Gladstone Healthy Harbour Partnership

TECHNICAL REPORT | GLADSTONE HARBOUR REPORT CARD 2015

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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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Partners in the Gladstone Healthy Harbour Partnership (GHHP) (listed below)

Members of the GHHP Management Committee (listed below)

Gladstone Healthy Harbour Partnership partners

Australian Government, Australian Institute of Marine Science, Australian Pacific LNG, Boyne Smelters, CQG Consulting, Central Queensland University, CSIRO, Dhou Woolkoom, Fitzroy Basin Association, Gidarjil Development Centre, Gladstone Area Water Board, Gladstone Ports Corporation, Gladstone Regional Council, Gladstone Region Environmental Advisory Network, Griffith University, NRG, Orica, QGC, Queensland Alumina Limited, Queensland Government, Queensland Energy Resources, Queensland University of Technology, Rio Tinto, Santos GLNG Project, The University of Queensland, Wiggins Island Coal Export Terminal.

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Disclaimer

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Executive Summary

Context

The 2015 Gladstone Harbour Report Card reports on the Environmental health of 13 zones in and around Gladstone Harbour, and the overall environmental, social, cultural and economic health of the harbour. This report card covers the period 1 July 2014 to 30 June 2015. Indicators were scored on a scale from 0.00 to 1.00, and then graded according to the scheme shown in 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 2015 Gladstone Harbour Report Card.

Overall component scores

The overall component scores for the 2015 report card were: Environmental 0.59 (C), Social 0.64 (C), Cultural 0.65 (B) and Economic 0.77 (B) (Figure 2).

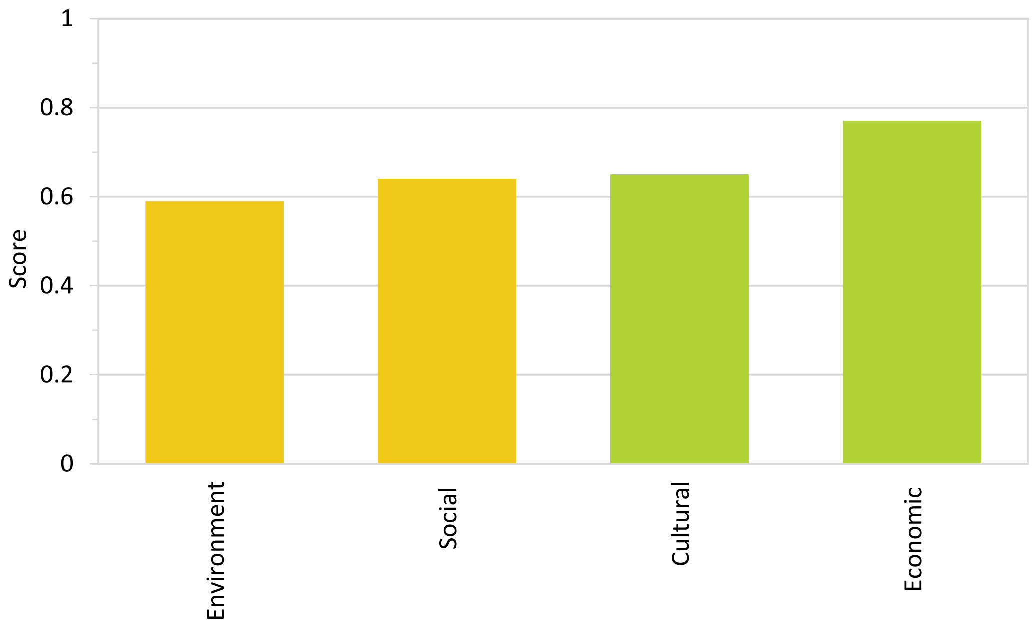


Figure 2: Overall scores for each of the four components of Gladstone Harbour health in the 2014–2015 year.

Environmental health

For the Environmental component, water and sediment quality received a score of 0.90 (A), habitats 0.30 (D) and connectivity 0.61 (C).

Water and sediment quality

For the water and sediment quality component, 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 with all zones except Boat Creek receiving good overall scores (Table 1). While nutrients (nitrogen and phosphorus) received satisfactory to very poor scores, dissolved metals (aluminium, copper, lead, manganese, nickel and zinc) and physicochemical indicators (pH, turbidity) generally received good to very good scores (Table 1). The reasons for nutrient levels generally exceeding guidelines are unclear and require further investigation. Five measures of water quality can be compared between 2014 and 2015: scores for turbidity, nitrogen, phosphorus and aluminium improved, whereas the score for copper declined.

Table 1: Water quality indicator scores for Gladstone Harbour zones in the 2014-15.

Water quality	Physicochemical	Nutrients	Dissolved metals	Overall
1. The Narrows	0.81	0.48	0.95	0.82
2. Graham Creek	0.88	0.58	0.95	0.86
3. Western Basin	0.85	0.44	0.94	0.82
4. Boat Creek	0.69	0.23	0.86	0.69
5. Inner Harbour	0.92	0.60	0.95	0.88
6. Calliope Estuary	0.97	0.49	0.89	0.88
7. Auckland Inlet	0.71	0.45	0.94	0.77
8. Mid Harbour	0.76	0.55	0.92	0.80
9. South Trees Inlet	0.89	0.42	0.95	0.85
10. Boyne Estuary	0.68	0.11	0.93	0.70
11. Outer Harbour	0.80	0.59	0.95	0.84
12. Colosseum Inlet	0.78	0.32	0.95	0.78
13. Rodds Bay	0.78	0.45	0.93	0.80

Sediment quality

Sediment quality scores were uniformly very good across all zones of Gladstone Harbour due to low levels of metals (cadmium, copper, lead, nickel and zinc) and total polycyclic aromatic hydrocarbons (Total PAHs) (Table 2).

Table 2: Sediment quality indicator scores for Gladstone Harbour zones in 2014-15.

Sediment quality	Metals and metalloids	Total PAH	Overall
1. The Narrows	0.87	1.00	0.94
2. Graham Creek	0.96	1.00	0.98
3. Western Basin	0.98	1.00	0.99
4. Boat Creek	0.92	1.00	0.96
5. Inner Harbour	0.95	1.00	0.98
6. Calliope Estuary	0.97	1.00	0.98
7. Auckland Inlet	0.91	1.00	0.95
8. Mid Harbour	0.97	1.00	0.99
9. South Trees Inlet	0.94	1.00	0.97
10. Boyne Estuary	0.99	1.00	1.00
11. Outer Harbour	0.92	1.00	0.96
12. Colosseum Inlet	1.00	1.00	1.00
13. Rodds Bay	0.96	1.00	0.98

Habitats

The overall score for habitats was poor (0.30, D), with seagrass having a poor score of 0.43 (D) and coral a very poor score of 0.18 (E). Flooding in 2011 and 2013 reduced the salinity of harbour waters, and increased turbidity and nutrient loads; these conditions would have had adverse impacts on the harbour's seagrass and corals. It is difficult to determine the relative extent to which those and other factors contributed to the poor habitat condition in the harbour.

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-indicators scores, the overall health of the seagrass meadow was still poor.

Three zones received satisfactory scores: Western Basin (0.51), Mid Harbour (0.56) and South Trees Inlet (0.52). Two zones, Inner Harbour (0.41) and Rodds Bay (0.45), received poor scores and one zone; The Narrows (0.15), received a very poor score (Table 3). These poor scores mainly resulted from low scores for biomass and meadow area.

Table 3: Scores for seagrass indicators (biomass, area and species composition), and overall meadow, zone and harbour scores for the 2014–15 reporting year.

Zone	Meadow	Biomass	Area	Species composition	Overall meadow score	Overall score
1. The Narrows	21	0.15	0.74	0.62	0.15	0.15
3. Western Basin	4	0.85	0.42	0.85	0.42	0.51
	5	0.53	0.41	0.66	0.41	
	6	0.67	0.83	0.67	0.67	
	7	0.53	0.68	1.00	0.53	
	8	0.66	0.60	0.35	0.35	
	52-57	0.67	0.94	0.88	0.67	
5. Inner Harbour	58	0.41	0.96	0.75	0.41	0.41
8. Mid Harbour	43	0.58	0.69	0.85	0.58	0.56
	48	0.58	0.54	0.61	0.54	
9. South Trees Inlet	60	0.52	0.96	1.00	0.52	0.52
13. Rodds Bay	94	0.42	0.92	0.84	0.42	0.45
	96	0.38	0.71	0.56	0.38	
	104	0.55	0.96	0.68	0.55	
Harbour score						0.43

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 4). Both the Mid Harbour and Outer Harbour zones received very poor scores for coral health of 0.23 (E) and 0.13 (E) respectively. This was due to very low coral cover, very high macroalgal cover and the low density of juvenile corals at most reefs.

Table 4: Coral indicator scores for the two surveyed harbour zones, and overall zone and harbour scores.

Zone	Coral cover	Macroalgal cover	Juvenile density	Overall score
8. Mid Harbour	0.08	0.37	0.23	0.23
11. Outer Harbour	0.05	0.00	0.33	0.13
Harbour score				0.18

Connectivity

The overall connectivity score in the 2014–15 reporting year was 0.61 (C). This score was derived from modelled data for three connectivity indicators: flushing rate (water exchange through the harbour), contaminant connectivity (potential movement of contaminants from discharge points to other zones of the harbour) and ecological connectivity (potential for larvae to move between spawning and nursery habitats within the harbour). Flushing rate and contaminant connectivity received similar scores, flushing rate 0.77 (B) and contaminant connectivity 0.78 (B), whereas ecological connectivity received a poor score of 0.29 (D) (Table 5).

Table 5: Connectivity scores for each zone and harbour-wide averages for 2014–15.

