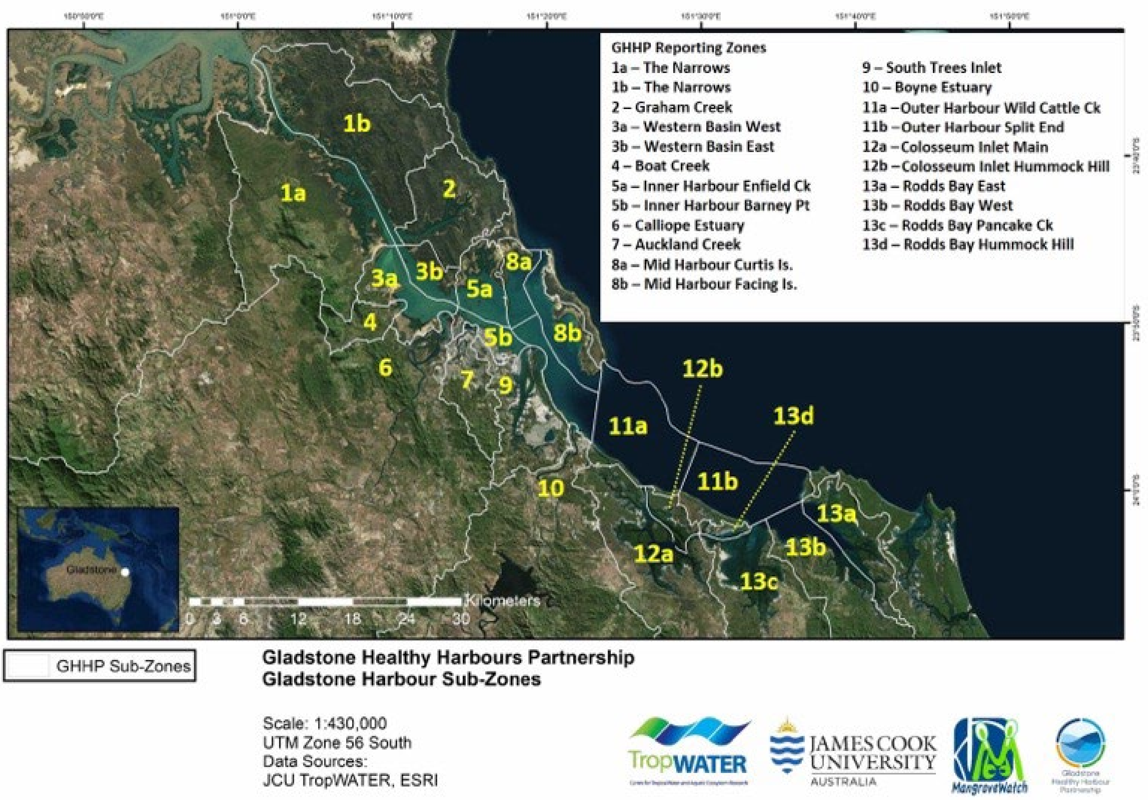

Figure 3.11 | Map showing the 13 GHHP zones and the 23 sub-zones used for mapping of tidal wetland vegetation and the factors influencing them.

Mangroves data collection

All Mangrove data for the report card grades and scores were obtained from 2023–24 satellite imagery (for extent and canopy) or aerial photography (for shoreline), following the Shoreline Video Assessment Method (Mackenzie et al., 2016). Baselines for extent and canopy were based on 2019 satellite imagery, while the shoreline metric was derived from the 2024 aerial imagery (Table 3.17).

Table 3.17 | Mangrove indicators and data used to calculate the 2024 Mangrove grades and scores.

Indicator	2024 data	Baseline data
Extent Change in the WCI from the 5 year mean and the year before	2023–24 satellite imagery (Sentinel 2)	2019 satellite imagery (Landsat 8)
Canopy Variation in NDVI from the 5 year mean and the year before	2023–24 satellite imagery (Sentinel 2)	2019 satellite imagery (Landsat 8)
Shoreline Percent live/dead tress each 50 m interval of mangrove shoreline	May 2024 helicopter filming of 23 sub-zones	No baseline, score calculated statistically (see Table 3.19)

WCI – Wetland cover index. NDVI – Normalised difference vegetation index.

Satellite imagery

To calculate the 2024 scores for the extent and canopy sub-indicators, Sentinel-2 imagery with a 10 m² spatial resolution was used. In previous mangrove assessments, Landsat 8 imagery with a 30 m spatial resolution (Gladstone Harbour: path 91, row 76; Rodds Bay: path 91, row 77) was used. Masks and models from an earlier study (Duke et al., 2017) were applied to analyse the satellite imagery.

Aerial photography

On 20–21 May 2024, an aerial survey of shorelines bordering the 23 mangrove sub-zones was conducted. A Nikon D800E camera with a 50 mm lens captured overlapping high-resolution photographs of the shoreline. The images were taken from an open R44 helicopter flying at approximately 150 m above the ground, perpendicular to the shoreline.

3.2.13 Development of mangrove indicators and grades

Mangrove extent

Mangroves, salt marsh, and salt pans in tidal wetlands in the Gladstone region typically occupy soft sediment slopes between mean sea level and the highest tide levels. The distribution of each type is influenced by factors such as climate (particularly rainfall) and sea levels. Changes in the extent of these vegetation types, measured by the total area they occupy, are often visible after extreme events like severe flooding, storms, oil spills, or large-scale reclamation (Duke and Mackenzie 2019). However, while such changes are important, they can be challenging to detect, especially along ecotones where different vegetation types converge.

The Wetland Cover Index (WCI) is used to measure the percentage of tidal wetlands occupied by mangroves. It is an important indicator of the hydrological conditions influencing mangrove health. The WCI for each sub-zone was calculated using a Random Forest algorithm, trained on Sentinel-2 satellite imagery. This method employed four specific bands of the imagery and the Normalised Difference Vegetation Index (NDVI) to classify land cover types. Elevation data from the Australian Digital Elevation Model was also included, as elevation influences tidal inundation and, therefore, the distribution of mangroves. Previous assessments used Landsat 8 imagery, but the higher resolution of Sentinel-2 used in 2024 offers improved accuracy.

The 2023–24 data was compared to 2019 to assess changes over time, highlighting areas of mangrove loss or gain. Three key indicators were derived:

- WCI 2023–24
- Extent change score (proportion of mangrove gained between 2019 and 2023–24) derived as:

$$1 - (\text{subzone net change }(\%) - \text{regional net change }(\%))/10$$

Where, the regional net change (%) was 5.39%

- Mangrove loss score (the proportion of mangrove lost between 2019 and 2023–24) derived as:

$$1 - \text{proportion lost}/10$$

The final Mangrove extent score was calculated by averaging these three indicators, first at the sub-zone level, then at the zone level to determine the overall Harbour score.

Table 3.18 | Mangrove extent scoring classification system.

	Very good (A)	Good (B)	Satisfactory (C)	Poor (D)	Very poor (E)
Wetland Cover Index 2024	0.85–1.00	0.65–0.84	0.50–0.64	0.25–0.49	0.00–0.24
Extent change (gain & loss) 2019 to 2024	0–1.5% deviation	1.6–3.5% deviation	3.6–5.0% deviation	5.1–7.5% deviation	> 7.5% deviation
Mangrove loss 2019 to 2024	0–1.5% loss	1.6–3.5% loss	3.6–5.0% loss	5.1–7.5% loss	> 7.5% loss

Canopy condition

The Canopy condition indicator assesses the health of mangrove forests using the normalised difference vegetation index (NDVI). Stress on mangroves reduces productivity and leaf production, potentially leading to tree death if the plants cannot maintain photosynthesis. However, healthy forests can recover when stressors are removed, as surviving trees increase leaf production and seedlings fill gaps left by dead trees. Canopy density reflects overall forest productivity, and resilience is measured by the rate and extent of recovery. Remote sensing helps assess mangrove canopy health by detecting light reflectance, where healthy forests absorb more red light and reflect more near-infrared light.

To evaluate canopy condition, NDVI was calculated for each sub-zone, using satellite imagery for 2023–24 and compared to the 2019 data. The NDVI measures vegetation greenness, with values ranging from -1 to 1. Higher positive values indicate healthier vegetation. For each sub-zone, the mean NDVI and its standard deviation were calculated, along with the proportion of areas where NDVI declined sharply. The minimum mangrove NDVI value was determined to be 0.3 and the maximum value 0.75. In addition to comparing canopy condition between 2019 and 2023–24, a long-term trend assessment was conducted using satellite imagery for the period 2014 to 2023. This data was used to track significant changes in NDVI over time, with major changes indicating shifts in mangrove density.

Two NDVI measures were used to determine the overall canopy condition score for each sub-zone. These scores were then averaged for each reporting zone then aggregated to produce the overall score for the harbour.

1) **2024 NDVI score:** The mean and standard deviation (SD) of the annual pixel maximum, or the average NDVI for the greenest days observed in 2023–24.
2) **5-year change:** The five-year mean mangrove NDVI point value between 2019 and 2023–24 NDVI was used to compare temporal change.

Table 3.19 | Classification of canopy condition scores derived from NDVI values 2019 to 2023–24.

	Very good (A)	Good (B)	Satisfactory (C)	Poor (D)	Very poor (E)
Mean NDVI 2023–24	Mean NDVI value 0.81 – 0.73	Mean NDVI value 0.72 – 0.63	Mean NDVI value 0.62 –0.55	Mean NDVI value 0.54 – 0.43	Mean NDVI value 0.42 – 0.30
Mean 5-year NDVI change 2013-14 to 2017–18	Mean inter-annual NDVI difference significantly ($p<0.05$) greater than regional mean and effect size (cohen's d) > 0.70	Mean inter-annual NDVI difference significantly ($p<0.05$) greater than regional mean and effect size (cohen's d) 0.69 to 0.30	Mean inter-annual NDVI difference not significantly ($p>0.05$) different from regional mean. OR Mean inter-annual NDVI difference significantly ($p<0.05$) greater than regional mean and effect size (cohen's d) 0.29 to 0.0	Mean inter-annual NDVI difference significantly ($p<0.05$) less than regional mean and effect size (cohen's d) -0.01 to -0.50	Mean inter-annual NDVI difference significantly ($p<0.05$) less than regional mean and effect size (cohen's d) -0.51 to -1.0

Shoreline condition

Shoreline mangroves play a crucial role in protecting shorelines from severe erosion events and serve as indicators of environmental change. These trees, particularly those at the sea edge (or sea edge ecotone), are exposed to various natural and human stressors, making them effective sentinels for monitoring changes in tidal conditions, water quality, and climate. Given their sensitivity to environmental shifts, shoreline mangroves can quickly reflect alterations in coastal conditions. To monitor their health, the Shoreline Aerial Assessment Method, adapted from earlier approaches (Mackenzie et al. 2016), was developed to assess the condition of mangroves on a large scale. This method matches high resolution oblique aerial photographs with shoreline sampling points at 50 m intervals created from the 0 m contour line using a 5 m Digital Elevation Model (Geoscience Australia, 2020). At each sampling point the presence or absence of individual dead mangroves along the shoreline or within the shoreline fringing zone was noted.

The aerial survey of shorelines bordering the Gladstone Harbour water quality zones took place in May 2024, using high-resolution photographs taken from a helicopter (Figure 3.12). The images focused on identifying dead mature canopy trees at regular intervals along the shoreline, which were used as indicators of mangrove health. Sampling points were spaced 100–150 m apart along the shoreline, aligned with the mean sea level, and the images were analysed to record the presence of dead mangroves. The images were matched to shoreline sampling points using ArcGIS, ensuring precise alignment with the shoreline features. Dead mangroves were identified as either standing or fallen trees in the images. Only dead canopy trees were considered for this assessment. Any images that did not clearly show the shoreline or were improperly matched were discarded.

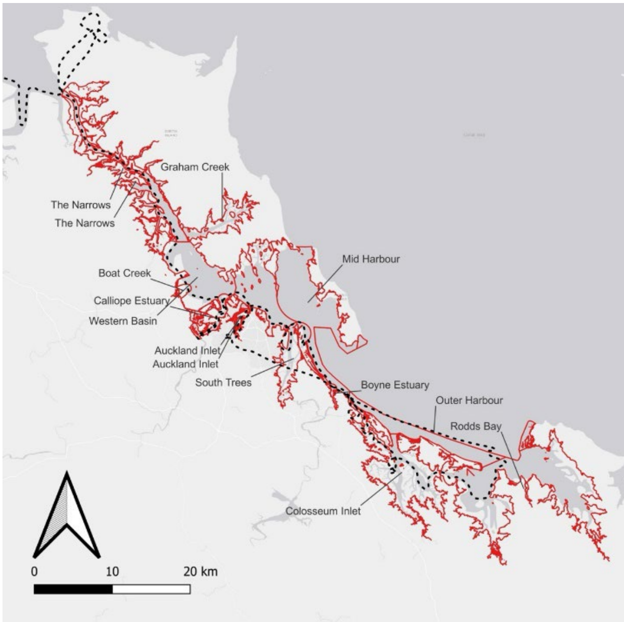

Figure 3.12 | Map showing 13 Gladstone Harbour reporting zones (red lines & labels) and the helicopter track (dashed black line) of the shorelines evaluated using imagery from 2023 (Canning & Duke 2023) for comparison with shorelines assessed in 2018 and 2019.

To derive scores, the frequency of dead mangroves in each GHHP zone was compared using a chi-square goodness of fit test. This analysis aimed to determine whether the frequency of dead mangroves differed significantly across zones compared to the overall study area (Table 3.20). This method provides a quantitative assessment of mangrove health along the shoreline.

Table 3.20 | Classification of shoreline condition scores.

	Very good (A)	Good (B)	Satisfactory (C)	Poor (D)	Very poor (E)

Shoreline condition score (observed dead mangrove frequency)	0–7.5%	7.6–17.5%	17.6–25%	25.1–37.5%	>37.5%
Seasonally adjusted Shoreline Condition Score (relative dead mangrove frequency)	Observed dead mangrove frequency significantly less than expected harbour value ($p<0.05$), Cramer's V 1.0 to 0.7	Observed dead mangrove frequency significantly less than expected harbour value ($p<0.05$), Cramer's V 0.69 to 0.30	Observed dead mangrove frequency not significantly different from expected harbour value ($p<0.05$) OR Observed dead mangrove frequency significantly greater than expected harbour value ($p<0.05$), Cramer's V 0.29 to 0.0	Observed dead mangrove frequency significantly greater than expected harbour value ($p<0.05$), Cramer's V 0.30 to 0.69	Observed dead mangrove frequency significantly greater than expected harbour value ($p<0.05$), Cramer's V 0.7 to 1.0

3.2.14 Mangroves results and discussion

In 2024, the overall Mangroves score for Gladstone Harbour was 0.63, receiving a satisfactory (C) grade. Six zones showed improved grades, four zones declined, and three remained unchanged (Table 3.21). The improvements were largely driven by better Canopy condition scores in eight out of 13 zones, influencing an increase in the overall harbour score (2019: 0.49, 2024: 0.65). Scores for Mangrove extent and Shoreline condition remained relatively stable.

Table 3.21 | Mangrove sub-indicator and indicator scores used in the 2024 Gladstone Harbour Report Card. Scores from 2019 are shown for comparison.

Zone	Mangrove extent	Canopy condition	Shoreline condition	2024	*2019*
1. The Narrows	0.73	0.76	0.39	0.63	*0.65*
2. Graham Creek	0.83	0.63	NA	0.73	*0.64*
3. Western Basin	0.64	0.71	0.40	0.65	*0.51*
4. Boat Creek	0.72	0.70	0.54	0.65	*0.46*
5. Inner Harbour	0.40	0.63	0.55	0.56	*0.55*
6. Calliope Estuary	0.90	0.73	0.57	0.73	*0.58*
7. Auckland Inlet	0.67	0.72	0.03	0.47	*0.65*
8. Mid Harbour	0.19	0.59	0.88	0.49	*0.55*
9. South Trees Inlet	0.84	0.65	0.29	0.59	*0.60*
10. Boyne Estuary	0.62	0.48	0.88	0.66	*0.26*
11. Outer Harbour	0.72	0.66	0.68	0.68	*0.66*
12. Colosseum Inlet	0.88	0.60	0.44	0.64	*0.72*
13. Rodds Bay	0.79	0.62	0.78	0.73	*0.64*
Harbour score	0.69	0.65	0.53	0.63	*0.57*

NA – Indicator not assessed due to insufficient data

Mangrove extent

This indicator is based on changes in mangrove canopy cover from 2019 to 2023–24, relative to saltmarsh and saltpan areas within tidal wetlands. Mangrove extent scores reflect the net gain or loss of mangrove area compared to saltmarsh and saltpan within each sub-zone. Compared to the 2019 assessment, Calliope Estuary improved a grade to very good (A), while Colosseum Inlet maintained a very good (A) grade. Seven zones achieved good (B) grades, and two zones received a satisfactory grade, similar to the 2019 results. However, Inner Harbour continued to have poor (D) grades, and Mid Harbour declined to a very poor (E) grade, indicating a net loss of mangrove area compared to the previous year and the five-year baseline (Table 3.22)

In Gladstone Harbour, Sentinel-2 imagery showed a 4.4% increase in Mangrove extent between 2019 and 2023–24. A ten-year comparison using Landsat 8 imagery indicated a 5% increase in Mangrove extent over the past decade, which aligns with periods of high annual rainfall over the past 10 years (Figure 8.4).

Table 3.22 | Wetland cover index, change scores and overall zone scores for mangrove extent.

Zone	Mangrove sub-zone	WCI 2023–24	WCI change score	Mangrove loss score	Sub-zone score	Zone extent score
1. The Narrows	1a. Mainland	0.63	0.81	0.88	0.77	0.73
	1b. Curtis Island	0.63	0.75	0.71	0.69	
2. Graham Creek	2. Graham Creek	0.76	0.85	0.89	0.83	0.83
3. Western Basin	3a. Mainland	0.34	0.39	0.81	0.51	0.64
	3b. Curtis Island	0.52	0.97	0.83	0.77	
4. Boat Creek	4. Boat Creek	0.47	0.87	0.81	0.72	0.72
5. Inner Harbour	5a. Enfield Creek	0.55	0.94	0.90	0.79	0.40
	5b. Barney Point	0.40	-0.42	0.51	0.00	
6. Calliope Estuary	6. Calliope Estuary	0.82	0.99	0.88	0.90	0.90
7. Auckland Inlet	7. Auckland Inlet	0.57	0.94	0.51	0.67	0.67
8. Mid Harbour	8a. Curtis Island	0.34	0.03	0.76	0.37	0.19
	8b. Facing Island	0.26	-0.14	0.74	0.00	
9. South Trees Inlet	9. South Trees Inlet	0.62	0.98	0.91	0.84	0.84
10. Boyne Estuary	10. Boyne Estuary	0.57	0.42	0.86	0.62	0.62
11. Outer Harbour	11a. Wild Cattle Creek	0.50	0.99	0.93	0.81	0.72
	11b. Split End	0.39	0.58	0.93	0.63	
12. Colosseum Inlet	12a Colosseum Creek	0.71	0.98	0.97	0.89	0.88
	12b. Hummock Hill	0.69	0.99	0.97	0.88	
13. Rodds Bay	13a. East	0.74	0.97	0.94	0.88	0.79
	13b. West	0.69	0.87	0.92	0.83	
	13c. Pancake Creek	0.64	0.98	0.94	0.86	
	13d. Hummock Hill	0.41	0.49	0.95	0.61	
Harbour score						0.69

Canopy condition

This indicator was calculated using estimates of the NDVI values for mangrove forest canopies within the 13 environmental reporting zones. Canopy condition improved across the harbour, with eight zones, The Narrows, Graham Creek, Western Basin, Boat Creek, Calliope Estuary, Auckland Inlet, Boyne Estuary and Outer Harbour improving a grade and only one zone, Colosseum Inlet, declining a grade. The scores in the remaining four zones remained stable (Table 3.23).

Despite short term improvements, the long term trends indicate a slight decrease (1.1%) in NDVI over the past 10-years. This decline aligns with annual rainfall trends, as drier conditions over the last decade have corresponded with lower NDVI values (Figure 8.4).

Table 3.23 | Canopy condition, NDVI scores, five-year change and overall scores for canopy condition.

Zone	Mangrove sub-zone	2024 NDVI score	Five-year change	Sub-zone score	Zone score
1. The Narrows	1a. Mainland	0.80	0.74	0.77	0.76
	1b. Curtis Island	0.81	0.69	0.74	
2. Graham Creek	2. Graham Creek	0.78	0.48	0.63	0.63
3. Western Basin	3a. Mainland	0.76	0.59	0.68	0.71
	3b. Curtis Island	0.81	0.69	0.75	
4. Boat Creek	4. Boat Creek	0.75	0.65	0.70	0.70
5. Inner Harbour	5a. Enfield Creek	0.79	0.65	0.72	0.63
	5b. Barney Point	0.66	0.39	0.53	
6. Calliope Estuary	6. Calliope Estuary	0.78	0.68	0.73	0.73
7. Auckland Inlet	7. Auckland Inlet	0.73	0.70	0.72	0.72
8. Mid Harbour	8a. Curtis Island	0.70	0.65	0.68	0.59
	8b. Facing Island	0.69	0.34	0.51	
9. South Trees Inlet	9. South Trees Inlet	0.79	0.51	0.65	0.65
10. Boyne Estuary	10. Boyne Estuary	0.75	0.21	0.48	0.48
11. Outer Harbour	11a. Wild Cattle Creek	0.78	0.45	0.62	0.66
	11b. Split End	0.75	0.65	0.70	
12. Colosseum Inlet	12a Colosseum Creek	0.81	0.45	0.63	0.60
	12b. Hummock Hill	0.82	0.32	0.57	
13. Rodds Bay	13a. East	0.83	0.47	0.65	0.62
	13b. West	0.78	0.54	0.66	
	13c. Pancake Creek	0.82	0.51	0.67	
	13d. Hummock Hill	0.73	0.28	0.50	
Harbour Score					0.65

Shoreline condition

Approximately 700 shoreline points were assessed for the presence of dead mangroves across 12 reporting zones, with shoreline conditions not observed in Graham Creek. The overall proportion of shoreline with dead mangroves increased to 27%, up from 15% in the 2019 assessment. Mid Harbour and Boyne Estuary improved to very good grades (A), while Boat Creek and Outer Harbour saw their grades improve to satisfactory (C) and good (B), respectively. Three zones – Western Basin, Inner Harbour and Rodds Bay – remained stable. Auckland Inlet had the highest proportion of dead mangroves (~57%), resulting in a very poor grade (E) with a score of 0.03.

Three other zones also saw their grades decline in 2024 (Table 3.24). Overall, shoreline condition declined slightly by 1.3% between 2019 and 2023–24.

Table 3.24 | Estimates of shoreline condition for harbour environmental monitoring zones and sub-zones.

Zone	Mangrove sub-zone	Dead mangrove frequency score	Seasonally adjusted dead mangrove frequency score	Sub-zone shoreline condition score	Zone shoreline condition score
1. The Narrows	1a. Mainland	0.27	0.41	0.34	0.38
	1b. Curtis Island	0.39	0.47	0.43	
2. Graham Creek	2. Graham Creek	NA	NA	NA	-
3. Western Basin	3a. Mainland	0.35	0.45	0.40	0.40
	3b. Curtis Island	NA	NA	NA	
4. Boat Creek	4. Boat Creek	0.54	0.55	0.54	0.54
5. Inner Harbour	5a. Enfield Creek	NA	NA	NA	0.55
	5b. Barney Point	0.56	0.55	0.55	
6. Calliope Estuary	6. Calliope Estuary	0.59	0.56	0.57	0.57
7. Auckland Inlet	7. Auckland Inlet	-0.14	0.21	0.03	0.03
8. Mid Harbour	8a. Curtis Island	NA	NA	NA	0.88
	8b. Facing Island	1.00	0.76	0.88	
9. South Trees Inlet	9. South Trees Inlet	0.20	0.37	0.29	0.29
10. Boyne Estuary	10. Boyne Estuary	1.00	0.76	0.88	0.88
11. Outer Harbour	11a. Wild Cattle Creek	0.73	0.63	0.68	0.68
	11b. Split End	NA	NA	NA	
12. Colosseum Inlet	12a Colosseum Creek	0.71	0.62	0.66	0.44
	12b. Hummock Hill	0.09	0.36	0.21	
13. Rodds Bay	13a. East	NA	NA	NA	0.78
	13b. West	1.00	0.76	0.88	
	13c. Pancake Creek	0.58	0.56	0.57	
	13d. Hummock Hill	1.00	0.76	0.88	
Harbour score					0.53

NA – Not assessed due to insufficient data

Discussion

The Mangrove indicators chosen for Gladstone Harbour capture a range of pressures affecting mangroves. These pressures include environmental factors like rainfall variability, rising sea levels, and the impact of floods or storms (cyclones), as well as human activities such as land reclamation, increased sediment and nutrient loads, and localised pollution. These indicators help track trends in mangrove health over time. As the dataset expands, the confidence in these indicators will continue to grow.

In 2023–24, several issues were observed across the study area, with human activities significantly impacting developed shoreline areas near mangroves. The most affected zones were Inner Harbour, Calliope Estuary, Auckland Inlet, Mid Harbour, South Trees Inlet and Boyne Estuary, while Western Basin showed lesser but still notable human influence. These findings were consistent with previous observations from 2018 and 2019. In addition to human-induced changes, natural climatic events, such as heavy rainfall, storms, and rising sea levels, continued to influence mangrove recovery, which has been slow but steady.

Over the past decade, there was an increase in Mangrove extent across reporting zones. This expansion was linked to long-term rainfall trends. However, a minor decline of Canopy condition (greenness) was also observed, attributed to short-term rainfall fluctuations during the same period. Similarly, Shoreline erosion scores declined between 2019 and 2023, primarily due to a combination of rising sea levels, storms, and human activities, which caused dieback and erosion of shoreline mangrove trees (Figure 3.13 and 3.14).

Figure 3.13 | Shoreline erosion has advanced at Fisherman's Landing in the Western Basin between 2015 (left) and 2024 (right).

Figure 3.14 | Shorelines at the mouth of South Trees Inlet showed significant erosion, with the once-living seaward edge of trees visible in 2019 (left) not present in 2024 (right). This erosion has led to further tree death and peat layer disruption.

Other observed effects included damage to mangroves along estuarine margins, particularly from flood and erosion events in the Calliope River estuary, and the dieback of upland trees at the upper tidal ecotone due to rising sea levels. Additionally, expansion of mangroves into saltpan areas indicated long-term increases in rainfall, but these changes require further study to fully understand their implications.

3.2.15 Mangroves trends

The overall grade for mangroves in the 2024 Gladstone Harbour Report Card was satisfactory (C) (Figure 3.15), and their condition appears to remain stable across the Gladstone Harbour Report Cards.

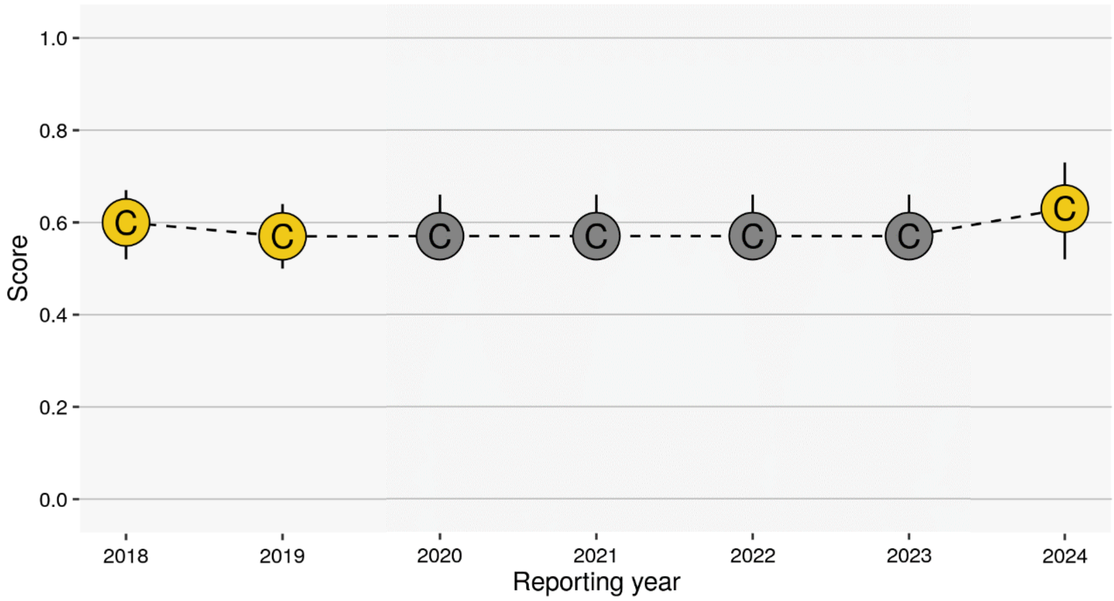

Figure 3.15 | Trends in the overall harbour score for the Mangroves indicator 2018–24 (Error bars show 95% bootstrap confidence intervals). Grey colour represents no new assessment; results carried over from previous assessment.

3.3 Fish and Crabs

3.3.1 Fish health

Figure 3.16 | Mangrove Jack caught during the Boyne Tannum HookUp ready to be measured, weighed and tagged. (Photo courtesy of Infofish).

Fish are one of the most important social, economic and ecological resources in Gladstone Harbour. As a result, they were identified as a major concern at community workshops conducted by GHHP in 2013 to develop a community-based vision for the Gladstone Harbour Report Card.

Commercial and recreational fishing in Gladstone occurs throughout the harbour and Gladstone hosts annual fishing competitions (Figure 3.16). Fish play a multitude of roles in aquatic ecosystems including nutrient cycling, ecosystem regulation and bioturbations. They are important in nutrient cycling as they store a large proportion of ecosystem nutrients like phosphorus and nitrogen in their tissue, transport nutrients further than other aquatic animals and the nutrients they excrete are readily available to primary producers such as algae or seagrass. Fish can also play a vital role in ecosystem regulation such as herbivorous fish keeping algae in check on coral reefs.

Two sub-indicators, Fish condition and Fish HAI, contribute to the Fish health indicator. These are assessed by two separate fish monitoring projects:

1. Fish condition (Automated visual assessment using mobile phones and length-weight data)
2. Fish HAI (Gross pathological analysis)

Relying on a citizen science approach for data collection Fish condition provides a less detailed assessment of fish health when compared to the Fish HAI. However, this approach incurs significantly lower costs and by using data collected during fishing competitions like the Australian Bass Tournaments and by recreational fishers (e.g., Gladstone Sportfishing Club), a large portion of the harbour can be assessed at a lower cost than more traditional methods.

Fish condition scores are based on two separate metrics. The first, visual fish condition, is an external assessment of fish health. This includes skin, eyes, fins, parasites and deformities. The second metric is a fish body condition index. This is calculated from length and weight data recorded at the time of capture. Measures of body condition are widely used to assess the health of individual or groups of fish. Generally, fish that are heavier than average for their length are considered healthier with more energy reserves for normal activities including reproduction.

The Fish HAI is a more detailed assessment of fish health which requires a gross pathological assessment during dissection and produces a score based on the condition of several organs and tissues. The index scores add together to reflect the acute and chronic stressors that are present in the fish’s environment. A fish with a high Fish HAI score is less healthy than a fish with a low score. Although providing a more rigorous assessment of fish health – owing to the time and expense involved in transporting fish for laboratory analysis – fewer fish are assessed compared to the Fish condition method. This sub-indicator was not assessed in 2023, and the 2021 data has been used in the calculation of the overall Fish health and Environmental score.

3.3.2 Fish health data collection

Fish mobility

Ideally, the Fish health monitoring program should reflect the prevailing conditions within Gladstone Harbour. Hence fish that remain resident within the harbour provide a more relevant localised measure of conditions than species that have large movements and may be affected by conditions outside of the harbour. The movements of potential target species for the two fish health monitoring programs were assessed in two previous fish health studies which conducted mobility assessments using Suntag fish tag and recapture data provided by Infofish Australia.

Flint et al. (2018), examined the movements of inshore and estuarine fish, that had available tagging data, for six species, including four species assessed for fish health in the 2019 report card (Barramundi, Dusky flathead, Yellowfin bream and Pikey bream). The majority of recorded movements were less than 20 km. Barramundi had the longest movements (mean 8.42 km, maximum 704 km) and the recorded movements of Pikey bream were entirely within Gladstone Harbour.

Sawynok et al. (2018) analysed the movements of four target species; Yellowfin bream, Pikey bream, Dusky flathead and Barred javelin, and found that in these species only 5% of the recorded movements were greater than 5 km.

While the analysis of fish movements demonstrated these species would generally be restricted to the harbour, the recorded movements were still larger than the spatial scale of the 13 environmental monitoring zones. Hence Fish health is scored at the harbour level with a single overall score generated for both projects being applied to all 13 environmental monitoring zones. This single score is because the health of each of the target species can not necessarily be attributed to the conditions within individual environmental monitoring zones. The survey methods for both projects reflect this approach and fish sampling has not been conducted in all 13 zones. However, data for both projects has been collected from north, south and central harbour areas and provides a good spatial coverage that included developed and undeveloped areas. As the location of each fish captured will be recorded it will be possible to identify any fish health ‘hot spots’ that may occur using this approach.

Fish condition

Data for the Fish condition sub-indicator was collected for six fish species. These are fish that are most likely to be caught during fishing competitions and represent fishes found in a range of environments. They include fish that are bottom dwellers such as Dusky flathead and those that feed higher in the water column. As these species occupy a variety of trophic level and habitats, they may be differentially affected by any fish health issues. For example, demersal or benthic species are in closer contact with pollutants accumulated in sediments and as a result are more likely than pelagic species to present with abnormalities (Cowled, 2016). The target species are:

- Yellowfin bream *Acanthopagrus australis*
- Pikey bream *Acanthopagrus berda*
- Barred javelin *Pomadasys kaakan*
- Dusky flathead *Platycephalus fuscus*
- Mangrove jack *Lutjanus argentimaculatus*
- Barramundi *Lates calcarifer*

Data for Fish condition was collected using the Trackmyfish app (Figure 3.17). The data recorded on the Trackmyfish app included:

- Photos of one side of the fish, preferable on a measuring ruler
- Photos collected by Infofish, both sides of the fish were recorded and assessed
- Total fish length ± 0.05cm

- Tag number from any tagged fish
- GPS location at point of capture, GHHP monitoring zone
- Weight of fish (g) caught for calculation of fish body condition

Data was collected over the course of the 2023–24 reporting year with the aim of collecting a minimum of 325 photographs of the six target species in the Gladstone Harbour environmental reporting area, spread evenly across the 13 environmental monitoring zones. Four methods of data collection were used:

- Data collected at the ABT Bream Tournament (July 2023)
- Data collected at the ABT Barramundi Tournament (February 2024)
- Data collected at the Boyne Tannum HookUp (May 2024)
- Data collected by Gladstone Sports Fishing Club members during normal fishing trips (July 2023 – May 2024)
- Data collected by the public when reporting the recapture of tagged fish
- Data collected by Infofish

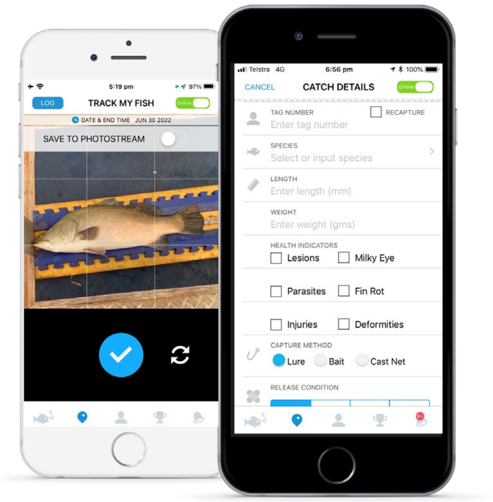

Figure 3.17 | Data for the visual fish condition index was collected by fishers using the Trackmyfish app.

Over the course of the study period, 1 July 2023 to 30 June 2024, a total of 1026 images of the six target species were captured using the app (Figure 3.18). These images were used to calculate the score for visual fish condition. Human and visual assessments were made for each condition with close to 100% agreement between the two.

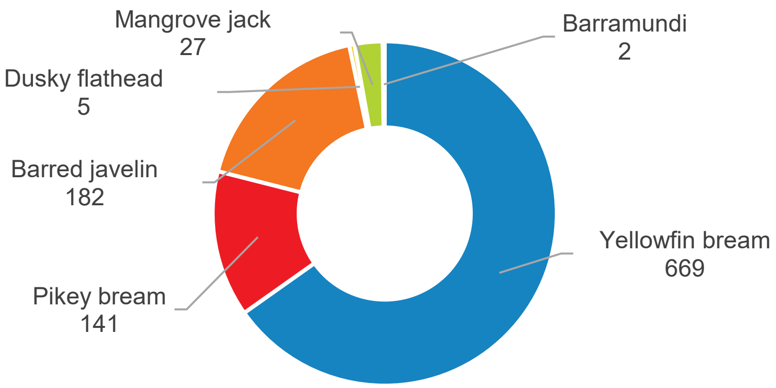

Figure 3.18 | Number of images of each of the six species captured using the Trackmyfish App over the 2024 reporting year.

Data for fish body condition were collected in Gladstone Harbour at the Boyne Tannum HookUp May 2024. Length-weight data from 664 fish were used to calculate the report card scores.

Fish HAI

Based on recommendations from previous fish health studies (Cowled, 2016; Kroon et al., 2016; Flint et al., 2018) and the GHHP Independent Science Panel the following fish species / taxa were identified as target species.

- Barramundi *Lates calcarifer*
- Bream: Pikey bream *Acanthopagrus berda* and Yellowfin bream *Acanthopagrus australis*
- Mullet: Diamond scale Mullet *Liza vaigiensis* and Sea mullet *Mugil cephalus*
- Barred javelin *Pomadasys kaakan*
- Dusky flathead *Platycephalus fuscus*

These species have been identified as being suitable for biomonitoring on the basis that they are present and abundant, commercially or recreationally fished and spend time low in the water column. Demersal or benthic species are in closer contact with pollutants in sediments and as a result are more likely than pelagic species to present with abnormalities (Cowled, 2016). These species were also caught in sufficient numbers in previous surveys to provide adequate sample sizes for the calculation of report card scores.

No new sampling for this sub-indicator was conducted in the 2023-24 reporting year. The results presented in this year's report card are based on sampling conducted in the previous reporting year. This sampling was conducted in Spring 2020 and Autumn 2021. The surveys in Gladstone Harbour were designed to produce an even catch effort across the northern, central and southern areas of the harbour with a focus on inshore and estuarine sites, this included 11 environmental monitoring zones.

At each survey site three 50 m long gill nets with stretched mesh sizes of 4.5 inches, 6 inches and 8 inches were deployed for an average soak time of 30 min. At some sites an additional 110 m long gill/ring net with a 2.13 inch stretched mesh size was also deployed to supplement the catch. Gear was deployed at times and locations designed to maximise the catch of the identified target species.

Captured fish were given a unique identification code and were either processed immediately or kept alive in an aerated swim tank. Bony fish were photographed, measured including length and weight, and the skin, fins and eyes were examined for abnormalities, parasites, lesions or erosion. Sharks and rays were recorded and photographed but were not handled other than to ensure their live release. Non-target fishes were released alive, and target species were euthanised for laboratory analysis. All euthanised fish were individually bagged in an ice slurry and returned to the laboratory on the same day.

A total of 126 fishes from 17 species were caught across Gladstone Harbour and the Baffle Creek reference site. Barred javelin (n = 31) and Blue catfish (n = 32) were caught in the highest numbers and Barred javelin were caught in the most zones. A total of 80 fishes from four of the five target species were caught, no bream were caught and only four diamond scale mullet were caught in the harbour. With the absence of bream and the low mullet numbers the report card scores were calculated based on three species: Barred javelin, Blue catfish and Barramundi.

3.3.3 Development of Fish health indicators and scoring

Fish condition

Visual fish condition

The visual fish condition measure is based on the HAI developed by Adams et al. (1993). However, unlike the Fish HAI in which the fish is euthanised and both external and internal health parameters are assessed, visual fish condition is based on external indicators of health only and fish are released alive after processing. The five variable conditions assessed are fins, skin, eyes, parasites, and deformities. All parameters are scored between 0 and 30 depending on the severity of the condition with the most severe conditions receiving the highest score (Table 3.25).

To calculate the visual fish condition score for each species, the variable condition scores for each fish were summed and the mean calculated for each species. The harbour wide score was generated by summing the individual species scores and then calculating the average score. All scores were converted to a report card score by standardising the scores to have a range of 0–1.

Table 3.25 | Scoring for five variable conditions used in the visual fish condition measure.

Measure	Variable condition	Score
Fins	No active erosion	0
	Light active erosion	10
	Moderate active erosion with some haemorrhage	20
	Severe active erosion with some haemorrhage	30
Skin	Normal no aberrations	0
	Mild skin aberrations	10
	Moderate skin aberrations	20
	Severe skin aberrations	30
Eyes	No aberrations	0
	Opaque / Milky eye	10
	Swollen eye	20
	Haemorrhaging or bleeding eye	30
	Missing eye	30
Parasites	No parasites	0
	Observed parasites	10
Deformities	No deformity	0
	Observed deformity	10

Fish body condition

Fish body condition was calculated using a relative condition factor. This length-weight relationship is a key measure of fish condition used by fisheries agencies across Australia and internationally (Schneider et al., 2000; King, 2007). The relationship is calculated from the length-weight curve of best fit (Le Cren, 1951) for each of the key species using data recorded in the years from 2003–19 during the Boyne Tannum HookUp described by the following formula:

$$W = a \times L^b$$

where W is the calculated weight and L is the total length of the fish. Values of W have been calculated from the logarithmic (base 10) equivalent:

$$\log W = \log a + b \cdot \log L$$

The relative condition factor (Kn) (Le Cren, 1951; Koushlesh et al., 2018) is calculated as the proportion of the observed weight (w) to the calculated weight from the length-weight relationship (W) where a condition factor Kn = 1 is consistent with a fish of average condition, Kn >1 being above average and $Kn < 1$ below average.

$$Kn = \frac{w}{W}$$

The minimum (Kn_{min}) and maximum (Kn_{max}) condition factors for the species were determined from the historical minimum and maximum conditions. Each fish is scored (S_{FISH}) by normalising the condition factor, relative to the historical minimum and maximum.

$$S_{FISH} = \frac{Kn - Kn_{min}}{Kn_{max} - Kn_{min}}$$

The final score for the species in the current year is calculated as the average score for the species (where n is the number of fish being assessed) in the current year.

$$S_{FINAL} = \frac{\sum_{i=1}^{n} S_{FISH}}{n} \frac{\sum_{i=1}^{n} S_{FISH}}{n} \frac{\sum_{i=1}^{n} S_{FISH}}{n}$$

Final grades are calculated using the standard Gladstone Harbour Report Card scores (Figure 2.1).

