Gladstone Healthy Harbour Partnership

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Authorship statement

This Gladstone Healthy Harbour Partnership (GHHP) Technical Report was written based on material from a number of separate project reports. Authorship of this GHHP Technical Report is shared by the authors of each of those project reports and the GHHP Science Team, which summarised the project reports and wrote additional material. The authors of the project reports contributed to the final product, and are listed here by the section/s of the report to which they contributed.

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Executive summary

Context

The 2016 Gladstone Harbour Report Card reports on the environmental health of 13 reporting zones in and around Gladstone Harbour and the overall environmental, social, cultural and economic health of the harbour. This report card covers monitoring undertaken in the period 1 July 2015 to 30 June 2016. Indicator scores range between 0.00 and 1.00 and are converted into grades (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 2016 Gladstone Harbour Report Card for each component of harbour health.

Overall component scores

The overall component scores and grades for the 2016 report card were: Environmental 0.50 (C), Social 0.66 (B), Cultural 0.62 (C) and Economic 0.75 (B). Compared to the 2015 report card; the Social grade has improved from a C to a B and the Economic component score was similar to the previous year (Figure 2). Direct comparisons between the 2015 results for the Environmental and Cultural components are not possible owing to changes in the indicators assessed. The indicator for connectivity was removed for the Environmental component (connectivity is now reported in the 'Drivers and Pressures' section of this report) and a fish (bream species) recruitment indicator was added. The Indigenous Culture indicator group was added to the Cultural component and contributes to the overall score.

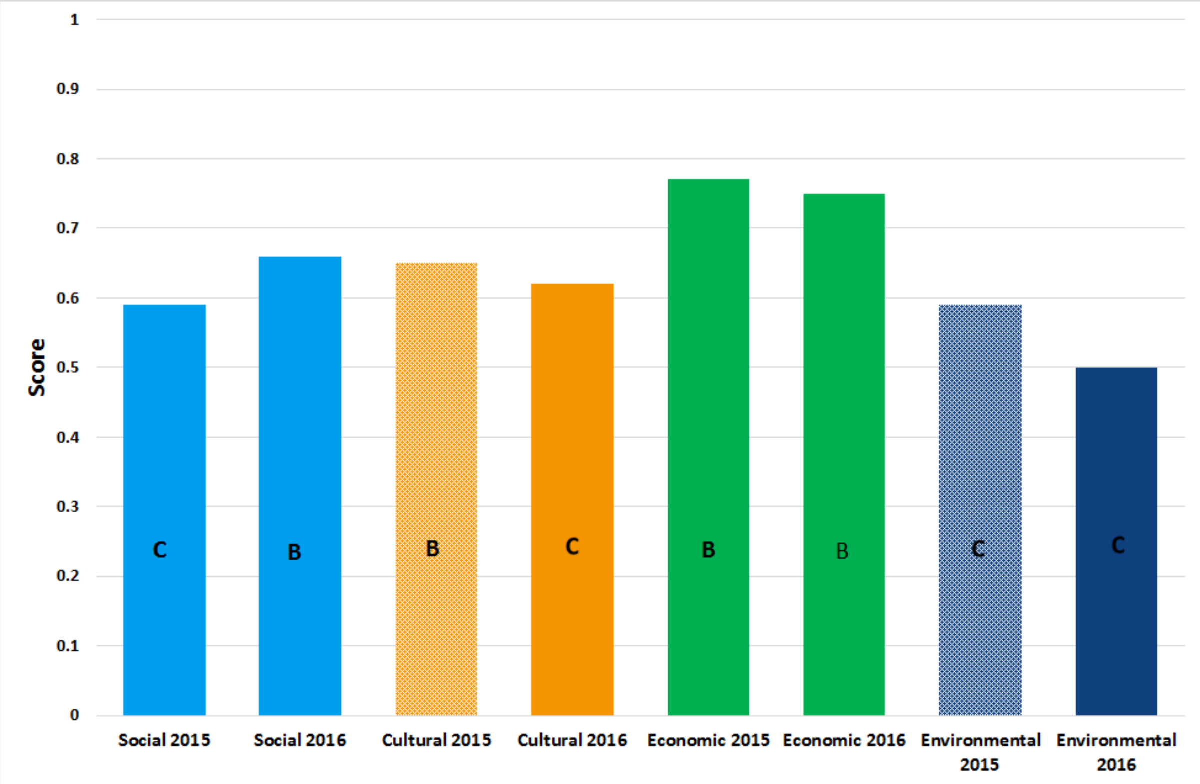


Figure 2: Overall scores for each of the four components of Gladstone Harbour health in 2016. The 2015 component results have been included for comparison. Direct comparisons between the 2015 results for the Environmental and Cultural components are not possible owing to changes in the indicators assessed (hashed columns).

Environmental health

Within the Environmental component, the water and sediment quality indicator group received a score of 0.84 (B), habitats 0.25 (D), and fish and crabs 0.40 (D). Overall scores in 2015 were water and sediment quality 0.90 (A), habitats 0.30 (D) and connectivity 0.61 (C). Environmental indicator group zone scores are presented in Table 1.

Table 1: Environmental indicator group scores and overall environmental scores for the 13 harbour zones and the overall harbour scores.

Zone	Indicator groups			**Overall zone score**
	Water and sediment quality	Habitats (seagrass and corals)	Fish and crabs (bream recruitment)	
1. The Narrows	0.80	0.33	0.30	**0.47**
2. Graham Creek	0.85	NA	0.44	**0.65**
3. Western Basin	0.84	0.55	0.36	**0.58**
4. Boat Creek	0.74	NA	0.36	**0.55**
5. Inner Harbour	0.86	0.14	0.33	**0.44**
6. Calliope Estuary	0.85	NA	0.44	**0.64**
7. Auckland Inlet	0.82	NA	0.53	**0.67**
8. Mid Harbour	0.86	0.26	0.29	**0.47**
9. South Trees Inlet	0.86	0.48	0.43	**0.59**
10. Boyne Estuary	0.85	NA	0.54	**0.69**
11. Outer Harbour	0.84	0.14	NA	**0.49**
12. Colosseum Inlet	0.86	NA	0.45	**0.66**
13. Rodds Bay	0.86	0.25	0.57	**0.56**
Harbour score	**0.84**	**0.25**	**0.40**	**0.50**

Water and sediment quality

The water quality indicator group received a score of 0.72 (B) and sediment quality a score of 0.96 (A). In 2015 water quality received a score of 0.81 (B) and sediment quality a score of 0.98 (A).

Water quality

Water quality was relatively uniform across the harbour and all zones received good overall scores, except Boat Creek that received a satisfactory score. Similar to 2015, water quality received a B, although the overall score declined slightly (Table 2) as a result of a decline in the turbidity scores. Nutrients received a satisfactory or good score in 8 of the 13 harbour zones. Chlorophyll-a was measured for the first time this year and scores for Total Nitrogen and Total Phosphorus improved from the 2015 scores in most harbour zones. As in 2015, scores for dissolved metals were very good in all zones.

Table 2: Water quality indicator scores for Gladstone Harbour zones in 2016 and 2015.

Water quality	Physico-chemical score	Nutrients score	Dissolved metals score	Zone score 2016	Zone score 2015
1. The Narrows	0.69	0.38	0.94	0.68	0.82
2. Graham Creek	0.81	0.47	0.95	0.75	0.86
3. Western Basin	0.71	0.42	0.92	0.70	0.82
4. Boat Creek	0.62	0.22	0.88	0.58	0.70
5. Inner Harbour	0.72	0.66	0.94	0.78	0.88
6. Calliope Estuary	0.68	0.51	0.93	0.71	0.86
7. Auckland Inlet	0.61	0.56	0.92	0.71	0.77
8. Mid Harbour	0.71	0.63	0.95	0.77	0.80
9. South Trees Inlet	0.85	0.57	0.93	0.79	0.85
10. Boyne Estuary	0.71	0.46	0.95	0.71	0.70
11. Outer Harbour	0.57	0.67	0.91	0.72	0.84
12. Colosseum Inlet	0.66	0.56	0.95	0.73	0.78
13. Rodds Bay	0.65	0.58	0.95	0.73	0.80

Sediment quality

Similar to 2015, sediment quality scores were uniformly very high across all zones of Gladstone Harbour owing to low concentrations of all measures (arsenic, cadmium, copper, lead, nickel and zinc) (Table 3). Polycyclic aromatic hydrocarbons (PAHs) were not monitored in 2016 owing to the very low levels recorded in the 2015 sediment monitoring.

Table 3: Sediment quality indicator scores for Gladstone Harbour zones in 2016 and 2015.

Sediment quality	Zone score 2016	Zone score 2015
1. The Narrows	0.92	0.94
2. Graham Creek	0.96	0.98
3. Western Basin	0.98	0.99
4. Boat Creek	0.90	0.96
5. Inner Harbour	0.94	0.98
6. Calliope Estuary	0.99	0.98
7. Auckland Inlet	0.94	0.94
8. Mid Harbour	0.97	0.99
9. South Trees Inlet	0.95	0.96
10. Boyne Estuary	0.98	1.00
11. Outer Harbour	0.96	0.96
12. Colosseum Inlet	1.00	1.00
13. Rodds Bay	0.99	0.98

Habitats

The overall score for habitats was poor (0.25, D) with seagrass having a poor score of 0.35 (D) and coral a very poor score of 0.15 (E). These were similar to the scores recorded in 2015 where the overall score for habitats was poor 0.30 (D), with a seagrass score of 0.43 (D) and a coral score of 0.18 (E). The grades for overall habitats, seagrass and corals were the same as those recorded in 2015.

Seagrass

Three seagrass sub-indicators biomass, area and species composition were assessed in six reporting zones. Unlike other indicators in the report card, the scores for seagrass meadows were based on the lowest score for those sub-indicators rather than the average score. This was because if any one of those three sub-indicators was in a poor condition, then irrespective of the other two sub-indicator scores, the overall health of the seagrass meadow was deemed to be poor.

The Western Basin received a satisfactory score (0.55); The Narrows (0.33), Mid Harbour (0.35), South Trees Inlet (0.48) and Rodds Bay (0.25) received poor scores; and one zone, The Inner Harbour (0.14), received a very poor score (Table 4). These scores resulted mainly from low scores for biomass and meadow area.

The overall seagrass score in 2016 of 0.35 (D) is lower than the score of 0.43 (D) in the 2014–15 reporting year. At the zone level, seagrass condition has declined in all zones except The Narrows where the overall zone score increased from 0.15 (D) to 0.33 (D). The largest decline was in the Inner Harbour where the overall zone score decreased from 0.41 (D) in 2015 to 0.14 (E) in the 2016 reporting year.

Multiple years of high rainfall, river flows and cyclone activity in the Gladstone region may have reduced the resilience and capacity for seagrass in Gladstone Harbour to recover. However, seagrasses in Queensland have a demonstrated ability to recover from past impacts. Condition improvements recorded for some meadows in Gladstone Harbour suggest that seagrasses remain resilient.

Table 4: Scores for seagrass indicators (biomass, area and species composition) and overall meadow, zone and harbour score for 2016 reporting year and overall zone score from 2015.

Zone	Meadow	Biomass score	Area score	Species composition score	Overall meadow score	Zone score 2016	Zone score 2015
1. The Narrows	21	0.33	0.87	0.57	0.33	0.33	0.15
3. Western Basin	4	0.83	0.52	0.78	0.52	0.55	0.51
	5	0.49	0.58	0.34	0.34		
	6	0.68	0.82	0.67	0.67		
	7	ND*	0.78	1.00	0.78		
	8	0.88	0.51	0.38	0.38		
	52–57	0.60	0.96	1.00	0.60		
5. Inner Harbour	58	0.42	0.92	0.14	0.14	0.14	0.41
8. Mid Harbour	43	0.25	0.78	0.68	0.25	0.35	0.56
	48	0.46	0.54	0.51	0.46		
9. South Trees Inlet	60	0.48	0.88	0.59	0.48	0.48	0.52
13. Rodds Bay	94	0.08	0.28	0.36	0.08	0.25	0.45
	96	0.40	0.76	0.66	0.40		
	104	0.28	0.29	0.46	0.28		
Harbour score						**0.35**	**0.43**

*ND = No data

Corals

Three coral sub-indicators—coral cover, macroalgal cover and density of juvenile corals—were assessed at four reefs in the Mid Harbour and two reefs in the Outer Harbour (Table 5). Both the Mid Harbour and Outer Harbour zones received very poor scores for coral health of 0.15 (E) and 0.14 (E), respectively. This was due to very low coral cover, very high macroalgal cover and the low density of juvenile corals at most reefs. Differences in the overall score between 2015 and 2016 can be attributed to a greater level of macroalgal cover at the monitored reefs. However, juvenile density in the Mid Harbour improved from an E (0.23) in 2015 to a D (0.33) in 2016 suggesting that the potential for recovery noted in 2015 remains (Table 5).

Table 5: Coral indicator scores for the two surveyed harbour zones for 2015 and 2016.

Zone	Coral cover score	Macroalgal cover score	Juvenile density score	Zone score 2016	Zone score 2015
8. Mid Harbour	0.05	0.10	0.33	0.15	0.23
11. Outer Harbour	0.09	0.00	0.33	0.14	0.15
Harbour score				**0.15**	**0.18**

Fish and crabs

For the first time, the 2016 Gladstone Harbour Report Card provides fish recruitment grades and scores. As all fish and mud crab health indicators are not included in this year's report card, the overall score for the fish and mud crab indicator group is based solely on fish recruitment (bream species). Projects are currently developing indicators for fish and mud crab health and these will be included in future report cards.

The overall score for fish recruitment was 0.40 (D). This was measured in two species: yellow-finned bream *Acanthopagrus australis* and pikey bream *Acanthopagrus pacificus.* The final scores (Table 6) were measured against a four-year baseline (2011–12 to 2014–15). The 2016 score for fish recruitment indicates a season with decreased catch rate relative to the median reference level determined over that baseline period. However, statistical analysis identified large differences in fish recruitment between years (seasons) over this short time period. Hence this result is regarded as provisional at this stage. Confidence in this indicator will improve as the data set (number of years sampled) grows.

Table 6: Bream recruitment score for 12 harbour zones and the overall harbour score.

Zone	Score
1. The Narrows	0.30
2. Graham Creek	0.44
3. Western Basin	0.36
4. Boat Creek	0.36
5. Inner Harbour	0.33
6. Calliope Estuary	0.43
7. Auckland Inlet	0.53
8. Mid Harbour	0.29
9. South Trees Inlet	0.43
10. Boyne Estuary	0.55
11. Outer Harbour	No bream survey sites
12. Colosseum Inlet	0.45
13. Rodds Bay	0.58
Harbour score	**0.40**

Social health

The overall social score in 2016 is 0.66 (B), similar to the score of 0.64 (C) in the 2015 report card. This score was based on three indicators of social health: harbour usability (0.66, B), harbour access (0.65, B), and liveability/wellbeing (0.66, B) (Table 7).

For two of the three indicator groups for the Social component, scores were similar to 2015. Harbour access was 0.62 (C) in 2015 and 0.65 (B) in 2016. Liveability and wellbeing was 0.64 (C) in 2015 and 0.66 (B) in 2016. Harbour usability remains unchanged with a B grade.

Table 7: Scores for social indicators groups and indicators for 2016 and 2015.

Indicator groups	2016 Score	2015 Score	Social indicators	2016 Score	2015 Score
Harbour usability	0.66	0.65	Satisfaction with harbour recreational activities	0.67	0.69
			Perceptions of air and water quality	0.55	0.52
			Perceptions of harbour safety for human use	0.76	0.72
Harbour access	0.65	0.62	Satisfaction with access to the harbour	0.69	0.68
			Satisfaction with boat ramps and public spaces	0.64	0.62
			Perceptions of harbour health	0.62	0.58
			Perceptions of barriers to access	0.65	0.61
Liveability and wellbeing	0.66	0.64	Liveability and wellbeing	0.66	0.64

Cultural health

The overall score for the cultural health of Gladstone Harbour for 2016 was 0.62 (C). Two indicator groups for cultural health were identified in the Gladstone Healthy Harbour Partnership vision, 'sense of place' 0.66 (B) (Table 8) and Indigenous cultural heritage 0.53 (C) (Table 9). The overall score for 'sense of place' was similar to that recorded in 2015 (0.65). Indigenous cultural heritage was assessed for the first time in 2016 so comparisons with the previous year are not possible.

Table 8: Scores for the 2016 and 2015 'sense of place' indicator group.

Indicator group	2016 Score	2015 Score	Indicators	2016 Score	2015 Score
'Sense of place'	0.66	0.65	Distinctiveness	0.59	0.55
			Continuity	0.59	0.57
			Self-esteem	0.74	0.72
			Self-efficacy	0.58	0.56
			Attitudes to harbour	0.81	0.80
			Values of harbour	0.66	0.68

The Indigenous cultural health indicator group was assessed using information collated from an in-depth desktop study and field data collected from four reporting zones: The Narrows, Facing Island, Wild Cattle Creek and Gladstone Central (Table 9).

Table 9: Scores for Indigenous cultural heritage indicators and overall harbour score for the 2016 report card.

Zone	Cultural health			Management strategies			Overall zone score
	Spiritual & social values	Scientific values	Physical condition	Protection	Land use	Cultural maintenance	
The Narrows	0.54	0.62	0.53	0.70	0.40	0.35	**0.53**
Facing Island	0.57	0.75	0.64	0.70	0.50	0.25	**0.57**
Wild Cattle Creek	0.40	0.51	0.45	0.60	0.40	0.25	**0.44**
Gladstone Central	0.85	0.50	0.60	0.40	1.00	0.40	**0.59**
Harbour score for Indigenous cultural heritage							**0.53**

Economic health

The overall score for the Economic component of the 2016 Report Card of 0.75 (B) is similar to the 2015 score of 0.77 (B). The three indicator groups measured to determine these grades were economic performance, economic stimulus and economic value (recreation) (Table 10).

The economic performance indicator group had three indicators: shipping activity, tourism and commercial fishing. These reflect the key industries using the harbour and were weighted according to economic activity and a survey of local industry and community leaders.

The overall score for the economic performance indicator group was 0.87 (A) compared to the score received in the 2015 report card of 0.79 (B). This reflected increased scores for shipping activity and tourism.

Economic stimulus received a score of 0.74 (B) compared to the 2015 score of 0.82 (B). This score was based on two indicators: employment and socio-economic status. The score for employment of 0.62 (C) was similar to the score for 2015 of 0.64 (C). Socio-economic status received a score of 0.80 (B) which was lower than the 2015 score of 0.95 (A).

Economic value received a score of 0.73 (B) which was similar to the score of 0.72 (B) in the 2015 report card.

Table 10: Scores for the 2016 economic indicator groups and scores from 2015.

Indicator group	2016 Score	2015 Score	Indicators	2016 Score	2015 Score
Economic performance	0.87	0.79	Shipping activity	0.87	0.82
			Tourism	0.72	0.64
			Commercial fishing	0.43	0.63
Economic stimulus	0.74	0.82	Employment	0.62	0.64
			Socio-economic status	0.80	0.95
Economic (recreational) value	0.73	0.72	Land-based recreation	0.76	0.73
			Recreational fishing	0.66	0.71
			Beach recreation	0.75	0.70

1. Introduction

1.1. The Gladstone Healthy Harbour Partnership

1.1.1. Overview

The Gladstone Healthy Harbour Partnership (GHHP) is a forum that brings together numerous parties to maintain and, where necessary, improve the health of Gladstone Harbour. The GHHP vision is that 'Gladstone has a healthy, accessible, working harbour'. The guiding principles of the partnership are open, honest and accountable management, annual reporting of the health of Gladstone Harbour and management advice. Actions are based on rigorous science and strong stakeholder engagement to ensure the ongoing and continuous improvement of the health of Gladstone Harbour.

AN ENVIRONMENTALLY HEALTHY HARBOUR
… has functioning and interconnected key ecosystems and ecosystem services, supports sustainable populations of marine species and has natural tidal and seasonal variations of water and sediment quality parameters.

A SOCIALLY HEALTHY HARBOUR
… is a place in which the community has civic and community pride and continues to support a sense of community (e.g. friendliness, easy access, personal relationships and lifestyle) and has infrastructure allows citizens to easily and safely use, access and enjoy the harbour and foreshore for recreation.

A CULTURALLY HEALTHY HARBOUR
… is a place in which the cultural heritage and cultural heritage sites (such as stone quarries and middens) are preserved and in which the community has a sense of identity and satisfaction with its condition.

AN ECONOMICALLY HEALTHY HARBOUR
… is a working harbour that contributes to a positive diverse economic future, supports existing and new industries and returns economic benefit to the whole community.

The GHHP partnership has 26 partners comprising 13 industry representatives; 6 research and monitoring agencies; local, state and federal government representatives and 4 community groups including Traditional Owners. The GHHP was formally launched on 6 November 2013 when partner representatives agreed to work together to achieve the GHHP vision that 'Gladstone has a healthy, accessible, working harbour'.

The Independent Science Panel (ISP) 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 Gladstone Healthy Harbour Partnership (GHHP) vision are supported by credible science.

1.1.2. Moving from a vision to objectives and indicators of harbour health

The GHHP vision was developed in a series of interactive workshops held with the local Gladstone and regional community (including Traditional Owner groups – Gooreng Gooreng, Taribelang Bunda, Bailai and Gurang tribal groups), industry (including commercial fishers), government representatives, research organisations, conservation groups and recreational fishers.

The ISP developed a set of 'report card objectives' from the GHHP vision that were accepted by the GHHP Management Committee on behalf of the partnership. The objectives are the measurable goals that underpin the GHHP monitoring and reporting program. In consultation with the GHHP partners, the ISP grouped the objectives into the identified Environmental, Cultural, Social and Economic components and used them to select the specific indicators to be measured and reported against (Figure 1.1).

The ISP commissioned a review of the international and national use of report cards (Connolly et al., 2013), a review of the available data relevant to Gladstone (Llewellyn et al., 2013) and reports to assist in selecting social, cultural and economic indicators (Greer & Kabir, 2013), and environmental indicators (Dambacher et al., 2013). The ISP used the recommendations from these reports and considers local issues to guide the final selection of indicators. These reports are available on the GHHP website.

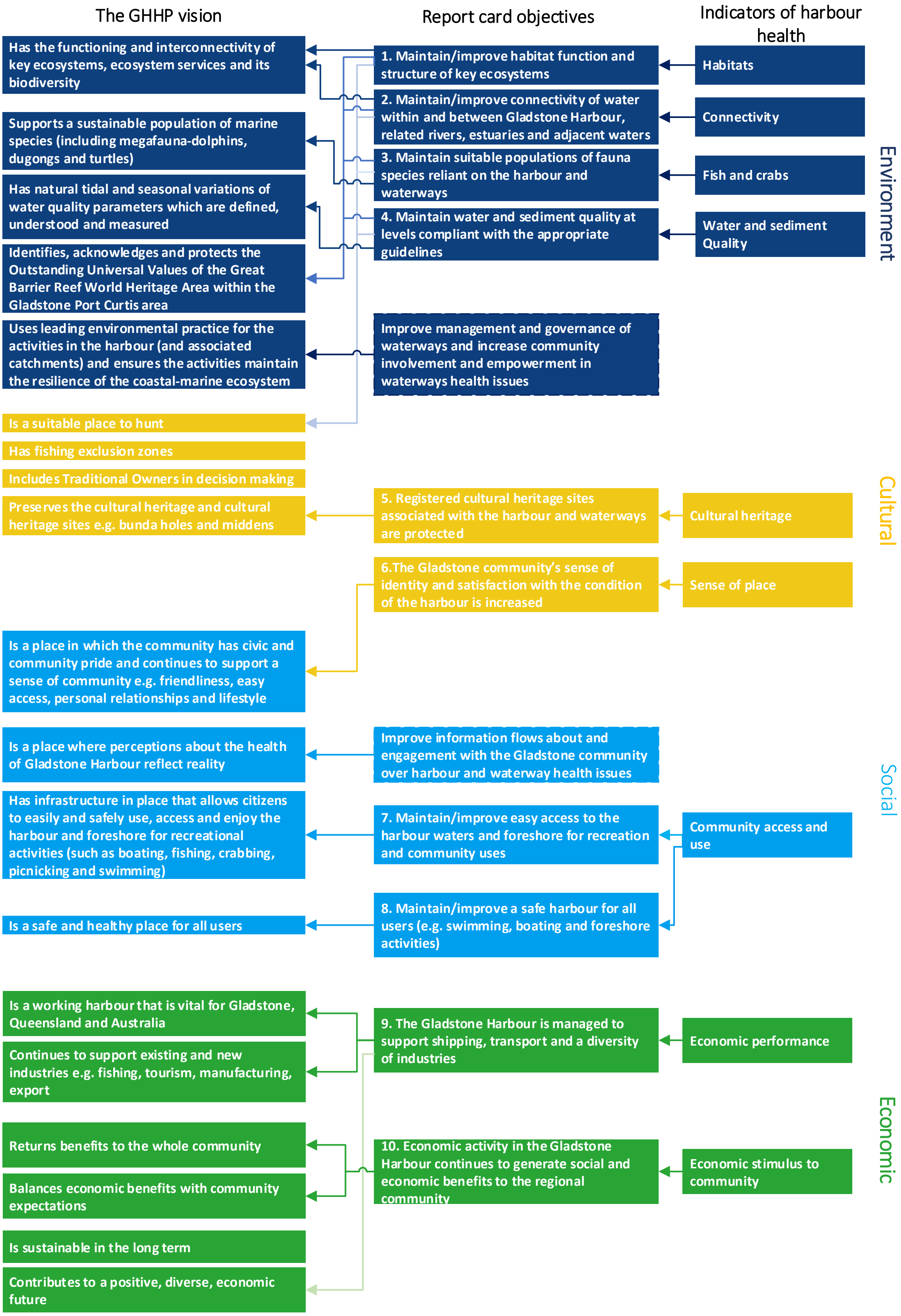


Figure 1.1: The Gladstone Harbour Report Card objectives and harbour health indicators were developed from the GHHP vision statements for the Environmental, Cultural, Social and Economic components of Gladstone Harbour health.

1.1.3 The four components of harbour health

The 2015 Gladstone Harbour Report Card is one of the first report cards in Australia to report on environmental, social, cultural and economic health (Figure 1.2). Stakeholder and community consultation identified these four components as important to the community.

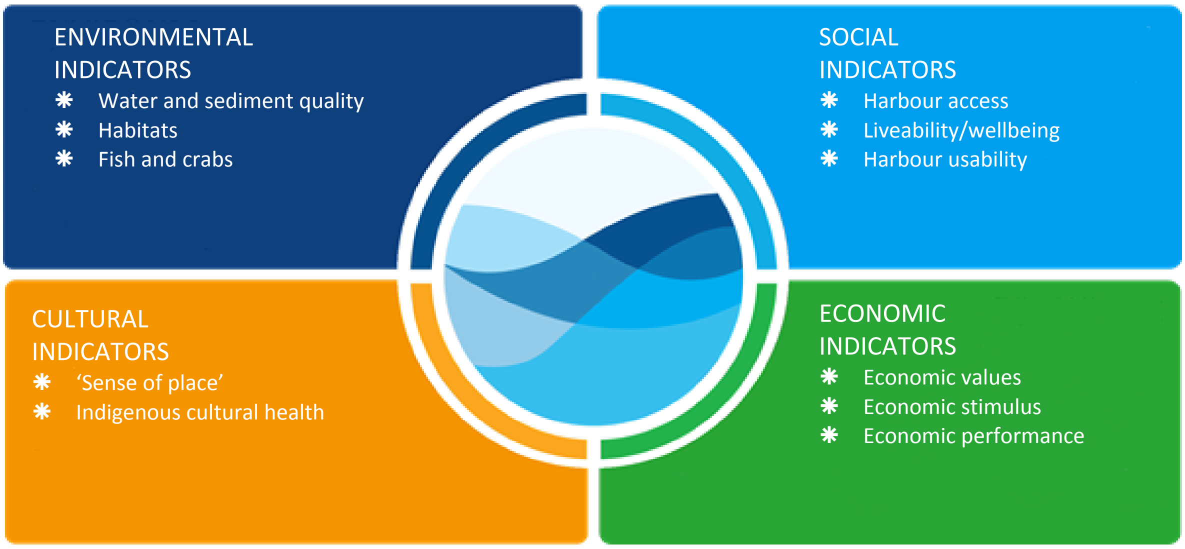


Figure 1.2: The four components of harbour health.

1.2. The science program

The GHHP science program commenced in 2013 and is now in its third year. It has passed through two key phases: the design phase (in 2013) and pilot phase (in 2014) and is moving into an operational phase beyond 2015 (Figure 1.3). The science program includes many projects that inform the report card indicators. The ISP, with the agreement of the GHHP Management Committee, develops these projects to help design and implement the Gladstone Harbour Report Card and its ongoing improvement. When completed, the final reports from each of these projects will be available on the GHHP website. A list of all GHHP projects is presented in Appendix 1.

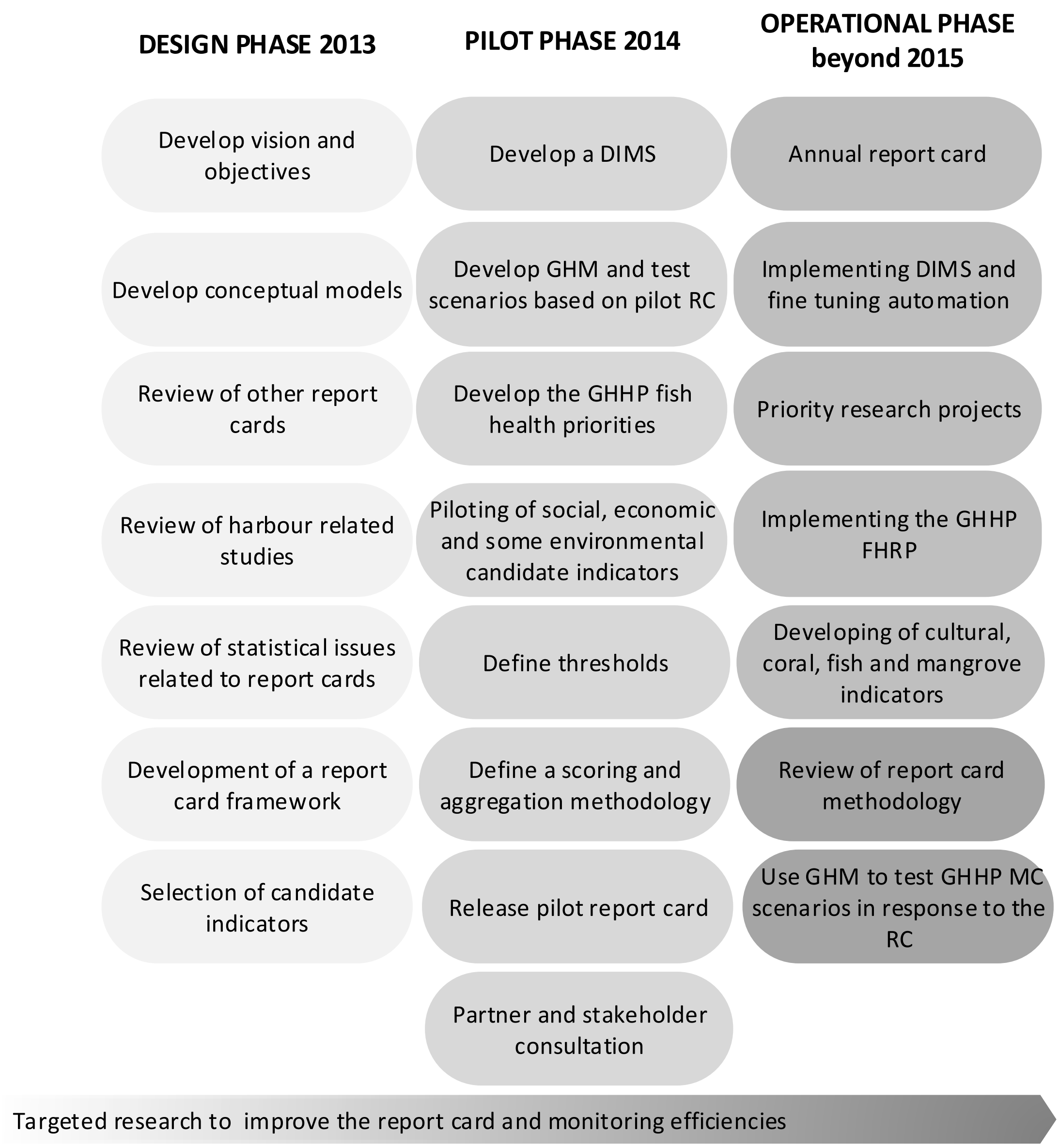


Figure 1.3: The three phases of the GHHP science program. DIMS = Data Information Management System, GHM = Gladstone Harbour Model; RC = Report Card; MC = Management Committee, FHRP = Fish Health Research Program.

1.3. Reporting periods

The reporting period for the 2016 Gladstone Harbour Report Card was 1 July 2015 to 30 June 2016. This was adopted so that the significant environmental changes that occur in the wetter summer months are captured in the annual data. However, some data collected prior to the 2015–16 financial year for the Social and Economic components were used as they were the most up-to-date available. The contaminant loads described in the drivers and pressures section are also from the preceding financial year as these are the latest data available.

2. From indicators to report card grades

2.1. Structure and indicators

Terminology has been developed to describe the hierarchy of scores for each component of harbour health. This can include up to five levels of aggregation: component, indicator group, indicator, sub-indicator and measure (Table 2.1). This structure derives component 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 2015 Gladstone Harbour Report Card.

Name	Explanation
Level 1: Component	The Gladstone Harbour 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 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 the 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 and total phosphorus.
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 determine 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 towards a component.

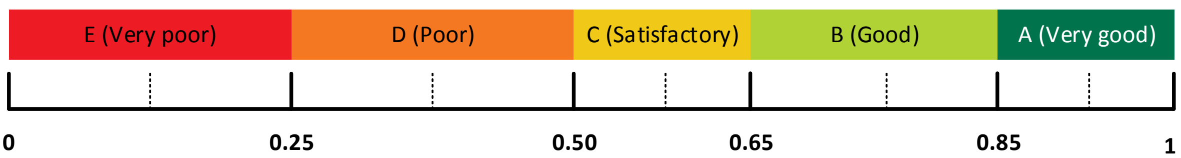


Figure 2.1: Grade ranges used in the 2016 Gladstone Harbour Report Card.

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) for the 2015–16 reporting period.

For example, the starting point for 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 2015–16 reporting year. The annual site means were used to develop indexed scores between 0 and 1 compared with relevant guidelines (DEHP water quality objectives or ANZECC/ARMCANZ guidelines as appropriate). This yielded final indexed scores at site level which could be aggregated to higher levels of reporting (Figures 2.2a–d). References have been provided to the methods used to calculate the indexed values for coral, seagrass, 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 2.3).

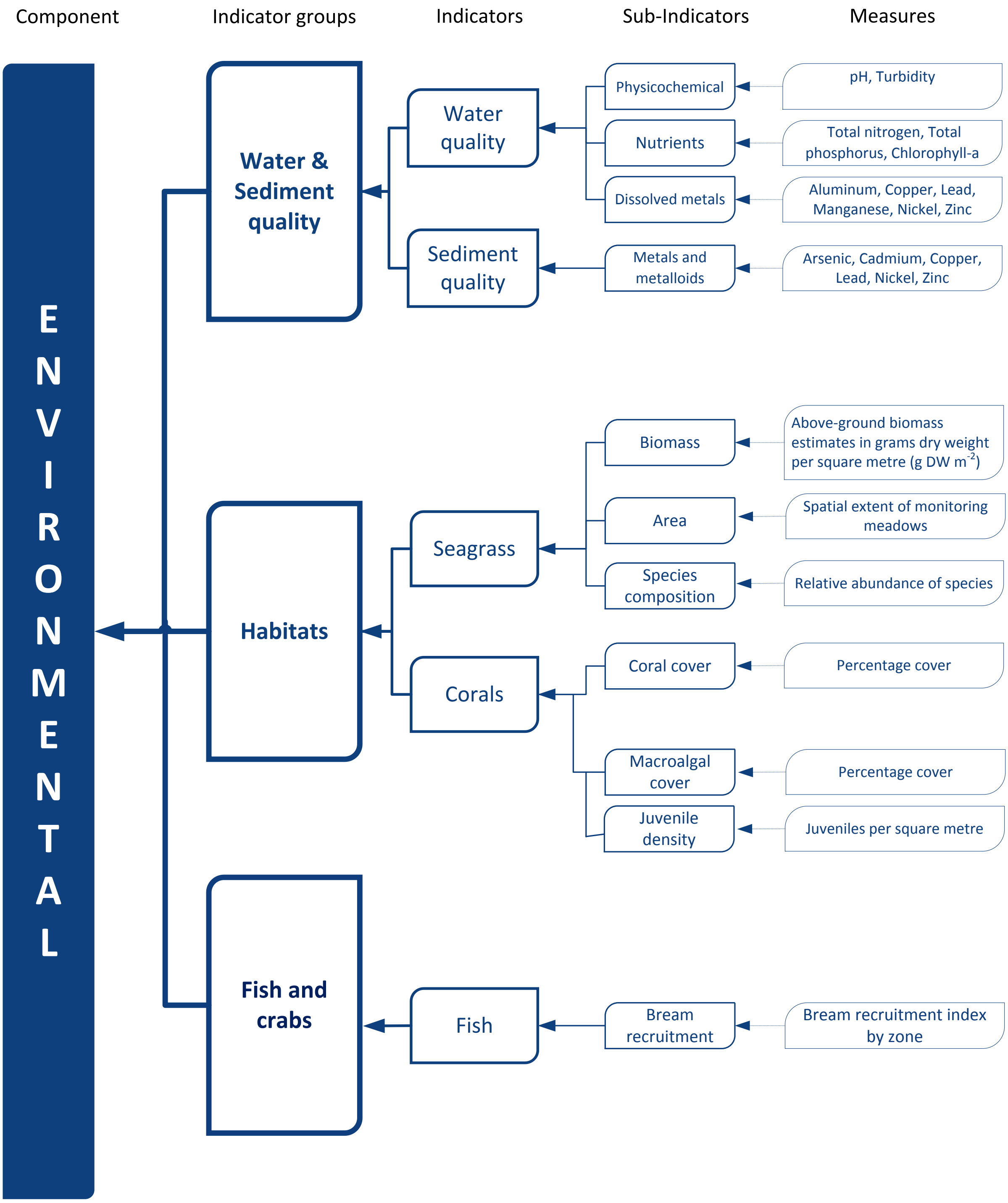


Figure 2.2a: The levels of aggregation used to determine the environmental scores and grades in the 2016 Gladstone Harbour Report Card.

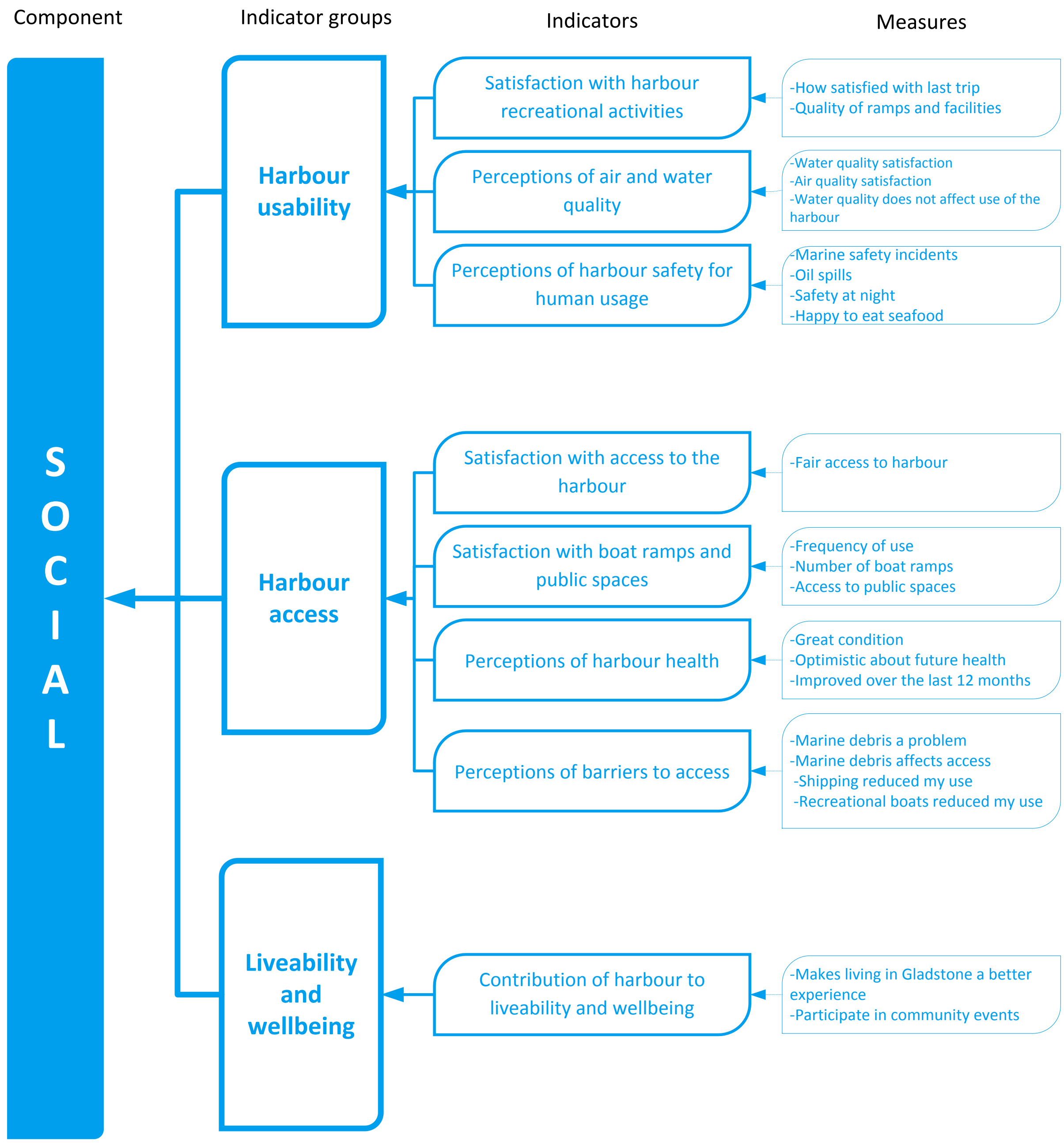


Figure 2.2b: The levels of aggregation used to determine the social scores and grades in the 2016 Gladstone Harbour Report Card.

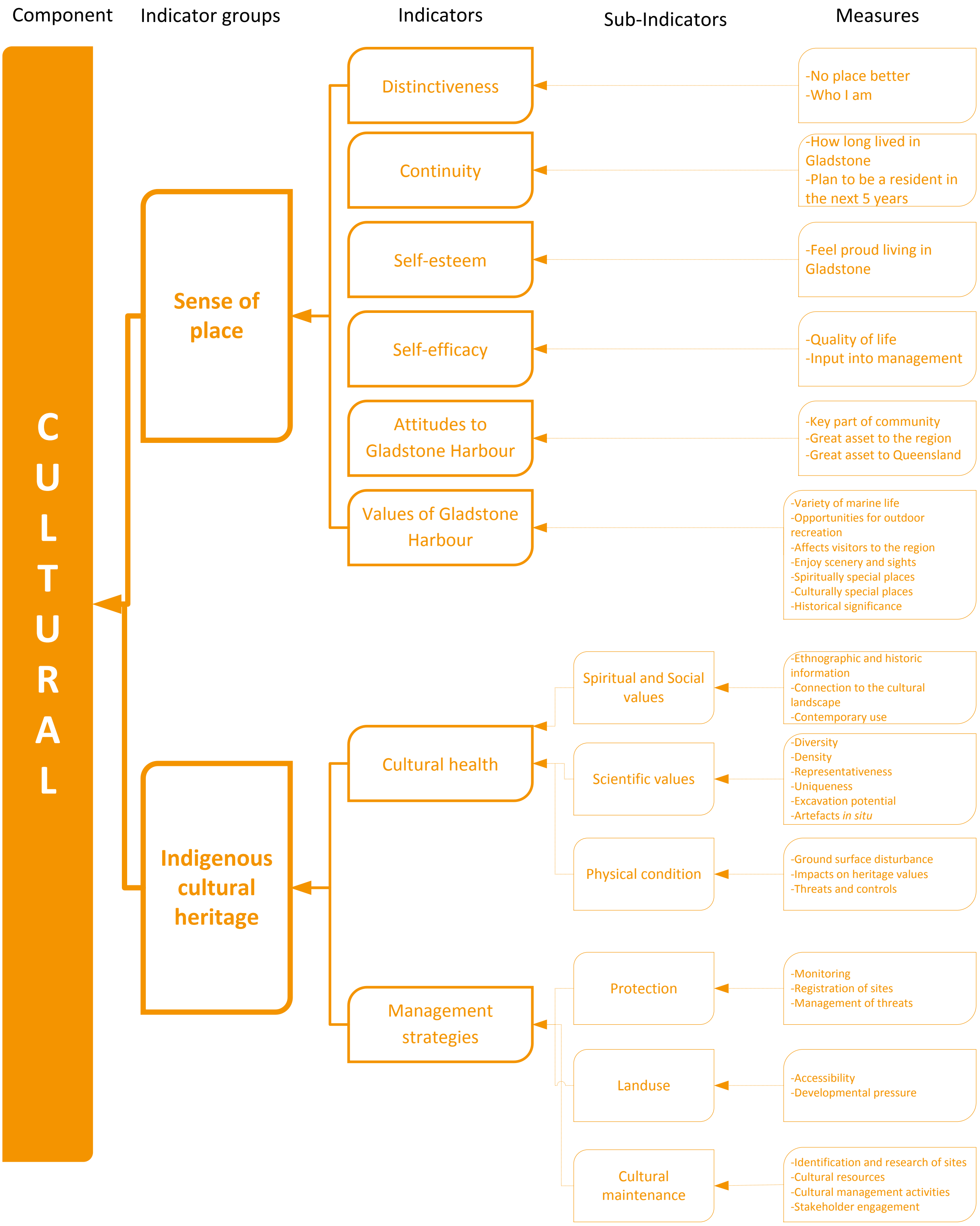


Figure 2.2c: The levels of aggregation used to determine the cultural grades and scores in the 2016 Gladstone Harbour Report Card.

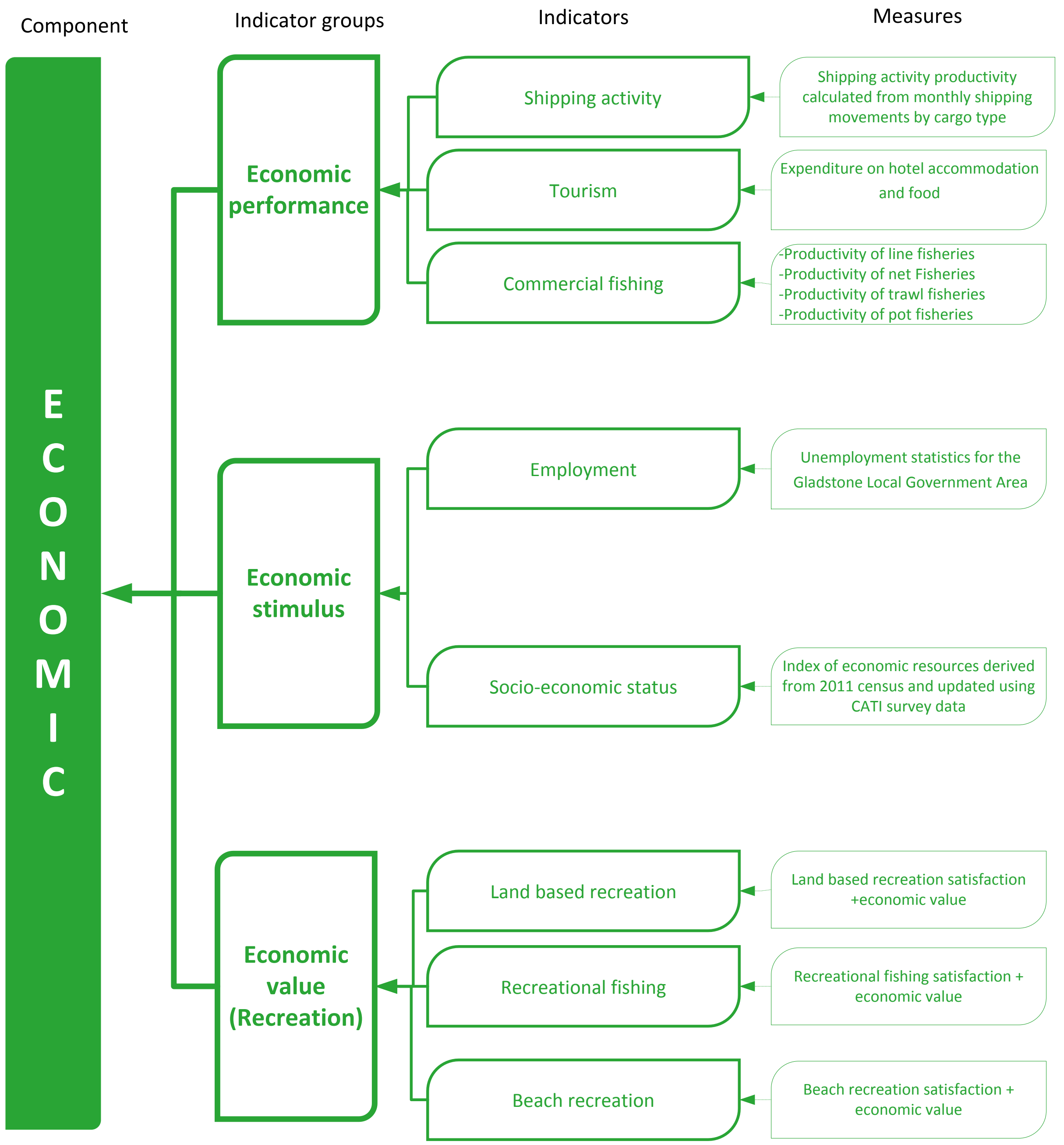


Figure 2.2d: The levels of aggregation used to determine the economic scores and grades in the 2016 Gladstone Harbour Report Card. (CATI: computer-assisted telephone interviewing)

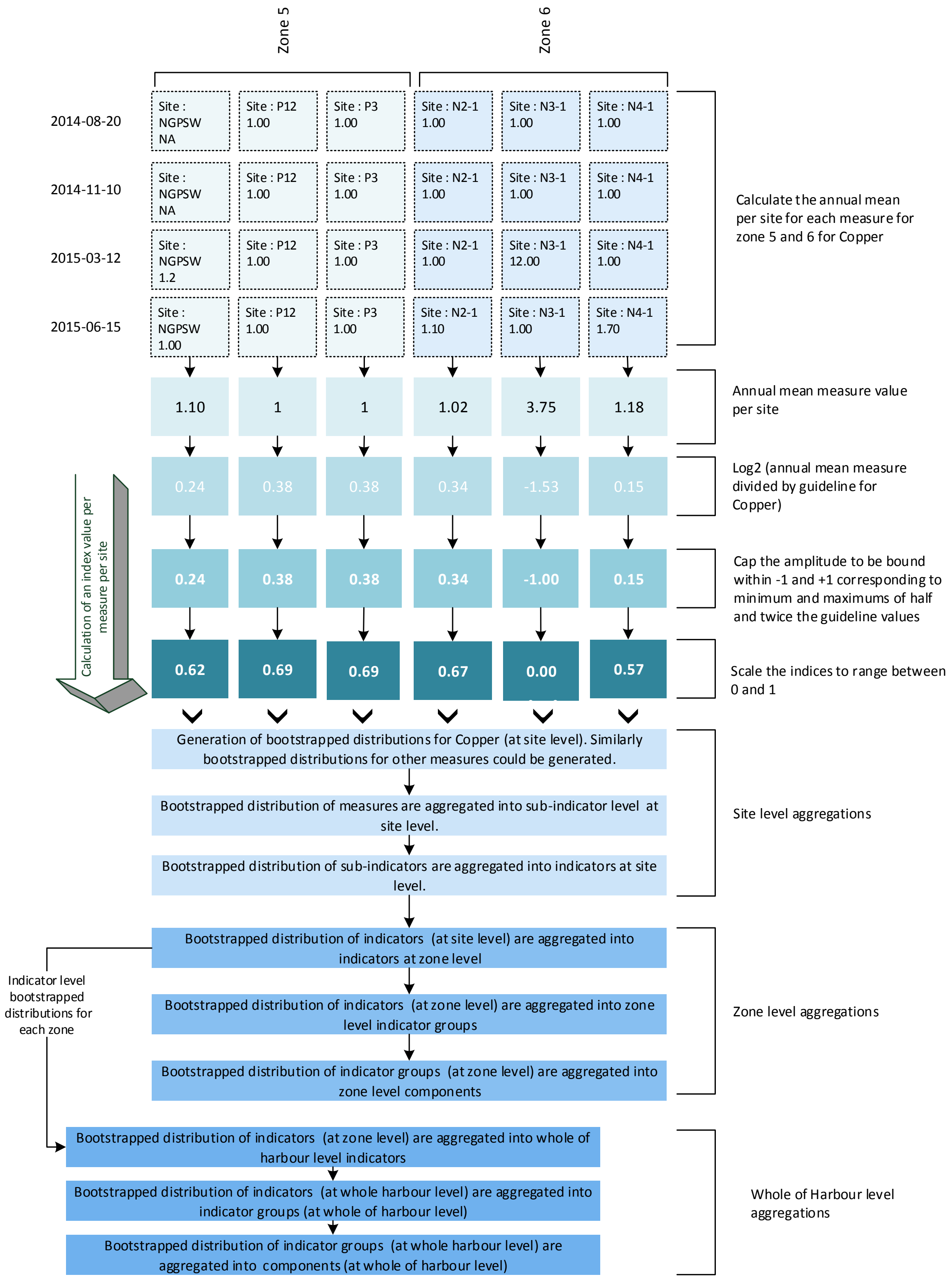


Figure 2.3: Aggregation of report card scores – a worked example using the water quality measure for copper in zones 5 and 6.