Zone	Flushing Rate	Ecological connectivity	Contaminant connectivity	Average connectivity
1. The Narrows	1.00	0.00	1.00	0.65
2. Graham Creek	1.00	0.81	0.00	0.61
3. Western Basin	0.95	0.27	0.81	0.68
4. Boat Creek	Not modelled owing to insufficient model resolution			
5. Inner Harbour	0.78	0.13	1.00	0.64
6. Calliope Estuary	0.34	0.23	0.73	0.43
7. Auckland Inlet	Not modelled owing to insufficient model resolution			
8. Mid Harbour	0.16	0.59	0.95	0.57
9. South Trees Inlet	1.00	0.11	0.59	0.57
10. Boyne Estuary	0.72	0.00	1.00	0.56
11. Outer Harbour	0.59	0.49	0.79	0.62
12. Colosseum Inlet	1.00	0.13	1.00	0.71
13. Rodds Bay	1.00	0.41	0.66	0.69
Harbour score	0.77	0.29	0.78	0.61

Rainfall contributed to lower-than-average ecological connectivity and increased flushing rate. However, it is not a simple relationship and factors such as the timing of rainfall events relative to tidal cycles and wind patterns may have also played a role.

Social health

The overall social score in the 2014–15 reporting year of 0.64 (C) is higher than the score of 0.58 (C) in the 2014 Pilot Report Card (Gladstone Healthy Harbour Partnership, 2014). This score was based on three indicators of social health: harbour usability (0.75, B), harbour access (0.62, C), and liveability/wellbeing (0.64, C) (Figure 3).

The harbour usability score of 0.75 (B) was higher than the score for this indicator in the 2014 Pilot Report Card of 0.60 (C) due to fewer reported oil spills and Maritime Safety Queensland changing its reporting protocols for shipping incidents to meet Commonwealth rather than state-based legislation. The harbour access score of 0.62 (C) was similar to the score of 0.61 (C) that this indicator received in the 2014 Pilot Report Card, whereas the liveability and wellbeing score of 0.64 (C) was the same as in 2014.

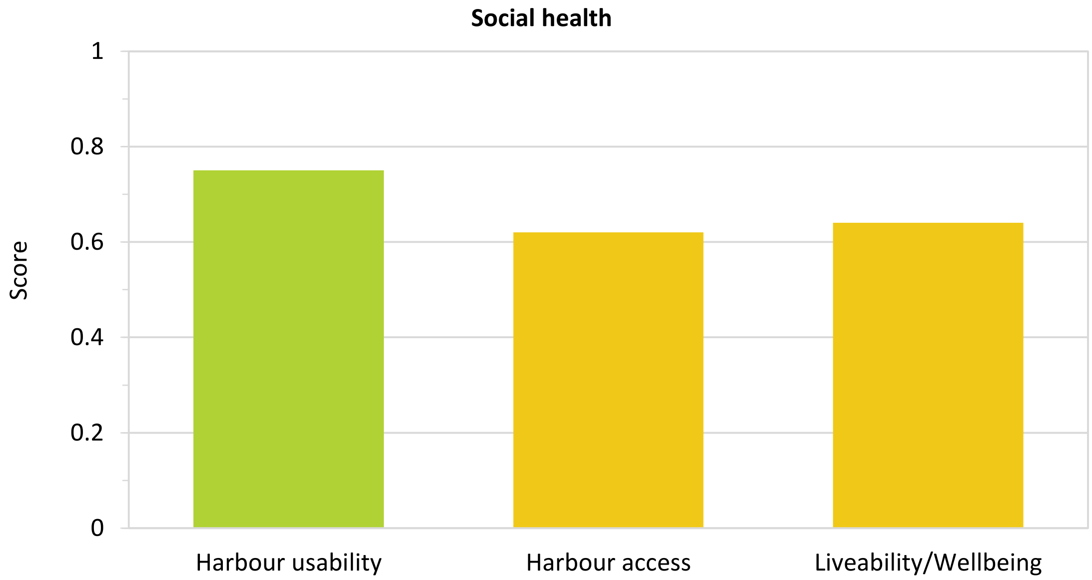


Figure 3: Scores for each of the three indicators of the social health of Gladstone Harbour in the 2014–15 year.

Cultural health

Two indicator groups for cultural health were identified in the GHHP vision, sense of place and Indigenous cultural heritage. Only sense of place is included in the 2015 report card as the Indigenous cultural heritage indicator is still under development.

The overall grade for sense of place was a B (0.65). This grade was based on responses to six measures in a Computer-Assisted Telephone Interview (CATI) survey. These measures and scores were: distinctiveness (0.55), continuity (0.57), self-esteem (0.72), self-efficacy (0.56), attitudes to the harbour (0.80) and values of the harbour (0.64) (Figure 4).

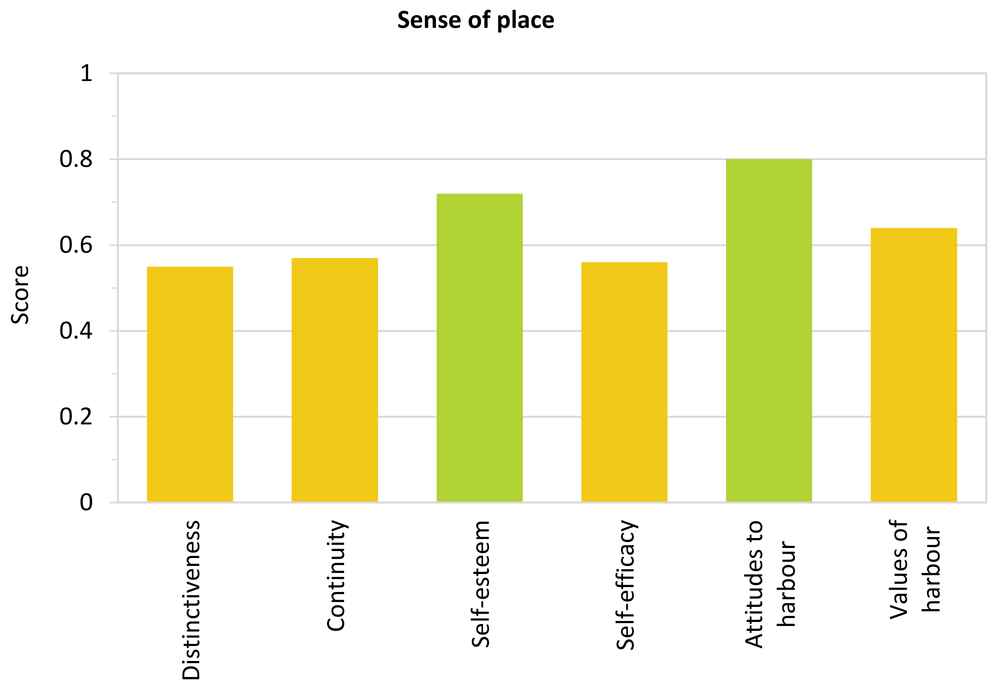


Figure 4: Scores and grades for each of the six measures of the sense of place indicator group used to indicate the cultural health of Gladstone Harbour in the 2014–15 year.

Economic health

The overall score for the Economic component of the 2015 report card of 0.77 (B) is lower than the 2014 score of 0.82 (B). The three indicator groups measured to determine these grades were economic performance, economic stimulus and economic value (recreation) (Figure 5).

The economic performance indicator group had three indicators: tourism, commercial fishing and shipping activity. These were selected to 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 0.79 (B) compared to the score received in the 2014 Pilot Report Card of 0.83 (B). This reflected weaker performance in the fishing and shipping sectors and an increase in the relative performance of the tourism sector.

Economic stimulus received a score of 0.82 (B) compared to the 2014 score of 0.87 (A). This score was based on two indicators: employment and socio-economic status. The score for employment of 0.64 (C) was lower than the score for 2014 of 0.72 (B). This was due to the unemployment rate in Gladstone not improving as rapidly as elsewhere in Queensland. Socio-economic status received a very high score of 0.95 (A) which is similar to the 2014 score of 0.90 (A).

Economic value received a score of 0.72 (B) which is similar to the score of 0.75 (B) in the 2014 Pilot Report Card.

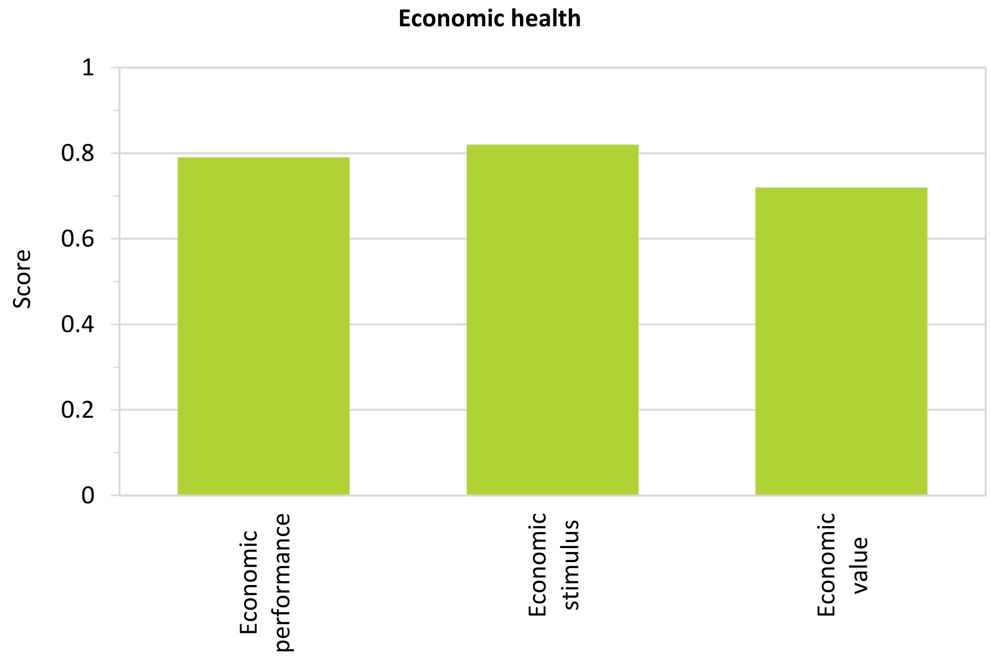


Figure 5: Scores and grades for each of the three indicators of the economic health of Gladstone Harbour in the 2014–15 year.