Fish HAI

The HAI was developed by Adams et al. (1993) and included 14 measures of fish health. The Gladstone Harbour Report Card employed a modified Fish HAI which has nine measures of fish health and was used in previous studies in Gladstone Harbour by Wesche et al. (2013). The nine measures include three external measures, four internal organs, and assesses gill condition and parasite load (Table 3.26). The total Fish HAI score was calculated for each individual fish as the sum of the nine measures and the average of the scores was calculated for each species/species group for the harbour. Barramundi, Blue catfish and Barred javelin are reported as individual species. Bream and mullet were analysed as species groups owing to their similar ecological characteristics and to increase sample size. The bream species group includes Pikey and Yellowfin bream, and the mullet species group includes Diamond scale and Sea mullet.

A distance to benchmark method has been employed to calculate report card scores from the average Fish HAI scores. This method involves using a benchmark, best possible condition, and a worst-case scenario. Benchmarks and worse-case scenarios were selected based on existing studies and the data collected during monitoring in 2018–19.

The possible Fish HAI score for an individual fish range from 0–270. However, even in pristine environments a Fish HAI average of 0 is unlikely as fish may have skin abrasions, parasites or slight fin erosion. Conversely, studies employing the Fish HAI (even in polluted environments) have shown that an average score of 270 is equally unlikely (Watson et al., 2012).

Benchmark: In this study, a score of 0 was recorded by 70 of the 223 fish assessed from Gladstone Harbour and five fish from 23 assessed at reference sites also received scores of 0. The occurrence of scores greater than 0 (88%) at the reference sites indicated that even in pristine environments a population score of 0 is unlikely. Hence a pilot benchmark of an average Fish HAI of 10 was used.

Worst Case Scenario: While studies in Gladstone have assessed fish populations in the harbour (Wesche et al., 2013), it is not clear if the HAI values represent a worst-case scenario. Watson et al. (2012) used the full HAI on fish populations in the polluted Loskop Dam and Mamba River in

South Africa and calculated average HAI scores of 113.8 and 108.0. Adjusting these scores to the nine Fish HAI measures used in this study gives maximum scores of 73.2 and 69.4. Based on these results a pilot worst-case scenario was set at an average Fish HAI score of 70.

Scores for the 2023 Gladstone Harbour Report Card were calculated using data from Spring 2020 as follows:

$$1 - \left(\frac{x - B}{WCS - B}\right)$$

Where, x is recorded value, B is benchmark and WCS is worst case scenario.

The Gladstone Harbour Report Card grade range equates to the following average Fish HAI values:

- Very good (A) = average HAI of 0–19
- Good (B) = average HAI of 20–31
- Satisfactory (C) = average HAI of 32–40
- Poor (D) = average HAI of 41–55
- Very poor (E) = average HAI of ≥56

Table 3.26 | Scoring for nine variable conditions used in the Fish HAI in 2021.

Measure	Variable condition	Score
Fins	No active erosion	0
	Light active erosion	10
	Severe active erosion	20
Skin	Normal no aberration	0
	Mild skin aberration	10
	Moderate skin aberration	20
	Severe skin aberration	30
	Extensive redness as a rash. Scales intact	40
Eyes	No aberration, good clear eyes	0
	Fresh haemorrhage (eg net damage)	0
	Opaque eyes (one or both)	30
	Cloudy and swollen, red or haemorrhaging	30
	Ruptured (one or both)	30
Parasites	No observed parasites	0
	Few observed parasites	10
	Moderate parasite infestation	20
	Numerous parasites	30
Spleen	Normal, black, very dark red or red	0
	Normal, granular rough appearance	0
	Nodular, containing fistulas or nodules	30
	Enlarged	30
	Other, aberrations not fitting any above	30
Hindgut	Normal, no inflammation or reddening	0
	Slight inflammation or reddening	10
	Moderate inflammation or reddening	20
	Severe inflammation or reddening	30
Kidney	Normal, firm, dark, flat	0
	Swollen, enlarged or swollen	30
	Mottled, grey discolouration	30
	Granular in appearance and texture	30
	Urolithiasis or nephrocalcinosis	30
	Other, aberrations not fitting any above	30
Liver	Normal, solid red or light red colour	0
	Fatty liver, coffee with cream colouring	30
	Nodules or cysts in liver	30
	Focal discolouration	30
	General discolouration	30
	Other, deviation not fitting any above	30
Gills	Normal no apparent aberration	0
	Frayed, ragged appearance	30
	Clubbed, swelling of tips	30
	Marginate, light discoloured margin	30
	Pale very light colour	30
	Other	30

3.3.4 Fish health results and discussion

In 2024, Fish health received an overall score of 0.78 and a good (B) grade. The 2024 results were calculated by the average of the Fish HAI score (0.90; results carried over from 2021) and new assessment of Fish condition (Table 3.27) which improved from the previous year (2023: 0.73, 2023: 0.78).

Fish condition

The Fish condition score calculated from the mean of the visual fish condition and fish body condition for three species of fish caught in Gladstone Harbour during the 2023–24 reporting year (Table 3.27). Barred javelin, Dusky flathead and Barramundi data were not included in the Fish condition score calculation due to low sample size and insufficient data.

Table 3.27 | Fish condition measures and overall sub-indicator scores for each of the five fish species used in the 2024 Gladstone Harbour Report Card.

Species	Visual fish condition	Fish body condition	Fish condition
Yellowfin bream	0.94	0.46	0.70
Pikey bream	0.94	0.68	0.81
Barred javelin	0.96	NC	NC
Dusky flathead	NC	NC	NC
Mangrove jack	0.93	0.75	0.84
Harbour score			0.78

NC – Scores not calculated due to low sample size.

Visual fish condition

From the total sample (n = 1026) the detection of visible pathologies was low: skin issues were detected in one fish (0.1% of total fish) and no eye health issues, detections of external parasites or deformities were recorded (Table 3.28). Incidences of fin condition were recorded for all species. While the rate of incidences was high (70%), the severity of this condition was low for most fish and only 0.1% displayed moderate or severe erosion (Table 3.29). It is likely that the use of inappropriate landing nets and containers for transporting fish during live weigh-ins contributed to the high level of fin issues.

Table 3.28 | Number of visual fish condition incidences detected and species scores for six species of fish in the 2023–24 reporting year.

Species	n	Fins	Skin	Eyes	Parasites	Deformities
Yellowfin bream	669	501 (75%)	1 (0.1%)	0	0	0
Pikey bream	141	113 (80%)	0	0	0	0
Barred javelin	182	78 (43%)	0	0	0	0
Dusky flathead	5	1 (20%)	0	0	0	0
Mangrove jack	27	25 (93%)	0	0	0	0
Barramundi*	2	3 (21%)	0	0	0	0
Total	1026	718 (70%)	1 (0.1%)	0	0	0

*Not included in the calculation of report card scores for Fish condition owing to the absence of fish body condition data.

Table 3.29 | Fin condition recorded for six species of fish in the 2023–24 reporting year.

Species	n	Condition (Score) No active erosion (0)	Light active erosion (10)	Moderate active erosion with some haemorrhage (20)	Severe active erosion with some haemorrhage (30)
Yellowfin bream	669	168	496	5	0
Pikey bream	141	28	110	3	0
Barred javelin	182	104	73	3	2
Dusky flathead	5	4	1	0	0
Mangrove jack	27	2	25	0	0
Barramundi*	2	2	0	0	0
Total	1026	308	705	11	2

*Not included in the calculation of report card scores for visual fish condition owing to the absence of fish body condition data.

Table 3.30 | Skin condition recorded for six species of fish in the 2023–24 reporting year.

Species	n	Condition (Score) No normal aberrations (0)	Mild skin aberrations (10)	Moderate skin aberrations (20)	Severe skin aberrations (30)
Yellowfin bream	669	668	1	0	0
Pikey bream	141	141	0	0	0
Barred javelin	182	182	0	0	0
Dusky flathead	5	5	0	0	0
Mangrove jack	27	27	0	0	0
Barramundi*	2	2	0	0	0
Total	1026	1025	1	0	0

*Not included in the calculation of report card scores for visual fish condition owing to the absence of fish body condition data.

Fish body condition

For fish body condition two species, Pikey bream and Barred javelin were graded as good (B), while Yellowfin bream received a poor (D) grade (Table 3.27). In 2024, no fish body condition data was collected for Barred javelin and Dusky flathead, as these fish species were not included in the Boyne Tannum HookUp live weight in. Fish body condition was not calculated for Barramundi, as no weight data is available due to lack of images. This limits comparisons with scores from previous years. Figure 3.19 shows the length-weight relationship for Barred javelin, Dusky flathead, Mangrove jack, Pikey bream and Yellowfin bream caught during the Boyne Tannum HookUp from 2003–24.

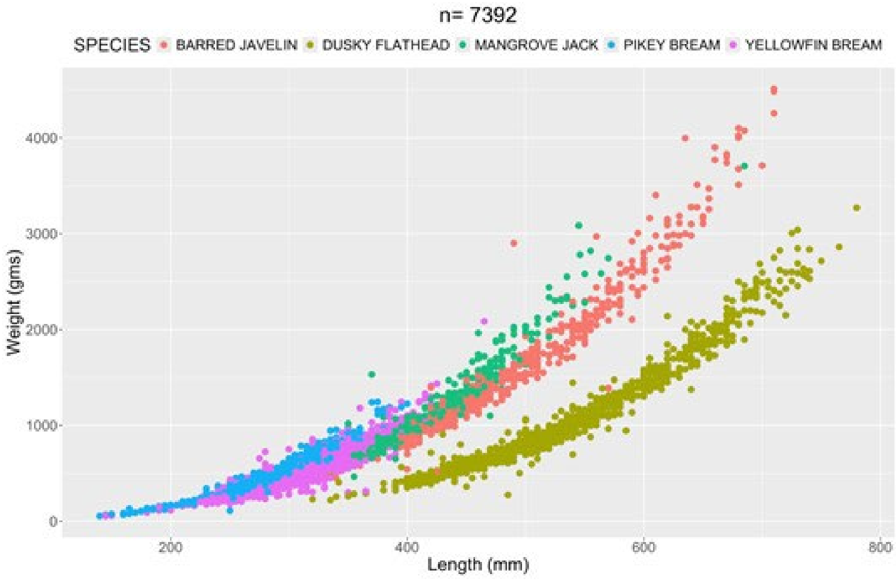

Figure 3.19 | Length-weight relationship for five fish species from the Boyne Tannum HookUp from 2013–23 (Sawynok et al., 2024).

Table 3.31 | Relative condition factor calculated for five fish species in 2024.

Species	n	Relative condition factor		
		Min	Max	Mean
Yellowfin bream	461	0.572	1.478	1.004
Pikey bream	168	0.607	1.432	1.005
Barred javelin	2	0.501	1.399	1.003
Dusky flathead	2	0.626	1.475	1.000
Mangrove jack	31	0.686	1.333	1.000

Fish HAI

As no new Fish HAI monitoring was conducted in the 2024 reporting year, the 2021 results have been used to calculate the Fish HAI scores for the 2024 Gladstone Harbour Report Card. The overall Fish HAI score for the 2021 reporting year was 0.90 and graded very good (A). Three of the five monitored fish species received a very good grades (A) and the two remaining species, Blue catfish and Mullet, received good (B) grades (Table 3.32).

The overall Fish HAI score was the average scores for nine measures (Table 3.33). Overall scores for external pathologies; skin, eyes and fins were low. For example, the highest average score for skin was 2.14 for Mullet. The highest scores (poorest health) in all species were for liver ranging from 5.63 in bream to 15.00 in Mullet.

Table 3.32 | Fish HAI sub-indicator scores for each of the five fish species used in the 2024 Gladstone Harbour Report Card.

Species	Fish HAI 2021
Bream	0.98
Barred javelin	0.90
Barramundi	0.98
Blue catfish	0.81
Mullet	0.81
Harbour score	0.90

Table 3.33 | Average measures and Fish HAI total scores for each species caught in Gladstone Harbour in the 2020–21 reporting year. Organ scores ranged from 0 to 30 and Fish HAI scores ranged from 0 to a possible maximum of 270.

Species	n	Skin	Eyes	Fins	Gills	Spleen	Kidney	Hindgut	Liver	Parasites	HAI score
Barramundi	9	0	0	0	0	0	0	0	6.67	4.44	11.11
Bream	16	0	0	0.63	0	0	3.75	0	5.63	1.25	11.25
Barred javelin	17	0	0	1.18	0	0	0	0	14.12	0.59	15.88
Blue catfish	39	0.77	0	0.26	0.77	0	3.85	0.26	13.85	1.54	21.28
Mullet	14	2.14	0	0.71	0	0	0	1.43	15	2.14	21.43

Overall Fish health

The overall score for Fish health in the 2024 Gladstone Harbour Report Card was the aggregation of the two fish health projects (Table 3.34). As no individual zone scores are calculated for Fish health, this score also constitutes the Fish health score for all 13 environmental monitoring zones.

Table 3.34 | Overall Fish health scores used in the 2024 Gladstone Harbour Report Card.

Indicator	Indicator Score	Overall score
Fish condition	0.78	0.84
Fish HAI*	0.90	

*Fish HAI not assessed in 2024; results carried over from 2021.

3.3.5 Fish health trends

Fish health has been assessed in the Gladstone Harbour Report Card since 2019 and has consistently received a good (B) grade (Figure 3.20).

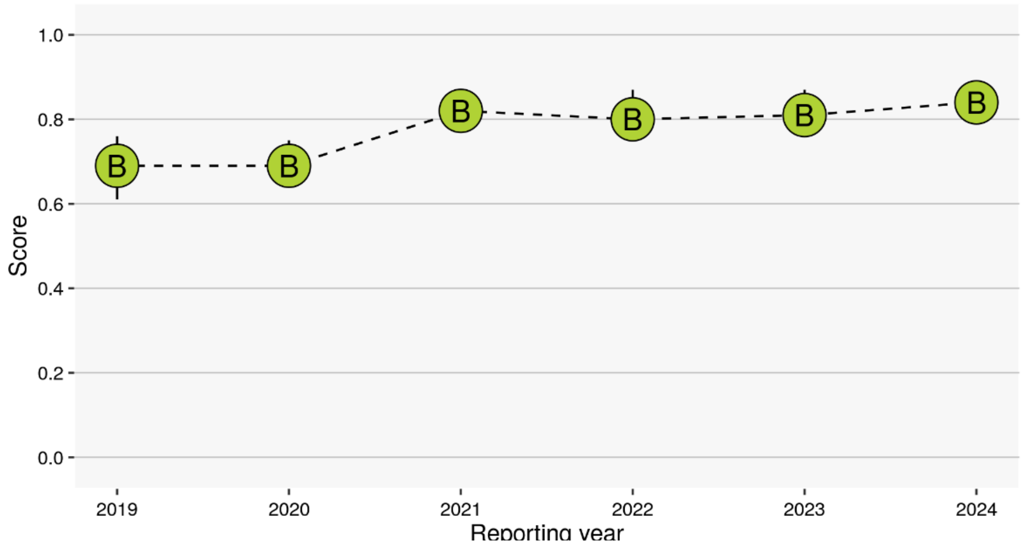

Figure 3.20 | Trends in the overall harbour score for Fish health 2019–24 (Error bars show 95% bootstrap confidence intervals).

3.3.6 Fish recruitment

Fish recruitment is one of the three key dynamic functions that affects a fish population, the other two are growth rate and mortality. The Fish recruitment index is based on the total catch of juveniles of two bream species and is defined as the annual production of juvenile fish entering the mature fish population in Gladstone Harbour (Sawynok and Venables, 2016). The Fish recruitment index captures the reproductive vigour and the spatial extent of two bream species.

A detailed Fish recruitment survey in 2014 helped identify potential species to monitor. Barramundi was considered an unsuitable recruitment indicator for Gladstone Harbour (Venables, 2015), whereas Yellowfin bream *Acanthopagrus australis* and Pikey bream *A. pacificus* (previously known as *A. berda*) were more suitable for long term monitoring. Bream surveys were conducted in the 2023–24 reporting year and data from these survey are reported below.

What fish were used as indicators of harbour health?

Yellowfin bream

Yellowfin bream is a slow growing (five years to reach 23 cm), silvery bronze body fish endemic to Australia with maximum length of about 60–65 cm. Its home range extends from Townsville (Queensland) to Gippsland Lakes in Victoria. Yellowfin bream inhabit mostly inshore areas and estuaries and forage for small fish, crustaceans, gastropods, bivalve molluscs, polychaete worms and ascidians.

Their spawning mostly occurs near estuary mouths during winter months. Larval stages are then moved to estuaries, develop into small juveniles and live in shallow waters sheltered by seagrass beds and mangrove channels. Yellowfin bream is a protandrous hermaphrodite meaning they undergo sex change during the life cycle.

Juvenile yellowfin bream
(Acanthopagrus australis)

Pikey bream

Pikey bream is a bottom living dark silvery grey body fish with a maximum length of about 50 cm. In Australia, its home range extends from Darwin (Northern Territory) to Port Clinton in Victoria. This species is not endemic to Australia and also reported in Southern Japan, Southern China, Vietnam, Philippines, Thailand, Malaysia, Indonesia and Papua New Guinea.

Pikey bream inhabit mostly shallow inshore areas and estuaries up to a depth of 50 m. Being benthic feeders, their diet includes crustaceans, amphipods and tanaids. Their spawning mostly occurs in estuarine environment in the months of May-August. Pikey bream is a protandrous hermaphrodite meaning they undergo sex change during the life cycle.

Juvenile pikey bream
(Acanthopagrus pacificus)

3.3.7 Fish recruitment data collection

Data for the two bream species were collected monthly from 26 sites across 12 harbour zones between December 2023 and February 2024 (Table 3.35). This was the same number of surveys conducted in 2020–21 but a reduction of one month from surveys conducted in previous years (2016–20). The Outer Harbour was excluded from the surveys as there were no suitable bream habitats. Where possible, within each zone, a minimum of two sites were selected to cover the upper tidal limit and another selected within the daily tidal range. Each survey was completed within two weeks, following the largest spring tides as recruitment of fish into nursery habitats is influenced by these large tides. A species fork length up to 100 mm defined juvenile or year 0 recruits (Sawynok and Sawynok, 2023).

Each site was sampled 20 times using a standard cast net (monofilament net with a drop of 2.4 m, mesh size 20 mm and spread of 3.6 m (Figure 3.22). Species were identified in the field and the length of each species, site ID, GPS coordinates, type of substrata, vegetation and site photographs were recorded at each site. Surveys were not done if the water temperature exceeded 32°C (Sawynok and Sawynok, 2024).

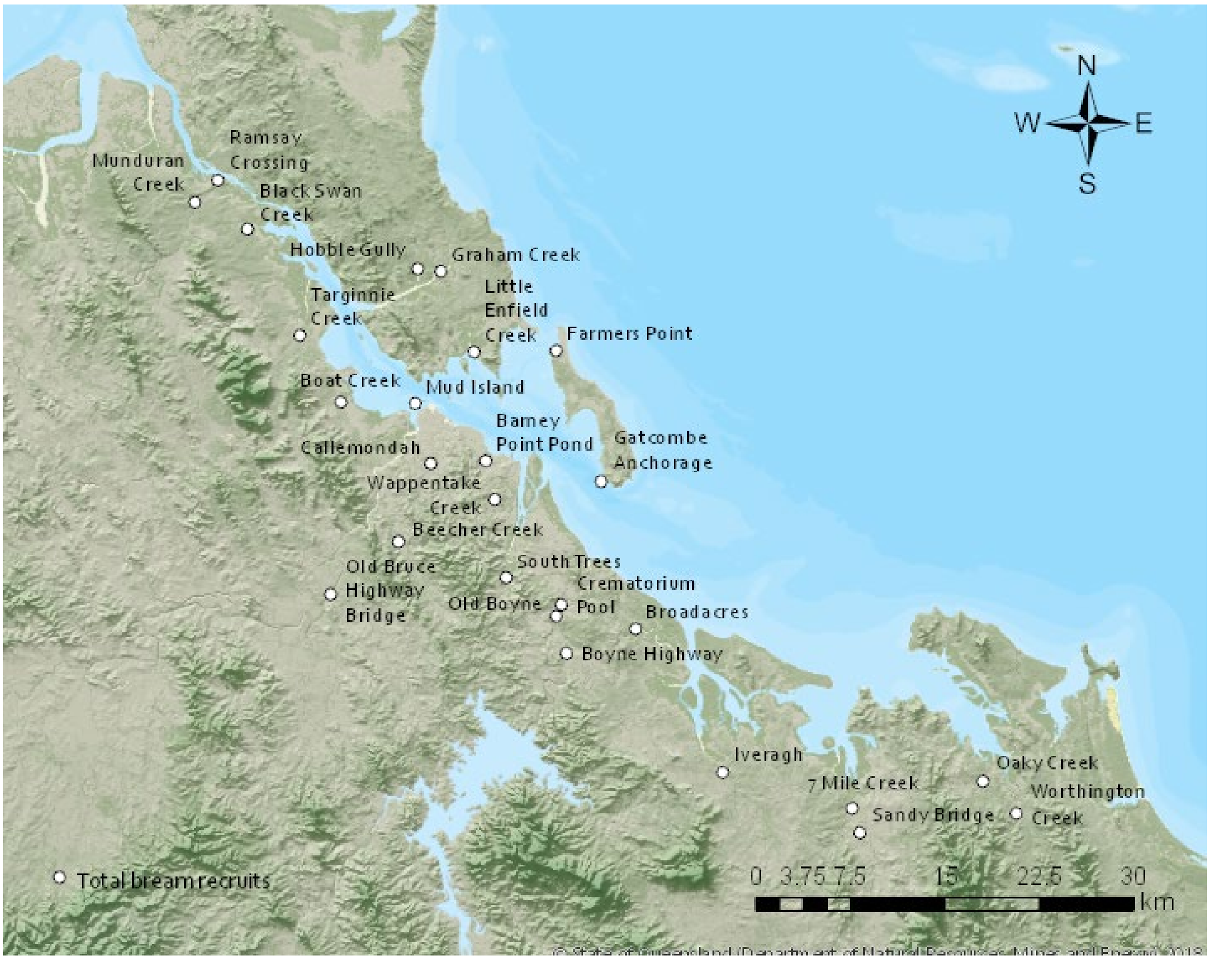

Figure 3.21 | Bream nursery habitats surveyed around Gladstone Harbour in December 2023, January 2024 and February 2024.

Figure 3.22 | Fish recruitment surveys using cast nets (right) and juvenile bream catch sample (left). Photos courtesy of Infofish Australia.

Table 3.35 | Number of sites surveyed and number of juvenile bream caught and released in each monitoring zone in 2023–24.

Zone	Sites	Yellowfin bream	Pikey bream
1. The Narrows	Ramsay Crossing	3	14
	Munduran Creek	6	2
	Black Swan Creek	5	8
	Targinnie Creek	21	12
2. Graham Creek	Graham Creek	0	33
	Hobble Gully	1	16
3. Western Basin	Wiggins Island	12	16
4. Boat Creek	Boat Creek	4	1
5. Inner Harbour	Little Enfield Creek	3	145
	Barney Point Pond	1	0
6. Calliope Estuary	Beecher Creek	6	12
	Old Bruce Highway Bridge	2	11
7. Auckland Inlet	Callemondah	4	14
8. Mid Harbour	Farmers Point	2	0
	Gatcombe Anchorage	2	8
9. South Trees Inlet	Wappentake Creek	1	0
	South Trees	2	10
	Crematorium Pool	14	13
10. Boyne Estuary	Old Boyne	25	30
	Boyne Highway	18	5
12. Colosseum Inlet	Broadacres	8	12
	Iveragh	33	0
13. Rodds Bay	Oaky Creek	8	27
	7 Mile Creek	25	9
	Worthington Creek	21	3
	Sandy Bridge	9	4
Total		236	405

3.3.8 Development of Fish recruitment indicators and scoring

A negative binomial statistical model (with a log link) was developed for the catch per trip to a site using data collected for this report card and other historical data collected since 2011. This model assesses the proportional changes in catch rate between years relative to a notional baseline. Several potential environmental predictors related to fish habitats were also tested to determine if they helped to explain variation in the juvenile catch data. The estimates were aggregated (using the bootstrapping technique) to obtain the report card results.

The final statistical model comprises:

- A response variable – total yellowfin and Pikey bream juvenile catch count per visit, together with an offset term of log (number of casts), giving an effective response of catch per cast.
- Random effect terms – sampling site (allowing for productivity differences between sites not explained by the fixed effects), year (as the main effect), year by site interaction (to better account for the variability in spatio-temporal scale).
- Log link – allows all difference or changes to be assessed on a proportional or relative scale rather than an absolute one.
- Fixed temporal effects – month term allowing for systematically different catch rates within the survey year.
- Fixed environmental effects – presence and absence of rocks, water depth at a site.

There are no external criteria available to set baseline levels for fish recruitment, therefore the scores were constructed with respect to internal criteria derived objectively from the data (Sawynok and Venables, 2016). A score of 0.50 indicates a season at the median reference level, indicating no increase or decrease in the catch rate from the long-term average.

3.3.9 Fish recruitment results and discussion

Fish recruitment

Overall, the Fish recruitment score for 2024 was 0.57 and improved a grade to satisfactory (C) from the previous year (2023: poor, D). 11 of the 12 assessed zones scores increased or remained the same, and only one zone Rodd's Bay, declined in score (Table 3.36).

Table 3.36 | Fish recruitment indicator scores for each zone used in the 2024 Gladstone Harbour Report Card. Results from 2019–23 are shown for comparison.

Zone	2024	*2023*	*2022*	*2021*	*2020*	*2019*
1. The Narrows	0.44	*0.37*	*0.65*	*0.54*	*0.63*	*0.18*
2. Graham Creek	0.54	*0.53*	*0.80*	*0.84*	*0.92*	*0.17*
3. Western Basin	0.82	*0.77*	*0.98*	*0.94*	*0.98*	*0.13*
4. Boat Creek	0.62	*0.58*	*0.35*	*0.35*	*0.38*	*0.32*
5. Inner Harbour	0.77	*0.58*	*0.69*	*0.61*	*0.63*	*0.16*
6. Calliope Estuary	0.50	*0.28*	*0.48*	*0.68*	*0.66*	*0.28*
7. Auckland Inlet	0.36	*0.36*	*0.61*	*0.63*	*0.80*	*0.53*
8. Mid Harbour	0.54	*0.49*	*0.58*	*0.78*	*0.62*	*0.12*
9. South Trees Inlet	0.39	*0.31*	*0.54*	*0.47*	*0.39*	*0.25*
10. Boyne Estuary	0.64	*0.37*	*0.64*	*0.53*	*0.51*	*0.32*
12. Colosseum Inlet	0.68	*0.41*	*0.29*	*0.56*	*0.63*	*0.39*
13. Rodds Bay	0.60	*0.64*	*0.47*	*0.51*	*0.52*	*0.33*
Harbour score	0.57	*0.47*	*0.59*	*0.62*	*0.64*	*0.27*

The total number of bream caught in 2024 from 1540 casts was 641; comprised of 236 Yellowfin bream and 405 Pikey bream (Table 3.35). For the 2020–24 report cards, the Fish recruitment results were calculated from three surveys (December, January and February), while prior to 2020, there were four surveys conducted (December, January, February and March). The reduction in the number of surveys has had little effect on the overall catch rates per cast (green marker, Figure 3.23).

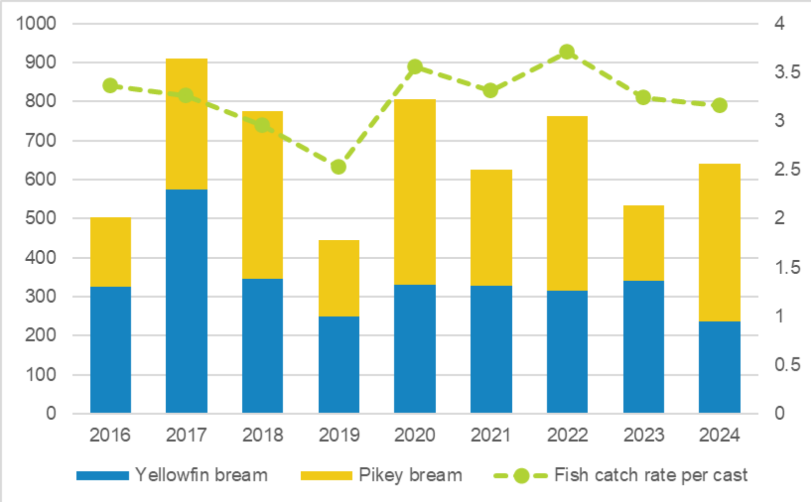

Figure 3.23 | Distribution of Yellowfin and Pikey bream recruits (primary axis) from total bream catch recorded and fish catch rate per cast (secondary axis) during the 2016–24 fish recruitment surveys.

Even though the average catch rates per cast increases, this does not have a direct relationship to the scores (Figure 3.23). The derived final score includes the site level effect and as such is more sensitive to individual site variation than the catch rate. At the individual sites there were variations that showed several sites underperformed relative to last year, and this is the likely explanation for the higher catch rate but lower scores.

Prawns

In 2024, the number of prawns caught per cast (2024: 1.17) decreased from the previous year (2023: 2.07) but is still a marked increase from the lowest recorded catch rate observed in 2022 (2022: 0.32). The number of prawns this year was low in the December (n = 267) and January (n – 258) but were boosted in February (n = 1,270) largely due to a record number of prawns caught at the Ramsay Crossing site in February (n = 686). Although rainfall from November to January was close to the long-term monthly average (Figure 8.4), isolated storms during this period led to freshwater flushes after the January surveys, which in turn increased prawn numbers in February.

3.3.10 Fish recruitment trends

Fish recruitment scores are the most varied across all environmental indicators (Figure 3.24). In 2024, the overall grade for Fish recruitment was satisfactory (C). Although scores have steadily declined since 2020, the satisfactory (C) grade in 2024 is a reversal from this decline.

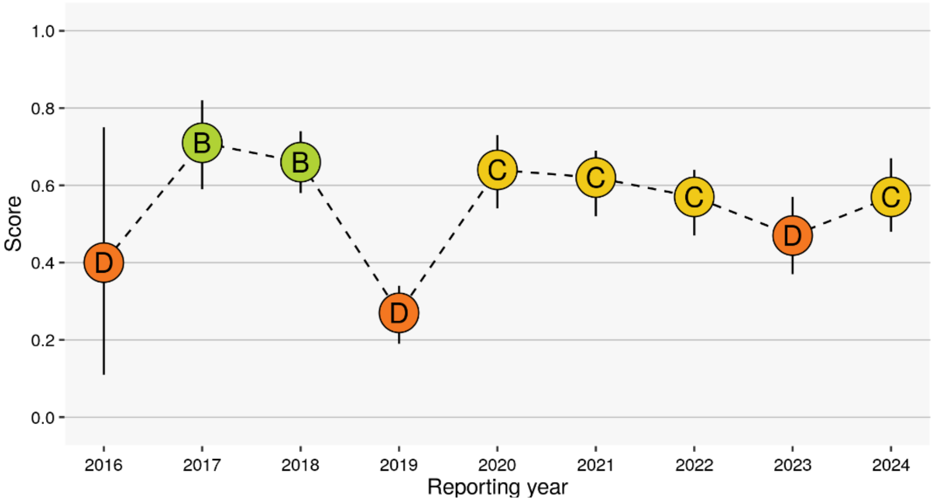

Figure 3.24 | Trends in the overall harbour score for Fish recruitment 2016–24 (Error bars show 95% bootstrap confidence intervals).

3.3.11 Mud crab

Mud crabs are one of Gladstone Harbour's iconic species (Figure 3.25). They were identified as a major community concern at workshops conducted by GHHP in 2013. This is due to their value to commercial and recreational fishers and the reported high rates of rust spot disease in the harbour's population (Andersen et al., 2000). Mud crabs spend most of their post-larval lives in burrows in estuarine mangrove habitats. Their abundance, size distribution and health are related to environmental conditions within these habitats. Based on conceptual models, Dambacher et al. (2013) indicated that the abundance of adult mud crabs was a highly interpretable variable and would be a meaningful indicator for the Gladstone Harbour Report Card.

The Mud crab indicator was developed specifically for the Gladstone Harbour Report Card to establish a long-term mud crab monitoring program that will be sufficiently sensitive to show change over time in response to either natural or anthropogenic pressures, or in response to management actions aimed at improving the health of Gladstone Harbour. A pilot study in 2017 evaluated mud crab monitoring sites and developed suitable indicators of mud crab health and a methodology for determining report card scores.

Figure 3.25 | Mud crab captured in Gladstone Harbour (Photo courtesy of CQUniversity).

3.3.12 Mud crab data collection

Monitoring site selection

Potential monitoring sites were selected based on historical sampling locations such as Queensland Fisheries Long Term Monitoring Program (Jebreen et al., 2008), local knowledge of mud crab populations, accessibility and a reconnaissance trip from 5–6 June 2017. Seven sites were selected for future report card monitoring: The Narrows, Graham Creek, Boat Creek, Inner Harbour, Calliope Estuary, Auckland Inlet and Rodds Bay (Figure 3.26).

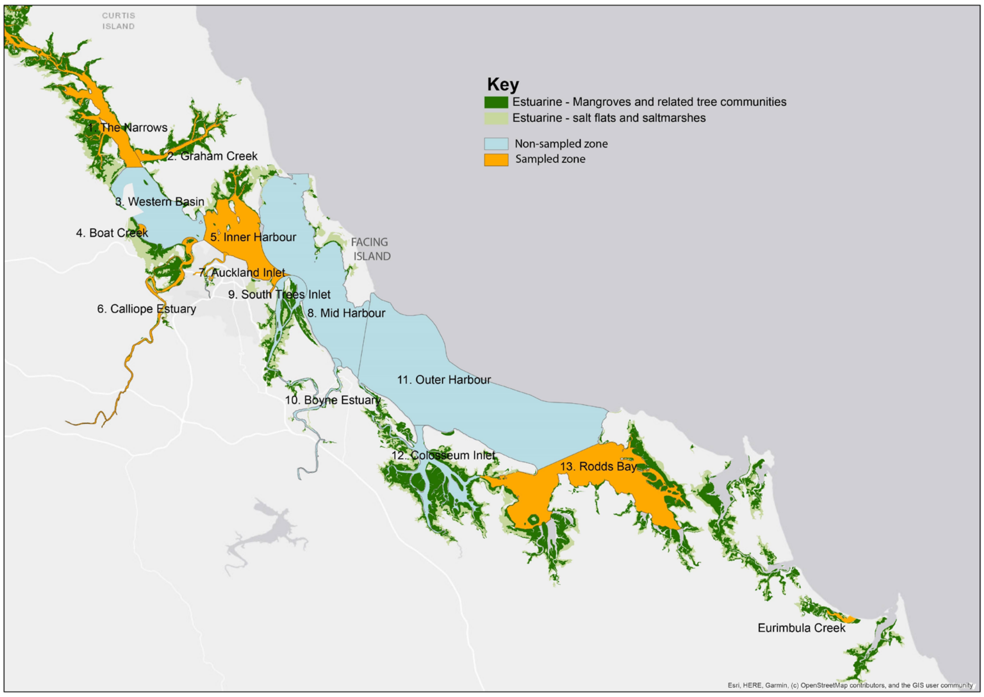

Figure 3.26 | Map of Gladstone Harbour Mud Crab Monitoring Zones. These zones have been surveyed annually from 2017-2024. Eurimbula Creek was sampled in 2018 and 2019 as a reference site.

Mud crab monitoring

Two rounds of Mud crab monitoring were conducted in 2024, a summer (warm, wet season) survey from 5–8 February and a winter (cool, dry season) survey from 1–17 July. Inclement weather (a strong wind warning and large swell) prevented fieldwork in Rodds Bay on the scheduled date of 4 July 2024, so sampling at Rodds Bay was delayed until the next suitable tide on 17 July 2024.

Twenty heavy-duty, four-entry collapsible crab pots were set at a minimum of 100 m apart at each site. The exception was Boat Creek where fewer pots could be placed within the confines of this small zone. Sampling dates and times were determined by tidal cycles. The baited crab pots were set at least three hours before the low tide, and collected at least two hours after the low tide, resulting in soak times of approximately five hours per pot. All pots were placed so that they would be submerged for the duration of deployment to prevent mortality of any fish or other bycatch. Pots were placed as close as possible to mangrove habitats within this limit.

Upon retrieval of the pots, the following data were collected at each site for mud crabs:

- Species
- Sex
- Carapace width (notch to notch; mm)
- Abnormalities: type, body location and number, dimensions and grade of rust spot lesions (Andersen and Norton, 2001)

For all bycatch (crabs and fish), the species was recorded. Blue swimmer crabs were also weighed, measured and checked for abnormalities. All mud crabs and bycatch were released alive at the site of capture. Used baits were kept on board the vessel and not discarded at the sampling site. This was to reduce interference with commercial and recreational mud crabbers in the area.

3.3.13 Development of Mud crab indicators and scoring

A literature search for potential Mud crab indicators identified nine classes of potential indicators (Table 3.37). This included the three sub-indicators identified by the GHHP Independent Science Panel for consideration: abundance, size distribution and visual health (McIntosh et al., 2014). Other potential indicators were identified in the literature or were those used in other mud crab surveys in the Gladstone area.

Table 3.37 | Potential Mud crab indicators were identified and ranked based on their suitability for calculating report card scores.

Potential Mud crab indicator measures	Total score (30 = highest possible score)
Size:Sex ratio *sex ratio based on legal size limit*	26.5
Biomass *ratio of carapace width to body weight*	25.3
Abundance *catch per unit effort (CPUE)*	25
Prevalence of rust lesions *visual assessment*	24
Bioaccumulation of toxicants *bioaccumulation of metals in tissues* *structural deformities of organs (associated with metals)* *bioaccumulation of persistent organic pollutants* *bioaccumulation of pesticides*	21.3
Nursery value *juvenile crabs (CPUE)*	18
Morphometrics *e.g. claw size ratio*	18
Prevalence of other diseases and parasites visual assessment	17.5
Biomarkers *Glutathione S-transferases induction and ChE inhibition* *RNA/DNA ratios* *glutathione peroxidase activity and lipid peroxides* *antioxidant enzymes and oxidative stress parameters*	14

The potential indicators were scored against 10 criteria by the project team (Flint et al., 2017a) and three indicators were selected for the report card:

1. Abundance: CPUE

$$\frac{(total\ number\ of\ mud\ crabs\ caught)}{(number\ of\ pots\ set)}$$

1. Prevalence of rust lesions

$$\frac{(number\ of\ mud\ crab\ with\ lesions)}{(number\ of\ mud\ crabs\ assessed\ for\ lesions)}$$

2. Sex ratio: based on legal size limit

$$\frac{(number\ of\ male\ mud\ crabs\ > 150\ mm\ carapace\ width)}{(number\ of\ female\ mud\ crabs\ > 150\ mm\ carapace\ width)}$$

The Gladstone Harbour Report Card scores were calculated using a methodology similar to that used in the South East Queensland Report Card (Fox, 2013) and the Fitzroy Basin Report Card (Flint et al., 2017b). The indices for sex ratio, abundance and visual health were calculated and compared to a benchmark and a worst-case scenario (Table 3.38). Calculated index values lower than the worst-case scenario scored 0; values higher than the benchmark value scored 1. This resulted in a range of scores between 0 and 1. Benchmarks and worse-case scenarios were selected based on existing data and data collected during the 2017 report card monitoring.

A potential fourth sub-indicator (biomass) was previously considered. Owing to a lack of baseline data, biomass was not included in the 2017 or 2018 report cards. In 2019, the GHHP Independent Science Panel discussed the potential inclusion of biomass as there was three years of baseline data; however, recommended that biomass not be included due to complications in assessment.

Table 3.38 | Calculation of Mud crab scores for the 2024 Gladstone Harbour Report Card.

Measure	Benchmark	Worst-case scenario	Method
Abundance (CPUE)	**1.3** *Moving average of 75th percentile of the combined 2017–24 scores*	**0.25** *Catch rate of < 1 crab per allowable 4 pots*	$1-((x-B)/(WCS-B))$ Where: x=recorded CPUE B=benchmark (1.3) WCS=worst-case scenario (0.25)
Prevalence of rust lesions	**0.04** *25th percentile of the 2017 data (4%)*	**0.35** *Prevalence recorded by Dennis et al. (2016) in Gladstone Harbour of 37%, rounded down to 35%*	$1-((x-B)/(WCS-B))$ Where: x=recorded prevalence B=benchmark (0.04) WCS=worst-case scenario (0.35)
Sex ratio	**2** *Male to female sex ratio of 2:1 from an unfished Central Queensland population at Eurimbula Creek (Flint et al., 2019)*	**0.25** *25th percentile of Long-Term Monitoring Program data*	$1-((x-B)/(WCS-B))$ Where: x=recorded ratio B=benchmark (2) WCS=worst-case scenario (0.25)

The sex ratio measure assessed fishing pressure, as only male crabs can be retained. A minimally disturbed benchmark requires data from an unfished population, where an undisturbed male to female crab ratio can be determined. The 2017 benchmark was set at 3:1 based on unfished populations in Micronesia (Alberts-Hubatsch et al., 2016). In 2018, the sex ratio benchmark was updated to 2:1 using data from unfished populations in northern NSW and an unfished section of Moreton Bay (Butcher, 2004; Pillans et al., 2005). In 2018–19, a GHHP-funded CQU study investigated the sex ratio from a more local population in Eurimbula Creek (an un-crabbed estuary in Central Queensland). Findings from this study corroborate the previously reported sex ratio benchmark of 2:1 (Flint et al., 2019). As the AIMS Long-Term Monitoring Program data are the longest time series available, the worst-case scenario was set from this data at the 25th percentile (0.25).

Abundance was indirectly measured as CPUE – total catch divided by the number of pots within each of the seven monitoring zones. The benchmark for abundance (measured as CPUE) was set as the 75th percentile of the past three years. An accumulating average of the 75th percentile will be used for up to 10 years to account for natural variability. Using the accumulating average from 2017–24, the benchmark for 2024 was 1.3 crabs/pot. The worst-case value was set at 0.25, equivalent to one crab from four pots. The maximum number of pots that a recreational crabber is allowed is four and a catch of less than one mud crab from four pots is undesirable.

The benchmark and worst-case scenario for the prevalence of rust lesions was set using historical data (e.g. Andersen et al., 2000; Dennis et al., 2016). A background level of 5% of crabs with rust spot lesions has previously been reported. However, the 25th percentile of the 2017 monitoring was approximately 4% (0.04) and this lower figure was adopted as the benchmark as a precautionary approach. The worst-case scenario (0.35) was based on a study by Dennis et al. (2016), which was conducted at a time of unusually high fish and crab disease and is representative of a population in poor condition.

In 2020, the GHHP Independent Science Panel recommended a change in Mud crab scoring methodology which was approved by the GHHP Management Committee. Boot-strapping processes described in Section 2.1 aside, calculation of the harbour score for Mud crabs is as follows:

- Calculate the scores for each sub-indicator in each zone
- Average the scores of the sub-indicators to get a harbour score for each sub-indicator
- Average the sub-indicator harbour scores to get the overall harbour score.

Previously the harbour score was derived by averaging the zone scores. This had the effect of omitting zones in which an insufficient catch (n < 5) occurred. Under the new method, the zero for abundance is captured for zones with an insufficient catch in the abundance sub-indicator score, which is then averaged with the prevalence of rust lesions and sex ratio sub-indicator scores to calculate the overall harbour score.