2.2. Confidence ratings

The ISP assigned the grade for each of the four components within the report card with a confidence rating 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 Environmental component received a moderate confidence rating. Although the habitat, water quality and sediment quality data used to derive the grade were regarded as reliable, the full suite of indicators was not available for this year's report card. Indicators for fish health, crabs and mangroves were not available for this year but they are in development. NO_x and orthophosphate were not included in the water quality indicator measures for ammonia, as analytical detection limits for these measures were insufficient to enable a comparison to guideline values. Within the sediment quality indicator, the measure for sediment mercury was excluded for the same reason. Further limitations were that water quality sampling was only conducted on four occasions in the 2015–16 reporting year and only at 'far field' sites (sites that were selected to be remote from point sources of pollutants) rather than at randomly selected sites.

The Social component received a high confidence rating. This was because the computer-assisted telephone interviewing (CATI) survey that contributed most of the data used to derive this grade is regarded as being reliable and repeatable and the survey was designed specifically for the Gladstone Harbour Report Card. There were some changes to the availability of Maritime Safety Queensland (MSQ) data on shipping incidents as the commercial shipping incidents data were not available from MSQ for 2015–16. It was considered that 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 Cultural component received a moderate confidence rating: this has improved from a low rating in 2015 owing to the inclusion of the Indigenous cultural heritage indicator. Although a full set of indicators is now measured for this component, including Indigenous cultural heritage into a report card is new and untested. Additionally, 'sense of place' is a complex concept that can be difficult to capture through survey data alone. 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 grade came from a variety of reputable sources (Table 7.1). 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. Geographical scope

3.1. Environmental reporting zones

The 13 environmental reporting zones in Gladstone Harbour have developed over time from an initial 7 zones proposed by Jones et al. (2005) in a risk assessment for contaminants in Gladstone Harbour. In their 2007 Port Curtis Eco Card, the Port Curtis Integrated Monitoring Program (PCIMP) increased the number of zones to 9 by including oceanic and estuarine reference sites (Storey et al., 2007). However, these 2 reference zones were combined in the Port Curtis Eco Card 2008–2010 (PCIMP, 2010) resulting in 8 zones. The Queensland Department of Environment and Heritage Protection (DEHP) developed the current 13 zones (Figure 3.1). These zones were also used to define regionally specific water quality objectives for the Capricorn Coast (DEHP, 2014a).

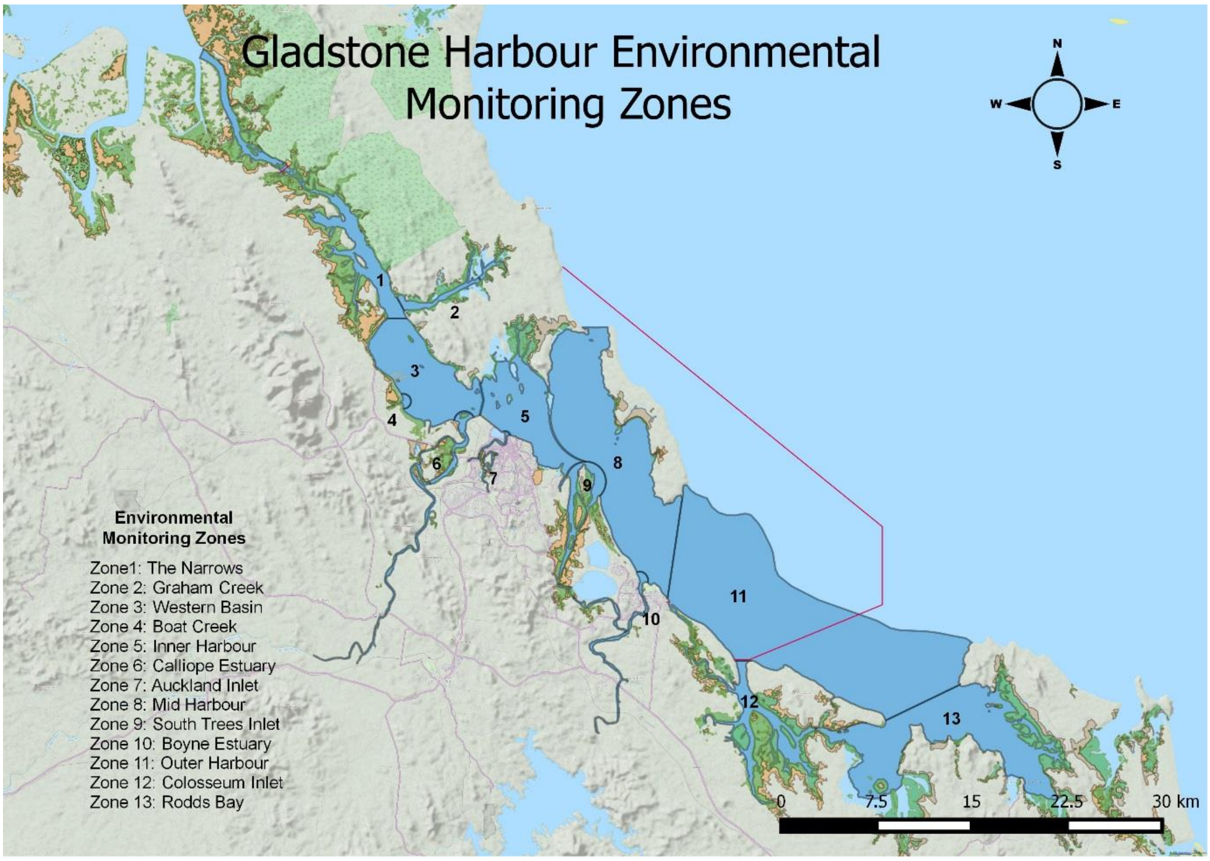


Figure 3.1: The 13 Gladstone Harbour zones for which environmental parameters were measured for the 2016 Report Card.

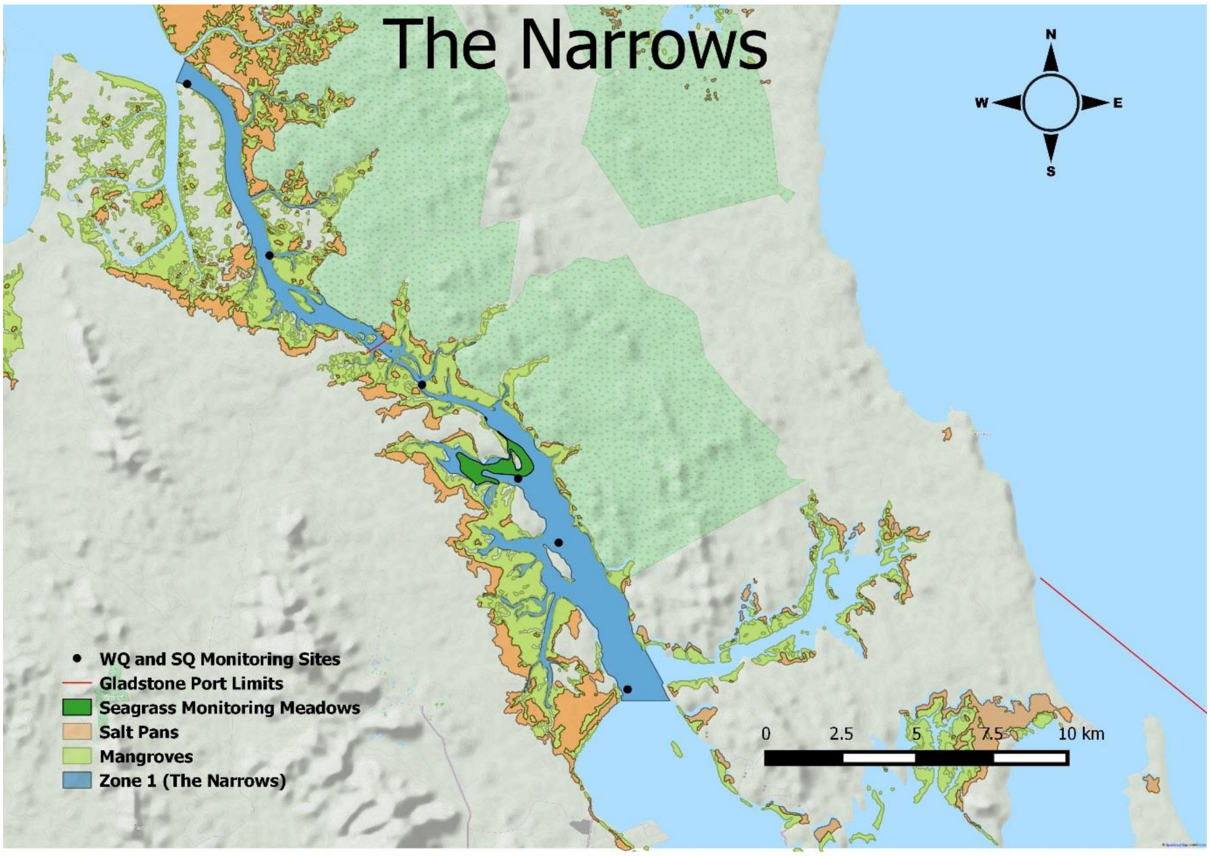


Figure 3.2: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 1: The Narrows.

Six water and sediment quality monitoring sites
One seagrass monitoring meadow

Zone area: 29.25km^2

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 (PCIMP, 2010). This zone has one monitored seagrass meadow—an intertidal meadow comprising aggregated patches of seagrass near Black Swan Island.

Figure 3.3: The Narrows photographed from the south with Keppel Bay in the distance.

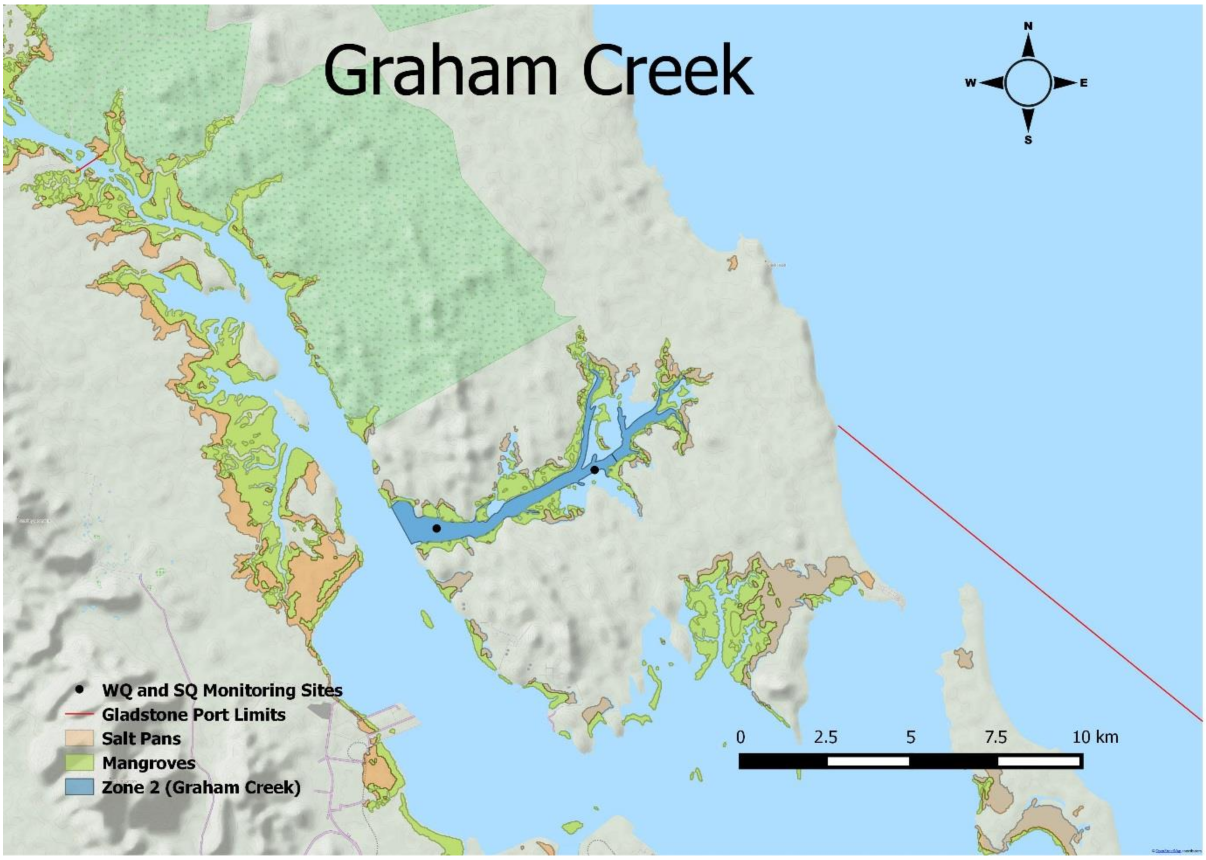


Figure 3.4: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 2: Graham Creek.

Two water and sediment quality monitoring sites

Zone area: 5.8km^2

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

Figure 3.5: 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.

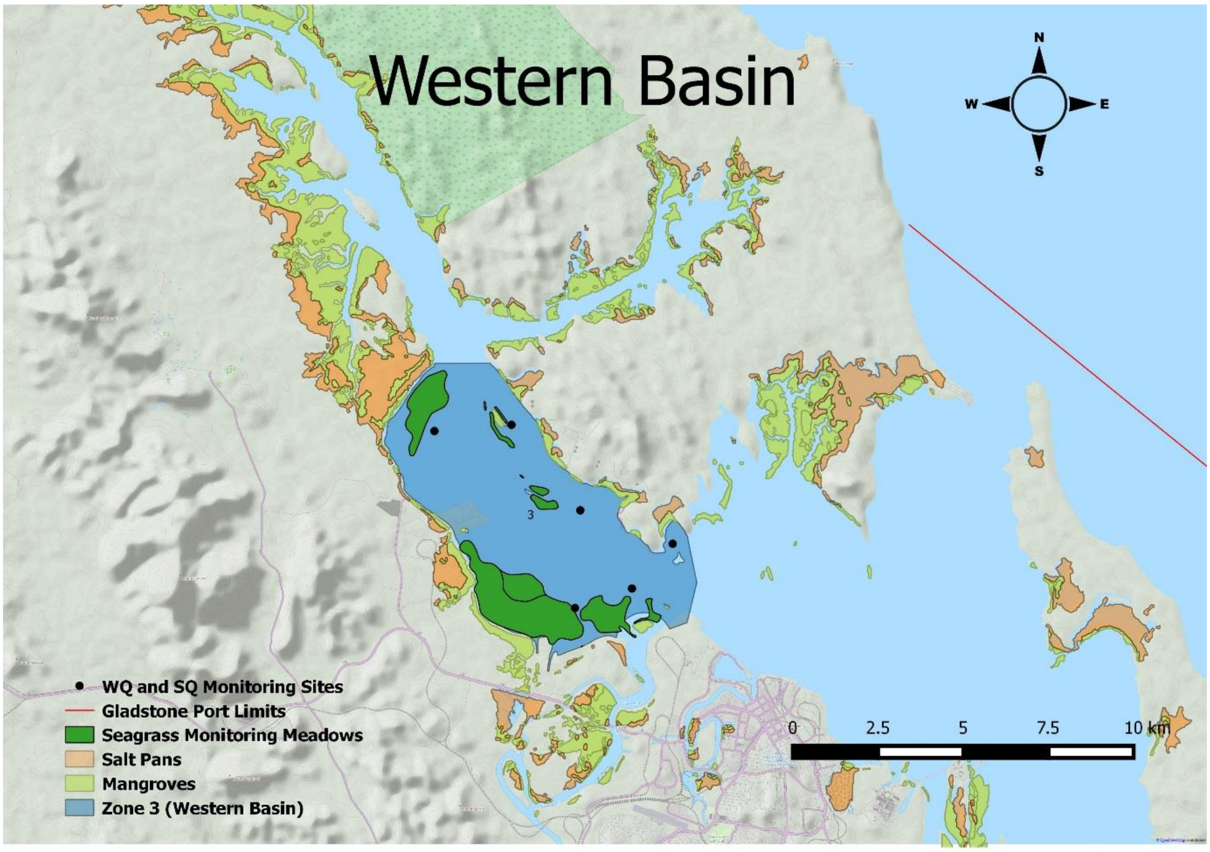


Figure 3.6: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 3: Western Basin.

Six water quality and sediment quality monitoring sites
Six monitored seagrass meadows

Zone area: 39.19km^2

The Western Basin is located near the north-western end of Gladstone Harbour. Three large-scale liquid natural gas (LNG) 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 3.7: The south-western corner of Curtis Island, showing two liquid natural gas plants in the foreground and the Western Basin in the distance.

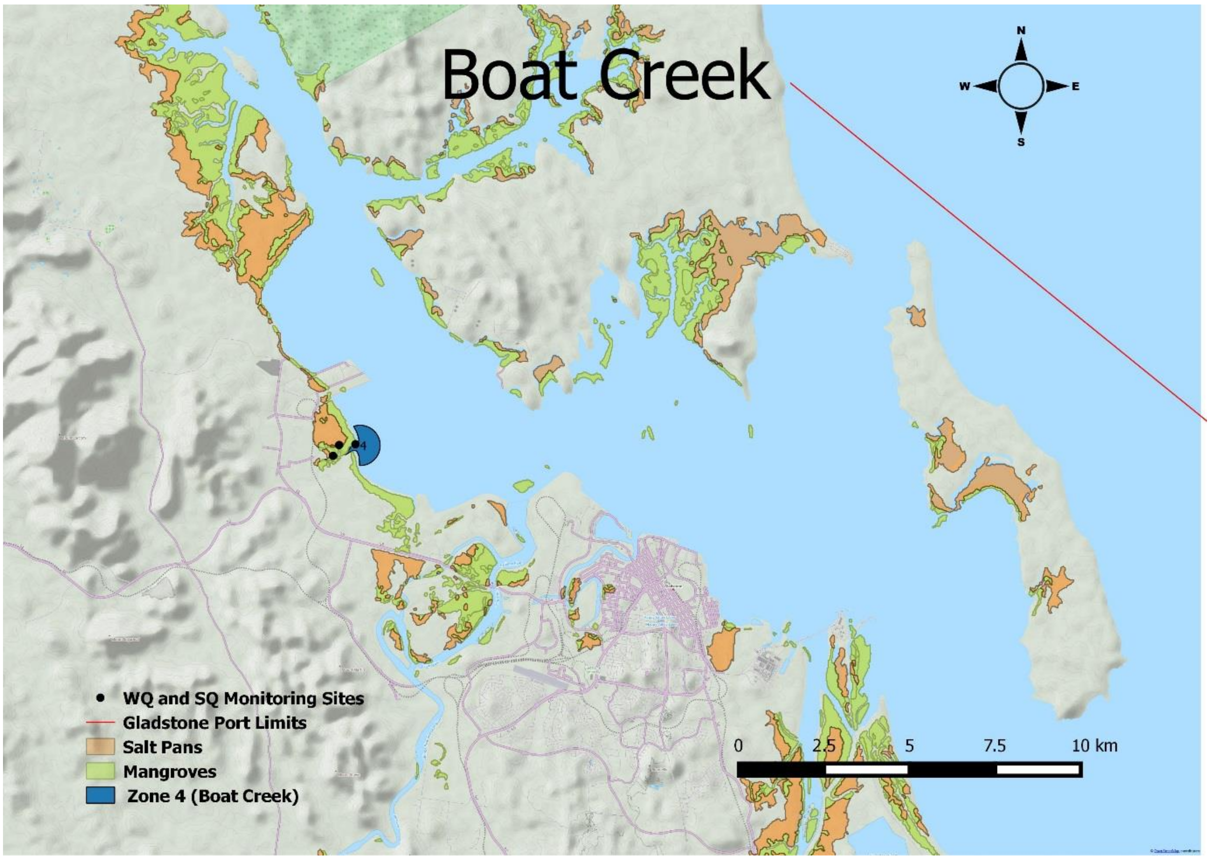


Figure 3.8: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 4: Boat Creek.

Three water and sediment quality monitoring sites

Zone area: 0.75km^2

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

Figure 3.9: Inlet to Boat Creek photographed from the Western Basin.

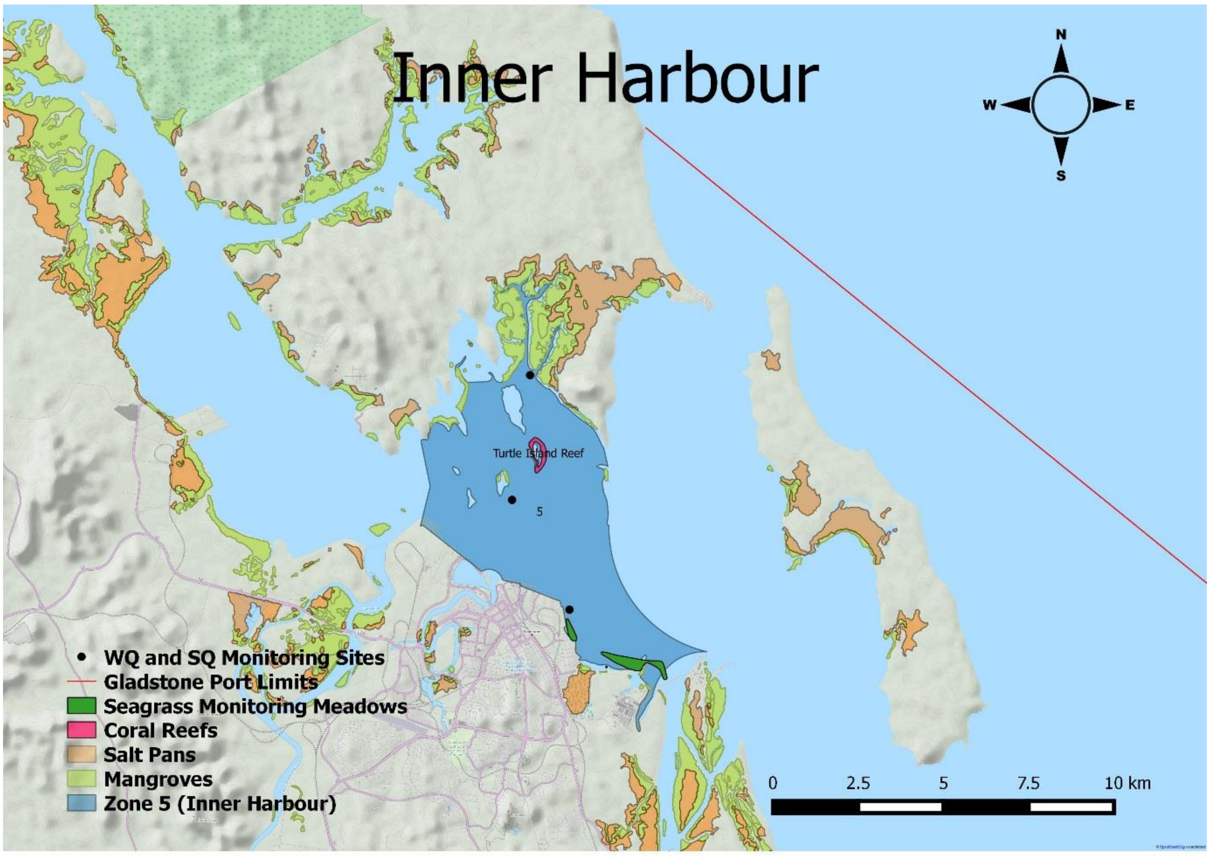


Figure 3.10: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 5: Inner Harbour.

Three water and sediment quality monitoring sites
One monitored seagrass meadow

Zone area: 33.68km^2

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. The Quoin Island Turtle Rehabilitation Centre is located in the centre of this zone and the Barney Point Coal terminal is located on the south-east banks of the zone.

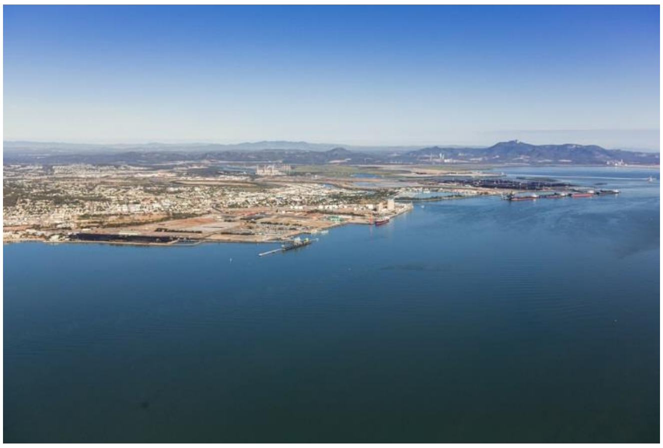


Figure 3.11: The Inner Harbour photographed from the north-east, with Auckland Point wharves and the City of Gladstone on the left and the RG Tanna coal loading facility on the right.

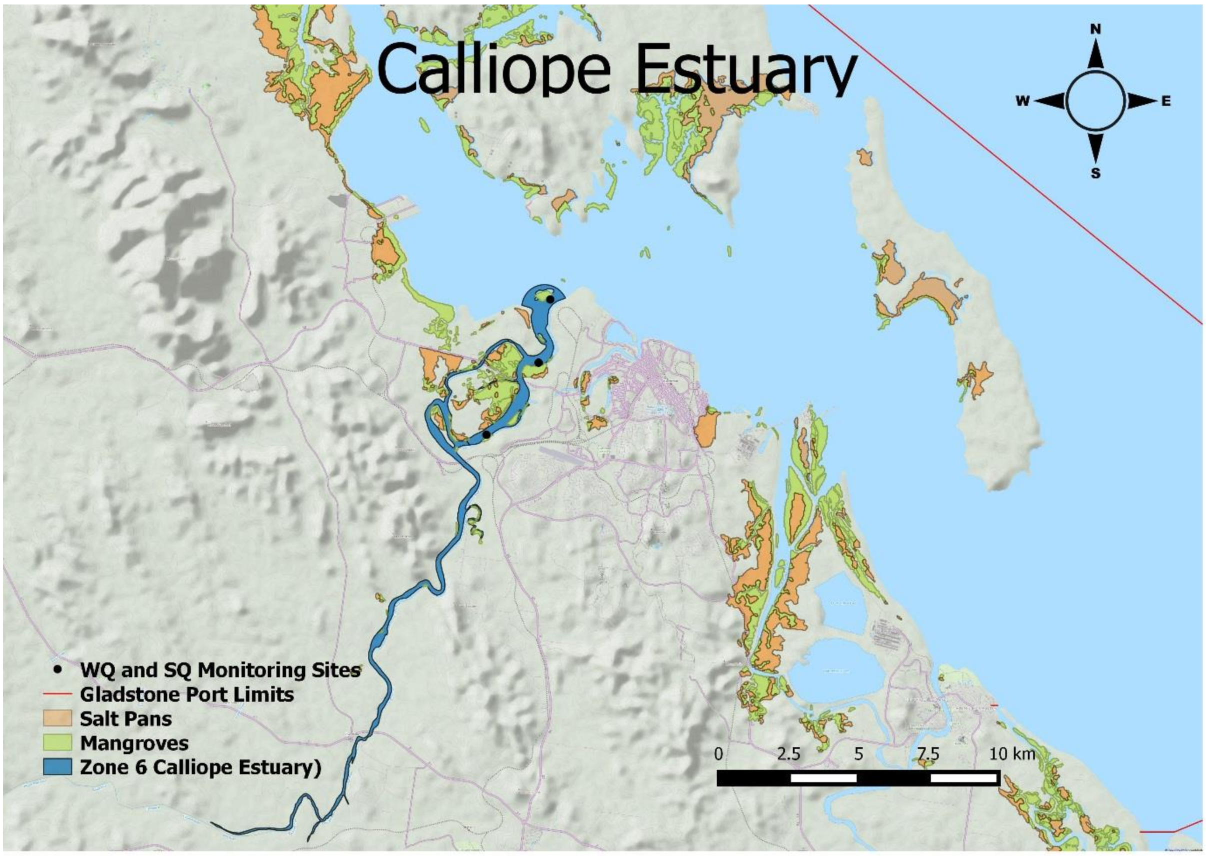


Figure 3.12: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 6: Calliope Estuary.

Three water and sediment quality monitoring sites Zone area: 7.71km^2

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 4km upstream from the river mouth, and has been operating since 1976.

Figure 3.13: The Gladstone coal-fired power station, on the bank of the Calliope Estuary photographed from the north-east.

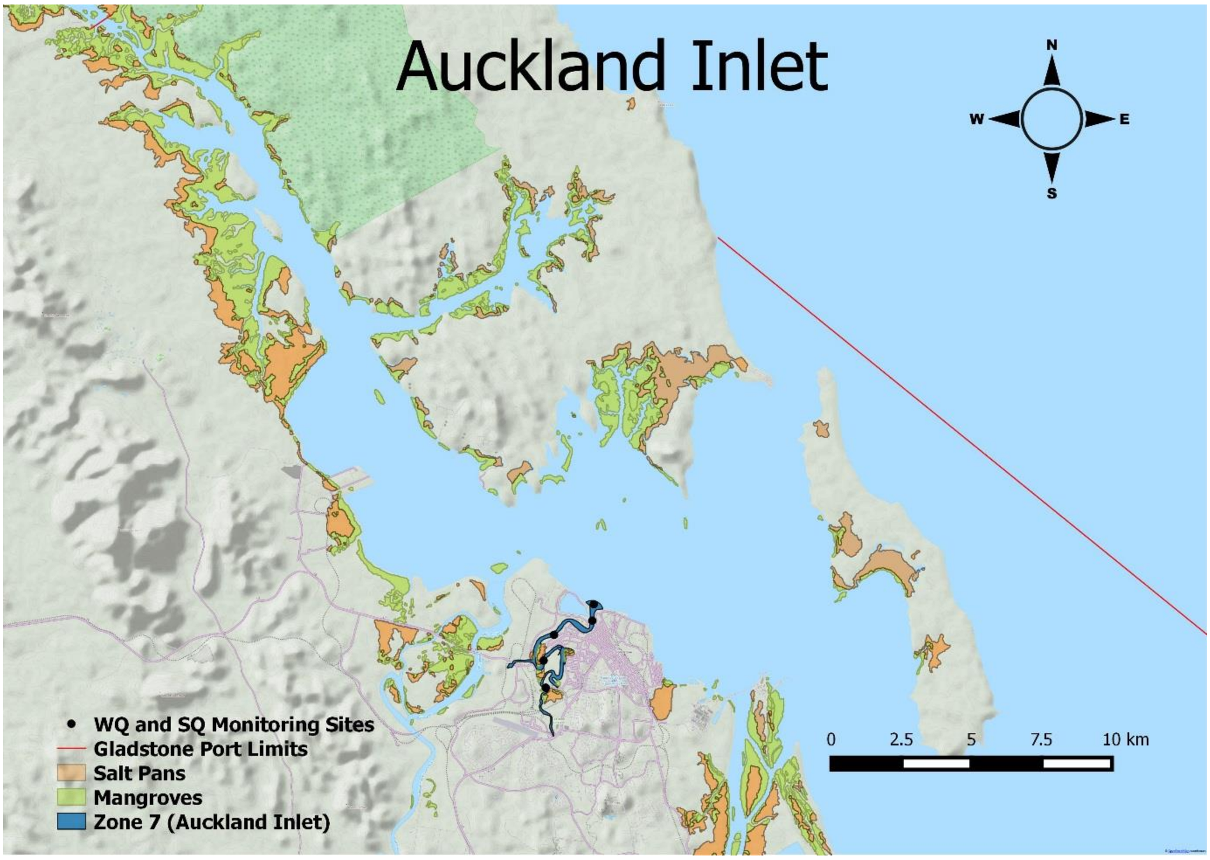


Figure 3.14: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 7: Auckland Inlet.

Five water and sediment quality monitoring sites Zone area: 1.33km^2

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 3.15: Auckland Inlet photographed from the south-west. Gladstone Marina is in the middle ground and the Auckland Point wharves to the left.

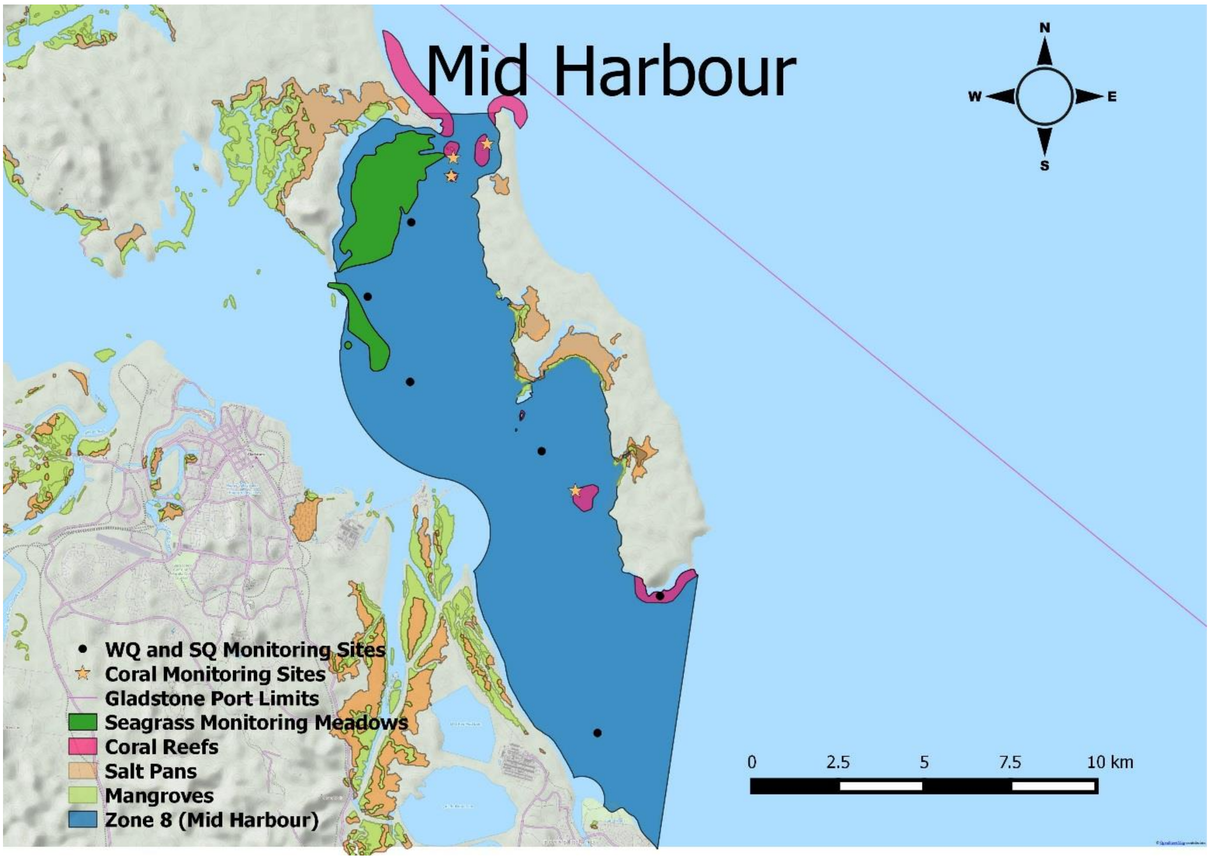


Figure 3.16: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 8: Mid Harbour.

Six water and sediment quality monitoring sites
Two monitored seagrass meadows
Four coral monitoring sites

Zone area: 95.73km^2

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 is adjacent to The Great Barrier Reef Marine Park.

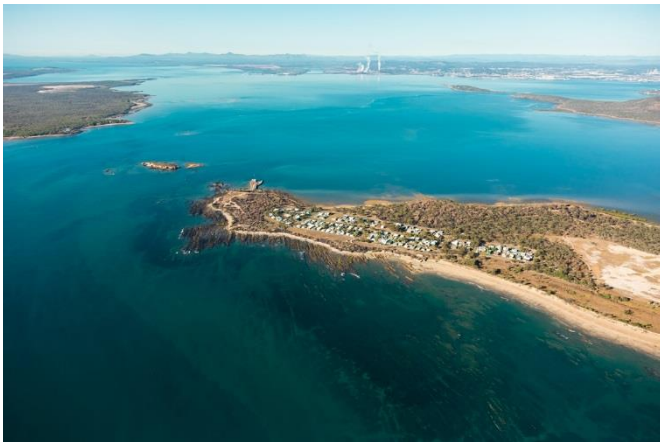


Figure 3.17: The Mid Harbour photographed from north-east. Curtis Island is in the foreground and the Inner Harbour is in the background.

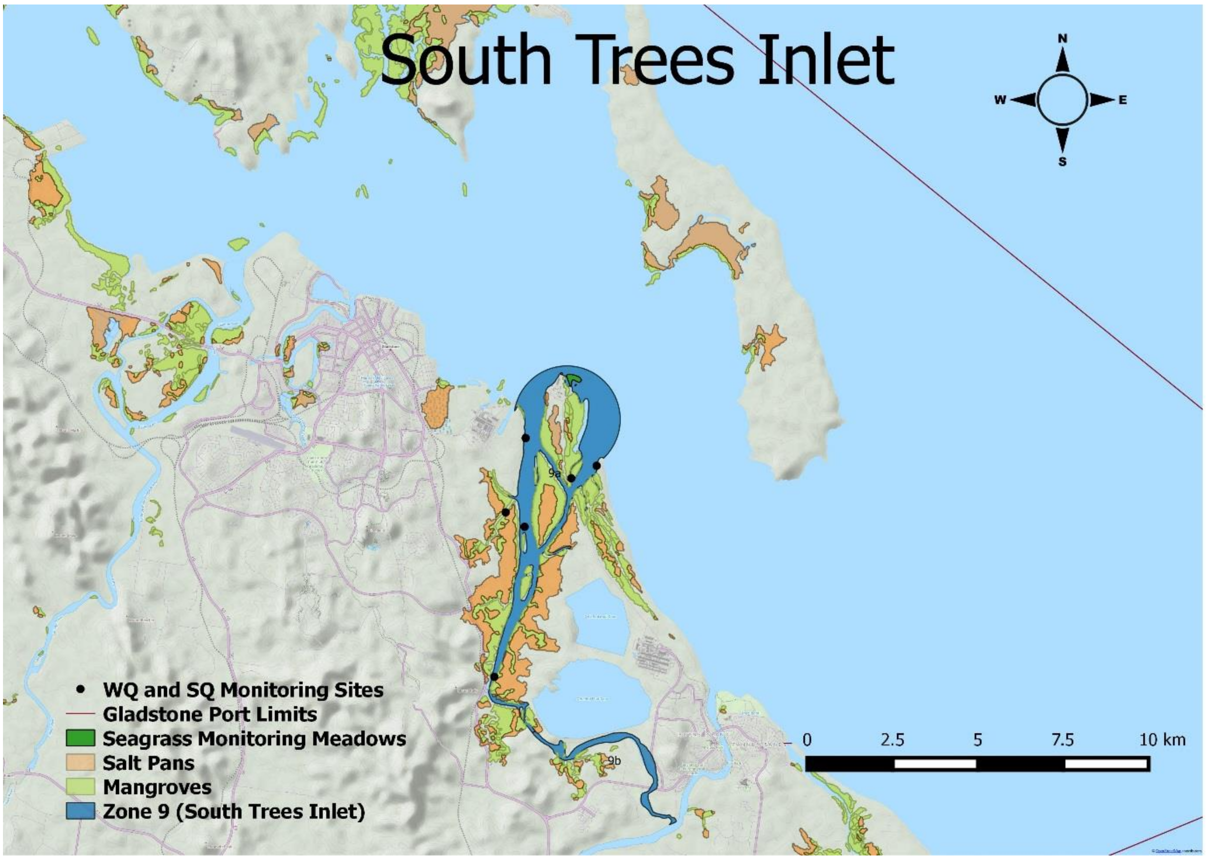


Figure 3.18: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 9: South Trees Inlet.

Six water and sediment quality monitoring sites
One seagrass monitoring meadow

Zone area: 9.45km^2

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 10.9ha 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 3.19: The mouth of South Trees Inlet photographed from the north, showing South Trees Island in the foreground and Boyne Island in the background.

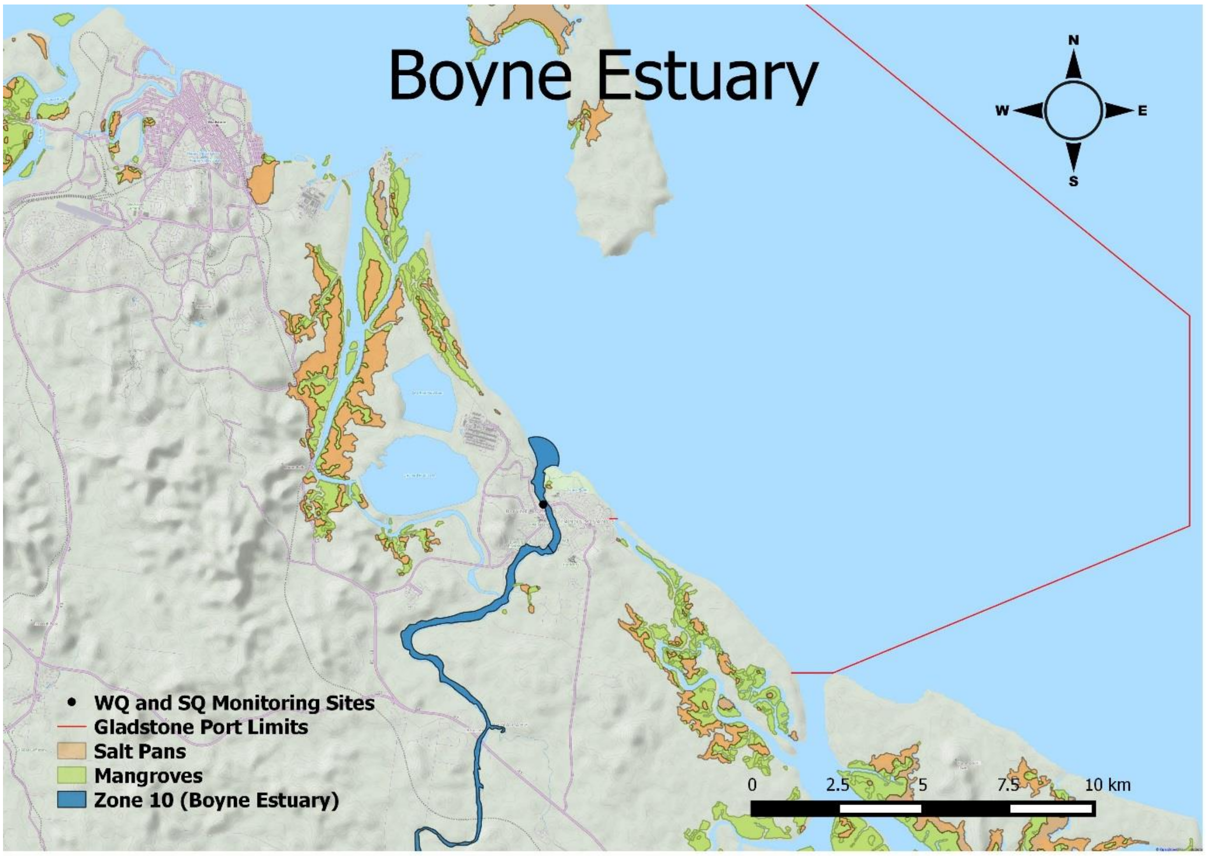


Figure 3.20: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 10: Boyne Estuary.

One water and sediment quality monitoring site   Zone area: 3.62km^2

The Boyne River is dammed at Lake Awoonga to provide potable water for the Gladstone area. Large numbers of barramundi 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 barramundi 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 3.21: The mouth of the Boyne River photographed from the north-east. Boyne Island is on the right and Tannum Sands on the left.

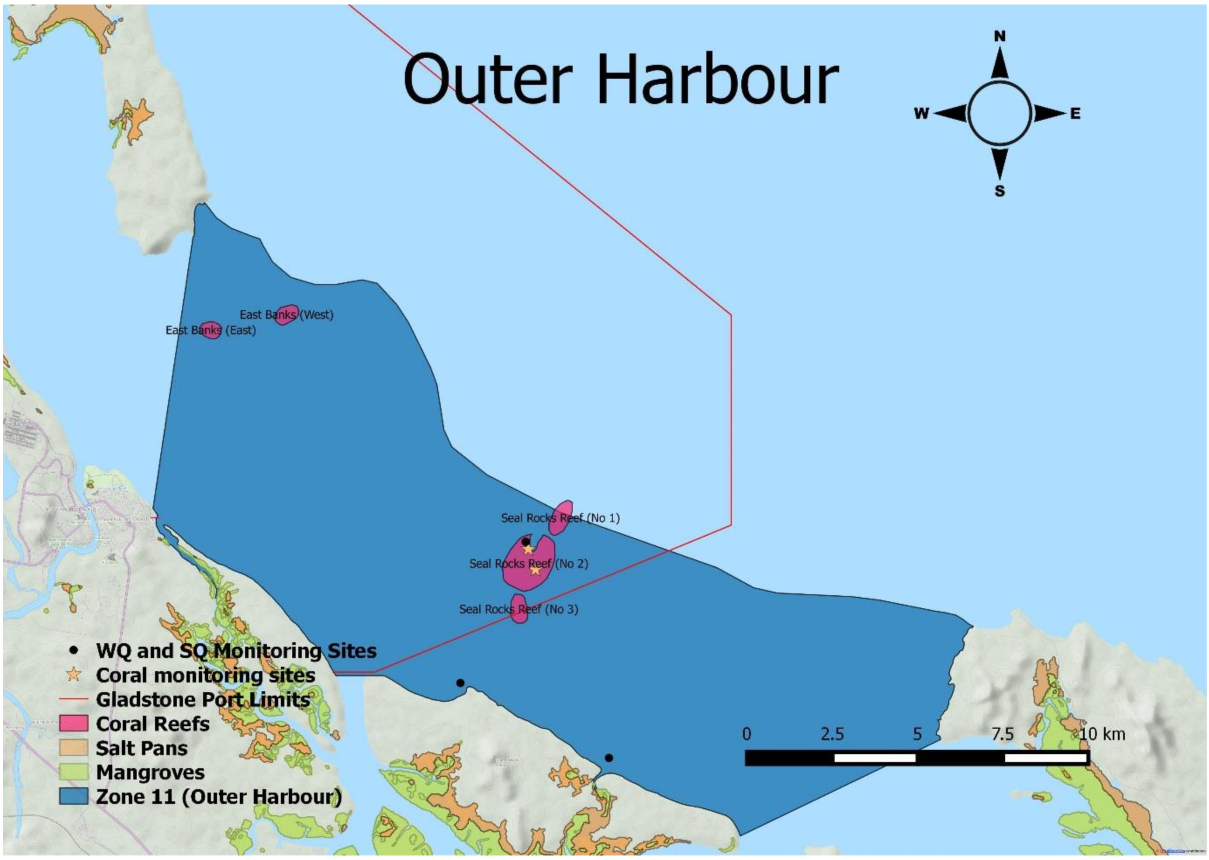


Figure 3.22: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 11: Outer Harbour.

Three water and sediment quality monitoring sites
Two coral monitoring sites

Zone area: 176.97km^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 spoil ground is located to the east of this boundary.

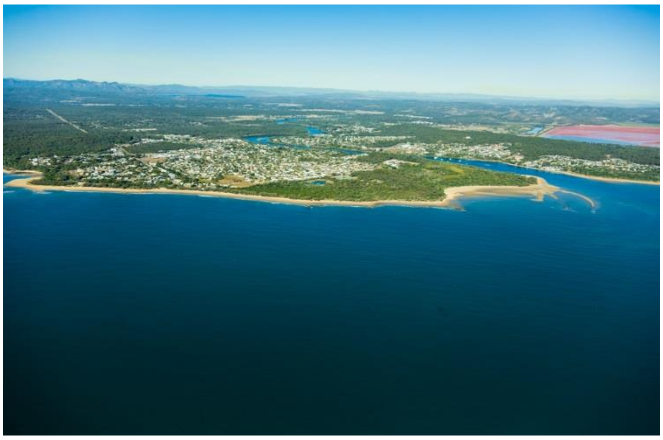


Figure 3.23: The Outer Harbour and Tannum Sands photographed from the north-east. Boyne Island and one of Gladstone's red mud (bauxite) dams are on the right.

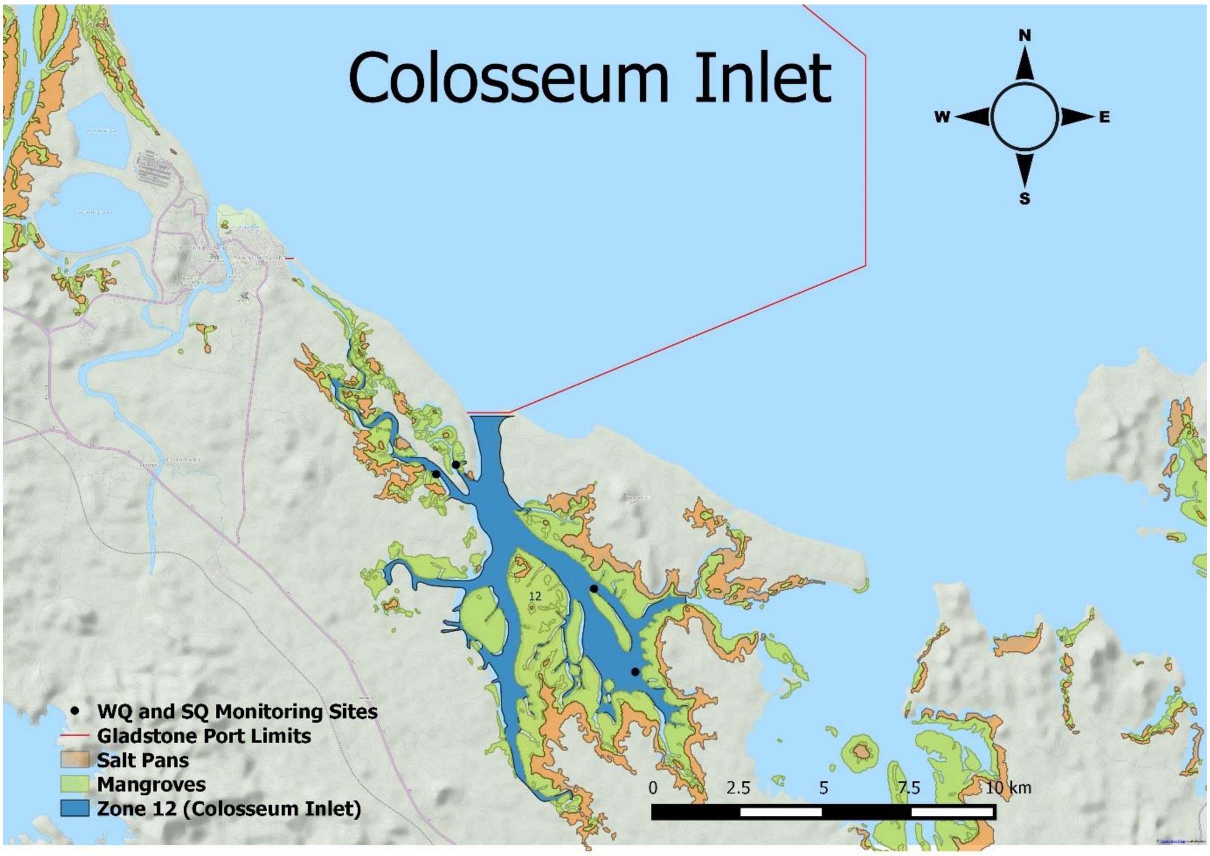


Figure 3.24: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 12: Colosseum Inlet.