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.

The GHHP partnership has 26 partners comprising 13 industry representatives; six research and monitoring agencies; local, state and federal government representatives and four 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 GHHP is advised by an Independent Science Panel (ISP) that provides independent scientific advice, review and direction to ensure that the environmental, social and economic challenges of policy, planning and actions to achieve the vision of GHHP are supported by credible science.

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 harbor 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 harbor that contributes to a positive diverse economic future, supports existing and new industries and returns economic benefit to the whole community.

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 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 consideration of local issues to guide the final selection of indicators. These reports are available on the GHHP website.

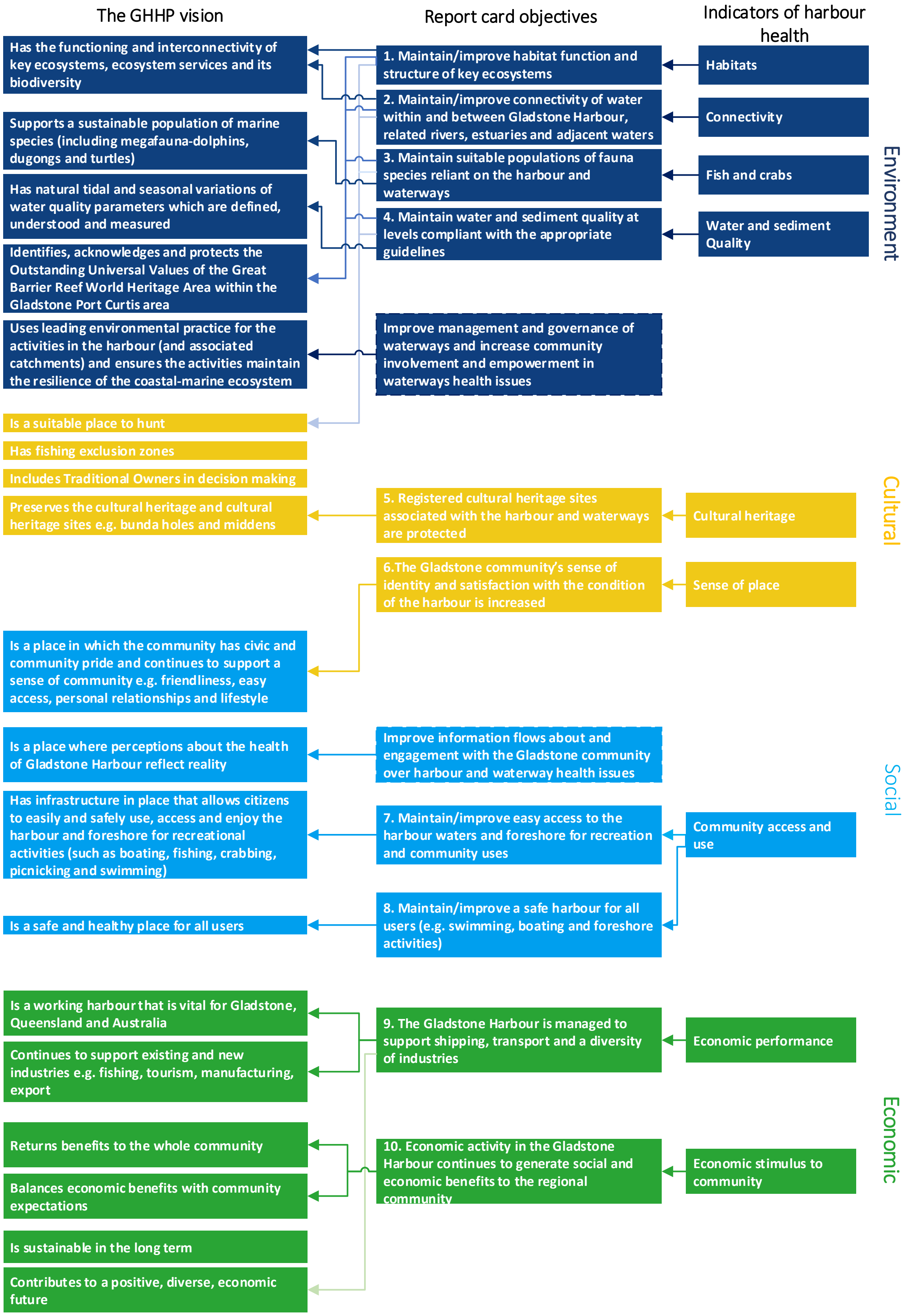


Figure 1.1: The Gladstone Harbour Report Card objectives and harbour health indicators were developed from the GHHP vision statements for the Environmental, Cultural, Social and Economic components of Gladstone Harbour health.

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.

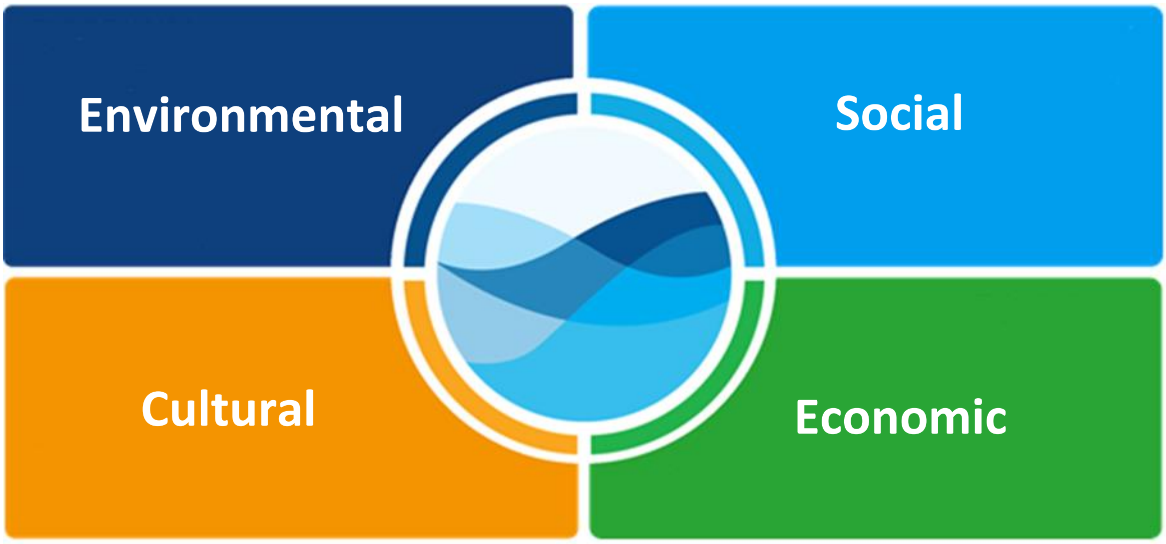


Figure 1.2: The four components of harbour health as defined by the GHHP vision.

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 and Gladstone Harbour Model. 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.