3.3.14 Mud crab results and discussion

Mud crabs received a poor (D) grade in the 2024 Gladstone Harbour Report Card, a decline from the satisfactory (C) grade in 2023 (Table 3.39). The overall score declined from 0.51 to 0.46.

Two zones received good (B) grades: Boat Creek, which improved from 0.67 in 2023 to 0.75 in 2024, and The Narrows, returning to a good (B) grade after five years of satisfactory (C) grades. In contrast, Calliope Estuary and Rodds Bay declined to poor (D) grades due to score decreases (from 0.54 in 2023 to 0.38 in 2024, and from 0.67 in 2023 to 0.35 in 2024, respectively). Inner Harbour achieved an overall score of 0.42 and poor (D) grade in 2024, showing a considerable improvement from 0.14 and very poor (E) grade in 2022. Graham Creek and Auckland Inlet scores remained consistent, with the poor (D) grades remaining stable over the past few years.

The Mud crab sub-indicators abundance, sex ratio and rust lesions, have been selected to represent a range of pressures on mud crabs in Gladstone Harbour. These pressures include commercial and recreational fishing and environmental condition. The Mud crab sub-indicators were designed to reveal change over time and elucidate trends in mud crab health.

Table 3.39 | Mud crab sub-indicator and indicator scores for the 2024 Gladstone Harbour Report Card. Scores from 2022 and 2023 are shown for comparison.

Zone	Abundance (CPUE)	Prevalence of rust lesions	Sex ratio	2024	*2023*	*2022*
1. The Narrows	0.88	1.00	0.03	0.65	*0.50*	*0.58*
2. Graham Creek	0.00	0.73	0.20	0.31	*0.36*	*0.33*
4. Boat Creek	1.00	1.00	0.25	0.75	*0.67*	*0.58*
5. Inner Harbour	0.21	0.96	0.09	0.42	*NC*	*0.14*
6. Calliope Estuary	0.14	1.00	0.00	0.38	*0.54*	*0.43*
7. Auckland Inlet	0.00	1.00	0.05	0.35	*0.33*	*NC*
13. Rodds Bay	0.04	1.00	0.00	0.35	*0.67*	*NC*
Harbour score	0.32	0.96	0.09	0.46	*0.51*	*0.39*

CPUE – catch per unit effort; NC – not calculated owing to inadequate sample size (n < 5)

Abundance

Two zones received very good (A) grades for abundance (Table 3.39). The Narrows score significantly improved, rising from 0.58 in 2023 to 0.88, with an average catch of 1.25 mud crabs per pot. Boat Creek achieved a score of 1.00, up from 0.31 in 2023, with an average catch per unit effort (CPUE) of 1.54 (Table 3.40). All other zones remained very poor (E), however, there were slight improvements in scores at Inner Harbour (2023: 0.00, 2024: 0.21) and Calliope Estuary (2023: 0.00, 2024: 0.14).

While abundance improved from a very poor (E) grade in 2023 to a poor (D) in 2024, caution is needed when interpreting these scores, as CPUE data can be highly variable. Similar to previous years, zone-level abundance grades ranged from very good (A) to very poor (E). Mud crab populations are influenced by both human activities and natural factors, including habitat, reproductive cycles, and environmental conditions like temperature and water movement (Knuckey, 1999; Alberts-Hubatsch et al., 2016). Sampling factors including capture techniques, sampling locations and timing may also influence catch rates. When these variables are controlled, abundance can reflect changes due to external pressures, including fishing, habitat availability, or recruitment limitations. As more consistent sampling data is gathered, the reliability of the abundance sub-indicator is expected to improve.

Table 3.40 | Catch per unit effort for pots set in seven harbour zones during the 2024 Mud crab surveys.

Zone name	**March 2024**			**July 2024**		
	Pots	Crabs caught	CPUE	Pots	Crabs caught	CPUE
1. The Narrows	20	25	1.25	20	25	1.25
2. Graham Creek	20	4	0.20	20	5	0.25
4. Boat Creek	16	14	0.88	16	35	2.19
5. Inner Harbour	20	7	0.35	20	12	0.20
6. Calliope Estuary	20	17	0.85	20	1	0.05
7. Auckland Inlet	20	1	0.05	20	4	0.20
13. Rodds Bay	20	12	0.60	20	1	0.05

CPUE – Catch per unit effort.

Rust lesions

None of the 79 mud crabs captured in March 2024 had rust lesions. There were three mud crabs with rust lesions encountered in July 2024 (of the 83 mud crabs caught), one from Graham Creek, Boat Creek and Inner Harbour (Table 3.41).

The prevalence of rust lesions was scored with moderately high confidence in the benchmark and worst-case scenario as they are based on research data from Gladstone Harbour (Andersen & Norton, 2001; Dennis et al., 2016) and data collected during the 2017 GHHP monitoring year. All six zones where this measure could be calculated received very good grades (A; Table 3.39). These scores indicate a very low prevalence of rust spot lesions across the harbour. The average incidence of rust spot lesions across the seven monitored zones was nil in March and 4.5% in July, considerably lower than the 37% incidence recorded in 2012 (Dennis et al., 2016) or less than half of the 22% recorded in the late 1990s by Andersen et al. (2000).

Table 3.41 | Number and percentage of mud crabs with rust spot lesions caught in March and July 2024, by zone.

Zone name	March 2024		July 2024	
	# with lesions	% with lesions	# with lesions	% with lesions
1. The Narrows	0	0	0	0
2. Graham Creek	0	0	1	20
4. Boat Creek	0	0	1	2.9
5. Inner Harbour	0	NC	1	8.3
6. Calliope Estuary	0	0	0	0
7. Auckland Inlet	0	NC	0	0
13. Rodds Bay	0	0	0	0

NC – not calculated owing to inadequate sample size (n < 5)

Sex ratio

In 2024, as in previous years in Gladstone Harbour, more oversized female crabs were caught than oversized male crabs. A total of 100 mud crabs over the legal size limit of 150 mm carapace width (equivalent to 143 mm notch width) were caught, of which 25 were male. Sex ratios were low in most zones in both March and July (Table 3.42).

In Queensland, it is illegal to take female crabs, hence changes in the ratio of male to female crabs can indicate changes in fishing pressures. Sex ratio across the harbour returned to very poor (E) grade in 2024, after an improvement to a poor (D) grade in 2023. Presently, the timing and population effect of the female spawning migration is not well understood and the possibility that this may be influencing the observed scores cannot be ruled out (Flint et al. 2024). In addition to changes in population dynamics, sex ratio may impact ecosystem processes owing to differences in behaviour between male and female crabs. For example, only male crabs dig burrows, a behaviour which may aid the process of bioturbation (disturbance of sedimentary deposits by living organisms) in mangrove ecosystems. Research is required to understand how a changed sex ratio impacts the health of mud crab populations.

Table 3.42 | Sex ratio of legal-sized mud crabs (carapace width >150 mm) in March and July 2024 by zone.

Zone name	March 2024			July 2024		
	Males	Females	Sex ratio	Males	Females	Sex ratio
1. The Narrows	5	6	0.83	3	16	0.19
2. Graham Creek	1	2	0.50	2	3	0.67
4. Boat Creek	3	3	1	6	10	0.60
5. Inner Harbour	2	2	1	2	8	0.25
6. Calliope Estuary	0	8	0	NC	NC	NC
7. Auckland Inlet	1	NC	NC	NC	NC	NC
13. Rodds Bay	2	10	0.20	NC	NC	NC

NC – not calculated owing to inadequate sample size (n < 5). Note figures for sex ratio represent actual male-to-female crab ratios and not Gladstone Harbour report card scores.

3.3.15 Mud crab trends

Despite significant improvements in abundance scores and consistently high prevalence of rust lesion scores, low sex ratio scores caused the 2024 overall Mud crab grade to decline from satisfactory (C) to poor (D; Figure 3.27).

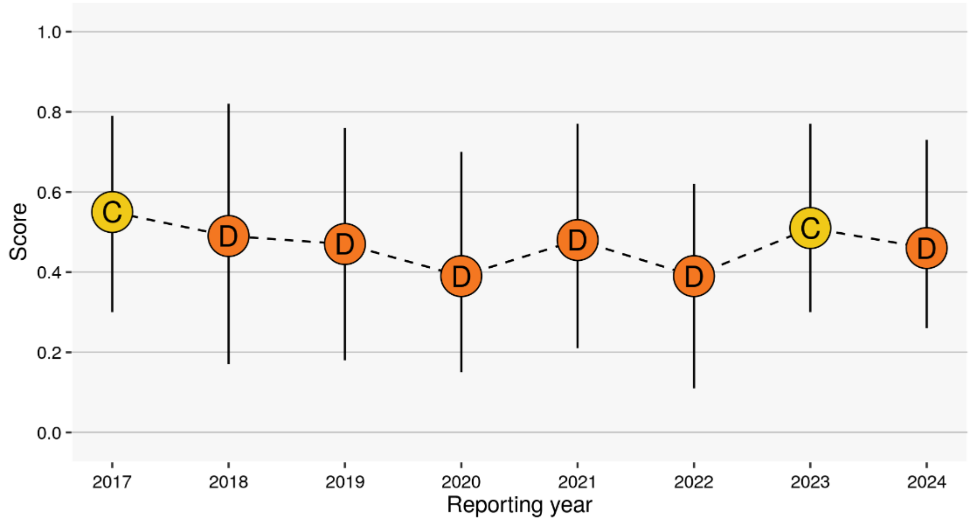

Figure 3.27 | Trends in the overall harbour score for Mud crab 2017–24 (Error bars show 95% bootstrap confidence intervals).

3.4 Overall Environmental Health results

The overall Environmental Health score for the 2024 report card was 0.67, an improvement from 0.63 in 2023, upgrading the grade to good (B) from satisfactory (C) (Figure 3.28). This score was calculated by aggregating three Environmental indicator groups – Water and Sediment Quality, Habitats, and Fish and Crabs – using the bootstrapping methodology (Logan, 2016).

The Water and Sediment Quality score (0.90) combined Water quality and Sediment quality indicators. The Habitats score (0.48) included Seagrass, Corals, and Mangroves, while the Fish and Crabs score (0.62) was based on Fish health, Fish recruitment, and Mud crab indicators. These overall grades for each indicator group, Water and Sediment Quality, Habitats, and Fish and Crab, matched the previous report card grades: very good (A), poor (D), and satisfactory (C), respectively (Table 3.43).

The Habitat indicator scores for each zone only reflect the habitat types present in that zone. Mangroves are found in all zones, Coral in two, and Seagrass in six. However, other key habitats, like benthic habitats, which occur in all zones, were not assessed. Fish health sampling took place in the northern, central, and southern areas of Gladstone Harbour, with a single score applied to all zones. Fish recruitment surveys covered all zones except the Outer Harbour, while Mud crab monitoring was conducted in six zones. Water and Sediment Quality sampling occurred in all zones.

Table 3.43 | Environmental indicator group scores used in the 2024 Gladstone Harbour Report Card.

Zone	Water and Sediment Quality	Habitats	Fish and Crabs
1. The Narrows	0.84	0.76	0.64
2. Graham Creek	0.93	0.73	0.56
3. Western Basin	0.89	0.67	0.83
4. Boat Creek	0.90	0.65	0.74
5. Inner Harbour	0.88	0.50	0.68
6. Calliope Estuary	0.92	0.73	0.57
7. Auckland Inlet	0.89	0.47	0.52
8. Mid Harbour	0.88	0.39	0.69
9. South Trees Inlet	0.91	0.70	0.61
10. Boyne Estuary	0.90	0.66	0.74
11. Outer Harbour	0.95	0.40	0.84
12. Colosseum Inlet	0.91	0.64	0.76
13. Rodds Bay	0.92	0.73	0.59
Harbour score	0.90	0.48	0.62

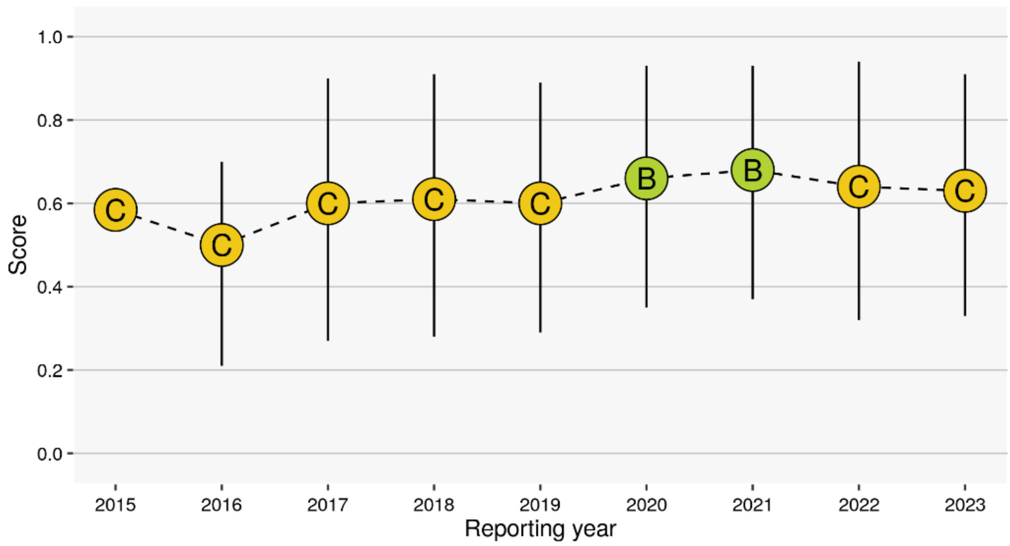

Figure 3.28 | Trends in Environmental Health scores 2015–24 (Error bars show 95% bootstrap confidence intervals).

4 The Social Health Component

Report cards have become an increasingly popular way to document environmental condition. The Gladstone Harbour Report Card also reports on the social, cultural and economic condition of the harbour. Eight indicators aggregated into three indicator groups (Harbour Usability, Harbour Access, and Liveability and Wellbeing) were used to assess the Social Health of the harbour (Table 4.1). These indicators were developed from the GHHP vision and piloted in 2014 (Pascoe et al., 2014). In 2023, no new assessment was conducted for Social Health and results have carried over from the 2022 report card.

4.1 Data collection

The GHHP Independent Science Panel suggested a series of candidate indicators to assess the social aspect of harbour health in 2014 (McIntosh et al., 2014). The appropriate measures to evaluate these candidate indicators were identified by the GHHP Independent Science Panel and through a workshop with experts in social science and economics (Pascoe et al., 2014). 'Appropriateness' was based on a measure's relationship with the indicator, indicator group and its measurability.

A Computer Assisted Telephone Interview (CATI) survey of residents from the Gladstone 4680 postcode area was conducted in June 2022. Participants were contacted using a random dialling technique to mobile phone numbers. Note that the CATI survey was administered via different avenues across years; with 2014–16 via landline only, 2017–18 via landline and mobile numbers, and 2019 and 2022 via landline, mobile numbers, and internet survey. Trained research interviewers administered the survey, which had been thoroughly monitored for data QA/QC. The survey questions were largely qualitative and related to the GHHP social, cultural (*Sense of Place*) and economic objectives. All questions were designed to be answered on a 10-point agree-disagree scale. In the CATI survey, each participant was asked a specific question to suggest the first three words that come to their mind when thinking about Gladstone Harbour.

The marine safety incidents and oil spills measures in the Social component were not assessed through the CATI survey and instead a secondary dataset was used with a 10-year moving average as the baseline for comparison. The questions and 10-point scale were designed so that the results would be comparable to other studies (e.g. Social and Economic Long-Term Monitoring Program for the Great Barrier Reef) and to elicit trends over time (Pascoe et al., 2014).

Table 4.1 | The indicator groups, indicators and measures used to determine Social Health scores for the Gladstone Harbour Report Card (Adapted from De Valck, 2022).

Indicator Groups	Indicators	Measures	Data Source	Baseline data
Harbour Usability	Satisfaction with harbour recreational activities	How satisfied with last trip	CATI Survey (avg: Questions: Q11b, Q12b1, Q15b, Q25)	10-point scale
		Quality of ramps and facilities	CATI Survey (avg: Q28, Q28a)	10-point scale
	Air and water quality	Water quality satisfaction	CATI Survey (Q40)	10-point scale
		Air quality satisfaction	CATI Survey (Q41)	10-point scale
		Water quality does not affect use of the harbour	CATI Survey (Q42)	10-point scale
	Harbour safety	Marine safety incidents	Marine incidents in Queensland 2020 Department of Transport and Main Roads, Maritime Safety Queensland	Data 2011-2020 (calendar year). Rate of incidents in Gladstone maritime region compared to other Qld regions
		Oil spills	Queensland Department Transport and Main Roads, Maritime Safety Queensland Branch, 2019-2020 and 2020-2021	Data 2011-2020 (calendar year). Rate of incidents in Gladstone maritime region compared to other Qld regions
		Safe at night	CATI Survey (Q44)	10-point scale
		Happy to eat seafood	CATI Survey (Q43)	10-point scale
Harbour Access	Satisfaction with access to the harbour	Fair access to harbour	CATI Survey (Q29)	10-point scale
	Satisfaction with ramps and public spaces	Frequency of use	CATI Survey (Q8)	10-point scale
		Number of ramps	CATI Survey (Q27)	10-point scale
		Access to public spaces	CATI Survey (Q26)	10-point scale
	Perceptions of harbour health	Great condition	CATI Survey (Q33)	10-point scale
		Optimistic about future health	CATI Survey (Q34)	10-point scale
		Improved over the last 12 months	CATI Survey (Q35)	10-point scale
	Barriers to access	Marine debris a problem	CATI Survey (Q36)	10-point scale
		Marine debris affects access	CATI Survey (Q37)	10-point scale
		Shipping reduced use	CATI Survey (Q31)	10-point scale
		Recreational boats reduced use	CATI Survey (Q32)	10-point scale
Liveability and Wellbeing	Contribution of harbour to liveability and wellbeing	Makes living in Gladstone a better experience	CATI Survey (Q45)	10-point scale
		Participate in community events	CATI Survey (Q46)	10-point scale
		Aesthetic value	CATI Survey (Q45a, Q45b))	10-point scale

4.2 Development of indicators and scoring

Although the Social indicator questions used in the CATI survey were qualitative, they were recorded on a 10-point agree-disagree scale and the average satisfaction rating has been used in the analysis. Scores of 9 or 10 indicated very strong agreement; scores of 1 or 2 indicated very strong disagreement. A response of 9 or 10 provided a grade of A, a response of 7 or 8 provided a grade of B, 5 or 6 provided a C, 3 or 4 provided a D, and 1 or 2 provided an E. The report card scores are derived from a distribution of responses (weighted average) across the A to E grades thus differ from the mean scores that are reported in the results from the CATI survey.

Each measure was also weighted to reflect its relative importance as a management objective using information collected through an online survey of 83 community participants, 31 management experts (those with a management or industry role) and 19 technical experts (marine or coastal-social scientists). As such, the combination of the measures for each indicator reflects the final grade and not the simple average of the measure scores. Three weighting techniques – simple ranking methods, scoring-based methods and analytic hierarchy processes – were trialled in 2014 and a scoring-based method was used for weighting as it had the lowest variance (Pascoe et al., 2014).

A Bayesian Belief Network (BBN) was used to aggregate measures into indicator scores, indicator groups and component. This BBN model provided the probabilities of each outcome rather than a deterministic outcome. From the conditional probability distributions, an expected mean outcome and confidence interval were determined. The final grade for each indicator was the most probable grade after the relevant weights have been applied (Pascoe et al., 2014).

What is a CATI survey?

CATI is the abbreviation used for Computer Assisted Telephone Interview, a popular qualitative and quantitative data collection technique in social science and economics. Before the interview begins, all survey questions are entered into a special computer software. The data collection begins when the interviewer randomly dials a person's landline or mobile in the chosen geographic area for the study. If the participants agrees, the interviewer then starts reading out each question prompted by the software and records responses using a computer keyboard. The software used for the data collection is also programmed to show questions in a planned order and skipped questions, and allow randomization of questions schedule re-dialling, automate record keeping and most importantly send data directly to statistical software for data analysis. Australian Bureau of Statistics and Queensland Government Statisticians Office often use CATI as their primary method of data collection in various annual surveys.

4.2.1 Harbour Usability

Community satisfaction with Harbour Usability was primarily assessed through the CATI survey. The Harbour Usability indicator group comprised three indicators: satisfaction with harbour recreational activities, perceptions of air quality and water quality (in the harbour area), and perceptions of harbour safety for human use. The harbour usability survey questions related to participants' satisfaction with their last trip to the harbour, quality of boat ramps and facilities, satisfaction with air and water quality, safety at night, and whether people were happy to eat seafood from the harbour. There were eleven harbour usability-related survey questions in total. Secondary data on marine pollution and marine safety incidents were also incorporated into the harbour safety indicator as measures. A ten-year moving average was used as the baseline for both marine safety incidents and oil spill measures.

There have been minor changes in the marine incidents and oil spill data since 2014. The marine safety incidents measure in 2014 and 2015 were estimated using the ratios of incidents, with both recreational and commercial vessels registered within each maritime region. However, in 2016 due to new regulations relevant to jurisdictional changes, Queensland reporting included only details of Queensland-regulated ships (99.8% recreational vessels) and not commercial vessels. Therefore, rates of oil spills and incident rates were available for recreational vessels only, and commercial vessel counts were not included in the assessment. This method was repeated in 2022 so that scores from 2016 continue to be comparable. The rate has been calculated as per 10,000 Queensland-regulated ships.

4.2.2 Harbour Access

The Harbour Access indicator group comprised four indicators: satisfaction with access to the harbour, satisfaction with boat ramps and public spaces, perceptions of harbour health, and perceptions of barriers to access. There were 11 harbour access survey questions such as perceptions on frequency of harbour use, number of boat ramps, access to public spaces, shipping and recreational boating, participants' perceptions on the state of the harbour health, and satisfaction with fair access to the harbour.

4.2.3 Liveability and Wellbeing

The indicator for the harbour's contribution to Liveability and Wellbeing in Gladstone was assessed using four questions in the CATI survey. The Liveability and Wellbeing survey questions related to whether Gladstone Harbour makes living in Gladstone a better experience, the level of participation in community events, and the aesthetic value of Gladstone Harbour to residents.

The aesthetic value measure was added to the Liveability and Wellbeing indicator group in 2018. Previous word cloud analysis highlighted the importance of the 'aesthetic aspect' of the harbour to Gladstone residents although there was no related measure in the indicator framework until that point. The addition of the aesthetic value measure complemented the Liveability and Wellbeing indicator group. By adding this measure, it was expected that the score of the indicator group would slightly improve compared to previous years, as aesthetic value is likely to attract a relatively high score. This means the score for the indicator group is not fully comparable with previous years.

4.3 Social Health results

No new assessment was undertaken this year, results from the 2022 assessment have been used to calculate the Social Health results for the 2024 report card. A total of 200 respondents participated in the 2022 CATI survey. A 'snapshot' impression of the harbour was captured from the community survey respondents when they were asked to provide three words to describe the harbour. As in previous years 'Beautiful' and 'Fishing' were the two most used words, followed by words evoking the industrial nature of the harbour ('Busy', 'Industry', 'Industrial').

The overall score for the Social Health was 0.68, which was comparable with the score received when the Social Health was previously assessed (2019: 0.67). Both scores correspond to a good grade (B). Although scores have been similar since 2016, the overall Social Health of Gladstone Harbour has shown a strong improvement since the 2014 Pilot Report Card (0.58).

Of the three indicator groups, Harbour Usability received a score of 0.62, Harbour Access a score of 0.68 and Liveability and Wellbeing a score of 0.71 (Table 4.2). All three indicator group scores were comparable ($\pm$0.02) with the scores received in 2019.

Table 4.2 | Social Health indicator group and indicator scores used in the 2024 Gladstone Harbour Report Card. Scores from previous assessments are included for comparison.

Indicator groups	Social indicators	2024*	2024*	*2019*	*2018*
Harbour Usability	Satisfaction with harbour recreational activities	0.73	0.62	*0.64*	*0.63*
	Perceptions of air and water quality	0.59			
	Perceptions of harbour safety for human use	0.55			
Harbour Access	Satisfaction with access to the harbour	0.75	0.68	*0.67*	*0.67*
	Satisfaction with boat ramps and public spaces	0.67			
	Perceptions of harbour health	0.63			
	Perceptions of barriers to access	0.69			
Liveability and Wellbeing	Liveability and wellbeing	0.71	0.71	*0.70*	*0.70*
Overall score			0.68	*0.67*	*0.67*

*Results have carried over from the 2022 assessment

4.3.1 Harbour Usability

As in previous years, the 2022 assessment indicated most of the community viewed the harbour area as a place that provides recreational facilities and an enjoyable environment for leisure activities. The residents continued to see the harbour as a producer of healthy seafood and a safe place to enjoy by day and night. Concerns remained about air and water pollutants, but these do not appear to impede the usability of the harbour area and its resources to the community. Air and water quality concerns may be an artefact of past issues and the proximity of industry in and around the harbour area.

The small decline in overall Harbour Usability score between the 2022 and 2019 assessments was due to a decline in people's perception of harbour safety for human use. Compared to 2019, the 2022 scores declined for oil spills (2019: 0.66, 2022: 0.38) and marine safety (2019: 0.54, 2022: 0.46). Over the 2018–20 period 1,360 new vessels were registered in Gladstone, with a new total of 49,115 vessels. The increased traffic may have contributed to the higher number of maritime incidents. It is also worth noting that many oil spill incidents reported in 2020 represent small amounts (in litres) whereas more pollution events in past years were reported in surface terms. As such, the significant reduction in oil spills score may be a data-entry artefact. Beyond these two measures, the other measures scored similar to the previous year.

4.3.2 Harbour Access

The 2022 Harbour Access results indicate that residents continue to enjoy the harbour, public spaces and boat ramps, and that perceptions of harbour health have not changed since 2019. Residents further agreed that they have fair access to the harbour compared to its other users, with increases in the recreational use of the harbour, boat ownership and use of boat ramps compared to 2018. Residents' perceptions around barriers to access has increased slightly since 2019. However, respondents continue to perceive that marine debris and litter is a problem in the harbour, although they did not see the levels of marine debris, commercial shipping and recreational boating activity as hindrances to harbour access. The harbour environment is viewed positively by many residents and they believe this will continue into the future.

4.3.3 Liveability and Wellbeing

Liveability refers to the elements in a region that affect how individuals feel about living there. These elements include the physical environment (natural and human) and social elements such as feelings of community spirit, personal health and wellbeing, culture and opportunities for work and recreation (Greer and Kabir, 2012). The Liveability and Wellbeing indicator score (0.71) was one point higher than the 2019 score (0.70) and seven points higher than the 2014 baseline (0.64).

Respondents are generally happy with the aesthetics of the harbour. However, many respondents state that they rarely participate in community events in the Gladstone Harbour area, indicating that improvements in community participation can still be made. Overall, the 2022 survey indicate that respondents enjoy going to the harbour because of its natural beauty.

4.4 Social Health trends

The overall Social Health of the harbour has been gradually increasing since the pilot year, indicating that the Gladstone community continue to enjoy the harbour (Table 4.2 and 4.3). The overall score was one-point higher than in 2019 and was similar to that in 2016, 2017 and 2018 assessments. The Social Component has received a good score (B) for the fifth consecutive year in which it was actively monitored (Figure 4.1). Note active monitoring was not completed in 2020, 2021, 2023 or 2024. A steady trend in people's perception of the harbour reflects that Gladstone Harbour reflects is an essential part of the experience of living in Gladstone.

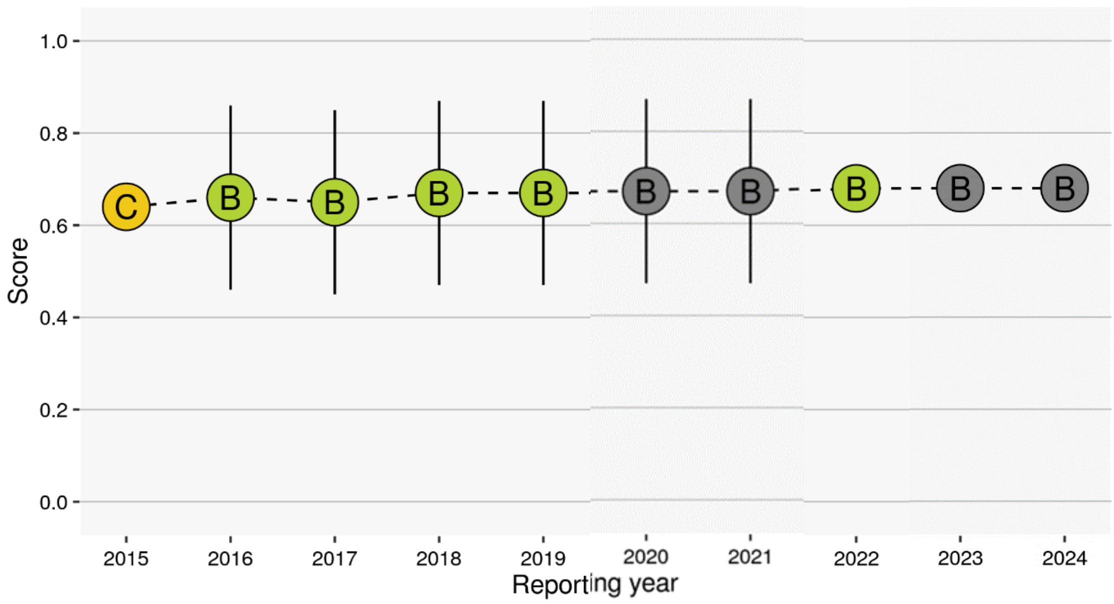

Figure 4.1 | Trends in Social Health scores from 2015–24 (Error bars show 95% bootstrap confidence intervals). Grey circles indicate years not assessed and results carried over from previous assessment.

4.4.1 Harbour Usability

Overall, scores have marginally improved from the 2014 baseline for Harbour Usability (Figure 4.2). In the 2022 assessment, the indicator scores declined slightly compared to the previous results, however maintained a satisfactory grade (C).

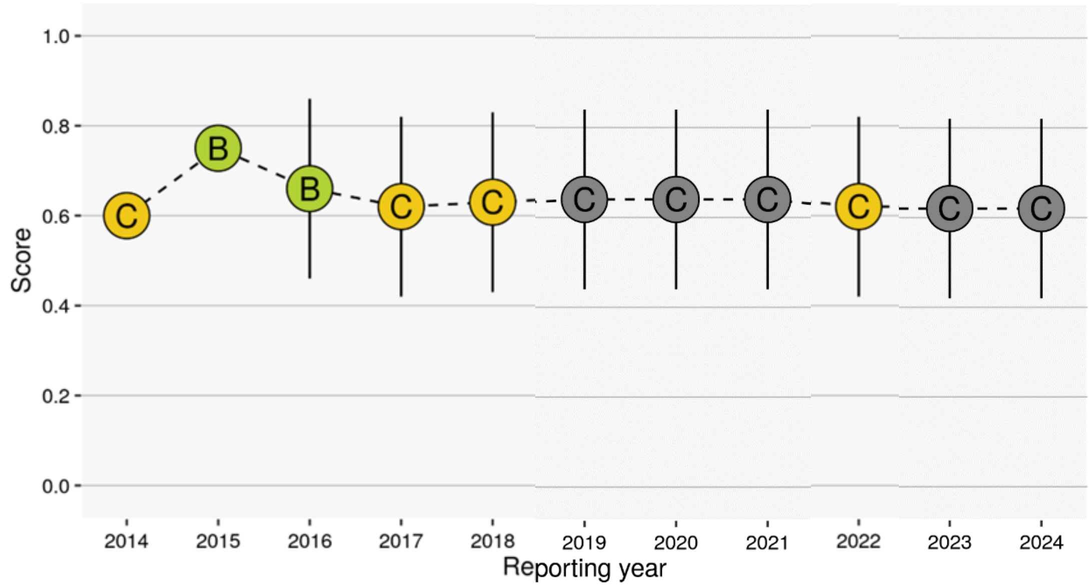

Figure 4.2 | | The trend of scores received for the Harbour Usability indicator group since year 2014. Note an error in the 2014–15 score which was reported at 0.75 instead of 0.65, hence there has been little real change from 2014–15 to 2015–16. Grey colour represents no new assessment; results carried over from previous year. Error bars show 95% bootstrap confidence intervals

4.4.2 Harbour Access

The Harbour Access scores have been stable over the last five years when monitoring occurred (Figure 4.3).

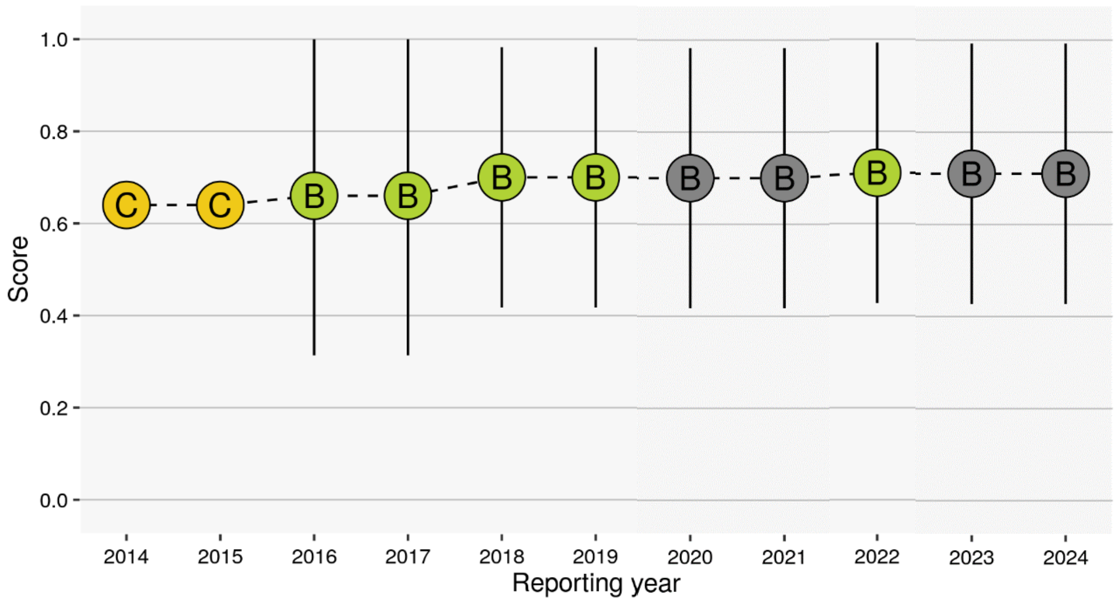

Figure 4.3 | The trend of scores received for the Harbour Access indicator group since year 2014. Grey colour represents no new assessment with results carried over from previous year. Error bars show 95% bootstrap confidence intervals.

4.4.3 Liveability and Wellbeing

Similarly, the Liveability and Wellbeing indicator has remained consistent over the past five assessments (Figure 4.4). In 2018, the addition of a new aesthetic measure contributed to an improvement to the overall Liveability and Wellbeing score for Gladstone Harbour.

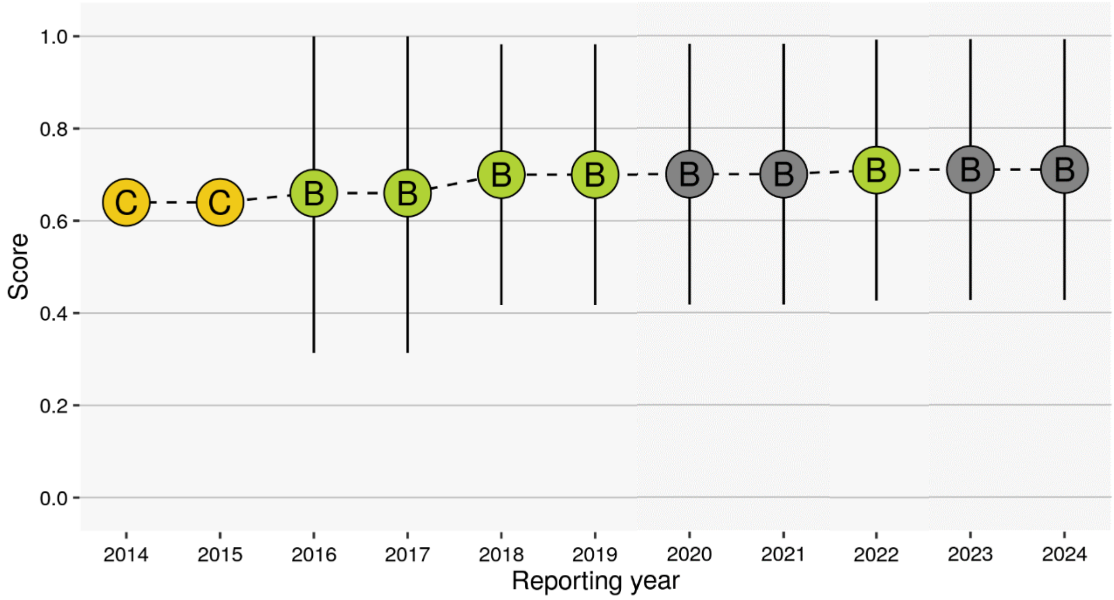

Figure 4.4 | The trend of scores received for the Liveability and Wellbeing indicator group since year 2014. Scores prior to 2018 were based on two measures. The third measure aesthetic value was added to the indicator group in 2018. Grey colour represents no new assessment; results carried over from previous year. Error bars show 95% bootstrap confidence intervals.

Table 4.3 | Social Health scores compared between 2014, 2019 and 2022 assessments.

Group	Score	Indicators	2022	2019	2014	Measures	2022	2019	2014
Harbour Usability	2022: 0.62 2019: 0.64 2014: 0.60	Satisfaction with harbour recreational activities	0.73	0.71	0.70	How satisfied last recreational trip	0.76	0.74	0.74
						Quality of ramps and facilities	0.66	0.67	0.63
		Perceptions of air and water quality	0.59	0.58	0.46	Water quality satisfaction	0.60	0.58	0.39
						Air quality satisfaction	0.47	0.48	0.40
						Water quality does not affect harbour use	0.69	0.67	0.58
		Perceptions of harbour safety for human use	0.55	0.63	0.38	Marine safety incidents	0.46	0.54	0.24
						Oil spills	0.38	0.66	0.15
						Safety at night	0.69	0.62	0.58
						Happy to eat seafood	0.69	0.68	0.55
Harbour Access	2022: 0.68 2019: 0.67 2014: 0.61	Satisfaction with access to the harbour	0.75	0.73	0.67	Fair access to harbour	0.75	0.73	0.67
		Satisfaction with boat ramps + public spaces	0.67	0.65	0.60	Frequency of use	0.51	0.51	0.46
						Number of boat ramps	0.70	0.69	0.65
						Access to public spaces	0.77	0.74	0.68
		Perceptions of harbour health	0.63	0.63	0.53	Great condition	0.68	0.68	0.54
						Optimistic about future health	0.62	0.63	0.56
						Improved over the last 12 months	0.60	0.59	0.50
		Perceptions of barriers to access (Note: scores are reversed. A higher score denotes a decrease in the barrier)	0.69	0.66	0.64	Marine debris a problem	0.51	0.48	0.51
						Marine debris affects access	0.74	0.72	0.70
						Shipping reduced my use	0.74	0.69	0.63
						Recreation boats reduced my use	0.74	0.72	0.69
Liveability and Wellbeing	2022: 0.71 2019: 0.70 2014: 0.64	Liveability and wellbeing	0.71	0.70	0.64	Makes living in Gladstone a better experience	0.78	0.76	0.71
						Participate in community events	0.55	0.56	0.53
						Aesthetic value	0.76	0.73	n/a

5 The Cultural Health Component

Cultural Health of the harbour is an evaluation of six *Sense of Place* indicators and two Indigenous Cultural Heritage indicators. In 2024, no new Cultural Health assessments were undertaken. The overall Cultural Health component score is aggregated from the 2022 *Sense of Place* scores (collected via CATI survey) and the 2018 Indigenous Cultural Heritage scores.

Indigenous Cultural Heritage values associated with the land and waterways adjacent to the harbour play a key role in the Cultural Health of Gladstone Harbour. This diverse and living heritage reflects the rich Indigenous heritage values and various cultural aspects of the First Australians in connection to the country. Including Indigenous Cultural Heritage related indicators in the report card acknowledges and recognises this ongoing connection of the Traditional Owners. The Indigenous Cultural Heritage indicators were developed and piloted during 2016, with further refinement to the indicator framework in 2018. The two indicators for Indigenous Cultural Heritage are: the Physical condition of sites and Management strategies of zones. These indicators were chosen to address two report card objectives: 'registered cultural heritage sites associated with the harbour and waterways are protected' and 'the Gladstone community's sense of identity and satisfaction with the condition of the harbour is increased'.

5.1 Data collection

The CATI survey conducted in June 2022 to assess Social Health also collected data for the *Sense of Place* indicator. That survey included 17 questions dedicated to gathering community views on six Cultural indicators (Table 5.1). *Sense of Place* was employed as a broad construct and it is assumed to incorporate elements of both place identity and place attachment (Twigger-Ross and Uzzell, 1996). *Sense of Place* may also be useful for exploring community stewardship.

The Indigenous Cultural Heritage scores for the report card are based on three physical condition measures assessed at site level and six management strategies measures assessed at the zone level (Table 5.1). A new framework developed in 2018 (Figure 5.2), simplifies the assessment and calculation of the Indigenous Cultural Heritage indicators, although the scores calculated through the new framework may not be fully comparable to 2016 and 2017 scores.

Field data for the Indigenous Cultural Heritage indicator were collected through a series of field surveys at Facing Island and Gladstone Central completed in July 2018 (Table 5.2). Sites are referred to as areas of concentrated group-of-heritage features within the landscape. One or more monitoring stations are established as key locations within sites from which the heritage features,

What are heritage elements and heritage features?

A heritage element refers to a single stone tool such as a flake or chopper tool (top left, Figure 5.2) which often becomes a part of a larger feature within a site (bottom left, Figure 5.2). A heritage element can also be an isolated artefact.

A heritage feature refers to a group of interrelated heritage elements such as a knapping floor or reduction sequence, a single element worthy of consideration as a feature such as a backed blade or stone arrangement, or cultural archaeological and ethnographic features such as signage monuments and gravestones (right, Figure 5.1).

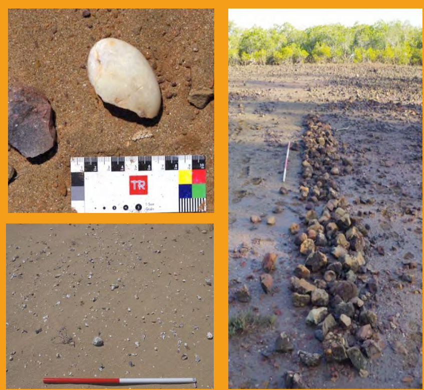

Figure 5.1| Pebble tools (top left) and shell scatter (bottom left) on Facing Island and a stone arrangement (right) in The Narrows.

heritage elements and non-heritage features are monitored (Terra Rosa Consulting, 2018). Overall, 11 sites were revisited in 2017–18 (Table 5.2).