Four water and sediment quality monitoring sites

Zone area: 18.98km^2

Colosseum Inlet is an estuarine zone that is sheltered by Hummock Hill Island. Colosseum Inlet connects to both 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 3.25: The northern entrance to Colosseum Inlet showing Wild Cattle Island on the right and Hummock Hill Island on the left.

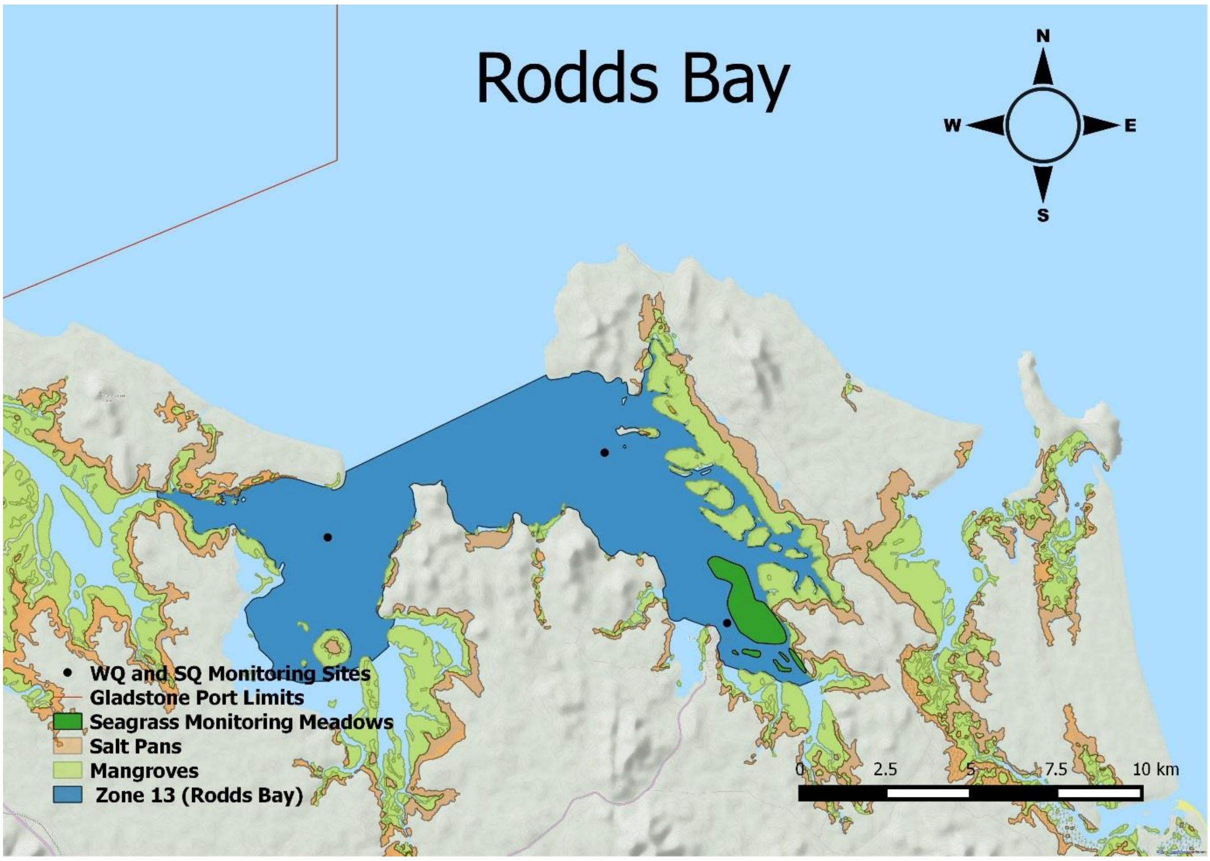


Figure 3.26: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 13: Rodds Bay.

Three water and sediment quality monitoring sites

Three seagrass monitoring meadows

Zone area: 70.14km^2

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 3.27: The eastern arm of Rodds Bay showing Rodds Peninsula in the foreground.

3.2. Social, cultural and economic reporting areas

Data that contributed to the social, cultural ('sense of place') and economic grades were collected from the Gladstone region. Participants in the CATI survey were selected from within the Gladstone 4680 postcode area (Figure 3.28). Hotel occupancy rates were based on the Gladstone Local Government Area (LGA) (Figure 3.28). The Gladstone Ports Corporation (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), including Gladstone Harbour and the open coastal waters immediately adjacent to the harbour (Figure 3.29).

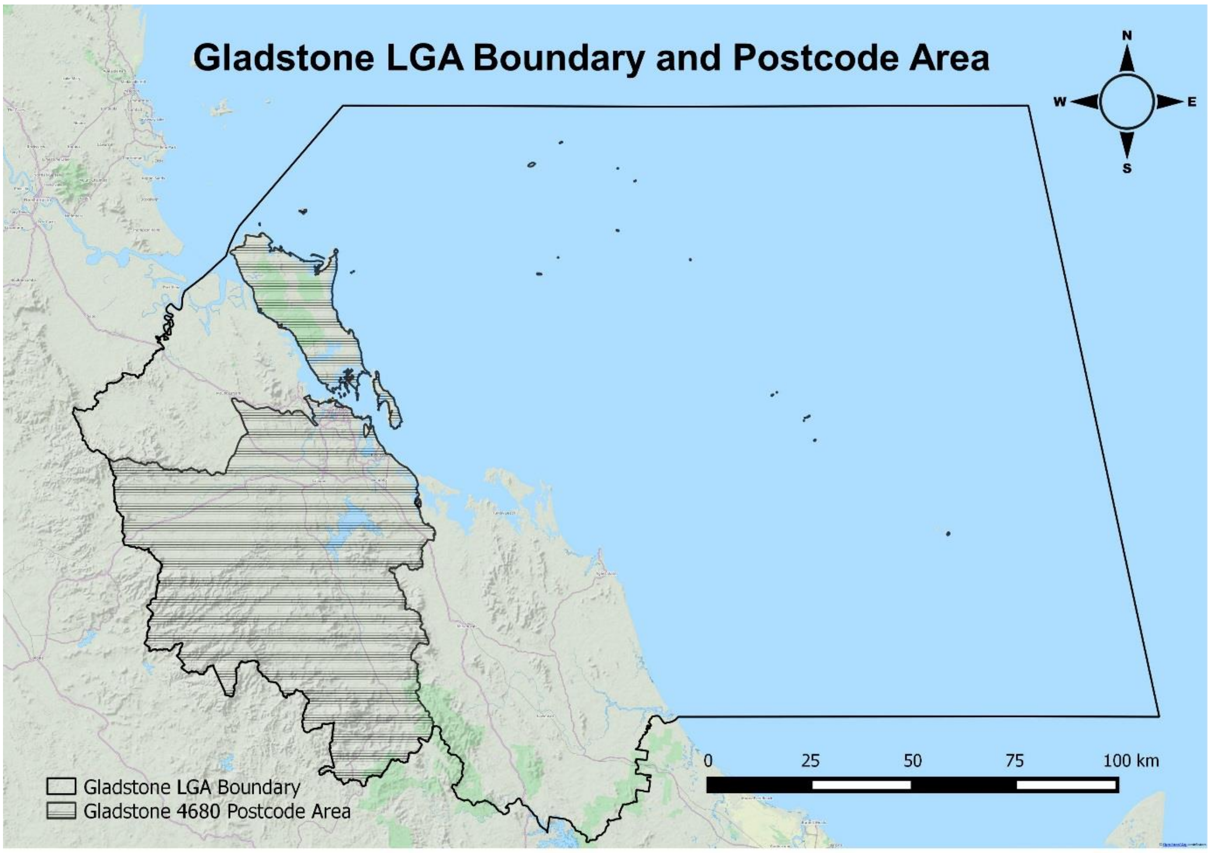


Figure 3.28: The Gladstone region showing the mainland extent of the Gladstone Local Government Area (LGA) and the Gladstone 4680 postcode area. Both were used to define areas from which some social, cultural and economic data were collected.

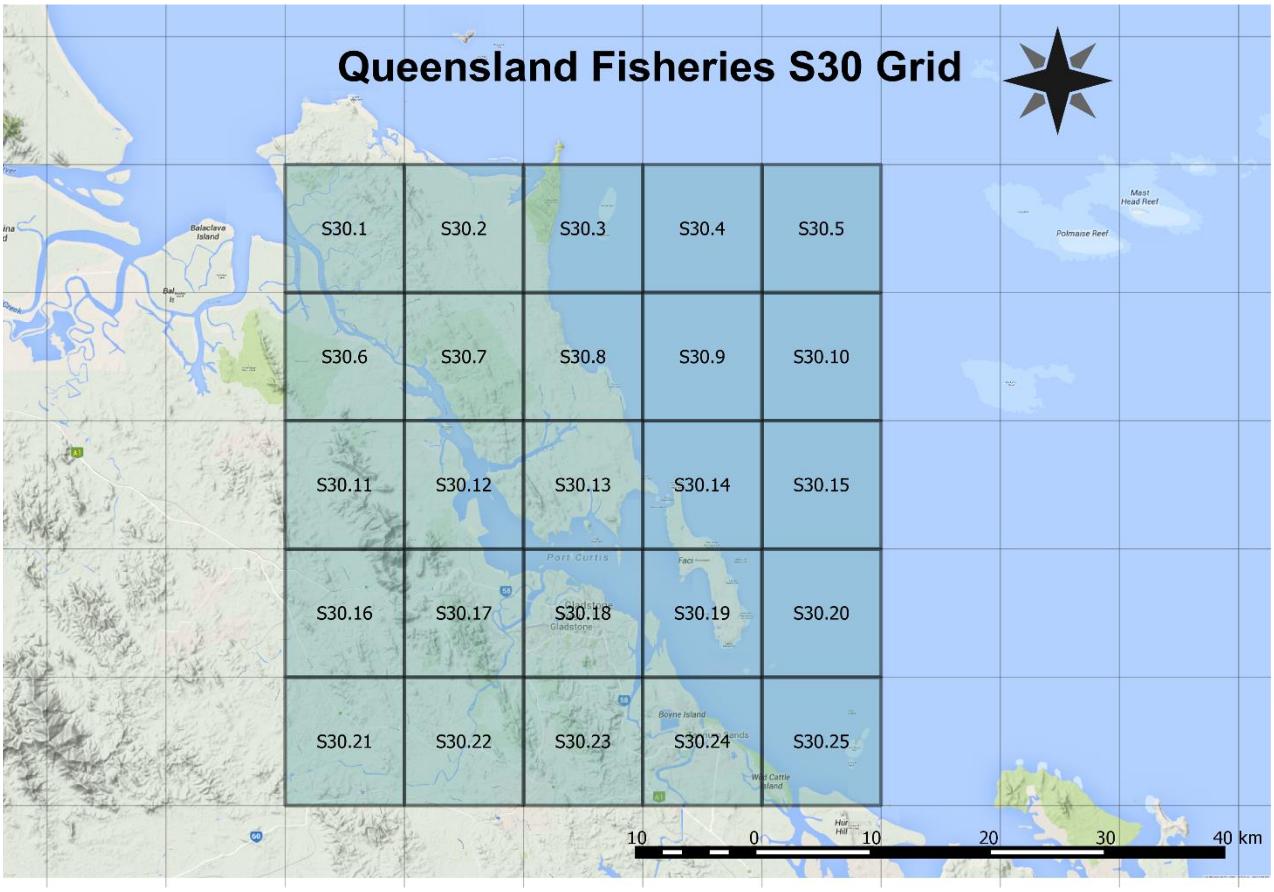


Figure 3.29: The Queensland Fisheries S30 Grid. Data from this grid are used to calculate the commercial fishing indicator.

Data for the Indigenous cultural heritage indicator group were collected from four zones within the LGA boundary: The Narrows, Facing Island, Gladstone Central and Wild Cattle Creek (Figure 3.30). Hummock Hill Island was identified as a potential zone of reporting for Indigenous cultural heritage indicator group, however data were not collected during the 2015–16 reporting year owing to access difficulties.

The Narrows

The Narrows is the largest zone and it extends from Deception Creek to the Calliope River anabranch to the south and covers approximately 381km^2 of both the mainland and parts of Curtis Island. Six sites were assessed during the field surveys. The cultural locus site is an extremely dense quarry that is 2km-long and was used by Aboriginal people to quarry silcrete raw material to manufacture stone tools. A number of stone arrangements were found in the north of The Narrows and a number of semi-permanent pools were located in the south-east parts of the zone. A close examination of the material found during the surveys suggested the area was disturbed by fire, water activity, cattle and trampling in the past.

Facing Island

Facing Island is located approximately 7km east of the Gladstone Central Business District. Facing Island covers approximately 57km^2 and mainly consists of long sandy beaches. Six sites were assessed in detail during the field surveys. The cultural locus site is a large shell midden, a number of stone tools and shell scatters are located in the south-eastern part of Facing Island.

Gladstone Central

The Gladstone Central zone covers approximately 83km^2 between Police Creek and South Trees Island. Three sites—Barney Point, Hector Johnson Park and Police Creek—have been assessed in detail during the field surveys. The cultural locus site was identified within the Police Creek area because of its significant heritage values in the context of settlement and development in Gladstone. At present, there are public walking tracks and interpretive signs in this zone explaining the ecology and history of Police Creek.

Wild Cattle Creek

The Wild Cattle Creek zone is the smallest of the cultural zones and it covers approximately 41km^2 running south for about 13km along the shore from the mouth of the Boyne River, near Tannum Sands. This zone includes the Wild Cattle Island National Park which is important for endangered migratory birds and nesting sea turtles. Access to sites within this zone was restricted due to its geographic location and availability of pre-registered site details. Eleven sites were assessed during the field surveys and the cultural locus site was a shell midden site near Tannum Sands. Most of the exposed shell middens located were found along Wild Cattle Creek.

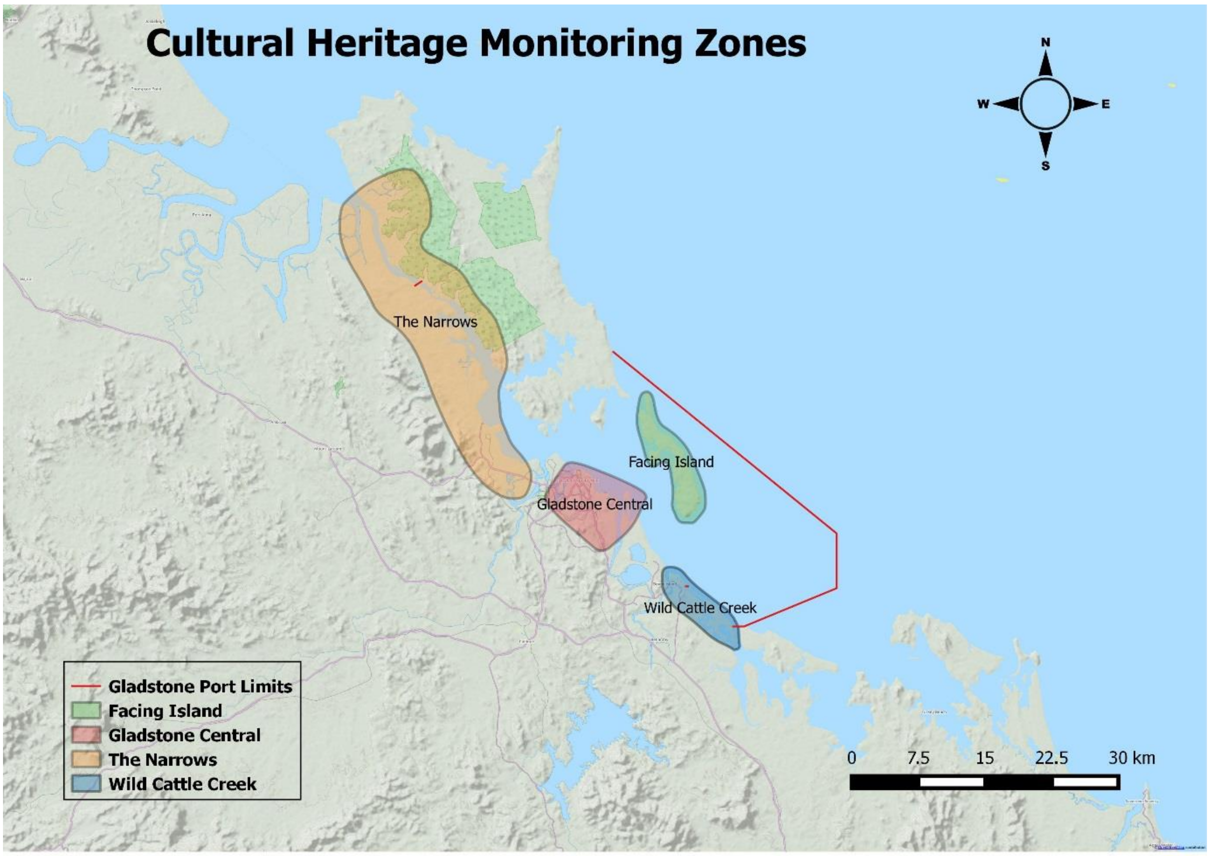


Figure 3.30: The four reporting zones from which data used to inform the Indigenous cultural heritage indicators for 2016 report card were collected.

4. The Environmental component

The Environmental component of the 2016 Report Card consists of three indicator groups: water and sediment quality, habitats, and fish and crabs. The connectivity indicator group has been removed from the Environmental component for 2016 as connectivity was considered to be a system driver rather than a measure of environmental health. Gladstone Harbour connectivity will continue to be modelled and will be reported in the Gladstone Harbour Report Card and the 'drivers and pressures' section of the Report Card Technical Report (Section 9).

In 2016, the fish and crabs indicator will only include fish recruitment. Separate indicators for fish and mud crab health are being developed and will be reported in future report cards. PAHs will not be reported as a sediment quality indicator as this measure was not monitored in 2016 owing to the low levels recorded in 2015. An additional habitat indicator, mangroves, will be included from 2017 subject to data availability.

The environmental indicators address the following Gladstone Harbour Report Card objectives:

- Maintain water and sediment quality.
- Maintain or improve habitat function and structure of key ecosystems.
- Maintain sustainable populations of fauna species reliant on the harbour and waterways.
- Maintain or improve connectivity of water within and between Gladstone Harbour, related rivers, estuaries and adjacent waters.

4.1. 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 and climatic factors play a major role in determining the water and sediment quality recorded in the harbour. The ISP selected the measures for water and sediment quality that are used in the Gladstone Harbour Report Card, all of which have local or national guidelines.

For the Gladstone Harbour Report Card, guideline values were provided by:

- DEHP Water Quality Objectives for the Capricorn Curtis Coast (DEHP, 2014a) for pH, turbidity and nutrients
- ANZECC/ARMCANZ (2000) for most metals in water and sediments
- Golding et al. (2014) for dissolved aluminium in water
- COAG Standing Council on Environment and Water (2013) for manganese in water.

See Appendix 6 for further details.

Guideline values differ among geographic zones within Gladstone Harbour (see for example DEHP, 2014a). The aluminium guidelines developed by Golding et al. (2014) ranged from 2.1ug/L in high ecological value (HEV) zones in Gladstone Harbour (The Narrows, Colosseum Inlet, Rodds Bay) to 24ug/L in moderately disturbed (MD) zones (all other zones). This led to similar actual concentrations of aluminium being graded as very poor in HEV zones and very good in MD zones. This created the misleading impression that the aluminium concentrations were far worse in HEV zones than in MD zones. For that reason, the ISP applied the MD guideline of 24ug/L across all zones. For the same reason, the ISP also selected a consistent guideline of 140ug/L for manganese which was the appropriate guideline for MD systems with coral (COAG Standing Council on Environment and Water, 2013). Manganese guidelines varied between 20ug/L and 390ug/L depending on whether the zone was classified as HEV or MD and whether or not corals were present.

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, 5667.9:1998 and 5667.10:1998)
- *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)
- *Handbook for sediment quality assessment* (Simpson et al., 2013)
- *Department of Environmental Resource Management monitoring and sampling manual* (DERM, 2010).

4.1.1. Data collection

Water quality

Under a data-sharing agreement, PCIMP provided GHHP with water quality data for calculating scores and grades for the 2016 Gladstone Harbour Report Card. Those data were based on samples collected from 50 sites across the 13 harbour zones in August and November 2015 and March and June 2016 (Figures 3.1–3.27).

Eleven water quality parameters were assessed for the 2016 Gladstone Harbour Report Card: two physicochemical measures, three nutrient measures and six dissolved metals (Table 4.1). Physicochemical parameters were measured using a multi-parameter water quality sonde (YSI6820). Measurements were taken at 0.5m depth intervals through the water column until the seabed was reached. Water samples for nutrient and dissolved metal analysis were collected from a depth of about 0.5m using a perspex pole sampler and a 1L acid-rinsed Nalgene bottle. Field blanks, duplicate and triplicate samples and field spikes were also collected during sampling in accordance with the standard protocols described above (Anderson & Melville, 2014a).

Vision Environment Queensland collected the field samples and prepared them for analysis by one of four independent laboratories: National Measurement Institute (NMI), Envirolab Services Pty Ltd, ALS

Global and Sydney Water. NMI is the Australian Government's peak measurement body for biological, chemical, legal, physical and trade measurement. The laboratories that analyse PCIMP data 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 (Flint, 2016).

Table 4.1: Water quality indicators included in the 2016 Gladstone Harbour Report Card.

Indicator	Sub-indicator	Measure	Guideline source
Water quality	Physicochemical	pH	DEHP, 2014a
		Turbidity	DEHP, 2014a
	Nutrients	Total nitrogen (TN)	DEHP, 2014a
		Total phosphorus (TP)	DEHP, 2014a
		Chlorophyll a	DEHP, 2014a
	Dissolved metals	Aluminium (Al)	Golding et al., 2014
		Copper (Cu)	ANZECC/ARMCANZ, 2000
		Lead (Pb)	ANZECC/ARMCANZ, 2000
		Manganese (Mn)	COAG Standing Council on Environment and Water (2013)
		Nickel (Ni)	ANZECC/ARMCANZ, 2000
		Zinc (Zn)	ANZECC/ARMCANZ, 2000

See Appendix 5 for a full list of water quality guidelines.

Sediment quality

The 2016 Gladstone Harbour Report Card assessed six sediment metals and one metalloid (arsenic) (Table 4.2). 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.

PCIMP sampled sediment for the 2016 Gladstone Harbour Report Card in June 2016. They collected this data from the same sites used for water quality sampling in that month (Figures 3.1–3.27). Grab samples were collected for the sediment quality measurements using a stainless steel Ponar grab sampler. 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 100mm of the sample. Four sub-samples were analysed from each site (Anderson & Melville, 2014b).

For quality assurance and quality control (QA/QC), separate grabs were made for duplicate and triplicate samples. NMI analysed all initial samples as well as duplicate samples from 10 sites and Envirolab analysed triplicate samples from five sites.

Table 4.2: Sediment quality indicators included in the 2015 Gladstone Harbour Report Card.

Indicator	Sub-indicator	Measure	Guideline source
Sediment quality	Metals and metalloid	Arsenic (As)	ANZECC/ARMCANZ, 2000
		Cadmium (Cd)	ANZECC/ARMCANZ, 2000
		Copper (Cu)	ANZECC/ARMCANZ, 2000
		Lead (Pb)	ANZECC/ARMCANZ, 2000
		Nickel (Ni)	ANZECC/ARMCANZ, 2000
		Zinc (Zn)	ANZECC/ARMCANZ, 2000

See Appendix 6 for a full list of guidelines.

What water and sediment quality measures were not included?

During early September 2016, the ISP held a meeting with the members from PCIMP and Vision Environment to discuss QA/QC issues associated with the water and sediment quality data collected for the 2016 report card**.** At the meeting, they discussed issues concerning the water and sediment quality raw dataset in relation to the draft scores received for 2016. Following the meeting, the ISP made a decision not to include ammonia, NO_x, orthophosphate and sediment mercury measures in the report card analysis due to inadequate analytical detection limits for these measures.

About 17 dissolved metals data (approximately 2% of overall water and sediment data) were also removed from the analysis. This was because, for these samples, the dissolved metal concentrations were higher than the total metal concentration, possibly due to contamination either during collection or analysis.

4.1.2. Why were these indicators measured

4.1.2.1. 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). The 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 contribute to turbidity. High turbidity decreases the light levels reaching the seabed which reduces photosynthesis and the production of dissolved oxygen. This can lead to mortality of algae, seagrasses and corals. The suspended material in the water may also clog fish gills and smother benthic invertebrates.

4.1.2.2. Nutrients

Nitrogen (N) and phosphorus (P) are essential nutrients for all organisms and occur in a number of forms in the natural environment. However, excess concentrations of these nutrients in the marine environment may lead to increased biomass of phytoplankton and other aquatic plants, which as they decay, may deplete the oxygen available for aquatic animals.

Total nitrogen

Total nitrogen (TN) is the sum of the four major chemical forms of nitrogen in the marine environment: nitrate, nitrite, organic nitrogen and ammonia nitrogen. Nitrogen is an essential nutrient for all organisms, but at high levels it can lead to algal blooms, deplete oxygen in the water (eutrophication) and impact the growth of corals.

Total phosphorus

In aquatic systems, phosphorus exists in different forms such as dissolved orthophosphate, organically bound phosphate and particulate phosphate. The total phosphorus (TP) measure gives an indication of all forms of phosphorus in the water body. Key sources of phosphorus in water include cleaning products, urban run-off, fertiliser run-off, rock weathering, partially treated sewage effluent and animal faeces. Phosphorus is an essential nutrient for all organisms, but at high levels it can lead to algal blooms, deplete oxygen in the water (eutrophication) and impact coral growth.

Chlorophyll-a

Chlorophyll-a is a plant pigment used in photosynthesis. In marine systems it is found in algae such as seaweeds and phytoplankton. High levels of chlorophyll-a may indicate blooms of algae which can occur when nutrients levels are elevated. This can lead to depleted levels of oxygen in the water and to fish kills.

4.1.2.3. Dissolved metals and metalloids

A suite of dissolved metals and one metalloid (arsenic) have been selected as indicators of harbour health.

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, urban run-off) or anthropogenic (e.g. mining waste, industrial discharges). 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 that may be toxic to aquatic species.

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. Similar to other metals, the sources of copper in oceanic waters may be natural (e.g. release 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. In water, lead is mostly adsorbed onto sediment and suspended particles. Its tendency to bioaccumulate up the food chain poses a potential hazard to higher level consumers, including humans. This metal has no known benefits to aquatic plants or animals.

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 is low. Two manganese deposits near Gladstone Harbour have previously been mined and produced over 1,000t of manganese ore. Those deposits were at Auckland Inlet (mined 1882–1900) and Boat Creek (mined 1901–1902) (Wilson & Anastasi, 2010).

Nickel

Nickel (Ni) is the 24th most abundant metal in the Earth's crust and is essential for all organisms (Cempel & Nikel, 2006). Nickel in waterways can come from sources that are industrial (e.g. industrial discharges, coal handling) 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 becomes toxic to organisms.

4.1.3. Results

4.1.3.1 Water quality

The overall water quality score was derived from three sub-indicator groups, physicochemical, nutrients and dissolved metals. The physicochemical group comprised pH and turbidity; the nutrients group comprised Chlorophyll-a, total nitrogen and total phosphorus, and the dissolved metals group comprised aluminium, copper, lead, manganese, nickel and zinc.

The overall grade for water quality in the 2016 report card was a B (0.72). All harbour zones received a good grade (B) for overall water quality except Boat Creek which received a satisfactory (C) grade (Table 4.3).

Table 4.3: Overall water quality, physicochemical, nutrient and dissolved metal scores for the 13 zones in the 2016 Gladstone Harbour Report Card. Overall zone scores for 2015 shown for comparison.

Water quality	Physico-chemical score	Nutrients score	Dissolved metals score	Zone score 2016	Zone score 2015
1. The Narrows	0.69	0.38	0.94	0.68	0.82
2. Graham Creek	0.81	0.47	0.95	0.75	0.86
3. Western Basin	0.71	0.42	0.92	0.70	0.82
4. Boat Creek	0.62	0.22	0.88	0.58	0.70
5. Inner Harbour	0.72	0.66	0.94	0.78	0.88
6. Calliope Estuary	0.68	0.51	0.93	0.71	0.86
7. Auckland Inlet	0.61	0.56	0.92	0.71	0.77
8. Mid Harbour	0.71	0.63	0.95	0.77	0.80
9. South Trees Inlet	0.85	0.57	0.93	0.79	0.85
10. Boyne Estuary	0.71	0.46	0.95	0.71	0.70
11. Outer Harbour	0.57	0.67	0.91	0.72	0.84
12. Colosseum Inlet	0.66	0.56	0.95	0.73	0.78
13. Rodds Bay	0.65	0.58	0.95	0.73	0.80

Of the two physicochemical measures, turbidity received poor or very poor scores in 11 harbour zones, indicating high levels of turbidity relative to the baseline for the zone (Appendix 5 and Table 4.4). Boat Creek, Auckland Inlet and Outer Harbour recorded the lowest scores for this measure. Very high scores for pH in all zones resulted in a very good grade (A) across the 13 monitoring zones (Table 4.4).

Scores for nutrients were typically satisfactory or above, however one harbour zone (Boat Creek) received a very poor score (0.22) and four harbour zones (The Narrows, Graham Creek, Western Basin and Boyne Estuary) received poor scores (0.38–0.47). Of the measures, scores for total nitrogen were the lowest, and one zone, Boat Creek, received a very poor score (0.18), and six zones received poor scores (0.29–0.49). The remaining six zones received satisfactory scores (0.51–0.59) (Table 4.4). Total phosphorus in nine harbour zones was satisfactory or good (0.52–0.84), although Boat Creek had a very poor score of 0.16 (Table 4.4). For Chlorophyll-a, nine harbour zones received satisfactory to very good scores (0.51–0.86). Graham Creek had a very poor score (0.23) and three zones (The Narrows, Western Basin and Boat Creek) had poor scores (0.34–0.39) (Table 4.4).

Low concentrations of dissolved metals were recorded across all 13 harbour zones. Very good scores (> 0.85) were recorded for lead, nickel and zinc across all zones. Aluminium and manganese also received very good scores in all zones except for Outer Harbour which received a good score for aluminium (0.75) and Boat Creek which received a good score for manganese (0.76). Copper scores were either satisfactory or good in all zones, with scores ranging from 0.54 to 0.69 (Table 4.4).

Table 4.4: Scores for water quality measures for each of the 13 zones in the 2016 Gladstone Harbour Report Card.

Zone	Physicochemical		Nutrients			Metals					
	pH	Turbidity	TN*	TP**	Chl-a***	Aluminium	Copper	Lead	Manganese	Nickel	Zinc
1. The Narrows	1.00	0.39	0.42	0.33	0.39	0.94	0.69	1.00	1.00	1.00	1.00
2. Graham Creek	1.00	0.61	0.36	0.84	0.23	1.00	0.69	1.00	1.00	1.00	1.00
3. Western Basin	1.00	0.42	0.51	0.52	0.25	0.91	0.62	1.00	1.00	1.00	1.00
4. Boat Creek	1.00	0.24	0.18	0.16	0.34	0.88	0.65	1.00	0.76	1.00	1.00
5. Inner Harbour	1.00	0.44	0.59	0.75	0.64	0.95	0.68	1.00	1.00	1.00	1.00
6. Calliope Estuary	1.00	0.36	0.42	0.49	0.62	1.00	0.56	1.00	1.00	1.00	1.00
7. Auckland Inlet	1.00	0.23	0.49	0.48	0.70	1.00	0.54	1.00	1.00	1.00	1.00
8. Mid Harbour	1.00	0.42	0.56	0.60	0.76	1.00	0.69	1.00	1.00	1.00	1.00
9. South Trees Inlet	1.00	0.70	0.54	0.64	0.54	0.92	0.69	1.00	1.00	1.00	1.00
10. Boyne Estuary	1.00	0.42	0.29	0.58	0.51	1.00	0.69	1.00	1.00	1.00	1.00
11. Outer Harbour	1.00	0.14	0.51	0.64	0.86	0.75	0.69	1.00	1.00	1.00	1.00
12. Colosseum Inlet	1.00	0.33	0.47	0.53	0.68	1.00	0.69	1.00	1.00	1.00	1.00
13. Rodds Bay	1.00	0.29	0.55	0.54	0.66	1.00	0.69	1.00	1.00	1.00	1.00

*Total nitrogen
**Total phosphorus
***Chlorophyll-a

4.1.3.2. Sediment quality

The overall sediment quality score was derived from one sub-indicator: metals and metalloids. Five metals (cadmium, copper, lead, nickel and zinc) and the metalloid arsenic were assessed.

The overall grade for sediment quality was an A (0.96) indicating concentrations that were below the guideline values.

Zone scores for sediment quality ranged from 0.90 in Boat Creek to 1.00 in Colosseum Inlet (Table 4.5) indicating low concentrations of sediment metals across the harbour. Cadmium, copper, lead and zinc received very good scores (> 0.85) in all zones (Table 4.6). Arsenic received very good scores in 8 of the 13 zones and good scores in the remaining zones. Nickel received very good scores in 11 harbour zones.

Table 4.5: Sediment quality indicator scores for Gladstone Harbour zones in 2016 and 2015.

Sediment quality	Metals and metalloids score	Zone score 2016	Zone score 2015
1. The Narrows	0.93	0.92	0.94
2. Graham Creek	0.96	0.96	0.98
3. Western Basin	0.98	0.98	0.99
4. Boat Creek	0.90	0.90	0.96
5. Inner Harbour	0.94	0.94	0.98
6. Calliope Estuary	0.99	0.99	0.98
7. Auckland Inlet	0.94	0.94	0.94
8. Mid Harbour	0.97	0.97	0.99
9. South Trees Inlet	0.94	0.95	0.96
10. Boyne Estuary	0.98	0.98	1.00
11. Outer Harbour	0.96	0.96	0.96
12. Colosseum Inlet	1.00	1.00	1.00
13. Rodds Bay	0.99	0.99	0.98

Table 4.6: Scores for sediment quality measures for each of the 13 zones in the 2016 Gladstone Harbour Report Card.

Zone	Metals and metalloids					
	Arsenic	Cadmium	Copper	Lead	Nickel	Zinc
1. The Narrows	0.79	1.00	1.00	1.00	0.77	1.00
2. Graham Creek	0.88	1.00	1.00	1.00	0.87	1.00
3. Western Basin	0.94	1.00	1.00	1.00	0.96	1.00
4. Boat Creek	0.87	1.00	0.95	1.00	0.60	1.00
5. Inner Harbour	0.70	1.00	1.00	1.00	0.97	1.00
6. Calliope Estuary	0.96	1.00	1.00	1.00	0.97	1.00
7. Auckland Inlet	0.92	1.00	0.94	1.00	0.76	1.00
8. Mid Harbour	0.80	1.00	1.00	1.00	1.00	1.00
9. South Trees Inlet	0.82	1.00	1.00	1.00	0.86	1.00
10. Boyne Estuary	0.87	1.00	1.00	1.00	1.00	1.00
11. Outer Harbour	0.75	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
13. Rodds Bay	0.91	1.00	1.00	1.00	1.00	1.00

4.1.4. Water and sediment quality conclusions

Water quality

Water quality was relatively uniform across the harbour, and all zones except for Boat Creek received good overall scores. Similar to 2015, water quality received a B, although the overall score declined from 0.81 in 2015 to 0.72 in 2016. This was a result of lower physicochemical scores. Although scores for pH remained consistently high, scores for turbidity were lower than in 2015 (Table 4.7). Nutrients received a satisfactory score in 8 of the 13 harbour zones. Chlorophyll-a was measured for the first time this year. Scores for TN and TP improved from the 2015 scores in most harbour zones. As in 2015, scores for dissolved metals were very good in all zones.

Table 4.7: Comparison of the scores for selected water quality measures from 2015 and 2016.

Zone	Turbidity 2015	Turbidity 2016	Total nitrogen 2015	Total nitrogen 2016	Total phosphorus 2015	Total phosphorus 2016
1. The Narrows	0.62	0.39	0.50	0.42	0.45	0.33
2. Graham Creek	0.76	0.61	0.47	0.36	0.69	0.84
3. Western Basin	0.69	0.42	0.48	0.51	0.41	0.52
4. Boat Creek	0.39	0.24	0.40	0.18	0.05	0.16
5. Inner Harbour	0.84	0.44	0.58	0.59	0.62	0.75
6. Calliope Estuary	0.93	0.36	0.46	0.42	0.53	0.49
7. Auckland Inlet	0.42	0.23	0.52	0.49	0.38	0.48
8. Mid Harbour	0.53	0.42	0.60	0.56	0.50	0.60
9. South Trees Inlet	0.78	0.70	0.48	0.54	0.35	0.64
10. Boyne Estuary	0.38	0.42	0.00	0.29	0.21	0.58
11. Outer Harbour	0.64	0.14	0.46	0.51	0.72	0.64
12. Colosseum Inlet	0.55	0.33	0.29	0.47	0.35	0.53
13. Rodds Bay	0.56	0.29	0.37	0.55	0.53	0.54

Sediment quality

Sediment quality scores were uniformly very good across all zones of Gladstone Harbour due to low concentrations of metals (cadmium, copper, lead, nickel and zinc). This is consistent with the results in 2015.

4.2. Seagrass

What is seagrass?

Seagrasses are the only flowering plants that can live submerged in the marine environment; and they play an important roles in the marine ecosystem. A range of marine species including turtles, dugongs, crabs, sea-cucumbers and some fish species graze on seagrass. There are four families of seagrass in the world. The seagrass indicators in the report card are based on five seagrass species from two of these families: Hydrocharitaceae and Zosteraceae.

Species of seagrass used to inform the indicator,

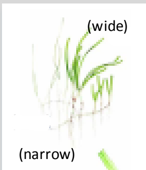
Zostera muelleri
Halophila ovalis
Halophila decipiens
Halophila spinulosa
Halodule uninervis

Zostera muelleri

Halophila ovalis

Halophila decipiens

Halophila spinulosa



Halodule uninervis

Seagrass meadows are one of the most important habitat types within 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 12,000ha. This area can include intertidal, shallow subtidal and deep-water habitats. Seagrasses can inhabit various substrata from mud to rock. The most extensive seagrass beds occur on soft substrata such as sand and mud. Seagrass meadows provide a range of important ecosystem functions, such as sediment stabilisation, nutrient cycling and carbon sequestration. They can also provide nursery areas for juvenile fish and foraging areas for dugongs, turtles and large fish such as adult 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 both seagrass growth and the size and extent of extant 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 that may be associated with flooding or dredging can result in deposits of silt on seagrass. The large tidal movements may also result in a significant resuspension of fine sediments (Condie et al., 2015). At a local scale, dredging can impact seagrasses by increasing turbidity, direct removal, burial by dredge spoil and the destabilisation of the seafloor allowing for resuspension of sediments (York & Smith, 2013).

Seagrass monitoring in Gladstone Harbour since 2002 has enabled changes in seagrass conditions to be assessed over that period.

The Gladstone Harbour Report Card objective for key ecosystems is to ‘maintain/improve habitat function and structure of key ecosystems’. Three indicators of seagrass health are measured to calculate the seagrass grades for the 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.

4.2.1. Data collection

The Seagrass Ecology Group from the Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) at James Cook University collected seagrass data to determine the seagrass scores and grades. This group has been monitoring seagrass at Gladstone Harbour and Rodds Bay since 2002 when 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 Gladstone Port Limits.

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 3.2, 3.6, 3.10, 3.16, 3.18 and 3.26). 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.

Biomass and species composition

Above-ground biomass was determined using visual estimates. At each site, 0.25m^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 where then converted into estimates of above-ground biomass in grams dry weight per square metre (gDWm^{-2}).

Area

The total area of the monitored seagrass meadows was determined in ArcGIS using GPS coordinates of meadow boundaries and presence of seagrass at sampling sites. Three seagrass GIS layers were created:

- site information – including percent seagrass cover, above-ground biomass, species composition, depth below mean sea level, sediment type, time and GPS coordinates
- meadow characteristics – summary information on meadow characteristics, including community type and abundance category (light, moderate or dense), based on the above-ground biomass of the dominant species
- seagrass landscape category – seagrass meadows were classified as isolated seagrass patches, aggregated seagrass patches or continuous seagrass cover.

A mapping precision estimate ranging from ±5m to ± 50m was determined for each meadow based on the mapping methodology (Table 4.8).

Table 4.8: Mapping precision and mapping methodology for seagrass meadows for seagrass surveys conducted in November 2014 (Source: Bryant et al., 2014).

Mapping precision	Mapping methodology
≥ 5m	Meadow boundaries mapped in detail 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
10m	Meadow boundaries determined from helicopter and diver/grab surveys Inshore boundaries interpreted from helicopter sites Offshore boundaries interpreted from survey sites and aerial photography Moderately high density of mapping and survey sites
20m	Meadow boundaries determined from helicopter and diver/grab surveys Inshore boundaries interpreted from helicopter sites Offshore boundaries interpreted from diver/grab survey sites Lower density of survey sites for some sections of boundary
50m	Meadow boundaries determined from helicopter and diver/grab surveys Inshore boundaries interpreted from helicopter sites Offshore boundaries interpreted from diver/grab survey sites Low density of survey sites for some sections of boundary

4.2.2. Development of indicators and grades

Seagrass scores and grades for the Gladstone Harbour Report Card were determined by comparing the results for each seagrass meadow with a predetermined baseline condition. Bryant et al. (2014) determined the most appropriate baseline to be a fixed 10-year (2002–2012) average calculated from previous seagrass surveys.

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

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

For biomass, area and species composition, different ranges of thresholds were developed for a range of meadow classes (Figure 4. 1). Grades for each indicator were determined based on these thresholds and a score between 0.00 and 1.00 was calculated to fit the GHHP range (Carter et al., 2015a).

The overall grade for each monitoring meadow was defined as the lowest grade received for each of the three indicators (biomass, area or species composition). The lowest score, rather than the mean of the three indicator scores, was applied in recognition that a poor grade for any one of the three described a seagrass meadow in poor condition.

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.

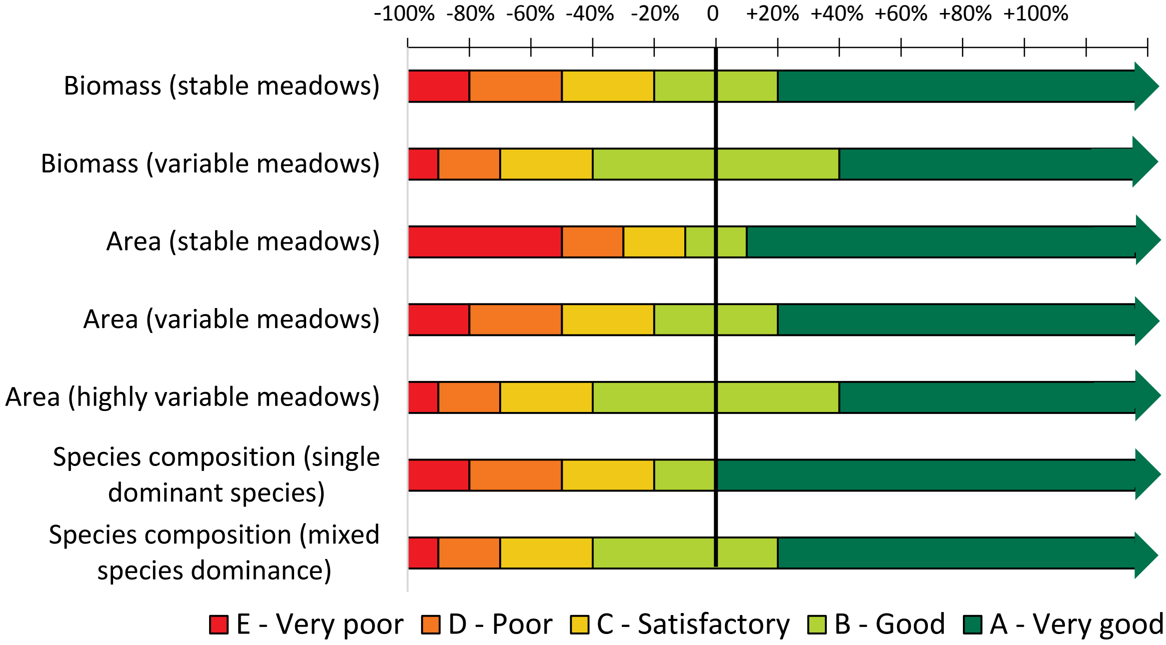


Figure 4.1: Threshold values between grades A to E varied for the seagrass meadow types for each of the three seagrass indicators (biomass, area and species composition). Each grade was determined by the percentage difference from a baseline of the 10-year mean.

4.2.3. Results

The overall score for seagrass in the 2015–16 reporting year of 0.35 (D) indicates that seagrass meadows in Gladstone Harbour were in poor condition overall. The Inner Harbour received the lowest zone score of 0.14 (E) owing to a low score for species composition. The Narrows (0.33), Mid Harbour (0.35), South Trees Inlet (0.48) and Rodds Bay (0.25) received scores that indicate a poor condition (D). This resulted from low biomass scores in these zones. The Western Basin 0.55 (C) was in a satisfactory condition. No zone was in a good (B) or very good (A) condition.

Table 4.9: Scores for seagrass indicators (biomass, area and species composition) and overall meadow, zone and harbour score for 2015–16 reporting year and overall zone score from 2014–15.

Zone	Meadow	Biomass score	Area score	Species composition score	Overall meadow score	Zone score 2016	Zone score 2015
1. The Narrows	21	0.33	0.87	0.57	0.33	0.33	0.15
3. Western Basin	4	0.83	0.52	0.78	0.52	0.55	0.51
	5	0.49	0.58	0.34	0.34		
	6	0.68	0.82	0.67	0.67		
	7	CR*	0.78	1.00	0.78		
	8	0.88	0.51	0.38	0.38		
	52–57	0.60	0.96	1.00	0.60		
5. Inner Harbour	58	0.42	0.92	0.14	0.14	0.14	0.41
8. Mid Harbour	43	0.25	0.78	0.68	0.25	0.35	0.56
	48	0.46	0.54	0.51	0.46		
9. South Trees Inlet	60	0.48	0.88	0.59	0.48	0.48	0.52
13. Rodds Bay	94	0.08	0.28	0.36	0.08	0.25	0.45
	96	0.40	0.76	0.66	0.40		
	104	0.28	0.29	0.46	0.28		
Harbour score						**0.35**	**0.43**

* CR = calculation restriction—a biomass score could not be calculated for 2015 due to a small sample size.

Zone 1 – The Narrows

The Narrows (Figure 3.2) has one monitored meadow at Black Swan Island. It is an intertidal meadow comprising aggregated patches of seagrass. Although the overall condition of this meadow declined from very good to very poor in the 2014–15 reporting year, the overall condition increased to satisfactory in the 2015–16 reporting year.

Zone 3 – Western Basin

The Western Basin (Figure 3.6) has six monitored meadows. These are predominantly intertidal meadows comprising aggregated patches of seagrass with the exception of Meadow 7 which is sub-tidal. In comparison to the 2014–15 reporting year, the zone score increased from 0.51 to 0.55 in the 2015–16 reporting year.

Meadow scores were determined as the lowest of the three indicator scores. In Meadow 52–57 this resulted from a biomass score of 0.60 indicating a satisfactory condition for this meadow. Meadow 4 received a score of 0.52 for meadow area indicating a satisfactory condition, and Meadow 6 received a score of 0.67 indicating a good condition. Species composition determined the overall score in three meadows: Meadows 5 and 8 received scores of 0.34 and 0.38, respectively, indicating a poor condition; and Meadow 6 received a score of 0.67 indicating a good condition (Table 4.9).

Zone 5 – Inner Harbour

The Inner Harbour (Figure 3.10) has one monitored meadow in the south-east corner of the zone near South Trees Inlet. This is an intertidal meadow comprising isolated patches of seagrass. The zone score was determined by the lowest indicator score for this meadow which was biomass (0.14) indicating a very poor condition. This meadow disappeared in 2010. When re-established in 2011, most of the previously dominant species, *Zostera muelleri*, was lost and replaced by *Halophila ovalis*. By 2015, *Z. muelleri* accounted for just 3% of the seagrass biomass in the meadow. Meadow biomass has remained low (0.42) since the meadow's return. Meadow area was in very good condition receiving a score of 0.92 in the 2015–16 reporting year.

Zone 8 – Mid Harbour

The Middle Harbour (Figure 3.16) has two monitored meadows in the north of the zone near the south-east tip of Curtis Island. The largest meadow (43), Pelican Banks, is the largest seagrass meadow in the harbour and covers an area of nearly 600ha. This meadow is considered to be the most abundant and productive seagrass in the Gladstone area and is the only one where all three indicators have been classified as stable. Pelican Banks is intertidal, while Meadow 48 contains both intertidal and sub-tidal areas.

In the 2015–16 reporting year, the Mid Harbour zone received an overall score of 0.35 indicating a poor condition. This score was down from 0.56 in the 2014–15 reporting year when the zone was considered to be in satisfactory condition.

Both meadows received poor scores for biomass, 0.25 for Meadow 43 and 0.46 for Meadow 48. Meadow 43 received good scores for area and species composition, 0.78 and 0.68, respectively, while Meadow 48 received satisfactory scores for both area and species composition of 0.54 and 0.51, respectively.

Zone 9 – South Trees Inlet

South Trees Inlet (Figure 3.18) has one monitored meadow which sits just of the northern tip of South Trees Island. Its area of 10.9ha makes it the second smallest of the monitored meadows. Meadow 60 is an intertidal meadow comprising aggregated patches of seagrass.

South Trees Inlet received an overall zone score of 0.48 for the 2015–16 reporting year (Table 4.9) as a result of a poor score for biomass. Biomass has fluctuated between satisfactory and poor since 2009 following a decline from very good condition in 2007–08. Meadow area was in very good condition (0.88) and species composition received a satisfactory score (0.59).

Zone 13 – Rodds Bay

There are three intertidal seagrass meadows in Rodds Bay (Figure 3.26) comprising aggregated seagrass patches dominated by *Z. muelleri* subsp. *capricorni.* In the 2015–16 reporting year, the overall zone score was 0.25 indicating a poor condition. All three zones received their lowest scores for biomass: Meadow 94 was in very poor condition (0.08) and meadows 96 and 94 received poor scores of 0.40 and 0.28, respectively. Meadow 96 received a good score for area (0.76), while meadows 94 (0.28) and 104 (0.29) had poor scores (Figure 4 2). Meadows 94 (0.36) and 104 (0.46) had poor scores for species composition, whereas Meadow 96 (0.66) returned a good score.