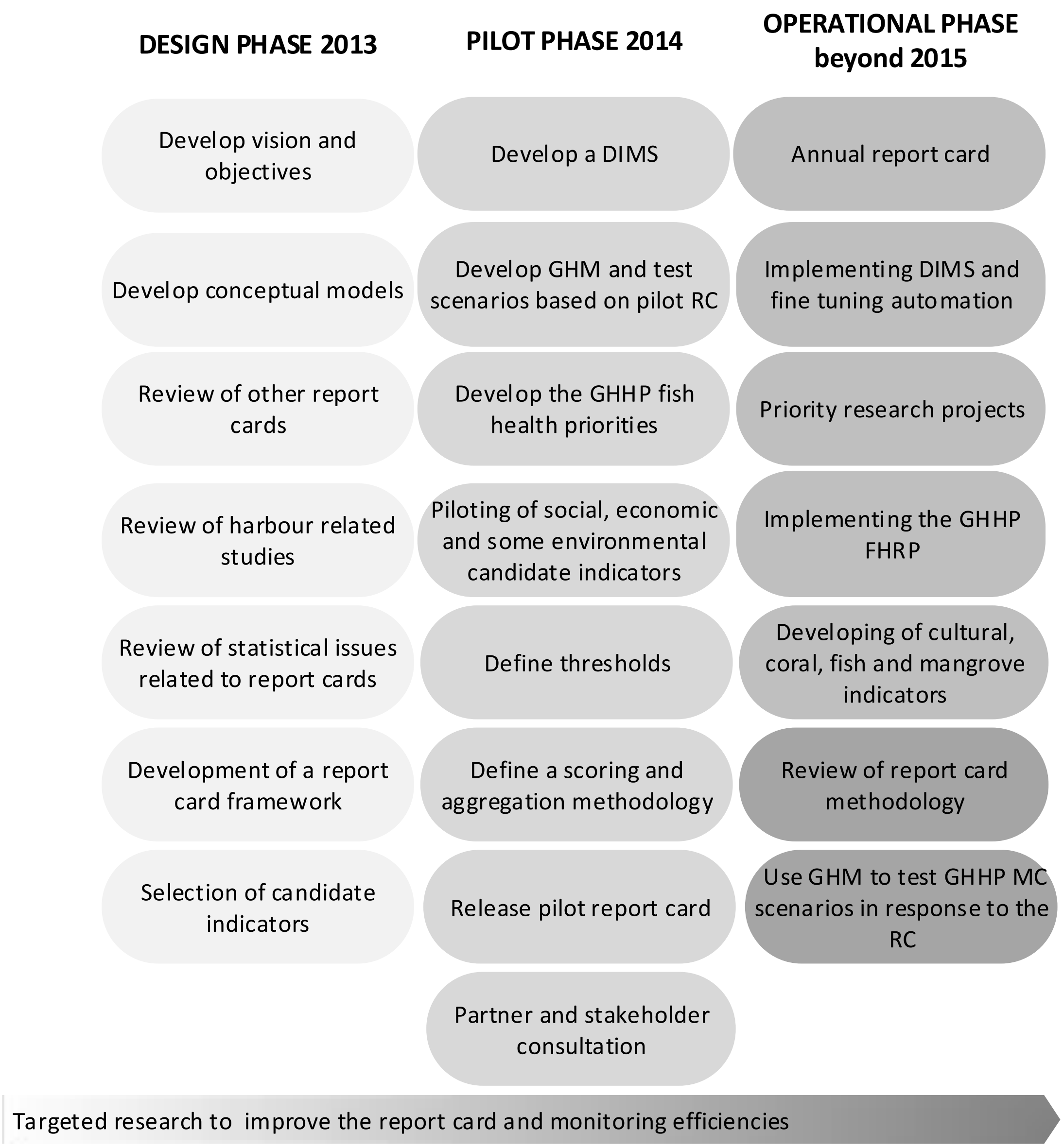


Figure 1.3: The three phases of the GHHP science program. (DIMS = data and information management system, GHM = Gladstone Harbour Model; RC = Report Card; MC = Management Committee, FHRP = Fish Health Research Program).

GHHP projects completed in the design phase included:

- ISP001: Mapping and synthesis of data and monitoring in Gladstone Harbour

  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 developed by this project.

- ISP002: Review of the use of report cards for monitoring ecosystem and waterway health

  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

  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.

  Download the final report for this project.

- ISP004: Guidance for the selection of social, cultural and economic indicators for the development of the GHHP Report Card

  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.

Ongoing projects:

- ISP005: Piloting of social, cultural and economic data for the Gladstone Healthy Harbour Partnership Report Card

  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.

  Download the 2014 report for this project.

  Cannard, T., Pascoe, S., Tobin, R., Windle, J and 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.

- ISP006: Development of a Gladstone Harbour Model to support the Gladstone Healthy Harbour Report Card (To be completed June 2016)

- ISP007: Development of Connectivity Indicators for the Gladstone Healthy Harbour Report Card

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.

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
- ISP008-2015: Provision of statistical support during the development of the Gladstone Harbour Report Card

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.

- ISP009: Development of a data and information management system for the GHHP report card monitoring data (To be completed March 2016)
- ISP010 Statistical Assessment of the Fish Indicators and Score for the Pilot Report Card (Completed in February 2015)

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

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 2014 report for this project.

- ISP012: Cultural Indicators Pilot Project (To be completed in 2016)
- ISP013 Fish Recruitment Index Project
- Sawynok, B., W. Parsons, J. Mitchell & S. Sawynok (2015) Gladstone fish recruitment 2015. Report for the Gladstone Healthy Harbour Partnership, Gladstone. 52 pp.ISP014: Coral Indicator Pilot Project

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.

- ISP015: Developing an indicator for mud crab (*Scylla serrata*) abundance in Gladstone Harbour.

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.

- ISP016a: Conduct of a critical review of the existing literature on the use of fish health indices worldwide and their potential use in Gladstone
- ISP016b: Conduct of a critical review of the existing literature on the use of biomarkers in fish health assessment worldwide and their potential use in Gladstone Harbour
- ISP017: PAH Sediment Additional PAH Monitoring 2015

Refer to Appendix 1 for summaries of GHHP projects.

1.3. Reporting periods

The reporting period for the 2015 Gladstone Harbour Report Card was 1 July 2014 to 30 June 2015. This was adopted so that the significant environmental changes that occur in the wetter summer months are captured in the annual data (Figure 1.4). However, some data collected prior to the 2014–15 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 connectivity section are also from the preceding financial year as this is the latest data available.

1.4. Gladstone Harbour drivers and pressures

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 which 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 which may have influenced the 2014–15 report card scores and grades.

In the reporting year from June 2014 to July 2015, acute climatic events, such as flooding, and changes to economic circumstances did not influence the report card grades.

Climate

Gladstone has a subtropical climate with an average maximum of 27 degrees Celsius and an average minimum of 18 degrees. Rainfall is highly variable; the average annual rainfall recorded at Gladstone (Radar Hill) for the period 1957-58–2014-15 was 875mm. The maximum and minimum annual rainfall totals recorded at this site were 1,732mm in 1971 and 155mm in 1994 respectively. Consistent with a subtropical climate, the summer months are wetter than winter months with December, January and February accounting for 49% of the annual average. The winter months of June, July and August account for only 12% of the annual average rainfall.

2014–15 rainfall

In the 2014–15 reporting year, total monthly rainfall for the winter months was below the monthly average over the past 58 years. However, the total rainfall recorded in December, January and February was 532mm, which was 104mm greater than the monthly averages for this period (Figure 1.4). The 2014–15 reporting year annual total of 834.4mm was close to the annual average of 891.4mm (Figure 1.5).

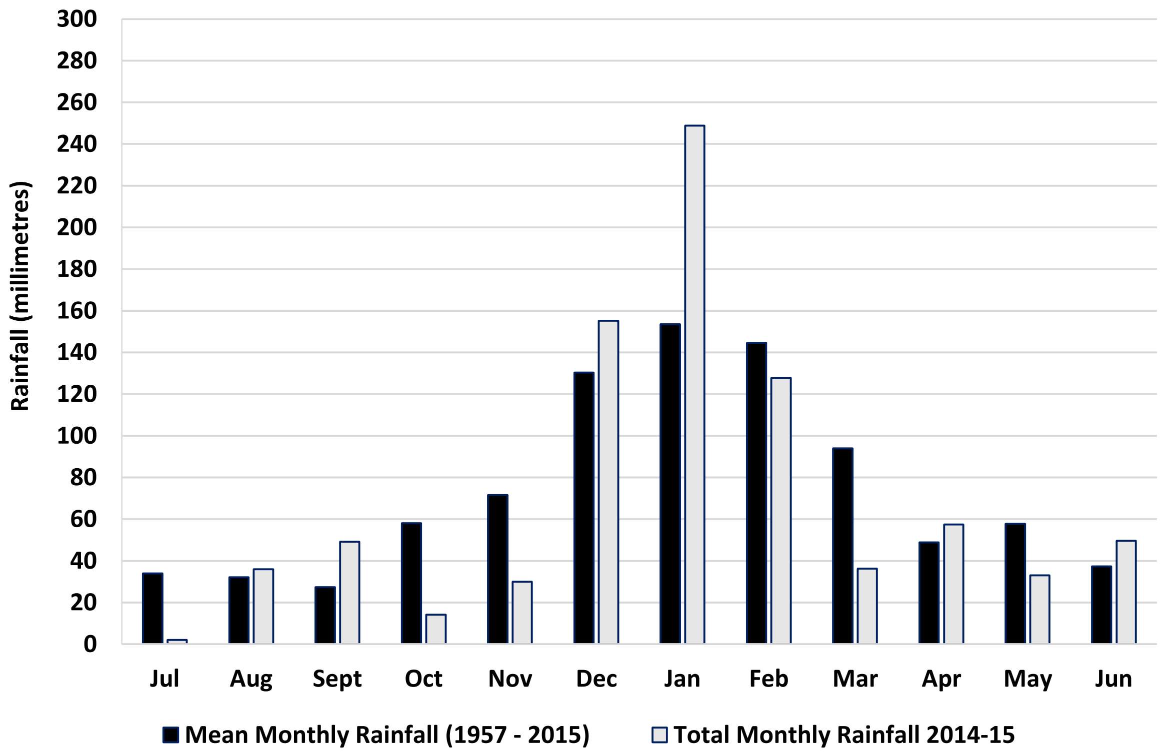


Figure 1.4: Mean monthly rainfall at the Gladstone Radar Hill weather station (1957-58–2014-15) compared to total monthly rainfall for the 2014–15 reporting year (data provided by the Australian Bureau of Meteorology).