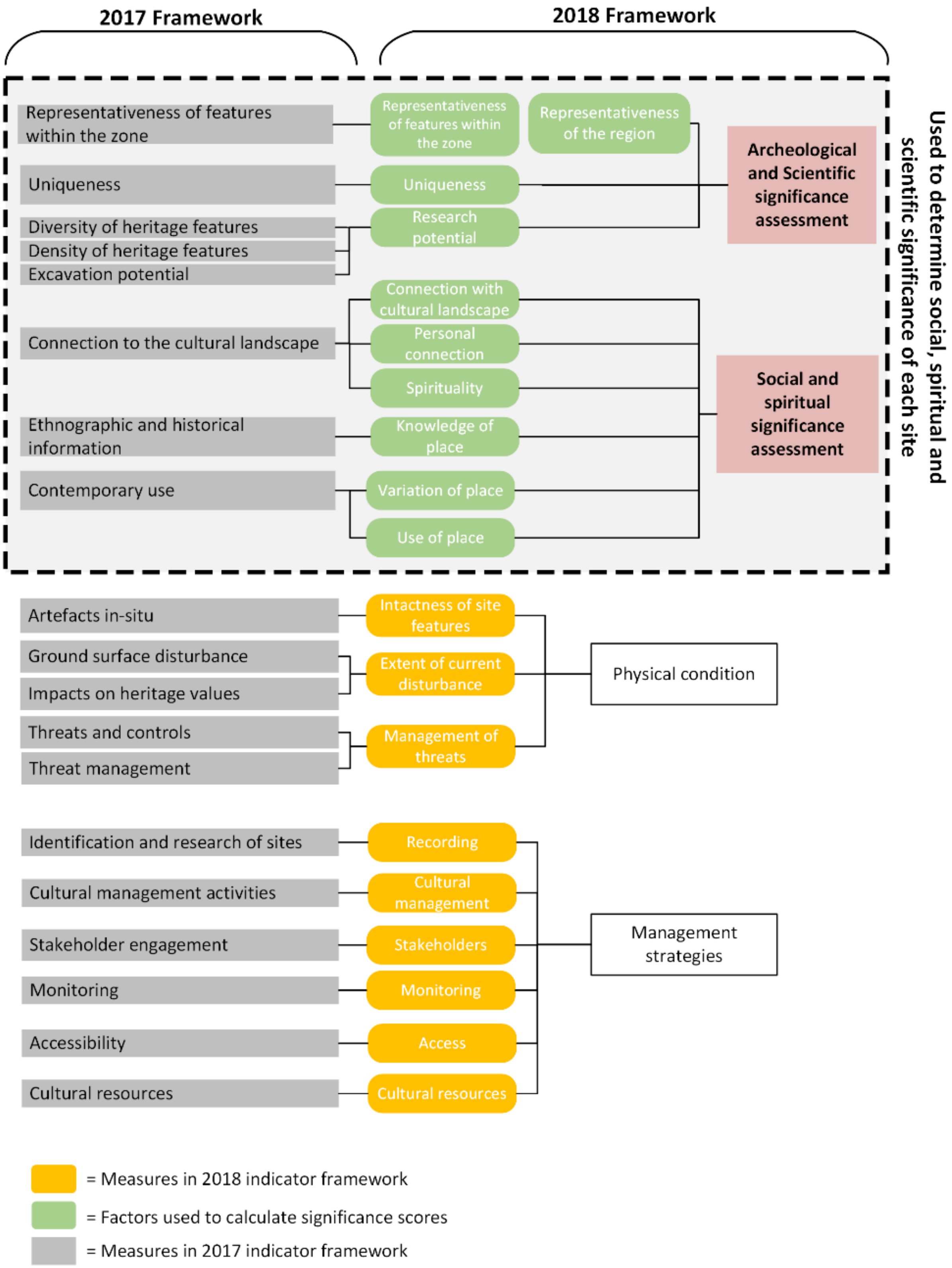

Figure 5.2 | 2017 Indigenous Cultural Health indicators are mapped to the 2018 indicator framework. Two measures which were in the 2017 framework site registration and developmental pressure measures are no longer assessed in the 2018 framework.

Data collection involved recording the health of various heritage aspects relevant to Cultural Health (e.g. knapping floor, chopper tools, signage, gravestones and monuments) in relation to pre-defined criteria (Terra Rosa Consulting, 2018). A series of 360° panoramic imagery were also captured during the surveys and used to build a photographic timeline for the ongoing assessment of the physical health of each site. All field data were then transferred to an Indigenous Cultural Heritage database (ICHD). The ICHD will be used to store detailed monitoring information on individual cultural heritage sites visited during annual surveys and will help track the scoring against the indicators of Cultural Health of the four zones over time (Terra Rosa Consulting, 2017). Data collected in 2016, 2017 and 2018 were used in the score calculation for the 2019 report card (Terra Rosa Consulting, 2016, 2017 & 2018).

Traditional Owners and Elders from Gooreng Gooreng and Byellee groups assisted the field studies.

Table 5.1 | Indicator groups, indicators and measures used to determine Cultural Health scores.

Group	Indicators	Measures	Data source	Baseline data
Sense of Place	Place attachment	No place better	CATI survey (Q30)	10-point scale
		Who I am	CATI survey (Q51)	10-point scale
	Continuity	How long lived in the area	CATI survey (Q3)	10-point scale
		Stay in area five years?	CATI survey (Q53)	10-point scale
	Pride in the region	Proud living in the area	CATI survey (Q50)	10-point scale
	Well-being	Quality of life	CATI survey (Q52)	10-point scale
		Input into management	CATI survey (Q47)	10-point scale
	Appreciation of the Harbour	Key part of the community	CATI survey (Q54)	10-point scale
		Great asset to the region	CATI survey (Q58)	10-point scale
		Great asset to Queensland	CATI survey (Q59)	10-point scale
	Values	Variety of marine life	CATI survey (Q55)	10-point scale
		Opportunities for outdoor recreation	CATI survey (Q56)	10-point scale
		Affects visitors to the region	CATI survey (Q57)	10-point scale
		Enjoy scenery and sights	CATI survey (Q60)	10-point scale
		Spiritually special places	CATI survey (Q61)	10-point scale
		Culturally special places	CATI survey (Q62)	10-point scale
		Historical significance	CATI survey (Q63)	10-point scale
Indigenous Cultural Heritage	Physical condition	Intactness of site features	Field survey	10-point scale
		Extent of current disturbance	Field survey	10-point scale
		Management of threats	Field survey	10-point scale
	Management strategies	Recording	Field survey	10-point scale
		Cultural management	Field survey	10-point scale
		Stakeholders	Field survey	10-point scale
		Monitoring	Field survey	10-point scale
		Access	Field survey	10-point scale
		Cultural resources	Field survey	10-point scale

Definition of indicators

- **Place attachment** is the degree to which the harbour provides an identity that is unique or distinct from other identities. This includes the distinctiveness of a place (e.g. coastal views, industry landmarks), the qualities which distinguish it from any other place (e.g. iconic marine species such as dolphins and dugongs), structure (the mental representation of a place) and meaning (subjective feelings linked to physically separate places).
- **Continuity** adds a temporal aspect to *Sense of Place*. It is the extent to which there has been continuity of 'self' (including ancestors) and activities in a place. It also includes both continuity in the way harbour resources have been used by past and present generations of a family as well as the ancestral links to places held by Indigenous Australians.
- **Pride in the region** concerns people's values and standards and assesses pride in one's identity in relation to place. It reflects the pride that an individual has in identifying with the place (Gladstone) and assesses the value and importance they assign to this association.
- **Well-being** relates to the extent to which a place facilitates or enables one's chosen lifestyle, or conversely, the extent to which a place does not hinder one's social and economic opportunities. This indicator assesses the sense of 'feeling at home' and the extent to which this provides spiritual fulfillment or is restorative.
- **Appreciation of the harbour** assesses the attitudes of people in Gladstone with particular emphasis on its importance as a great asset to the local community and Central Queensland.
- **Values** assesses community values on marine life, recreational and tourism activities, and the cultural, spiritual and historical significance of the harbour.
- **Physical condition** indicator considers three measures:
  - *Intactness of site features* relates to heritage features within the site being undisturbed and artefacts are *in situ*. A score of 10 is allocated when over 90% of the features are intact.
  - *Extent of current disturbance* relates to the percentage of site currently being disturbed by human and natural processes such as vehicle damage, erosion processes, animal or trampling impacts, dumping rubbish and camping. A site attracts a score of 10 if less than 10% of a site is subjected to current or active disturbances.
  - *Management of threats* is based on a threats assessment for the site and identifying any management strategies that are in place to minimise the impacts or threats to the site. When a site has management strategies in place to minimise over 90% of threats it receives a score of 10.
- The **Management strategies** indicator monitors six measures:
  - *Recording* examines the degree to which sites have been researched and investigated during monitoring. A score of 10 is given when all sites were revisited in the zone and new monitoring stations were established.
  - *Cultural management* relates to preparing and implementing a cultural heritage management plan. A zone would receive a score of 10 if a heritage management plan is implemented for the zone and all management activities are in progress.
  - *Stakeholders* relates to the engagement of various stakeholders towards a long-term management plan for the zone. A score of 10 reflects representatives from all stakeholder groups are actively engaged and support ongoing activities.
  - *Monitoring* relates to the annual monitoring of each site each year. A score of 10 is given when all monitoring stations have been revisited.
  - *Access* relates to the percentage of sites within a zone that can be easily accessed for heritage management. A score of 10 is allocated for this measure when all sites within the zone are easily accessible for heritage management activities.
  - *Cultural resources* relates to the availability of both physical and digital resources that store knowledge of cultural heritage within a zone. A score of 10 reflects that all sites within a zone have both physical and digital interpretive resources.

Table 5.2 | Sites within each zone surveyed during 2016, 2017 and 2018.

Zone	Sites surveyed in 2016	Sites surveyed in 2017	Sites surveyed in 2018		Total sites in the database
			New	Revised	
The Narrows	6	3	1	1	10
Facing Island	6	0	1	5	7
Wild Cattle Creek	11	5	0	0	16
Gladstone Central	3	3	0	5	6
Total	26	11	2	11	39

5.2 Development of indicators and scoring

5.2.1 Sense of Place

Responses to cultural indicator questions in the CATI survey were converted to grades in the same manner as for the Social Health component. Thus, a response of 9 or 10 on a 10-point agree–disagree scale provided a grade of A, a response of 7 or 8 provided a grade of B, 5 or 6 provided a C, 3 or 4 provided a D, and 1 or 2 provided an E. As for the social indicators, each *Sense of Place* indicator was given a weighting that was developed during the pilot phase in 2014 via online surveys (Pascoe et al., 2014). A BBN aggregated measure scores into indicators and then to the *Sense of Place* indicator.

5.2.2 Indigenous Cultural Heritage

The initial list of sites and zones were selected following an in-depth literature review and extensive consultation with the Gidarjil Development Corporation in 2016 (Terra Rosa Consulting, 2016). Information related to the cultural heritage sites documented in the Aboriginal and Torres Strait Islander Cultural Heritage Register Database, Queensland Heritage Register, Cultural Heritage Information Management System, National Heritage List, Commonwealth Heritage List, register of the National Estate, UNESCO World Heritage List and works by Burke (1993) were also used in the review. Some sites from this list were revised and new sites were surveyed in 2018 with the help of Gooreng Gooreng and Byellee Traditional Owners and Elders.

The indicators of Indigenous Cultural Heritage were assessed based on a range of cultural heritage elements and features. Each measure was assessed based on 10 pre-defined criteria and given a score between 1 and 10 (see Terra Rosa Consulting, 2018 for details of the criteria). GHHP grading thresholds were only applied to aggregated scores.

The indicators under physical condition were weighted on a spatial scale. The processes involved determining the social, spiritual and scientific significance of all sites based on 10 factors (green boxes, Figure 5.2). The average values were then used as a guide together with cultural knowledge of the Traditional owners and Elders to determine the weightings for cultural locus site. The determination of social, spiritual and scientific significance of sites was completed in 2017 through consultation with the Gooreng Gooreng and Byellee Elders and investigation of sites (Terra Rosa Consulting, 2018).

A cultural locus site is considered to be the most important for ongoing monitoring and management of that zone (Terra Rosa Consulting, 2017). There is one cultural locus site for each monitoring zone. The health of the cultural locus sites was assessed independently and then used to benchmark other sites within each zone (Figure 5.3). The management strategies indicators were given fixed weightings at sub-indicator level.

Figure 5.3 | Weightings derived from ethnographic consultation for cultural locus and other sites within each zone for Cultural Health indicators.

5.3 Cultural Health results and discussion

The overall results for the Cultural Health of the Gladstone Harbour Report Card for 2023 was a score of 0.61 and graded satisfactory (C). There were no new assessments completed in 2023 and the results have been carried over from previous years. Cultural Health is comprised two indicator groups: *Sense of Place* results from the 2022 assessment and Indigenous Cultural Heritage results from the 2018 assessment. *Sense of Place* received a score of 0.68 and Indigenous Cultural Heritage received a score of 0.54, which corresponds to good (B) and satisfactory (C) grades, respectively.

5.3.1 Sense of Place

Overall, the score for *Sense of Place* use in the 2023 report card was 0.68 corresponding to a good grade (B). This result suggests that the community's expectations of Gladstone Harbour area are mostly being met. This report card used the 2022 assessment for *Sense of Place*. Place attachment was slightly higher than previous years (Table 5.3), suggesting an increased engagement with and appreciation of the harbour. The continuity score (0.65) also improved compared to the previous year's receiving a good grade (B) for the first time. This indicator measures the length of time people have lived in the area and whether they planned to stay for the next five years and the improvement of scores trend may suggest that the community is becoming less transient and more stable. The pride in the region score (0.76) has also remained stable indicating that residents continue to feel proud living in the Gladstone community. Wellbeing was one of the lowest scoring indicators (0.62) of the *Sense of Place* group and may suggest the community's view on quality of life is being met. The score for appreciation of the harbour remains the highest scoring indicator (0.84) and this has remained relatively stable since 2014. This shows that residents continue to have a positive outlook for the harbour area and what it provides to the community. The values indicator scores (0.68) have also been stable across assessments. The scores and stability suggest that residents of the Gladstone region continue to value the harbour area because it supports a variety of marine life, provides opportunities for outdoor recreation, attracts visitors to the region and is aesthetically appealing. However, fewer residents valued Gladstone Harbour highly based on its spiritual, cultural and historical significance.

Table 5.3 | *Sense of Place* indicator and indicator group scores used in the 2024 Gladstone Harbour Report Card. Scores from previous assessments are shown for comparison.

Indicator group	Indicators	2024*	2024*	*2019*	*2018*
Sense of Place	Place attachment	0.61	0.68	*0.66*	*0.65*
	Continuity	0.65			
	Pride in the region	0.76			
	Wellbeing	0.62			
	Appreciation of the harbour	0.84			
	Values	0.68			

*Results have carried over from the 2022 assessment

5.3.2 Indigenous Cultural Heritage

The 2023 Gladstone Harbour Report Card used the results from the 2018 Indigenous Cultural Heritage assessment. The overall score for Indigenous Cultural Heritage in 2018 was 0.54, similar to the 2017 score of 0.55. Both assessments received satisfactory grades (C). The score for this indicator group is based on the scores received for physical condition (0.56) and management strategies (0.52) indicators (Table 5.4). Overall, the physical condition and management strategies grades remain satisfactory (C) for all zones except for the Wild Cattle Creek, which received a score of 0.49 and a poor grade (D) for management strategies.

Table 5.4 | Indigenous Cultural Heritage indicator scores for each of the four zones used in the 2024 Gladstone Harbour Report Card. Assessment was completed in 2018.

Indicator group	Indicators	The Narrows	Facing Island	Wild Cattle Creek	Gladstone Central
Physical condition	Intactness of site features	0.82	0.95	0.67	0.85
	Extent of current disturbance	0.63	0.64	0.59	0.44
	Management of threats	0.28	0.11	0.24	0.50
	Zone scores	0.58	0.56	0.50	0.60
Management strategies	Recording	0.80	0.90	0.80	1.00
	Cultural management	0.10	0.10	0.10	0.10
	Stakeholders	0.50	0.40	0.60	0.40
	Monitoring	0.80	0.90	0.70	1.00
	Access	0.60	0.90	0.60	0.60
	Cultural resources	0.20	0.10	0.10	0.10
	Zone scores	0.50	0.55	0.48	0.53
Overall zone scores		0.54	0.56	0.49	0.57
Overall score		0.54			

The Physical condition indicator is based on three measures: intactness of site features, extent of current disturbance and management of threats. The intactness of site features received good to very good grades for all zones. When over 50% of the cultural features within a zone are undisturbed and artefacts are *in situ* good to very good results are likely. Although intactness of site features received high scores, if management strategies are not implemented properly, further disturbance continues to occur resulting in a lower score for this measure over time. The management of threats measure scores in the Facing Island and Wild Cattle Creek were very low; The Narrows received a poor grade (D) and Gladstone Central received a satisfactory grade (C), indicating the disturbed nature of the sites. The scores reflect a range of anthropogenic and natural impacts and threats on the cultural elements and features at each site. Some of these impacts and threats include off-road vehicle use, trampling, camping, rubbish, development, wind erosion, inundation and weeds (Figure 5.4) (Terra Rosa Consulting, 2018).

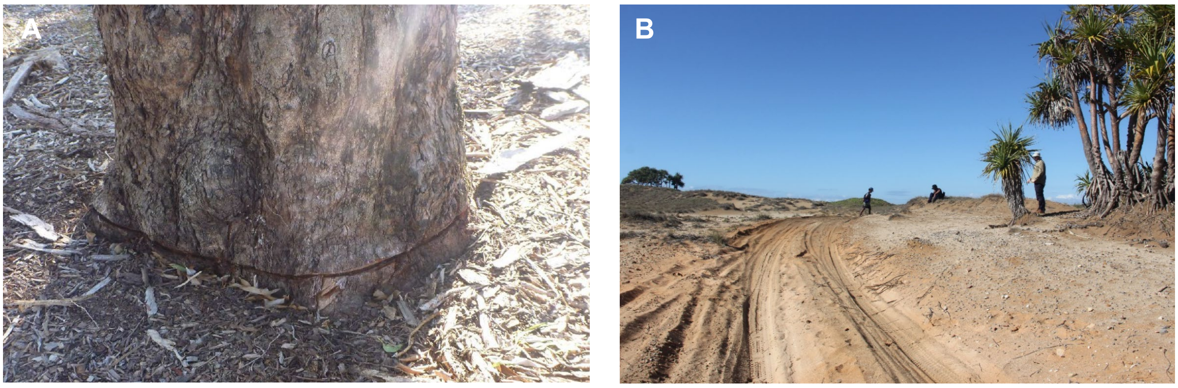

Figure 5.4 | Police Creek site in Gladstone Central zone (**A**) – The area has high cultural and historical significance due to its association with a native police camp in 1854 and Aboriginal fringe camp in 1890. The field team has noticed chainsaw marks along the base of one of the scar trees at Police Creek. FAC15-01 site in Facing Island zone (**B**) – Highly disturbed by vehicle tracks running through the site. The field team recommended establishing signage, fencing and designated tracks to inform the visitors and residents about the cultural significance of the area and to minimise further damage.

Within the Management Strategies indicator, Cultural management and Cultural resources measures received very poor grades (E) across all zones (Table 5.4). The Cultural management score is based on the availability of a heritage management plan and evidence of a range of active cultural management activities occurring within the zone. The Cultural resources score is based on the availability of physical and digital interpretive elements. The poor scores reflect the lack of a cultural management plan, lack of cultural management activities, and minimal availability of physical and digital interpretive elements in the monitoring zones. If these scores are to be improved, a proactive heritage management plan is needed. Although not directly comparable, the low cultural maintenance scores received for all zones for 2016 and 2017 reflect the non-availability of a proactive cultural management plan in the monitoring zones. Recording and monitoring measures received very high scores for all zones. Scores for The Narrows and the Wild Cattle Creek zones are based on sites revisited in 2017. Overall, the good scores for the monitoring measure indicate that a good proportion of existing monitoring stations have been revisited. The stakeholder engagement grades were poor (D) to satisfactory (C) highlighting the need for improved engagement activities with all key stakeholders relevant to site and zone management. When there is a good relationship with stakeholders, agreements can be put in place to mitigate the impacts of development on cultural sites within the zone, and stakeholders can be effectively engaged in conversations regarding management strategies, which will improve scores over time (Terra Rosa Consulting, 2018). The access measure for Facing Island received very good score meaning that all sites within the zone are easily accessible for heritage management activities.

5.4 Cultural Health trends

The Cultural Health component of the Gladstone Harbour Report Card for 2024 was graded satisfactory (C) for the past six years (Figure 5.5). As no new Cultural Health monitoring was completed in 2024, the results have been carried over from previous assessments with *Sense of Place* results from 2022 and Indigenous Cultural Heritage results from 2018.

The score for *Sense of Place* was 0.68 and graded good (B). This score has showed little variation since monitoring began in 2014 (Table 5.5).

The Indigenous Cultural Heritage indicator framework was revised for the 2018 report card. The overall score for Indigenous Cultural Heritage is a result of nine measures (21 measures in the previous framework) and based on physical condition and management strategies indicators (these were further subdivided into six sub-indicators as in the previous framework). The new scoring structure takes into consideration the social, spiritual and scientific values of sites, includes anthropogenic and natural impacts on a number of Indigenous heritage resources, and also acknowledges the constantly changing cultural landscape. Although not directly comparable, the overall cultural heritage for 2018 report card remains at satisfactory, similar to the 2016 and 2017 scores (Table 5.6).

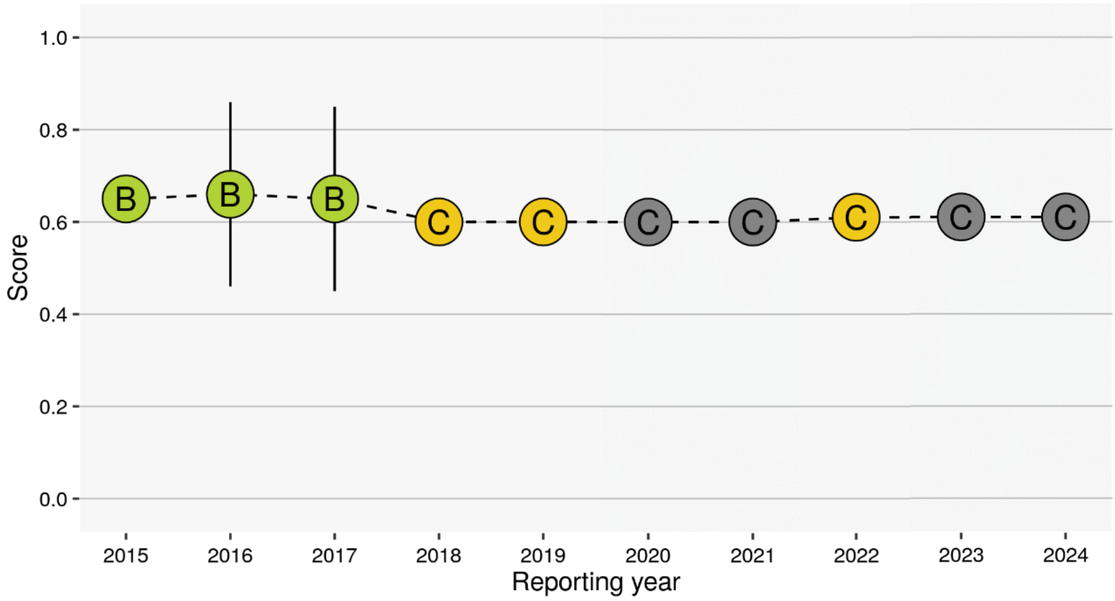

Figure 5.5 | Trends in Cultural Health scores 2015–24. Grey colour indicates no new monitoring; results have carried over from the previous year. Error bars show 95% bootstrap confidence intervals.

Table 5.5 | *Sense of Place* scores compared between assessments 2014, 2019 and 2022.

***Sense of Place* overall score**	**Indicators**	**Score 2022**	**Score 2019**	**Score 2014**	**Measures**	**Score 2022**	**Score 2019**	**Score 2014**
2022: 0.68 2019: 0.66 2014: 0.64	Place attachment	0.61	0.58	0.55	No place better	0.56	0.51	0.49
					Who I am	0.65	0.64	0.61
	Continuity	0.65	0.58	0.57	How long lived in area	0.55	0.44	0.46
					Plan to stay the next 5 years	0.76	0.71	0.68
	Pride in the region	0.76	0.74	0.69	Feel proud living in Gladstone	0.76	0.74	0.69
	Well-being	0.62	0.61	0.55	Quality of life	0.69	0.69	0.64
					Input into management	0.55	0.54	0.46
	Appreciation of the harbour	0.84	0.83	0.80	Key part of community	0.82	0.82	0.79
					Great asset to region	0.83	0.82	0.79
					Great asset to Queensland	0.83	0.81	0.81
	Values	0.68	0.66	0.64	Variety of marine life	0.72	0.73	0.64
					Opportunities for outdoor recreation	0.79	0.78	0.76
					Affects visitors to the region	0.74	0.73	0.67
					Enjoy scenery and sights	0.79	0.76	0.75
					Spiritually special places	0.54	0.50	0.52
					Culturally special places	0.55	0.51	0.50
					Historical significance	0.57	0.52	0.58

Table 5.6 | Overall Indigenous Cultural Heritage indicator scores compared between assessments.

Zone	2018*	2017	2016
The Narrows	0.54	0.56	0.53
Facing Island	0.56	0.55	0.57
Wild Cattle Creek	0.49	0.50	0.44
Gladstone Central	0.57	0.60	0.59
Overall score	0.54	0.55	0.53

*Indigenous Cultural Heritage indicator framework was simplified in 2018. As such, scores are not directly comparable to previous years.

6 The Economic Health Component

To assess the Economic Health of Gladstone Harbour, this report card uses eight indicators aggregated into three indicator groups: Economic Performance, Economic Stimulus and Economic Value (recreation). These indicator groups were developed from the GHHP vision and piloted in 2014. For the 2024 Report Card, new assessment was undertaken for Economic Performance and partial assessment was undertaken for Economic Stimulus. Economic Value scores were based on the 2022 results.

6.1 Data collection

The Gladstone Local Government Area (LGA) was used as the broader geographic area for collecting economic data (Figure 10.28). However, slightly different geographic boundaries within the broader Gladstone LGA were used for some primary and secondary data as described below.

- Shipping data: collected for the Port of Gladstone
- CATI survey: administered to residents within the Gladstone 4680 postcode area (Figure 10.28)
- Commercial fishing data: collected from the area within QFish S30 which includes Gladstone Harbour and the open coastal waters immediately adjacent to the harbour. Data collected from Grid O25 and R29 were also used in the analysis to control for spatial differences in catch across years (Figure 10.29).

In comparison to the measures developed for the Social Component of the report card, most economic measures were more quantitative and different approaches were required to calculate indicator scores (Table 6.1). These include the following measures:

- Capacity utilisation – capacity used as a proportion of the total capacity available.
- Revenue-based information – based on total revenue over a particular time period.
- Index of Economic Resources (IER) – a weighted index based on income, housing expenditure and ownership, cost of living and household assets.
- Travel cost method (TCM) – assesses the value of a recreational activity from the expenditure made to participate in that activity, including travel costs, travel time and site costs.

Revenue-based information was used when the capacity utilisation method was too difficult or complex (e.g. for tourism and to some extent fisheries). Other economic data required to supplement the Economic Value of recreation and Economic Stimulus were collected through the CATI survey. A section of this survey was devoted to household economics, including questions related to income and home ownership. A section on the non-market Economic Values of recreation in the Gladstone Harbour area was also included. Scores for these values were determined using the TCM. Other data types were sourced from a range of organisations to derive other economic measures (Table 6.1).

Overall, the data collection and analytical techniques in 2023 remained the same as the 2019 reporting year for all economic indicators. To improve the quality of the indicator framework, minor modifications have been made since the pilot report card in 2014:

- Using 2021 national census data to calculate socio-economic status indicator (scores for this indicator were previously based on 2011 and 2016 census data).
- Removing the line fishing measure from the Commercial fishing indicator due to considerable data gaps in the database.
- Adding a new indicator ‘water-based recreation’ to the Economic Value (recreation) indicator group in 2018.

Table 6.1 | Data sources and baselines employed to derive the Economic Health scores for the 2024 Gladstone Harbour Report Card.

Group	Indicator	Measure	Data source	Baseline data
Economic Performance	Shipping activity	Shipping activity productivity calculated from monthly shipping movements by cargo type (2023–24 financial year)	GPC https://content3.gpcl.com.au/viewcontent/CargoComparisonsSelection/	Time series data from 2012–13 to 2021–22
	Tourism expenditure	Gladstone region's total tourism expenditure output (2018–19 financial year)	Tourism Research Australia's information at the LGA level (Gladstone) https://app.remplan.com.au/gladstone/economy/tourism/output?state=B6JmCj!WAe3inVjpT3xXymU8R7nwHdibIKOkcmyMyOHv9A9kIpI7zfIldhyx5vFJav	10-year average 2009–10 to 2018–19
	Commercial fishing	Productivity of net fisheries Productivity of trawl (otter) fisheries Productivity of pot fisheries	Production (fishing effort) Queensland Fishing (QFish), Queensland Department of Agriculture and Fisheries Prices (fish, prawns & crabs) Australian Bureau of Agricultural and Resource Economics and Sciences – Australian fisheries and aquaculture statistics 2020 (published Aug 2021)	10-year average (time series data from 2012–13 to 2022–23
Economic Stimulus	Employment	Gladstone LGA unemployment data (2024 March quarter)	Australian Department of Employment, *Small Area Labour Markets*	Queensland 2021 distribution (Dec quarter)
	Socio-economic status	Index of economic resources derived from 2016 ABS census and updated using the community CATI survey	2022 CATI survey; Australian Bureau of Statistics, 2016 census	Australian 2016 distribution
Economic Value (recreation)	Land-based recreation	Land-based recreation satisfaction + economic value	Satisfaction: CATI survey + economic value (Pascoe et al., 2014)	10-point scale
	Recreational fishing	Recreational fishing satisfaction + economic value	Satisfaction: CATI survey + 2018 updated economic value (Cannard et al., 2015; Windle et al., 2018)	10-point scale
	Beach recreation	Beach recreation satisfaction + economic value	Satisfaction: CATI survey + 2019 updated economic value	10-point scale
	Water-based recreation	Water-based recreation satisfaction + economic value	Satisfaction: CATI survey + economic value (Windle et al., 2017)	10-point scale

6.2 Development of indicators and scoring

6.2.1 Economic Performance

The Economic Performance indicator group consists of three indicators: Shipping activity, Tourism (expenditure), and Commercial fishing. These were selected to reflect the key industries using the harbour and weighted according to relative contributions to revenue share across the three activities.

Shipping activity

The GPC provided data on monthly shipping movements by cargo type, destination and origin. The report card score for Shipping activity was based on capacity utilisation (current level of activity relative to potential level of activity) and estimated through data envelopment analysis (DEA).

Time series data from 2012–13 to 2021–22 was used in the analysis. Prior to 2017, a 20-year array was used. The Shipping activity is weighted higher than the other two sectors due to its greater contribution to the economy in Gladstone.

Tourism expenditure

The Tourism score is based on the expenditure on hotel accommodation, food and other local services relative to a 10-year average from 2009–19 in the Gladstone Region. This information is sourced from Tourism Research Australia's information at the LGA level (Gladstone):

https://www.tra.gov.au/Regional/local-government-area-profiles.

Commercial fishing

The indicator score for Commerical fishing was based on production (fishing effort based on number of licences and number of days fished) and the value of the landed catch (in kg) in three sectors: the net (fish), pot (mud crab) and otter trawl (prawns) fisheries in Gladstone Harbour relative to a 10-year average starting from 2012. Production figures come from the three grids, but prices are Queensland state-wide estimates (Figure 10.29).

Capacity Utilisation

Capacity utilisation measures the productive efficiency (performance) of an industry for a given time period. It is often expressed as a percentage. Reasons for increased capacity utilisation include increased market demand and availability of new technology to increase production. Reasons for decreased capacity utilisation include seasonal variations, reduction in market demand, reduced production or, perversely, increased capacity.

For example: A factory produces cement. It has a maximum output of 10,000kg per month. During January the actual output was 5,000kg. So, what was the capacity utilisation in January? It can be calculated as a percentage using the following formula:

Capacity utilisation

$$= \frac{(actual\ level\ of\ output\ (5{,}000)}{(maximum\ possible\ output\ (10{,}000))} \times 100$$

= 50%

Data Envelopment Analysis (DEA)

The DEA or frontier analysis is a tool developed in 1978 by Charnes, Cooper and Rhodes as a technique to measure the performance or relative efficiency of organisations such as banks, hospitals and schools. During the analysis, a reference is set, including the best- performing organisations, which is called and 'efficiency frontier'. The efficiency frontier acts as the threshold for assessing the performance of other organisations. The organisations in the frontier are considered 100% efficient and the others within the efficiency frontier are considered less than 100% efficient. This analysis is very important when we need to compare organisations with multiple inputs and outputs and need a special software tool to calculate the efficiency scores. The DEA analysis is performed on the capacity utilisation measures in two of the report card indicators: shipping and commercial fishing.

Index of Economic Resources (IER)

The IER is a composite measure of the economic wellbeing of a community. For the 2019 Gladstone Harbour Report Card this was calculated using census data collected by the ABS. The index focuses on census variables such as the income, housing expenditure and ownership, cost of living, and assets of households. The variables used in the index are also weighted by the ABS. This index does not consider educational and occupation variables as these are not direct measures of economic resources.

Commercial fishers operating in Queensland's state-managed fisheries are required to complete daily catch and effort logbooks. These logbooks enable fishers to record approximately where, when and how fishing took place, and what was caught. Catch-and-effort data are available from the *QFish database* maintained by Queensland Department of Agriculture and Fisheries. Those data are recorded from 30 x 30 nautical mile grids and therefore provide only a very general indication of the location of fishing activity. Fishing production data collected from Grid S30 was used as the primary data source for the Commercial fishing indicator. This covers most of the Gladstone Harbour and open coastal waters immediately adjacent to the harbour (Figure 10.29).

The total value of Commercial fishing was estimated based on catch data by fishing method data from the QFish database and average prices for each species group (fish, prawns and crabs) was derived from the most recent *Australian fisheries and aquaculture statistics* published by ABARES statistics in 2020. The total value of fisheries production in Mackay (Grid O25) and Yeppoon (Grid R29) was also included in the analysis to control for spatial differences in catch across years as they provided more balanced information on fishing productivity in the region, and to control for fish mobility (Windle et al., 2018).

A capacity utilisation approach is applied, and the measures of relative productivity were estimated using the DEA. The three fisheries sector scores were weighted by their relative contribution to gross value of production.

6.2.2 Economic Stimulus

The Economic Stimulus indicator group consists of two indicators: Employment and Socio-economic status.

Employment

The score for employment was based on the unemployment rate for the Gladstone LGA compared with the benchmark of the Queensland unemployment rate. This comparison used the most recent Australian Bureau of Statistics data available which were for the 2024 March quarter.

Socio-economic status

The score for Socio-economic status was derived using the IER which is a composite measure of the economic wellbeing of a community. It takes into account 14 variables including income extremes (both high and low) in a population, household ownership, cost of living and other indicators relevant to economic wellbeing in the community. The IER was calculated using 2016 Australian census data. A system of weightings for the variables and estimates for the Gladstone Region were further refined using data collected through the CATI survey. The IER for Gladstone is compared with the IER for other LGAs in Australia to generate a report card score.

6.2.3 Economic Value (recreation)

The Economic Value (recreation) indicator group was assessed through four indicators: Land-based recreation, Recreational fishing, Beach-based recreation and Water-based recreation (non-fishing). The Water-based recreation indicator was added to the Economic Component in 2018 and based on the estimated trip value.

Two elements of the recreational values can be assessed:

- The commercial value of the recreation and tourism (estimated based on financial records of commercial tourist operators).
- The non-market value (value associated with residents who use the harbour for recreation but their activity is not reflected in financial records of commercial providers).

While the former is already captured in the Economic Performance indicator, the latter is included in the Economic Value (recreation) indicator group.

The scores for the four indicators in the Economic Value (recreation) indicator group are based on the satisfaction ratings for each recreation activity type and the non-market economic value of the recreation activity type.

Information on the non-market Economic Value (recreation) of harbour area activities was collected through a community survey of 200 people within the Gladstone Region via the CATI survey. Data on travel costs, travel time, and other access and site costs were used in the TCM to calculate the economic value of using a recreational site based on the investment that people have made. In 2014, the economic value of land-based ($61 per trip) and beach-based recreational trips ($40 per trip) were estimated (Pascoe et al., 2014). Additional information was collected in 2015 and 2017 to estimate the value of a recreational fishing trip ($141) and water-based recreation ($95) (Cannard et al., 2015; Windle et al., 2017). The per-trip recreational values will be updated every five years.

TRAVEL COST METHOD (TCM)

Travel cost method is an important economic non market-evaluation technique developed by Clawson (1959). It assesses the monetary value of natural resources used extensively for recreation (e.g. fishing, the beach) that cannot be evaluated through market prices. The key principle behind the TCM is that the cost of travel and time a person invests to visit a place can be used to assign a dollar value to the place and hence would be extremely useful in resource management.

The Economic Value assessment has been established in 2014 and 2015 and updated annually through the data (participation frequency rates) collected from the CATI survey. The user satisfaction information on the four types of recreational activities are also collected from the CATI survey.

The indicator scores for land-based recreation, recreation fishing, beach recreation and water-based recreation were determined by the satisfaction rating (from CATI survey) for each activity. These were then weighted by their relative contribution to the Economic Value of recreation (value of a recreation trip multiplied by the participation frequency rate).

6.3 Economic Health results and discussion

In 2024, Economic Health remained strong with a score of 0.71 and a good (B) grade (Table 6.2). A new assessment was conducted this year for all Economic Performance and Economic Stimulus indicators, while the Economic Value scores were carried over from the 2022 evaluation. Economic Performance earned a very good grade (A) owing to high Shipping activity and Tourism expenditure scores, despite a low Commercial fishing score. Economic Stimulus remained with a satisfactory (C) grade, however, scores declined down from the last report card due to a decrease in the Employment score. Economic Value was not reassessed this year, with 2022 results being used instead.

Table 6.2 | Economic indicator and indicator group scores used in the 2024 Gladstone Harbour Report Card.

Indicator group	Indicators	2024	2024	*2023*	*2022*
Economic Performance	Shipping activity	0.90	0.90	*0.87*	*0.90*
	Tourism	0.90			
	Commercial fishing	0.34			
Economic Stimulus	Employment	0.19	0.50	*0.63*	*0.64*
	Socio-economic status	0.74			
Economic Value (recreation)	Land-based recreation^	0.79	0.77	*0.77*	*0.77*
	Recreational fishing^	0.73			
	Beach recreation^	0.77			
	Water-based recreation^	0.77			
Overall score			0.71	*0.74*	*0.76*

^No assessment was undertaken in 2024; results carried over from 2022.

6.3.1 Economic Performance

In 2024, the Economic Performance score (0.90) and very good grade (A) remained consistent with the results from 2023 and 2022 (Table 6.2). High scores in Shipping activity (0.90) and Tourism expenditure (0.90) were key drivers of the overall strong performance. The Tourism expenditure score matched the 0.90 recorded in 2023, showing stability across years. However, Commercial fishing continued a declining trend scoring 0.34 in 2024 (2023: 0.37, 2022: 0.41). Notably, the estimated value of recreational fishing in 2022 ($61.2M) was much higher than commercial fishing ($0.53M) in the harbour.

6.3.2 Economic Stimulus

The Economic Stimulus score of 0.50 was based on two indicators: Employment and Socio-economic status (Table 6). In 2024, the Employment score dropped to 0.19 from 0.43 earning a very poor grade (E). In contrast, despite some minor fluctuations, the Socio-economic status indicator maintained a stable good grade (B) over the past four assessments (2019 and 2022–2024).

6.3.3 Economic Value (recreation)

As no new assessment for Economic Value was performed in 2024, scores have carried over from the 2022 assessment. In 2022, all four indicators received good grades (B) and the overall Economic Value received a score of 0.77 and good grade (B) was similar to previous reporting years (Table 6.2). The Economic Value (recreation) indicator group scored slightly better than in 2019 and has remained on a continuingly improving trend since 2014. All four types of recreation appear to be greatly valued by residents of the Gladstone region and represent an important element of the Gladstone lifestyle.

6.4 Economic Trends

The overall grade for the Economic Health of Gladstone Harbour remains good (B) and has been stable since the first full report card in 2015, with only a small fluctuation in scores (Figure 6.1). In contrast, the trends for the three indicator groups and the indicators have varied.

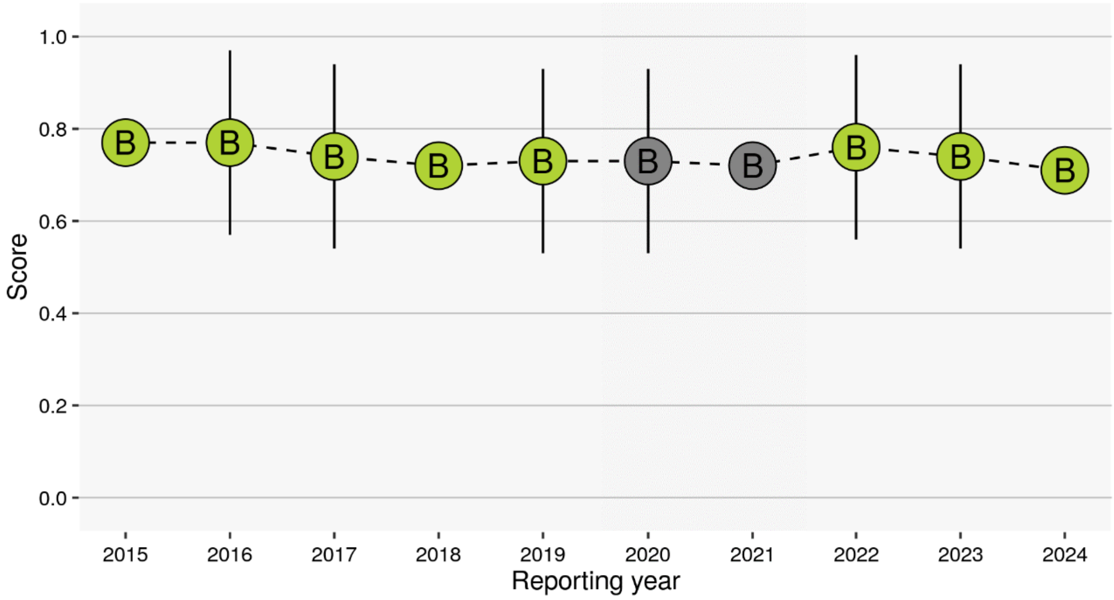

Figure 6.1 | Trends in Economic Health scores 2015–24. No new assessments were performed in 2020 or 2021 (grey circle) and results carried over from the previous year. Error bars show 95% bootstrap confidence intervals.