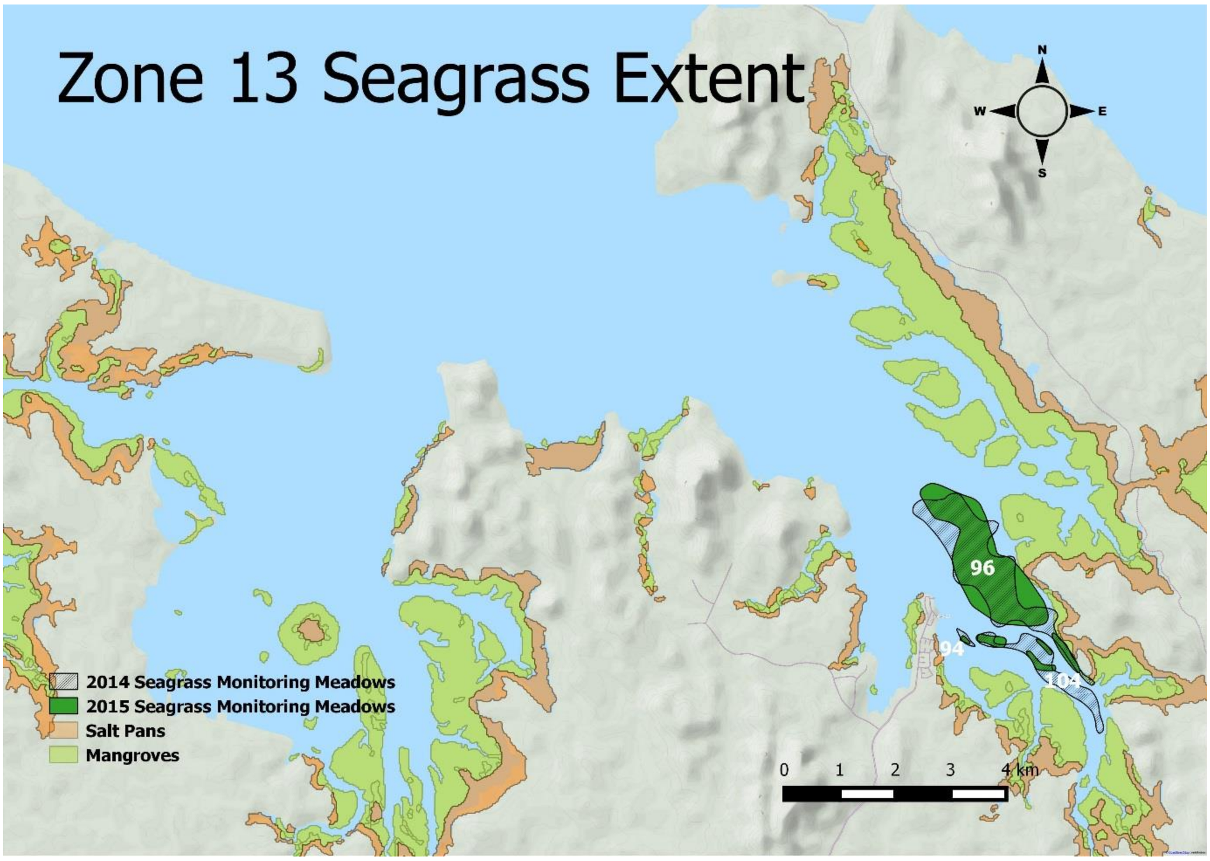


Figure 4.2: Changes to seagrass meadow area in Rodds Bay between 2014-15 and 2015–16.

4.2.4. Seagrass conclusions

The overall seagrass condition for the 2015–16 reporting year was poor owing to poor zone scores in The Narrows, Mid Harbour, South Trees Inlet and Rodds Bay, and very poor condition in the Inner Harbour. The Western Basin was the only zone in a satisfactory condition. There was no sign of seagrass recovery in Gladstone Harbour between the reporting years (2014–15 to 2015–16). Relative to 2014–15, overall seagrass condition in 2015–16 had improved from very poor to satisfactory in The Narrows; remained stable in the Western Basin (satisfactory) and Rodds Bay (poor); and declined in the Inner Harbour (poor to very poor), Mid Harbour and South Trees Inlet (satisfactory to poor). Consecutive years of poor seagrass condition have likely reduced meadow resilience to further impacts.

Since monitoring started in 2002, seagrasses in the Gladstone region have undergone significant declines during and immediately following years of above average rainfall and flow from the Calliope River. Years with a large number of poor and very poor overall meadow grades correspond with observed declines also occurring at Rodds Bay. This monitoring zone, originally established as a reference site, sits entirely outside the Gladstone Port limits just over 50km from the Western Basin. Declines in seagrass biomass were also associated with high flows in the Calliope River. The strongest associations occur at the monitored meadows closest to the river mouth (e.g. Wiggins Island in the Western Basin). The timing of flood-related seagrass declines in 2010 and 2011 prior to the start of the capital dredging program makes it difficult to ascertain what additional impacts dredging may have had on seagrass condition and the subsequent rate of recovery. However, monitoring during the Western Basin Dredging and Disposal Project indicates that light levels were maintained above locally derived guidelines at seagrass meadows outside dredging locations.

There was little improvement in species composition grades in the 2015–16 reporting year following declines that began in 2011. This was mostly a result of a shift from the more stable and persistent species *Z. muelleri* to meadows dominated by the colonising *H. ovalis*. Shifts back to *Z. muelleri* dominance in some meadows indicate both propagule availability and suitable conditions for recruitment of this species. Monitoring in Gladstone Harbour detected seedbanks for this species (McCormack et al., 2013) and TropWATER is investigating their viability.

Multiple years of high rainfall, river flows and cyclone activity in the Gladstone region may have reduced the resilience and capacity for recovery of seagrass communities in Gladstone. However, seagrasses in Queensland have a demonstrated ability to recover from past impacts. Condition improvements recorded for some meadows in Gladstone Harbour suggest that seagrasses remain resilient.

Table 4.10: Grades for individual seagrass monitoring meadows from annual (November) surveys, 2002–2015 (Source: Carter et al., 2016).

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

4.3. Corals

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 and 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 GHHP monitoring zones include fringing, platform, headland and rubble fields with both 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 (> 5m) in The Narrows and around Passage Island and the North Passage. Regions of hard and soft coral also occur along the northern edge of Hummock Island and limited coral reef development has also been identified in Rodds Bay (BMT WBM, 2013; DHI, 2013).

Threats to coral reefs include both 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).

GHHP aims to establish a long-term coral monitoring program consistent with the report card objective for key ecosystems to 'maintain/improve habitat function and structure of key ecosystems'. Three indicators of coral health were measured to calculate the coral score for the 2015 Gladstone Harbour Report Card.

1. Coral cover (%): the combined cover of hard and soft corals relative to a baseline determined by the Australian Institute of Marine Science (AIMS) Reef Plan Marine Monitoring Program (MMP)
2. Macroalgal cover (%): the cover of macroalgae relative to a baseline consistent with the MMP
3. Juvenile coral density (no.m^{-2}): relative to the MMP baseline

A fourth indicator, coral cover change, measures changes in coral cover from the previous year. It will be added in subsequent report cards but cannot be included in the 2016 Gladstone Harbour Report Card as the baseline from which to measure it (two consecutive years of data) is unavailable.

4.3.1. Coral data collection

Site search

Coral surveys between 6 and 8 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 Reef, Farmers Reef, Facing Reef 2 and Manning Reef and two permanent sites were established in the Outer Harbour at Seal Rocks North and Seal Rocks South (Figures 3.16 and 3. 22).

Coral monitoring

Coral monitoring for the 2016 report card was conducted on 26 May 2016 and included the following three methodologies.

Photo point intercept transects

The methodology outlined below closely follows that outlined in the AIMS Long-term Monitoring Program (Jonker et al., 2008). At each 20m transect, digital photographs were taken at 50cm 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 the genus level.

Juvenile corals

Juvenile coral colonies, up to 10cm in diameter were counted within a 34cm band along each permanently marked transect. Each colony was identified to genus level and assigned to a size class of 0–2cm, 2–5cm or 5–10cm. 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.

Disturbances

Incidences of coral disease, coral bleaching, coral predation by crown-of-thorns starfish, overgrowth by sponges, and smothering by sediments were counted along a 2m-wide band centred on the transect tape. These data are not used in the calculation of report card grades and scores. In the long term, however, they may be valuable for explaining changes in coral condition.

4.3.2. Development of indicators and grades

Each of the three coral indicators was scored against a baseline founded on expert opinion and data from the MMP for inshore reefs. The baseline for each of the three indicators represented the threshold between report card grades of C (satisfactory condition) and D (poor condition). 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 4.11). The lowest score of 0.00 was set to represent the worst condition that could be expected in the local environment (Table 4.11). 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 and increases the potential of other reefs in the vicinity to recover from disturbance. Additionally, high coral cover contributes to the structural complexity of a reef. This can increase its biodiversity by providing additional habitat for fish and other marine organisms. Both hard and soft coral cover were included in the assessment.

Macroalgal cover

Macroalgae can suppress coral by increased competition for space and by changing the micro-environment and inhibiting coral colonisation and growth (e.g. Foster et al., 2008; Cheal, et al., 2010 cited in Thompson et al., 2015). Once established, macroalgae occupy space that might otherwise be available for coral growth and recruitment. For this 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 C/D threshold for coral communities in Gladstone Harbour (Table 4.11).

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 (< 10cm) 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 cited in Thompson et al., 2015). High rates of sediment deposition will also negatively impact the number of juvenile colonies observed (Rogers, 1990). This shows that juvenile coral density can indicate a reef's potential for recovery from disturbance given the current conditions.

Thresholds for juvenile coral density are based on the MMP thresholds. These thresholds were set based on data on the densities of juvenile colonies recorded over four years of the MMP (2005–2009). That monitoring determined the mean density of juvenile corals for inshore reefs at sites 2m 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 the 10th and 90th percentiles of the distribution, or 1 and 16 juvenile colonies per m^2, respectively (Table 4.11).

Percentage change in combined cover

Table 4.11: Coral indicator thresholds for the Gladstone Harbour Report Card.

Indicator	Baseline (aligned with the report card C/D threshold of 0.50)	Upper bound (score = 1.00)	Lower bound (score = 0.00)
Combined cover of hard and soft corals	40%	90% (This has been reduced from 100% as coral cover rarely attains 100% coverage due to areas of colonisable substrate and variable population dynamics.)	0%
Macroalgal cover	14%	5%	20% of hard substrate area
Juvenile coral density	$5.8m^{-2}$	$16m^{-2}$	$1m^{-2}$

Aggregation of indicator scores

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

4.3.3. Results

The overall coral grade in the 2016 report card was an E. This was a result of a low cover of living coral, low abundance of juvenile corals and a high macroalgal cover at most of the surveyed reefs (Table 4.12). Both zones surveyed received very poor grades. All indicators received poor to very poor scores at all surveyed sites (Table 4.13).

Table 4.12: Coral indicator scores for the Mid Harbour and Outer Harbour and overall zone and harbour scores (Thompson et al., 2016).

Zone	Coral cover	Macroalgal cover	Juvenile density	Overall score
8. Mid Harbour	0.05	0.10	0.33	0.15
11. Outer Harbour	0.09	0.00	0.33	0.14
Harbour score				**0.15**

Table 4.13: Individual coral indicator scores site level (Thompson et al., 2016[a]).

Zone/Reef	Coral cover		Macroalgal cover		Juvenile density	
	Value (%)	Score	Value (%)	Score	Value (m^{-2})	Score
8. Mid Harbour						
Facing Island 2	6.1	0.08	30.6	0.00	4.57	0.37
Farmers Reef	7.1	0.09	35.8	0.00	3.72	0.34
Manning Reef	0.1	0.00	33.6	0.00	3.36	0.25
Rat Island	5.5	0.07	16.5	0.29	4.77	0.39
11. Outer Harbour						
Seal Rocks North	0.00	0.00	53.0	0.00	4.69	0.38
Seal Rocks South	13.8	0.17	53.1	0.00	3.65	0.28

Coral cover (%) was very low at all reefs and substantially lower than the 40% threshold required to receive a grade of C. The present cover remains considerably lower than that recorded in previous published surveys. In 2009, a mean cover of 39% was recorded for hard corals for reefs in the Mid Harbour zone (BMT WBM, 2013). Similarly, a visual estimate of coral cover at Seal Rocks North (Outer Harbour) in December 2012 was around 50% (R.C. Babcock, personal communication in Thompson et al., 2015).

At both Seal Rocks sites and Facing Island 2, the high cover of macroalgae was dominated by the large brown algae genera *Sargassum* and *Lobophora*. Brown algae is the dominant macroalgae at Rat Island but this makes up a lower percentage of the total cover of algae, sponges and sand and silt than at either Seal Rocks or Facing Island 2. Rat Island was the only reef to receive a poor score for this indicator; all other reefs received a very poor score. In other areas of the inshore Great Barrier Reef, both taxa form persistent communities following declines in coral cover. In contrast, macroalgae cover at Farmers and Manning reefs were predominantly composed of the red algae *Asparagopsis*.

Scores for juvenile coral density were higher than coral cover and macroalgal cover at the surveyed sites and all reefs returned a poor score for this indicator (Table 4.13.). Table 4.14 presents the number of juvenile coral colonies in each size class recorded in the coral surveys. The results of the 2015 surveys are also presented for comparison.

The size of juvenile coral communities can indicate their age as corals spawn annually. Juvenile coral colonies in the 0–2cm range can broadly be considered a result of the previous spawning event. Juvenile coral colonies in the 2–5cm range are estimated to be between one and two years old. Juvenile coral colonies in the 5–10cm range are estimated to be greater than two years old. The very low number of juvenile coral colonies in the 5–10cm class (Table 4.14) suggests a lack of settlement of juveniles spawned in late 2012. Higher numbers of very small colonies could be the result of higher settlement of juveniles occurring following the 2014 spawning event or low survival rates among juveniles that settled after the previous spawning.

Table 4.15 presents causes of coral mortality recorded in the 2015 and 2016 Gladstone Harbour coral surveys.

Table 4.14: Number of juvenile hard coral colonies in three size classes (Thompson et al., 2016a).

Zone	Reef	Year	Size-class categories		
			< 2cm	2–5cm	5–10cm
8. Mid Harbour	Facing Island 2	2015	107	28	0
		2016	67	58	7
	Farmers Reef	2015	32	17	5
		2016	37	26	9
	Manning Reef	2015	52	6	2
		2016	55	40	0
	Rat Island	2015	19	23	8
		2016	48	43	10
11. Outer Harbour	Seal Rocks North	2015	111	31	1
		2016	80	48	8
	Seal Rocks South	2015	52	30	3
		2016	27	55	9

Table 4.15: Causes of coral mortality at the time of the 2015 and 2016 Gladstone Harbour coral surveys. No data is presented for Manning Reef and Seal Rocks North owing to the very low coral cover at these sites (Thompson et al., 2016a).

Zone	Reef	Year	Cause	Coral genus	Colonies affected
8. Mid Harbour	Facing Island 2	2015	Bio-eroding sponge (*Cliona orientalis*)	*Porites*	13
		2016	Bio-eroding sponge	*Turbinaria*	1
			Bio-eroding sponge	*Porites*	8
	Farmers Reef	2015	Bio-eroding sponge	*Cyphastrea*	4
			Bio-eroding sponge	*Favia*	1
		2016	Bio-eroding sponge	*Cyphastrea*	9
	Rat Island	2015	Bleaching	*Favites*	1
			Bio-eroding sponge	*Cyphastrea*	6
				Turbinaria	5
		2016	Bio-eroding sponge	*Cyphastrea*	7
				Turbinaria	4
11. Outer Harbour	Seal Rocks South	2015	Bio-eroding sponge	*Turbinaria*	3
		2016	AN*	*Turbinaria*	1
			Bleaching	*Pocillopora*	2
			Bio-eroding sponge	*Turbinaria*	4
			Unknown	*Turbinaria*	1

*AN = *Atramentos necrosis* (coral disease)

4.3.4. Coral conclusions

Coral communities in Gladstone Harbour remain in a very poor condition. The overall score for coral in 2016 was 0.12, similar to the score of 0.15 recorded in 2015. However, an overall increase in the scores for juvenile density moved this indicator from a very poor to poor condition. The increase was offset by increased cover of macroalgae resulting in lower scores for this indicator. Scores for coral cover were very low and similar to those recorded in 2015 (Table 4.16).

Table 4.16: A comparison of coral indicator scores for the Mid Harbour and Outer Harbour for surveys conducted in 2015 and 2016 (Thompson et al., 2016a).

Zone	Reef	Year	Score			Reef score	Grade
			Coral cover	Macroalgal cover	Juvenile density		
8. Mid Harbour	Facing Island 2	2015	0.16	0.00	0.41	0.19	E
		2016	0.08	0.00	0.37	0.15	E
	Farmers Reef	2015	0.006	1.00	0.26	0.44	D
		2016	0.09	0.00	0.28	0.12	E
	Manning Reef	2015	0.00	0.00	0.12	0.04	E
		2016	0.00	0.00	0.25	0.08	E
	Rat Island	2015	0.08	0.50	0.11	0.23	E
		2016	0.07	0.29	0.39	0.25	D
11. Outer Harbour	Seal Rocks North	2015	0.00	0.00	0.42	0.14	E
		2016	0.00	0.00	0.38	0.13	E
	Seal Rocks South	2015	0.10	0.00	0.25	0.12	E
		2016	0.17	0.00	0.28	0.15	E

The available information strongly suggests that the low coral cover observed at these survey sites resulted from flooding in 2013. Reduced salinity levels from freshwater run-off in flood plumes is a recognised cause of coral mortality. Major flooding of the Boyne and Calliope rivers, a result of heavy rainfalls associated with Tropical Cyclone Oswald in January 2013, temporarily lowered salinity levels within Gladstone Harbour. Converting temperature and conductivity data to practical salinity units (psu) for the Mid Harbour (Vision Environment Queensland, 2013a,b) revealed a period of approximately three days from 27 January to 29 January during which salinity levels remained below 20psu at a depth of 0.75m. A minimum level of 5psu was reached on 28 January. These sustained low levels are likely to have caused high coral mortality within the harbour. Berkelmans et al. (2012) demonstrated a salinity threshold for *Acropora* (e.g. staghorn and elkhorn corals) of 22psu for three days; beyond this level mortality can be expected.

The loss of coral cover caused by freshwater plumes from flooding is not limited to Gladstone Harbour. Flooding of the Fitzroy River caused severe coral mortality in Keppel Bay in 1991 and 2011. The Great Barrier Reef Report Card 2015 indicated that coral reefs in the Fitzroy region remained in poor condition.

Another factor potentially limiting coral cover in 2016 was the bio-eroding sponge *Cliona orientalis* (Table 4.15). At Facing Island Reef, there was an increase in cover of *C. orientalis* from 1% in 2015 to 3.5% in 2016. In combination, such observations suggest that these sponges are playing a role in limiting the recovery of coral in the Mid Harbour zone.

The harbour-wide mean density of juvenile corals increased between the 2015 and 2016 surveys, resulting in a change of grade from very poor to poor. The size class distribution of juvenile corals (Table 4.14) shows an increase in the number of juvenile corals in the larger size classes of 2–5cm and 5–10cm indicating that juvenile colonies are surviving and growing beyond their first year. The survival of these juvenile colonies is a positive sign for the recovery of corals within Gladstone Harbour.

In 2016, macroalgal cover was high at all reefs and had increased since 2015 resulting in very poor scores at all surveyed reefs with the exception of Rat Island Reef which received a poor score. An increase from 4% cover in 2015 to 36% cover in 2016 was observed at Farmers Reef (Table 4.16).

This high cover of macroalgae indicates high levels of nutrients within the harbour. Macroalgal cover is typically variable at reefs predisposed to high cover (Thompson et al., 2016b). Contributing factors to the observed cover could include an earlier survey time, May instead of July, and increased water temperatures in 2016 compared to 2015. The water temperatures in April and May 2016 surveys were substantially higher than those recorded at the same time in 2015 which potentially extended the growth period for macroalgae (Thompson et al., 2016a). However regardless of the changes, the high levels of macroalgae observed in both years are likely to be contributing to the suppression of coral community recovery in Gladstone Harbour (Figure 4.3).

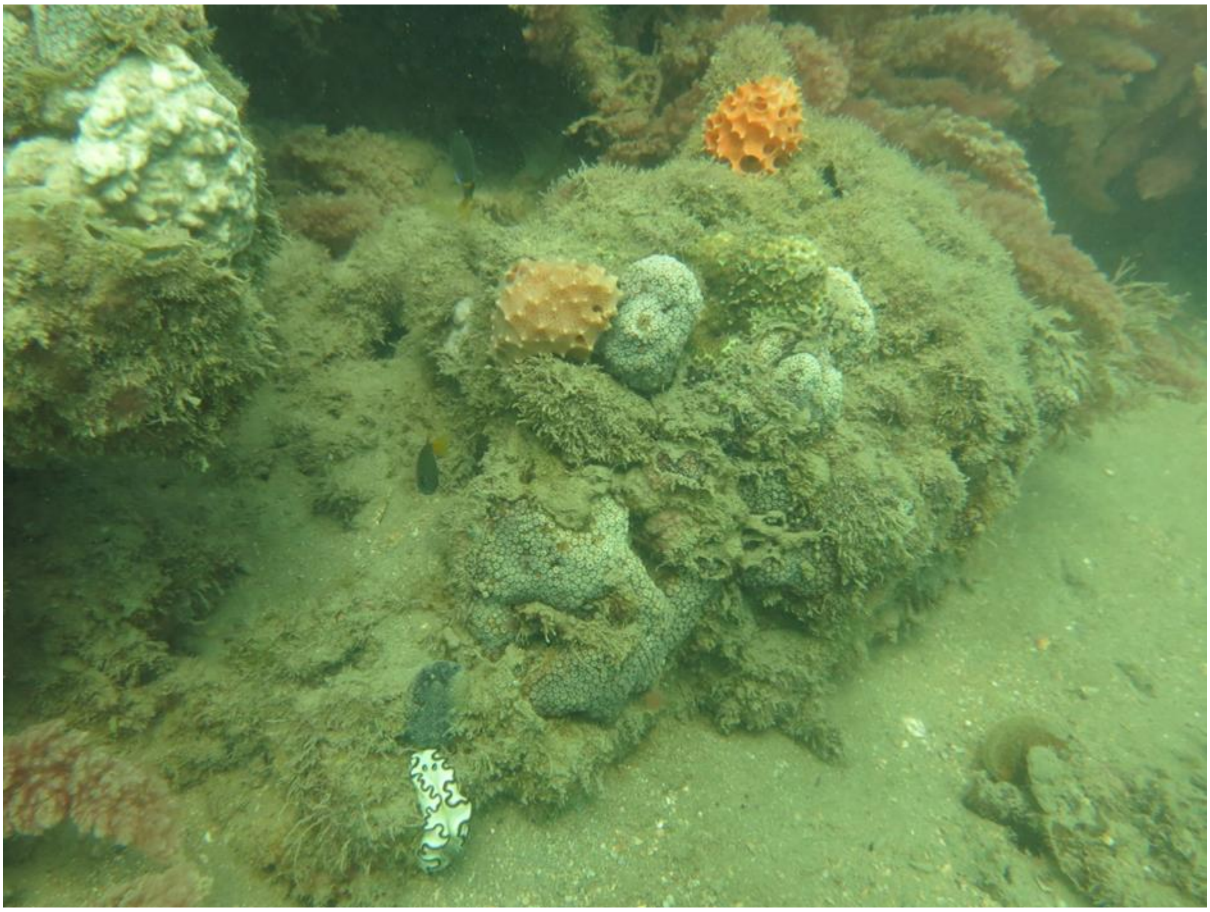


Figure 4.3: Framers Reef juvenile coral colonies and high levels of macroalgal cover (Photo Johnston Davidson).

4.4. Fish and crabs

A fish recruitment index was developed to address the report card objective ‘maintain suitable populations of fauna species reliant on the harbour and waterways’. Fish recruitment is one of the three key dynamic functions that affects a fish population, the other two being growth rate and mortality.

A detailed fish recruitment survey in 2014 helped identify potential species to monitor. Barramundi was considered an unsuitable recruitment indicator for the Gladstone Harbour Report Card (Venables, 2015), whereas yellowfin bream *Acanthopagrus australis* and pikey *A. berda* looked promising. Bream surveys were conducted in the 2015–16 reporting year and data from this survey are reported here. In 2016, the fish and crabs indicator group only comprises the one indicator, fish recruitment, as crab data were not available in this reporting year.

What fish were used as indicators of harbour health ?

Yellowfin bream

Yellowfin bream is a slow growing (5 years to reach 23cm), 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 occur 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.

Pikey bream

Pikey bream is a bottom living dark silvery grey body fish with a maximum length of about 50cm. 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 50m. 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.

Yellowfin bream
(*Acanthopagrus australis*)

Pikey bream
(*Acanthopagrus berda*)

(Source: Department of Agriculture and Fisheries, Fishes of Australia.Net, Garratt 1993, Harrison 1991 and James et al 2003)

The fish recruitment index is based on the total catch of juveniles of the 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 developed for Gladstone Harbour will be refined in subsequent years to improve its robustness and representativeness as more data become available.

4.4.1. Fish data collection

Data for the two bream species were collected monthly from 26 sites across 12 harbour zones between December 2015 and March 2016. The Outer Harbour zone was excluded from the surveys as there were no suitable bream habitats (Table 4.17). Where possible within each zone, a minimum of two sites were selected to cover the upper tidal limit and another within the daily tidal influence. 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 100mm defined juvenile or year 0 recruits. The fork length profiles of both species for key periods across the reporting year are shown in Figure 4.4.

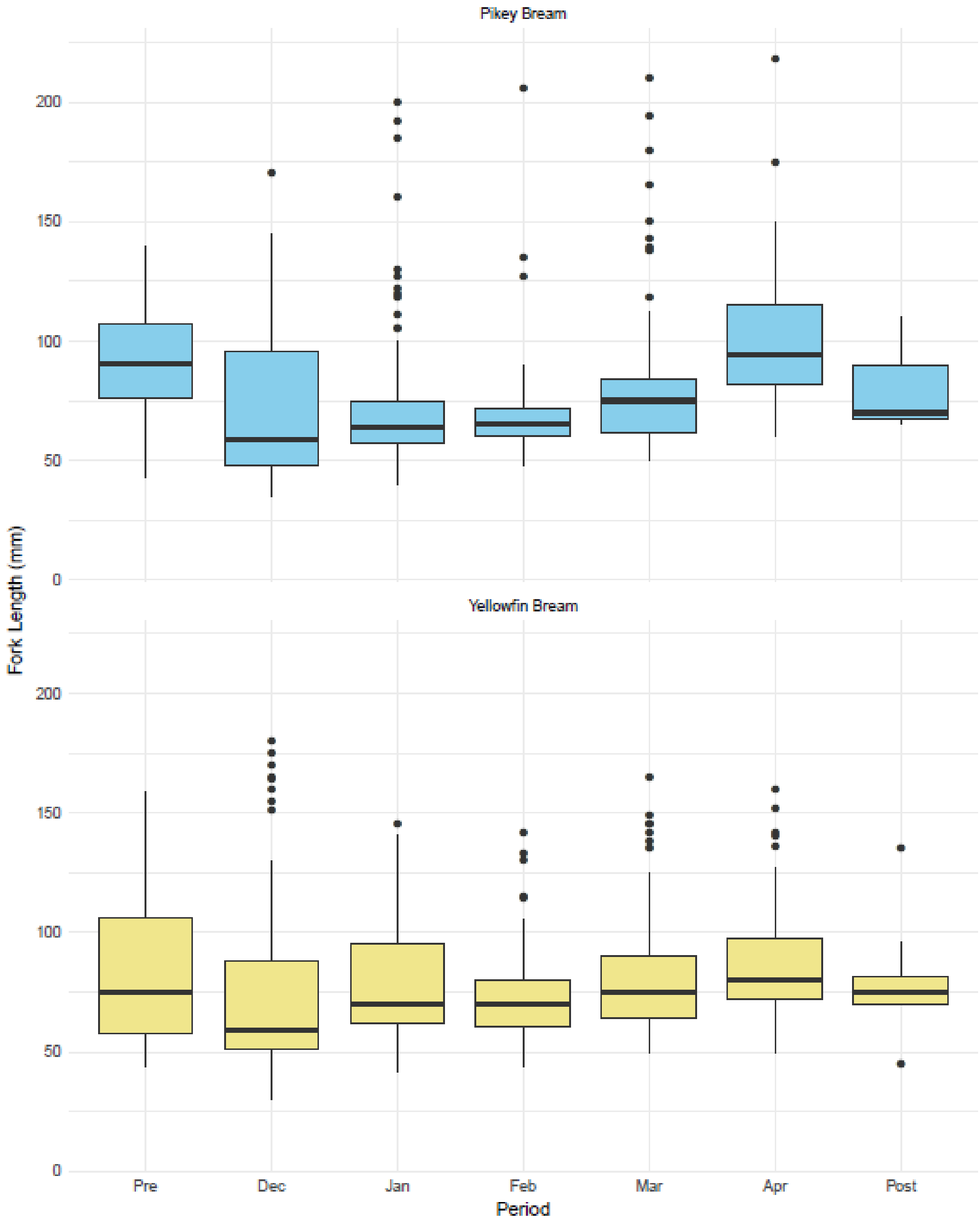


Figure 4.4: Fork length profiles of two bream species used in the study for all available data (Sawynok & Venables, 2016).

Each site was sampled 10 to 20 times using a standard cast net (monofilament net with a drop of 2.4m, mesh size 20mm and spread of 3.6m). Species were identified in the field and the length of each species, site ID, GPS coordinates, type of sub-strata, vegetation and site photographs were recorded at each site. Surveys were not done if the water temperature exceeded 32°C. If there were any fish health issues noted during the surveys, these were also recorded in the field data sheets. There were 103 surveys conducted over four months catching 325 yellowfin bream and 179 pikey bream. Three experienced cast netters were involved in the surveys (Sawynok and Venables, 2016).

Table 4.17: Number of sites surveyed in each zone to collect bream recruitment data.

Harbour zone	Number of sites
Zone 1. The Narrows	4
Zone 2. Graham Creek	2
Zone 3. Western Basin	1
Zone 4. Boat Creek	1
Zone 5. Inner Harbour	2
Zone 6. Calliope Estuary	2
Zone 7. Auckland Inlet	1
Zone 8. Mid Harbour	2
Zone 9. South Trees Inlet	3
Zone 10. Boyne Estuary	2
Zone 11. Outer Harbour	Not surveyed
Zone 12. Colosseum Inlet	2
Zone 13. Rodds Bay	4
Total sites	**26**

4.4.2. Statistical model specification

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 as well as the pilot data and other historical data collected since 2011. This model assesses proportional changes in catch rate between years relative to a notional baseline. A number of potential environmental predictors related to fish habitats were also tested to determine if they helped to explain variation in the juvenile catch data.

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), gives an effective response of catch per cast
- random effect terms **–** sampling site, season, season by zone interaction
- fixed temporal effects – month, period (within the Oct–Sep reporting period, Oct–Nov are aggregated and referred to as pre-survey months, whereas May–Sep are aggregated and form the post-survey period)
- fixed environmental effects – rock, 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 & 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.

4.4.3. Results

Overall the fish recruitment score in the 2016 report card was 0.40 (D), indicating a poor result. Out of the 12 zones monitored, 9 zones indicated poor scores and only 3 zones (Auckland Inlet, Boyne Estuary and Rodds Bay) had satisfactory scores (Table 4.18).

Table 4.18: Fish recruitment scores for all harbour zones and overall harbour score for fish recruitment.

Zone	Score
1. The Narrows	0.30
2. Graham Creek	0.44
3. Western Basin	0.36
4. Boat Creek	0.36
5. Inner Harbour	0.33
6. Calliope Estuary	0.43
7. Auckland Inlet	0.53
8. Mid Harbour	0.29
9. South Trees Inlet	0.43
10. Boyne Estuary	0.54
11. Outer Harbour	Not surveyed
12. Colosseum Inlet	0.45
13. Rodds Bay	0.58
Harbour average	**0.40**

4.4.4. Fish recruitment conclusions

Recruitment plays a key role in a fishery population. The 2016 score of 0.40 (D) for fish recruitment means a season with decreased catch rate relative to the median reference level. In other words, the model identified large differences in fish recruitment between years (seasons) and that the 2015–16 year had a lower recruitment rate than previous years after correcting for a number of important environmental variables.

4.5. Environmental component and indicator groups results

The overall Environmental component score for the 2016 report card was 0.50 (C). This score was derived by aggregating the three environmental indicator groups (water and sediment quality, habitats, and fish and crabs) using the bootstrapping methodology (Logan, 2016).

Direct comparisons to the 2015 results for the Environmental component are not possible owing to changes in the indicators assessed. Within the Environmental component, the indicator for connectivity was removed (connectivity will now be reported in the 'Drivers and Pressures' section of this report) and a fish (bream species) recruitment indicator was added.

The indicator group score for water and sediment quality was derived from the aggregation of the water and sediment quality indicator scores, while for habitats this was derived from the aggregation of the seagrass and coral indicator scores. The overall harbour scores for these three indicator groups were: water and sediment quality 0.84 (B), habitats 0.25 (D), and fish and crabs 0.40 (D) (Table 4.19).

Table 4.19: Environmental indicator group scores and overall environmental scores for the 13 harbour zones and the overall harbour scores.

Zone	Indicator groups			**Overall zone score**
	Water and sediment quality	Habitats (seagrass and corals)	Fish and crabs (bream recruitment)	
1. The Narrows	0.80	0.33	0.30	**0.47**
2. Graham Creek	0.85	NA	0.44	**0.65**
3. Western Basin	0.84	0.55	0.36	**0.58**
4. Boat Creek	0.74	NA	0.36	**0.55**
5. Inner Harbour	0.86	0.14	0.33	**0.44**
6. Calliope Estuary	0.85	NA	0.44	**0.64**
7. Auckland Inlet	0.82	NA	0.53	**0.67**
8. Mid Harbour	0.86	0.26	0.29	**0.47**
9. South Trees Inlet	0.86	0.48	0.43	**0.59**
10. Boyne Estuary	0.85	NA	0.54	**0.69**
11. Outer Harbour	0.84	0.14	NA	**0.49**
12. Colosseum Inlet	0.86	NA	0.45	**0.66**
13. Rodds Bay	0.86	0.25	0.57	**0.56**
Harbour score	**0.84**	**0.25**	**0.40**	**0.50**

5. The Social component

Report cards have become an increasingly popular way to document environmental condition. The 2016 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 harbour (Table 5.1). These indicators were developed from the GHHP vision and piloted in 2014 (Pascoe et al., 2014).

The social indicators address the following Gladstone Harbour Report Card objectives:

- maintain or improve easy access to the harbour waters and foreshore for recreation and community uses
- maintain or improve a safe harbour for all users
- enhance liveability and wellbeing in the region.

Table 5.1: Indicator groups, indicators and measures used to determine social grades and scores for the 2016 report card (Source: Windle et al., 2016).

Indicator groups	Indicators	Measures	Data source	How grades were determined
Harbour usability	Satisfaction with harbour recreational activities	How satisfied with last trip	CATI survey	10-point scale
		Quality of ramps and facilities	CATI survey	10-point scale
	Perceptions of air and water quality	Water quality satisfaction	CATI survey	10-point scale
		Air quality satisfaction	CATI survey	10-point scale
		Water quality does not affect use of the harbour	CATI survey	10-point scale
	Perceptions of harbour safety for human use	Marine safety incidents	Marine safety incidents: Department of Transport and Main Roads, Maritime safety Queensland (2016) – Marine incidents in Queensland, 2015	10 year moving average (Data from 2006–15 calendar year – rate of incidents in Gladstone as compared to other ports in Queensland)
		Oil spills	Oil spills and marine pollution data: Queensland Government (2016) – Marine pollution data 2002–16	10 year moving average (Data from 2006–15 calendar year – rate of oil spills in Gladstone as compared to other ports in Queensland)
		Safe at night	CATI survey	10-point scale
		Happy to eat seafood	CATI survey	10-point scale

Table 5.1 (cont.): Indicator groups, indicators and measures used to determine social grades and scores for the 2016 report card (Source: Windle et al., 2016).

Indicator groups	Indicators	Measures	Data source	How grades were determined
Harbour access	Satisfaction with access to the harbour	Fair access to harbour	CATI survey	10-point scale
		Input into management	CATI survey	10-point scale
	Satisfaction with ramps and public spaces	Frequency of use	CATI survey	10-point scale
		Number of ramps	CATI survey	10-point scale
		Access to public spaces	CATI survey	10-point scale
	Perceptions of air and water quality	Great condition	CATI survey	10-point scale
		Optimistic about future health	CATI survey	10-point scale
		Improved over the last 12 months	CATI survey	10-point scale
	Perception of barriers to access	Marine debris a problem	CATI survey	10-point scale
		Marine debris affects access	CATI survey	10-point scale
		Shipping reduced use	CATI survey	10-point scale
		Recreational boats reduced use	CATI survey	10-point scale
Liveability and wellbeing	Contribution of harbour to liveability and wellbeing	Makes living in Gladstone a better experience	CATI survey	10-point scale
		Participate in community events	CATI survey	10-point scale

5.1. Data collection

The GHHP ISP 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 ISP 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 CATI survey interviewed 401 residents from the Gladstone 4680 postcode area in June 2016 (Figure 3.28). Participants in the Gladstone 4680 postcode area were contacted using a random dialling technique. Trained research interviewers administered the survey which was monitored for QA/QC. The survey questions were largely qualitative and related to the GHHP social, cultural and economic objectives. Questions were designed to be answered on a 10-point agree–disagree scale to produce quantifiable results. The questions and 10-point scale were designed so that the results would be comparable to other studies, such as the Social and Economic Long Term Monitoring Program for the Great Barrier Reef, to elicit trends over time and to facilitate translation into the A–E report card grades (Pascoe et al., 2014).

5.2. Development of indicators and grades

Although the social indicator questions used in the CATI survey were qualitative, they were recorded on a 10-point agree–disagree scale and then converted to grades. 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.

Each indicator was also weighted to reflect its relative importance as a management objective using information collected through an online survey of 200 community participants, 31 community leaders and 19 social scientists and economists. Three weighting techniques—simple ranking methods, scoring-based methods and analytic hierarchy processes—were used to determine the final weights. Inputs from the 19 social scientists and economists were also used to develop the relationships between measures, indicators and indicator groups (Pascoe et al., 2014).

A Bayesian belief network (BBN) was used to aggregate indicator scores into indicator groups and component scores. This BBN model provided the probabilities of each outcome rather than a deterministic outcome. Thus, mean outcomes and confidence intervals were also determined through the BBN model. The final grade for each indicator was the most probable grade after the relevant weighting had been applied.

Harbour usability

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. Community satisfaction with harbour usability was primarily assessed through the CATI survey. The harbour usability survey questions related to participants' satisfaction with their last trip to the harbour, quality of ramps and facilities, satisfaction with air and water quality, safety at night, and whether people were happy to eat seafood from the harbour. Secondary data on marine pollution and marine safety incidents (sourced from MSQ, Department of Transport and Main Roads) were also incorporated as measures into the final score. A 10-year moving average was used as the baseline for both marine safety incidents and oil spill measures.

The marine safety incidents measure in 2015 was estimated using the ratios of incidents with both recreational and commercial vessels registered within each maritime region. However, in 2016 relevant information was only available for recreational vessels and hence commercial counts were not included in the assessment.

Harbour access

The harbour access indicator group comprised four indicators: satisfaction with access to the harbour, satisfaction with boat ramps/public spaces, perception of harbour health, and perception of barriers to access. The harbour access section of the CATI survey was based on a range of questions concerning 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 access to the harbour.

Liveability and wellbeing

The indicator for the harbour's contribution to liveability and wellbeing in Gladstone was assessed through the CATI survey. The liveability and wellbeing survey questions related to whether Gladstone Harbour makes living in Gladstone a better experience and the level of participation in community events.

5.3. Results

The 2016 survey respondents were evenly divided by gender with 50.4% males and 49.6% females (Table 5.2). Overall, 11% of participants identified themselves as Traditional Owners of the area. Unlike last year where the younger age group was under-represented and older age groups were over-represented, the 2016 survey was more successful at capturing the views of younger age groups (Table 5.2). However, the representation was lower than the 11% of Australian Bureau of Statistics (ABS) population proportion. The Traditional Owner representation was 11%, slightly less than the 13% in the 2015 CATI survey. Similar to 2014 and 2015, the highest representation was in the over $156,000 annual household income bracket. There were no known major events that influenced the opinion of respondents during the CATI survey period (Windle et al., 2016).

Table 5.2: Demographics of 2016 CATI survey participants (Source: Windle et al. 2016).

Percentage of respondents	CATI survey 2014	CATI survey 2015	CATI survey 2016	ABS Census data (2011)
Gender				
Percentage of male	51%	49.5%	50.4%	52%
Age category				
18–24 yrs	3%	3%	6%	11%
25–34 yrs	7%	9%	10%	18%
35–44 yrs	20%	16%	17%	20%
45–54 yrs	25%	26%	27%	19%
55–64 yrs	21%	25%	18%	13%
65+ yrs	24%	22%	21%	19%
Annual household income				
Less than $20,799	12%	13%	11%	8%
$20,800 – $41,599	13%	12%	13%	13%
$41,600 – $64,999	10%	11%	11%	12%
$65,000 – $77,999	5%	7%	7%	7%
$78,000 – $103,999	18%	14%	15%	15%
$104,000 – $129,999	12%	14%	13%	11%
$130,000 – $155,999	11%	8%	11%	16%
Greater than $156,000	20%	21%	19%	20%

The overall grade for the social component of the 2016 Gladstone Harbour Report Card was 0.66 (B). The overall social health of Gladstone Harbour has gradually increased from 0.58 (C) in the 2014 Pilot Report Card and 0.64 (C) in the 2015 report card.

Of the three indicator groups, harbour usability received a score of 0.66 (B), harbour access a score of 0.65 (B), and liveability and wellbeing received a score of 0.66 (B) (Figure 5.1). The scores for harbour access (0.62 to 0.65) and liveability and wellbeing (0.64 to 0.66) increased from 2015, but the score for harbour usability declined from 0.75 in 2015 to 0.66 in 2016. Note that an error in the 2015 scores means they were reported as 0.75 instead of 0.65, hence there has been little real change from 2015 to 2016.

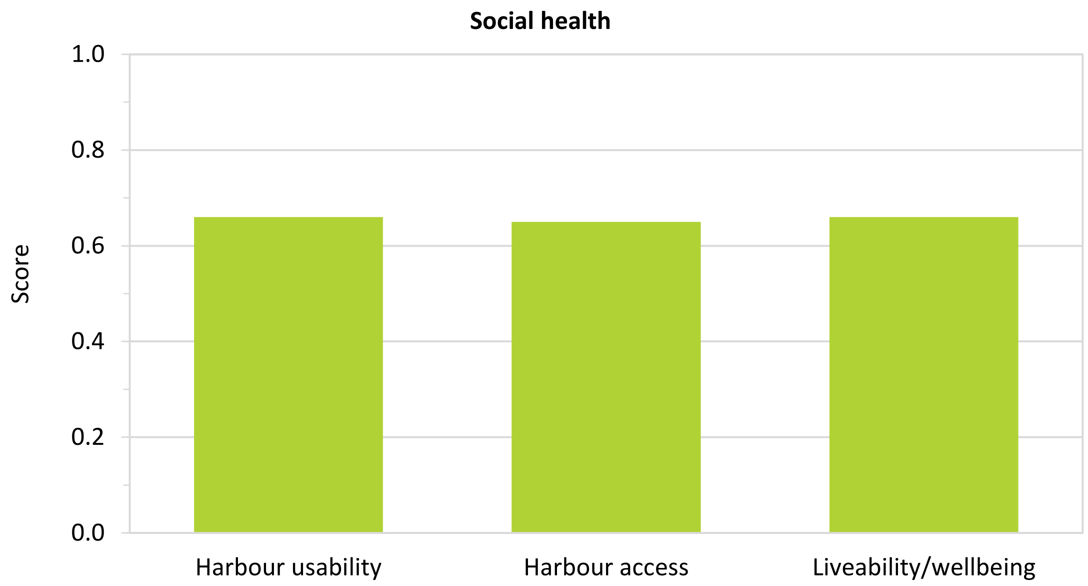


Figure 5.1: Indicator group scores within the Social component of harbour health in the 2016 Gladstone Harbour Report Card.

Harbour usability

In 2016 this was assessed using a single measure, 'quality of boat ramps and facilities'. Between 2015 and 2016, the score decreased from 0.69 to 0.67.

The scores for the three indicators of harbour usability ranged from 0.55 (C) for perceptions of air and water quality, up to 0.67 (B) and 0.76 (B) for satisfaction with harbour recreational activities and perceptions of harbour safety, respectively (Figure 5.2).

The satisfaction with recreational activities indicator was only assessed in 2016 using the quality of ramps and facilities measure. In 2015, this indicator was assessed using two measures—how satisfied with the last trip, and quality of ramps and facilities. The indicator score increased from 0.69 to 0.67 in 2016. Overall, respondents indicated a higher level of satisfaction with quality of boat ramps available in the Gladstone Harbour area (78% in 2016 compared to 73% in 2015) facilities associated with boat ramps (73% in 2016).

The score for the perceptions of air and water quality has steadily increased over the last two years (0.46 in 2014, 0.52 in 2015, 0.55 in 2016). Both the water quality (0.51 in 2015 to 0.56 in 2016) and air quality (0.43 in 2015 to 0.45 in 2016) satisfaction scores increased from 2015 to 2016. About 61% (47% in 2015) of the respondents agreed that the water quality was good, but only 42% (36% in 2015) thought the air quality was satisfactory in the harbour area.

The score for perceptions of harbour safety for human use indicator improved in 2016 (0.76) and 2015 (0.72) compared to 2014 (0.38). A majority of respondents (68% in 2016, 61% in 2015) were happy to eat seafood caught in the harbour area and 69% (63% in 2015) felt safe being in the harbour area at night.

The marine safety incidents (0.90) and oil spill (0.88) measures scored highly in 2016, similar to respective 2015 scores of 0.88 and 0.82. This may be due to decline in marine safety incidents and as a result of non-availability of commercial vessel data to calculate the score in 2016.

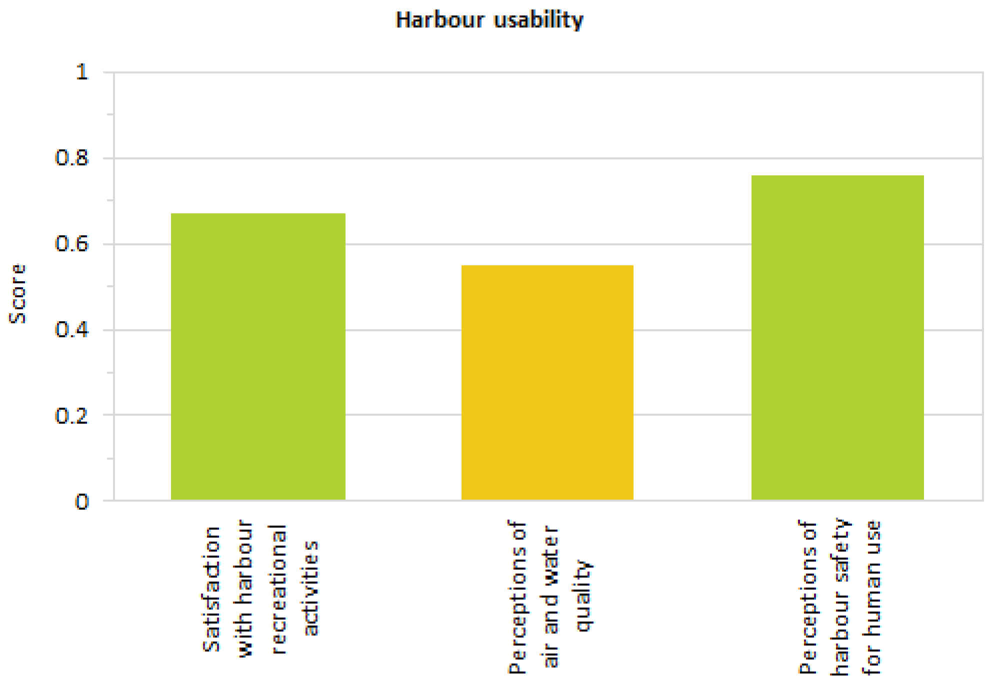


Figure 5.2: Scores for the three indicators of harbour usability in the 2016 Gladstone Harbour Report Card.

Harbour access

The scores for the four indicators of harbour access ranged from 0.62 for perceptions of harbour health to 0.69 for satisfaction with harbour access (Figure 5.3).

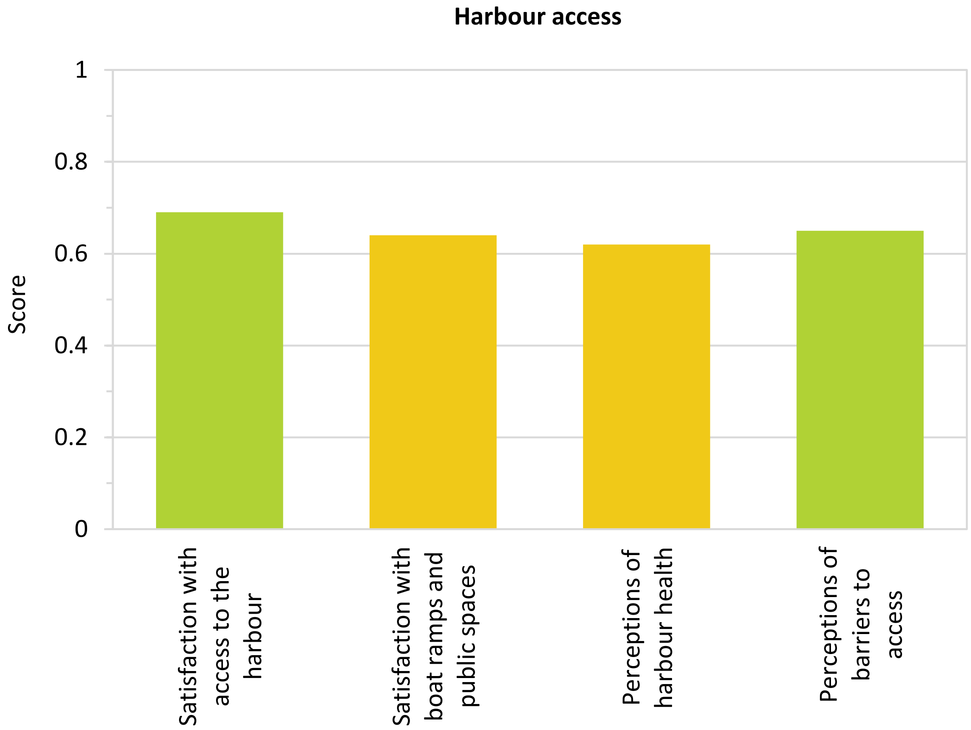
Out of 401 survey participants, 347 (87%) visited the Gladstone Harbour for recreation. The 2016 figures were very similar to results from 2015 (86%) and 2014 (87%). About 35% of the respondents owned a boat for the last 12 months and there had been little change in their use of boat ramps since 2014 (39%, 40% and 41% of respondents used a boat ramp in 2014, 2015 and 2016, respectively).

The satisfaction with access to the harbour score, which was assessed through a single measure (I have fair access to Gladstone Harbour compared to other users of the harbour*),* increased from 0.67 (in 2014) to 0.68 (in 2015) to 0.69 in 2016. About 79% respondents thought they have fair access to Gladstone Harbour compared to other uses of the harbour. The satisfaction with boat ramps and public spaces score was stable over the past three years (0.60 in 2014, 0.62 in 2015, 0.64 in 2016). The perceptions of harbour health score has also steadily increased from 2014 (0.53) to 0.58 in 2015 and 0.62 in 2016.

The satisfaction with boat ramps and public spaces indicator was assessed using three measures—frequency of use, satisfaction with number of boat ramps, and satisfaction with access to public spaces around Gladstone Harbour. Most survey respondents (87%) were satisfied with the level of access to public spaces and 75% were satisfied with the number of boat ramps.

Perceptions of harbour health was assessed using three measures. A majority (76%) believed that the harbour was in good condition and about 69% were optimistic about the future health of the harbour. A slight majority (66%) believed that the health of the harbour had improved over the past 12 months (an increase from 48% who also believed that in 2014 and from 57% in 2015).