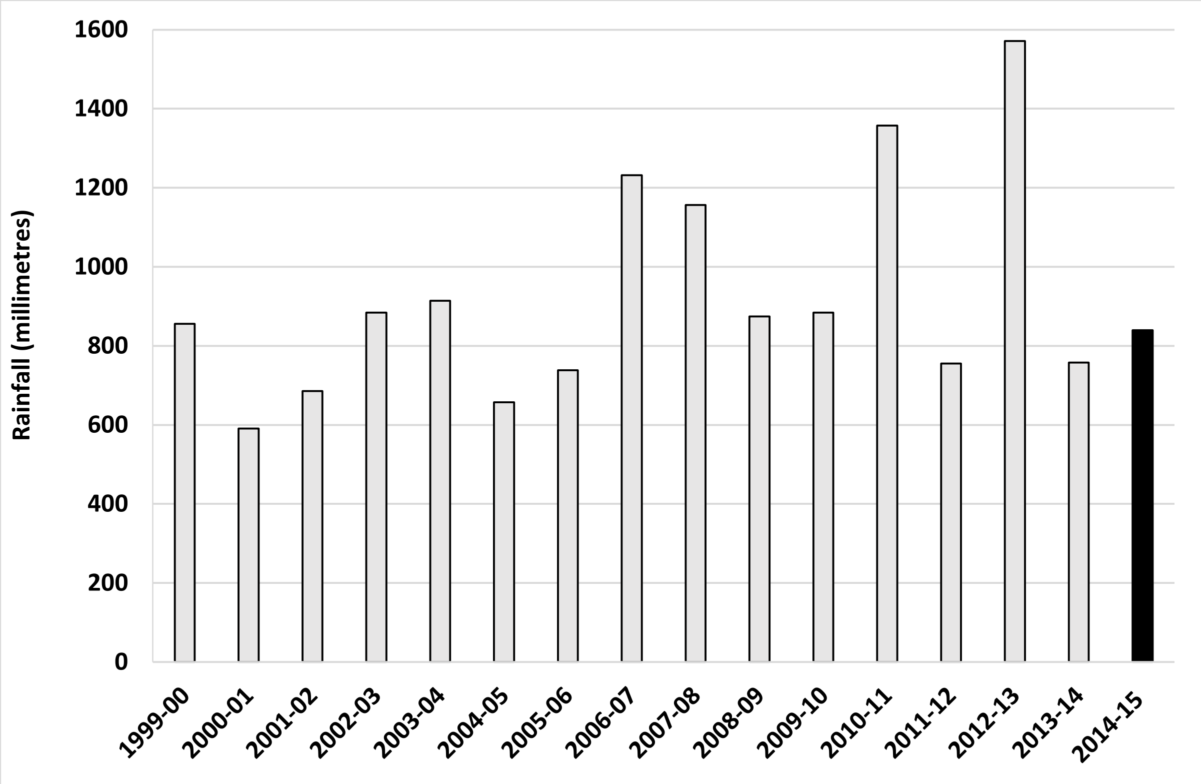


Figure 1.5: Annual rainfall (reporting year) at the Gladstone Radar Hill weather station from 1999–2000 to 2014–2015 (Australian Bureau of Meteorology data).

Freshwater flow into Gladstone Harbour

The two major sources of freshwater flow into the Gladstone Harbour are the Boyne River which discharges into the Mid Harbour and the Calliope River which discharges into the Western Basin. Freshwater flows may also enter the harbour via The Narrows when the Fitzroy River floods. Significant changes in land use have occurred in both catchments since European settlement resulting in increased sediment and nutrient loads in the Port of Gladstone (DSEWPaC, 2013).

While stream flow in the Boyne River is highly modified, owing to the presence of Awoonga Dam, flow in the Calliope River is relatively unmodified. Annual average stream flows for the Boyne and Calliope rivers are presented in Table 1.1.

Table 1.1: Stream flow summary for the Boyne River (1984-85 – 2011-12) and the Calliope River (1938-39 – 2014-15) (Source: DNRM, 2015).

Boyne River at Awoonga Dam Headwaters (1984-85 – 2011-12)			
Annual stream flows (ML)		December stream flows (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 – 2014-15)			
Annual stream flows (ML)		December stream flows	
Mean	168,474	Mean	22,214
Median	105,112	Median	31,770
Maximum flow (Total flow 2012-13)	916,693	Maximum flow (Total flow December)	401,837

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 and 2013, as well as during the current reporting year from January to March. This latest overtopping was relatively minor in comparison to the large event which occurred in 2013 (Table 1.2, Figure 1.6). The overtopping in March was immediately prior to the water and sediment sampling that occurred in that month. Daily stream flow data are currently not available for the Boyne River below Awoonga Dam.

Table 1.2: Awoonga Dam levels and initial 2015 overtopping in comparison 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	31-Aug-15	39.68	755,379	97.24	6,653
Level one month ago	31-Jul-15	39.49	742,808	95.62	6,578
Level one year ago	31-Aug-14	39.28	729,334	93.84	6,494
Initial overflow of 40m spillway	22-Jan-15	40.1	783,673	100.88	6,818
Highest level	27-Jan-13	48.30	1,498,586	192.90	10,810

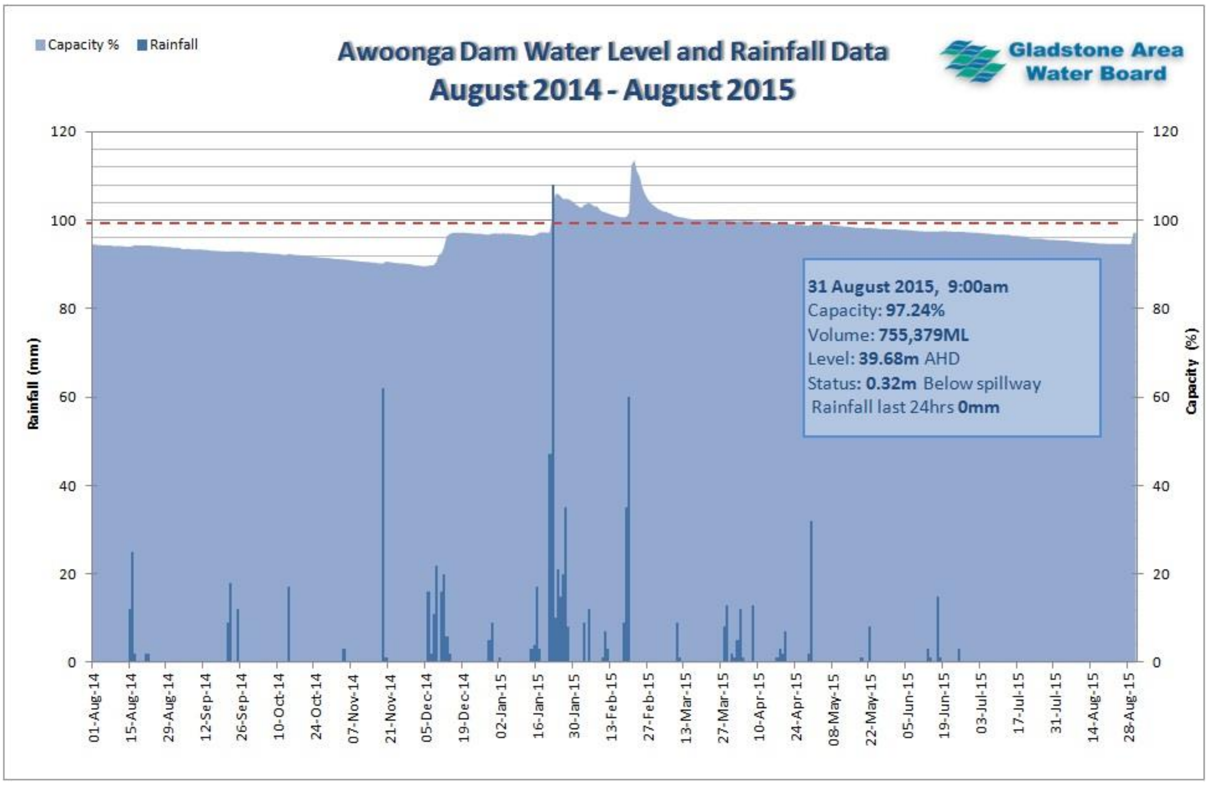


Figure 1.6: Awoonga Dam levels August 2014 to August 2015 (Source: Gladstone Area Water Board).

Stormwater and other inputs

There is currently no estimate of the potential impacts of stormwater on water quality in Gladstone Harbour. However, when completed in 2016 the Gladstone Harbour Model will incorporate stormwater flows and allow for some assessment of the effects of stormwater flow.

No sewage is discharged directly into Gladstone Harbour. Treated effluent is reused either via land irrigation or by surrounding heavy industry (DSEWPaC, 2013).

Tidal movement and turbidity

Turbidity in Gladstone Harbour is strongly influenced by the large tidal movement. This results in significant resuspension of fine sediments that is directly related to the tidal cycle; larger tides result in increased turbidity (Figure 1.7). 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 amongst sites is largely determined by the timing of sampling.

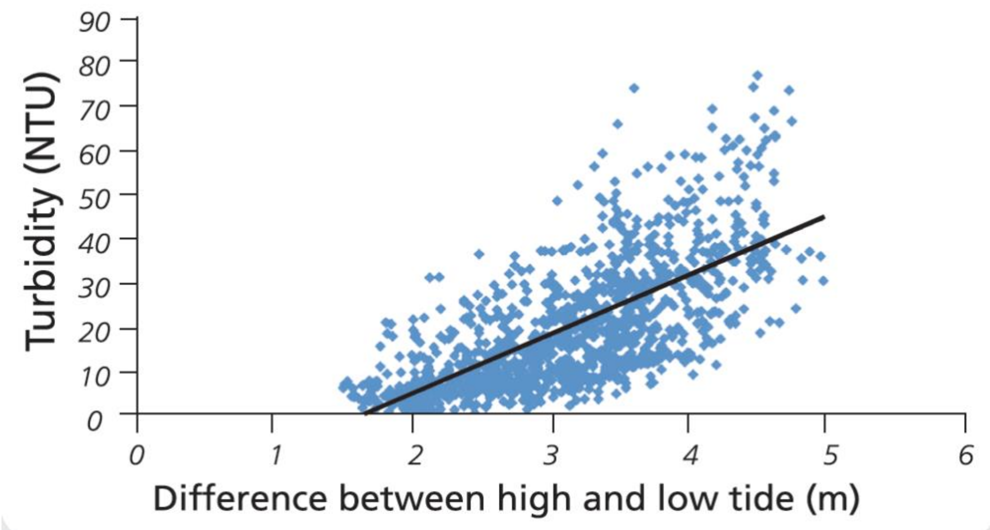


Figure 1.7: The relationship between tidal movement and turbidity in Gladstone Harbour (DEHP 2014 personal communication). NTU: Nephelometric Turbidity Unit

Tropical Cyclone Marcia

Tropical Cyclone Marcia passed Gladstone on 20 February 2015 and a storm surge of 2m occurred at Port Alma at near low tide. Although there was some rainfall associated with the cyclone, the rainfall recorded on 20 February was substantially less than the highest rainfall event of the year in January. Increased wave action during the cyclone may have caused a short-term rise in harbour turbidity levels.