Within the Economic Performance indicator group (Figure 6.2 **A**) there has been an improvement in overall scores, particularly due improved Shipping activity and Tourism expenditure scores since 2014 (Table 6.3). Notably, Tourism expenditure has improved 30 points since 2014. However, in contrast, Commercial fishing has declined 32 points over the same period (Table 6.3). Within the Economic Stimulus indicator group (Figure 6.2 **B**) both Employment and Socio-economic status scores declined between 2014 and 2018 (Table 6.3), however since then grades have remained stable despite a slight decrease in scores in 2024. In contrast to the previous two indicator groups, the score for Economic Value (recreation) has remained relatively stable since 2015 and it has received a good grade (B) in all years.

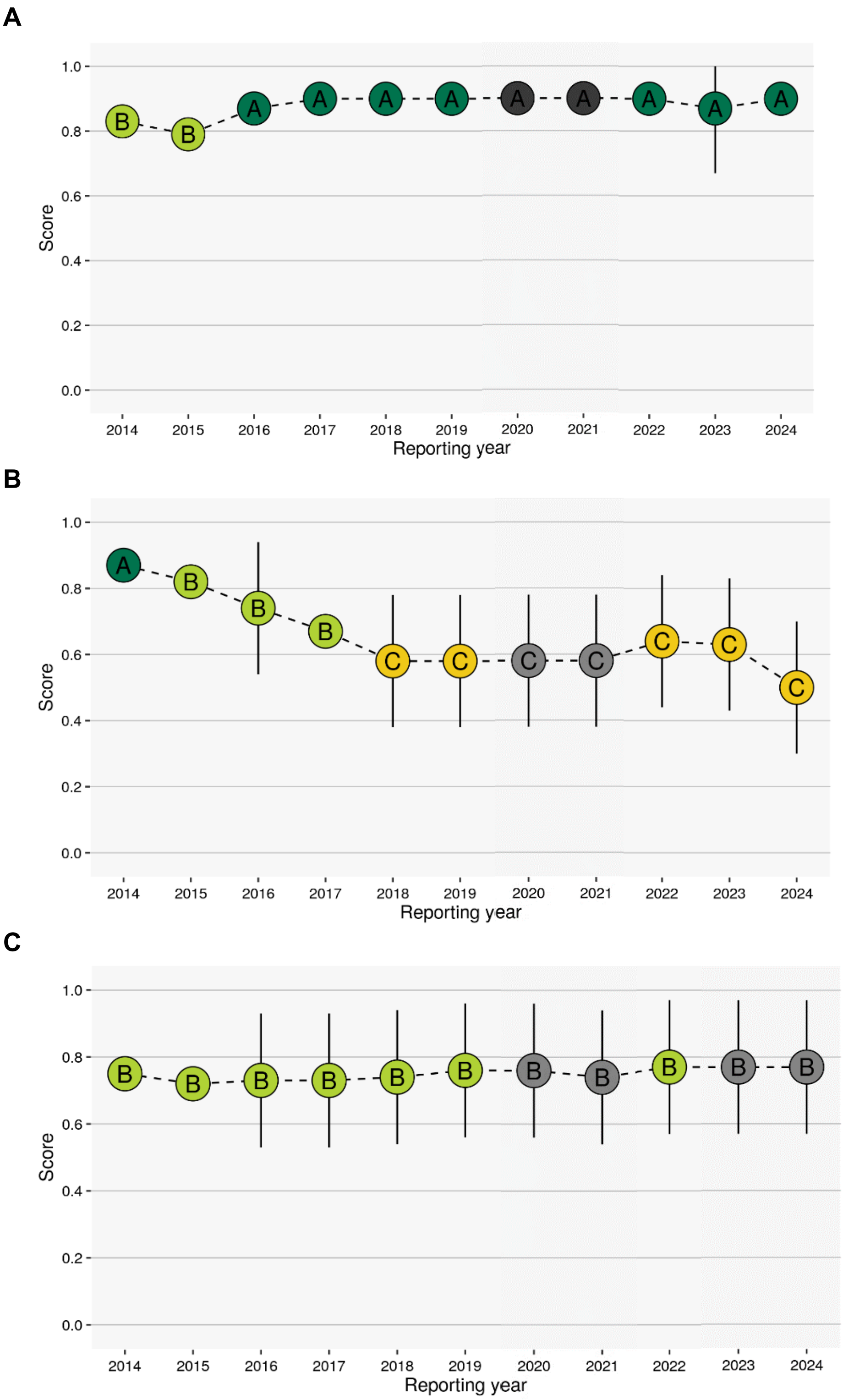

Figure 6.2 | Trends in Economic indicators **A** Economic Performance, **B** Economic Stimulus and **C** Economic Value (recreation) 2015–24. Grey circles represent no new assessment; results carried over from the previous year. Error bars show 95% bootstrap confidence intervals.

Table 6.3 | Economic Health scores compared between report cards 2014–24.

Economic Component 2024: 0.71 (B) | 2023: 0.74 (B) | 2022: 0.76 (B) | 2019: 0.73 (B) | 2014: 0.75 (B)												
Indicator group Score/grade	**Indicators**	**Score** 2024	2023	2022	2019	2014	**Measures**	**Score** 2024	2023	2022	2019	2014
Economic Performance 2024: 0.90 2023: 0.87 2022: 0.90 2019: 0.90 2014: 0.83	Shipping activity	0.90	0.86	0.90	0.90	0.83	Shipping activity: productivity	0.90	0.86	0.90	0.90	0.83
	Tourism	0.90	0.90	0.90	0.90	0.60	Tourism expenditure	0.90	0.90	0.90	0.90	0.60
	Commercial fishing	0.34	0.37	0.41	0.36	0.66	Net fisheries: productivity	0.46	0.45	0.45	0.25	na
							Trawl fisheries: productivity	0.10	0.24	0.31	0.29	na
							Pot fisheries: productivity	0.55	0.52	0.55	0.64	na
Economic Stimulus 2024: 0.50 2023: 0.63 2022: 0.64 2019: 0.58 2014: 0.87	Employment	0.19	0.43	0.45	0.44	0.72	Unemployment statistics for the Gladstone LGA	0.20	0.43	0.45	0.44	0.72
	Socio-economic status	0.74	0.75	0.74	0.64	0.90	Index of economic resources	0.74	0.75	0.74	0.64	0.90
Economic Value (recreation) 2024: 0.77* 2023: 0.77* 2022: 0.77 2019: 0.76 2014: 0.75	Land-based recreation	0.79*	0.79*	0.79	0.77	0.76	Satisfaction rating from CATI survey + value from 2014 survey	0.79*	0.79*	0.79	0.77	0.76
	Recreational fishing	0.73*	0.73*	0.73	0.71	0.67	Satisfaction rating from CATI survey + value from 2015 survey	0.73*	0.73*	0.73	0.71	0.67
	Beach recreation	0.77*	0.77*	0.77	0.76	0.71	Satisfaction rating from CATI survey + value from 2014 survey	0.77*	0.77*	0.77	0.76	0.71
	Water-based recreation	0.77*	0.77*	0.77	0.76	na	Satisfaction rating from CATI survey + value from 2017 survey	0.77*	0.77*	0.77	0.76	na

*No new assessment; results carried over from assessment.

7 Litter indicator

7.1 Litter

Litter is included as a formal indicator in the 2024 Gladstone Harbour Report Card, but separately to the four components of harbour health (Environment, Social, Cultural and Economic).

The litter index is comprised of a single indicator to assess the “pressure” that the amount of litter and/or marine debris (from here on referred to as 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 and the ReefClean Project and its partners.

Technical expertise for the calculation of scores and grades was provided to this project by Dinny Taylor and Bill Venables. 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), Healthy Waters Partnership for the Dry Tropics (HWP), 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.

As this metric is based on a dataset collected by volunteers, there is some inconsistency with sample sizes and sampling locations across zones and years. Scores and grades are therefore presented at the site level, rather than rolled up into a zone level score. This reduces biases on scores that would come with changes in sampling effort from year-to-year and will allow better representation and comparison of how the amount of litter has changed at particular sites across report cards.

The following methods are described as per that designed for the Dry Tropics Partnership for Healthy Waters Report Card (Whitehead, 2020) with filtering methods applied by UNSW as per Appendix 4. Note, different methods may have been applied to the other regional report cards.

GHHP acknowledges the AMDI®, TBF®, the community organisations, and individuals involved in the collection and the provision of data used in this report. This includes ReefClean which is funded by the Australian Government’s Reef Trust and delivered by Tangaroa Blue Foundation in partnership with Reef Check Australia, Capricornia Catchments, Eco Barge Clean Seas, OceanWatch Australia, South Cape York Catchments and Australian Microplastics Assessment Project.

7.2 Litter data collection

Forty-nine clean-ups were recorded in the AMDI Database in 2022–23 in the Gladstone region. These clean-ups were one of two types: standardised ‘ReefClean’ sampling and non-standardised clean-ups.

7.2.1 Standardised ‘ReefClean’ sampling

The ReefClean project began in early 2019 with funding from the Australian Government’s Reef Trust, led by the Tangaroa Blue Foundation and several partner organisations. Volunteers collected litter along measured transects for a designated length of time. Standardised clean-ups began in mid-2018 and will continue quarterly until June 2023. This standardised method enables comparisons across years. All debris were sorted into one of 127 categories and recorded in the AMDI Database. ReefClean data are incorporated into the litter metric where available.

7.2.2 Non-standardised clean-ups

Non-standardised clean-ups were also conducted across the Gladstone region, varying in location and frequency across years. Generally, easy-to-access and 'volunteer friendly' sites (such as popular beaches) are cleaned more frequently than other beaches. Non-standardised clean-ups have no defined boundary and while the number of participants and the total duration of the clean-up event is recorded, individual effort is not (leading to unequal effort of individuals across the duration of the event). All debris collected was sorted into the AMDI categories and entered into the database. Due to inconsistency in how rigorous the debris sorting and recording process was among volunteers, the litter could not be divided into individual categories, so litter was totalled into a 'total litter' category.

7.3 Development of litter indicators and scoring

Initial development of the litter indicator was completed by Bill Venables and Tegan Whitehead (Dry Tropics Partnership) and first incorporated in the Townsville Dry Tropics Report Card 2019. The current analysis was completed by Dinny Taylor from Healthy Waters Partnership Dry Tropics and involves a revision of the initial modelling.

The litter that is collected is sorted and recorded in a number of categories, but currently total litter is used in the analysis and scoring.

7.3.1 Establishing the baseline

Total litter collected at each site in the current reporting year is compared against a baseline derived from historical data collected across the five GBR report card areas from 2009 to June 2019 (data was only available at the GHHP sites from 1 July 2014). This baseline period was chosen to represent a time before many of the Queensland Government state-wide management restrictions were put in place (plastic bag ban from 1 July 2018 the container refund scheme from 1 November 2018 and the single use plastics ban from 1 September 2021).

During the baseline period to 30 June 2019, clean-ups occurred at 42 sites across 12 GHHP monitoring zones in the Gladstone region (Appendix 5). The frequency that each site was cleaned during this baseline period varied.

7.3.2 Litter index scoring

To calculate scores and grades for total rubbish, scores and grades for the 2022-23 reporting year were determined by relating annual data to a reference distribution (Taylor 2024). Data were scaled from 0 to 1 for the report card, with close to zero equating to "near pristine" and close to 1 being a "highly littered" state.

In simplified terms, the process can be summarised as (Taylor 2024):
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

Each Year of Data for Reporting

- 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.

Figure 7.1 shows the histogram as the proportional density for each of the regions included in the model: Wet Tropics (WT), Dry Tropics (DT), Mackay-Whitsunday-Isaac (MWI), and Gladstone Harbour (GHHP), and the Kernel Density Estimate (curve) for the total data set. This shows that the largest proportion of the data is from the WT and MWI regions. Further, that the GHHP data has a smaller distribution range.

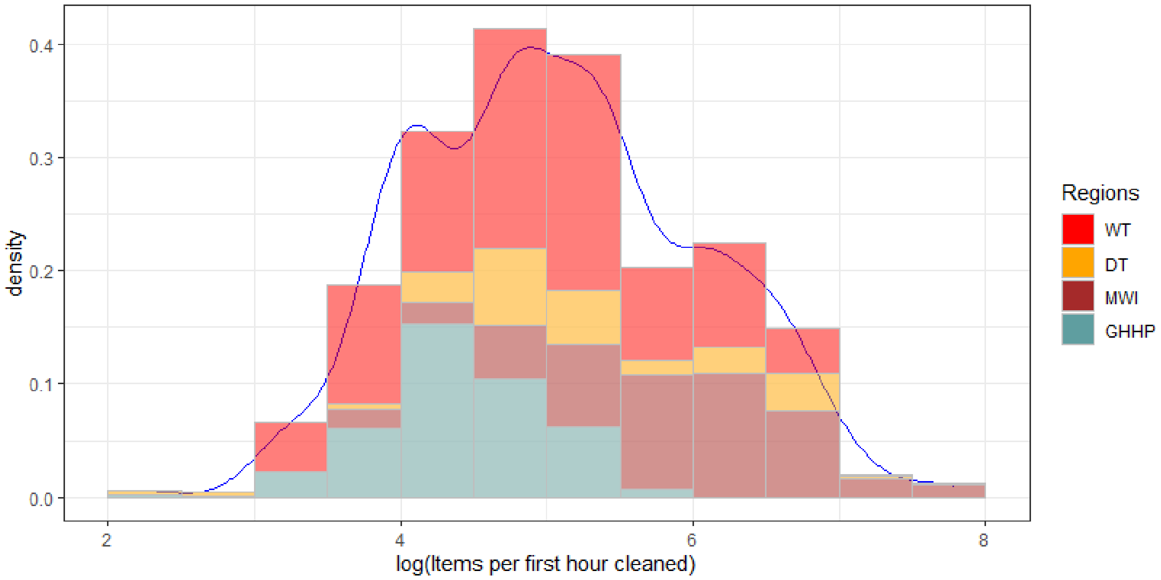

Figure 7.1 | Proportional histogram density plot of the Kernel Density Estimate for the baseline litter model

7.3.3 Note about scoring used for litter indicator

It is important to note that scoring for the litter indicator is different to the standard scoring system used by all other GHHP indicators (see Table 7.1). This was to ensure consistency in the scoring system among other regional report cards such as Wet Tropics, Dry Tropics and Mackay-Whitsundays Isaac. Although the scoring system and thresholds are consistent between the four partnerships, it is not appropriate to directly compare grades/scores between regional report cards. This is because grades/scores for each report card are based on a four-year baseline which is unique to the dataset in their region. Thus, a 'moderate pressure' score for one partnership is not equal to a 'moderate pressure' score for another partnership. Comparability is only relevant in terms of site improvement or deterioration (e.g., the number of sites that showed less rubbish and thus had a better score than the previous year, and vice versa).

Table 7.1 | Scoring range guide to colours and textual context. Note that scoring range cut-offs are dependent on annual data distribution.

Colour	Context	Score range
(red)	Very high pressure	0 to 5
(orange)	High pressure	>6 to 36
(yellow)	Moderate pressure	>36 to 65
(light green)	Low pressure	>66 to 79
(dark green)	Slight/Very low pressure	>80 to 100

7.4 Litter results

For interpreting litter results, it is notable that score cut-off points are based on annual data distribution (see Figure 7.1) and refer to a scale of 'very high pressure' to 'slight pressure' (Table 7.1). Refer to Table 7.2 and Figure 7.2 for sites scores, with results summarised as:

- All clean-up sites within the Gladstone Harbour Report Card zones in 2022–23 (n = 14) had a lower average total rubbish compared to the four-year baseline, resulting in a classification of 'low or very low pressure.'
- Six out of the eight sites that were cleaned up in both 2022 and 2023 showed improved scores, suggesting that the clean-up efforts had a positive impact.
- Only two revisited sites, East Beach and Lilley's Beach, received lower scores in 2023 compared to previous assessments.
- Esplanade Beach recorded very low pressure and demonstrated the largest improvement in score from 2022.

Table 7.2 | Litter scores by site across the Gladstone region for the 2024 Report Card using data collected between July 2022 and June 2023. Note that scoring range cut-offs are dependent on annual data distribution. 2022 recalculated scores are shown for comparison, with change in scores between 2022 and 2023 also illustrated.

Zone	Site Name	2023	2022	Score Change
5. Inner Harbour	Barney Point	79	77	↑
	Spinnaker Park Beach	99	-	-
6. Calliope Estuary	Calliope River Boat Ramp	90	-	-
7. Auckland Inlet	Auckland Creek, Hanson Road	70	42	↑
	Auckland Creek, Sandpiper Park	95	-	-
8. Mid Harbour	Canoe Point (Site ID 796)*	98	93	↑
	East Beach	92	93	↓
	Esplanade Beach*	98	32	↑
	Tannum Sands Main Beach	97	87	↑
9. South Trees Inlet	Lillys Beach North End*	82	-	-
10. Boyne Estuary	Boyne Island State School	98	-	-
	Eastern Foreshore*	84	70	↑
	Lilleys Beach*	67	74	↓
11. Outer Harbour	Wild Cattle Island National Park	93	-	-

Scoring range: ■ Very high pressure = 0 to 5 | ■ High pressure = >6 to 35 | ■ Moderate pressure = >36 to 65
■ Low pressure = >66 to 79 | ■ Very low pressure = >80 to 100 | *ReefClean survey sites

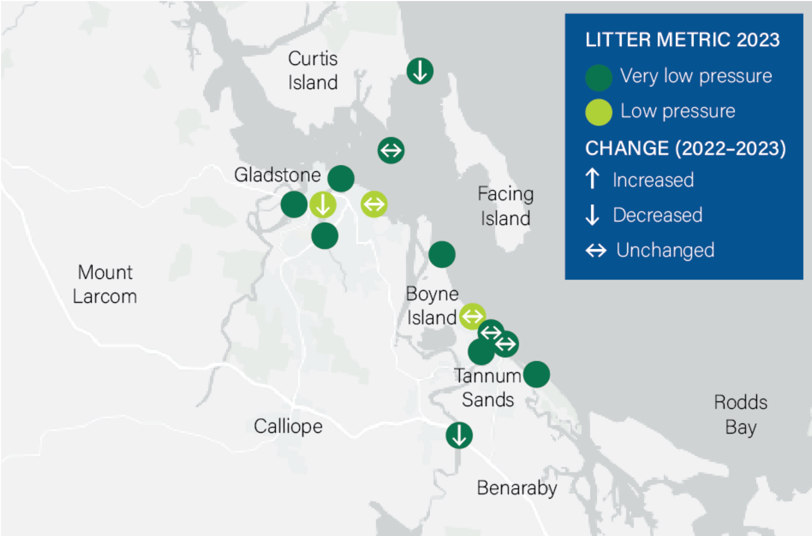

Figure 7.2 | Map and grades of total litter at 14 Gladstone Harbour sites in the 2022–23 reporting year.

8 Gladstone Harbour drivers and pressures

8.1 Background

Drivers and pressures are external forces that play key roles in the health of Gladstone Harbour. As a busy industrialised harbour in a subtropical climate with distinct wet and dry seasons, Gladstone Harbour is influenced by a number of environmental, social, cultural and economic drivers. Changes in the demographics of the human population or major climatic events are examples of drivers; both may have strong influences over the environmental, social, cultural and economic condition of the harbour (McIntosh et al., 2014; Figure 8.1). Pressures are the human forces that may change the environmental condition of the harbour. Examples of pressures are the release of toxic material, physical disturbance of habitats such as mangroves or seagrass, and alterations to the coastline (McIntosh et al., 2014; Figure 8.2).

The Environmental, Social, Cultural and Economic Health of Gladstone Harbour could be influenced by major events that operate on scales that extend spatially or temporally beyond the reporting boundaries specified for the four components. For instance, connectivity may be driven by changes in oceanic circulation and wind and rainfall patterns; water chemistry may be influenced by pressures originating from human activities in river catchments. This section summarises some key drivers and pressures that may have influenced the 2024 Gladstone Harbour Report Card scores.

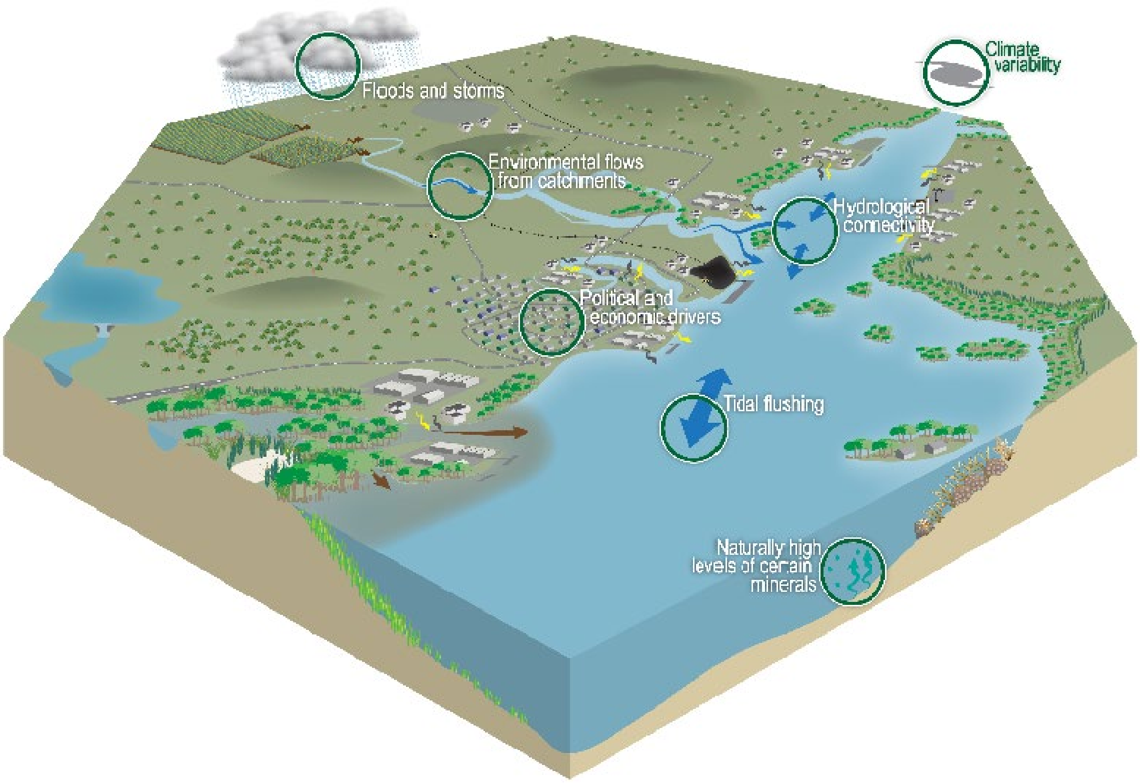

Figure 8.1 | Major drivers of environmental change within Gladstone Harbour (Source: McIntosh et al., 2014).

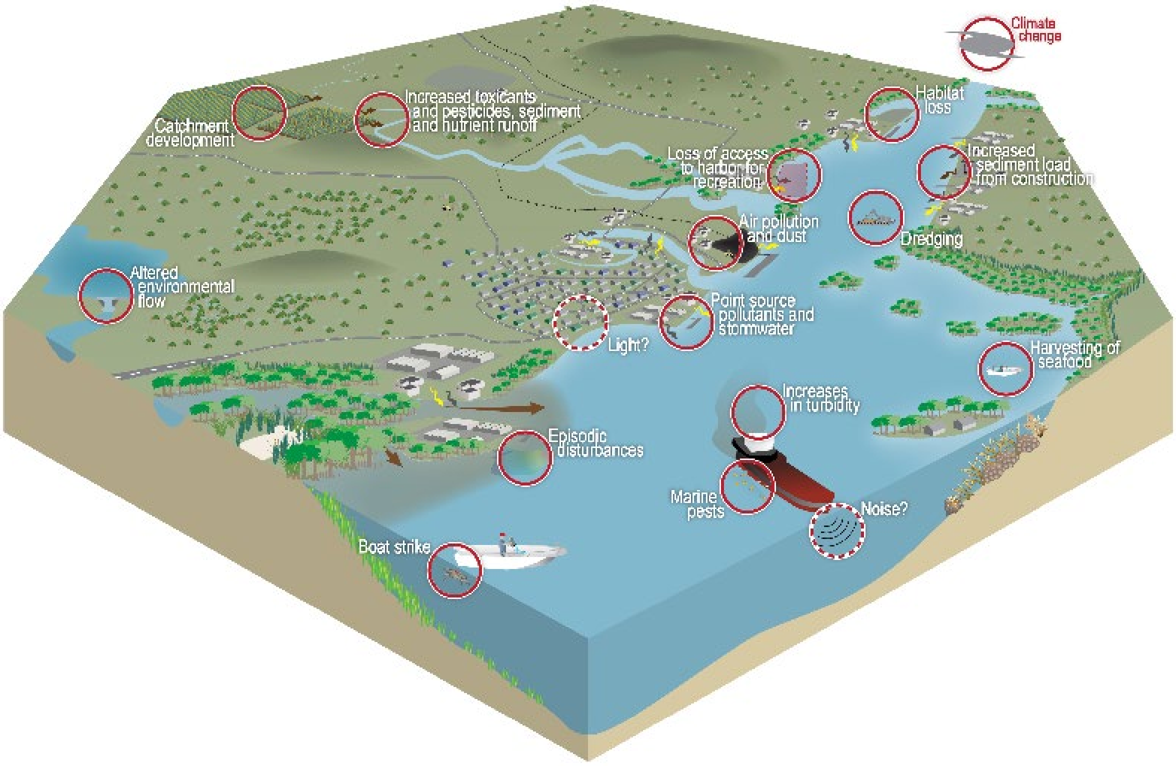

Figure 8.2 | Pressures which can drive environmental change within Gladstone Harbour (Source: McIntosh et al., 2014).

8.2 Climate

Temperature

Gladstone has a subtropical climate with an average maximum of 27.5˚C and an average minimum of 18.2˚C (Figure 8.3).

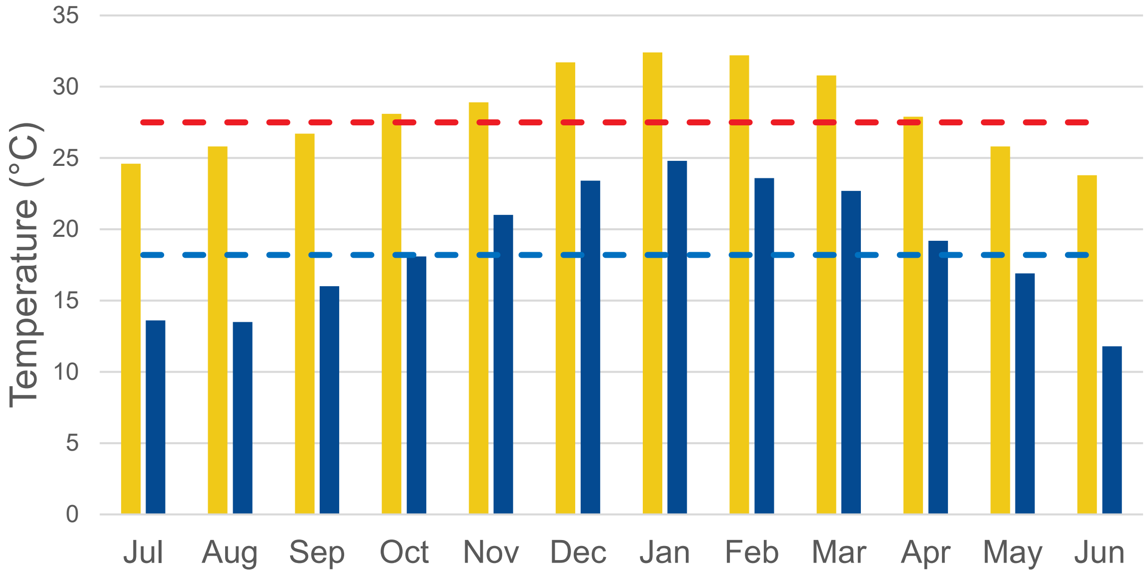

Figure 8.3 | Average maximum and minimum monthly temperatures at the Gladstone Airport weather station for the 2023–24 reporting period (July 2023–June 2024). The average maximum monthly (yellow bars) and average minimum monthly (navy bars) for the 2023-24 reporting period are shown in comparison to the 1994–24 annual maximum average (red dashed line, 27.4˚C) and minimum average (blue dashed line, 18.2˚C). Values obtained from BOM (http://www.bom.gov.au/climate/data/index.shtml).

Rainfall

Rainfall is highly variable; the average annual rainfall recorded at Gladstone (Airport) for the period 1994–24 was 860 mm. The maximum and minimum annual rainfall totals recorded at this site were 1,542 mm in 2010 and 308 mm in 2001 respectively. Consistent with a subtropical climate, the summer months are wetter than winter months (BOM, 2024).

In the 2024 reporting year (July 2023 to June 2024), total rainfall recorded at Gladstone Airport was 644 mm. This was 216 mm less than the 1994–24 average (860 mm) and the first year in which total rainfall fell below the 1994-24 average after two years of higher than average rainfall (Figure 8.4). Total monthly rainfall was variable when compared to mean monthly rainfall of the past 27 years (Figure 8.5). Two months, November and April, had rainfall totals well above the monthly average, while seven months recorded dryer than average conditions.

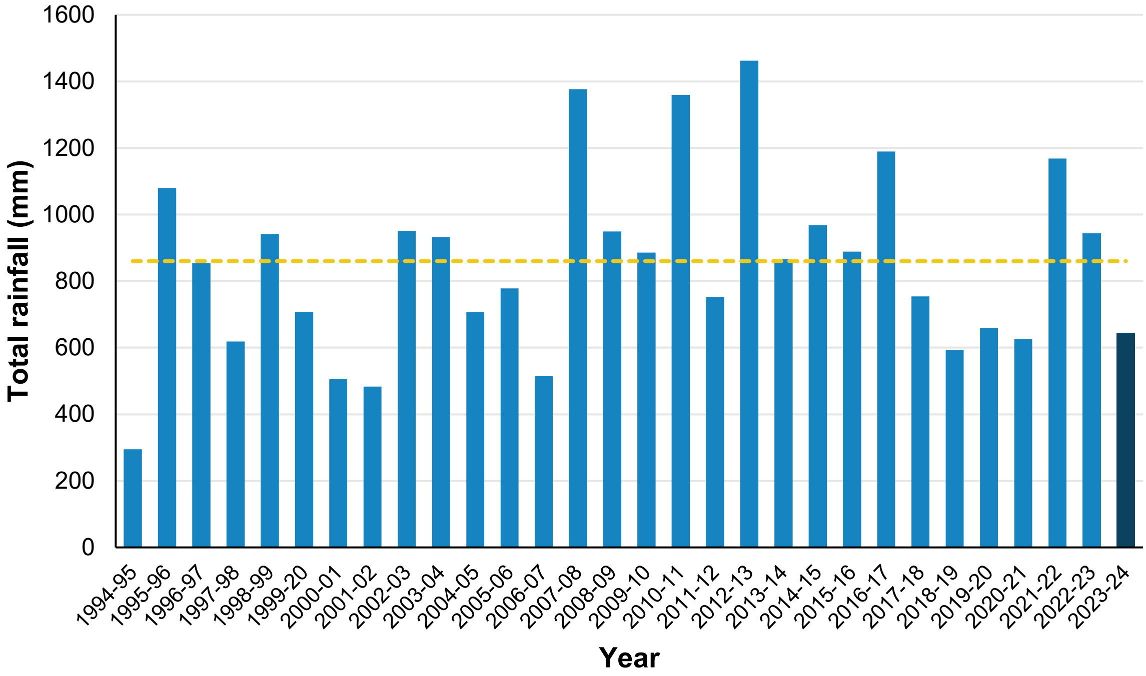

Figure 8.4 | Annual rainfall (mm) by reporting year at the Gladstone Airport weather station from 1994–95 to 2022–23 (light blue bars) and 2023–24 (dark blue bar). Yellow dashed line represents the annual mean for 1994–23 (860 mm). Values were obtained from BOM (http://www.bom.gov.au/climate/data/index.shtml).

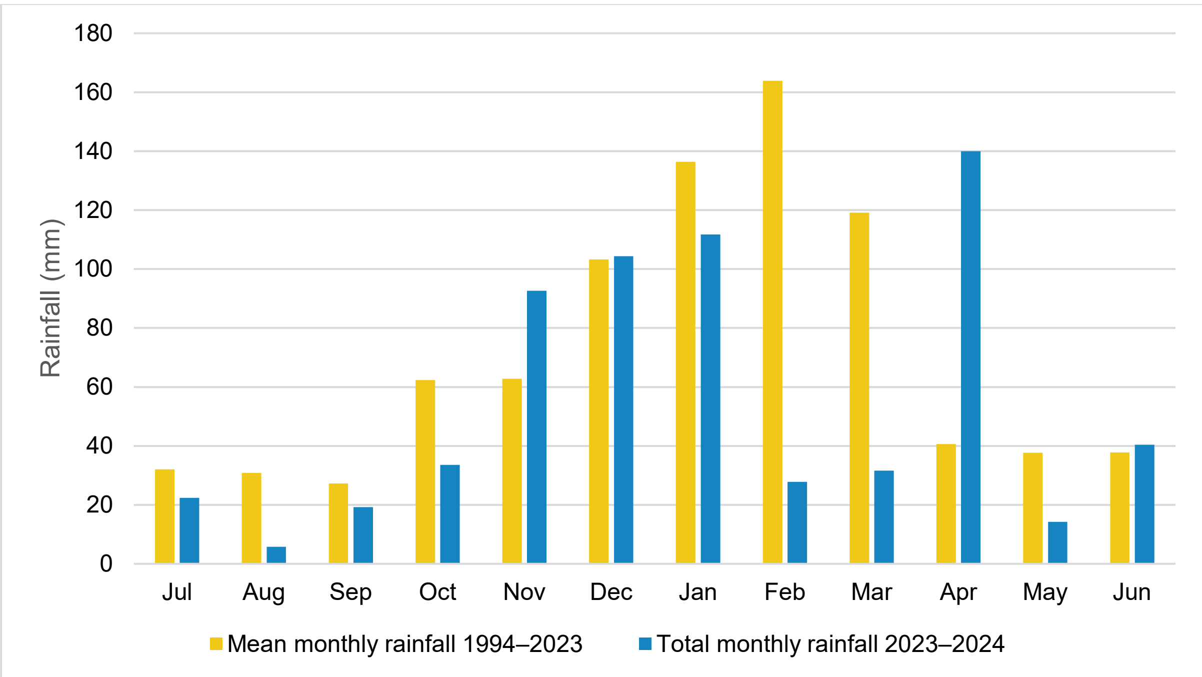

Figure 8.5 | Mean monthly rainfall (mm) at the Gladstone Airport weather station 1994–23 (yellow bars) compared to total monthly rainfall for the 2023-24 reporting year (blue bars). Values were obtained from BOM (http://www.bom.gov.au/climate/data/index.shtml).

Freshwater inflow

The two major sources of freshwater flow into Gladstone Harbour are the Boyne River that discharges into the Mid Harbour and the Calliope River that discharges into the Western Basin. Small amounts of freshwater flow may also enter the harbour via The Narrows when the Fitzroy River floods. Since European settlement, significant changes in land use in both catchments have resulted in increased sediment and nutrient loads in the Port of Gladstone (DSEWPaC, 2013).

Streamflow in the Boyne River is highly modified owing to Awoonga Dam, whereas flow in the Calliope River is relatively unmodified. Average annual stream discharges for the Boyne and Calliope rivers are presented in Table 8.1. Average annual stream discharge from the Calliope River is approximately 1.7 times higher than that of the Boyne River.

Flows measured at the Calliope River between January 2014 and June 2024 show two brief but significant high flow events occurring with the passage of TC Marcia and ex TC Debbie (Figure 8.6). Rainfall associated with TC Marcia caused a peak flow of 91,666 ML/day on 21 February 2015 and rainfall associated with ex TC Debbie produced a peak flow of 105,980 ML/day on 30 March 2017. This compares to a median daily flow of 13.9 ML/day from October 1938 to June 2024 (DRDMW Water Monitoring Information Portal).

In the 2023-24 reporting year, below average rainfall resulted in lower than average monthly discharge volume for all months except December and January. (Figure 8.7). However, total monthly discharge in January was more than twice the median monthly discharge (1938-2024) (Figure 8.7).

Table 8.1 | Streamflow summary for the Boyne River (1984–85 to 2011–12) and the Calliope River (1938–39 to 2018–19). Source: Queensland Department of Regional Development, Manufacturing and Water (https://water-monitoring.information.qld.gov.au/).

Annual stream discharge (ML)		**December stream discharge (ML)**	
Boyne River at Awoonga Dam Headwaters (1984–85 to 2011–12)			
Mean	97,728	Mean	24,279
Median	-	Median	-
Maximum flow (2010–11)	1,194,335	Maximum flow (2010–11)	634,999
Calliope River at Castlehope (1938–39 to 2019–20)			
Mean	163,783	Mean	20,724
Median	99,040	Median	2,727
Maximum flow (2012–13)	916,693	Maximum flow (1973–74)	401,837

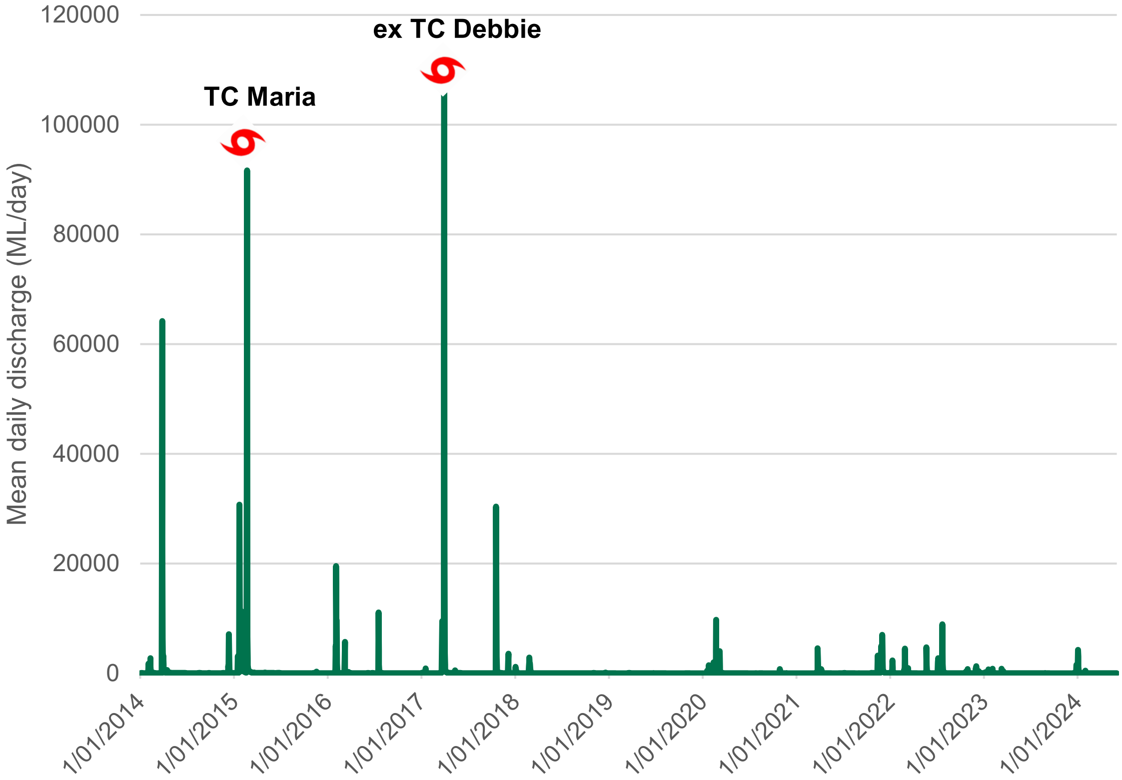

Figure 8.6 | Mean daily Calliope River flows recorded at Castlehope January 2014–June 2024. Values were obtained from Queensland Department of Regional Development, Manufacturing and Water (https://water-monitoring.information.qld.gov.au/).

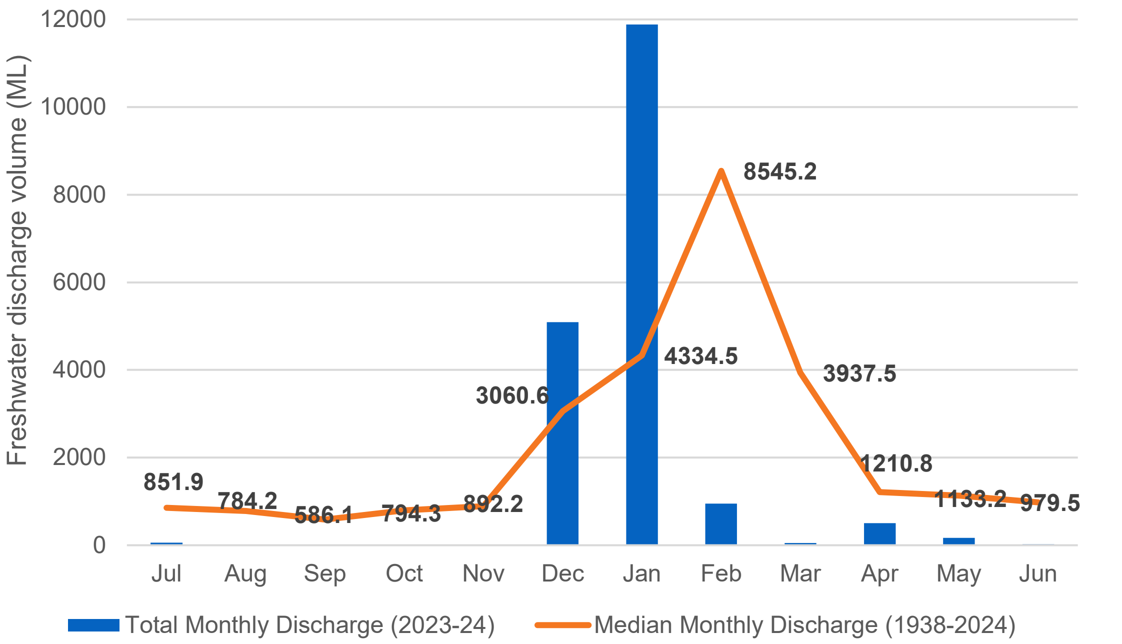

Figure 8.7 | Monthly water discharge for July 2023–June 2024 (blue bars) and median monthly water discharge for October 1938–June 2022 (orange line) of the Calliope River at Castlehope. Values were obtained from Queensland Department of Regional Development, Manufacturing and Water (https://water-monitoring.information.qld.gov.au/).

The main water storage for Gladstone is the Awoonga Dam located on the Boyne River approximately 25 km south-west of Gladstone. The dam has a storage capacity of 250,000 ML and is overtopped when the storage level exceeds 40 m Australian Height Datum (Table 8.2). Since the height of the dam wall was raised in 2002, it has overtopped eight times – in 2002, 2010, 2013, 2015, 2017 and 2018. No overtopping occurred in the 2023-24 report card year.

Table 8.2 | Highest Awoonga Dam levels and last overtopping (Source: Gladstone Area Water Board).