The community perceptions of barriers to access indicator was assessed using four measures. Its overall score increased from 0.61 in 2015 to 0.65 in 2016. Three out of four measures used to assess this indicator scored well, however, the overall score was impacted by the low score of 0.51 received for the measure 'marine debris as a problem' (assessed through marine debris and litter is a problem in Gladstone Harbour*).* In the past 12 months, there has been a notable decrease in the proportion of respondents who agreed that commercial shipping activity had reduced their use of the harbour area (17% in 2016, 33% in 2015)[1]. In comparison, there has been little change in the impacts of recreational boating activity with 24% in 2016 agreeing that it had reduced their use of the harbour area compared with 25% in 2015[2]. Further, about 14% of respondents agreed that the amount of marine debris and litter did affect their access to the harbour area. This was lower than the 21% who agreed with this issue in 2015.



[1] In the 2015 report, commercial shipping activity had reduced their use of the harbour area but this was reported as 57% and should be corrected as 33%.

[2] Similarly, the recreational boats reduced their use measure but received a score of 72% in 2015 and it should be corrected to 25%. The 2016 score was 24%.

Figure 5.3: Scores for the four indicators of harbour access in the 2016 Gladstone Harbour Report Card.

Liveability and wellbeing

The contribution of Gladstone Harbour to the liveability of Gladstone and wellbeing was scored at 0.66 (B) (Figure 5.4). Liveability refers to the elements in a region that affect how individuals feel about living there. These elements include 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 et al., 2012).

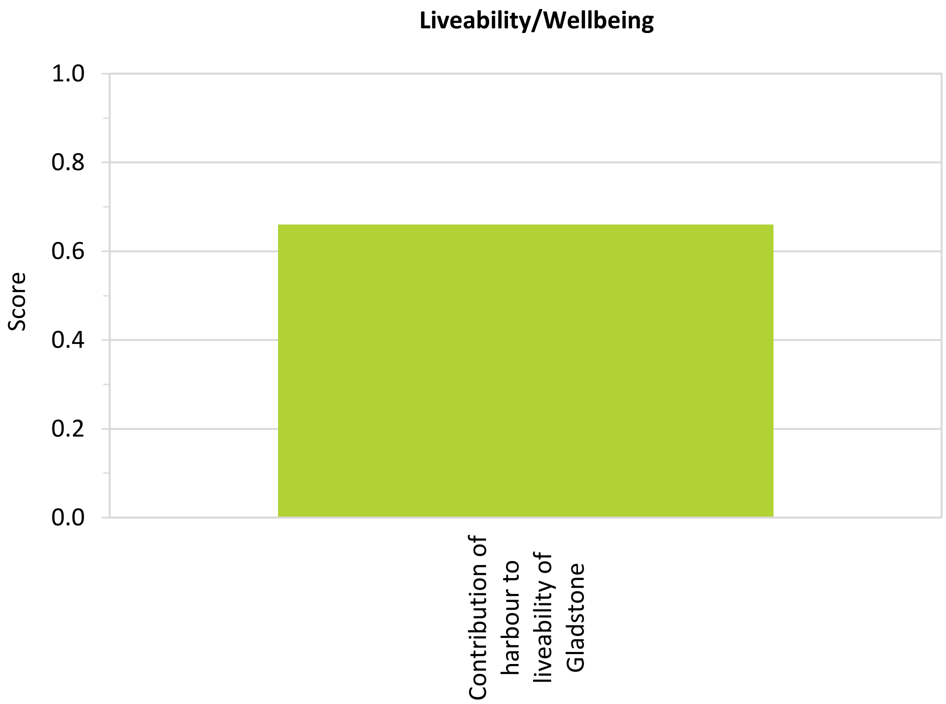


Figure 5.4: Score for the contribution of Gladstone Harbour to the liveability and wellbeing of Gladstone in the 2016 Gladstone Harbour Report Card.

Over 87% (70% in 2015) people surveyed agreed that Gladstone Harbour makes living in Gladstone a better experience, and about 60% (53% in 2015) of the respondents regularly participated in community events in the harbour area. Compared with last year, more people agreed that the harbour makes living in Gladstone a better experience and are happy to participate more in community events in the harbour area.

5.4. Social indicator conclusions

The overall social health of the harbour has increased from 0.58 (in 2014) to 0.64 (in 2015) and 0.66 in 2016 indicating that the community seems to be enjoying the harbour more than previous years (Table 5.3). Both harbour access and liveability/wellbeing changed grade from C to a B in 2016.

Overall, most indicator scores improved from the 2015 reporting year resulting in an overall improvement of the social health from C to a B in 2016. Responses received towards different measures under harbour usability, harbour access, and liveability and wellbeing indicator groups were also very similar to the 2015 reporting year. The strongest improvements were evident in 'perception of harbour safety for human use', 'perceptions of harbour health' and 'barriers to access' indicators this year.

Harbour usability

There has been an increase in the community perceptions of air and water quality (0.46 in 2014, 0.52 in 2015, 0.55 in 2016) and perceptions around harbour safety for human use (0.38 in 2014, 0.72 in 2015, 0.76 in 2016).

This may be due to the decrease in oil spills reported for the same period, further improving the community perceptions of harbour health. CATI survey results also indicated more respondents were feeling safe being in the Gladstone Harbour area (63% in 2015 to 69% in 2016) and would eat seafood caught from Gladstone Harbour (61% in 2015 to 68% in 2016).

Similar to last year, a majority of the community viewed the harbour area as a place that provides recreational facilities and an environment for leisure activities. The residents continue to see the harbour as a producer of healthy food for consumption and a safe place to enjoy by day and night. Community feelings of safety in the harbour area at night improved compared to 2015 which is also positive.

Concerns continue about pollutants (air and water) but these do not appear to impede the community's usability of the harbour area and its resources. Air and water quality concerns may be an artefact of past issues and the proximity of industry in and around the Gladstone Harbour area.

Harbour access

Compared to last year, a lower percentage of survey respondents agreed that both commercial and recreational shipping in Gladstone Harbour reduce their use of the area. This is a positive result considering the increased number of shipping activities associated with recent growth of LNG exports from Curtis Island. This could also be as a result of less shipping and boating activity associated with transport and construction work on Curtis Island.

The Gladstone Harbour area remains a key area for residents to visit, and recreation levels increased compared to 2015 levels. Compared to last year, residents are feeling more satisfied with their perceptions of barriers to harbour access such as marine debris, litter, commercial and recreational boating activity. Similarly, residents' recreation experience is not affected by public space access or concerns about the quality of boating facilities. The harbour environment is viewed positively by many residents and they hold strong beliefs of this continuing into the future.

Liveability and wellbeing

Generally, people living in the Gladstone region feel that Gladstone Harbour provides them with a positive living experience and quality of life. Many residents continue to participate in community events that are held in and around the harbour area (e.g. The Gladstone Harbour Festival, Eco-fest, Boyne-Tannum Hook Up) and their involvement supports the physical and mental health of the community.

Table 5.3: Social indicator group scores of reporting years.

		2014	2015	2016
Indicator group	**Harbour usability**	**0.60**	**0.65** [a]	**0.66**
Indicators	Satisfaction with harbour recreational activities	0.70	0.69 [b]	0.67
	Perceptions of air and water quality	0.46	0.52	0.55
	Perceptions of harbour safety for human use	0.38	0.72	0.76
Indicator group	**Harbour access**	**0.61**	**0.62**	**0.65**
Indicators	Satisfaction with access to the harbour	0.67	0.68	0.69
	Satisfaction with boat ramps and public spaces	0.60	0.62	0.64
	Perceptions of harbour health	0.53	0.58	0.62
	Perceptions of barriers to access	0.64	0.61	0.65
Indicator group	**Liveability and wellbeing**	**0.64**	**0.64**	**0.66**
Overall harbour score		**0.58**	**0.64**	**0.66**

[a] An error in the 2015 scores means they were reported at 0.75 instead of 0.65, hence there has been little real change from 2015 to 2016.

[b] The indicator 'satisfaction with harbour recreational activities' scored 0.67, compared with 0.69 in 2015 and 0.70 in 2014, but anomalies in data analysis negate any meaningful comparison. An error in the 2016 calculation meant that only one of the two measures was assessed ('quality of boat ramps and facilities') with a score of 0.68 in 2016 and 0.66 in 2015.

6. The Cultural component

To assess the cultural health of the harbour, the 2016 report card uses six ‘sense of place’ indicators and two Indigenous cultural heritage indicators. The latter has been developed and piloted during 2016. These indicators were developed from the GHHP vision. The cultural indicators in the 2016 Gladstone Harbour Report Card address the following report card objectives:

- The Gladstone community’s sense of identity and satisfaction with the condition of the harbour is increased.
- Registered cultural heritage sites associated with the harbour and waterways are protected.

6.1. Data collection

‘Sense of place’

A CATI survey of 401 people conducted in June 2016 assessed the ‘sense of place’ indicator. That survey included 17 questions dedicated to gathering community views on six cultural indicators (Table 6.1). ‘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 & Uzzell, 1996). ‘Sense of place’ may also be useful for exploring community stewardship.

Indigenous cultural heritage

Field data for the Indigenous cultural heritage indicator group were collected through a series of field surveys at The Narrows, Facing Island, Wild Cattle Creek and Gladstone Central (Figure 3.30). These were conducted in collaboration with the members from the Gidarjil ranger team between November and December 2015. Heritage aspects relevant to assessing the cultural health (e.g. knapping floor, chopper tools, signage, gravestones, monuments) were recorded in detail at each site. A total of 45 monitoring stations were established across four zones during field surveys. A series of 360° panoramic imagery was also captured during the site visits 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.

Definition of indicators 'sense of place'

The 'sense of place' indicator had 17 measures grouped into the following six indicators.

- 'Distinctiveness' 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.

- 'Self-esteem' 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.

- 'Self-efficacy' 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.

- 'Attitudes to Gladstone Harbour' assesses the attitudes of people in Gladstone with particular emphasis on its importance as a great assets to the local community and central Queensland.

- 'Values of Gladstone Harbour' assesses community values on marine life, recreational and tourism activities, cultural, spiritual and historical significance of the harbour.

Indigenous cultural heritage

Cultural health and management strategies of zones consists of 21 measures grouped into 6 sub-indicators, namely spiritual and social values, scientific values, physical condition, protection, land use, and cultural maintenance.

The spiritual and social values sub-indicator for cultural health uses three measures:

- ethnographic and historical information – relates to the availability of such information (e.g. detailed written archaeological recording of site features and elements) significant to sites and awareness of Traditional Owners of such information.

- connection to the cultural landscape – relates to the level of spiritual and social value attached to a site in the context of the traditional patterns of cultural activities within a zone. During the 2015–16 reporting year, in the absence of ethnographic interviews, ethno-historical desktop research was used to collate information for report card scores and grades.

- contemporary use – relates to visits to the site by those for whom it is most significant. In the absence of ethnographic interviews during the 2015–16 reporting year, this measure was assessed by consulting the Gidarjil management team and the rangers about the visits by their family members to the sites in each zone.

The scientific values sub-indicator for cultural health uses six measures:

- diversity of heritage features – assesses the complexity of the heritage features and elements that have been recorded within a monitoring station.

- density of heritage features – assesses the density of the heritage features and number of elements in each monitoring station.

- representativeness – refers to how reflective a certain heritage feature or element in one site is compared to other sites in a reporting zone.

- uniqueness – relates to monitoring stations and sites containing heritage features that have not been identified anywhere else in the reporting zone.

- excavation potential – assesses the stratification through visual inspection and sub-surface probing where appropriate to understand whether the deposit exhibits clear and deep stratification.

- artefacts in-situ – relates to percentage of local heritage features and elements that have been retained over time in their original positions.

The physical condition sub-indicator for cultural health uses three measures:

- ground surface disturbance – assesses the proportion of a site surface that has not been disturbed versus that which has been impacted by environmental, animal or human causes. By comparing annual scores over time, the speed of site deterioration could be calculated.

- impacts on heritage values – relates to the impact of ground surface disturbance on the heritage values of a particular site. By comparing scores over time, the speed at which the heritage features within a site deteriorate over time could be calculated.

- threats and controls – relates to the number of threats and ongoing control measures to remove the effects of these threats on the cultural heritage values of a site. Threats could be environmental (e.g. storm surges, inundation and erosion), animal (e.g. burrowing, animal waste) or human related (e.g. tracks, vehicles, paths, trampling).

The protection sub-indicator for management strategies uses three measures:

- monitoring – assesses the ability of a monitoring team to continue with the establishment of new monitoring stations and visit existing monitoring stations annually.

  Site registration – relates to the immediate response to site discovery and registration with GHHP ICHD.

- threat management – relates to the percentage of implemented control measures to remove the effect of identified threats on cultural heritage values.

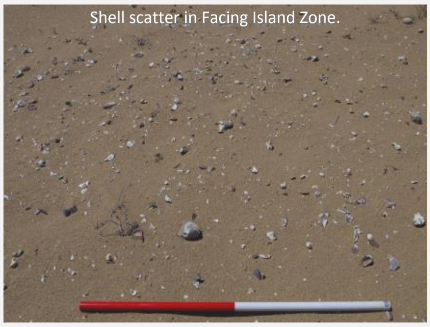
What are heritage elements and heritage features?

A heritage element refers to a single stone tool such as flake or chopper tool often become a part of a larger feature within a site. A heritage element can also be an isolated artefact.

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


A stone arrangement in the Narrows Zone.


Pebble tools in Facing Island Zone.


Shell scatter in Facing Island Zone.

(Images courtesy Terra Rosa Consulting)

The land use sub-indicator for management strategies uses two measures:

- accessibility – relates to the percentage of sites within a zone that can be easily accessed for heritage management.

- developmental pressure – relates to the pressures impacting on sites due to tourism, housing recreational and industrial development activities.

The cultural maintenance sub-indicator for management strategies uses four measures:

- identification and research of sites – relates to the heritage sites identified or researched within the zone to be included in the ICHD annually.

- cultural resources –relates to availability of digital and physical resources (e.g. ICHD, panoramic tours, and signage) that store knowledge and information about cultural heritage within each zone.

- cultural management activities – relates to proactive heritage management activities in operation within a zone such as installation of fencing, signage, interpretive information and environmental restoration.

- stakeholder engagement – ranks the ability of the project to interface with associated stakeholders such as Traditional Owners, Gidarjil rangers, GHHP representatives, landholders, government agencies and other local agencies to facilitate further monitoring and research that achieve joint cultural heritage and land management aims.

Table 6.1: Indicator groups, indicators and measures used to determine cultural grades and scores for the 2016 Gladstone Harbour Report Card.

Indicator group	Indicators	Sub-indicator	Measures	Data source	How grades determined
'Sense of place'	Distinctiveness		No place better	CATI survey	10-point scale
			Who am I	CATI survey	10-point scale
	Continuity		How long lived in the area	CATI survey	10-point scale
			Plan to be a resident in the next five years	CATI survey	10-point scale
	Self-esteem		Feel proud living in Gladstone	CATI survey	10-point scale
	Self-efficacy		Quality of life	CATI survey	10-point scale
			Input into management	CATI survey	10-point scale
	Attitudes to Gladstone Harbour		Key part of the community	CATI survey	10-point scale
			Great asset to the region	CATI survey	10-point scale
			Great asset to Queensland	CATI survey	10-point scale
	Values of Gladstone Harbour		Variety of marine life	CATI survey	10-point scale
			Opportunities for outdoor recreation	CATI survey	10-point scale
			Attracts visitors to the region	CATI survey	10-point scale
			Enjoy scenery and sights	CATI survey	10-point scale
			Spiritually special places	CATI survey	10-point scale
			Culturally special places	CATI survey	10-point scale
			Historical significance	CATI survey	10-point scale
Indigenous cultural heritage	Cultural health	Spiritual and social values	Ethnographic and historical information, connection to the cultural landscape, contemporary use	Desktop study and field data collection	5-point scale
		Scientific values	Diversity, density, representativeness, uniqueness, excavation potential, artefacts in-situ	Field data collection	5-point scale
		Physical condition	Ground surface disturbance, impacts on heritage values, threats and controls	Field data collection	5-point scale
	Management strategies	Protection	Monitoring, site registration, threat management	Field data collection	5-point scale
		Land use	accessibility, developmental pressure	Field data collection	5-point scale
		Cultural maintenance	Identification and research of sites, cultural resources, cultural management activities, stakeholder engagement	Field data collection	5-point scale

6.2. Development of indicators and grades

'Sense of place'

Responses to cultural indicator questions in the CATI survey were converted to grades in the same manner as for the social 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 group.

Indigenous cultural heritage

The sites and zone were selected following an in-depth literature review and extensive consultation with the Gidarjil Development Corporation. Information related to the cultural heritage sites documented in 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. The cultural health indicators were assed at site level, whereas the management strategy indicators were assed at zone level. Final scores were aggregated to yield an overall zone score for each indicator group.

The measures of cultural heritage were on a qualitative scale from A–E and were converted into numerical values between 1 and 5 (1=E and 5=A). These measures were both quantitative (e.g. number of heritage features at each monitoring station) and qualitative (e.g. ethnographic and historical information). Similar to ‘sense of place’, the grades were equidistant and converted to a raw score by dividing the numerical grade (1–5) to give a value in range of 0.2–1.0 (e.g. A=1.0, B=0.8, C=0.6, D=0.4, E=0.2) (Pascoe & Venables, 2016).

Within each zone, the project team identified a cultural locus site in consultation with the Gidarjil Development Corporation as a reference site. The health of the cultural locus sites was assessed independently and then used to benchmark other sites within each zone. The cultural locus in each zone received a grade of either C or above (e.g. cultural locus site of The Narrows – B grade, Facing Island – A grade, Wild Cattle Creek – C grade, and Gladstone Central – A grade). A cultural locus site was given a 50% weighting and other sites within that zone were treated equally and allocated the remaining 50%. A cultural locus was used to assess cultural health indicators of all zones (Terra Rosa, 2016).

6.3. Results

The overall score for the Cultural component of the Gladstone Harbour Report Card for 2016 was 0.62 (C). This comprised two indicator groups, 'sense of place' and Indigenous cultural health (Figure 6.1). 'Sense of place' received a score of 0.66 (B) and Indigenous cultural heritage received a score of 0.53 (C). This grade was based on six 'sense of place'-related indicators and two Indigenous cultural heritage indicators.

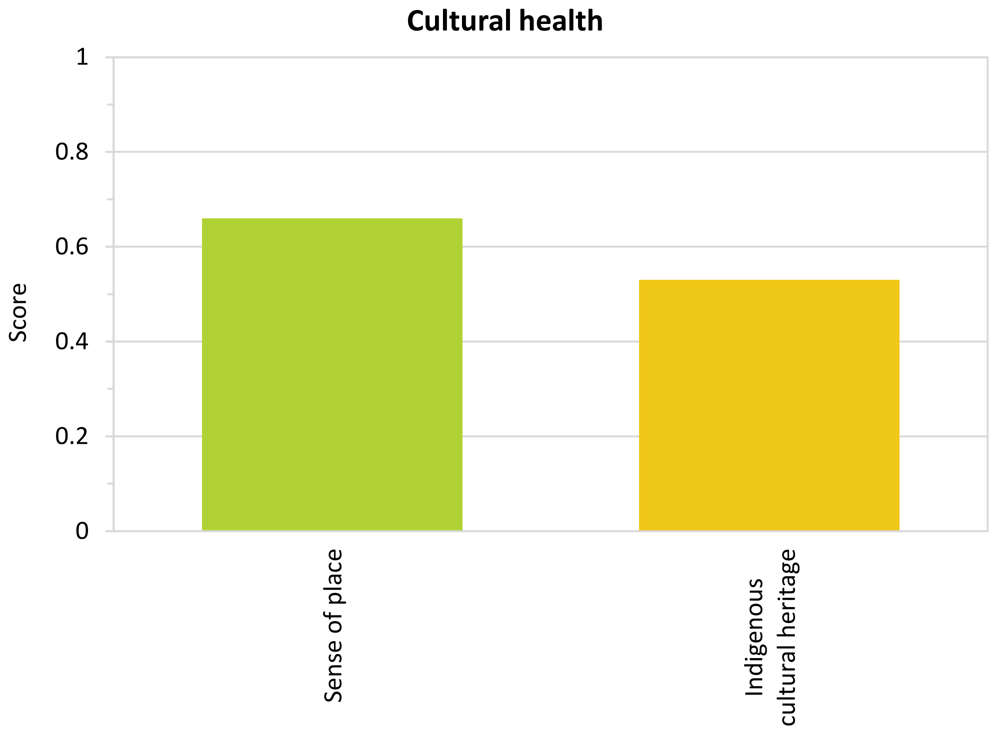


Figure 6.1: Results of the 'sense of place' and Indigenous cultural heritage indicator groups.

'Sense of place'

The 'sense of place' indicator scores ranged from 0.58 (C) for self-efficacy to 0.81(B) for attitudes to the harbour (Figure 6.2). Distinctiveness (0.59), continuity (0.59) and self-efficacy (0.58) received similar scores; self-esteem (0.74), attitudes to harbour (0.81) and values of harbour (0.66) received slightly increased scores.

The highest score of 0.81 received for self-esteem was driven by three measures which received equally high scores (key part of community – 0.79, great asset to region – 0.80 and great asset to Queensland – 0.80). The lowest score of 0.58 for self-efficacy was influenced by a high score (quality of life – 0.67) and a lower score (input into management – 0.49).

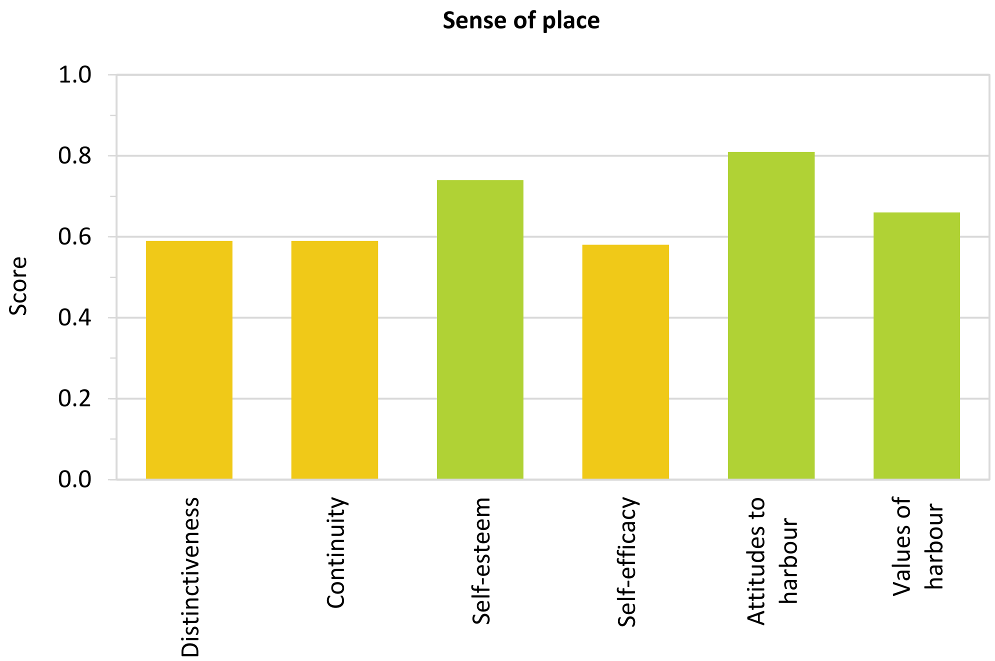


Figure 6.2: Indicator scores for 'sense of place' indicator group used for cultural health in the 2016 Gladstone Harbour Report Card.

Indigenous cultural heritage

The overall harbour score for Indigenous cultural heritage was satisfactory (0.53, C). All zones received a satisfactory grade except for Wild Cattle Creek which scored poorly (0.44, D) mainly due to poor scores for the sub-indicators spiritual and social values, physical condition, land use, and cultural maintenance.

The cultural maintenance sub-indicator for all zones scored poorly due to poor scores for cultural management activities, cultural resources and identification and research of sites (Table 6.2).

Development pressures affected the poor scores for land use in the Narrows and Wild Cattle Creek. Where the sites are located on offshore islands or on private property, the access becomes difficult and impacts on the land use score. Sites on Gladstone Central zone were largely within parks and reserves and accessibility was not an issue, hence this zone received a very good grade for land use.

The protection sub-indicator also received similar and good scores for The Narrows and Facing Island. This score was driven by the monitoring measure which assesses the ability of the monitoring team to continue with the establishment of new monitoring stations and visit existing monitoring stations annually.

Table 6.2: Scores for Indigenous cultural heritage indicators and overall harbour score for the 2016 report card.

Zone	Cultural health			Management strategies			**Overall zone score**
	Spiritual & social values	Scientific values	Physical condition	Protection	Land use	Cultural maintenance	
The Narrows	0.54	0.62	0.53	0.70	0.40	0.35	**0.53**
Facing Island	0.57	0.75	0.64	0.70	0.50	0.25	**0.57**
Wild Cattle Creek	0.40	0.51	0.45	0.60	0.40	0.25	**0.44**
Gladstone Central	0.85	0.50	0.60	0.40	1.00	0.40	**0.59**
Harbour score for Indigenous cultural heritage							**0.53**

6.4. Cultural indicator conclusions

'Sense of place'

Overall the score for 'sense of place' is similar (0.65 in 2015 and 0.66 in 2016) and remains classified in good condition (Table 6.3).

The 'sense of place' indicators showed relatively little temporal variation compared with the 2015 report card. The scores for all six indicators of 'sense of place' suggest that the community's expectations of the Gladstone Harbour area are mostly being met.

Table 6.3: Comparison of 'sense of place' indicator grade and score between 2015 and 2016 report cards.

		2015	2016
Indicator group	'Sense of place'	0.65	0.66
Indicators	Distinctiveness	0.55	0.59
	Continuity	0.57	0.59
	Self-esteem	0.72	0.74
	Self-efficacy	0.56	0.58
	Attitudes to Gladstone harbour	0.80	0.81
	Values of Gladstone harbour	0.64	0.66
Overall harbour score		**0.65**	**0.66**

The higher scores received for the distinctiveness indicator shows greater engagement with, and appreciation of, the harbour-related activities.

The scores received for the continuity indicator reveal increased stability. This indicator was assessed through two CATI questions, 'how long you have lived in the Gladstone region' and 'do you plan to stay in the Gladstone region in the next 5 years'. The overall low score (0.47) for the former indicates that many respondents had moved to Gladstone but not lived there all their lives, however the high score of the latter (0.71) indicates that community is becoming less transient and more stable (this may be a reflection of the downturn in construction work). Survey participants' intention to stay in the Gladstone region was also not dependent on length of time residing in the area, locality, their gender, boat ownership or identifying as a Traditional Owner (Windle et al., 2016).

The harbour is viewed as a place of pride and this is reflected in the relatively high self-esteem score which has increased from 0.72 in 2015 to 0.74 in 2016. There was a moderately significant correlation ($r = 0.33$) between this self-esteem measure and intention to remain in the area for the next five years. This suggests that those who feel proud to be living in Gladstone also intend to stay in the area for the immediate future (Windle et al., 2016).

Compared to 2015, the increased scores for the attitudes to and values of the harbour show that people have a positive outlook about the harbour area and what it provides to the community.

Indigenous cultural heritage

The overall grade for Indigenous cultural heritage is a result of 21 measures used to assess the various aspects of Indigenous cultural heritage under six sub-indicators in four zones. The scoring structure not only looked at impacts of ongoing development on a number of Indigenous heritage resources, but also acknowledged the constantly changing cultural landscape. The scoring structure focused on management and implementation strategies to mitigate the primary impacts observed in the reporting zones. The overall satisfactory score of C for the 2015–16 reporting year was strongly influenced by the following factors.

- Land use pressures such as industrial and residential developments and other land use changes
- Erosion of coastal foreshore and dune systems
- Ongoing damage by the recreational vehicle access in reporting zones
- Lack of effort to systematically record and understand the area
- Lack of documented information about cultural heritage sites
- Gladstone Central being the only zone where interpretive activities (e.g. signage describing the history and cultural values of the place) were carried out strategically.
- Lack of proper agency structure to manage sites and interpretive activities (Terra Rosa, 2016).

2016 is the first year the GHHP is reporting on Indigenous cultural health and no previous grades or score are available for comparison.

7. The Economic component

To assess the economic health of the 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. The economic indicator groups address the following report card objectives:

- Gladstone Harbour is managed to support shipping, transport and diverse industries.
- Economic activity in Gladstone Harbour continues to generate social and economic benefits to the regional community.
- The values of Gladstone Harbour's recreational and environmental assets are enhanced.

7.1. Data collection

The Gladstone LGA was used as the broader geographic area for collecting economic data (Figure 3.28). 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

- commercial fishing data: collected from the area within QFish S30 which includes Gladstone Harbour and the open coastal waters immediately adjacent to the harbour, but not Colosseum Inlet and Rodds Bay (Figure 3.29). Data collected from Grid O25 and R29 were also used in the analysis to control for spatial differences in catch across years (map information provided in Windle et al., 2016).

- CATI survey: administered to residents within the Gladstone 4680 postcode area

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 7.1). 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 used to assess 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 7.1).

Table 7.1: Data sources and baselines employed to derive the economic scores and grades for the 2016 Gladstone Harbour Report Card.

Indicator group	Indicator	Measure	Data source	Baseline
Economic performance	Commercial fishing	Productivity of line fisheries Productivity of net fisheries Productivity of trawl (otter) fisheries Productivity of pot fisheries	ABARES – Australian fisheries and aquaculture statistics 2014 (published Dec 2015) Queensland Fishing (QFish), Queensland Department of Agriculture and Fisheries Average prices (in $/kg) for prawns, crab and fish derived from the Queensland production table in the ABARES – Australian fisheries and aquaculture statistics 2014 (published Dec 2015)	Queensland fisheries and aquaculture total production value 2013–14. 12-year average (time series data from 2004–05 to 2015–16)
	Shipping activity	Shipping activity productivity calculated from monthly shipping movements by cargo type (2015–16 financial year)	Gladstone Ports Corporation	Time series data from 1996–97 to 2015–16
	Tourism expenditure	Gladstone Region's total tourism output – Expenditure on hotel accommodation and food in $M (2014–15 financial year)	Expenditure on hotel accommodation (for 2005–06 to 2012–13 financial years) Expenditure on hotel accommodation and food (2013–14 and 2014–15 financial years) Gladstone Regional Council Economic Profile – REMPLAN 2016: www.economicprofile.com.au/gladstone/t	Last ten years' average for 2014–15

Table 7.1 (Cont.): Data sources and baselines employed to derive the economic scores and grades for the 2016 Gladstone Harbour Report Card.

Indicator group	Indicator	Measure	Data source	Baseline
Economic stimulus	Employment	The State of Queensland (Queensland Treasury) 2016: Unemployment statistics for the Gladstone Local Government Area (2016 June quarter)	Queensland Office of Economic and Statistical Research (via the Queensland Government Statistician's Office, Queensland Treasury)	Queensland 2016 distribution
	Socio-economic status	Index of economic resources derived from 2011 ABS census and updated using the community CATI survey	CATI survey; Australian Bureau of Statistics, 2011 census	Australian 2011 distribution
Economic value (Recreation)	Beach recreation	Beach recreation satisfaction* and economic value	CATI survey and economic value (Pascoe et al., 2014)	10-point scale
	Recreational fishing	Recreational fishing satisfaction * and economic value	CATI survey and economic value (Pascoe et al., 2014)	10-point scale
	Land-based recreation	Land-based recreation satisfaction* and economic value	CATI survey and economic value (Pascoe et al., 2014)	10-point scale

* Satisfaction refers to the frequency of use combined with the preferences

7.2. Development of indicators and grades

Economic performance

The economic performance indicator group consisted of three indicators: tourism (expenditure), commercial fishing and the level of shipping activity. These were selected to reflect the key industries using the harbour and weighted according to economic activity and a survey of local industry and community leaders.

Shipping

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). Data for the 2015–16 financial year were compared to actual and potential shipping activity from 1996–97 to 2015–16 and potential future shipping activity related to developments on Curtis Island and at Fisherman's Landing. The 20-year dataset was used as the baseline for 2016 and this differs from previous years (9-year array in 2015 and 8-year array in 2014). A 20-year array provides more information on the overall trend than an 8- or 9-year array.

Tourism

The report card grade for tourism was based on estimated expenditure on hotel accommodation, food and other local services in the Gladstone region in 2014–15. A 10-year moving average starting from 2005–06 was used as the baseline. Expenditure on hotel accommodation and food were derived from the Gladstone Regional Council Economic Profile.

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:

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

$$= 50\%$$

INDEX OF ECONOMIC RESOURCES (IER)

The IER is a composite measure of the economic wellbeing of a community. For the 2016 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.

TRAVEL COST METHOD (TCM)

Travel cost method is an important economic non market-evaluation technique developed by Clawson (1959). It is used to assess 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.

Commercial fishing

The indicator is based on the estimated value of the gross value of production (GVP) for Gladstone Harbour relative to a 12-year average starting from 2004–05.

The score for commercial fishing was based on fishing effort and the value of the landed catch (both fish and crustaceans) in four sectors: the net, line, pot (mud crab) and otter trawl fisheries. The four fisheries sector scores were weighted by their relative contribution to GVP. 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 Fisheries Queensland (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 data collected from Grid S30 over the period 2004–05 to 2015–16 were used as the basis for comparison. The net, line and pot fishery data reported for Grid S30 were based on catches from inside Gladstone Harbour. The otter trawl fishery data for Grid S30 were based on catches both inside and outside the harbour. The fishers involved in the four fishery sectors are primarily based in Gladstone. The total value of fish and crustaceans caught in QFish S30 in 2015–16 was estimated based on catch data by fishing method data from the QFish database and average prices for different species as derived from the most recent Australian fisheries and aquaculture statistics published by ABARES statistics. The total value of fisheries production in Mackay (Grid O25) and Yeppoon (Grid R29) were also included in the analysis for two reasons—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., 2015).

Economic stimulus

The economic stimulus indicator group consists of two indicators: unemployment and socio-economic status.

The score for employment was based on the unemployment rate for the Gladstone LGA compared with the benchmark of unemployment rates across all Queensland LGAs. This comparison used the most recent Australian Bureau of Statistics (ABS) data available which were for the 2016 June quarter.

The score for socio-economic status was derived using the IER. The IER was calculated using 2011 Australian census data and estimates for the Gladstone region were further refined using data collected through the CATI survey. The IER does not include information on savings or equities as these were not collected through the 2011 census.

Economic value (Recreation)

The economic value (recreation) indicator group was assessed through three indicators: land-based recreation, recreational fishing and beach recreation. As with the previous year, the economic value of recreation combines the average economic value per trip type (which was used to weight the contributions of each component) and the level of satisfaction experienced by those who undertook the activity.

Information on the non-market economic value (recreation) of harbour area activities was collected through a community survey of 401 people within the Gladstone region (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.

Land-based recreation activities included walking, running, cycling, picnicking or barbecuing, relaxing by the water, and community and sporting events. The total annual value of beach recreation and land-based recreation was estimated from the information collected about trip frequency (this survey) and the travel cost values elicited from the 2014 community survey for the 2014 Pilot Report Card.

Using this data, a score was calculated based on the satisfaction rating for the last recreational trip and weighted according to the relative proportion of the total non-market value of recreation. Previously estimated recreational trip values for each recreational type were used for 2016 estimates. The total annual value of recreational activity was updated by activity frequency data collected through CATI survey and extrapolated for the Gladstone population (Windle et al., 2016). Land-based recreation activities included walking, running, cycling, picnicking or barbecuing, relaxing by the water, and community and sporting events.

As for social and cultural indicators, economic indicators were weighted based on surveys of general community and individuals with management responsibility in the Gladstone region either directly (e.g. local government or industry) or via industry (e.g. advisory role, key stakeholder group). The survey results were also used to develop the relationships between measures, indicators and indicator groups (Pascoe et al., 2014). A BBN was used to aggregate indicator scores into indicator groups and the overall Economic component in the same manner used for the Social and Cultural components (Pascoe et al., 2014).

7.3. Results

The scores for each of the three economic indicator groups were high (Figure 7.1) and this contributed to an overall score for the Economic component of the 2016 Gladstone Harbour Report Card of 0.75 (B). Of those indicator groups, economic performance received the highest score of 0.87 (A), economic stimulus received a score of 0.74 (B) and economic value of recreation received a score of 0.73 (B) (Figure 7.1).

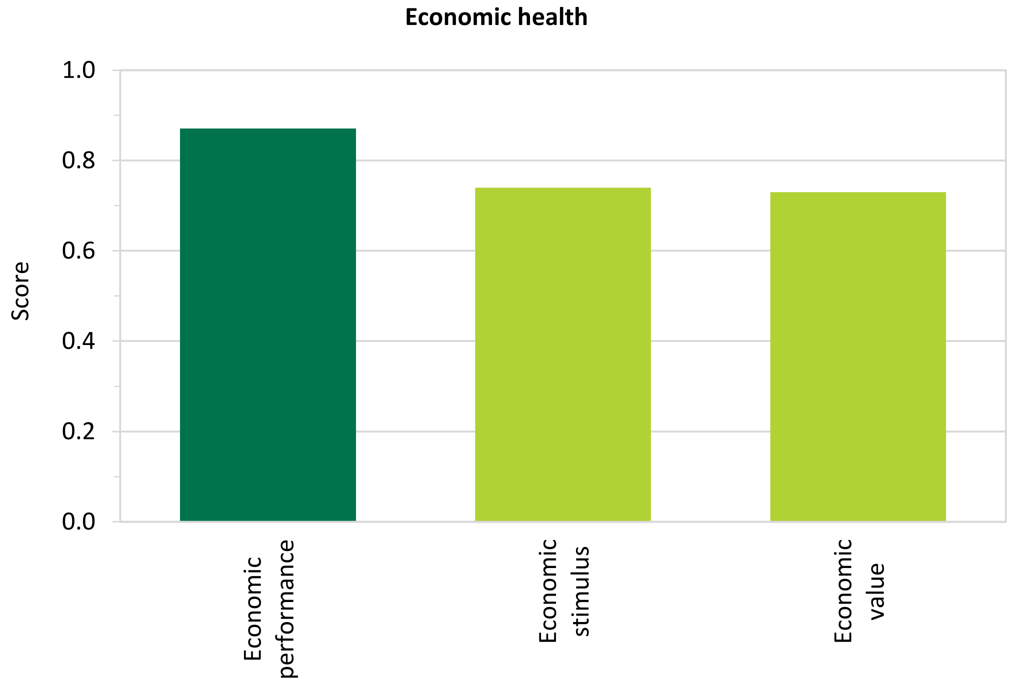


Figure 7.1: The scores for each of the three economic indicator groups in the 2016 Gladstone Harbour Report Card.

Economic health

Economic performance

Compared to 2015, the economic performance of Gladstone Harbour has increased from a good (0.79) to a very good (0.87) state in 2016.

The highest score was received by shipping activity (0.87), followed by tourism (0.72) and commercial fishing (0.43) (Figure 7.2). The shipping activity is weighted more highly than the other two sectors due to its greater economic contribution. Similar to the 2015 report card, the economic performance score of 0.87 (A) was strongly influenced by the high scores for shipping activity and tourism. However, the commercial fishing score declined from good to poor over the last three years (0.66 in 2014, 0.63 in 2015, 0.43 in 2016).

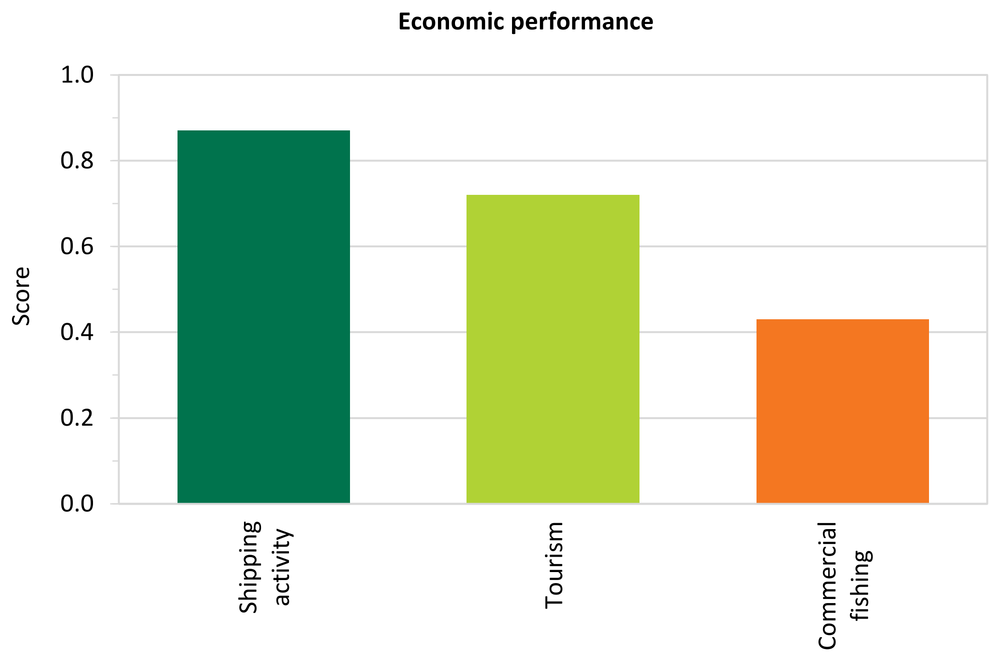


Figure 7.2: Scores for the three indicators of economic performance in the 2016 Gladstone Harbour Report Card.

Shipping activity

The shipping activity indicator, based on the movement of shipping by cargo type in Gladstone Harbour, increased from good (0.82) to very good (0.87) in 2016.

In early 2016, coal exports in Gladstone dropped about 10% but remained stable over the rest of the reporting months. LNG exports also steadily increased during the 2015–16 reporting year and overtook alumina exports which historically have been the second largest export from Gladstone Harbour (Figure 7.3). Regardless of the slight drop in total shipping numbers over the last year, the ship movements improved in 2016 and total monthly vessel count exceeded 150 (Figure 7.4).

Although capacity utilisation remained high relative to past years, the underused capacity for shipping from the Curtis Island LNG plants (in progress) and the expansion of Fisherman's Landing meant that the port was not at full capacity. This limited the shipping score to 0.87 but this was still high compared to 2015 (0.82).

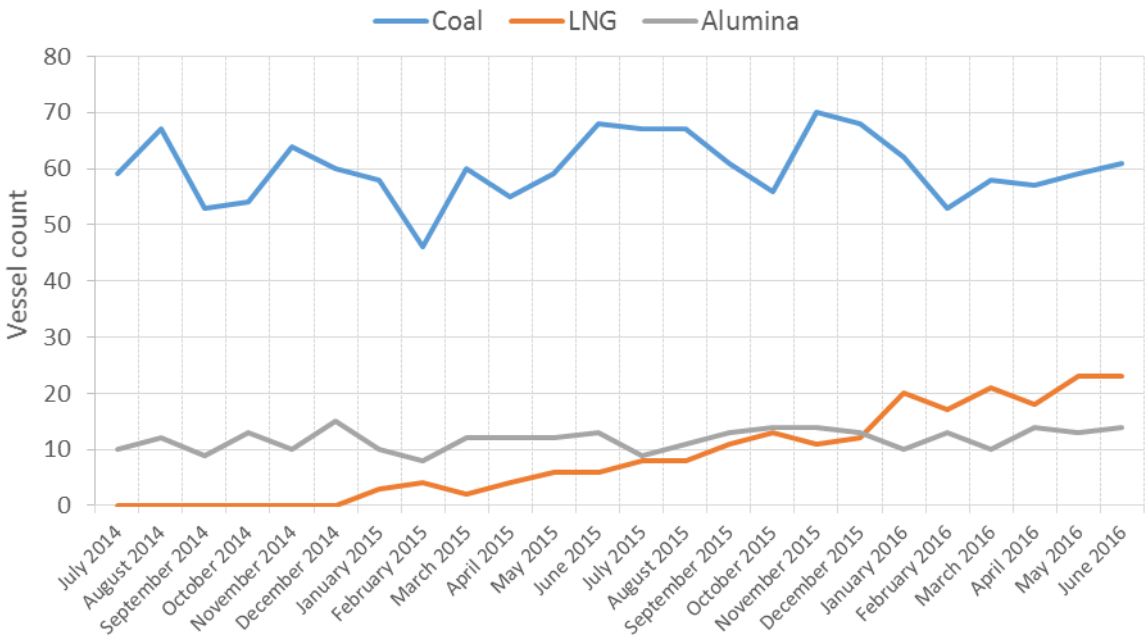


Figure 7.3: Trends in the three main commodity exports from Gladstone Harbour (Source: Gladstone Ports Corporation trade statistics prepared by Windle et al., 2016).

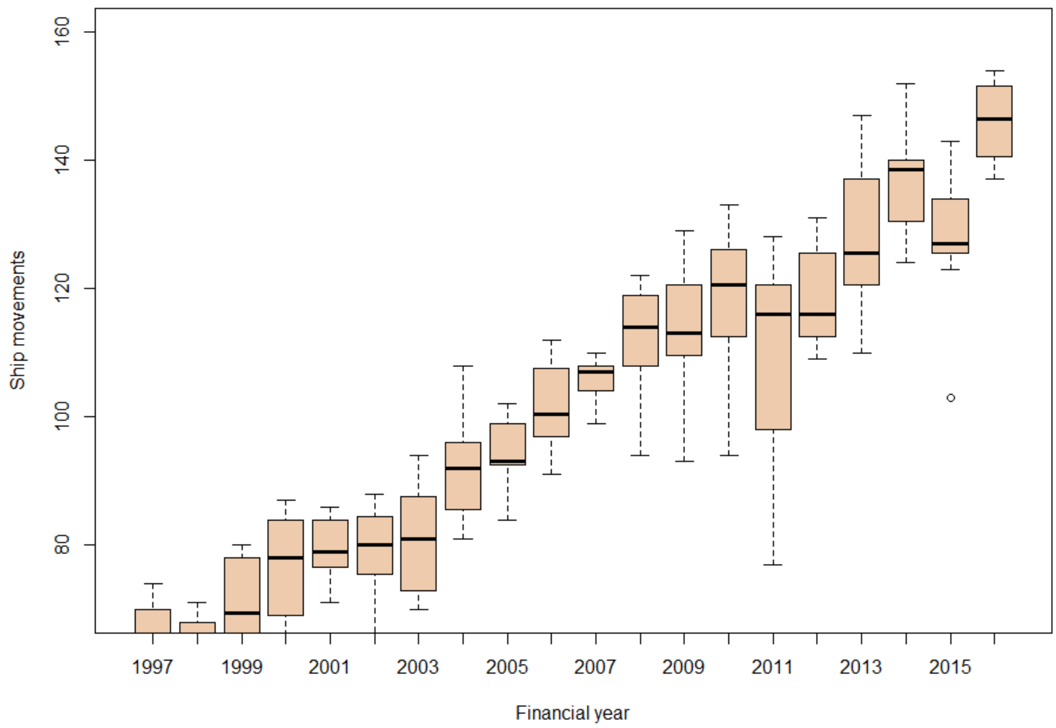


Figure 7.4: Trends in shipping movements (monthly) since 1997 (Source: Gladstone Ports Corporation trade statistics prepared by Windle et al., 2016).

Tourism

The tourism indicator increased from satisfactory (0.64) in 2015 to good (0.72) in 2016.

Expenditure on tourism (accommodation, food and other local services) in the Gladstone region was $274.8 million in 2014–15 compared with $266.7 million in 2013–14. Although there were some analytical differences since the 2014 pilot year, generally the score has increased over time. This improvement is further supported by less pressure on accommodation and other facilities in the Gladstone region as the construction phase of many developments has been completed.

Commercial fishing

The calculated gross value of production (GVP) for Gladstone Harbour fisheries in 2015–16 was $2.83 million, well below the 2014–15 figure of $4.19 million and 2013–14 figure of $4.68 million[3]. Similar to the previous year, commercial fishing remained relatively strong compared with neighbouring regions with similar fisheries. The low score for the commercial fishing was strongly influenced by low scores for all fisheries (line fisheries – 0.27, net fisheries – 0.34, trawl fisheries – 0.38) except for pot fisheries. The line and net sectors performed very poorly because the line sector was effectively no longer active in the region. Combining the fishing effort and productivity data for the four sectors (weighted by their relative contribution to GVP) yielded a score of 0.43 for this indicator (0.63 in 2015).

Some minor updates made to the QFish database (managed by Department of Agriculture, Fisheries and Forestry) since the release of the last report card have had some influence on the report card scores in 2016. Gladstone GVP values reported for 2015 were $3.5 million and $4.5 million for 2014. After the update, these two estimates changed to $4.19 million (for 2015) and $4.68 million (for 2014), respectively. Although all calculations were made in the same way as in 2015, the updates to the QFish database modified the data file for the baseline period.

Economic stimulus

The score for economic stimulus of 0.74 (B) was aggregated from the scores of two indicators: employment 0.62 (C) and socio-economic status 0.80 (B) (Figure 7.5).

[3] The Gladstone GVP values reported for the 2013–14 and 2014–15 reporting years differ from last year's report (where they equalled to $4.5 million and $3.5 million, respectively). All calculations were made in the same way in 2016 and the disparity was due to the recurrent updates made to the QFish database (on which all fishery productivity scores are based) and that modified the entire source data file (Windle et al., 2016).

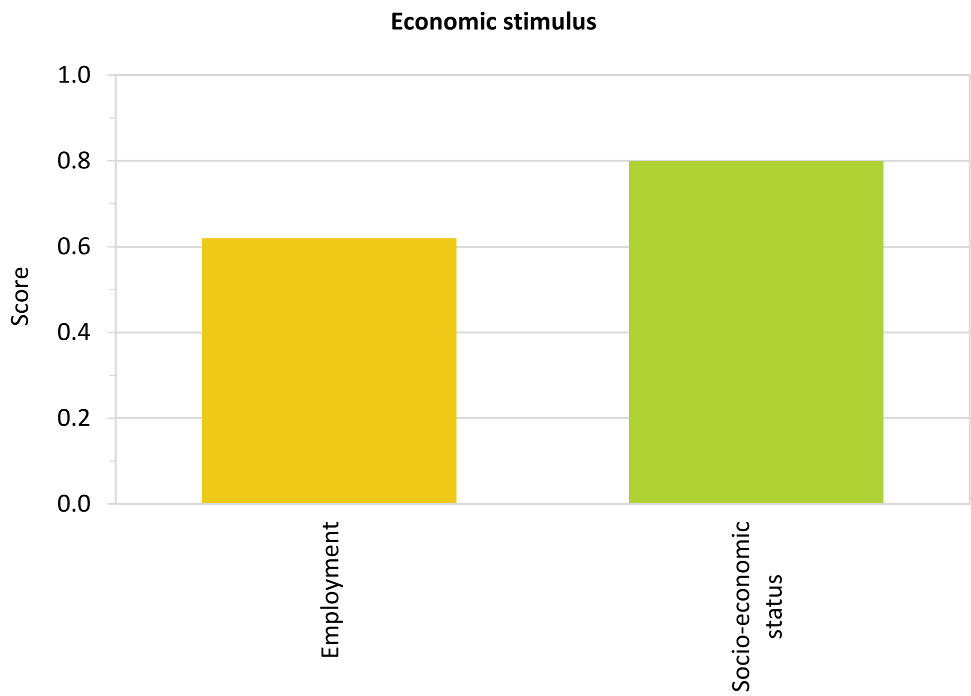


Figure 7.5: Scores for economic stimulus in the 2015–16 reporting year.

The unemployment rate of 6.3% for the 2016 June quarter was higher than the previous year (4.7%) but lower than the state average of 6.5%. Although unemployment increased slightly from the previous year's rate, the relative position of Gladstone deteriorated slightly compared to other LGAs in Queensland in the past 12 months. The score for employment declined steadily from 0.72 in 2014 to 0.64 in 2015 and to 0.62 in 2016.