Social, cultural and economic pressures

Gladstone is an industrial hub of international significance due 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 66,097 in 2014 (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 (Gladstone Regional Council, 2015).

A comparison of business counts (number of actively trading businesses) showed a slight decline in the total number of businesses trading in June 2014 (4,084) compared to June 2013 (4,139). There was also a slight decline in the number of businesses with turnover of greater than $2 million dollars, down from 278 in 2013 to 266 in 2014. Similarly, the number of businesses with a turnover of between $500,000 and $2 million dropped from 665 in 2013 to 608 in 2014. The number of businesses turning over between 0 and $50,000 increased, whereas for those turning over between $200,000 and $500,000 the general trend was downwards (Gladstone Regional Council, 2015).

The changes outlined above did not appear to unduly influence the report card grades for the 2014–15 reporting year.

2. From indicators to report card grades

2.1. Structure and indicators

A common 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 publically 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 which are then aggregated upwards towards a component.

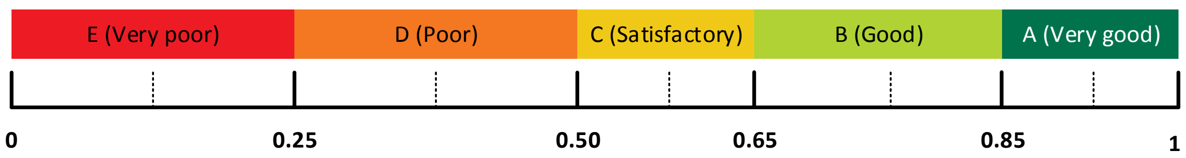


Figure 2.1: Grade ranges used in the 2015 Gladstone Harbour report card.

Aggregation of report card grades and scores

A number of methods has 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 2014–15 monitoring 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 2014–15 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 (Figure 2.2a–d). References have been provided to the methods used to calculate the indexed values for coral, seagrass and connectivity 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).

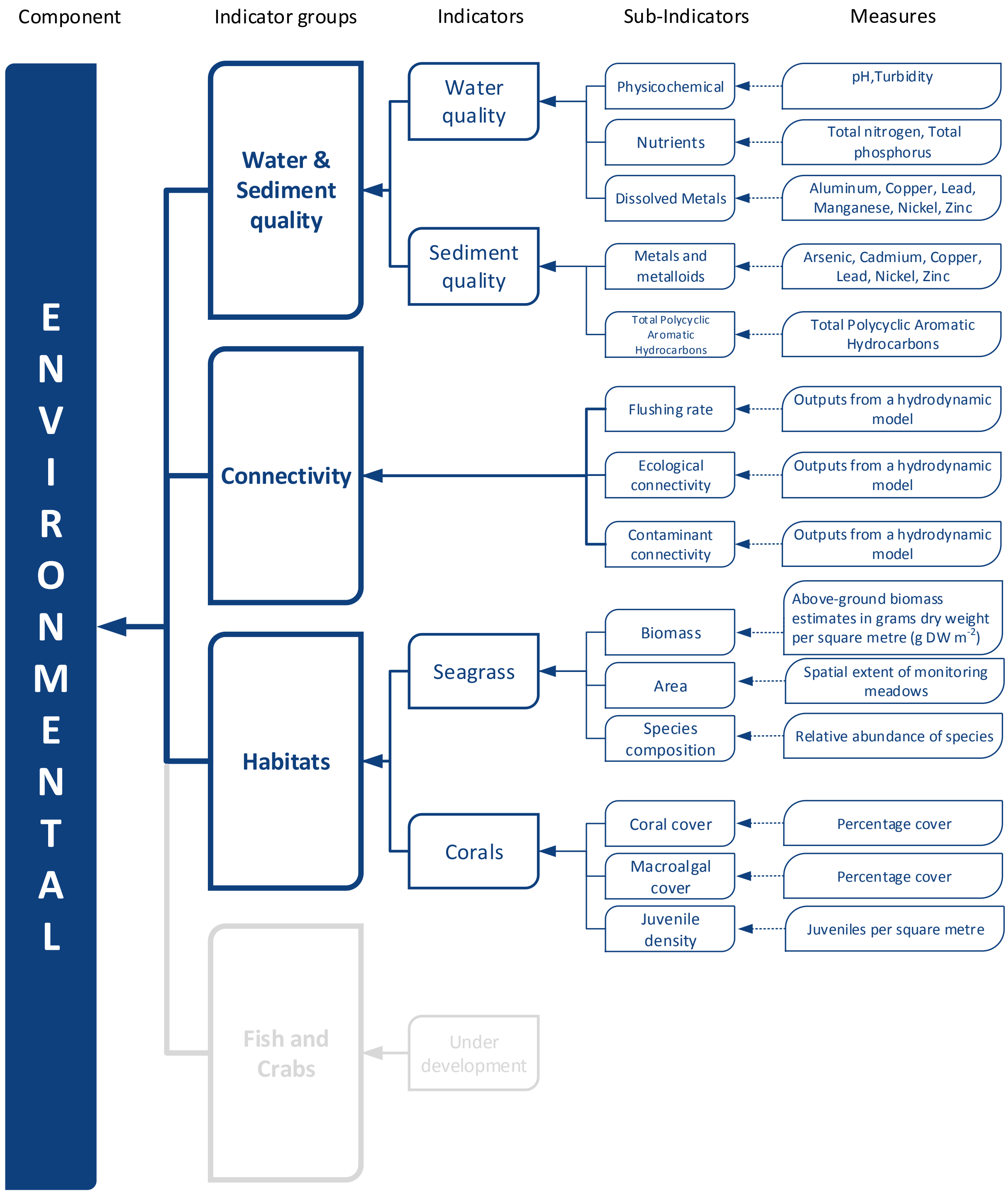


Figure 2.2a: The levels of aggregation used to determine the environmental scores and grades in the 2015 Gladstone Harbour Report Card. Grey boxes denote items to be included in future report cards.

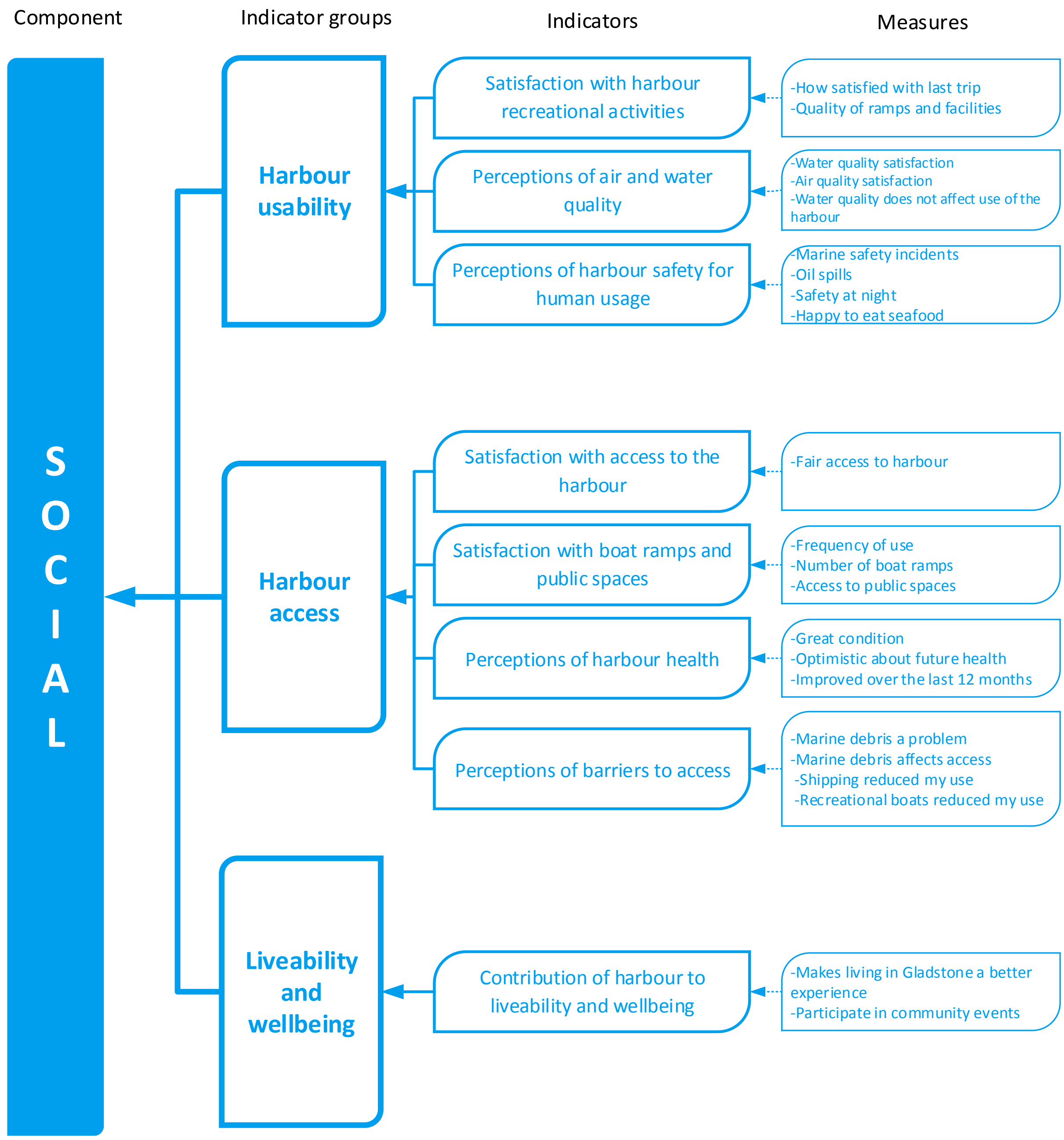


Figure 2.2b: The levels of aggregation used to determine the social scores and grades in the 2015 Gladstone Harbour Report Card.