Storage level	Date	Level (m AHD)	Volume (ML)	Capacity (%)	Surface area (ha)
Last overflow of 40m spillway	3 Jan 18	40.30	778,900	100.26	6,791
Highest level	27 Jan 13	48.3	1,498,586	192.9	10,810

AHD – Australian Height Datum

8.3 Land use and catchment run-off

Gladstone Harbour is bordered by five drainage basins, the Fitzroy (142,545 km^2), the Calliope (2,241 km^2), the Boyne (2,496 km^2), Curtis Island (577 km^2) and Baffle Creek (4,085 km^2), data sourced from wetlandinfo.des.qld.gov.au/wetlands/ (Figure 8.8).

The primary sources of riverine discharge into Port Curtis come from the Calliope and Boyne rivers, with some flow through The Narrows when the Fitzroy River is in flood. Compared to the Fitzroy River catchment area (142,665 km^2), the Calliope and Boyne are small with catchment areas of 2,236 km^2 and 2,590 km^2 respectively. The predominant land use within these two catchments is grazing (Figures 8.9 and 8.10). Much of the flow from the Boyne River into Port Curtis is restricted by Awoonga Dam, constructed in phases beginning in the 1960s. The current spillway height of 40 m Australian height datum was achieved in 2002. In periods of normal flow, it would be expected that coarser sediment particles would settle behind the structure.

Catchment run-off can strongly influence water quality within estuarine systems. It is a major source of sediments, nutrients and pesticides delivered to marine waters (Waterhouse et al., 2024). Land use within a catchment will influence the type and volume of material exported from that catchment. Suspended sediments are dominated by grazing inputs, while pesticides and nutrients are sourced from dryland and irrigated cropping and grazing lands (Waterhouse et al., 2024).

Turbidity in Gladstone Harbour is also strongly influenced by the large tidal movements. This results in significant resuspension of fine sediments which is directly related to the tidal cycle; larger tides result in increased turbidity (Figure 8.11). Turbidity levels in Gladstone Harbour tend to be much higher on falling tides than on rising tides (Baird & Margvelasvili, 2015). Collecting water quality samples throughout the day provides samples at various times in the tidal cycle. Thus, the measured variation in turbidity among sites can be influenced by the timing of sampling.

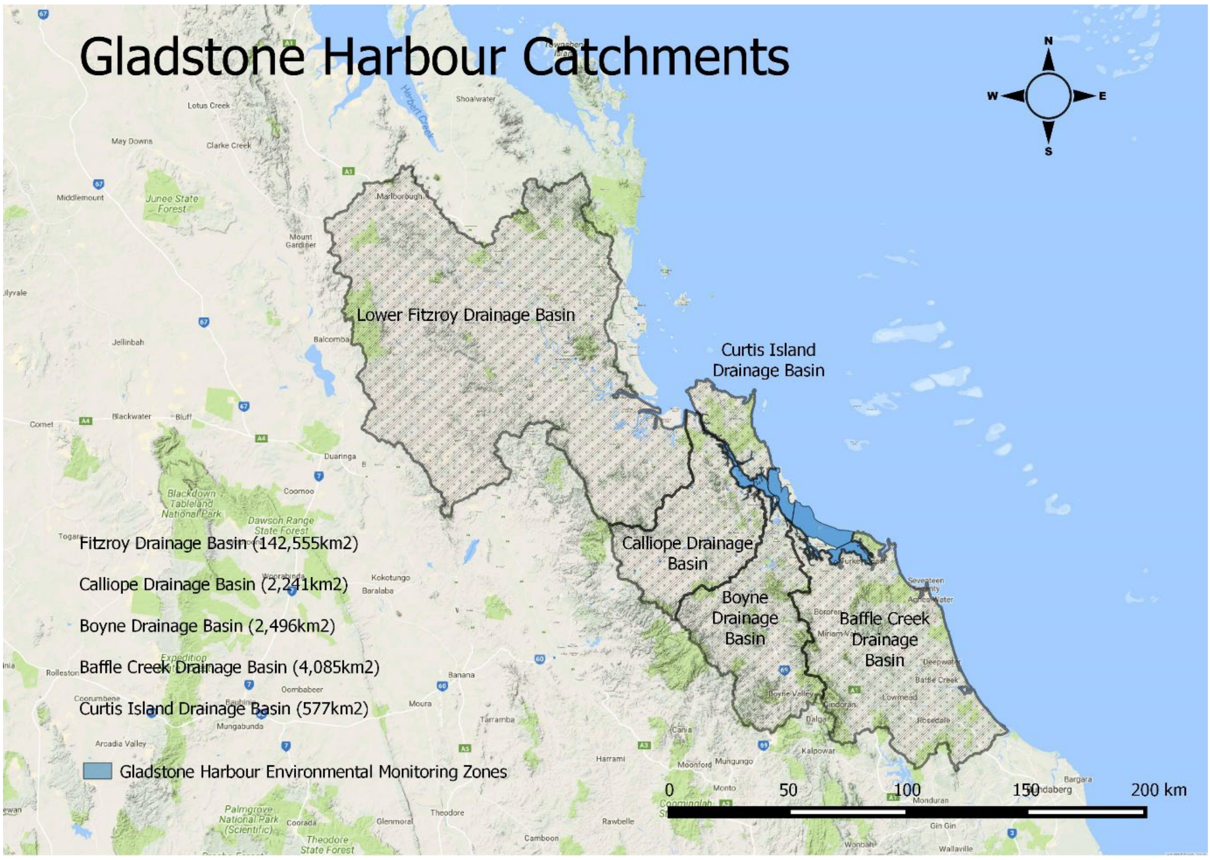

Figure 8.8 | Drainage basins surrounding the Gladstone Harbour environmental monitoring zones. Adapted from data available at wetlandinfo.des.qld.gov.au/wetlands/.

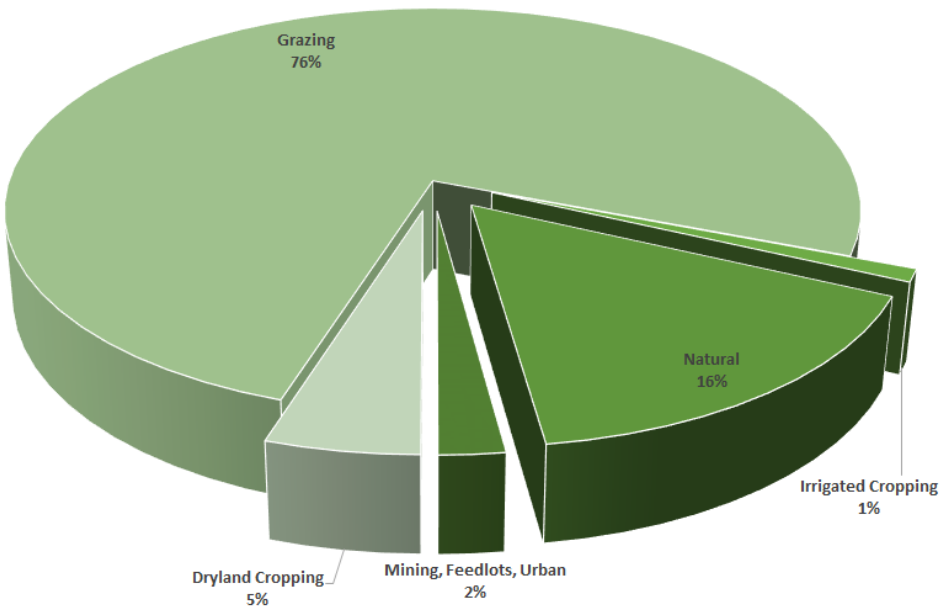

Figure 8.9 | Land use in the Boyne catchment (Data source QSpatial, Land use mapping – Fitzroy NRM region 2009, Catchment boundaries, Queensland Wetland*Info*).

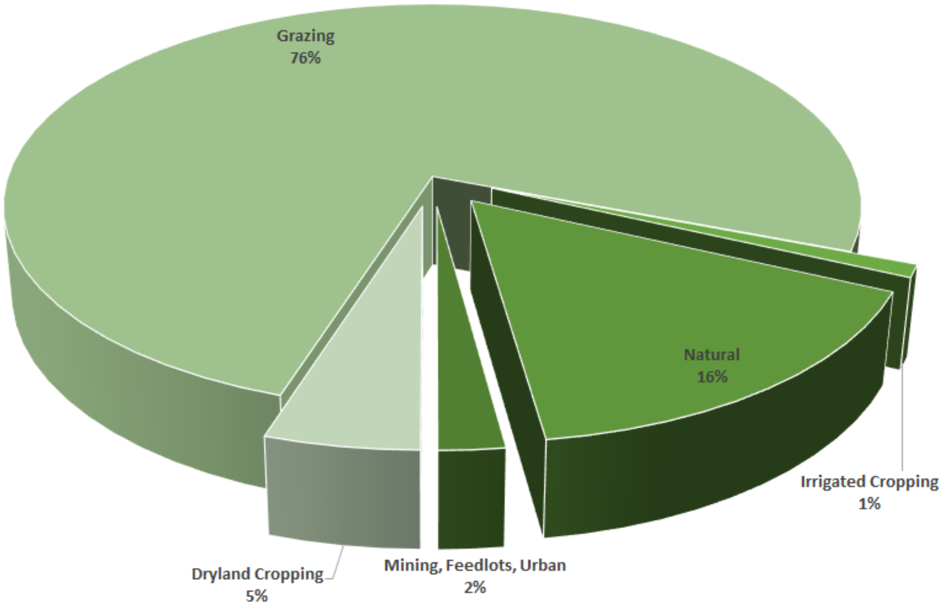

Figure 8.10 | Land use in the Calliope catchment (Data source QSpatial, Land use mapping – Fitzroy NRM region 2009, Catchment boundaries, Queensland Wetland*Info*).

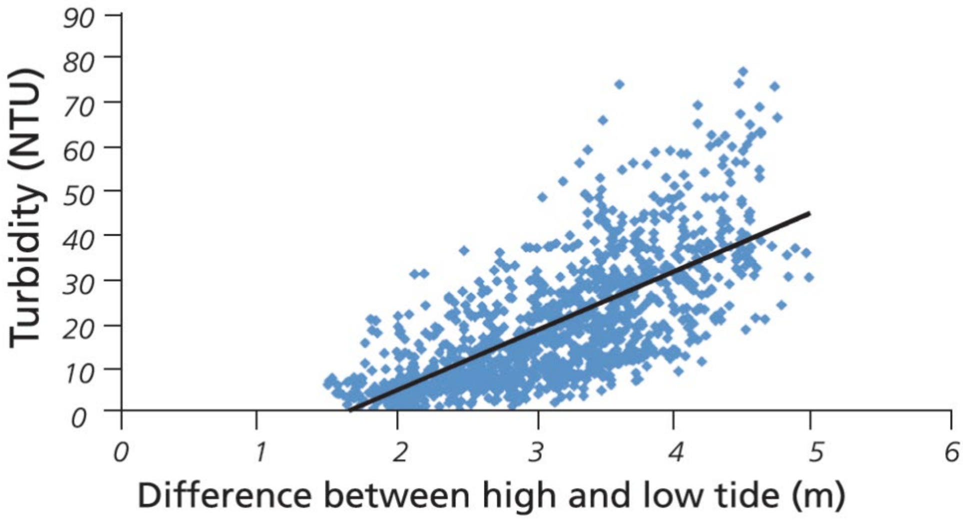

Figure 8.11 | The relationship between tidal movement and turbidity in Gladstone Harbour (DEHP, 2014; personal communication). NTU: nephelometric turbidity unit.

9 Guide to the infrastructure supporting the report card

9.1 Data Information Management System

The GHHP Data Information Management System (DIMS) is an essential infrastructure developed by the Australian Institute of Marine Science which allows a range of users to store, calculate and visualise report card raw data and results (Figure 9.1). Given the large social, cultural, economic and environment monitoring datasets used to inform a report card, this system helps to manage the data systematically and consistently with a reliable backup system. The DIMS is also an information source for the website that can collate and analyse different data types and produce graphical outputs and tables.

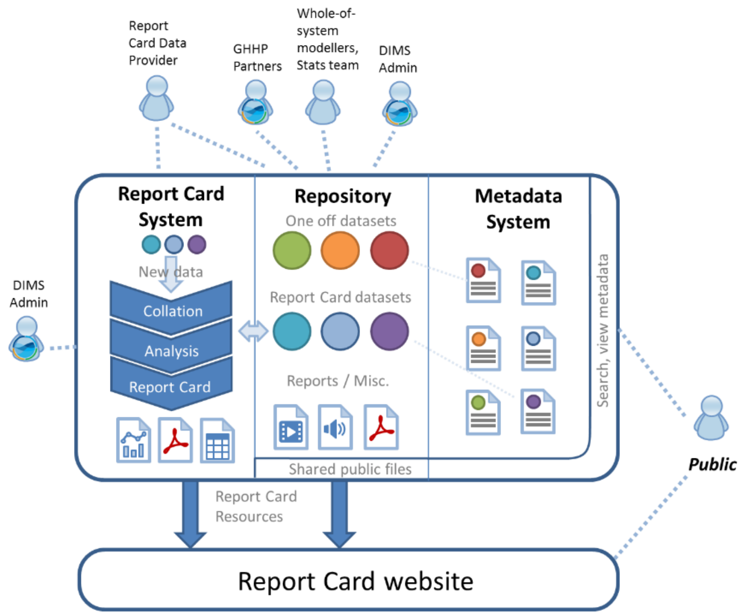

Figure 9.1 | Schematic diagram of the links between the report card website and the Data Information Management System (DIMS) to illustrate major components and primary inputs and outputs (Diagram courtesy of Australian Institute of Marine Science).

The DIMS server consists of the following four key components:

1. Metadata system – This is a metadata catalogue and provides public access to all metadata records related to report card raw data. The metadata system ensures that all raw data in the DIMS are documented appropriately using ISO19115 Marine Community Profile metadata standard. This system consists of a metadata entry system based on open-source metadata catalogue software Geo Network and a public front-end based on the e-Portal Metadata Viewer.
2. DIMS repository – This is a web-based, file-sharing and storage application that provides storage for all report card-related files. The DIMS repository is based on Pydio open-source, file-sharing platform.
3. Report card system – This is the core of the DIMS that is responsible for data ingest, script execution and report card score generation for review by the GHHP Independent Science Panel. The report card system is based on Java servlet, Ember.js and R programming language (Figure 9.2).

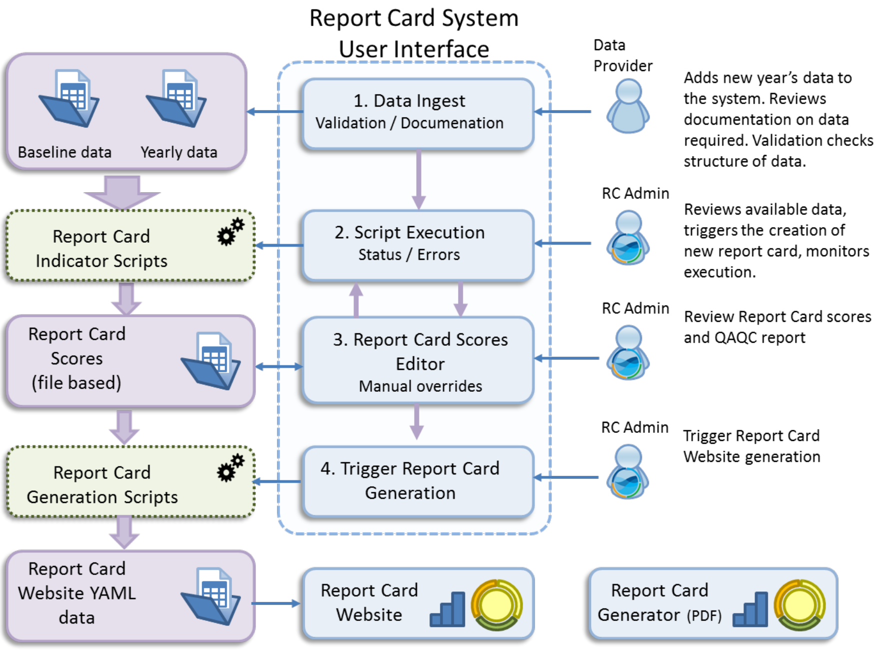

Figure 9.2 | Schematic diagram of the report card system showing all data ingestion, script execution and report cards results generation modules (Diagram courtesy of Australian Institute of Marine Science).

To enable DIMS to perform the above tasks, a range of off-the-shelf and custom-built software packages has been deployed on Amazon server Amazon EC2 (Elastic Cloud Virtual Servicers) with S3 (reliable storage services) backup (Figure 9.3). This approach makes the system highly portable and not dependent on Australian Institute of Marine Science systems. A core advantage of using the Amazon system for backup is its ability to scale-up the server capacity as the needs of the DIMS services expand over time.

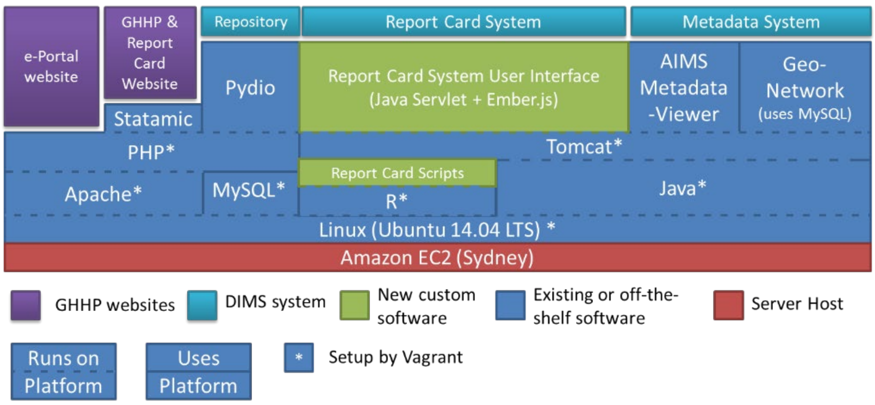

Figure 9.3 | Software infrastructure underlying the Data Information Management System (DIMS) operations (Diagram courtesy of Australian Institute of Marine Science).

10 Geographical scope

10.1 Environmental reporting zones

The 13 environmental reporting zones in Gladstone Harbour have developed over time from an initial seven zones proposed by Jones et al. (2005) in a risk assessment for contaminants in Gladstone Harbour. In their 2007 Port Curtis Ecosystem Health Report Card, PCIMP increased the number of zones to nine by including oceanic and estuarine reference sites (Storey et al., 2007). However, these two reference zones were combined in the 2011 Port Curtis Ecosystem Health Report Card (Vision Environment QLD, 2011) resulting in eight zones. The DEHP developed the current 13 zones (Figure 10.1). These zones were also used to define regionally specific Water Quality Objectives for the Capricorn Coast (DEHP, 2014).

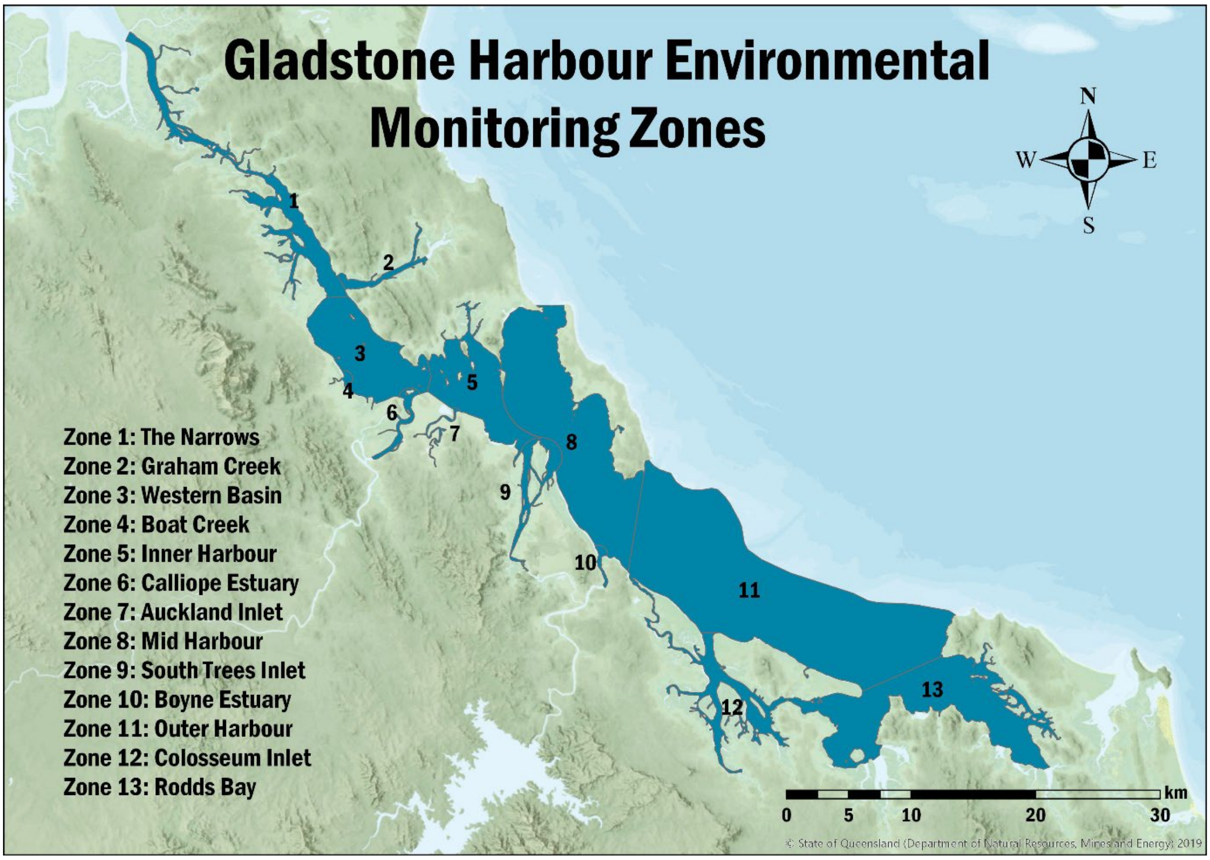

Figure 10.1 | The 13 Gladstone Harbour zones for which environmental parameters were measured for the 2019 Gladstone Harbour Report Card.

10.1.1 The Narrows

Figure 10.2 | Habitat types and sampling sites in The Narrows.

MONITORING SITES

Water and Sediment Quality	6
Seagrass	1
Fish Recruitment	2
Mud Crab	1
Fish Health	Yes

The Narrows is the northern outlet of Gladstone Harbour. It connects the harbour to Keppel Bay near the mouth of the Fitzroy River and separates Curtis Island from the mainland. Curtis Island has a number of conservation zones including national parks, regional parks and state forests and is considered to have significant environmental and cultural value (Commonwealth of Australia, 2013). The Narrows is lined by mangroves and saltmarsh; it provides sheltered water and is an important area for recreational and commercial fisheries (Vision Environment QLD, 2011). This zone has one monitored seagrass meadow—an intertidal meadow comprising aggregated patches of seagrass near Black Swan Island.

Figure 10.3 | The Narrows photographed from the south with Keppel Bay in the distance.

10.1.2 Graham Creek

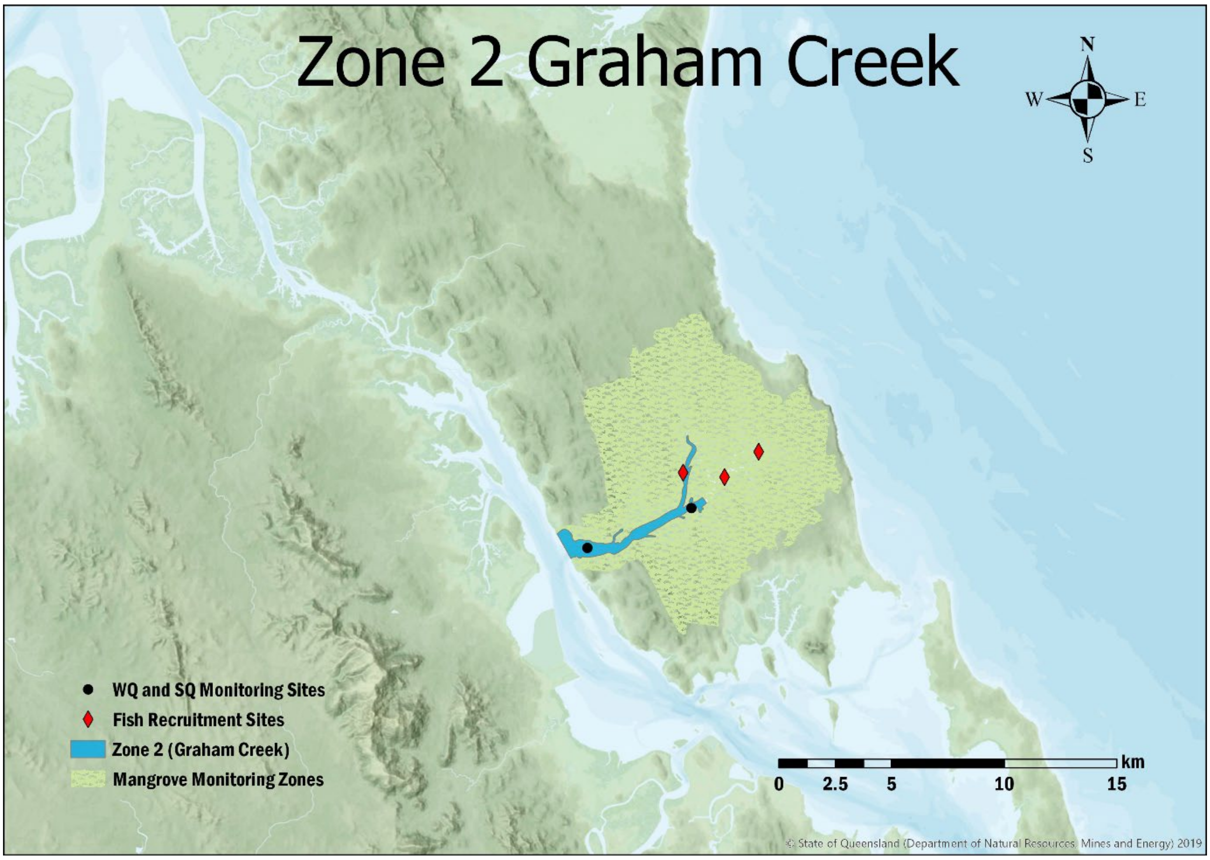

Figure 10.4 | Habitat types and sampling sites in Graham Creek.

MONITORING SITES

Water and Sediment Quality	2
Seagrass	0
Fish Recruitment	3
Mud Crab	1
Fish Health	Yes

Graham Creek is a mangrove-lined tidal inlet located near the south-west corner of Curtis Island. It is approximately 9 km long and flows into the southern end of The Narrows. It is considered one of the best fishing spots in Gladstone Harbour. Three major creeks – Rawbelle, Hobble Gully and Logbridge – flow into Graham Creek.

Figure 10.5 | The south-western end of Curtis Island photographed from the north. Graham Creek is in the middle of the picture and the Western Basin is in the distance.

10.1.3 Western Basin

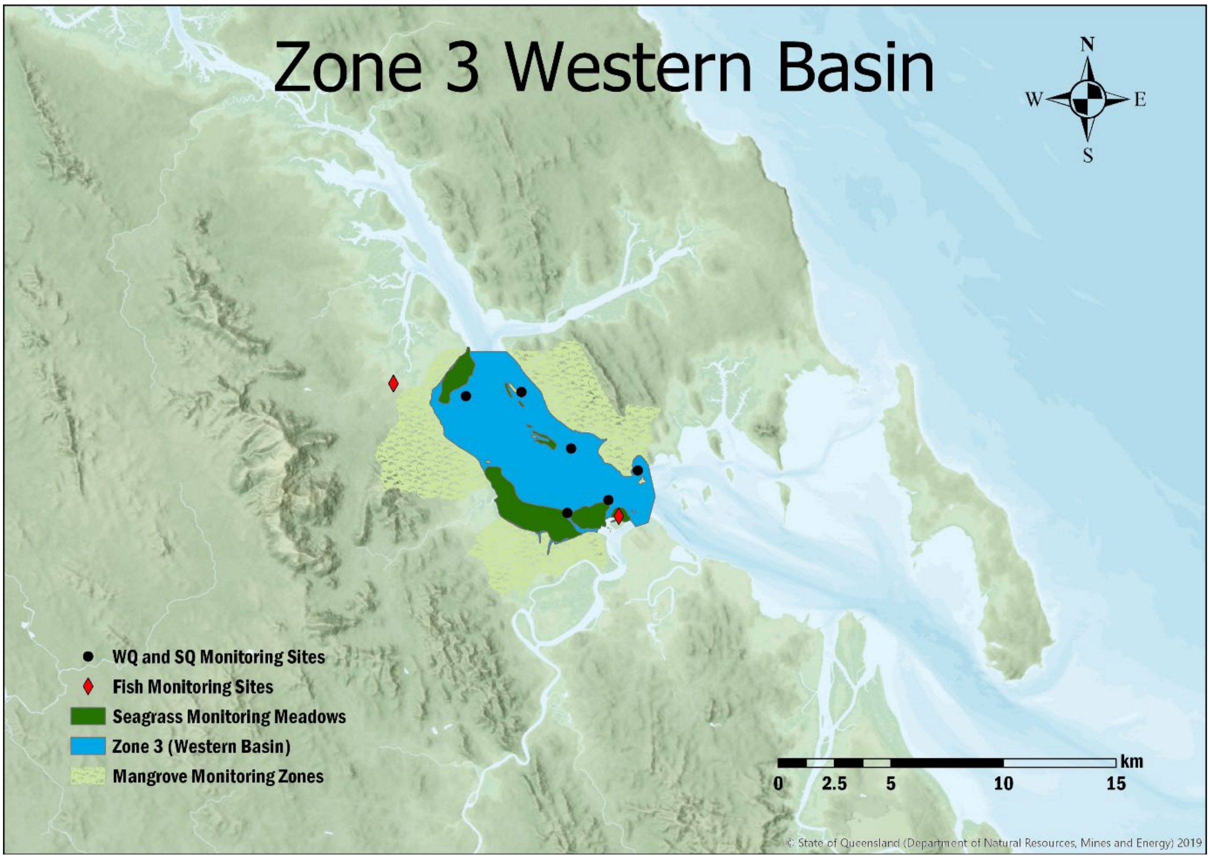

Figure 10.6 | Habitat types and sampling sites in the Western Basin.

MONITORING SITES

Water and Sediment Quality	6
Seagrass	6
Fish Recruitment	2
Mud Crab	0
Fish Health	Yes

The Western Basin is located near the north-western end of Gladstone Harbour. Three large-scale liquid natural gas plants have been constructed on the south-western shore of Curtis Island. The first of these started operating in late 2014. Large industrial plants located on the western shore of this zone include Queensland Energy Resources, Rio Tinto Yarwun, Orica, Transpacific Waste and Cement Australia. The zone includes six monitored seagrass meadows. Areas of mangroves and mudflats remain between Fisherman's Landing and the Wiggins Island Coal Export Terminal (WICET) and on the southern tip of Curtis Island.

Figure 10.7 | The south-western corner of Curtis Island, showing two liquid nitrogen gas plants in the foreground and the Western Basin in the distance.

10.1.4 Boat Creek

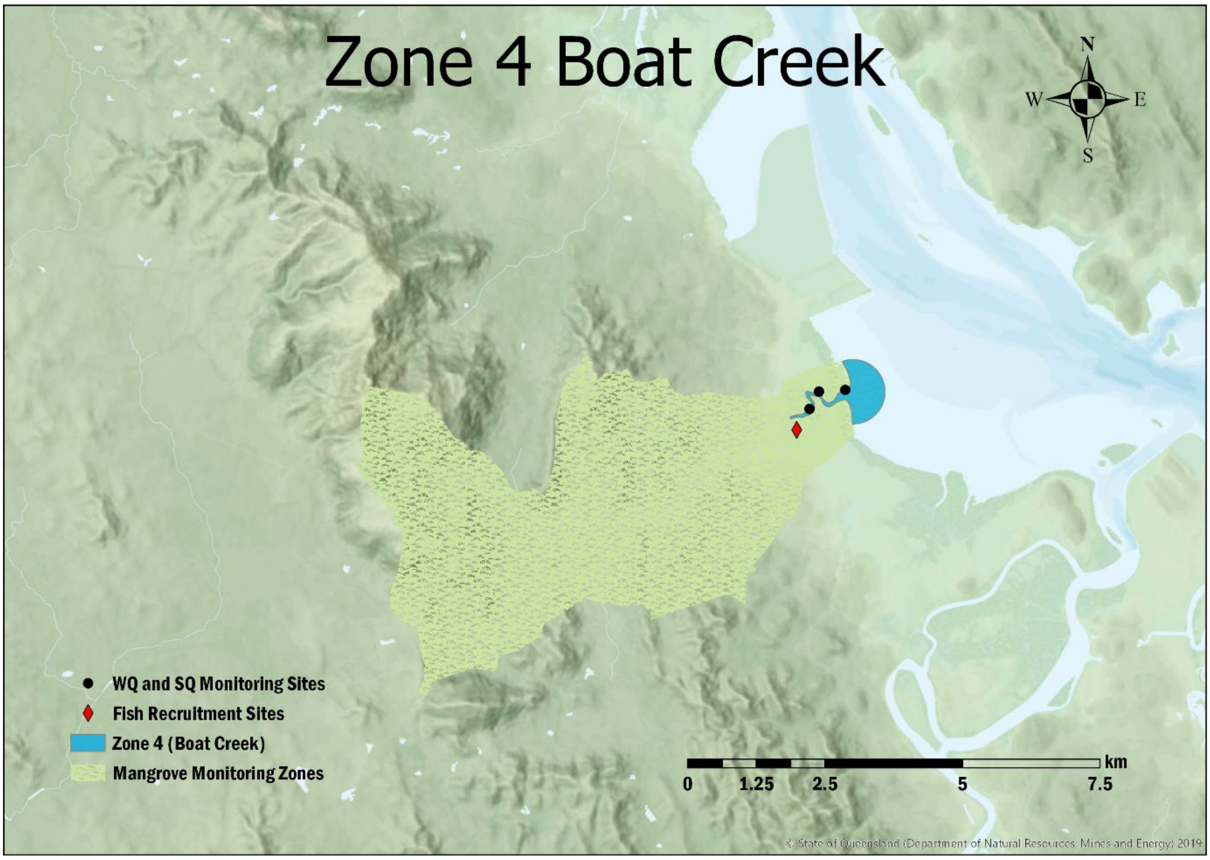

Figure 10.8 | Habitat types and sampling sites in Boat Creek.

MONITORING SITES

Water and Sediment Quality	3
Seagrass	0
Fish Recruitment	2
Mud Crab	1
Fish Health	No

Boat Creek is a small mangrove-lined estuary connected to the western side of the Western Basin. This long (approximately 9 km), narrow water body is not well flushed during regular tides. It is a small zone that includes 2 km of waterway and a small open harbour area near the mouth.

Figure 10.9 | Inlet to Boat Creek photographed from the Western Basin.

10.1.5 Inner Harbour

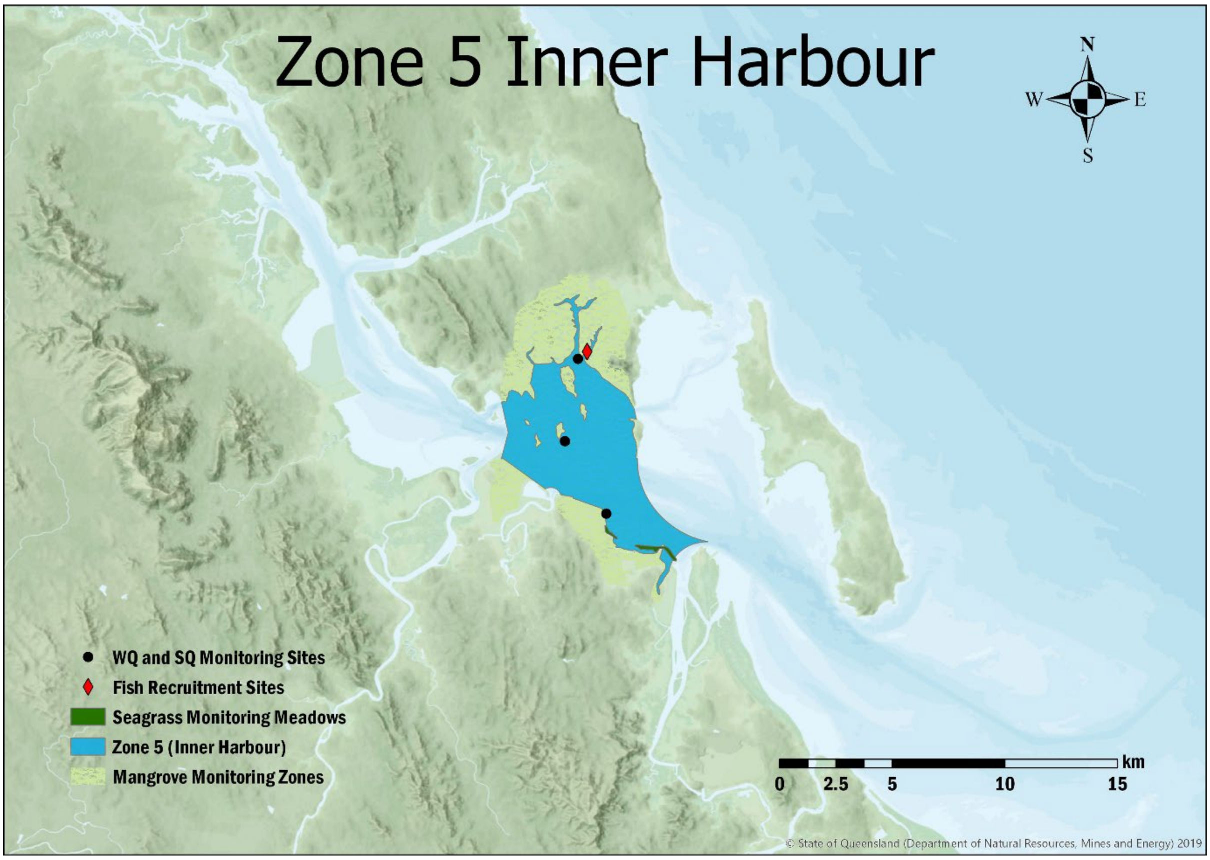

Figure 10.10 | Habitat types and sampling sites in the Inner Harbour.

MONITORING SITES

Water and Sediment Quality	3
Seagrass	1
Fish Recruitment	2
Mud Crab	1
Fish Health	Yes

The Inner Harbour is located immediately to the east of the Western Basin and is bounded by a mangrove-dominated intertidal system on Curtis Island and the town of Gladstone on the southern edge. Coral reefs have been recorded at Turtle, Quoin and Diamantina Islands although there is little evidence that these areas have recently supported viable coral communities (BMT WBM, 2013). There are several seagrass meadows, including one that is monitored in the south of this zone.

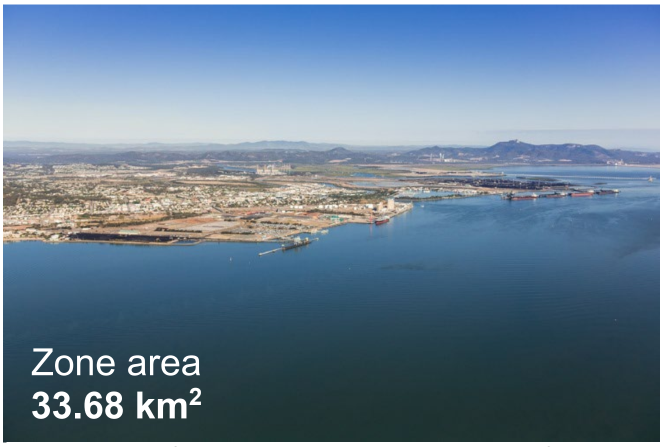

Figure 10.11 | The Inner Harbour photographed from the north-east, with Auckland Point wharves and the City of Gladstone on the left and the RG Tanna Coal Terminal on the right.

10.1.6 Calliope Estuary

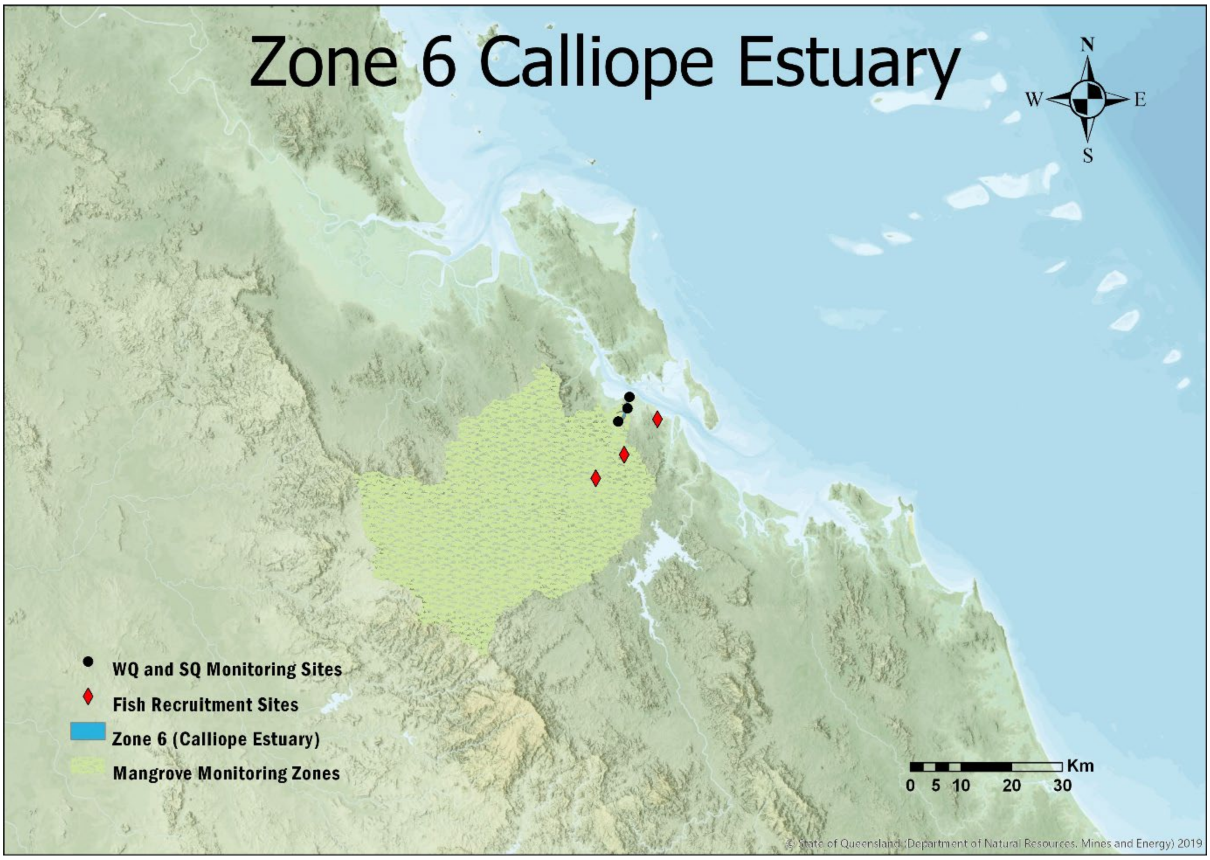

Figure 10.12 | Habitat types and sampling sites in Calliope Estuary.