The socio-economic status score for 2016 (0.80, B) has declined slightly for the Gladstone region from a score of 0.95 (A) in 2015. The high score for socio-economic status was driven by the high proportion of residents who were in high income groups, the relatively high proportion of home ownership, and the relatively large size of houses in the region. However, the impact of job losses and increase in unemployment were apparent. The completion of major construction projects has reduced employment opportunities and the unemployment rate has risen. The influence of the high proportion of home ownership has declined and been replaced by the influence from the higher proportion of adults (over 18 years) in the household during the 2015–16 reporting period. There are also fewer high income employment opportunities. These have an adverse impact on the socio-economic status of the Gladstone community which has declined from 2014 and 2015 levels.

Economic value (Recreation)

The overall economic value received a score of 0.73 (B) and has not changed considerably compared to previous reporting years (2015 – 0.72 and 2014 – 0.75). Similar good scores were received for land-based recreation (0.76), recreational fishing (0.66) and beach recreation (0.75) (Figure 7.6).

The beach recreation indicator score increased slightly from the previous year's score of 0.70 to 0.75. Similarly, land-based recreation satisfaction increased from 0.73 to 0.76 in 2016. However, the recreational fishing satisfaction decreased slightly from 0.71 to 0.66 but the grade B remained the same as 2015. It is not clear from the CATI data whether this decline is associated with lower catch rates or other factors.

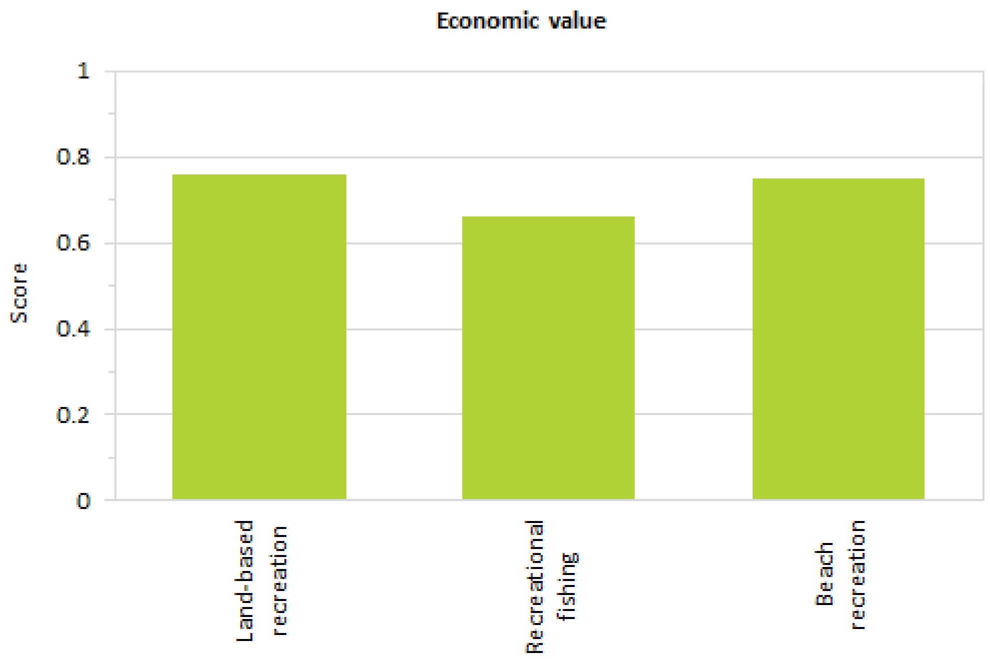


Figure 7.6: Scores for the three indicators of economic value (recreation) in the 2016 Gladstone Harbour Report Card.

According to the CATI survey, the most popular land-based activities along the shores of Gladstone Harbour were walking (similar to 2015), relaxing by the water, and picnicking or barbecuing. The most popular beach visited by the survey participants, similar to last year, was Tannum Sands followed by Spinnaker Park artificial beach and Boyne Island. Land-based and beach recreational activity were much more prevalent than recreational fishing. Over 90% of respondents had participated in land-based (93%) and beach recreation (92%), but only 39% had undertaken recreational fishing. Again, these percentages were very similar to values reported in 2015.

The highest average annual value of $54.75 million ($45.43 million in 2015) was reported for land-based recreation followed by $31.79 million for beach recreation ($27.98 million in 2015) and $24.43 million for recreational fishing ($21.34 million in 2015). Overall, estimates were higher than the 2015 values.

Although the recreational fishing value increased from 2015 to 2016, the score decreased from 0.71 to 0.66 because of lower participation and trip rates.

The mean value of a recreational fishing trip is estimated at $143 per trip and ranged from $73 to over $4,137 per trip.

Of the survey respondents who had visited the Gladstone Harbour area for recreation, about 83% (83% in 2015) were satisfied with the last beach trip. Similarly, high percentages of respondents indicated they were satisfied overall with their last shore-based recreational trip (91%) and last recreational fishing trip (80%).

7.4. Economic indicator conclusions

The overall economic health of Gladstone Harbour remains good, similar to 2015 and 2014 reporting years. However, the overall score has declined from 0.82 (in 2014) to 0.77 (in 2015) and to 0.75 in 2016 (Table 7.2).

The overall grade for 2016 was strongly influenced by growth in LNG exports, a decline in the construction boom, improvements in beach and land-based recreational activity (17% increase due to more people participating in recreational activities in high frequency) and reduced employment opportunities due to the end of major construction projects and less pressure on the tourism sector as accommodation bottlenecks eased in the 2015–16 year in the Gladstone region.

The recreational fishing scores declined from 0.71 (in 2015) to 0.66 in 2016 but it is not evident from the survey whether the decline was related to lower catch rates or some other factor. The other two economic value indicators, land-based recreation and beach recreation scores improved from last year.

Economic performance

Economic performance assesses the performance of three key industries based on Gladstone Harbour. The performance of these industries underpins the stimulus to the regional economy.

Shipping activity provides a proxy for economic activity in key exports such as coal and gas, as well as the imports and exports associated with harbour-based industries such as mineral processing. The high score for shipping activity confirms that these export-focused industries are generating a major economic stimulus to the local economy. Tourism and fishing remain important sectors for the harbour-based city of Gladstone.

The commercial fishing indicator score declined sharply from 2015 to 2016. This result must be interpreted cautiously as there have been some revisions to the QFish database that have affected data for both the current and previous years. It is possible that the downgrade is a combination of lower activity in at least one of the four catch types (line, otter trawl, pot, and net fishing) as well as data changes.

Economic stimulus

Economic stimulus captures the potential stimulus from economic activities that may flow through to the community. The high unemployment rate indicates that the economic stimulus from harbour-based industries on the local economy and job creation is lower than it has been in the past.

The high score for socio-economic status indicates that the economic stimulus from harbour-based industries was flowing through the local economy to create greater income and wealth and provide better access to economic resources such as housing. The influence of the high proportion of home ownership has declined in 2016, whereas the influence from a higher proportion of adults over 18 years in the household has increased. The impacts of increases in unemployment, particularly declines in high income employment, is also evident in the low socio-economic status scores.

Economic value

Economic value (recreation) assesses how the community generates economic value from the harbour through recreational activities. Economic activity in Gladstone generates income and wealth to the local community. The contribution of harbour-based recreation can then be assessed by how much of that wealth is spent on recreational activities in the harbour.

Land-based recreation was the most important recreational activity. The average annual value for the Gladstone population was estimated at $54.75 million ($45.43 million in 2015). Beach recreation was estimated to have an annual value of at $31.79 million ($27.98 million in 2015).

Recreational fishing had a higher per trip value than beach and land-based recreation but with a lower frequency across the population, the annual value was estimated at $24.43 million ($21.34 million in 2015).

Table 7.2: Comparison of economic indicator scores between 2014 and 2016 report cards.

		2014	2015	2016
Indicator group	**Economic performance**	0.83	0.79	0.87
Indicators	Shipping activity	0.83	0.82	0.87
	Tourism	0.60	0.64	0.72
	Commercial fishing	0.66	0.63	0.43
Indicator group	**Economic stimulus**	0.87	0.82 [a]	0.74
Indicators	Employment	0.72	0.64	0.62
	Socio-economic status	0.90	0.95 [b]	0.80
Indicator group	**Economic value (Recreation)**	0.75	0.72	0.73
	Land-based recreation	0.76	0.73	0.76
	Recreational fishing	0.67	0.71	0.66
	Beach recreation	0.71	0.70	0.75
Overall harbour score		**0.82**	**0.77**	**0.75**

[a] A value of 0.715 was estimated when the same 2015 datasets were recalculated using the automated process from the R script as applied for the 2016 data. It is possible there was an error in the original 2015 analysis.

[b] A value of 0.74 was estimated when the 2015 datasets were recalculated using the automated process from the R script as applied for the 2016 data. It is possible there was an error in the original 2015 analysis.

8. Iconic species of Gladstone Harbour

Gladstone Harbour and its associated water bodies and islands provide important habitat, breeding sites and roosting locations for a number of iconic marine species such as dolphins, dugongs, marine turtles and migratory shorebirds. However, these species are not necessarily the best indicators of annual harbour health. In some instances, there can be a considerable lag between an environmental impact and a response in these species. For example, a decline in seagrass cover will provide a signal of change long before malnourishment or fewer sightings are detected in marine turtles or dugongs within the harbour. Additionally, the range of most of this marine megafauna usually extends well beyond the confines of Gladstone Harbour making it difficult to associate change in their condition or population with impacts in the harbour. This may be even more difficult with migratory shorebirds as changes in numbers observed may be influenced to a greater extent by impacts in the northern hemisphere or other parts of their flyways.

Although these species may not be suitable as report card indicators, research on the distribution, population and trends and the use of the harbour by these species is vital for understanding and managing/mitigating potential impacts within Gladstone Harbour—both natural and anthropogenic. As these species are listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), there are also legislative requirements to protect and mitigate anthropogenic impacts on these species.

Dolphins

The Indo-Pacific humpback dolphin *Sousa chinensis*, the bottlenose dolphin *Tursiops truncates*, and the Indo-Pacific (inshore) bottlenose dolphin *Tursiops aduncus* have been observed in Gladstone Harbour (DEHP, 2014b). The Indo-Pacific humpback dolphin is an EPBC-listed migratory species and is listed as near threatened in Queensland under the *Nature Conservation Act 1992*. Humpback dolphins in the Capricorn–Curtis coast region form two geographically distinct sub-populations, referred to as the Fitzroy River and the Port Curtis Indo-Pacific humpback dolphins sub-populations (Cagnazzi, 2013). In surveys conducted between 2006 and 2008, the Fitzroy River and Port Curtis populations were estimated to be 115 and 84 individuals, respectively. In 2011, abundance estimates for both sub-populations declined to about 104 and 45 dolphins, respectively (Cagnazzi, 2013).

In dolphin surveys conducted in the Port Alma and Port Curtis area (including Rodds Bay) between May and August 2014, a total of 140 Indo-Pacific humpback dolphins were identified from unique markings on their dorsal fins (Cagnazzi, 2015). With the exception of the smaller estuaries, groups of Indo-Pacific humpback dolphins were recorded in all harbour zones including The Narrows and the mouth of Graham Creek (Cagnazzi, 2015). Although not directly comparable to the results of previous surveys, these results indicate that Indo-Pacific humpback dolphins continue to use extensive areas of Gladstone Harbour. Small numbers of bottlenose dolphins were also sighted during those surveys.

Dugongs

The dugong, *Dugong dugon*, is an EPBC Act-listed marine and migratory species that is also listed as vulnerable in Queensland under the Nature Conservation Act. Dugongs are found throughout the western Indo-Pacific region (eastern Africa to eastern Australia) in tropical and subtropical waters. Within the Gladstone Harbour area, including Rodds Bay, dugongs are predominantly associated with the *Halophila ovalis* seagrass meadows which are the major component of their diet. A review of the status of the dugong population in the Gladstone area was conducted by Sobtzick et al. (2013) as part of the Ecosystem Research and Monitoring Program (ERMP) funded by GPC. This review found that the Port Curtis–Rodds Bay area provides important habitat for a relatively small population of dugongs. The authors indicated that as these areas overlap with areas of human use, the risk to dugongs from human activity may be substantial. This review also considered the seagrass meadows within the Gladstone area to be of regional significance as they may provide valuable connecting habitat between dugong populations in southern Queensland (Sobtzick et al., 2013).

Small numbers of dugongs were sighted during recent dolphin surveys of the Port Alma and Port Curtis region (Cagnazzi, 2015) and dugong feeding trails were mapped at five seagrass meadows within Port Curtis and Rodds Bay, Pelican Banks, South Tree Inlet, Wiggins Island and Rodds Bay.

Although these incidental sightings indicate the continued presence of dugongs in Gladstone Harbour, they are insufficient to identify any trends in the harbour's dugong population.

Marine turtles

Six species of marine turtle have been observed in the Port Curtis region. However, nesting has only been recorded for three of these species: the loggerhead, green and flatback turtles. Sightings of the other three species are rare. The status of turtles within Gladstone Harbour has also been reviewed as a component of the ERMP (Limpus et al., 2013) as follows.

- green turtle *Chelonia mydas* – EPBC status: vulnerable, marine and migratory. Isolated green turtle nesting has been recorded within the port limits of Port Curtis, but not annually
- flatback turtle *Natator depressus* – EPBC status: endangered, marine and migratory. The flatback turtle is the dominant species of turtle recorded as nesting on the beaches of Port Curtis. Most nesting occurs on the southern end of Curtis Island, with low density nesting on seaward beaches within the port limits.
- loggerhead turtle *Caretta caretta* – EPBC status: endangered, marine, and migratory. Isolated loggerhead turtle nesting has been recorded within the port limits of Port Curtis, but not annually.
- hawksbill turtle *Eretmochelys imbricata* – EPBC status: vulnerable, marine and migratory. There are no records of this species nesting within a 500km radius of Port Curtis.
- olive ridley turtle *Lepidochelys olivacea* – EPBC status: endangered, marine and migratory. There are no records of this species nesting in eastern Australia.
- leatherback turtle *Dermochelys coriacea* – EPBC status: endangered, marine and migratory. Leatherback turtles are rarely recorded in the waters of Port Curtis.

An acoustic and satellite tagging study conducted between 2013 and 2014 documented the movement of green turtles within the harbour (Babcock et al., 2015). The study revealed that during high tide green turtles would move into shallower areas that generally contained more food than the deeper areas of the harbour and would shift into slightly deeper water at the edge of channels at low tide. Babcock et al. (2015) also found that green turtles in the vicinity of Wiggins Island feed predominantly on red algae growing on mangroves, whereas turtles at Pelican Banks feed primarily on seagrasses.

Migratory shorebirds

Migratory shorebirds are EPBC Act-listed species. Surveys of migratory shorebirds have been conducted in the Gladstone area since 2011 as a component of the ERMP.

In February 2016, a total of 157 roosts were surveyed over five days at Port Curtis, Fitzroy Estuary, North Curtis, Mundoolin-Colosseum, Rodds Peninsula, Mainland Shoreline and the Western Basin Reclamation Area (Wildlife Unlimited, 2016). In these surveys, 11,574 migratory shorebirds of 20 species were recorded. This was 2,178 (16%) fewer birds than recorded in the 2015 shorebird surveys but only 4% fewer than the overall average for the summer counts. The ten most abundant species accounted for 97% of these observations. These species were: bar-tailed godwit *Limosa lapponica*, whimbrel *Numenius phaeopus*, eastern curlew *Numenius madagascariensis*, terek sandpiper *Xenus cinereus*, grey-tailed tattler *Tringa brevipes*, great knot *Calidris tenuirostris*, red-necked stint *Calidris ruficollis*, grey plover *Pluvialis squatarola,* lesser sand plover *Charadrius mongolus* and greater sand plover *Charadrius leschenaultia*.

9. Gladstone Harbour drivers and pressures

9.1. Background

Drivers and pressures are defined as 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). 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).

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 2015–16 report card scores and grades.

In the reporting year from June 2015 to July 2016, acute climatic events, such as flooding and cyclones, and changes to economic circumstances did not influence the report card grades.

9.2. Climate

Gladstone has a subtropical climate with an average maximum of 27.7°C (Figure 9.1) and an average minimum of 18°C. Rainfall is highly variable; the average annual rainfall recorded at Gladstone (Radar Hill) for the period 1958–2015 was 891mm. The maximum and minimum annual rainfall totals recorded at this site were 1,732mm in 1971 and 43mm in 1965, respectively (note that four years were excluded from this analysis owing to an incomplete dataset). Consistent with a subtropical climate, the summer months are wetter than winter months with December, January and February accounting for 40% of the annual average. The winter months of June, July and August account for only 12% of the annual average rainfall.

2015–16 rainfall

In the 2015–16 reporting year, total monthly rainfall for all months except March and June were below the monthly average over the past 58 years. Total rainfall recorded in March 2016 was 338mm (over three times the March average of 98mm), whereas total rainfall for June 2016 was 108mm (nearly three times the June average of 39mm) (Figure 9.2). However, the 2014–15 reporting year's annual total of 843mm was close to the annual average of 891mm (Figure 9.3).

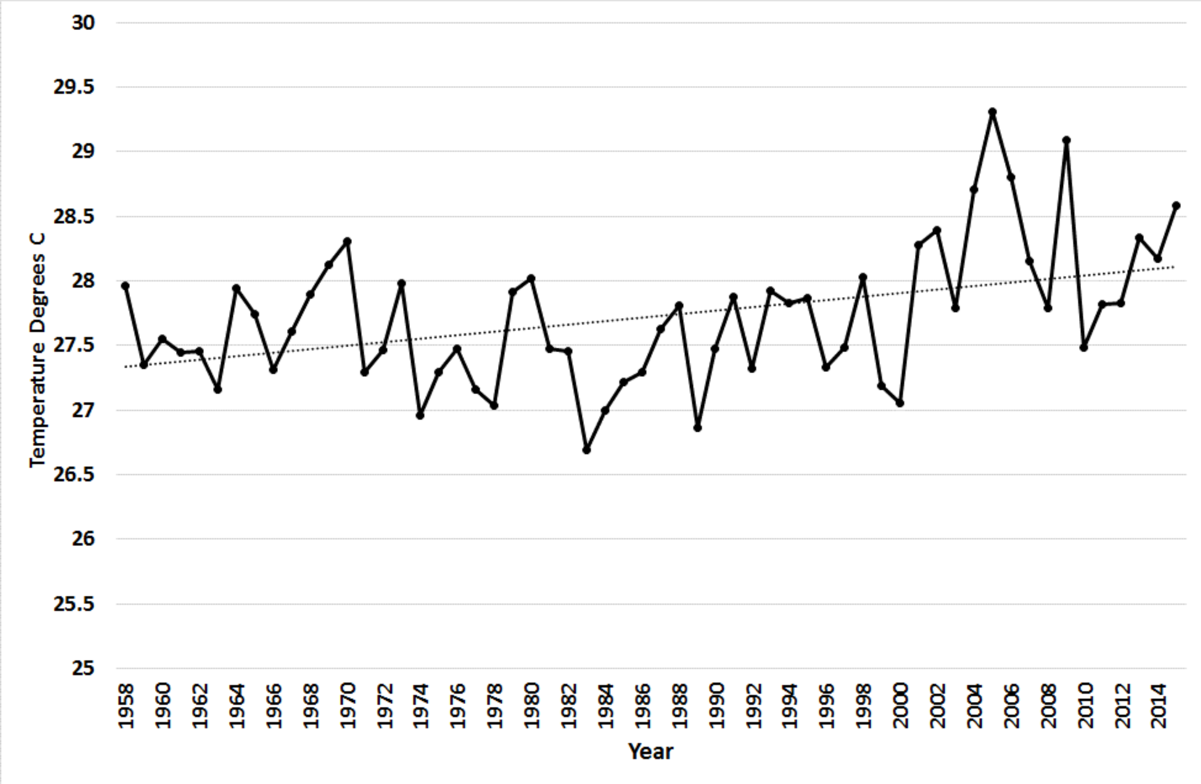


Figure 9.1: Average maximum temperatures at the Gladstone Radar Hill weather station from 1958–2015 (Australian Bureau of Meteorology data).

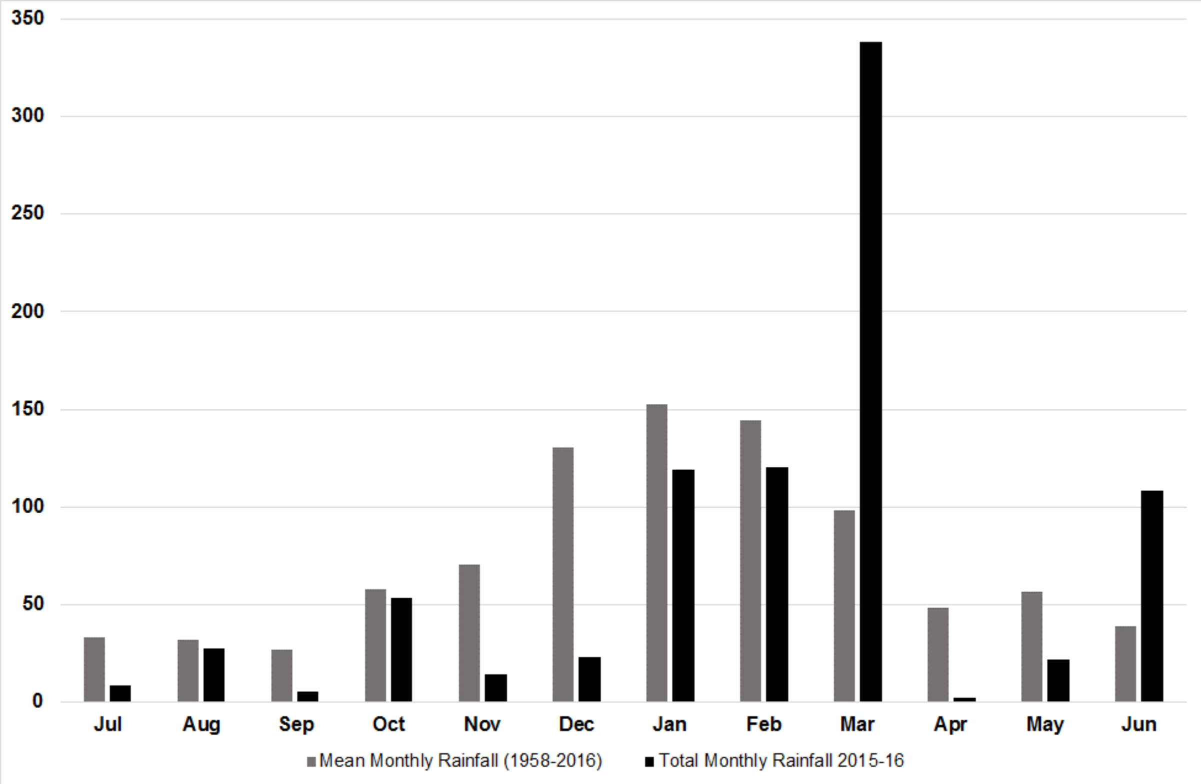


Figure 9.2: Mean monthly rainfall (mm) at the Gladstone Radar Hill weather station (1958–2016) compared to total monthly rainfall for the 2015–16 reporting year (Australian Bureau of Meteorology data).

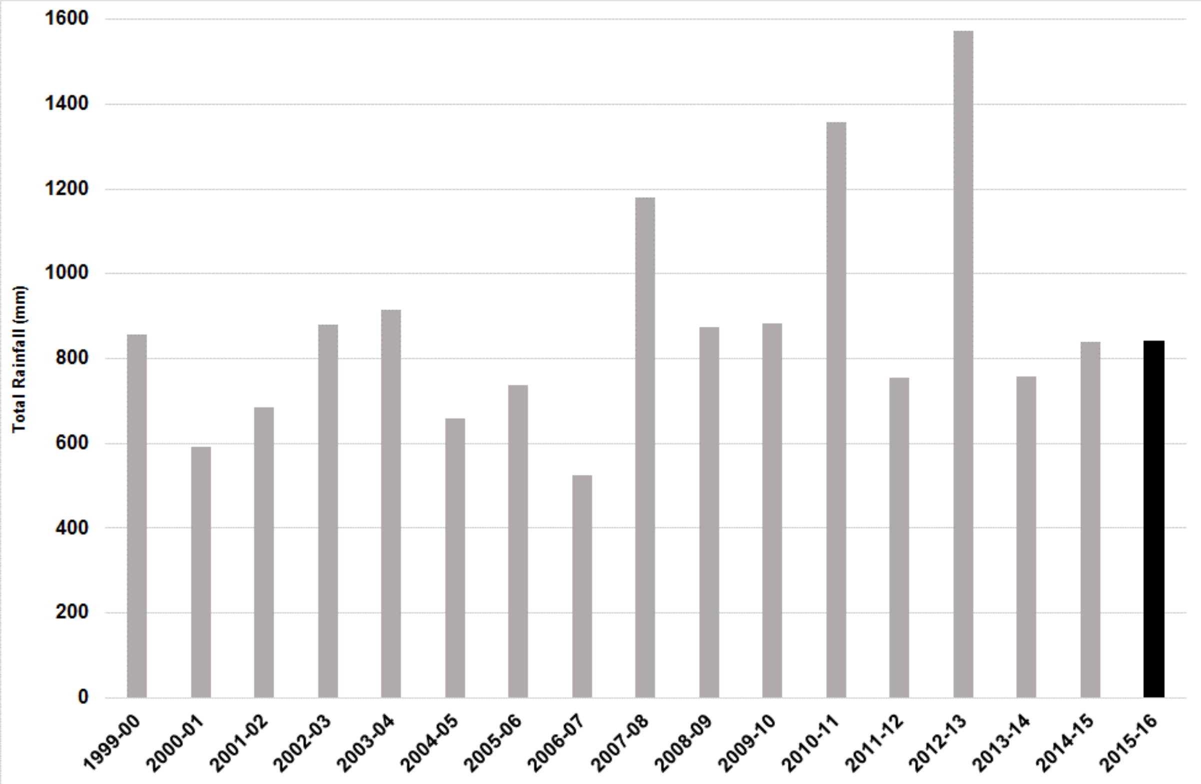


Figure 9.3: Annual rainfall (reporting year) at the Gladstone Radar Hill weather station from 1999–2000 to 2014–2015 (Australian Bureau of Meteorology data).

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. Freshwater flows 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 the presence of Awoonga Dam, whereas flow in the Calliope River is relatively unmodified. Annual average streamflows for the Boyne and Calliope rivers are presented in Table 9.1.

Flows measured at the Calliope River between January 2014 and June 2016 show a brief but significant high flow event occurring in association with the passage of Tropical Cyclone Marcia. The event lasted approximately one week and reached a peak flow of 91,666ML/day on 21 February 2015 compared to a median daily flow of 36ML/day for the January 2014–June 2016 period (DNRM Water Monitoring Information Portal downloaded 08/09/16) (Figure 9.4). High flows associated with Tropical Cyclone Marcia were also recorded in the Fitzroy River, daily flow data from the Boyne River below Awoonga Dam was not available for this period.

Although the high flow event lies outside the 2015–16 reporting year, it does fall between the dates for the 2014–15 and 2015–16 seagrass monitoring. Therefore, disturbance associated with the high flow event, such as increased harbour turbidity, may have affected seagrass scores and grades for the 2015–16 reporting year. However, had a flood plume increased turbidity due to suspended solids within the plume this would probably have been short-lived.

Table 9.1: Streamflow summary for the Boyne River (1984–85 to 2011–12) and the Calliope River (1938–39 to 2014–15) (DNRM Water Monitoring Information Portal downloaded 08/09/16).

Boyne River at Awoonga Dam Headwaters (1984–85 to 2011–12)			
Annual streamflows (ML)		December streamflows (ML)	
Mean	97,728	Mean	24,279
Median	0	Median	0
Maximum flow (2010–11)	1,194,335	Maximum flow (Total flow December)	634,999
Calliope River at Castlehope (1938–39 to 2014–15)			
Annual streamflows (ML)		December streamflows	
Mean	166,392	Mean	22,214
Median	105,112	Median	31,770
Maximum flow (Total flow 2012–13)	916,693	Maximum flow (Total flow December)	401,837

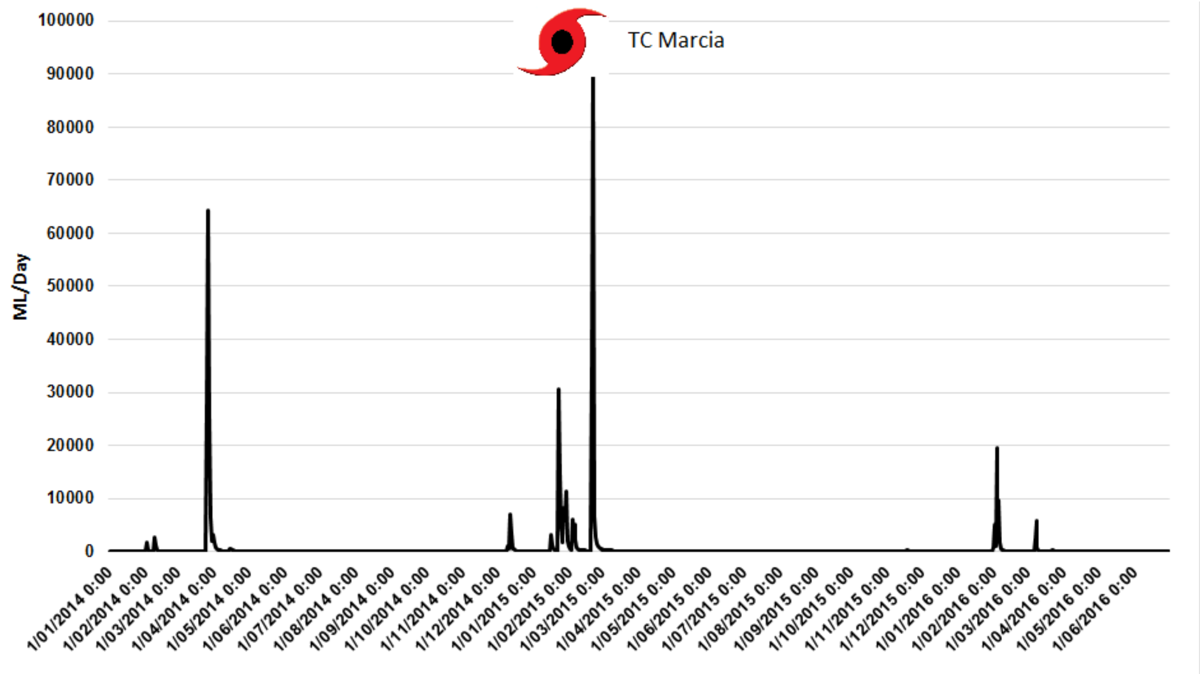


Figure 9.4: Calliope River flows recorded at Castlehope between January 2014 and June 2016. A peak flow of 91,666ML/day was recorded on 21 February 2015 in association with the passage of Tropical Cyclone (TC) Marcia. This peak flow compares with a daily median flow of 36 ML/day for the same time period (DNRM Water Monitoring Information Portal downloaded 08/09/16).

The main water storage in the area is the Awoonga Dam located on the Boyne River approximately 25km south-west of Gladstone. The dam has a storage capacity of 250,000ML and is overtopped when the storage levels exceed 40m Australian height datum (AHD). Since the height of the dam wall was raised, it has overtopped four times—in 2002, 2010, 2013 and 2015. The dam did not overtop in the 2015–16 reporting year (Table 9.2 and Figure 9.5).

Table 9.2: Awoonga Dam levels and initial 2015 overtopping compared to the largest overflow recorded in 2013 (Source: Gladstone Water Board).

Storage level	Date	Level (m AHD)	Volume (ML)	Capacity (%)	Surface area (ha)
Current storage	30-June-16	38.86	701,505	90.30	6,329
Level one month ago	31-May-16	38.92	705,949	90.87	6,355
Level one year ago	30-June-15	39.68	755,379	97.24	6,653
Last overflow of 40m spillway	22-Jan-15	40.1	783,673	100.88	6,818
Highest level	27-Jan-13	48.3	1,498,586	192.9	10,810

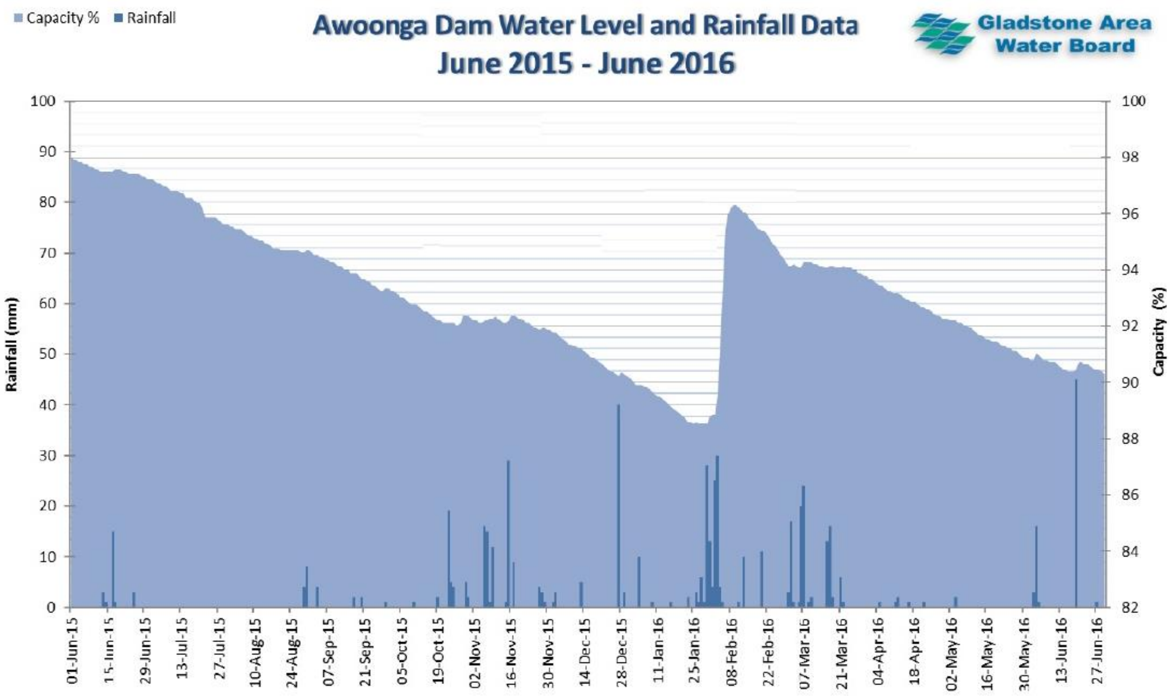


Figure 9.5: Awoonga Dam levels January 2015 to January 2016 (Source: Gladstone Area Water Board).

9.3. Catchment run-off

Gladstone Harbour is bordered by five recognised drainage basins, the Fitzroy (142,555km^2), the Calliope (2,241km^2), the Boyne (2,496km^2), Curtis Island (577km^2) and Baffle Creek (4,085km^2) (Queensland Government Wetland*Info* downloaded 01/06/2016) (Figure 9.6).

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 relatively small. Their catchment areas are 2,236 km^2 and 2,590 km^2, respectively. The predominant land use within these two catchments is grazing (Figures 9.7 and 9.8). Much of the flow from the Boyne River into Port Curtis is restricted by Awoonga Dam, constructed in phases beginning in the 1960s with the current spillway height of 40m AHD achieved in 2002.

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. 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 are sourced from dryland and irrigated cropping and grazing lands (Dougall et al., 2014). Modelled catchment exports from a number of rivers that discharge into the Great Barrier Reef Lagoon including the Boyne, Calliope and Fitzroy rivers. The modelled data show increases in a range of parameters from the pre-development period compared to the loads modelled for 2013 (Table 9.3). For example, the average annual loads of total suspended solids from the Calliope River has increased to 44,000 tonnes per year compared to 16,000 tonnes per year in the pre-development period.

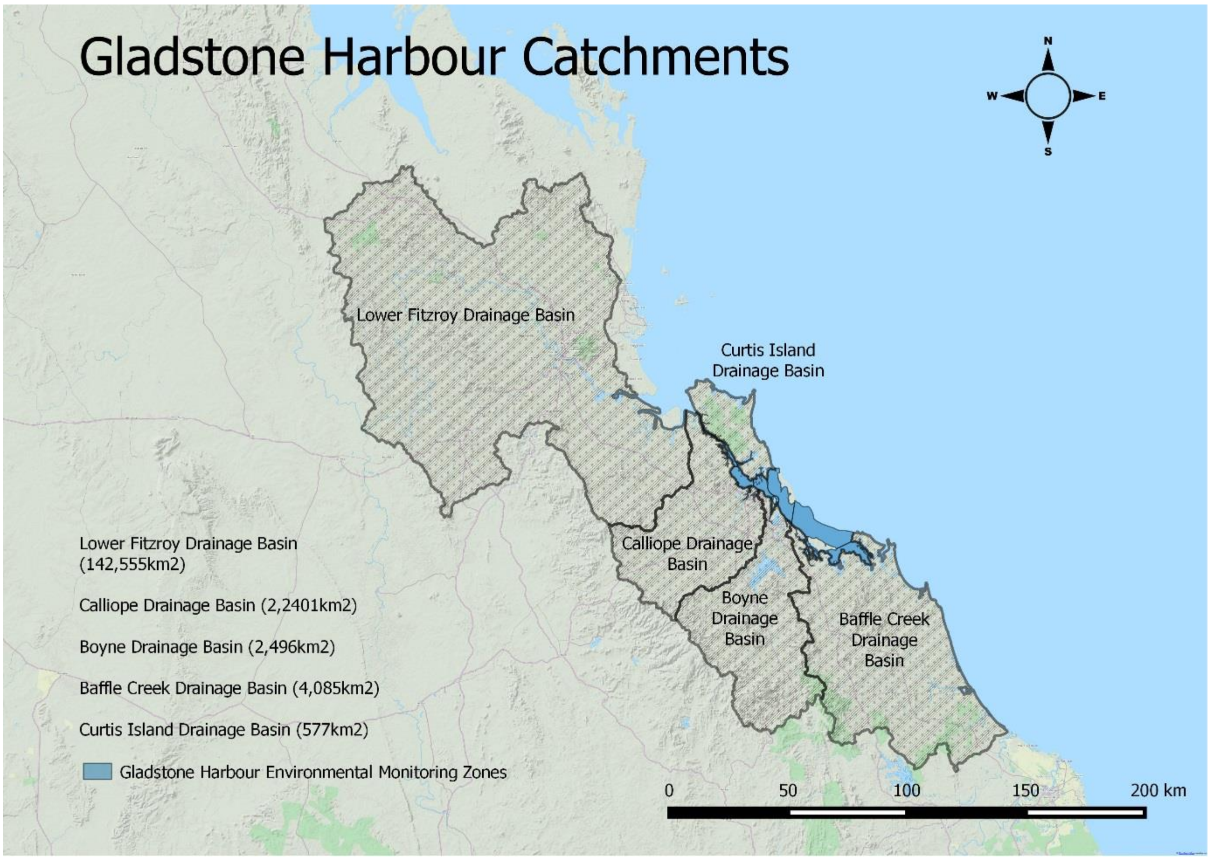


Figure 9.6: Drainage basins surrounding the Gladstone Harbour Environmental monitoring zones.

Table 9.3: Modelled exports from the Boyne, Calliope and Fitzroy Catchments (Dougall et al., 2014).

Catchment	Pre-development load	Total load (2013)	Anthropogenic load (2013) % of total load
Total suspended solids (kilotonnes per year)			
Boyne River	3	11	73%
Calliope River	16	44	63%
Fitzroy River	440	1,740	75%
Total nitrogen loads (TN) (tonnes per year)			
Boyne River	16	24	33%
Calliope River	67	90	26%
Fitzroy River	2,768	3688	25%
Total phosphorous loads (TP) (tonnes per year)			
Boyne River	2	6	67%
Calliope River	13	27	41%
Fitzroy River	414	983	58%
PSII herbicides toxic equivalent loads (kilograms per year)			
Boyne River	0	2	100%
Calliope River	0	10	100%
Fitzroy River	0	521	100%

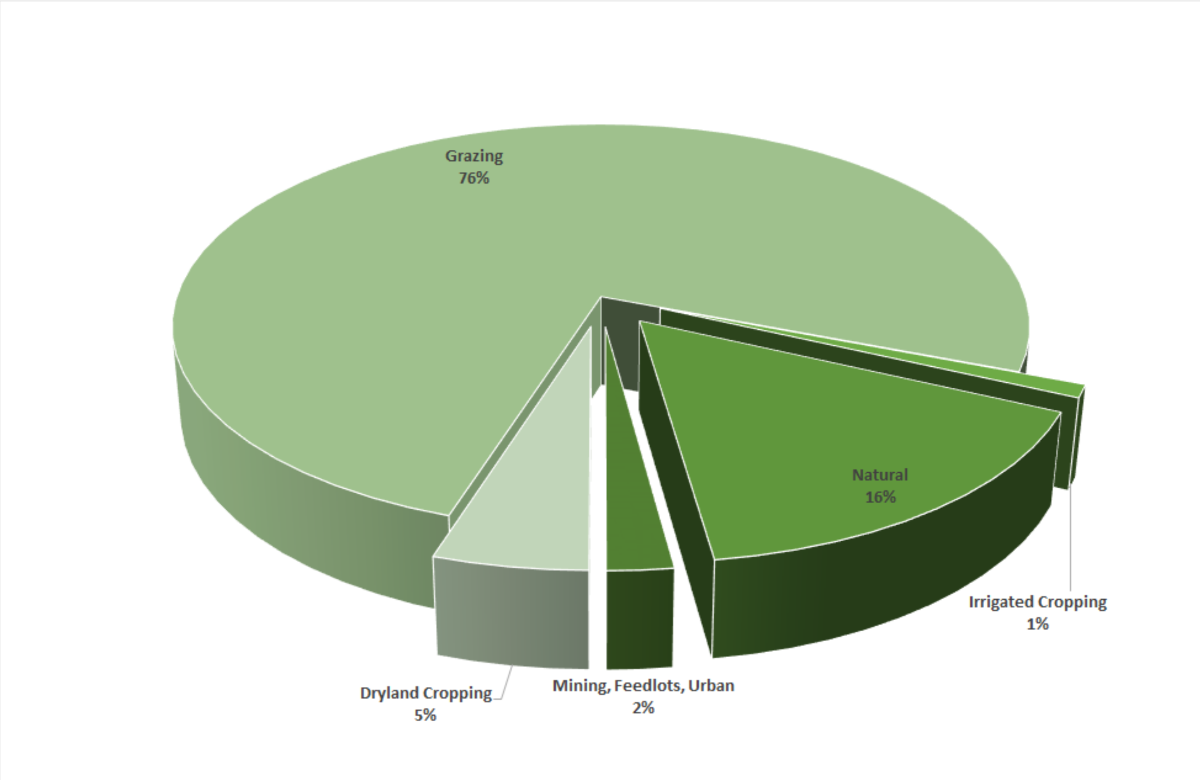


Figure 9.7: Land use in the Boyne catchment (Data source QSpatial , Land use mapping – Fitzroy NRM region 2009, Catchment boundaries, Queensland Wetland*Info*).

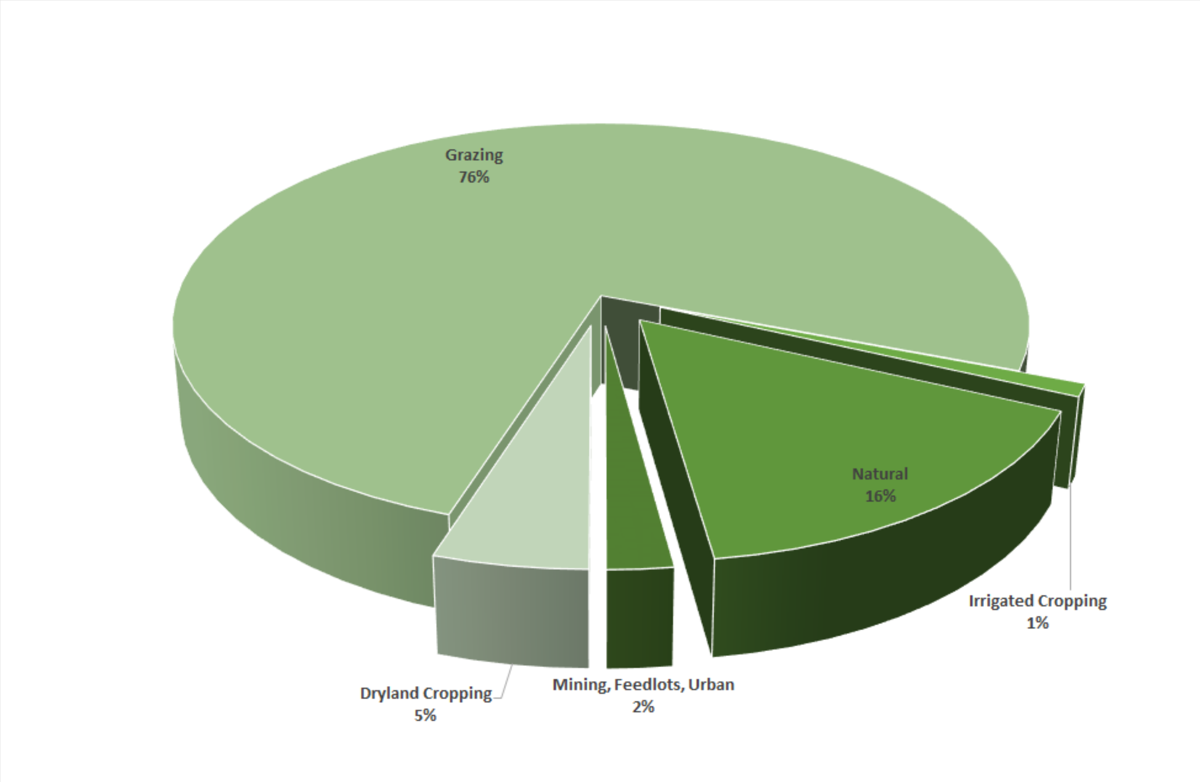


Figure 9.8: Land use in the Calliope catchment (Data source QSpatial , Land use mapping - Fitzroy NRM region 2009, Catchment boundaries, Queensland Wetland*Info*).

Tidal movement and turbidity

Turbidity in Gladstone Harbour is strongly influenced by the large tidal movement. This results in significant resuspension of fine sediments which is directly related to the tidal cycle; larger tides result in increased turbidity (Figure 9.9). 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 is largely determined by the timing of sampling.

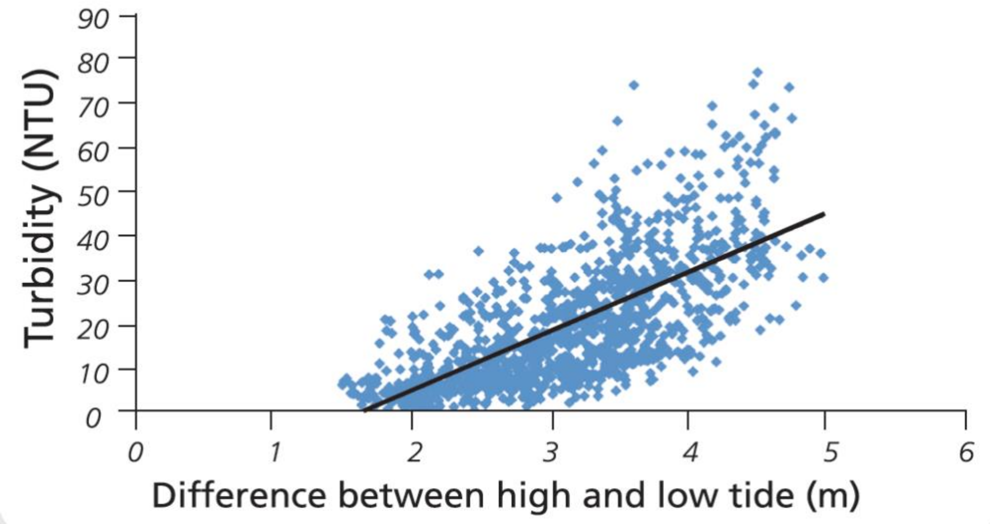


Figure 9.9: The relationship between tidal movement and turbidity in Gladstone Harbour (DEHP 2014 personal communication). NTU: nephelometric turbidity unit.

9.4. Social, cultural and economic pressures

Gladstone is an industrial hub of international significance owing to its large-scale production and export facilities. The Gladstone region's social and economic growth and development patterns have been strongly influenced by the rapid development of the manufacturing, construction and retail trade sectors. This has resulted in a steady increase in Gladstone's population from 45,479 in 2001 to 66,464[4] in 2015 (Gladstone Regional Council, 2015).

Despite this steady population growth, there has been a noticeable reduction in the value of both residential and non-residential building approvals following the sharp peak in 2012–13 when residential and non-residential approvals reached $450.1 million and $402.0 million, respectively. In 2014–15, residential approvals had declined to $63.7 million and non-residential approvals had dropped to $35.7 million[5] (Gladstone Regional Council, 2015).

Comparing business counts (number of actively trading businesses[6]) showed a slight decline in the total number of businesses trading in June 2015 (4,048) compared to June 2014 (4,053).

From 2014 to 2015, there was a slight decrease in businesses with turnovers of greater than $2 million, $50k to less than $2 million, and $200k to less than $500k. However, compared to June 2014, businesses with less than $50k turnover, $50k to 100k, and $100k to 200k indicated an upward trend in June 2015 (Gladstone Regional Council, 2015).

[4] 2015 figure is based on the Estimated Resident Population information by the Australian Bureau of Statistics as of 30 March 2016.
[5] Based on Building Approval data released by the Australian Bureau of Statistics in Sep 2015. Next data update will be in Sep 2016.
[6] This is a snapshot of actively trading businesses in the market sector as of 30 June each year and taken from the Australian Bureau of Statistics Register.

Based on Small Area Labour Market data, the unemployment rate declined from December 2015 (6.6%) to 6.2% in March 2016. The June 2016 figures (6.3%) for Gladstone are slightly lower than the Queensland state rate of 6.4% (Gladstone Regional Council, 2016).

During the 2015–16 financial year, the three LNG processing and export facilities projects on Curtis Island, QCLNG, APLNG and GLNG, moved from the construction to operational phase. This involved dismissing employees, offloading equipment and machinery and releasing leased rental properties back to the rental market in Gladstone (Source: Australian Mining 31 July 2015, https://www.australianmining.com.au/news/massive-lng-project-layoffs-on-curtis-island).

During the 2015–16 financial year, the first cruise ship Pacific Dawn arrived at Gladstone's Auckland Point Terminal with 2,000 passengers (abc.net.au 2016).

9.5. Connectivity

From 2016, 'connectivity' will not contribute to the report card score for the Environmental component as it is considered to be a driver of ecological systems and not a measure of environmental health. Additionally, the connectivity indicators—ecological connectivity, containment connectivity and flushing rate—are generally not affected by human intervention. However, connectivity is an important explanatory variable that contributes to our understanding of the environmental grades and scores and the environmental health of Gladstone Harbour. It will therefore continue to be reported as a system driver.

The connectivity of water bodies is an important driver of productivity in marine ecosystems and helps to maintain ecosystem function. Hydrological connectivity contributes to the health of habitats found within Gladstone Harbour (such as seagrass beds, mangroves and coral reefs) by cycling nutrients, facilitating biological and genetic connectivity, and by diluting and flushing contaminants. However, connectivity between contaminant inputs (e.g. from industrial discharges) and vulnerable habitats (e.g. seagrass beds) can also have negative effects on harbour health. The development of shipping channels, land reclamation and coastline armouring has the potential to alter connectivity within the harbour and is also being assessed by this project.

CSIRO has developed a state-of-the art-hydrodynamic model to address the Gladstone Harbour Report Card objective relevant to connectivity: 'maintain/improve connectivity of water within and between Gladstone Harbour, related rivers, estuaries and adjacent waters'. This model calculates connectivity indices and scores for the report card. It also constitutes a key component of a separate Gladstone Harbour Model that CSIRO is developing on behalf of GHHP (see Appendix 1 for details).

Three indicators have been developed to inform the overall connectivity for the Gladstone Harbour Report Card (Figure 9.10):

1. flushing time – a measure of water exchange through the system. This indicator is commonly used as an indirect indicator of water quality.
2. ecological connectivity – a measure of water exchange between known spawning grounds and nursery areas
3. contaminant connectivity – a measure of the potential of contaminants to move to other parts of the harbour from the input source.