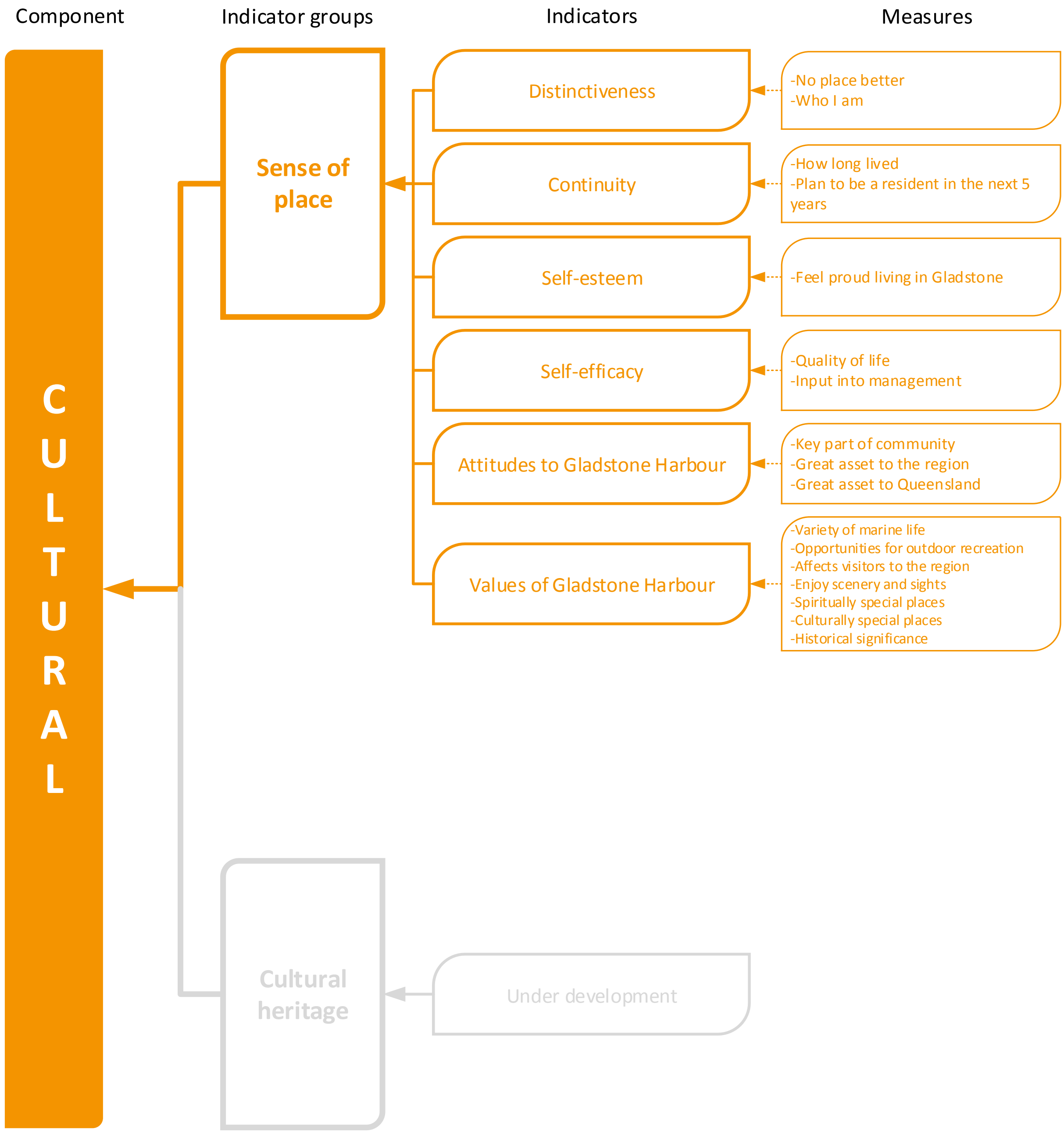


Figure 2.2c: The levels of aggregation used to determine the cultural grades and scores in the 2015 Gladstone Harbour Report Card. Grey boxes denote items to be included in future report cards.

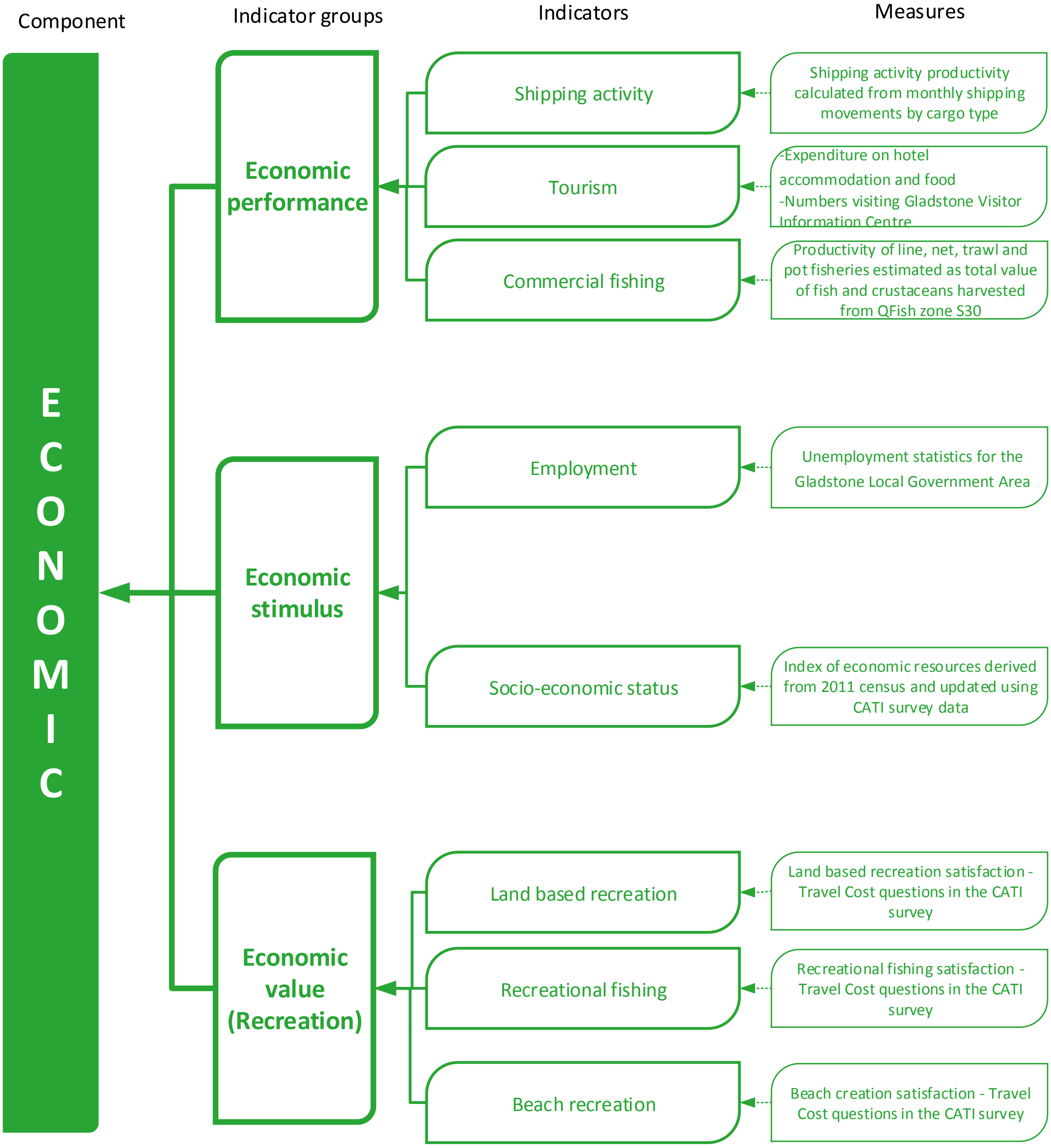


Figure 2.2d: The levels of aggregation used to determine the economic scores and grades in the 2015 Gladstone Harbour Report Card. CATI: Computer-Assisted Telephone Interview.