MONITORING SITES

Water and Sediment Quality	3
Seagrass	0
Fish Recruitment	2
Mud Crab	1
Fish Health	Yes

The Calliope River is fed by Gladstone Harbour's largest freshwater catchment. The river's main tributaries include Oakey, Paddock, Double and Larcom creeks. The Calliope River flows into the Western Basin and is a source of turbid freshwater during floods or other high flow events. The WICET and the RG Tanna Coal Terminal are located at the mouth of the Calliope Estuary. Queensland's largest coal-fired power station is located alongside the Calliope Estuary, approximately 4 km upstream from the river mouth, and has been operating since 1976.

Figure 10.13 | The Gladstone coal-fired power station, on the banks of the Calliope Estuary photographed from the north-east.

10.1.7 Auckland Inlet

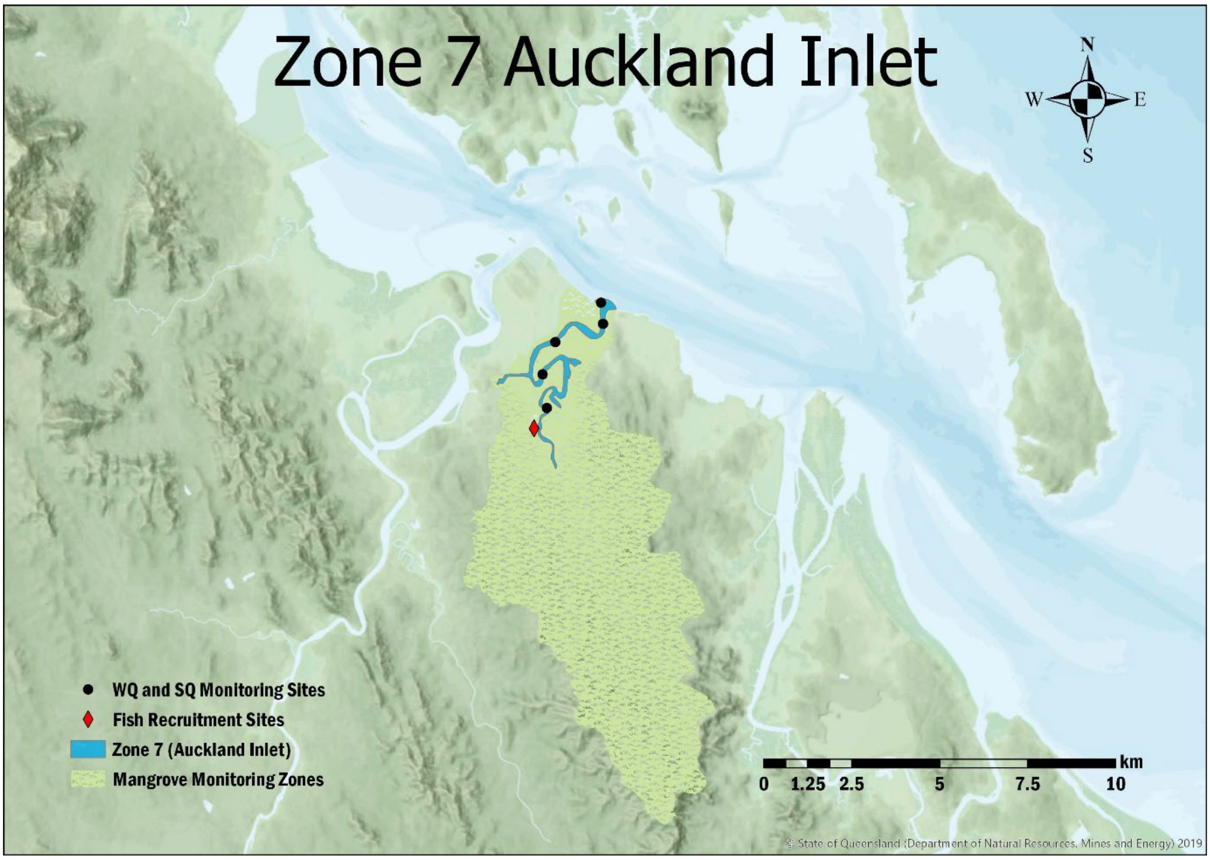

Figure 10.14 | Habitat types and sampling sites in Auckland Inlet.

MONITORING SITES

Water and Sediment Quality	5
Seagrass	0
Fish Recruitment	1
Mud Crab	1
Fish Health	Yes

Auckland Inlet is a tidal inlet that connects to the Inner Harbour through a complex of small streams meandering through mangrove-lined mudflats that are often inundated at high tide. Seawater extracted from Auckland Creek is used to cool the Gladstone Power Station. Stormwater run-off outlets are located along Auckland Creek.

Figure 10.15 | Auckland Inlet photographed from the south-west. Gladstone Marina is in the middle ground and the Auckland Point Terminal to the left.

10.1.8 Mid Harbour

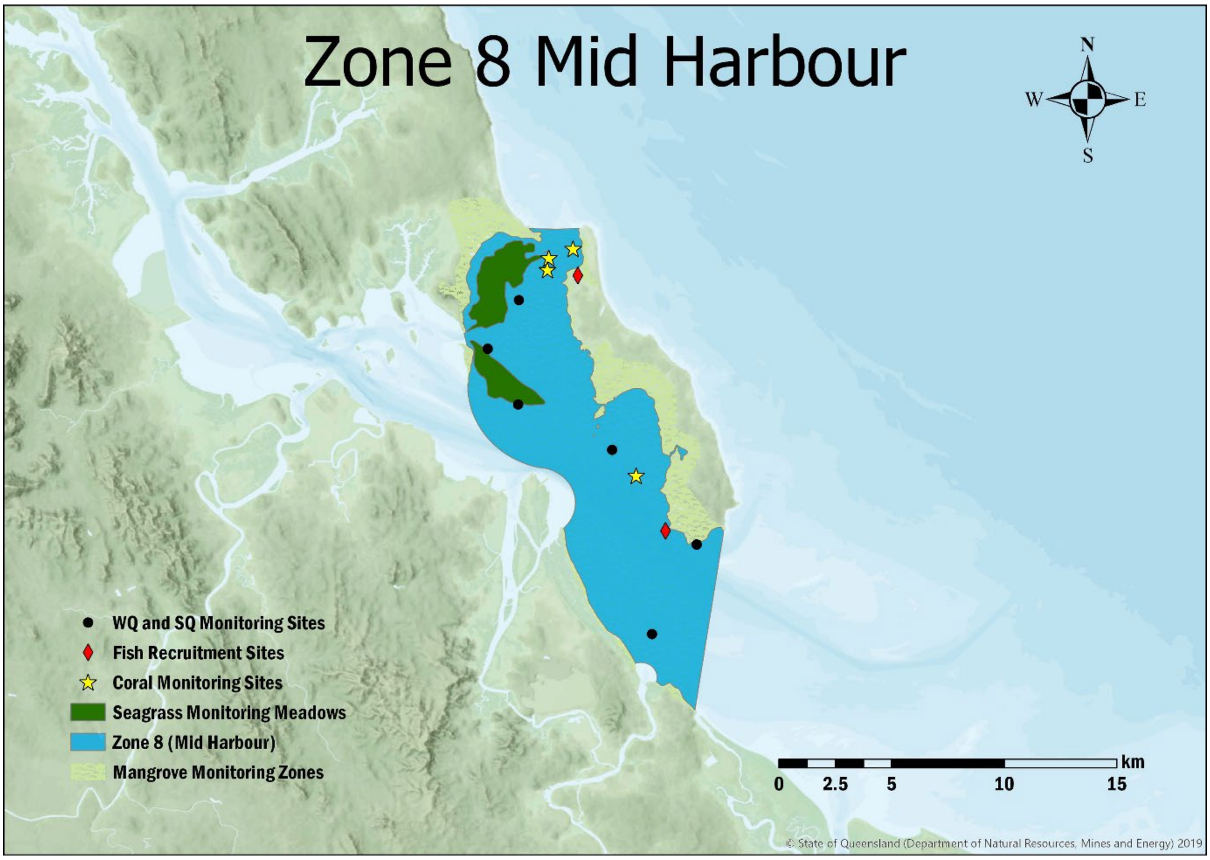

Figure 10.16 | Habitat types and sampling sites in the Mid Harbour.

MONITORING SITES

Water and Sediment Quality	6
Seagrass	2
Fish Recruitment	2
Mud Crab	0
Fish Health	Yes
Coral	4

The Mid Harbour is the second largest of the harbour zones and is bounded by Facing, Curtis and Boyne islands. Most shipping enters the harbour along the Gatcombe channels in the southern end of this zone. This zone contains two monitored seagrass meadows, including the largest seagrass meadow in the harbour at Pelican Banks. Within the zone, coral reefs occur along the western side of Facing Island and on the south-east tip of Curtis Island. There are four coral monitoring sites in this zone that are adjacent to the Great Barrier Reef Marine Park.

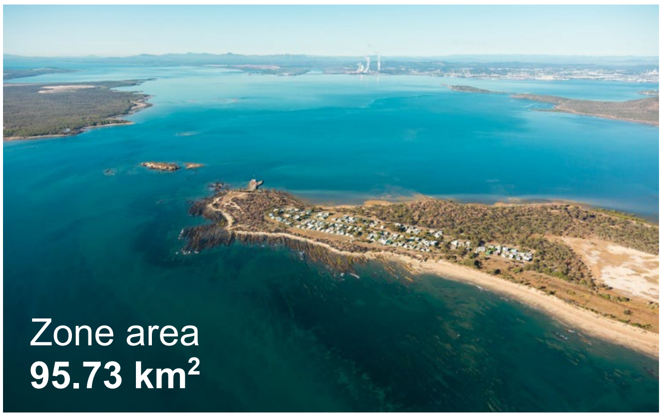

Figure 10.17 | Auckland Inlet photographed from the south-west. Gladstone Marina is in the middle ground and the Auckland Point Terminal to the left.

10.1.9 South Trees Inlet

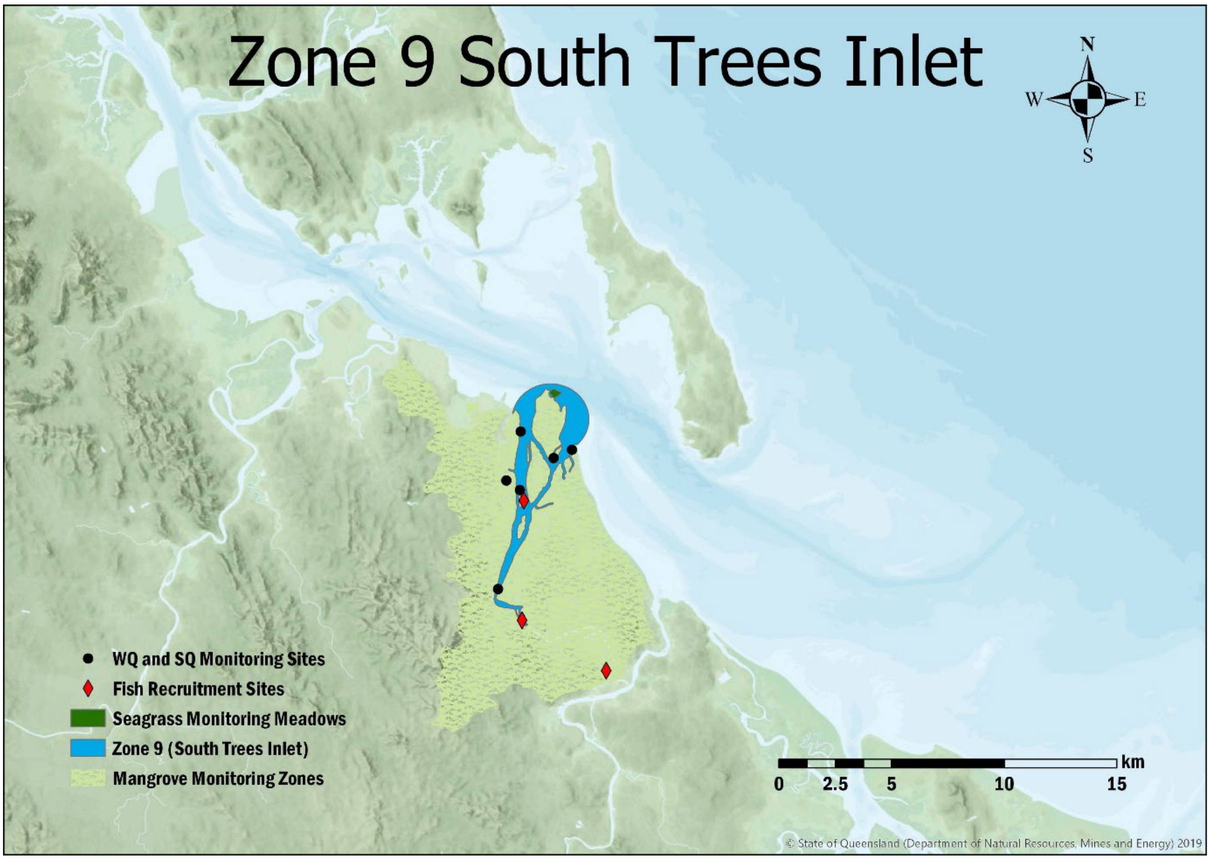

Figure 10.18 | Habitat types and sampling sites in South Trees Inlet.

MONITORING SITES

Water and Sediment Quality	6
Seagrass	1
Fish Recruitment	2
Mud Crab	0
Fish Health	Yes

South Trees Inlet is a mangrove and salt pan-lined tidal inlet that flows into the Mid Harbour zone. The zone contains one monitored seagrass meadow which sits just off the northern tip of South Trees Island. At 10.9 ha it is the second smallest of the monitored meadows. The area contains a large number of industrial developments, including South Trees Wharf on South Trees Island at the inlet's mouth, Queensland Alumina Ltd to the west of the inlet, and Boyne smelters to the south-west of the inlet. The South Trees Industrial Estate is located next to Wapentake Creek which flows into the western side of the inlet just south of South Trees Island.

Figure 10.19 | The mouth of South Trees Inlet photographed from the north, showing South Trees Island in the foreground and Boyne Island in the background.

10.1.10 Boyne Estuary

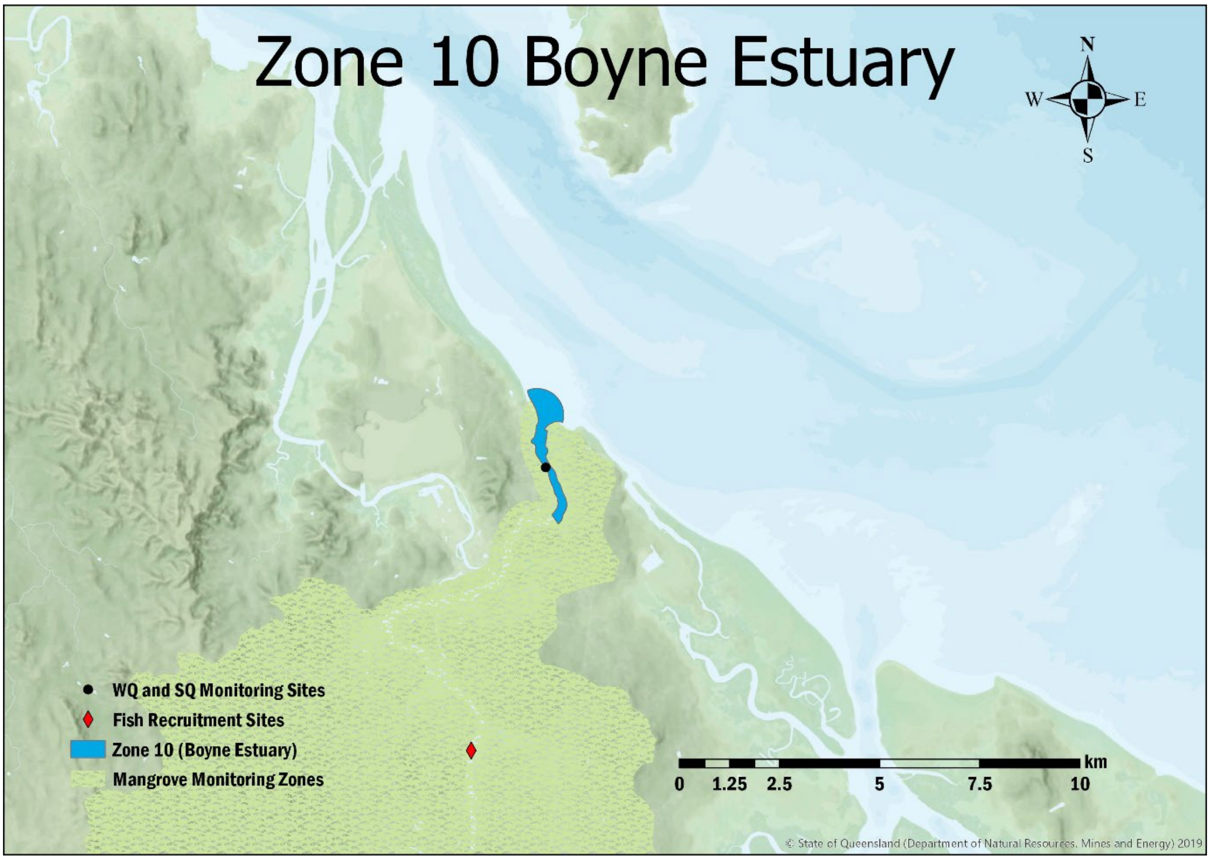

Figure 10.20 | Habitat types and sampling sites in Boyne Estuary.

MONITORING SITES

Water and Sediment Quality	1
Seagrass	0
Fish Recruitment	2
Mud Crab	0
Fish Health	Yes

The Boyne River is dammed at Lake Awoonga to provide potable water for the Gladstone area. Large numbers of Barranundi are stocked in Lake Awoonga and may be introduced into the Boyne Estuary when the dam overtops. The Boyne Estuary was the site of large-scale mortality of many of these introduced Barranundi and other fish in 2011. The lower reach of the Boyne River flows from the dam through predominantly agricultural land that has pockets of remnant vegetation. Before entering the south-eastern section of the Mid Harbour zone, the Boyne River flows through the residential communities of Boyne Island and Tannum Sands.

Figure 10.21 | The mouth of the Boyne River photographed from the north-east. Boyne Island is on the right and Tannum Sands on the left.

10.1.11 Outer Harbour

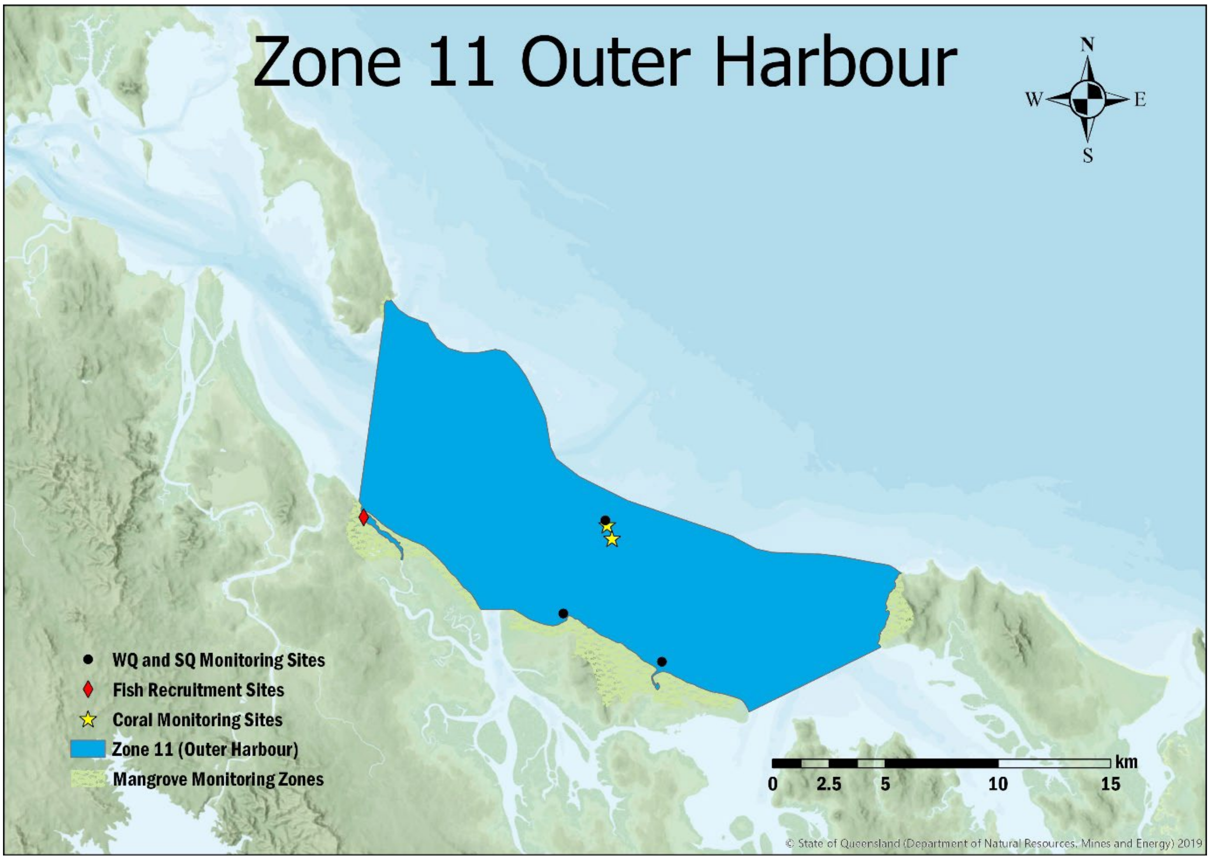

Figure 10.22 | Habitat types and sampling sites in the Outer Harbour.

MONITORING SITES

Water and Sediment Quality	3
Seagrass	0
Fish Recruitment	1
Mud Crab	0
Fish Health	Yes
Coral	2

Situated in open coastal waters between Facing Island and Rodds Bay, the Outer Harbour is the largest of the 13 monitoring zones. Just over 50% of this zone lies within the Gladstone Port Limits. The south-western boundary consists of long sandy beaches and salt pans and mangroves around the entrance to Colosseum Inlet. There are no major industries located along the coastlines of this zone. Coral reefs occur within the zone and there are two coral monitoring sites. The north-eastern boundary consists of open coastal water and a dredge material relocation area is located to the east of this boundary.

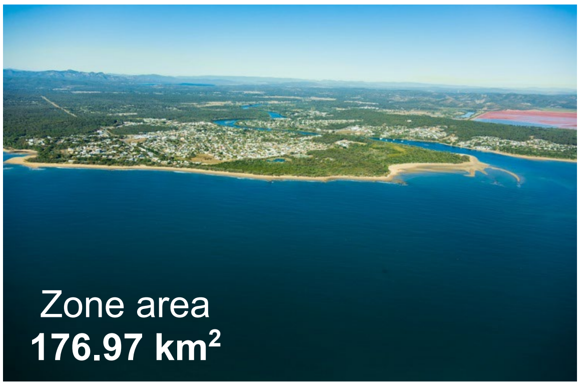

Figure 10.23 | The Outer Harbour and Tannum Sands photographed from the north-east. Boyne Island and one of Gladstone's red mud (bauxite) dams are on the right.

10.1.12 Colosseum Inlet

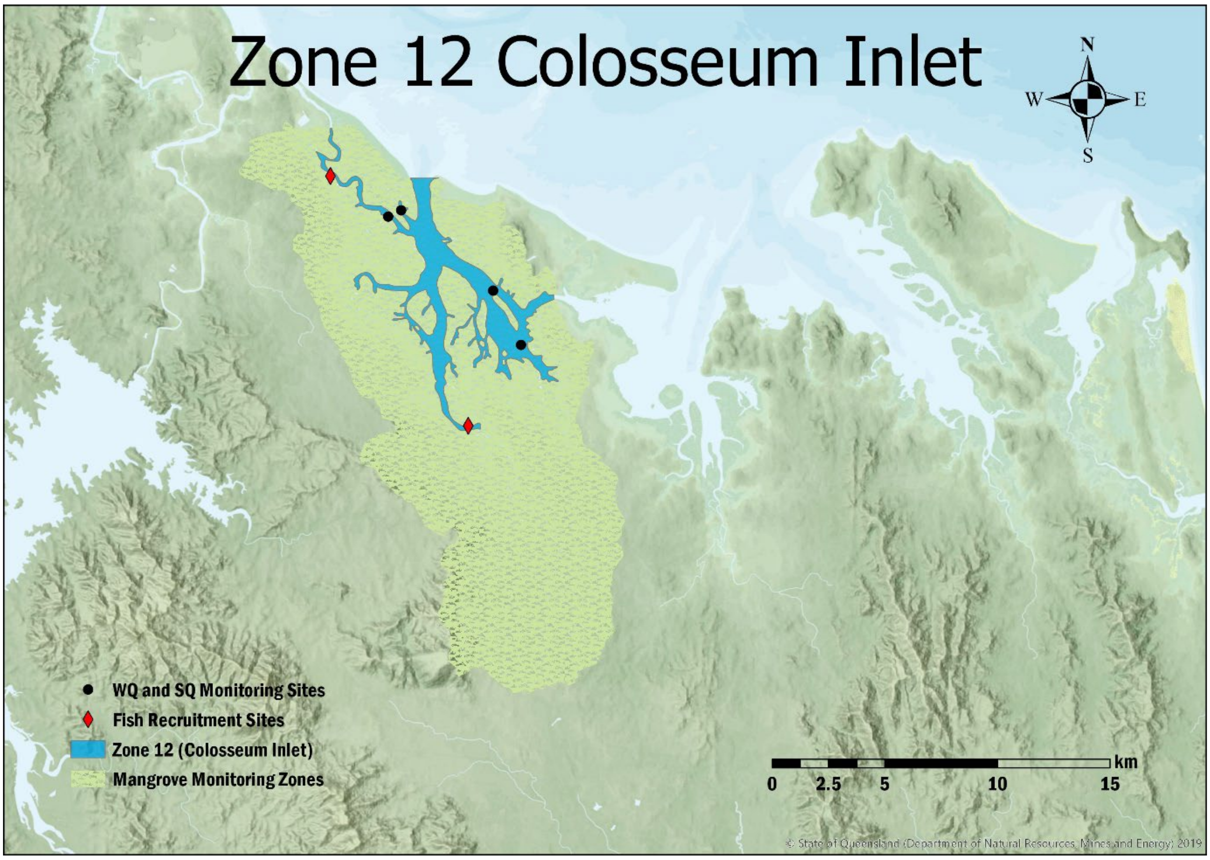

Figure 10.24 | Habitat types and sampling sites in Colosseum Inlet.

MONITORING SITES

Water and Sediment Quality	4
Seagrass	0
Fish Recruitment	2
Mud Crab	0
Fish Health	Yes

Colosseum Inlet is an estuarine zone that is sheltered by Hummock Hill Island. Colosseum Inlet connects to the Outer Harbour and Rodds Bay zones. The inlet has several large tributaries branching off the main creek and all are lined with mangroves and salt pan areas. There are no urban or industrial areas along the coastline of this zone.

Figure 10.25 | The northern entrance to Colosseum Inlet showing Wild Cattle Island on the right and Hummock Hill Island on the left.

10.1.13 Rodds Bay

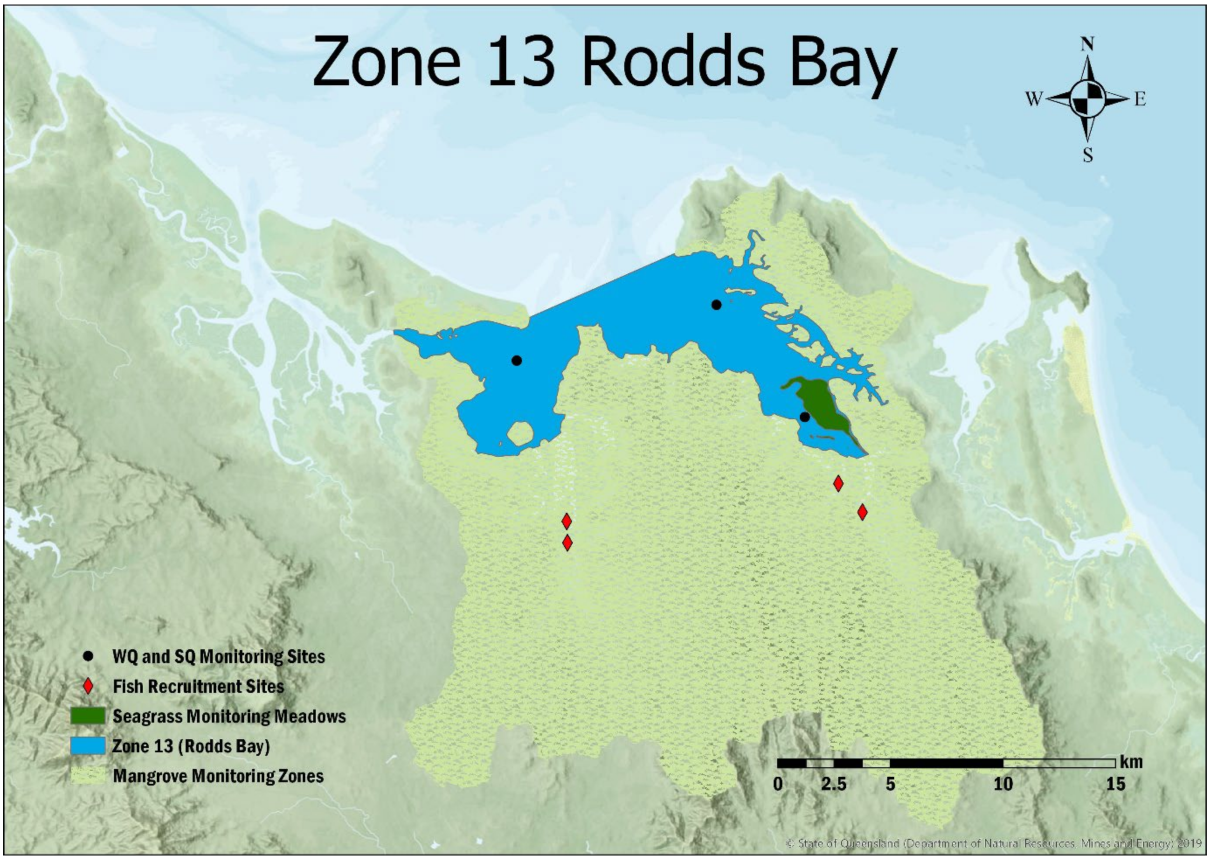

Figure 10.26 | Habitat types and sampling sites in Rodds Bay.

MONITORING SITES

Water and Sediment Quality	2
Seagrass	3
Fish Recruitment	4
Mud Crab	1
Fish Health	Yes

Rodds Bay is located to the south-east of the Outer Harbour zone. It is connected to Colosseum Inlet by a narrow channel behind Hummock Hill Island. The eastern side of Rodds Bay includes a number of mangrove islands. The creeks that flow into the bay are also mangrove-lined and contain large areas of salt pans. This zone also includes three monitored seagrass meadows and the Rodds Bay Dugong Protection area. This is a relatively pristine zone that has significant biodiversity value (Vision Environment Queensland, 2011).

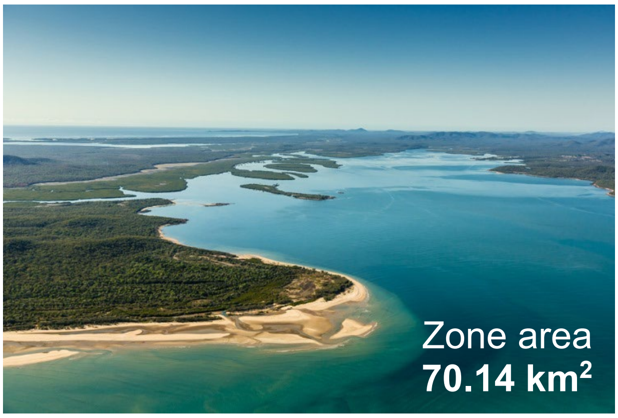

Figure 10.27 | The eastern arm of Rodds Bay showing Rodds Peninsula in the foreground.

10.2 Social, Cultural and Economic reporting areas

Data that contributed to the Social, Cultural (*Sense of Place*) and Economic scores were collected from the Gladstone Region. Participants in the CATI survey were selected from within the Gladstone 4680 postcode area (Figure 10.28). Hotel occupancy rates were based on the Gladstone Local Government Area. The GPC provided the shipping data for the Port of Gladstone.

Commercial fishing data were collected from the area within the Queensland Fisheries S30 Grid (QFish S30) and nearby open coastal waters of Mackay (Grid O25) and Rockhampton/Yeppoon (Grid R29). The latter two grids were used in the analysis to control for spatial differences in catch across years (Figure 10.29)

However, for the marine safety incidents and oil spills social indicator, data originated from Gladstone Maritime Region which includes 1868 km of mainland coastline from Double Island Point to St. Lawrence, 132 km of island coastline and 26,190 km of inland waterways. This region incorporates the Port of Gladstone, Port Alma, Port of Bundaberg and marinas in Hervey Bay, Bundaberg, and Rosslyn Bay (Windle et al., 2018).

Data for the Indigenous Cultural Heritage indicator group were collected from four zones within the Gladstone Local Government Area boundary: The Narrows, Facing Island, Gladstone Central and Wild Cattle Creek (Figure 10.30).

The Narrows

The Narrows is the largest zone. It extends from Deception Creek to the Calliope River anabranch to the south and covers approximately 430 km^2 of the mainland and parts of Curtis Island. The score for the Narrows is based on six sites documented in 2016, three sites documented in 2017 and one site documented in 2018. The cultural locus site is a two-kilometre-long quarry site which was used by Traditional Owners to quarry silcrete to manufacture stone tools. The Traditional Owners and Elders also identified a stone arrangement which resembles a crocodile and linked with ‘Gu-ra-bi’ dreaming at Mt Larcom as of similar cultural significance, so weighted it similar to the quarry site. A number of stone arrangements were found in the north of The Narrows and a number of semi-permanent pools were found in the south-east parts of the zone. A close examination of the material found during the surveys suggested the area was disturbed in the past by fire, water activity, cattle and trampling.

Facing Island

Facing Island is located approximately seven km east of the Gladstone Central Business District. The island covers approximately 57 km^2 land area and mainly consists of long sandy beaches. A total of seven sites have been identified in annual field surveys since 2016 and six sites within this zone were resurveyed in 2018. The cultural locus site for the Facing Island is a large shell midden. Stone tools and shell scatters are located in the south-eastern part of the Facing Island.

Gladstone Central

The Gladstone Central zone covers approximately 173 km^2 area around the Gladstone Central Business District. This zone has been chosen for monitoring as it has a large number of sites which are of cultural significance to Traditional Owners and Elders for fishing, hunting, boating, traditional meetings and ceremonies. This zone had been further extended in 2017 and includes sites near Boyne and Calliope rivers. Barney Point was identified as the cultural locus site in 2017 as Traditional Owners and Elders see this site as being a positive place of significant cultural and social meaning, and more representative of the area than the Police Creek area previously chosen as a cultural locus site in 2016. There are public walking tracks and interpretive signs in this zone explaining the ecology and history of Barney Point. A total of six sites have been identified for annual surveys within this zone since 2016 of which five were revisited in 2018.

Wild Cattle Creek
The Wild Cattle Creek zone covers approximately 92 km^2, running south along the shore from the mouth of the Boyne River, near Tannum Sands, for about 23 km. This zone includes the Wild Cattle Island National Park which is important for endangered migratory birds and nesting sea turtles. The southern part of this zone consists of Hummock Hill Island. In 2017, additional sites from Hummock Hill Island were surveyed. The cultural locus site for the Wild Cattle Creek area is an artefact scatter/shell midden and quarry site at Hummock Hill Island. Traditionally, access to these islands would have been through tidal mudflats and small creek crossings.

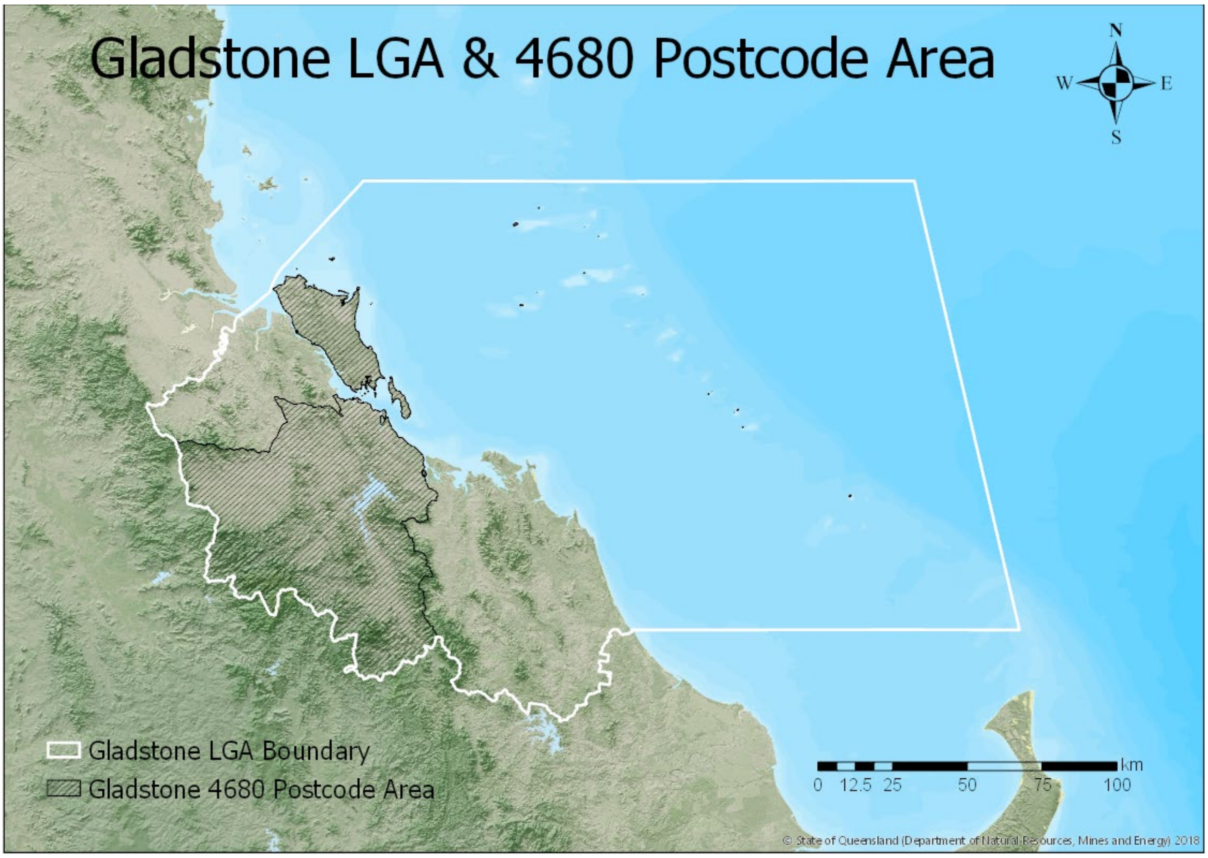

Figure 10.28 | The Gladstone Region showing the mainland extent of the Gladstone Local Government Area and the Gladstone 4680 postcode area. Both were used to define areas from which some social, cultural, and economic data were collected.

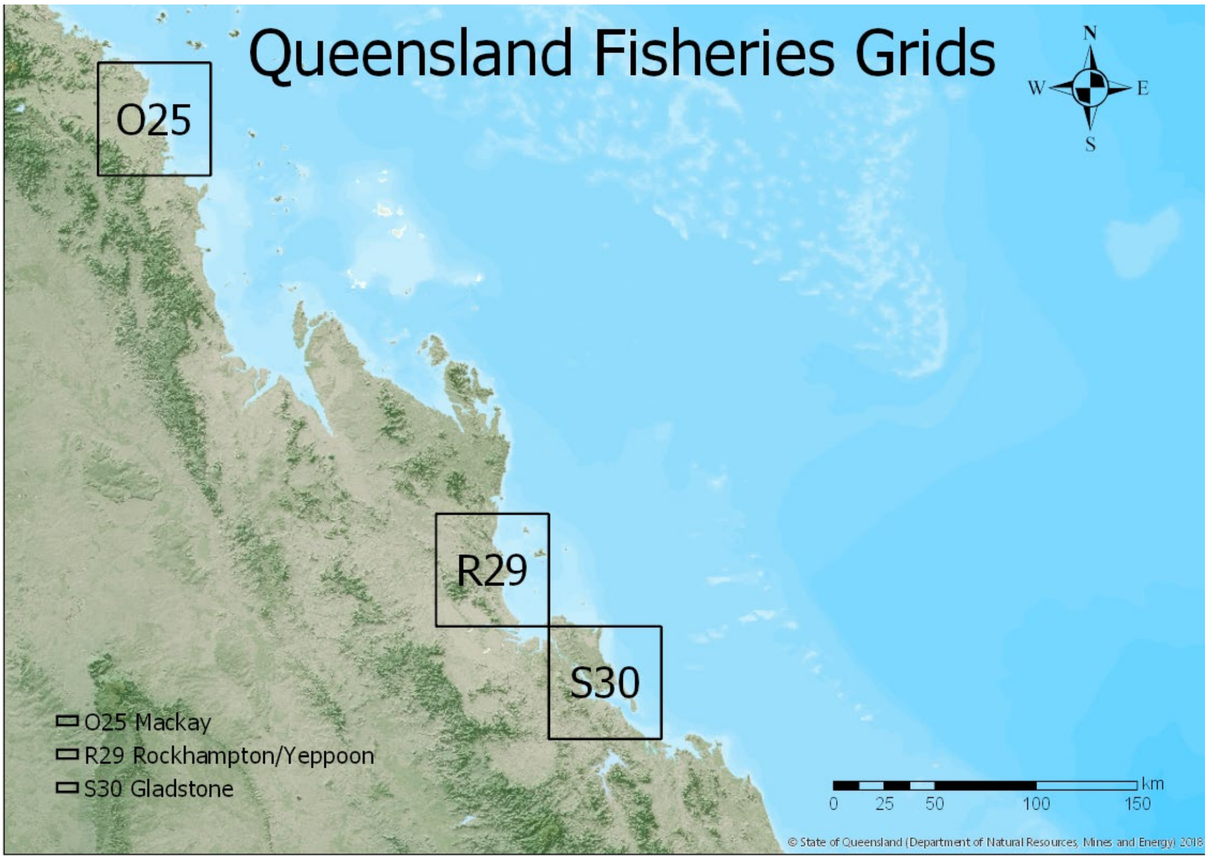

Figure 10.29 | The Queensland Fisheries S30 (Gladstone), R29 (Rockhampton and Yeppoon) and O25 (Mackay) Grids. Data from these grids are used to calculate the Commercial fishing indicator.