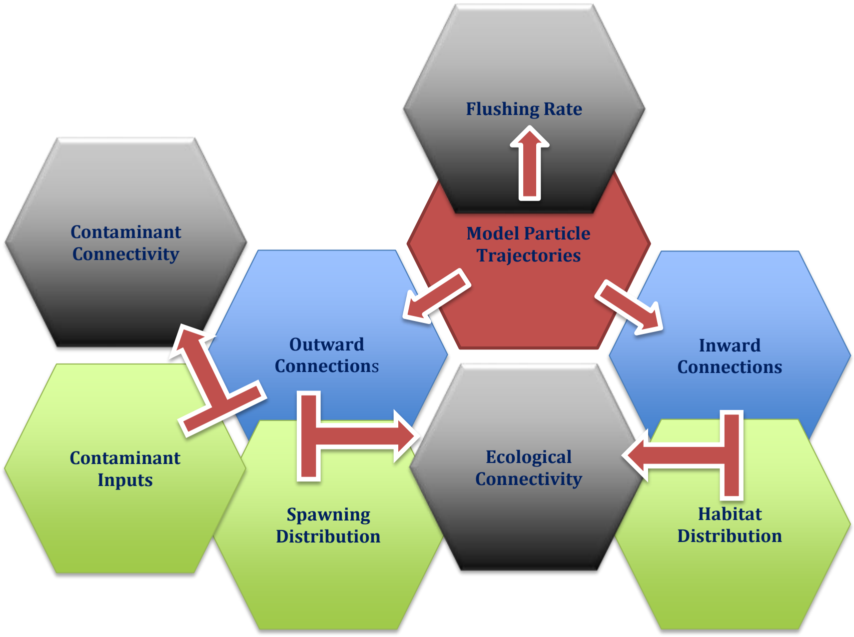


Figure 9.10: The three connectivity indicators calculated from the trajectories of virtual particles within the hydrodynamic model.

Data collection

CSIRO developed a three-dimensional hydrodynamic computer model of Gladstone Harbour for the GHHP which generated the data for calculating connectivity scores for the report card. This model uses a three-dimensional curvilinear grid bounded by the harbour and includes the Boyne and Calliope rivers. There are two open boundaries. One is the curvilinear grid extending offshore in an arc from Curtis Island to Rodds Peninsula and the other is formed by The Narrows (Figure 9.11). The resolution is variable over the grid and ranges from 100–250m within Gladstone Harbour to approximately 1,000m at the offshore boundary. The model has 21 vertical layers with depth ranges of between 0.4m at the surface to 5.0m in the deepest offshore waters. Two layers above mean sea level are included to take tidal movement into account.

Initial and open boundary conditions were provided by CSIRO's eReefs model (eReefs Marine Modelling Overview), atmospheric forcing was included using data supplied by the ACCESS-A meteorological model run by the Bureau of Meteorology (ACCESS NWP Data Information), and freshwater flow information was based on flow data at Castlehope for the Calliope River and at Awoonga Dam Headwaters for the Boyne River (Water Monitoring and Data Portal). Real-time data for the Boyne River are no longer available.

A detailed technical description of the hydrodynamic model and its implementation is provided in Condie et al. (2015).

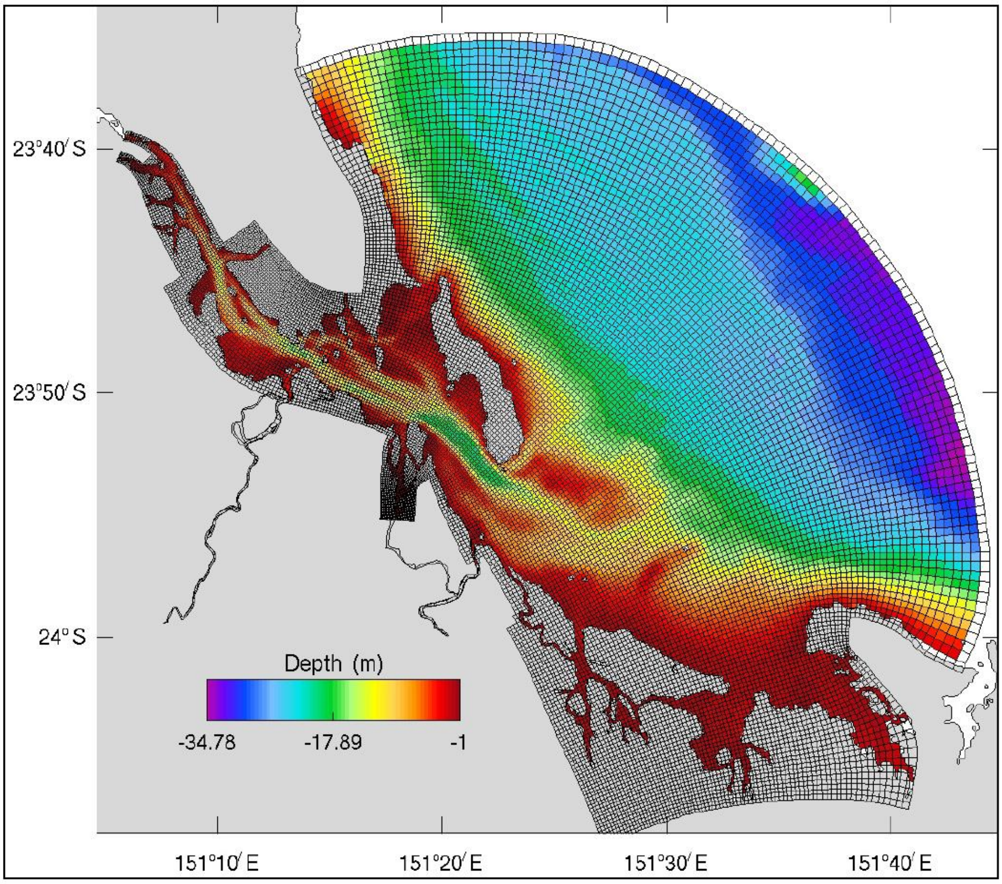


Figure 9.11: The Gladstone Harbour hydrodynamic model's curvilinear grid overlayed on harbour bathymetry (Source: Condie et al., 2015).

Two model runs covering the period September 2010 to August 2014 generated the data for determining baseline conditions. A model run from July 2015 to June 2016 generated the scores for the 2016 report card. The 2010 to 2014 period was required to generate a sufficient baseline for calculating report card grades and scores. The Western Basin Dredging and Disposal Project resulted in changes to the harbour bathymetry and coastline. This required separate model runs for the periods before and after capital dredging to incorporate these changes (Table 9.4).

Table 9.4: Hydrodynamic model runs used to determine a connectivity baseline and scores for 2016.

Model run	Outputs
Pre-capital dredging: September 2010–August 2012	Pre-capital dredging baseline values Estimation of pilot indicator values
Post-capital dredging: September 2012–August 2014	Post-capital dredging baseline values Estimation of pilot indicator values
Near real time: June 2015–June 2016	2016 connectivity assessments and scores

Each of the three connectivity indicators was assessed on the basis of particle tracking from all three model runs. In each model run, 2,000 neutrally buoyant 'particles' were randomly seeded throughout the virtual water column within the computer model. This model included 11 of the 13 water quality reporting zones in Gladstone Harbour. Auckland Inlet and Boat Creek Estuary were not included in this analysis as these small estuaries are not sufficiently resolved by the hydrodynamic model to support particle tracking. In the remaining zones, reseeding of particles occurred every 20 days to account for particles lost through the outer edges of the zones. This timing ensured that particles were released at different points of the tidal cycle, thus minimising tidal bias in the long-term statistics.

Particles were moved in 10-minute time steps by currents generated by the hydrodynamic model. A small 'random walk' element was added to the particle trajectory to represent the dispersive influence of small-scale turbulent motion that is not included in the circulation model. All particles were individually tracked and their virtual locations were recorded once every hour.

Flushing rate

The flushing rate indicator was calculated for each 20-day reseeding by plotting the number of particles remaining in a zone over time and calculating the time until only 36.8% of particles remained.

Ecological connectivity

Significant areas of potential nursery habitat (wetlands, seagrass meadows or coral reefs) and spawning grounds of key species (e.g. barramundi, yellowfin bream and mud crabs) were identified in the 11 harbour zones for which connectivity scores are reported (Table 9.5). A habitat score for each zone (1 to 3) was calculated by adding the number of habitats recorded in each zone (1 point for each habitat type) plus one additional point to account for less well documented habitat types (e.g. soft sediments). A similar approach was used to derive a spawning score for each zone (Table 9.5). Each zone was allocated one point for each key spawning ground it contained plus one point to account for undocumented spawning grounds and/or other species. Although this is a simple scoring system, it effectively differentiated between zones with and without key habitats. In the future, refinements to this scoring system could be made if suitable data become available (e.g. if additional habitats are located).

The ecological connectivity score is based on the modelled movement of virtual particles between zones for each of the 20-day reseedings. Movement of particles into a zone weighted by the habitat score provides a relative measure of how favourable the system connectivity was for recruitment to habitats within that zone. The movement of particles out of a zone into other zones weighted by the spawning scores provides a relative measure of how favourable the system connectivity was to the dispersal of eggs and larvae from that zone.

Contaminant connectivity

The contaminant connectivity indicator was based on annual loads of toxic substances discharged into the waterways as reported to the National Pollutant Inventory (www.npi.gov.au). These figures are reported annually in January, seven months after the end of each financial year. Thus, the 2013–14 data are the most recent available and so were used as the best available estimate for the 2014–15 loads. This approach was tested back to 2007–08 and found to result in smaller errors than averaging over the previous two or three years.

Within each of the 11 zones for which a connectivity score is reported, annual loads that occurred within the zones were multiplied by a relative measure of their aquatic ecotoxicology and then summed to obtain a relative annual toxicity load for each zone. These calculations were made for the four harbour zones from which contaminant release was reported: Western Basin, Inner Harbour, Calliope Estuary and South Trees Inlet (Table 9.6). Although there are no data available for directly estimating background pollutant release into the harbour, the model was set to give a ratio of recorded loads to the harbour to diffuse background loads that were within the range typical of impacted estuarine systems. This background load was applied equally to all zones.

The contaminant score is based on the movement of particles (for each 20-day reseeding) out of a zone weighted with the zone score (annual load multiplied by aquatic toxicity) into other harbour zones.

Table 9.5: Key sites with the potential to support ecological connectivity. Particle trajectories were not available for Boat Creek and Auckland Inlet (Source: Condie et al., 2015).

Zone	Key nursery habitats				Key spawning grounds			
	Wetlands	Seagrass	Reefs	Habitat score	Barra-mundi	Bream	Mud crab	Spawning Score
1. Graham Creek	1			2				1
2. The Narrows	1	1		3				1
3. Boat Creek	1			2				1
4. Calliope Estuary	1			2				1
5. Western Basin		1		2	1			2
6. Auckland Inlet				1				1
7. Inner Harbour				1	1			2
8. South Trees Inlet	1			2				1
9. Boyne Estuary				1				1
10. Mid Harbour		1	1	3	1	1		3
11. Colosseum Inlet	1			2				1
12. Rodds Bay	1	1		3				1
13. Outer Harbour		1	1	3		1	1	3

Table 9.6: Relative aquatic ecotoxicology (Wright et al., 1998) and four years of annual loads from some industrial facilities as reported to the National Pollutant Inventory (www.npi.gov.au) (Source: Condie et al., 2016).

	Substance (including compounds)	Relative aquatic eco-toxicology	Annual loads (kg)																			
			Calliope Estuary Gladstone Power Station					**Western Basin** Yarwun Site Stuart Project Rio Tinto Alcan Yarwun					**Inner Harbour** Gladstone Terminal Port Central					**South Trees Inlet** Boyne Smelters Queensland Alumina				
			2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015
Metals	Arsenic	0.20			10.0	2.7		91.5	93.5	208	257	12.0						560	568	543	270	
	Beryllium	1.0							17.6	40.3												
	Cadmium	2.0	0.84					8.61			11.9	0.12						18.6	6.8	5.8	22.6	
	Chromium	0.33		8.1	17.9	13.3		14.1		21.8			0.58		0.03	0.01	0.01					
	Copper	1.0	7.0		25.1	8.1					18.1		0.15	0.03	0.03	0.05		18		84.3	363	
	Iron	0.005																				
	Lead	0.20			6.9	1.62							0.04	0.01	0.01	0.01		1.3		23.1	0.41	
	Manganese	0.10	46			129													58.0			
	Mercury	16.7	0.7						0.01			0.05										
	Nickel	0.17		15.6					11.7				0.16	0.01	0.02		0.01		54.5	192		
	Vanadium	0.05																				
	Zinc	0.125	35	21.3	18.8			363	485	695	708		2.0	0.08	0.30	0.01		380	288	3780	257	
Other substances	Ammonia	0.24						5906	6833	6279	6321											
	Benzene	0.10													0.11							
	Carbon	0.42																				
	Chlorine	0.50						132	128	117												
	Chlorobenzene	1.0																				
	Chloroform	0.42																				
	Cyanide	0.10																				
	Dichloroethane	0.50																				
	Fluoride	0.01						16412	13504	29928	49940	570000						134000	129240	239500	111000	102000
	Formaldehyde	1.0																				
	Hexochloroben	167																				
	Hexochlorobut	50																				
	Methylenechlo	0.50																				
	Nitrobenzene	0.25																				
	Nitrophenol	0.50																				
	Tetrachloroeth	0.50																				
	Toluene	0.13											0.01	0.01	0.52	0.02	0.01					
	Trichloroethyle	0.50																				
	Xylene	0.17											0.01	0.01	0.28	0.01	0.01					

Connectivity grades and scores for the 2016 report card were calculated relative to zone-specific baseline values for the flushing rate, ecological connectivity and contaminant connectivity indicators. These baselines were calculated using the four-year model run (September 2010–August 2014). This period gives equal weighting to pre-capital and post-capital dredging conditions to the baseline. Connectivity can be influenced by factors with high seasonal and inter-annual variability, such as rainfall, which may influence flushing rates in zones containing estuaries. Although the baseline period largely captures the variability of rainfall over the last 10 years (Australian Bureau of Meteorology rainfall data for Gladstone Airport), drier conditions such as those experienced in the preceding decade would have resulted in lower flushing rates.

Flushing rates for all 20-day reseedings over the four baseline years were used to calculate a mean flushing rate and standard deviation for each zone. These values form the baseline (Figure 9.12) to which the 2014–15 flushing time statistics were compared to derive the flushing rate scores.

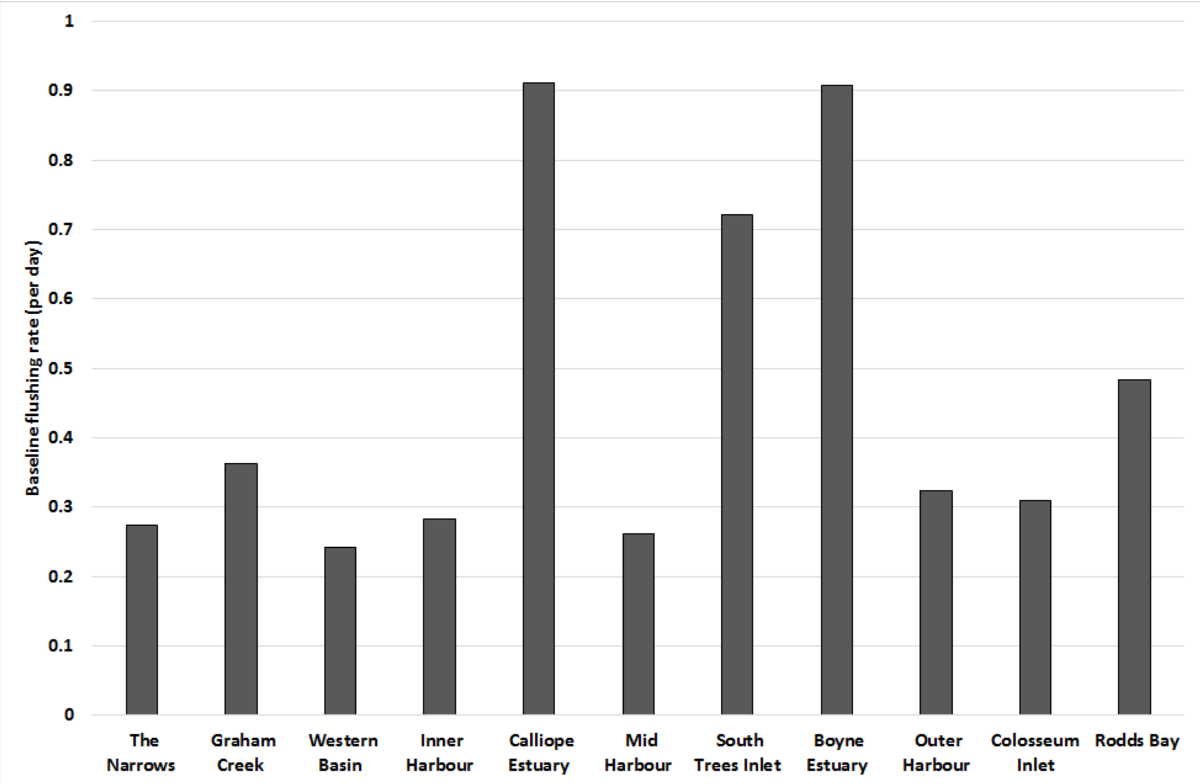


Figure 9.12: Baseline four-year average flushing rates in each of the modelled harbour zones.

The baseline for ecological connectivity was calculated from the 20-day reseeding scores of the weighted in-degree (movement of particles from other zones into a zone weighted by the habitat score) and the weighted out-degree (movement of particles out of a zone into other zones weighted by the spawning scores). The average of these two scores produced the ecological connectivity score. Means and standard deviations were calculated from these scores over the four years of model runs to give baseline values for ecological connectivity (Figure 9.13).

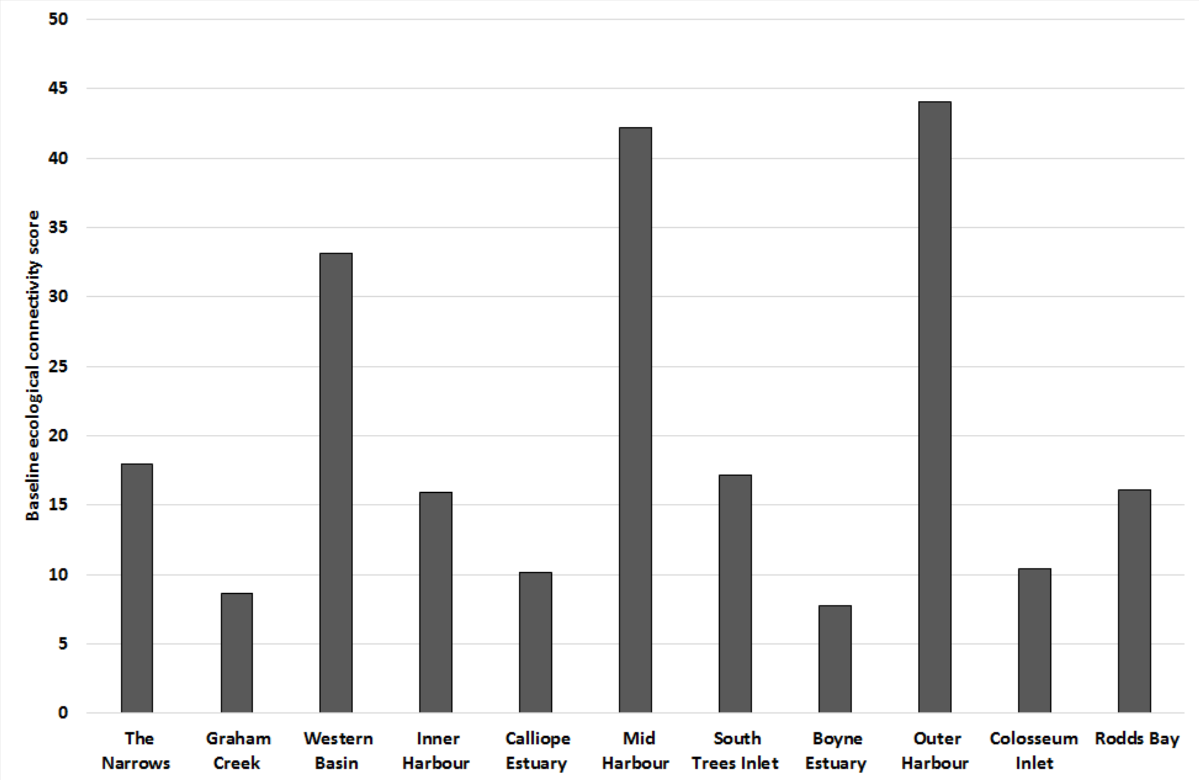


Figure 9.13: Baseline four-year average ecological connectivity in each of the modelled harbour zones.

Baseline values for contaminant connectivity were calculated from the weighted out-degree scores (the movement and number of particles from each zone into other zones) in each of the 20-day reseedings over the model run 2010–2014. Means and standard deviations of the weighted out-degree scores were then computed over the four years to give the baseline values to which the 2014–15 data were compared to derive the 2016 report card score for this indicator (Figure 9.14).

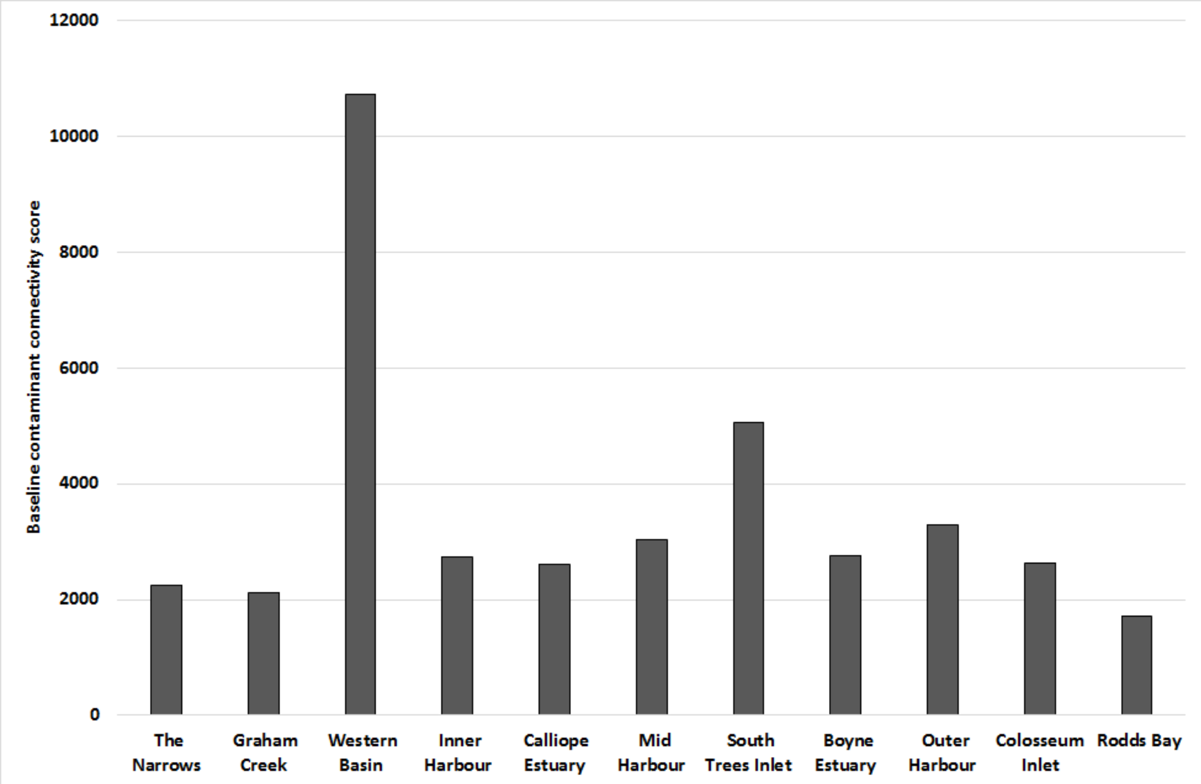


Figure 9.14: Baseline four-year average contaminant connectivity in each of the modelled harbour zones.

Scores for each indicator were calculated by comparing the means and variability in the 2015–16 indicators relative to the mean and variability of the baseline using the t-statistic. A numerical score consistent with the GHHP ranges of scores and grade descriptions was derived by applying a linear transformation to the t-statistics.

Average connectivity for each zone is the average of the three indicators.

Results

The overall score for connectivity in 2016 was 0.61 indicating a satisfactory condition for connectivity. Nine of the eleven zones in which connectivity was measured received satisfactory or good scores; and only three zones (Graham Creek, Calliope Estuary and Boyne Estuary) received poor scores (Table 9.7).

The overall score for flushing rate of 0.63 indicates a satisfactory flushing rate across the harbour zones. Eight of the eleven zones in which this indicator was measured received scores that were higher than the four-year flushing rate average. However, three zones (Calliope Estuary, Mid Harbour and Boyne Estuary) received very poor scores.

Ecological connectivity (0.28) was low compared to the baseline, although the Mid Harbour and Outer Harbour both received very good scores of 1.00 owing to a high recruitment potential (particles moving in to these zones). The low scores in the other zones were associated with lower water exchange rather than habitat changes.

The overall score for containment connectivity of 0.92 (very good) indicates a low export of contaminants to other zones relative to the four-year baseline. All zones received very good score (0.85–1.00).

Table 9.7: Connectivity scores for each zone and harbour-wide averages for 2016.

Zone	Flushing rate	Ecological connectivity	Contaminant connectivity	Average connectivity
1. The Narrows	1.00	0.00	1.00	0.67
2. Graham Creek	1.00	0.00	1.00	0.37
3. Western Basin	1.00	0.50	1.00	0.83
4. Boat Creek	Not modelled owing to insufficient model resolution			
5. Inner Harbour	0.61	0.27	1.00	0.63
6. Calliope Estuary	0.16	0.00	1.00	0.39
7. Auckland Inlet	Not modelled owing to insufficient model resolution			
8. Mid Harbour	0.00	1.00	1.00	0.67
9. South Trees Inlet	1.00	0.03	1.00	0.68
10. Boyne Estuary	0.00	0.00	1.00	0.33
11. Outer Harbour	0.51	1.00	1.00	0.84
12. Colosseum Inlet	1.00	0.00	1.00	0.67
13. Rodds Bay	0.66	0.28	0.99	0.64
Harbour score	**0.63**	**0.28**	**0.92**	**0.61**

Connectivity conclusions

The connectivity indicator scores provide a measure of connectivity in 2015–16 compared to the four-year baseline period (2010–2014). In comparison to 2014–15 scores for flushing rate generally declined, while scores for containment connectivity increased and ecological connectivity were similar. These changes were largely due to changes in water circulation rather than changes in containment loads or habitat distribution.

10. Guide to the infrastructure supporting the GHHP website

The GHHP Data Information Management System (DIMS) is an essential infrastructure developed by AIMS which allows a range of users to store, calculate and visualise report card raw data and results (Figure 10.1). Given the large social, cultural, economic and environment monitoring datasets used to inform a report card, this system will help to systematically and consistently manage the data with a reliable backup system. The DIMS will also be an information source for the website that can collate and analyse different data types and produce graphical outputs and tables.

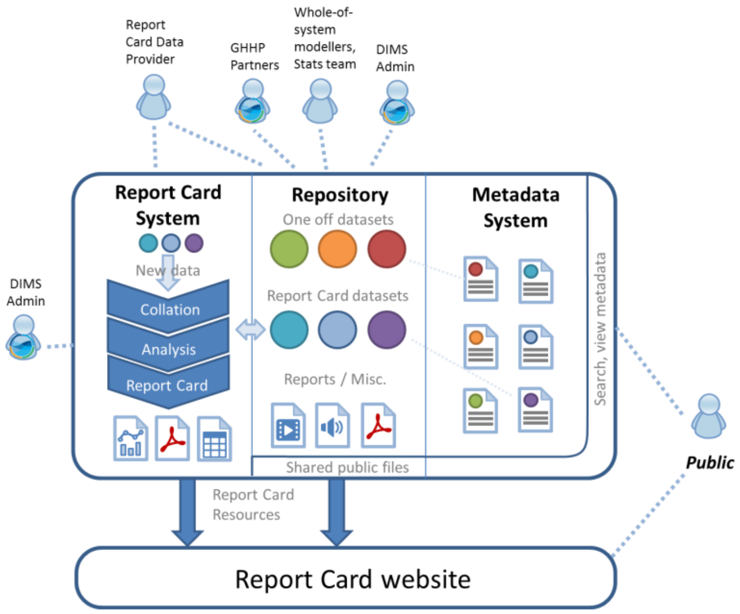


Figure 10.1: Schematic diagram of the links between the report card website and the Data Information Management System (DIMS) to illustrate major components and primary inputs and outputs (Diagram courtesy Australian Institute of Marine Science).

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. 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/grades generation for review by the ISP. The report card system is based on Java servlet, Ember.js and R programming language (Figure 10.2).

4. **GHHP and report card website –** The GHHP website is the primary interface for the public to access all levels of report card information, GHHP activities, and GHHP publications. The Gladstone Harbour Report Card web pages will source information from the DIMS.

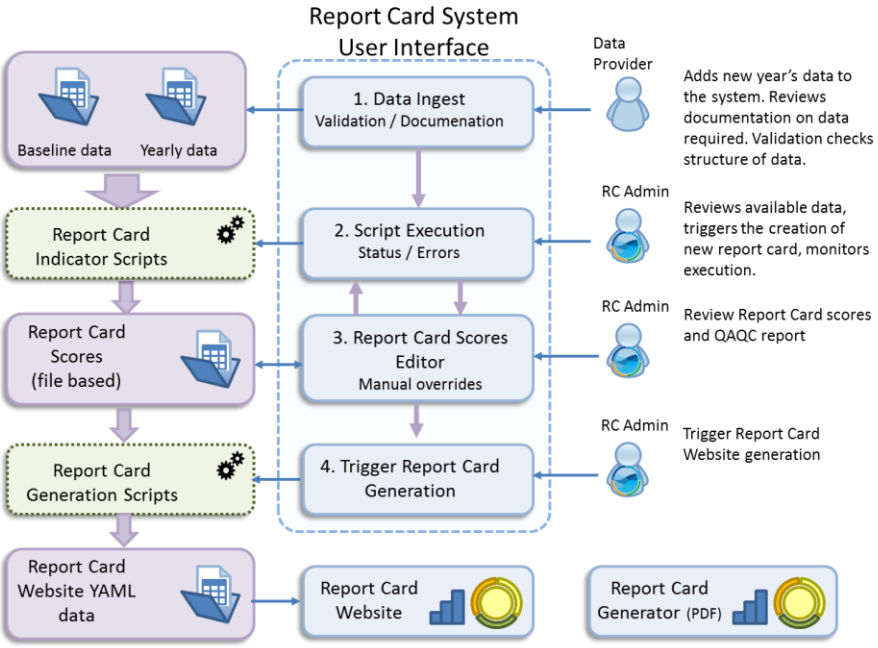


Figure 10.2: Schematic diagram of the report card system showing all data ingestion, script execution and report cards results generation modules (Diagram courtesy Australian Institute of Marine Science).

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 10.3). This approach makes the system highly portable and not dependent on AIMS 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.

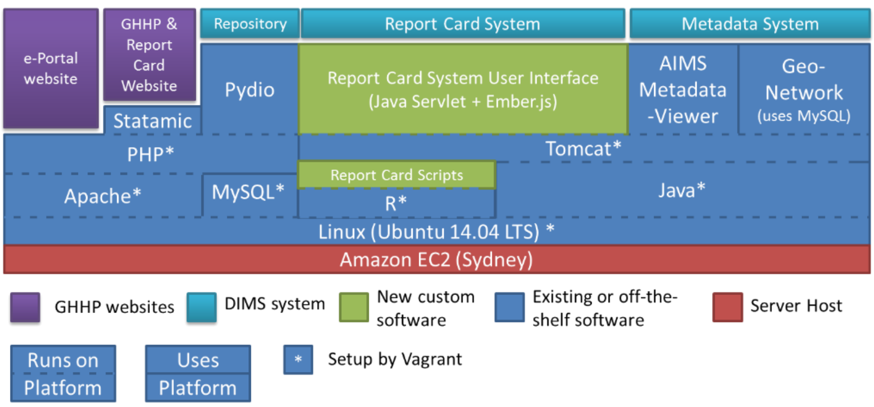


Figure 10.3: Software infrastructure underlying the Data Information Management System (DIMS) operations (Diagram courtesy Australian Institute of Marine Science).

11. References

Anderson, L., & Melville, F. (2014a). *Port Curtis Integrated Monitoring Program water quality field report*. Vision Environment Queensland, Australia.

Anderson, L., & Melville, F. (2014b). *Port Curtis Integrated Monitoring Program sediment analytical report*. Vision Environment Queensland, Australia.

ANZECC. (1992). *Australian water quality guidelines for fresh and marine waters*. Australian and New Zealand Environment and Conservation Council, Canberra.

ANZECC. (1998). *Interim ocean disposal guidelines*. Australian and New Zealand Environment and Conservation Council, Canberra.

ANZECC. (2014). *Water quality guidelines for the protection of aquatic ecosystems*. Toxicants manganese – marine water. Australian and New Zealand Environment and Conservation Council, Canberra.

ANZECC/ARMCANZ. (2000). *Australian and New Zealand guidelines for fresh and marine water quality*. Australia and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

APHA. (2005). *Standard methods for the examination of water and wastewater* (21st ed.). Port City Press, Baltimore, Maryland.

Babcock, R.C., Baird, M.E., Pillans, R., Patterson, T., Clementson, L.A., Haywood, M.E., Rochester, W., Morello, E., Kelly, N., Oubelkheir, K., Fry, G., Dunbabin, M., Perkins, S., Forcey, K., Cooper, S., Adams, M., O'Brien, K., Wild-Allen, K., Donovan, A., Kenyon, R., Carlin, G., & Limpus, C. (2015). *Towards an integrated study of the Gladstone marine system.* CSIRO Oceans and Atmosphere Flagship, Brisbane. ISBN: 978-1-4863-0539-1. 229 pp.

Baird, M., & Margvelasvili, N. (2015). *Receiving water and sediment scenarios*. Draft technical report. CSIRO, Australia.

Berkelmans, R., Jones, A. M., & Schaffelke, B. (2012). Salinity thresholds of *Acropora* spp. on the Great Barrier Reef. *Coral Reefs,* 31(4), 1103-1110.

BMT WBM. (2013). *Central Queensland corals and associated benthos: Monitoring review and gap analysis*. April 2013. Prepared for the Gladstone Ports Corporation. BMT WBM, Brisbane.

Burke, C. (1993). *A survey of Aboriginal archaeological sites on the Curtis Coast, Central Queensland*. Unpublished report to the Queensland Department of Environment and Heritage, Rockhampton, DATSIP Report A-QLD-0176.

Bryant, C.V., Jarvis, J.C., York, P.H., & Rasheed, M.A. (2014). *Gladstone Healthy Harbour Partnership Pilot Report Card: ISP011 Seagrass final report – October 2014*. Centre for Tropical Water & Aquatic Ecosystem Research Publication 14/53, James Cook University, Cairns.

Cagnazzi, D. (2013). *Review of coastal dolphins in central Queensland, particularly Port Curtis and Port Alma region*. Gladstone Port Corporation, Gladstone.

Cagnazzi, D. (2015). *First Project Report: Increase understanding of the status of the Australian snubfin and Australian humpback dolphins within Port Curtis and Port Alma.* Report Produced for the Ecosystem Research and Monitoring Program Advisory Panel as part of Gladstone Ports Corporation's Research and Monitoring Program.

Carter, A.C., Jarvis, J.C., Bryant, C.V., & Rasheed, M.A. (2015a). *Gladstone Healthy Harbour Partnership 2015 Report Card ISP011: Seagrass final report*. Centre for Tropical Water & Aquatic Ecosystem Research Publication 15/29, James Cook University, Cairns.

Carter, A.C., Davies, J.D., Bryant, C.V., Jarvis, J.C., McKenna, S.A., & Rasheed, M.A. (2015b). *Seagrasses in Port Curtis and Rodds Bay 2014: Annual long-term monitoring, biannual Western Basin, and updated baseline survey*. Centre for Tropical Water & Aquatic Ecosystem Research Publication, James Cook University, Cairns.

Carter, A.C., Bryant, C.V., Davies, J.D. & Rasheed, M.A. (2016). *Gladstone Healthy Harbour Partnership 2016 Report Card ISP011: Seagrass final report*. Centre for Tropical Water & Aquatic Ecosystem Research Publication 15/29, James Cook University, Cairns.

Cempel, M., & Nikel, G. (2006). Nickel: A review of its sources and environmental toxicology. *Polish Journal of Environmental Studies*, 15(3), 375-382.

Clawson, M. (1959). Methods of measuring the demand for and value of outdoor recreation. *Outdoor recreation* (36).

COAG Standing Council on Environment and Water (2013). *Australian and New Zealand guidelines for fresh and marine water quality guidelines for the protection of aquatic systems*. Aquatic ecosystems toxicant trigger values: Manganese – marine. August 2013.

Commonwealth of Australia. (2013). Independent Review of the Port of Gladstone: Report on Findings. Commonwealth of Australia, Canberra.

Condie, S., Herzfeld, M., Andrewartha, J., & Gorton, R. (2015). *Project ISP007: Development of connectivity indicators for the GHHP Gladstone Harbour Report Card*. CSIRO Wealth from Oceans Flagship, Hobart, University of Queensland.

Condie, S., Gorton, R., Andrewartha, J., & Hock, K. (2016). *2015–16 Connectivity indicators for the Gladstone Harbour Report Card*. CSIRO Wealth from Oceans Flagship, Hobart, University of Queensland.

Connolly, R., Bunn, S., Campbell, M., Escher, B., Hunter, J., Maxwell, P., & 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.

Dambacher, J.M., Hodge, K.B., Babcock, R.C., Fulton, E.A., Apte, S.C., Plagányi, É.E., Warne, M., & Marshall, N.A. (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.

DEHP. (2014a). *Environmental Protection (Water) Policy 2009: Environmental values and waste quality objectives Curtis Island, Calliope River and Boyne River basins*. Environmental Policy and Planning Division, Department of Environment and Heritage Protection, Queensland.

DEHP. (2014b). Wildlife of Gladstone local government area, Wetland*Info*, Department of Environment and Heritage Protection, Queensland. [Online] Available from: <http://wetlandinfo.ehp.qld.gov.au/wetlands/facts-maps/wildlife/?AreaID=lga-gladstone> (2 February 2015).

DERM. (2010). *Monitoring and sampling manual 2009*. Version 2, September 2010. Water and Corporate Services Division, Department of Environment and Resource Management, Queensland.

De Sherbinin, A., Reuben, A., Levy, M.A., & Johnson, L. (2013). *Indicators in practice: How environmental indicators are being used in policy and management contexts*. Yale and Columbia Universities, New Haven and New York.

DHI. (2013). *Gladstone coral desktop study: Desktop study of the distribution and ecological value of corals and coral reef in the Gladstone region and wider bioregion*. Report prepared for the Gladstone Ports Corporation Limited by DHI Water and Environment. Singapore.

DNRM. (2015). *Water Monitoring Data Portal.* [Online] Available from: <https://www.dnrm.qld.gov.au/water/water-monitoring-and-data/portal> (12 November 2015).

Dougall, C., McCloskey, G.L., Ellis, R., Shaw, M., Waters, D., & Carroll, C. (2014). *Modelling reductions of pollutant loads due to improved management practices in the Great Barrier Reef catchments* – Fitzroy NRM region, Technical Report, Volume 6, Queensland Department of Natural Resources and Mines, Rockhampton, Queensland (ISBN: 978-0-7345-0444-9).

DSEWPaC. (2013). *Independent review of the Port of Gladstone: Report on findings.* DSEWPaC, Canberra.

Foster, N.L., Box, S.J., & Mumby, P.J. (2008). Competitive effects of macroalgae on the fecundity of the reef-building coral *Montastrea annularis*. *Marine Ecology Progress Series, 367*, 143-152.

Flint, N., Jackson, E., Wilson, S., Verlis, K., & Rolfe, J. (2015). *Synthesis of water quality influences in ports of the Fitzroy region, Queensland.* A report to the Fitzroy Basin Association for the Fitzroy Water Quality Improvement Plan. CQ University Australia, North Rockhampton, Queensland.

Furnas, M. (2003). *Catchments and corals: Terrestrial runoff to the Great Barrier Reef*. Australian Institute of Marine Science and CRC Reef Research Centre, Townsville, 334.

Garelick, H., Jones, H., Dybowska, A., & Valsami-Jones, E. (2008). Arsenic pollution sources. *Reviews of Environmental Contamination and Toxicology*, 197, 17-60.

Gladstone Healthy Harbour Partnership (GHHP). (2014). *Technical report for the Gladstone Harbour 2014 Pilot Report Card: 1 Methodology and Results*, Technical Report No.1. GHHP, Gladstone.

Gladstone Regional Council. (2016). Economic profile. [Online] Available from: <http://www.economicprofile.com.au/gladstone> (27 January 2016).

Golding, L.A., Angel, B.M., Batley, G.E., Apte, S.C., Krassoi, R., & Doyle, C.J. (2014). Derivation of a water quality guideline for aluminium in marine waters. *Environmental Toxicology and Chemistry*. 34, 141-151. doi:10.1002/etc.2771

Greer. L., Akbar, D., Stokes, K., & Kabir, Z. (2012). *Liveability of Mackay, Isaac and Whitsunday Local Government Areas, Queensland – Household survey.* Report was prepared for REDC by the Centre for Environmental Management, CQ University. [Online] Available from: <http://www.mwredc.org.au/docs/Publications/LiveabilityAudits/Liveability%20Audit%20Mackay%202013.pdf> (27 January 2016).

Greer, L., & Kabir, Z. (2013). *Guidance for the selection of social, cultural and economic indicators for the development of the GHHP Report Card*. Report to the Gladstone Healthy Harbour Partnership, School of Human Health and Social Science. CQ University, Rockhampton.

Jones, M.A., Stauber, J., Apte, S., Simpson, S., Vicente-Beckett, V., Johnson, R., & Duivenvoorden, L. (2005). A risk assessment approach to contaminants in Port Curtis, Queensland, Australia, *Marine Pollution Bulletin,* 51, 448-458.

Jonker, M., Johns, K., & Osbourne, K. (2008). *Surveys of benthic reef communities using underwater digital photography and counts of juvenile corals*. Long-term monitoring of the Great Barrier Reef, Standard Operational Procedure Number 10. Australian Institute of Marine Science, Townsville.

Limpus C.J., Parmenter C.J., & Chaloupka M. (2013). *Monitoring of coastal sea turtles: Gap analysis in the Port Curtis and Port Alma region. Parts 1 to 6.* Report produced for the Ecosystem Research and Monitoring Program Advisory Panel as part of Gladstone Ports Corporation's Ecosystem Research and Monitoring Program.

Llewellyn, L., Wakeford, M., & 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.

Lockwood, C.L., Mortimer, R.J.G., Stewart, D.I., Mayes, W.M., Peacock, C.L., Polya, D.A., & Burke, I.T. (2014). Mobilisation of arsenic from bauxite residue (red mud) affected soils: Effect of pH and redox conditions. *Applied Geochemistry*, 51, 268-277.

Logan, M. (2015) *Provision of final environmental grades and scores for the 2015 Gladstone Harbour Report Card.* Report prepared by the Australian Institute of Marine Science for Gladstone Healthy Harbour Partnership. December 3, 2015.

Logan, M (2016). Provision of final environmental grades and scores for 2016 Gladstone Harbour Report Card. Report prepared by the Australian Institute of Marine Science for Gladstone Healthy Harbour Partnership. November 9, 2016, (113 pp).

McCormack, C., Rasheed, M., Davies, J., Carter, A., Sankey, T., & Tol, S. (2013). *Long term seagrass monitoring in the Port Curtis Western Basin: Quarterly seagrass assessments and permanent transect monitoring progress report, November 2009 to November 2012.* Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication. James Cook University, Cairns.

McIntosh, E.J., Poiner, I.R., & ISP Members. (2014). *Gladstone Harbour Report Card framework recommendations - March 2014*. Report prepared for the Gladstone Healthy Harbour Partnership Management Committee. Brisbane.

Pascoe, S., Cannard, T., Marshall, N., Windle, J., Kabir, Z., Flint, N., & Tobin R. (2014). Piloting of social, cultural and economic indicators for Gladstone Healthy Harbour Partnership Report Card. CSIRO Oceans and Atmosphere Flagship, Australia.

Pascoe S., & Venables B. (2016). Draft report on the Development of R scripts to calculate, aggregate and integrate Cultural heritage indicators with GHHP Data and Information Management System, CSIRO Draft report to the Gladstone Healthy Harbour Partnership, September 2016, 28 pp.

PCIMP. (2010). *Port Curtis Ecosystem Health Report 2008–2010*. Gladstone Ports Corporation Ltd. Gladstone.

Rasheed, M.A., Thomas, R., Roelofs, A.J., Neil, K.M., & Kerville, S.P. (2003). *Port Curtis and Rodds Bay seagrass and benthic macro-invertebrate community baseline survey - November/December 2002*. DPI&F, Fisheries Queensland, Cairns, 48 pp.

Rogers, C.S. (1990). Responses of coral reefs and reef organisms to sedimentation. *Marine Ecology Progress Series,* 62, 185-202.

Sawynok, B., & Venables, B. (2016). *Developing a fish recruitment indicator for the Gladstone Harbour Report Card using data derived from castnet sampling*, Infofish Australia.

Simpson, S.L., Batley, G.E., & Chariton, A.A. (2013). *Revision of the ANZECC/ARMCANZ sediment quality guidelines*. Prepared for the Department of Sustainability, Environment, Water, Population and Communities. Canberra.

Sobtzick, S., Grech, A., Coles, R., Cagnazzi, D. & Marsh, H. (2013). *Status of the dugong population in the Gladstone area.* A Report for Gladstone Ports Corporation Limited for Project CA 120017: Monitoring of Dugongs, Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication, James Cook University, Townsville.

Storey, A.W., Andersen, L.E., Lynas, J., & Melville, F. (2007). *Port Curtis Ecosystem Health Report Card*. Port Curtis Integrated Monitoring Program, Centre for Environmental Management, Central Queensland University.

Terra Rosa Consulting. (2016). Task 9: Final Project Report: ISP012 – Developing the cultural heritage indicators for the Gladstone Healthy Harbour Partnership, Terra Rosa Consulting, Western Australia

Thompson, A., Davidson, J., & Costello, P. (2016a). *Coral Indicators for the 2016 Gladstone Harbour Report Card*. Report prepared for Gladstone Healthy Harbour Partnership. Australian Institute of Marine Science, Townsville.

Thompson, A., Costello, P., & Davidson, J., Logan, M., Gunn K., & Schaffelke, B. (2016b). *Annual Report for Coral Reef Monitoring 2014–15*. Report for the Great Barrier Reef Marine Park Authority. Australian Institute of Marine Science, Townsville.

Thompson, A., Costello, P., & Davidson, J. (2015). *Developing coral indicators for the Gladstone Harbour Report Card, ISP014: Coral*. Australian Institute of Marine Science, Townsville.

Twigger-Ross, C.L., & Uzzell, D.L. (1996). Place and identity processes. *Journal of environmental psychology*, 16(3), 205-220.

UNEP. (2010). *Final review of scientific information on Cadmium*, United Nations Environment Programme-Chemicals Branch, DTIE [Online] Available from: http://www.unep.org/chemicalsandwaste/Portals/9/Lead_Cadmium/docs/Interim_reviews/UNEP_GC26_INF_11_Add_2_Final_UNEP_Cadmium_review_and_apppendix_Dec_2010.pdf (30 November 2015).

van Dam, J.W., Negri, A.P., Uthicke, S., & Muller, J.F. (2011). Chemical pollution on coral reefs: exposure and ecological effects. In: F. Sanchez-Bayo, P. J. van den Brink, R. M. Mann (Eds.), *Ecological impact of toxic chemicals* (pp. 187-211). Bentham Science Publishers Ltd, Online.

Venables, W.N. (2015). *GHHP barramundi recruitment index project final report*. Gladstone Health Harbour Partnership [Online] Available from: https://dims.ghhp.org.au/repo/data/public/7d9e4c.php (27 January 2016).

Vision Environment Qld. (2011). *Port Curtis Ecosystem Health Report Card*. Port Curtis Integrated Monitoring Program, Gladstone.

Vision Environment Qld. (2013a). *Western Basin Dredging and Disposal Program 013 Event Sampling – March 2013*. Gladstone, Qld.

Vision Environment Qld. (2013b). *Western Basin Dredging and Disposal Program Water Quality Monitoring – April 2013*. Gladstone, Qld.

Wildlife Unlimited. (2015). *Report for migratory shorebird monitoring, Port Curtis and the Curtis Coast, February 2015*. Report Prepared for GPC by Wildlife Unlimited Bairnsdale Vic.

Wildlife Unlimited. (2016). *Gladstone Ports Corporation Report for Migratory Shorebird Monitoring*, Port Curtis and the Curtis Coast Annual Summer Survey – 2016. Bairnsdale, Victoria.

Wilson, S.P., & Anastasi, A. (2010). A review of manganese in subtropical estuaries: Port Curtis-A case study. *Australasian Journal of Ecotoxicology*, 16, 119-133.

Windle, J., DeValck, J., Flint, N., & Star, M. (2016). *Report on the status of the social, cultural (sense of place) and economic components for the Gladstone Harbour 2016 Report Card*. Central Queensland University, Rockhampton.

Wright, M., Allan, D., Clift, R., & Sas, H. (1998). Measuring corporate environmental performance: The ICI environmental burden system. *Journal of Industrial Ecology*, 1, 117-127.

York, P., & Smith, T. (2013). *Research, monitoring and management of seagrass ecosystems adjacent to port developments in Central Queensland: Literature review and gap analysis*. Deakin University, Waurn Ponds, Victoria.

Zumdahl S., & DeCost, G.J. (2010). *Basic Chemistry, 7th Edition,* Brooks/Cole, Belmont, USA. ISBN-10: 0538736372

12. Glossary

Terms and acronyms	Definition
ABS	Australian Bureau of Statistics
AHD	Australian height datum
AIMS	Australian Institute of Marine Science
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
BBN	Bayesian belief network
CATI	computer-assisted telephone interviewing
component	The Gladstone Harbour Report Card will report on four components of harbour health: environmental, cultural, social and economic.
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFF	Department of Agriculture, Fisheries and Forestry
DEHP	Department of Environment and Heritage Protection
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)
ERMP	Ecosystem Research and Monitoring Program
FHRP	Fish Health Research Program
GHHP	Gladstone Healthy Harbour Partnership
GHM	Gladstone Harbour Model
GPC	Gladstone Ports Corporation
guidelines and criteria	science-based numerical concentration limits or descriptive statements recommended to support a designated water use. Guidelines are not legally enforceable.
GVP	gross value of production

HEV	high ecological value
ICHD	Indigenous Cultural Heritage Database
indicator	numerical values that provide insight into the state of the environment, or human health etc. As the environment is highly complex, indicators provide a simple, practical way to track changes in the state of the environment over time.
IER	index of economic resources
ISP	Independent Science Panel
LAT	lowest astronomical tide
LGA	local government area
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.
LNG	liquid natural gas
MC	Management Committee
MD	moderately disturbed
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.
MSQ	Maritime Safety Queensland
NMI	National Measurement Institute
NTU	nephelometric turbidity units
PAH	polycyclic aromatic hydrocarbons
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
psu	practical salinity units
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
TCM	travel cost method
TropWATER	Centre for Tropical Water & Aquatic Ecosystem Research (James Cook University)
WICET	Wiggins Island Coal Export Terminal

Appendix 1: The Gladstone Healthy Harbour Partnership (GHHP) science program

ISP001 Mapping and synthesis of data and monitoring in Gladstone Harbour (Completed)

Australian Institute of Marine Science, Townsville

This study identified the state of knowledge of Gladstone Harbour and identified knowledge gaps that if addressed could assist in the development of the Gladstone Harbour Report Card and the Gladstone Harbour Model. Environmental, social, cultural and economic data were considered and three primary outputs were produced:

- a report including a synthesis of available information relating to environmental, social, cultural and economic aspects of Gladstone Harbour
- identification of potential baseline and landmark studies
- a centralised online metadata repository (GHHP ePortal).

The report assessed potential information sources that were within the Gladstone Harbour Port Limits, neighbouring locations that may influence the harbour, and areas that the harbour itself may influence. Where possible, the data were associated with subregions of Gladstone Harbour. A total of 100 data sources from universities, publicly funded research organisations, government databases and reports, and readily available data holdings from stakeholder groups were identified.

There was a large volume of data related to water and sediment quality and iconic species (including dolphins, turtles and dugongs and macroscopic flora, particularly seagrass and to a lesser extent mangroves). A large portion of this data was considered to be of high quality although some gaps remain. By contrast, large gaps remain in social, cultural and economic information, including gaps that could link to the environmental condition of the harbour. In many cases, data in these categories could only be associated with broader regions such as the Fitzroy catchment or the Gladstone Local Government Area.

The report identified 45 potential landmark or baseline studies across 19 topic areas, although it was acknowledged that the potential baseline studies may not reflect the final choice of indicators for the report card selected by the Independent Science Panel. The GHHP ePortal contains nearly 340 metadata records and is updated regularly. Many records relate to multiple reports or datasets resulting in 600 files being included. Scientific reports and other published work owned by commercial entities were not included owing to copyright restrictions, however a separate bibliography with links to their abstracts is included.

Reports and publications

Llewellyn, L., Wakeford, M., & 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.

Download the final report for this project.

View the GHHP ePortal

ISP002 Review of the use of report cards for monitoring ecosystem and waterway health (Completed)

Central Queensland University, Griffith University, The University of Queensland

Effectively communicating monitoring results and the free flow of relevant information is critical in supporting management decisions about ecosystem health and ensuring that environmental management is achieving its stated goals. This project conducted a critical review of the regional, national and international use of report cards with an emphasis on coastal marine areas including estuarine and tropical systems. The project assessed the effectiveness of report cards at communicating monitoring results to a wide range of audiences, including the general public, industry groups, Indigenous groups and various levels of government. It also considered the ability of a report card program to support management decisions concerning ecosystem health as well as to synthesise and communicate monitoring results and other scientific information. Fourteen report card programs were reviewed in this study.

The review found that:

- report cards were an effective tool for communicating complex results in an easily understood format
- few programs report social, cultural and economic indicators
- challenges and opportunities are presented by new and emerging technologies, particularly around online interactive report cards, data portals and visualisations and new tools for data collection, storage and analysis.

This review identifies five key elements critical to the successful implementation and ongoing effectiveness of a report card program. These are:

1) clear goals
2) strong links to all stakeholders
3) flexible implementation
4) effective communication
5) rigorous science.

The findings of this study continue to guide the development of The Gladstone Healthy Harbour Partnership program.

Reports and publications

Connolly, R.M., Bunn, S., Campbell, M., Escher, B., Hunter, J., Maxwell, P., Page, T., Richmond, S., Rissik, D., Roiko, A., Smart, J., & 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.

Download the final report for this project.

ISP003 Models and indicators of key ecological assets in Gladstone Harbour (Completed)

CSIRO Wealth from Oceans Flagship, Hobart

To determine potential indicators for the Gladstone Harbour Report Card and monitoring program this project developed models of key ecological assets within the Gladstone Harbour system. These models were developed to capture a conceptual understanding of cause-and-effect relationships between social, cultural and economic pressures on environmental and ecological components of the system. In essence these models provide a rigorous analytical framework to predict how a system will respond to disturbance and to identify key indicators for tracking the health of Gladstone Harbour. Developing the model was strongly driven by stakeholder engagement building on the experience of Gladstone Healthy Harbour Partnership (GHHP) stakeholders (including community members, industry, scientists and regional managers) through a series of workshops held in Gladstone over three days.

The final set of assets selected for qualitative modelling by the Independent Science Panel were based on the GHHP vision statement and included non-migratory species resident in the harbour or ecosystems that provided critical habitats or ecological services. These assets were: barramundi, yellowfin bream, mud crab, tidal wetlands, mangroves, mangrove ecosystems, coral reefs and seagrass ecosystems.

The results of this work have provided the information and conceptual understanding to determine key indicators that are relevant to community-based values and consistent with the GHHP vision statement. The qualitative models developed during this project will be incorporated into the Gladstone Harbour Model being developed (see ISP 006). The long-term predictions from the qualitative models will be tested against data from the monitoring program to provide a sound platform for improve our understanding of the key ecological assets in Gladstone Harbour.

Reports and publications

Dambacher, J.M., Hodge, K.B., Babcock, R.C., Fulton, E.A., Apte, S.C., Plagányi, É.E., Warne, M., & Marshall, N.A. (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.

Dambacher, J.M., Hodge, K.B., Babcock, R.C., Fulton, E.A., Apte, S.C., Plagányi, É.E., Warne, M., & Marshall, N.A. (2013). *Précis for 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.

Download the final report for this project.

ISP004 Guidance for the selection of social, cultural and economic indicators for the development of the Gladstone Healthy Harbour Report Card (Completed)

Central Queensland University, Rockhampton

The Gladstone Harbour Report Card will extend beyond environmental health to include Social, Cultural and Economic components. In the long term, it will consider the links between these four components. This project considered and made recommendations for the selection of social, cultural and economic indicators that measure progress towards the Gladstone Healthy Harbour Partnership (GHHP) vision for Gladstone Harbour developed in conjunction with the community of Gladstone. These recommendations were based on reviews of the use of social, cultural and economic indicators in report cards and more specifically the use of these indicators in rural Queensland. The final report also considered appropriate frameworks to provide a structure for the selection, measurement and combinations of indicators. The key recommendations from this study are presented below:

- Provide a clear hierarchal structure in the report card.
- Base the report card on a balanced reporting of the Environmental, Social, Cultural and Economic components of the health of Gladstone Harbour.
- Subject the selection of social, cultural and economic indicators to a pilot process.
- Select the final indicators following consultation with the Gladstone community.
- Include both objective and subjective measures to broaden the opportunity for those affected by harbour health (positive or negative) to contribute to the overall grade.
- Present environmental health separately from the Social, Cultural and Economic components.
- Report on the performance of the report card and the direct outcomes of its application to the Gladstone community.

Reports and publications

Greer, L., & Kabir, Z. (2013). *Guidance for the selection of social, cultural and economic indicators for the development of the GHHP Report Card*. Report to the Gladstone Healthy Harbour Partnership, School of Human Health and Social Science. Central Queensland University Australia, Rockhampton.

Download the final report for this project.

ISP005 Piloting of social, cultural and economic data for the Gladstone Healthy Harbour Report Card (Completed)

CSIRO Marine and Atmospheric Research

Report cards have become an increasingly popular method to document progress towards environmental goals. In general, these report cards focus on the biophysical components of the system. These include water quality and the condition of key ecosystems such as seagrass meadows and coral reefs. The Gladstone Harbour report card is unique in that, in addition to reporting on progress towards environmental goals, it will also report on progress towards social, cultural and economic goals for the Gladstone Harbour region. These goals developed by the Gladstone Healthy Harbour Partnership (GHHP) in conjunction with stakeholders have been outlined in the vision statement for Gladstone Harbour. The specific objectives for cultural, social and economic indicators are listed below:

Cultural objectives

- Registered cultural heritage sites associated with the harbour and waterways are protected.
- The Gladstone community's sense of identity and satisfaction with the condition of the harbour is increased.

Social objectives

- Maintain/improve easy access to the harbour waters and foreshore for recreation and community users.
- Maintain/improve a safe harbour for all users (e.g. swimming, boating and foreshore activities.
- Enhance liveability and wellbeing in the region.

Economic objectives

- The Gladstone Harbour is managed to support shipping, transport and a diversity of industries.
- Economic activity in the Gladstone Harbour continues to generate social and economic benefits to the regional community.

The key aim of this project was to develop and pilot a system for collecting and analysing data relating to appropriate cultural, social and economic indicators guided by these objectives and to report on these for the 2014 Pilot Report Card. A summary of the findings of this study is presented in the body of this document and the full report can be downloaded via the link included below.

Reports and publications

Pascoe, S., Cannard, T., Marshall, N., Windle, J., Flint, N., Kabir, Z., & 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., Pascoe, S., Tobin, R., Windle, J., & Rolfe J. (2015). *Social, cultural and economic indicators for the Gladstone Healthy Harbour Partnership Report Card*. Draft report for the Gladstone Healthy Harbour Partnership. CSIRO Oceans and Atmosphere Flagship. Australia.

Download the final report for this project.

ISP006 Development of a Gladstone Harbour Model to support the Gladstone Healthy Harbour Report Card (In progress)

CSIRO Wealth from Oceans Flagship, Hobart

When completed, this full system model will comprise a suite of models that will be collectively referred to as the Gladstone Harbour Model. The primary purpose of the model is to enable the GHHP Management Committee (MC) to undertake annual scenario analysis to effectively road test management strategies before implementing them. These analyses will assist the MC to advise how the Gladstone Healthy Harbour Partnership (GHHP) should respond to annual report card results and provide stakeholders with a tool to explore various future management options.

As outlined below, the Gladstone Harbour Model will include existing models and new models being developed by CSIRO and it will be delivered in three stages.

1) Receiving water quality model

In addition to providing direct inputs into the report card, the receiving water quality model will provide a direct link between the hydrodynamic models and system models. This component of the model will enable management scenarios to be developed and run that involve water-column processes. This component of the project will use the CSIRO's Environmental Modelling Suite which integrates hydrodynamic, sediment transport and biogeochemical modules. These will effectively capture the water quality dynamics of Gladstone Harbour and allow realistic distributional modelling of the key habitats within the harbour.

2) Qualitative (conceptual) model of the Social and Economic components of Gladstone Harbour

This component of the project will develop qualitative models that synthesise a conceptual understanding of the cause-and-effect relationships between human pressures and the Environmental and Ecological components of the Gladstone Harbour region. These models will be based on workshops with key social, economic and cultural experts and consultation with the Gladstone community. The community will include people with expertise/interest in areas such as agriculture, commercial fishing, recreational fishing, retail, real estate, tourism, media and communication, shipping and ports, mining, heavy industry, the environment and education.

The aim of the workshop and subsequent consultation will be to identify:

- the human behavioural drivers that explain anthropogenic pressures on the harbour
- how these pressures may increase or reduce other pressures on the harbour
- the key connections within the social and economic aspects of the Gladstone Harbour region that define its overall behaviour
- where the social, economic and stewardship indicators sit in the broader social and economic context of Gladstone Harbour.

The models developed from this process will help define the human components and interactions modelled within the Gladstone Harbour Model.

3) Full systems model (using the Atlantis framework) for the Gladstone Harbour and immediate surrounds. The full systems model will be fully operational in 2017.

The final stage of this project is the development of the Gladstone Harbour Model. This model will improve our understanding of the potential outcomes of an expanding list of possible interactions between factors that may directly or indirectly affect the health of Gladstone Harbour.

Conceptualising a system-wide understanding of the interacting components and developing a structural basis for quantitative modelling has several steps. The first will be linking the qualitative modelling work already completed (ISP 003) with the conceptual models developed during Stage 2 of this project. Building on this, the construction of the full system model will involve collating and adding large volumes of data on all aspects of the system including biological, physical, social, cultural and economic data. This information will come from a range of sources. These include environmental and ecological research and monitoring, economic input and output statistics for all major industries in the area and Australian census data for the region. A review of system-relevant information will enable an inventory of the key drivers of change in and around Gladstone Harbour to be compiled. Close collaboration with stakeholders during model development will ensure that the Gladstone Harbour Model is fit-for-purpose and that it is flexible enough to handle modifications as new information becomes available.

A workshop with the GHHP MC in early 2016 formulated scenarios to be run on the full system model. These scenarios will be developed in conjunction with the MC in response to the first full report card delivered in 2015. The final technical reports for this project will be delivered early in 2017.

Reports and publications

Fulton, E.A. & van Putten, I. (2014) Project ISP006: Milestone Report December 2014. CSIRO, Australia.

Baird M., Margvelashvili N. (2015) *Receiving Water Quality & Sediment Scenarios:* Final Report. CSIRO, Australia.

ISP007 Development of connectivity indicators for the Gladstone Healthy Harbour Report Card (Completed)

CSIRO Wealth from Oceans Flagship, Hobart, University of Queensland

Connectivity of water bodies is an important driver of productivity in marine ecosystems that helps to maintain ecosystem function. It contributes to the health of habitats found within Gladstone Harbour (such as seagrass beds, mangroves and coral reefs) by cycling nutrients, facilitating biological and genetic connectivity and diluting and flushing contaminants. However, connectivity between contaminant inputs and vulnerable habitats, such as between dredging activities and seagrass beds, can also have negative effects on harbour health. Developing shipping channels, land reclamation and coastline armouring has the potential to alter connectivity within the harbour due to altered bathymetry and is also being assessed as a component of this project.

To address the Gladstone Harbour Report Card objective for connectivity, 'maintain/improve connectivity of water within and between Gladstone Harbour, related rivers, estuaries and adjacent waters', CSIRO is developing a state-of-the art hydrodynamic model to calculate connectivity indices for the Gladstone Harbour Report Card and to provide sufficient information for calculating report card scores. This model will also constitute a key component of the Gladstone Harbour Model.

Three classes of indicator have been developed to inform the connectivity score for the Gladstone Harbour Report Card:

1) flushing time – This indicator will provide a measure of water exchange through the system and is commonly used as an indirect indicator of water quality.
2) ecological connectivity – This indicator will provide a measure of water exchange between spawning grounds and nursery areas for iconic species such as barramundi.
3) contaminant connectivity – This indicator will provide a measure of the potential of contaminants to move to other parts of the system from the input source.

The results of this project are detailed in the project report (below) and a summary of the project appears in the body of this document.

Reports and publications

Condie, S., Herzfeld, M., Andrewartha, J., Gorton, B., & 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.

Download the final report for this project.

Condie, S., Herzfeld, M., Andrewartha, J., Gorton, B., & Hock, K. (2015). *2014-15 Connectivity Indicators for the 2015 GHHP Gladstone Harbour Report Card*. CSIRO Wealth from Oceans Flagship, Hobart, University of Queensland.

ISP008 Provision of statistical support during the development of the Gladstone Harbour Report Card (Completed)

Queensland University of Technology

Providing statistical support covers two critical elements for developing the pilot report card—assessing the indicators and reference conditions and developing the report card scoring methodologies. This involves assisting in determining reference conditions for each report card indicator, statistical support to develop new monitoring programs and to validate existing ones, developing methods to calculate indicator scores, developing methods to aggregate overall report card scores, and assessing report card indicators. In the pilot report card year, particular attention was paid to developing indicators for water and sediment quality and developing the methods to be used to aggregate report card grades and scores.

Specific objectives for this project include working with project teams, developing indicators and scores for the pilot report card and full report card to:

- assist with refining report card indicators and indices
- provide advice on aggregating indices and report card scoring methodology
- perform investigative and validation studies required to inform the monitoring program design
- develop methods to address statistical quality assurance and quality control issues.

ISP008-2015 Provision of statistical support during the development of the Gladstone Harbour Report Card (Completed in December 2015)

Australian Institute of Marine Science

This project played a key role in developing grades and scores for the 2015 Gladstone Harbour Report Card. Working closely with the Data Information Management System, this project provided statistical support for a number of tasks specifically aimed at:

- reviewing the statistical methods used for the pilot report card
- updating the statistical methods suitable for 2015 report card in collaboration with the ISP
- documenting QA/QC assurance protocols for water and sediment quality data
- providing environmental scores and grades for the 2015 report card.

The final report for this project will be made available through the Gladstone Healthy Harbour Partnership (GHHP) website after the review process has been completed.

Reports and publications

Johnson, S., Logan, M., Fox, D. & 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.

Download the final report for this project.

Logan, M. (2015) *Provision of final environmental grades and scores for the 2015 Gladstone Harbour Report Card.* Report prepared by the Australian Institute of Marine Science for Gladstone Healthy Harbour Partnership. December 3, 2015.

Download the final report for this project.

ISP009 Development of a Data Information Management System for the Gladstone Harbour Report Card monitoring data (Completed)

Australian Institute of Marine Science, AIMS, Townsville

To facilitate knowledge transfer across the monitoring and project areas and to the broader community, a Data Information Management System (DIMS) is being developed in parallel with the pilot report card. When completed this system will:

- allow report card data providers, GHHP partners, and modellers to upload datasets and other information to an online repository
- contain an automated report card system which analyses and collates data to generate a report card score that includes graphs and figures
- allow the public, through the report card website and metadata system, to view the current and past report cards and to search and view DIMS for reports and other information related to the health of Gladstone Harbour.

The DIMS will be linked to the Gladstone Harbour Report Card website and consist of three major components: the report card system, the repository and the metadata system. These components and the linkages between system administrator's data providers and user groups are illustrated in Figure 10.1 in the main body of this report.

A limited but operational version of DIMS was delivered in October 2014 and was used to generate the pilot report card.

Reports and publications

AIMS. (2014). *Design and architecture of the Data Information Management System (DIMS) for the GHHP 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 (Completed in February 2015)

Dr Bill Venables, CSIRO Research Fellow

The Gladstone Healthy Harbour Partnership (GHHP) vision statement 'Supports a sustainable population of marine species (including megafauna—dolphins, dugongs and turtles)' will be addressed by measuring indicator species such as barramundi *Lates calcarifer*, yellowfin bream *Acanthropagus australis* and pikey bream *A. berda* and mud crabs *Scylla serrate.* These species have been chosen as indicators as they will respond rapidly to environmental change and provide information about the overall environmental and ecological health of the harbour. Species of megafauna were not selected as indicators as there can be a long lag time between an environmental impact and a change in their condition. Additionally, their ranges will usually extend beyond the limits of Gladstone Harbour and may make it difficult to associate changes in condition to impacts within the harbour. This project deals exclusively with the suitability of existing datasets and monitoring programs to derive report card scores.

Infofish Australia performs an annual barramundi recruitment assessment for Gladstone Harbour and the Fitzroy River that could inform the barramundi indicator for the report card. They have also collected data for the two bream species of interest. The historical datasets, including recruitment data, provide details of surveys conducted in the estuarine regions from 1999 to the present. Data collection on individual tagged fish which contributes to the recruitment index began in 1990.

To assess the suitability of the Infofish data for developing report card scores and to provide recommendations for ongoing monitoring suitable for report card use, this project aims to achieve the following.

- In collaboration with Infofish review the utility of Infofish's barramundi data including:
  - documenting the data collection and analysis method
  - reviewing the statistical methods used to produce the recruitment indices
  - providing recommendations to Infofish on improved sampling and statistical methods used to calculate the barramundi recruitment index.
- Provide advice on the statistical methods to develop the GHHP report card barramundi indicator from the Infofish recruitment index and the methods used to combine the three indicators (barramundi and two bream species) into a report card fish score.
- Provide advice on the potential application of the barramundi statistical methods to the bream species data.

Reports and publications

Venables, W.N. (2015). *GHHP Barramundi Recruitment Index Project Final Report*. Gladstone Healthy Harbour Partnership, Gladstone.

Download the final report for this project.

ISP011 Gladstone Healthy Harbour Partnership seagrass pilot report card (Completed)

Centre for Tropical Water & Aquatic Ecosystem Research, Cairns

Seagrass meadows are one of the most important habitat types within Gladstone Harbour. Although the area and distribution of the seagrass meadows can vary annually, at peak distribution seagrass meadows can cover an area of approximately 12,000ha. This area can include intertidal, shallow, subtidal and deep-water habitats, in addition to providing a range of important ecosystem functions such as sediment stabilisation, nutrient cycling and carbon sequestration. The seagrass meadows can also provide nursery areas for juvenile fish, including barramundi, and food for dugongs and turtles.

The Gladstone Harbour Healthy Partnership (GHHP) Report Card objective for key ecosystems is to 'maintain/improve habitat function and structure of key ecosystems'. In order to measure progress against this objective for seagrass in the Gladstone Harbour report card, the GHHP required quality-assured seagrass data and ongoing annual monitoring of seagrass beds within the harbour. This identified the baseline conditions needed to measure change against and to develop seagrass indicators and scores.

The Seagrass Ecology Group within TropWATER at James Cook University has been monitoring seagrass at least annually in Port Curtis and in Rodds Bay since 2002 and was engaged by GHHP to:

- develop a set of thresholds and five condition categories (grades) for the assessment of each of the seagrass indicators (area, biomass and species composition). This is based on the existing datasets.
- identify baseline conditions against which yearly assessments will be benchmarked to determine seagrass condition.

The results of this project are detailed in the project reports (below) and a summary of the 2016 project report appears in the body of this document.

Reports and publications

Bryant, C.V., Jarvis, J.C., York, P.H., & Rasheed, M.A. (2014). *Gladstone Healthy Harbour Partnership Pilot Report Card: ISP011 Seagrass Draft Report – October 2014*. Research Publication 14/53. Centre for Tropical Water & Aquatic Ecosystem, James Cook University.

Download the final report for this project.

Carter, A.C., Jarvis, J.C., Bryant, C.V., & Rasheed, M.A. (2015). *Gladstone Healthy Harbour Partnership 2015 Report Card ISP011: Seagrass final report*. Centre for Tropical Water & Aquatic Ecosystem Research Publication 15/29, James Cook University, Cairns.

Download the final report for this project.

Carter, A.C., Bryant, C.V., Davies, J.D. & Rasheed, M.A. (2016). *Gladstone Healthy Harbour Partnership 2016 Report Card ISP011: Seagrass final report*. Centre for Tropical Water & Aquatic Ecosystem Research Publication 15/29, James Cook University, Cairns.

Download the final report for this project.

ISP012 Cultural indicators pilot project (Completed)

Terra Rosa Consulting

The Cultural component of the report card consists of two indicator groups: 'sense of place' and cultural heritage. The 'sense of place' indicator group was assessed using computer-assisted telephone interviewing during 2014 and 2015. This project was initiated to address the cultural heritage indicator group of the report card from 2016. Working collaboratively with Port Curtis Capricorn Coast Tumara Coordinator, Gidarjil Development Corporation Ltd, this project will develop:

- an Indigenous Cultural Heritage Database for the Gladstone Harbour area that includes an assessment of the condition (intactness) and the size (physical space) and the type of registered cultural heritage site
- indicator option(s) to annually assess the 'number of registered cultural heritage sites protected along the waterways and harbour' for use in the Gladstone Harbour Report Card.

Reports and publications

Terra Rossa Consulting. (2016). *Gladstone Healthy Harbour Partnership Indigenous Cultural Heritage Indicators Milestone 1 Report.* Terra Rossa Consulting, Perth.

Terra Rossa Consulting. (2016). *Gladstone Healthy Harbour Partnership Indigenous Cultural Heritage Indicators Milestone 2* Report. Terra Rossa Consulting, Perth.

Terra Rossa Consulting. (2016). *Developing Cultural Heritage Indicators for the Gladstone Healthy Harbour Partnership: Project ISP012 Final Report.* Terra Rossa Consulting, Perth.

Download the final report for this project.

ISP013-2015 fish recruitment study (Completed)

Infofish Australia and Dr Bill Venables

'Fish and crabs' is one of the indicator groups under the Environmental component of the report card. These indicators are still under development.

In 2014, Gladstone Harbour Healthy Partnership (GHHP) commissioned a project (ISP010) to investigate the possibility of using existing fish recruitment data to devise a statistically robust and defensible barramundi recruitment index to include in the Gladstone Healthy Harbour Report Card (Venables, 2015). That project concluded that existing data were unsuited to developing a recruitment index for barramundi because:

- barramundi recruits were too rare in the existing dataset and their occurrence was too sporadic to enable a reliable index of recruit abundance
- barramundi recruits were not targeted by fishers, so their occurrence in the data was as bycatch
- there was no reliable way to standardise fishing effort, so no reliable way to estimate abundance from catch data (Venables, 2015).

At the same time, the GHHP commissioned a separate project (ISP013) to sample fish recruits, targeting barramundi but also collecting yellow-finned and pikey bream. This sampling was conducted in Gladstone Harbour and associated estuaries and inlets from December 2014 to May 2015. The ISP013 project identified that both bream species appeared to be sufficiently abundant and widespread to warrant investigation of their suitability as indicator species for the Gladstone Harbour Report Card. Therefore, Gladstone Harbour Healthy Partnership GHHP commissioned another project ISP013-2015 later in 2015 to:

- design an optimal, quantitative cast-net sampling program to collect fish recruits from Gladstone Harbour and its inlets and estuaries, from The Narrows to Rodds Bay
- conduct a cast-net sampling program based on the approved sampling design over the 2015–16 recruitment season
- undertake a statistical assessment of the new dataset in conjunction with existing datasets held by Infofish Australia to pilot preliminary recruitment indicators for yellow-finned bream (*Acanthopagrus australis*) and pikey bream (*A. berda*) in Gladstone Harbour.

GHHP intends that this project run for one year in the first instance. Subject to confirmation of ongoing funding, GHHP sees it being followed by a five-year study to collect data for successive report cards and to refine indicators of the abundance of fish recruits in each recruitment season.

Reports and publications

Sawynok, B., Parsons, W., Mitchell J., & Sawynok, S. (2015) *Gladstone fish recruitment 2015.* Report for the Gladstone Healthy Harbour Partnership, Gladstone.

Venables, W.N. (2015). *GHHP barramundi recruitment index project final report*. Gladstone Health Harbour Partnership.

Download the final report for this project.

ISP014 Coral indicator pilot project (Completed)

Australian Institute of Marine Science (AIMS), Townsville

Coral communities are iconic components of marine ecosystems in northern Australia. They have high biodiversity values and 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 including echinoderms (sea stars, sea cucumbers and 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 values, coral reefs have considerable socio-economic importance.

Gladstone Harbour Healthy Partnership (GHHP) aims to establish a long-term coral monitoring program consistent with the report card objective for key ecosystems to 'maintain/improve habitat function and structure of key ecosystems'. Three indicators of coral health were measured to calculate the coral score for the Gladstone Harbour Report Card:

1. coral cover (%) – the combined cover of hard and soft corals relative to a baseline determined by the AIMS Reef Plan Marine Monitoring Program (MMP)
2. macroalgal cover (%) – the cover of macroalgae relative to a baseline consistent with the MMP
3. juvenile coral density (no.m^{-2}): density relative to the MMP baseline.

A fourth indicator, coral cover change, measures change in coral cover from the previous year. It may be added in subsequent report cards but cannot be included in the 2015 Gladstone Harbour Report Card as there is no baseline from which to measure it.

The results of this project are detailed in the AIMS project report (below) and a summary of the project appears in the body of this document.

Reports and publications

Thompson, A., Costello, P., & Davidson, J. (2015). *Development of coral indicators for the Gladstone Harbour Report Card, ISP014: Coral*. Australian Institute of Marine Science, Townsville.

Download the report for this project.

Thompson, A., Costello, P., & Davidson, J. (2016). *Development of coral indicators for the Gladstone Harbour Report Card, ISP014: Coral*. Australian Institute of Marine Science, Townsville.

Download the final report for this project

ISP015: Developing an indicator for mud crab (*Scylla serrata*) abundance in Gladstone Harbour. (To be completed in 2017)

Mud crabs are one of Gladstone Harbour's 'iconic species'. They were identified as a major community concern at workshops conducted by the Gladstone Harbour Healthy Partnership (GHHP). This is in part a result of reported high rates of rust spot disease in the harbour's population. Mud crabs spend most of their post-larval lives in burrows in estuarine mangrove habitats and their abundance, size distribution and health is related to environmental conditions within these habitats. Based on the development of 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 report card framework nominated size distribution, abundance and visual health assessment as candidate indicators of mud crab status (Mackintosh et al., 2014).

Mud crabs are important commercial species that are harvested using baited traps in estuarine waters throughout Queensland, including within Gladstone Harbour. Each licensed commercial fisher in Queensland has to record their daily fishing effort and catch in a logbook. Data from those logbooks are collated and recorded in the QFish database by the Queensland Government Department of Agriculture and Fisheries. The first component of this project was a review of the suitability of the data for developing report card indicators. This review concluded that logbook data were unsuitable (Brown, 2015). The report recommended that the GHHP develop and implement a fishery-specific logbook to record data on commercial catch and effort within Gladstone Harbour's mud crab fishery. These logbooks would be implemented to monitor the abundance, size distribution and health of mud crabs. The data would then be used to develop report card indicators.

Reports and publications

Brown, I.W. (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.

ISP016: GHHP Gladstone fish health research program (In progress)

Gladstone Harbour Healthy Partnership, Fisheries Research and Development Canberra, AusVet Animal Health Services, Australian Institute of Marine Sciences

The Gladstone Healthy Harbour Partnership Management Committee has asked the Independent Science Panel (ISP) to develop priority research areas for identifying the cause of recent fish health issues in Gladstone Harbour and to develop approaches to enhance early detection of fish health issues.

The broad goals of the Gladstone Harbour fish health research program are to:

- better understand outstanding questions around causal links of fish ill health and other environmental or anthropogenic impacts
- develop approaches to enhance early detection of fish health issues in the harbour in the future.

To identify priority research projects an invitation-only Fish Health Workshop was conducted in Gladstone in 2015. The workshop involved a small panel of experts and was coordinated by the Fisheries Research and Development Corporation in conjunction with the ISP. This workshop resulted in two research projects (ISP016a & ISP016b) that, when completed, will guide the development of a tool for early detection of fish health issues. It is hoped that this research would be completed within five years from commencement and that the early detection tool would be available at its conclusion. Initially projects will have a research focus, however, it is expected that research outcomes will ultimately contribute to the annual Gladstone Harbour Report Card.

- ISP016a: Conduct a critical review of the literature on the use of fish health indices worldwide and their potential use in Gladstone Harbour fish health research program

- ISP016b: Conduct a critical review of the literature on the use of biomarkers in fish health assessment worldwide and their potential use in Gladstone Harbour

Reports and publications

Fisheries Research Development Corporation. (2015). *Development of the Gladstone Healthy Harbour Partnership Fish Health Research Program.* FRDC, Canberra.

Download the final report for this project

Kroon, F.J., Streten, C., & Harries, S.J. (2016) *The Use of Biomarkers in Fish Health Assessment Worldwide and Their Potential Use in Gladstone Harbour.* Australian Institute of Marine Science, Townsville.

Download the final report for this project.

ISP017: Additional PAH monitoring 2015 (Completed)

Port Curtis Integrated Monitoring Program (PCIMP)

The Gladstone Harbour Healthy Partnership (GHHP) objective for water and sediment quality is to 'Maintain water and sediment quality at levels compliant with the appropriate guidelines.' In reviewing the sediment indicators available for use in the Pilot Report Card, the Independent Science Panel (ISP) identified measurement of polycyclic aromatic hydrocarbons (PAHs) as a clear omission. Appropriate guidelines do exist for PAHs (ANZECC/ARMCANZ 2000, Simpson et al., 2013). There are several potential sources of PAHs associated with Gladstone Harbour, including petrogenic (from fossil fuels – coal, oil and gas), pyrogenic (formed through incomplete combustion of organic matter – fossil fuels and biomass), and diagenic sources (formed through biological breakdown processes).

Previous surveys of PAHs in Gladstone Harbour sediments have reported either no detectable levels or generally low levels but with exceedances of the ANZECC/ARMCANZ (2000) guideline for the PAH naphthalene at six sites (WBM Oceanics, 2000). Previous studies have found that naphthalene was of potential ecological concern in Gladstone Harbour. Given this potential ecological concern, the ISP determined that there was a need to establish baseline levels of PAHs in the harbour and to develop an indicator for environmental health based on PAH concentrations in harbour sediments.

This project addresses these concerns by including annual PAH monitoring with the existing annual sediment monitoring conducted by PCIMP. Data analysis will be conducted by the National Measurement Institute (NMI) which is routinely used by PCIMP for the existing sediment monitoring program. Data will be supplied to GHHP for inclusion in the Annual Gladstone Harbour Report Card.

Reports and publications

The results of the PAH sediment sampling were included in the 2015 Gladstone Harbour Report Card and supporting technical report and website.

These GHHP products can be accessed here.

ISP018: Development of mangrove indicators for the Gladstone Harbour Report Card (Under development)

The health of mangrove communities can be impacted by both natural and anthropogenic processes, either separately or in combination. These processes include sediment deposition and erosion, nutrient enrichment, disease, hydrological and climatic changes, extreme events pollution, water extraction, changes to land use and land reclamation. Indicators of mangrove health are required to document changes over time in relation to interactions among these processes, or in response to them.

Mangroves were identified as an important indicator during the report card visioning process. The Independent Science Panel selected the following potential indicators for mangrove health for inclusion in the report card:

- aerial coverage
- changes in distribution
- changes in species composition.

To avoid duplication in data collection, a project is being developed to include mangroves in the 2017 report card using data collected as a component of the Port Curtis and Port Alma Coastal Habitat Archive and Monitoring Program (PCPA CHAMP) and other data as required. The aim of this project is to:

- develop mangrove health indicators, baselines and a suitable scoring system for report card use based on the annual data collected as a component of PCPA CHAMP
- provide report card grades and scores for the 2017 Gladstone Harbour Report Card with an accompanying project report which describes all methods employed and provides an overview of the current status of mangroves within the Gladstone Harbour Healthy Partnership reporting area.

ISP019: Coral coring in Gladstone Harbour to enable a comparison of pre- and post-industrial eras in Gladstone Harbour (In progress)

Australian Institute of Marine Science (AIMS), Townsville

The skeletons of long-lived massive corals (e.g. *Porites* and *Cyphastrea*) provide annually dated growth and records of environmental conditions. This information can extend existing observational records of the marine environment in which the corals grew.

Coral reef communities within Gladstone Harbour and the report card zone may be impacted by natural processes including floods, storms and biological interactions as well as historical and current human activity, including land use within the catchment area, dredging and other port-related activities.

The Gladstone Healthy Harbour Partnership (GHHP) requires a coral coring study to document pre-industrialisation conditions of Gladstone Harbour and document any changes over time. This study will be conducted in two stages. The first stage will involve surveys to identify suitable massive coral colonies in the region within and surrounding Gladstone Harbour. These colonies will need to be approximately 0.75 to 1.00m in height to obtain records that cover the pre-industrial history of the harbour dating back to the 1970s and beyond. A minimum of four in-harbour (sites considered to be influenced by the port) with a suitable number of corals, and four out-harbour sites (those sites not impacted by port activities) will be required. The CSIRO's 3D-hydrodynamic model of Gladstone Harbour may be employed to determine how much influence the port has on selected sites. If a sufficient number of suitable sites is not located, the project will not proceed beyond this point.

The second phase of this project will involve coral coring in Gladstone Harbour, analysis of the cores and a subsequent assessment of the results. If suitable sites are found within and outside the area that is influenced by the port, core analysis will reconstruct the continuous records of sediment inputs for the presence of heavy metals (Al, As, Zn, Pb, Mn and Cu), nutrient inputs ($\delta15N$ as a proxy for nutrients), coral growth rates comparing pre- and post-industrial development levels and levels within and outside the harbour area.

AIMS was contracted in June 2016 to undertake this project. The final results will be available in June 2017.

ISP020: Development of R scripts to calculate, aggregate and integrate cultural heritage indicators with Bayesian model and Data Information Management System (Completed)

CSIRO/Bill Venables

The Cultural component of the report card consists of two indicator groups, 'sense of place' and cultural heritage. 'Sense of place' data are collected as a component of the computer-assisted telephone interviewing survey conducted annually to obtain data for the social and economic indicator groups. Information on Indigenous culture has been collected by Terra Rosa Consulting (see ISP012). The purpose of this project is to integrate these two indicators into the Data Information Management System (DIMS) workflow to calculate report card grades and scores. This project will:

- develop R scripts to calculate heritage indicator scores and grades using the documented methods endorsed by the Independent Science Panel
- integrate cultural heritage indicators with Bayesian network model (in R) and 'sense of place' indicator group to generate scores and grades at all levels of reporting in the Cultural component of the Gladstone Healthy Harbour Partnership Report.
- provide assistance to successfully integrate and implement the code base and data input module with the Gladstone Healthy Harbour Partnership DIMS.

Reports and publications

Pascoe, S. & Venables, B. (2016). *Draft report on the Development of R scripts to calculate, aggregate and integrate Cultural heritage indicators with GHHP Data Information Management System*. CSIRO, Brisbane.

Appendix 2: The role of the Independent Science Panel (ISP)

The Independent Science Panel (ISP) provides independent scientific advice, review and direction. Its role is to ensure that the environmental, social and economic challenges of policy, planning and actions as they relate to achieving the Gladstone Healthy Harbour Partnership (GHHP) vision are supported by credible science. This is a review and oversight role, and ISP project work will be carried out by collaborators or consultants with the ISP providing advice. This is reflected by the time commitment agreed to by ISP members. In this role, the panel will engage with stakeholders such as the Gladstone community and industry to ensure their participation in the process.

Chair of the ISP

The ISP Chair is responsible for championing the integrated and collaborative approach to research and monitoring. The Chair will be an ex-officio member of the GHHP Management Committee and will work with the GHHP to convene the ISP. The Chair is also responsible for managing conflict-of-interest issues that may arise among ISP members and is the ISP spokesperson.

The ISP will be supported by the Secretariat and a Science Convener. The role of the Science Convenor is to support the ISP including by coordinating the operations, recommendations and outputs from the panel (e.g. preparation, synthesis and collation of information). With the ISP Chair, the Science Convenor is also responsible for progressing the ISP deliverables by overseeing and managing ISP projects, keeping projects on task and reporting any delays or changes in project scope to the Chair.

Composition of the ISP

The ISP will comprise up to 11 members (including the Chair and the Convenor) with expertise on one or more of the following:

- water quality
- ecosystem health
- marine biogeochemistry
- marine ecotoxicology
- decision support tools/modelling
- social science
- resource economics
- computational informatics, statistics, decision support and modelling
- dredging (technical) and engineering
- marine biodiversity (including fish and seagrass).

Roles and responsibilities

The role of the ISP is to provide independent scientific advice on the piloting and system testing of the GHHP-endorsed Gladstone Harbour Report Card. This includes:

- the monitoring program to support the report card
- overseeing the synthesis work required to ascertain report card grades to ensure the independence of the grades

- overseeing the continued development of the Gladstone Harbour Model that will be used by the GHHP to underpin advice to policy, management and regulatory agencies, industry and other stakeholders
- research projects (if required) to improve the Gladstone Harbour Report Card
- monitoring improvement plans that may be needed to improve the efficiency and/or effectiveness of the Gladstone Harbour Report Card, its monitoring program and/or the Gladstone Harbour Model.

The ISP will also provide independent scientific advice when requested by the GHHP. The key output from the ISP in 2015 is the review of scientific reports commissioned by the GHHP and the review of the 2015 report card and associated material.

Other roles of ISP

Enhancement of research partnerships

The ISP will ensure that partnerships and collaboration are enhanced in the generation of science advice to GHHP. The ISP will facilitate the links with research partnerships and initiatives (e.g. research alliances, centres of excellence) and other researchers and academics (e.g. in-house industry scientists) to address scientific and technical key issues identified by the ISP and the GHHP. Leveraging of resources to address research questions will also be facilitated.

Scientific quality assurance

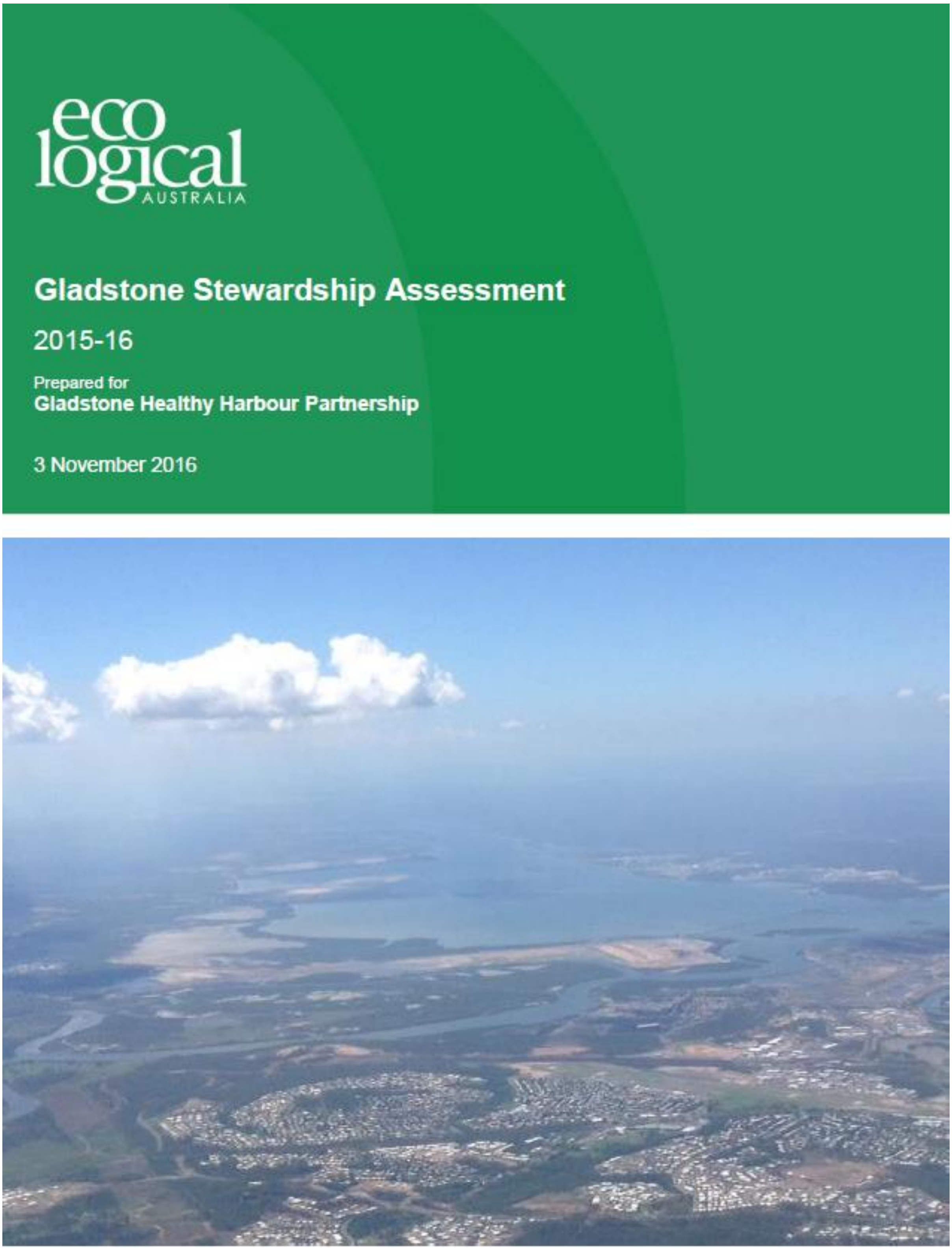
The ISP will ensure that the recommendations are based on science activities that are designed, conducted, coordinated, integrated and peer-reviewed in accordance with best practice in scientific community.

Effective scientific communication

The ISP will support stakeholder decision making through the provision and access to synthesised knowledge and, information and robust decision-support tools. The ISP will ensure, to the best of its capability, that a common science consensus/recommendation on any particular issue in relation to Gladstone Harbour will be presented to the GHHP and the community, as required. The ISP will work with GHHP to facilitate the effective communication of results and recommendations to the wider community as required.

Appendix 3: Stewardship

The 2015–16 Stewardship report can downloaded here.



eco logical AUSTRALIA

Gladstone Stewardship Assessment

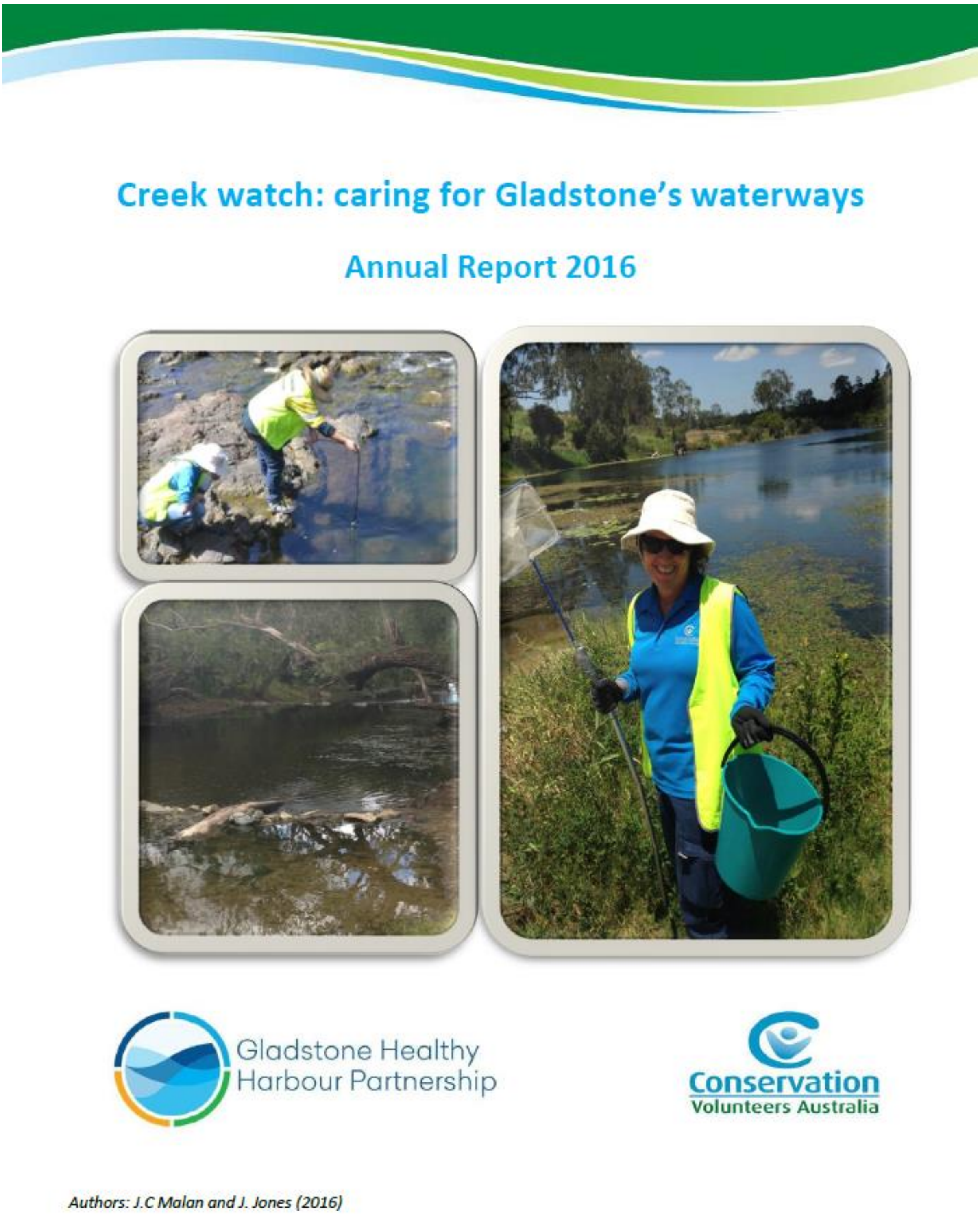
2015-16

Prepared for
Gladstone Healthy Harbour Partnership

3 November 2016

Appendix 4: Citizen Science

The 2015–16 Citizen Science report can downloaded here.


Creek watch: caring for Gladstone's waterways

Annual Report 2016

Gladstone Healthy Harbour Partnership

Conservation Volunteers Australia

Authors: J.C Malan and J. Jones (2016)

Appendix 5: Water quality guidelines used to calculate water quality scores

Table A5.1: Water quality guidelines used to calculate water quality scores.

		Turbidity (NTU)		pH range (20-80%ile)														
	Level of protection	Dry (May-Oct) (50%ile)	Wet (Nov-Apr) (50%ile)	when conductivity <40mS/cm	when conductivity >40mS/cm	Ammonia (ug/L) (50%ile)[a]	Total N (ug/L) (50%ile)	Total P (ug/L) (50%ile)	NOx(ug/L) (50%ile)[a]	DO range (%) (20 and 80%ile)[a]	Orthophosphate (FRP) ug/L (50%ile)[a]	Chlorophyll-a (ug/L) (50%ile)	Aluminium (ug/L)[b]	Copper (ug/L)	Lead (ug/L)	Manganese (ug/L)[c]	Nickel (ug/L)	Zinc (ug/L)
The Narrows	HEV	7	15	7.2 - 8.2	7.4 - 8.3	3	170	20	3	87-95	3	1	24	1.3	4.4	140	7	15
Graham Creek	MD	8	13	7.2 - 8.2	7.4 - 8.3	3	170	20	3	83-94	4	1	24	1.3	4.4	140	7	15
Western Basin	MD	8	13	7.2 - 8.2	7.4 - 8.3	3	170	18	4	91-100	3	1	24	1.3	4.4	140	7	15
Boat Creek	MD	14	25	7.2 - 8.2	7.4 - 8.3	4	190	22	3	85-98	3	2	24	1.3	4.4	140	7	15
Inner Harbour	MD	8	13	7.2 - 8.2	7.4 - 8.3	3	160	21	5	93-98	3	1	24	1.3	4.4	140	7	15
Calliope Estuary	MD	11	11	7.2 - 8.2	7.4 - 8.3	6	175	22	3	91-100	4	1.7	24	1.3	4.4	140	7	15
Auckland Inlet	MD	6	8	7.2 - 8.2	7.4 - 8.3	6	160	16	6	93-100	3	1.9	24	1.3	4.4	140	7	15
Mid Harbour	MD	4	9	7.2 - 8.2	7.4 - 8.3	3	135	14	3	94-101	2	1	24	1.3	4.4	140	7	15
South Trees Inlet	MD	11	13	7.2 - 8.2	7.4 - 8.3	3	170	20	3	86-99	4	1.1	24	1.3	4.4	140	7	15
Boyne Estuary	MD	3	5	7.2 - 8.2	7.4 - 8.3	3	120	11	1	90-102	1	0.8	24	1.3	4.4	140	7	15
Outer Harbour	MD	3	7	8.0 - 8.2		4	130	13	3	94-100	1	1	24	1.3	4.4	140	7	15
Colosseum Inlet	HEV	3	7	7.2 - 8.2	7.4 - 8.3	3	130	10	3	86-97	1	1	24	1.3	4.4	140	7	15
Rodds Bay	All	4	5	7.2 - 8.2	7.4 - 8.3	3	160	13	1	93-98	1	1	24	1.3	4.4	140	7	15

[a] These measures were not included in 2015–16 reporting card.

[b] Aluminium guideline for moderately disturbed conditions (24ug/L, 95% species protection) is now applicable to all harbour zones.

[c] A single manganese guideline (140ug/L, 95% species protection and corals present) is applied to all harbour zones.

Appendix 6: Sediment quality guidelines used in the calculation of sediment quality scores

Table A6.1: Sediment quality guidelines used to calculate sediment quality scores.

Indicator group	Measure	Concentration (mg/kg)	Guideline based on
Metals and metalloid	Arsenic (As)	20	ANZECC/ARMCANZ, 2000
	Cadmium (Cd)	1.5	ANZECC/ARMCANZ, 2000
	Copper (Cu)	65	ANZECC/ARMCANZ, 2000
	Lead (Pb)	50	ANZECC/ARMCANZ, 2000
	Mercury (Hg)	0.15	ANZECC/ARMCANZ, 2000
	Nickel (Ni)	21	ANZECC/ARMCANZ, 2000
	Zinc (Zn)	200	ANZECC/ARMCANZ, 2000
Total PAHs	Total PAHs	10 (normalised to 1% organic carbon, dry weight)	Simpson et al., 2013[a]

[a] Simpson, S.L., Batley, G.E., & Chariton, A.A. (2013). *Revision of the ANZECC/ARMCANZ sediment quality guidelines.* Prepared for the Department of Sustainability, Environment, Water, Population and Communities.

Total PAHs were calculated from 18 parent PAHs: naphthalene, acenaphthylene, acenaphthene, fluorene, anthracene, phenanthrene, fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo(a)pyrene, perylene, benzo(b)fluoranthene, benzo(k)-fluoranthene, benzo(e)pyrene, benzo(ghi)perylene, dibenz(a,h)anthracene and indeno(1,2,3-cd)pyrene