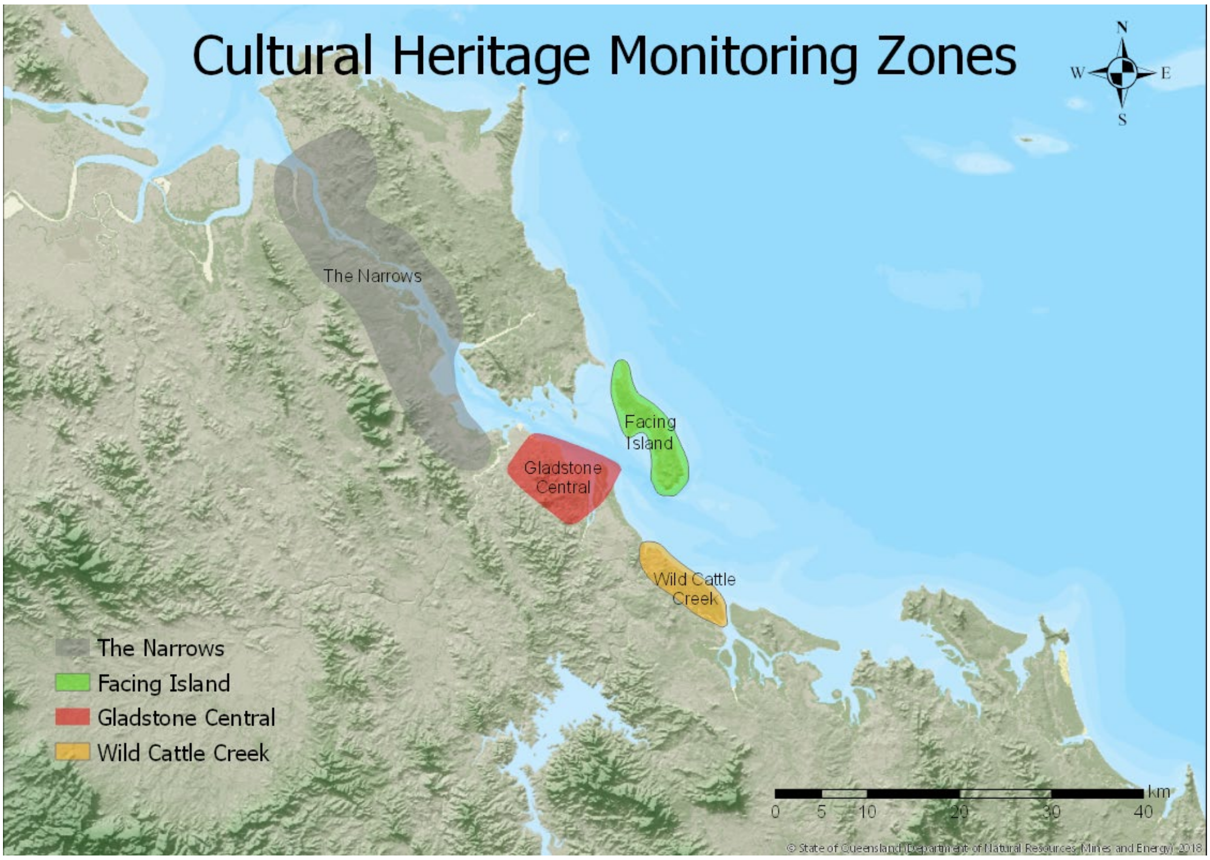

Figure 10.30 | The four reporting zones from which data used to inform the Indigenous Cultural Heritage indicators for 2019 report card were collected.

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12 Glossary

Terms and acronyms	Definition
Asset	A particular feature of value to the GHHP for monitoring and reporting, e.g. seagrass meadows or swimmable beaches
Baseline	A point of reference from which to measure change
CATI	Computer-assisted telephone interviewing
Component	The Gladstone Harbour Report Card will report on four components of harbour health: Environmental, Cultural, Social and Economic.
CPUE	Catch per unit effort
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DIMS	Data Information Management System
Ecosystem health	An ecosystem that is stable and sustainable, maintaining its organisation and autonomy over time and its resilience to stress. Ecosystem health can be assessed using measures of resilience, vigour and organisation. Source: http://www.biodiversity.govt.nz/picture/doing/nzbs/glossary.html
Environmental indicators	Metrics derived from observation used to identify indirect drivers of environmental problems (e.g. population growth), direct pressures on the environment (e.g. overfishing), environmental condition (e.g. contaminant concentrations), broader impacts of environmental condition (e.g. health outcomes) or effectiveness of policy responses (de Sherbinin et al., 2013)
GHHP	Gladstone Healthy Harbour Partnership
Guidelines and criteria	Science-based numerical concentration limits or descriptive statements recommended to support a designated water use. Guidelines are not legally enforceable.
Visual fish condition	An automated visual assessment of images captured by fishers using a mobile phone app.
Fish HAI	Health Assessment Index A thorough assessment of the health of individual fish based on visual condition and the condition of several internal organs and tissues.
Indicator	Numerical values that provide insight into the state of the environment, or human health etc. The environment is highly complex and indicators provide a simple, practical way to track changes in the state of the environment over time.
Liveability	In this report, liveability is used to refer to a *Sense of Place*, quality of housing, provision of health services, recreation facilities, attraction of the urban environment and availability of services.
Metadata	‘data about data’, the series of descriptors used to identify a particular dataset (e.g. author, date of creation, format of the data, location of the data points)
MMP	Marine Monitoring Program
Model/modelling	The creation of conceptual, graphical or mathematical models to describe, visualise or test abstract concepts and processes. Models

	help explain complex real-world interactions and add to our ability to understand how human actions impact on ecosystems. Models can be used to analyse scenarios to support decision making.
PCIMP	Port Curtis Integrated Monitoring Program
Physicochemical	Physical and chemical forces that influence the environment and the biodiversity and people within e.g. temperature, salinity
Point source	A single, identifiable localised source of a release e.g. a stormwater outlet
QA/QC	Quality assurance/quality control – the processes used to ensure the quality of a product (QA), and then to assess whether the product or services meet quality standards then correct where necessary to meet those standards (QC). Raw data may contain errors or be in formats unsuitable for further analysis, so appropriate QC needs to be applied to assess and correct data.
QFish	Queensland Fishing
Raw data (also 'primary data')	Data that have not been processed or otherwise manipulated apart from QA/QC to ensure accuracy
Reference condition	Recorded indicator values are compared against values from sites not impacted by human disturbance or alteration, or, which represent a control site considered to be 'healthy' (Connolly et al., 2013)
Standards	Legal limits permitted for a specific water body
TC	Tropical cyclone
TCM	Travel cost method
TropWATER	Centre for Tropical Water & Aquatic Ecosystem Research (James Cook University)
WICET	Wiggins Island Coal Export Terminal

Appendix 1. GHHP science projects

All project reports can be found on the GHHP website: www.ghhp.org.au/project-reports.

Project name and institution	Reports and publications
ISP001 Mapping and synthesis of data and monitoring in Gladstone Harbour Australian Institute of Marine Science	Llewellyn L, Wakeford M and McIntosh E (2013). *Mapping and synthesis of data and monitoring in Gladstone Harbour*. A report to the Independent Science Panel of the Gladstone Healthy Harbour Partnership, August 2013. Australian Institute of Marine Science, Townsville.
ISP002 Review of the use of report cards for monitoring ecosystem and waterway health	Connolly RM, Bunn S, Campbell M, Escher B, Hunter J, Maxwell P, Page T, Richmond S, Rissik D, Roiko A, Smart J, and Teasdale P (2013). *Review of the use of report cards for monitoring ecosystem and waterway health*. Report to: Gladstone Healthy Harbour Partnership, November 2013. Queensland, Australia.
ISP003 Models and indicators of key ecological assets in Gladstone Harbour CSIRO Wealth from Oceans Flagship	Dambacher JM, Hodge KB, Babcock RC, Fulton EA, Apte SC, Plagányi ÉE, Warne M and Marshall NA (2013). *Models and indicators of key ecological assets in Gladstone Harbour*. A report prepared for the Gladstone Healthy Harbour Partnership. CSIRO Wealth from Oceans Flagship, Hobart.
ISP004 Guidance for the selection of social, cultural and economic indicators for the development of the Gladstone Healthy Harbour Report Card CQUniversity	Greer L and Kabir Z (2013). *Guidance for the selection of social, cultural and economic indicators for the development of the Gladstone Harbour Report Card*. Report to the Gladstone Healthy Harbour Partnership, School of Human Health and Social Science. CQUniversity Australia, Rockhampton.

ISP005 Social, cultural and economic components CSIRO (2014 – 2015) CQUniversity (2016 – 2022)	Pascoe S, Cannard T, Marshall N, Windle J, Flint N, Kabir Z and Tobin R (2014). *Piloting of social, cultural and economic indicators for the Gladstone Healthy Harbour Partnership Report Card*. Draft report prepared for the GHHP by CSIRO, Oceans and Atmosphere Flagship. Cannard T, Windle J and Tobin R (2015). *Final Report on the Status of Economic, Social and Selected Cultural Indicators for the Gladstone Harbour 2015 Report Card.* Report for the Gladstone Healthy Harbour Partnership. CSIRO Oceans and Atmosphere Flagship. Australia. Windle J, De Valck J, Flint N and Star M (2016). Final report on the status of the social, cultural (*Sense of Place*) and economic components for the Gladstone Harbour 2016 Report Card. CQUniversity, Rockhampton. Windle J, De Valck J, Flint N and Star M (2017). Final report on the status of the social, cultural (*Sense of Place*) and economic components for the Gladstone Harbour 2016 Report Card. CQUniversity, Rockhampton. Windle J, De Valck J, Flint N and Star M (2018) Report on the status of the social, cultural (*Sense of Place*) and economic components for the Gladstone Harbour 2018 Report Card. CQUniversity, Rockhampton. De Valck J, Star M and Flint N (2019) Report on the status of the social, cultural (*Sense of Place*) and economic components for the Gladstone Harbour 2019 Report Card. CQUniversity, Rockhampton. De Valck J (2022) Final report on the status of the Social, Cultural (*Sense of Place*) and Economic components for the 2022 Gladstone Harbour Report Card. CQUniversity. Report to the Gladstone Healthy Harbour Partnership, July 2022.
ISP006 Development of a Gladstone Harbour Model to support the Gladstone Healthy Harbour Report Card CSIRO Wealth from Oceans Flagship	Fulton EA and van Putten I (2014) *Project ISP006: Milestone report December 2014*. CSIRO, Australia. Baird M and Margvelashvili N (2015) *Receiving Water Quality & Sediment Scenarios:* Final Report. CSIRO, Australia. Fulton EA, Hutton T, van Putten IE, Lozano-Montes H and Gorton R (2017) *Gladstone Atlantis Model – Implementation and initial results*. Report to the Gladstone Healthy Harbour Partnership. CSIRO, Australia.

ISP007 Development of connectivity indicators for the Gladstone Healthy Harbour Report Card CSIRO Wealth from Oceans Flagship, University of Queensland	Condie S, Herzfeld M, Andrewartha J, Gorton B and Hock K (2015). *Project ISP007: Development of connectivity indicators for the 2014 Gladstone Harbour Report Card*. CSIRO Wealth from Oceans Flagship, Hobart, University of Queensland. Condie S, Herzfeld M, Andrewartha J, Gorton B and Hock K (2015). *Connectivity indicators for the 2015 Gladstone Harbour Report Card*. CSIRO Wealth from Oceans Flagship, Hobart, University of Queensland. Condie S, Herzfeld M, Andrewartha J, Gorton B and Hock K (2017). *Connectivity indicators for the 2016 Gladstone Harbour Report Card.* CSIRO Wealth from Oceans Flagship, Hobart, University of Queensland. Gorton R, Condie S and Andrewartha J (2017) *2016-17 Connectivity indicators for the Gladstone Harbour Report Card*. CSIRO Oceans and Atmosphere, Hobart.
ISP008 Provision of statistical support during the development of the Gladstone Harbour Report Card Queensland University of Technology	Johnson S, Logan M, Fox D and Mengersen K (2015). ISP008 Final Report (revised) *Provision of statistical support during the development of the Gladstone Harbour Report Card*. Queensland University of Technology, Brisbane.
ISP008 Provision of statistical support during the development of the Gladstone Harbour Report Card Australian Institute of Marine Science	Logan M (2015) Provision of final environmental grades and scores for the 2015 Gladstone Harbour Report Card. Australian Institute of Marine Science, Townsville.
ISP009 Development of a Data Information Management System for the Gladstone Harbour Report Card monitoring data	Australian Institute of Marine Science (2014). *Design and architecture of the Data Information Management System (DIMS) for the Gladstone Harbour Report Card monitoring data*. Project ISP009. Australian Institute of Marine Science, Townsville.

ISP010 Statistical assessment of the fish indicators and score for the pilot report card Bill Venables, CSIRO Research Fellow	Venables WN (2015). *GHHP Barramundi Recruitment Index Project Final Report*. Gladstone Healthy Harbour Partnership, Gladstone.
ISP011 Seagrass indicators Centre for Tropical Water & Aquatic Ecosystem Research (James Cook University)	Bryant CV, Jarvis JC, York PH and Rasheed MA (2014). *Gladstone Healthy Harbour Partnership Pilot Report Card: ISP011 Seagrass Draft Report – October 2014*. Centre for Tropical Water & Aquatic Ecosystem James Cook University. Carter AB, Jarvis JC, Bryant CV and Rasheed MA (2015). *Gladstone Healthy Harbour Partnership 2015 Report Card ISP011: Seagrass final report*. Centre for Tropical Water & Aquatic Ecosystem Research James Cook University, Cairns. Carter AB, Bryant CV, Davies JD and Rasheed MA (2016). *Gladstone Healthy Harbour Partnership 2016 Report Card ISP011: Seagrass final report*. Centre for Tropical Water & Aquatic Ecosystem Research James Cook University, Cairns. Carter AB, Wells JN & Rasheed MA (2017). *Gladstone Healthy Harbour Partnership 2017 Report Card, ISP011: Seagrass*. Centre for Tropical Water & Aquatic Ecosystem Research James Cook University, Cairns. Bryant CV, Carter AB, Chartrand KM, Wells JN & Rasheed MA (2018) *Gladstone Healthy Harbour Partnership 2018 Report Card, ISP011: Seagrass.* Centre for Tropical Water & Aquatic Ecosystem Research James Cook University, Cairns. Carter AB, Chartrand KM, Wells JN & Rasheed MA (2019) *Gladstone Healthy Harbour Partnership 2019 Report Card*, *ISP011: Seagrass*. Centre for Tropical Water & Aquatic Ecosystems Research James Cook University, Cairns. Carter AB, Bryant CV, Smith, T, Rasheed MA (2020) *Gladstone Healthy Harbour Partnership 2020 Report Card Summary, ISP011: Seagrass*. Centre for Tropical Water & Aquatic Ecosystem Research James Cook University,, Cairns. Smith T, Carter AB and Rasheed MA (2021) *Gladstone Healthy Harbour Partnership 2020 Report Card Summary, ISP011: Seagrass.* Centre for Tropical Water & Aquatic Ecosystem Research James Cook University, Cairns.

ISP011 Seagrass indicators Centre for Tropical Water & Aquatic Ecosystem Research (James Cook University)	Smith T, Carter AB and Rasheed MA (2022) *Gladstone Healthy Harbour Partnership 2022 Report Card Summary, ISP011: Seagrass*. Centre for Tropical Water & Aquatic Ecosystem Research James Cook University, Cairns. Smith T, Reason C and Rasheed MA (2023) *Gladstone Healthy Harbour Partnership 2023 Report Card Summary, ISP011: Seagrass*. Centre for Tropical Water & Aquatic Ecosystem Research James Cook University, Cairns. Smith T, Reason C and Rasheed MA (2024) *Gladstone Healthy Harbour Partnership 2024 Report Card Summary, ISP011: Seagrass*. Centre for Tropical Water & Aquatic Ecosystem Research James Cook University, Cairns.
ISP012 Cultural heritage indicators Terra Rosa Consulting	Terra Rossa Consulting (2016). *Developing Cultural Heritage Indicators for the Gladstone Healthy Harbour Partnership: Project ISP012 Final Report.* Terra Rossa Consulting, Perth. Terra Rossa Consulting (2017). *Developing Cultural Heritage Indicators for the Gladstone Healthy Harbour Partnership: Project ISP012 Final Report.* Terra Rossa Consulting, Perth. Terra Rossa Consulting (2018) *Final Report: ISP012-2018: Indigenous cultural heritage Indicators for the Gladstone Harbour Report Card*. Terra Rossa Consulting, Western Australia.

ISP013 Fish recruitment indicators Infofish Australia Pty Ltd and Dr Bill Venables	Sawynok B, Parsons W, Mitchell J and Sawynok S (2015) *Gladstone fish recruitment 2015.* Report for the Gladstone Healthy Harbour Partnership, Gladstone. Venables WN (2015). *GHHP Barramundi recruitment index project final report*. Gladstone Health Harbour Partnership, Gladstone. Sawynok B and Venables B (2016). *Developing a Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2016.* Report for the Gladstone Healthy Harbour Partnership, Gladstone. Sawynok B and Venables B (2017). *Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2017.* Report for the Gladstone Healthy Harbour Partnership, Gladstone. Sawynok B and Venables B (2018). *Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2018.* Report for the Gladstone Healthy Harbour Partnership, Gladstone. Sawynok B and Sawynok S (2019). *Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2019.* Report for the Gladstone Healthy Harbour Partnership, Gladstone. Sawynok B and Sawynok S (2020). *Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2020*. Report for the Gladstone Healthy Harbour Partnership, Gladstone. Sawynok B and Sawynok S (2021) *Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2021.* Report for the Gladstone Healthy Harbour Partnership, Gladstone. Sawynok B and Sawynok S (2022) *Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2022.* Report for the Gladstone Healthy Harbour Partnership, Gladstone. Sawynok B and Sawynok S (2023) *Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2023.* Report for the Gladstone Healthy Harbour Partnership, Gladstone.

ISP013 Fish recruitment indicators Infofish Australia Pty Ltd and Dr Bill Venables	Sawynok B and Sawynok S (2024) *Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2024.* Report for the Gladstone Healthy Harbour Partnership, Gladstone.
ISP014 Coral indicators Australian Institute of Marine Science	Thompson A, Costello P and Davidson J (2015). *Development of coral indicators for the Gladstone Harbour Report Card, ISP014: Coral*. Australian Institute of Marine Science, Townsville. Costello P, Thompson A, Davidson J (2018) *Coral Indicators for the 2018 Gladstone Harbour Report Card: ISP014.* Report prepared for Gladstone Healthy Harbour Partnership. Australian Institute of Marine Science, Townsville. Costello P, Thompson A, Davidson J (2019) *Coral Indicators for the 2019 Gladstone Harbour Report Card 2019: ISP014.* Report prepared for Gladstone Healthy Harbour Partnership. Australian Institute of Marine Science, Townsville. Costello P, Thompson A, Davidson J (2020) *Coral Indicators for the 2020 Gladstone Harbour Report Card: ISP014.* Report prepared for Gladstone Healthy Harbour Partnership. Australian Institute of Marine Science, Townsville. Thompson A, Costello P and Davidson J (2021) *Coral Indicators for the 2021 Gladstone Harbour Report Card: ISP014.* Report prepared for Gladstone Healthy Harbour Partnership. Australian Institute of Marine Science, Townsville. Thompson A, Thompson C and Davidson J (2022) *Coral Indicators for the 2022 Gladstone Harbour Report Card: ISP014.* Report prepared for Gladstone Healthy Harbour Partnership. Australian Institute of Marine Science, Townsville. Thompson C, Thompson A and Davidson J (2023) *Coral Indicators for the 2023 Gladstone Harbour Report Card: ISP014.* Report prepared for Gladstone Healthy Harbour Partnership. Australian Institute of Marine Science, Townsville. Thompson C, Thompson A and Davidson J (2024) *Coral Indicators for the 2024 Gladstone Harbour Report Card: ISP014.* Report prepared for Gladstone Healthy Harbour Partnership. Australian Institute of Marine Science, Townsville.

ISP015 Developing an indicator for mud crab (*Scylla serrata*) abundance in Gladstone Harbour	Brown IW (2015). *Comments on Gladstone Healthy Harbour Partnership (GHHP) proposed Project ISP015: Developing an indicator for mud crab* Scylla serrata *abundance in Gladstone Harbour.* Report prepared for the Gladstone Healthy Harbour Partnership, Gladstone.
ISP015 Mud crab indicators CQUniversity	Flint N, De Valck J, Anastasi A and Jackson EL (2019) *Mud crab indicators for the Gladstone Harbour Report Card.* Report to the Gladstone Healthy Harbour Partnership. CQUniversity, Rockhampton. Flint N, De Valck J, Anastasi A and Jackson EL (2020). *Mud crab indicators for the Gladstone Harbour Report Card.* Report to the Gladstone Healthy Harbour Partnership. CQUniversity, Rockhampton. Flint N, De Valck J and Anastasi A (2021). *Mud crab indicators for the Gladstone Harbour Report Card.* Report to the Gladstone Healthy Harbour Partnership. CQUniversity, Rockhampton. Flint N, De Valck J and Anastasi A (2022). *Mud crab indicators for the Gladstone Harbour Report Card.* Report to the Gladstone Healthy Harbour Partnership. CQUniversity, Rockhampton. Flint N, De Valck J and Anastasi A (2023). *Mud Crab Indicators for the 2023 Gladstone Harbour Report Card.* Report to the Gladstone Healthy Harbour Partnership. CQUniversity, Rockhampton. Flint N, De Valck J and Anastasi A (2024). *Mud Crab Indicators for the 2024 Gladstone Harbour Report Card.* Report to the Gladstone Healthy Harbour Partnership. CQUniversity, Rockhampton.
ISP016 GHHP Gladstone fish health research program (a) Gladstone Harbour Healthy Partnership, Fisheries Research and Development Canberra, AusVet Animal Health Services	Fisheries Research Development Corporation (2015). *Development of the Gladstone Healthy Harbour Partnership Fish Health Research Program.* FRDC, Canberra.
ISP016 GHHP Gladstone fish health research program (b) Australian Institute of Marine Sciences	Kroon FJ, Streten C and Harries SJ (2016). *The use of biomarkers in fish health assessment worldwide and their potential use in Gladstone Harbour*. Australian Institute of Marine Science, Townsville.

ISP016 GHHP Gladstone fish health research program (c) Infofish Australia Pty Ltd	Sawynok W, Sawynok S and Dunlop A (2018). *New Tools to Assess Visual Fish Health.* FRDC report, Infofish Australia Pty Ltd, Rockhampton.
ISP017 Additional PAH monitoring Port Curtis Integrated Monitoring Program	The results of the PAH sediment sampling were included in the 2015 Gladstone Harbour Report Card and supporting technical report and website.
ISP018 Development of mangrove indicators for the Gladstone Harbour Report Card JCU/TropWATER	Duke NC and Mackenzie J (2018). *Project ISP018: Development of Mangrove Indicators for the Gladstone Harbour Report Card.* Report to Gladstone Healthy Harbour Partnership by TropWATER Centre. James Cook University, Townsville. Duke NC and Mackenzie J (2019). *Project ISP018-2019: Development of Mangrove Indicators for the 2019 Gladstone Harbour Report Card*. Report to Gladstone Healthy Harbour Partnership by TropWATER Centre. James Cook University, Townsville. Duke NC and Canning A (2024). Project ISP018-2024: *Development of mangrove indicators for the 2024 Gladstone Harbour Report Card*. Report to Gladstone Healthy Harbour Partnership by TropWATER Centre. Publication 24/59, James Cook University, Townsville.
ISP019 Coral coring in Gladstone Harbour to enable a comparison of pre- and post-industrial eras in Gladstone Harbour Australian Institute of Marine Science	Cantin NE, Fallon S, Wu Y and Lough JM (2018). *Project ISP019: Calcification and Geochemical Signatures of Industrial Development of the Gladstone Harbour from Century Old Coral Skeletons.* Report prepared for Gladstone Healthy Harbour Partnership. Australian Institute of Marine Science, Townsville, Qld.
ISP020 Further development of R scripts to calculate, aggregate and integrate cultural heritage indicators with Bayesian model and Data Information Management System	Pascoe S and Venables B (2017). *Further Development of R Scripts to Calculate, Aggregate and Integrate Cultural Heritage Indicators with GHHP Data Information Management System*. CSIRO, Brisbane.

ISP023a Fish health indicators CQUniversity	Flint N, Irving A, Anastasi A, De Valck J and Jackson EL (2019). *A Fish Health Indicator for the 2019 Gladstone Harbour Report Card.* Final report to the Gladstone Healthy Harbour Partnership. CQUniversity, Rockhampton. Flint N, Irving A, Anastasi A, De Valck J and Jackson EL (2020). *A Fish Health Indicator for the 2020 Gladstone Harbour Report Card*. Final report to the Gladstone Healthy Harbour Partnership. CQUniversity, Rockhampton. Flint N, Irving A, Anastasi A, De Valck J (2021). *A Fish Health Indicator for the 2021 Gladstone Harbour Report Card: Project Report ISP023-2021*. CQUniversity, Rockhampton.
ISP023b Visual fish health indicators Infofish Australia Pty Ltd	Sawynok S, Sawynok B, Dunlop A and Sawynok P (2019). *Visual Fish Health Indicators for the Gladstone Harbour Report Card 2019*. Infofish Australia Pty Ltd, Rockhampton Queensland. Sawynok S, Sawynok B, Dunlop A and Sawynok P (2020). *Visual Fish Health Indicators for the Gladstone Harbour Report Card 2020*. Infofish Australia Pty Ltd, Rockhampton Queensland. Sawynok S, Sawynok B, Reid J and Sawynok P (2021). *Visual Fish Health Indicators for the Gladstone Harbour Report Card 2021*. Infofish Australia Pty Ltd, Rockhampton Queensland. Sawynok S, Sawynok B and Sawynok P (2022). *Fish Condition Indicators for the Gladstone Harbour Report Card 2022.* Infofish Australia Pty Ltd, Murarrie Queensland. Sawynok S, Sawynok B and Sawynok P (2023). *Fish Condition Indicators for the Gladstone Harbour Report Card 2023.* Infofish Australia Pty Ltd, Murarrie Queensland. Sawynok S, Sawynok B and Sawynok P (2024). *Fish Condition Health Indicators for the Gladstone Harbour Report Card 2024.* Infofish Australia Pty Ltd, Murarrie Queensland.
Water and Sediment Quality Reports Gladstone Healthy Harbour Partnership. Data provided by Port Curtis Integrated Monitoring Program.	Schultz M, Uthpala P and Hansler M (2019). *Water and Sediment Quality Indicators for the Gladstone Harbour Report Card 2017.* Gladstone Healthy Harbour Partnership, Gladstone. Hansler M, Schultz M and Uthpala P (2020). *Water and Sediment Quality Indicators for the Gladstone Harbour Report Card 2018.* Gladstone Healthy Harbour Partnership, Gladstone.

Appendix 2. Water Quality Objectives and guidelines used to calculate water quality scores

Zone	Level of Protection	Physicochemical				Nutrients			Metals					
		Turbidity		*pH range*										
		Dry (NTU)	Wet (NTU)	<40 ms/cm	>40 ms/cm	TN (µg/L)	TP (µg/L)	Chl-*a* (µg/L)	Al (µg/L)	Cu (µg/L)	Pb (µg/L)	Mn (µg/L)	Ni (µg/L)	Zn (µg/L)
1. The Narrows	HEV	7	15	7.2–8.2	7.4–8.3	170	20	1	24	1.3	4.4	80	7	15
2. Graham Creek	MD	8	13	7.2–8.2	7.4–8.3	170	20	1	24	1.3	4.4	80	7	15
3. Western Basin	MD	8	13	7.2–8.2	7.4–8.3	170	18	1	24	1.3	4.4	80	7	15
4. Boat Creek	MD	14	25	7.2–8.2	7.4–8.3	190	22	2	24	1.3	4.4	80	7	15
5. Inner Harbour	MD	8	13	7.2–8.2	7.4–8.3	160	21	1	24	1.3	4.4	80	7	15
6.Calliope Estuary	MD	11	11	7.2–8.2	7.4–8.3	175	22	1.7	24	1.3	4.4	80	7	15
7.Auckland Inlet	MD	6	8	7.2–8.2	7.4–8.3	160	16	1.9	24	1.3	4.4	80	7	15
8.Mid Harbour	MD	4	9	7.2–8.2	7.4–8.3	135	14	1	24	1.3	4.4	80	7	15
9. South Trees Inlet	MD	11	13	7.2–8.2	7.4–8.3	170	20	1.1	24	1.3	4.4	80	7	15
10. Boyne Estuary	MD	3	5	7.2–8.2	7.4–8.3	120	11	0.8	24	1.3	4.4	80	7	15
11. Outer Harbour	MD	3	7	8.0–8.2		130	13	1	24	1.3	4.4	80	7	15
12. Colosseum Inlet	HEV	3	7	7.2–8.2	7.4–8.3	130	10	0.8	24	1.3	4.4	80	7	15
13. Rodds Bay	HEV	4	5	7.2–8.2	7.4–8.3	160	13	1	24	1.3	4.4	80	7	15

Note: Water Quality Objectives and guideline values provided by DEHP Water Quality Objectives for the Capricorn Curtis Coast (DEHP, 2014) for pH, turbidity and nutrients; ANZG (2018) for metals in water and sediments (except aluminium); and Golding et al. (2014) for aluminium in marine waters.

Turbidity: The 50th percentile from the guideline values is applied to all harbour zones. Dry season guidelines apply from May to October. Wet season guidelines apply from November to April. NTU: nephelometric turbidity unit.

pH range: The pH range falls between the 20th and 80th percentile of the guideline values. Different guideline values are applied for conductivity measurements of <40 ms/cm and >40 ms/cm.

Nutrients: For all nutrients, total nitrogen (TN), total phosphorus (TP) and chlorophyll-*a* (Chl-*a*) the 50th percentile from the guideline values is applied.

Aluminium: The aluminium (Al) guideline for moderately disturbed (MD) systems (24 µg/L, 95% species protection) is applied to all harbour zones.

Manganese: The manganese (Mn) guideline (80 µg/L) from the ANZG (2018) water quality guidelines is applied to all harbour zones.

Other Metals: The 95% species protection value from the ANZG (2018) water quality guidelines is applied to copper (Cu), lead (Pb), and zinc (Zn) while the 99% species protection value is applied to nickel (Ni). Trigger values were selected for moderately disturbed systems.

Appendix 3. Sediment quality guidelines used to calculate sediment quality scores

Indicator	Measure	Concentration (mg/kg)	Guideline based on
	Arsenic (As)	20	ANZG, 2018
	Cadmium (Cd)	1.5	ANZG, 2018
	Copper (Cu)	65	ANZG, 2018
Metals and metalloid	Lead (Pb)	50	ANZG, 2018
	Mercury (Hg)	0.15	ANZG, 2018
	Nickel (Ni)	21	ANZG, 2018
	Zinc (Zn)	200	ANZG, 2018

Appendix 4. Data filtering methods for Natural Resource Management (NRM) area litter metric report card

By: Jordan Gacutan (UNSW, Sydney)
Prepared for: Fitzroy Basin Association (FBA) [host of Gladstone Healthy Harbour Partnership in 2021–22]
On behalf of: Tangaroa Blue Foundation and UNSW, Sydney

Summary
The following brief provides an overview of the methods used to process the Australian Marine Debris Initiative (AMDI) database (henceforth **'raw data'**) to a '**custom dataset'**, as in input for the model described in Whitehead and Venables (2019).

Rationale

- Support continued monitoring of litter to detect changes due to source reduction / policy implementation within Great Barrier Reef catchments.
- Standardise litter reporting across NRMs, supported by the AMDI database.
- Implementation of Australian Marine Debris Initiative in reporting and decision-making.
- Support the UN Sustainable Development Goals [14.1.1, marine plastic pollution].

Figures
Figure A4.1 | Data pipeline for project, to extract key items# (plastic bags, plastic bottles, single-use cutlery, and cigarettes) from the Australian Marine Debris Initiative (AMDI) database for annual use in a statistical model, for production of litter scores and grades. NRM = Natural Resource Management area, NB = Negative binomial.

Tables
Table A4.1 | Data quality filters used to process the Australian Marine Debris Initiative database. Filters are in sequential order.
Table A4.2 | Provided shapefiles used to classify data by NRM reporting needs.

Description

This project extends the statistical model and analyses presented in the report "Litter Score and Grade Proposal for Townsville". The existing model has been implemented for the Natural Resource Management (NRM) area 'Dry Tropics' (DT). The model, and required data processing, have been extended to the 'Wet Tropics' (WT) and 'Mackay-Whitsunday-Isaac' (MWI) NRMs.

In December 2020, Tangaroa Blue Foundation (TBF) and UNSW, Sydney were asked to provide a data pipeline, to process raw data from the AMDI dataset for use in a statistical model. The pipeline facilitates the extraction and processing of data for future reporting needs. Tasks to be performed by UNSW, Sydney are described in the '**data sharing agreement**' between Tangaroa Blue Foundation, UNSW, Sydney, and the report card body.

The data pipeline involves filtering (1) data quality, (2) spatially to the reporting area, and (3) model use, described in Figure A4.1. Treatment of **ReefClean** data is described in Section 1.

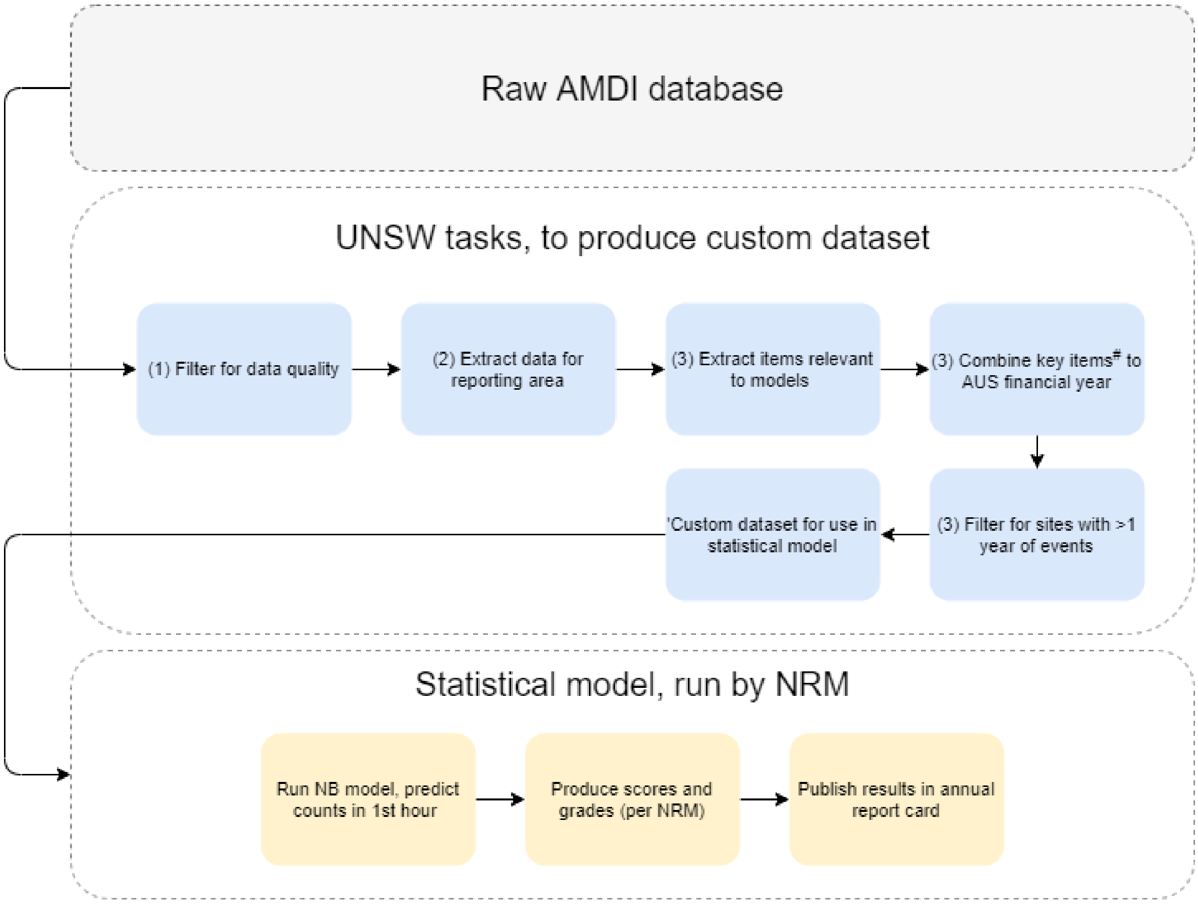

Figure A4.12.1 | Data pipeline for project, to extract key items# (plastic bags, plastic bottles, single-use cutlery, and cigarettes) from the Australian Marine Debris Initiative (AMDI) database for annual use in a statistical model, for production of litter scores and grades. NRM = Natural Resource Management area, NB = Negative binomial.

Filter for data quality

Filtering for data quality is taken from methods and related scripts of the publication, 'Continental trends in marine debris revealed by a decade of citizen science' (*in prep*). The filters used are presented in Table A4.1. As the work in is in preparation, scripts are currently unavailable.

ReefClean data was identified and processed separately, aggregating all transects and debris collected in surrounding areas, to align with data from community clean-ups stored within the AMDI database. Loss of resolution was justified by model needs.

Table A4.12.1 | Data quality filters used to process the Australian Marine Debris Initiative database. Filters are in sequential order.

Cleaning theme	Tool used	Cleaning step	Examples / Description
Original database	DB Browser for SQL lite	Original database (Downloaded January 2021)	N/A
Limit to Australia	ArcMap 10.6	Remove foreign entries	Hawaii / Tonga / NZ / PNG / Timor Leste
	ArcMap 10.6 / Nearmap	Remove Australian external territories	Christmas island / Norfolk Island / Cocos Islands
Limit timeframe	DB Browser for SQL lite	Filter for Jan 2009 - Dec 2018	-
Clean by event entries	DB Browser for SQLite / R	Remove duplicate sites	-
		Clean-up time < 0.25 hours	Non-exhaustive clean-up.
		One volunteer, < 1 kg	A single volunteer collecting less than 1 kg indicates a non-exhaustive or informal clean-up
Clean by event entries	R / Excel	One volunteer, > 10 hours	Single volunteer cleaning more than 10 hours (indicates multiple days / weeks / months collecting)
		Not a clean-up	Daily walk / hike / Anecdotal as described in notes
		Estimated / incomplete	Stated in event notes
		Anecdotal (stated in notes)	Stated in event notes
		Clean-up over multiple days / weeks / month	Stated in notes, hours reported > 24
		Data quality poor	Number of volunteers / time / date or other details missing.
		Single item reported	Stated in event notes
		Timor Leste	Incorrectly entered as Australian site w/ incorrect coordinates
		Remove fishing line bin entries	Fishing bin Initiative hosted in the AMDI database
Event clean (Ratios of variables used to clean database)	R	bags / volunteer > 8	Volunteers collected more than 8 bags each (accuracy of data)
		Weight / volunteer > 10 & wt /bag > 10	Volunteers collected more than 10 bags weighing 10 kg each (accuracy of data)
		Hours per volunteer > 10 (i.e. each volunteer worked + 10 hrs)	Indicates poor data quality or multiple clean-ups over a longer timeframe
Clean events by item entries	R	Single item	Single item reported at the event (not in notes)
		Components < 10	Less than 5 item categories reported
		Estimated (div 10, integers)	Entries with integers divisible by 10 (estimated item categories > 50%)

Extract data for reporting areas

Processed data was classified according to NRM reporting areas and 'Water Type', as defined in Environmental Protection (Water) Policy 2009 (Qld, s. 12). Reporting areas and water types were classified by provided spatial data. Provided data and **custom dataset** were manipulated in ArcMap 10.7.

Table A4.12.2 | Provided shapefiles used to classify data by NRM reporting needs.

Shapefile name	Providing organisation
FPRH_Catchments	Fitzroy Partnership for River Health (FPRH)
2013_14 WQ Zones All Zones	Gladstone Healthy Harbour Partnership (GHHP)

Manipulate extracted data for use in model

To align with model structure, the following steps were performed:

a) Policy relevant items (plastic bags, plastic pottles, single-use items) were extracted.
b) Events were classified to financial year. Multiple events per site, per year were classified as 'Replicates'.
c) To avoid model collapse, sites with less than **one financial year** were filtered from analysis.

The resulting data was then provided to each NRM.

Appendix 5. Gladstone litter clean-up site data 2014–18

Table A5.1: Scores and grades for Gladstone litter clean-up sites from 2014–2028 (financial years (FYs)) sourced from the Australian Marine Debris Initiative (AMDI) Database.

Zone	Site	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
The Narrows	Phillipies Landing Rd, Targinnie	NA	NA	NA	55 (MP)	NA
Mid Harbour	Canoe Point, Tannum Sands	NA	86 (VLP)	87 (VLP)	79 (LP)	86 (VLP)
	Esplanade Beach, Curtis Island	NA	NA	NA	NA	26 (HP)
	Facing Island North Point	NA	NA	NA	37 (HP)	NA
	North West Shore, Facing Island	NA	NA	NA	52 (MP)	NA
	Tannum Sands Main Beach	NA	NA	93 (VLP)	86 (VLP)	85 (VLP)
Western Basin	Fisherman's Landing, Gladstone	NA	96 (VLP)	NA	89 (VLP)	93 (VLP)
Calliope Estuary	Barney Point, Gladstone	NA	NA	82 (VLP)	81 (VLP)	35 (HP)
South Trees Inlet	Lillys Beach North End, Tannum Sands	NA	NA	NA	66 (LP)	48 (MP)
Boyne Estuary	Bray Park to Boyne River mouth	76 (LP)	80 (VLP)	NA	100 (NA)	65 (LP)
	Lilleys Beach	NA	86 (VLP)	88 (VLP)	81 (VLP)	62 (LP)
Outer Harbour	Wild Cattle Creek Boat Ramp, Tannum Sands	NA	NA	NA	74 (LP)	41 (MP)
	Wild Cattle Creek Mouth, Tannum Sands	91 (VLP)	85 (VLP)	65 (LP)	56 (MP)	53 (MP)
Rodds Bay	The Esplanade Beach, Turkey Beach	NA	NA	NA	81 (VLP)	68 (LP)
Calliope	Auckland Creek, Gladstone	NA	NA	NA	90 (VLP)	59 (MP)
	Auckland Creek, Golf Course Rd	NA	NA	NA	89 (VLP)	87 (VLP)
	Auckland Creek, Hanson Road, Gladstone	NA	NA	NA	NA	48 (MP)
	Auckland Creek, Lions Park	NA	NA	NA	NA	69 (LP)
	Boat Creek Gladstone	NA	NA	NA	95 (VLP)	NA
	Briffney Creek, Gladstone	NA	NA	98 (VLP)	44 (MP)	58 (MP)
	Calliope River Campgrounds Old Bruce Hwy	NA	NA	NA	55 (MP)	32 (HP)
	Calliope River, Gladstone Power Station	NA	NA	NA	NA	78 (LP)
	Hazelbrook Park, Calliope	NA	NA	NA	NA	91 (VLP)
	Lake Callemondah	NA	91 (VLP)	95 (VLP)	54 (MP)	51 (MP)
	Tigalee Creek, Sun Valley Park, Gladstone	NA	NA	97 (VLP)	91 (VLP)	78 (LP)