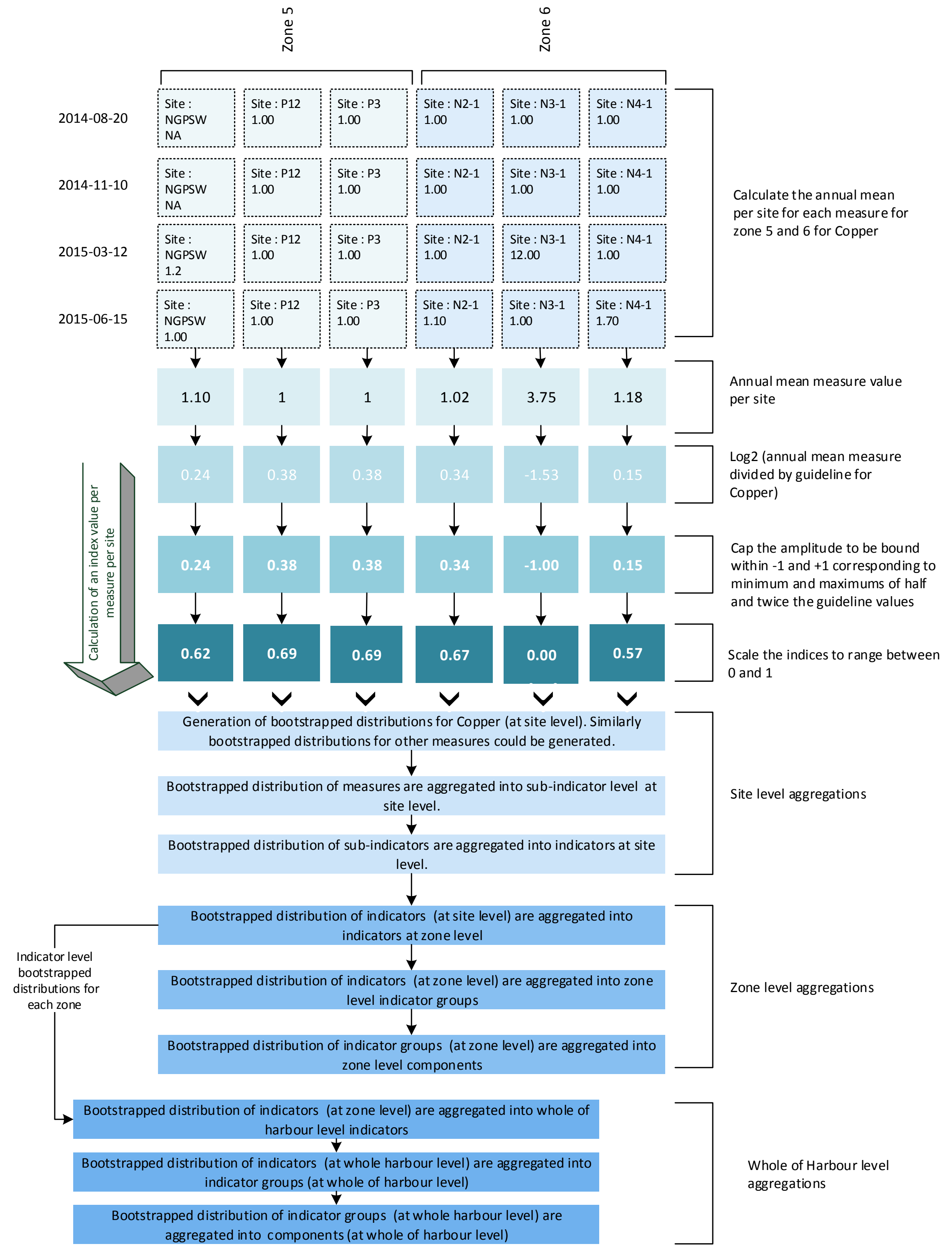


Figure 2.3: Aggregation of report card scores – a worked example using the water quality measure for copper in Zones 5 and 6.

2.2. Confidence ratings and trends

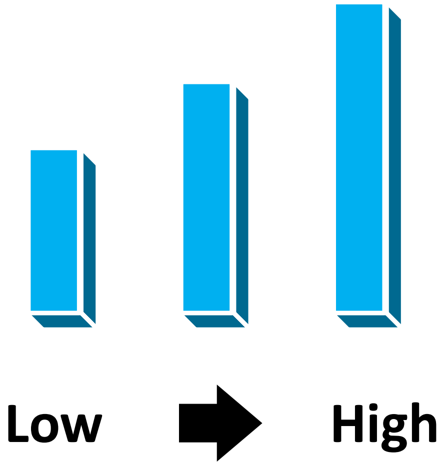
The grade for each of the four components within the report card was assigned a confidence rating on a three point scale (Low, Moderate and High) by the Independent Science Panel. These ratings were informed by an assessment of the appropriateness of the indicators, the number of missing indicators, the adequacy of sampling designs and the availability, completeness and quality of the monitoring data.

The environmental grade received a moderate confidence rating. Although the habitat, water quality and sediment quality data used to derive the grade were regarded as reliable, there were issues with some other data that meant that the full suite of indicators was not available for this year's report card. Indicators for fish and crabs are under development and mangrove data were not available for the 2014-15 year. There were also laboratory issues with some of the water and sediment quality data. The measures chlorophyll-a, orthophosphate and NOx in water, and mercury in sediments, were not reported with sufficient accuracy to determine whether or not they met guidelines, while the data for ammonia in water were regarded as being unreliable due to analytical problems in the laboratory (D. Parry, PCIMP, pers. comm., 9 December 2015). Furthermore, water quality sampling was only conducted on four occasions in 2014-15, and at 'far field' sites (that is sites that were selected to be remote from point sources of pollutants) rather than randomly-selected or representative sites.

The social grade received a high confidence rating. This was because the Computer Assisted Telephone Interviewing (CATI) survey design 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. Some data from Maritime Safety Queensland (MSQ) also contributed to the social grade. The grade for the Social component was based on a complete set of indicators, and there were no issues with data availability, adequacy or quality.

The Cultural grade received a low confidence rating. This was because the Indigenous Cultural Heritage indicator group (which will comprise 50% of this component in future report cards) was not available for 2015. This indicator group will be included from 2016 onwards. Additionally 'sense of place', the sole indicator group on which the 2015 report card score was based, 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 will lead to improved confidence for this indicator group.

The economic grade received a high confidence rating. This was because the CATI survey design that contributed much of the data used to derive this grade is regarded as being reliable, repeatable and the survey was designed specifically for the Gladstone Harbour Report Card. Other data that contributed to the economic grade came from a variety of reputable sources (Table 7.12). The grade for the Economic component was based on a complete set of indicators, and there were no issues with data availability, adequacy or quality.



- Environmental Component
  Moderate confidence
- Social Component
  High confidence
- Cultural Component
  Low confidence
- Economic Component
  High confidence

Figure 2.4: Confidence ratings assigned to the four report card components on a three point scale from low to high.

2.3 Comparisons with the 2014 Pilot Report Card

Comparisons with the 2014 Pilot Report Card are possible for the Social and Economic components, as well as for the five water quality measures that are common to both report cards (turbidity, nitrogen, phosphorus, copper and aluminium). However, comparisons with the overall environmental and cultural grades are not possible as there was no grade for the Cultural component in 2014, and in 2014 the environmental grade was based on six measures of water quality only.

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 nine by including oceanic and estuarine reference sites (Storey et al., 2007). However, these two reference zones were combined in the Port Curtis Eco Card 2008–2010 (PCIMP, 2010) resulting in eight 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).

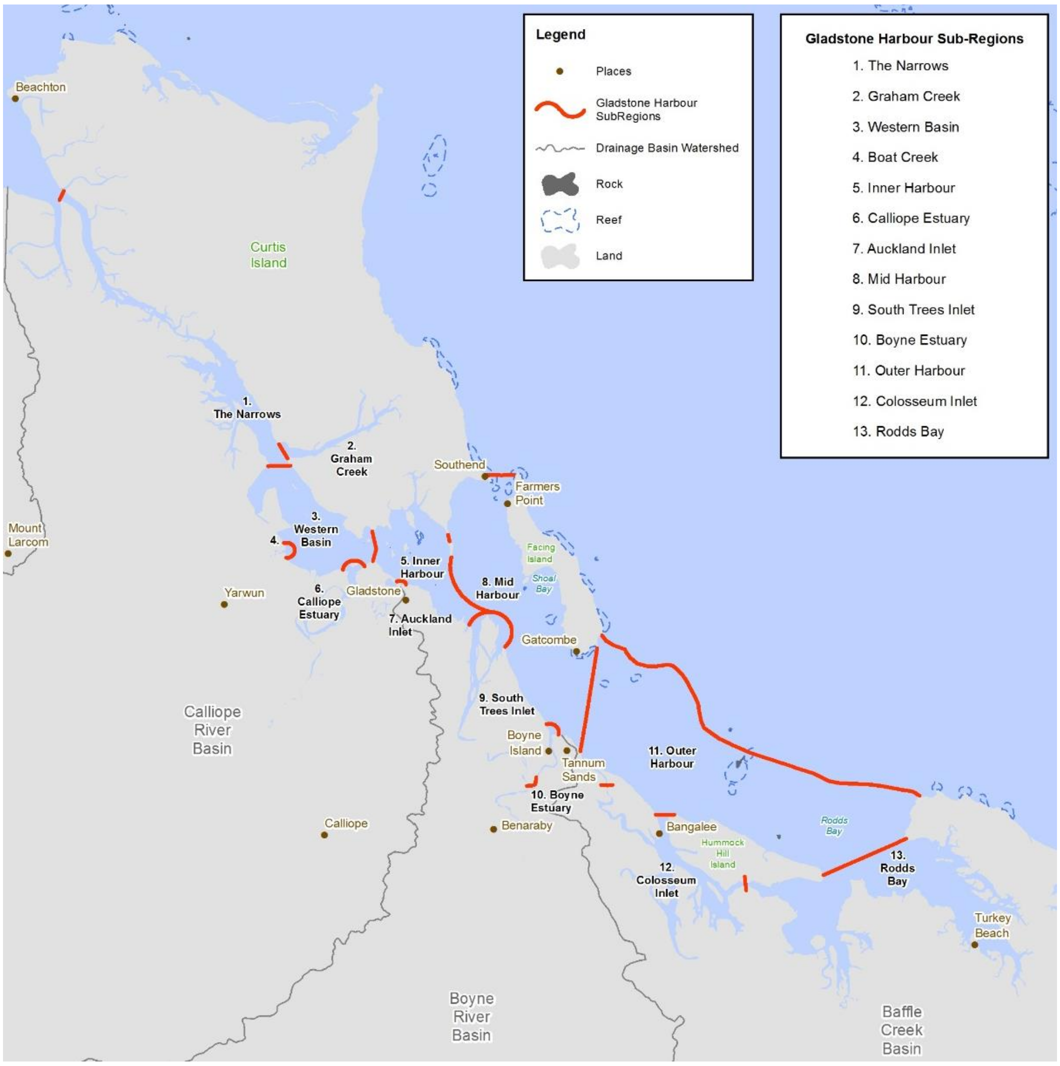


Figure 3.1: The 13 Gladstone Harbour zones for which environmental parameters were measured for the 2015 report card.

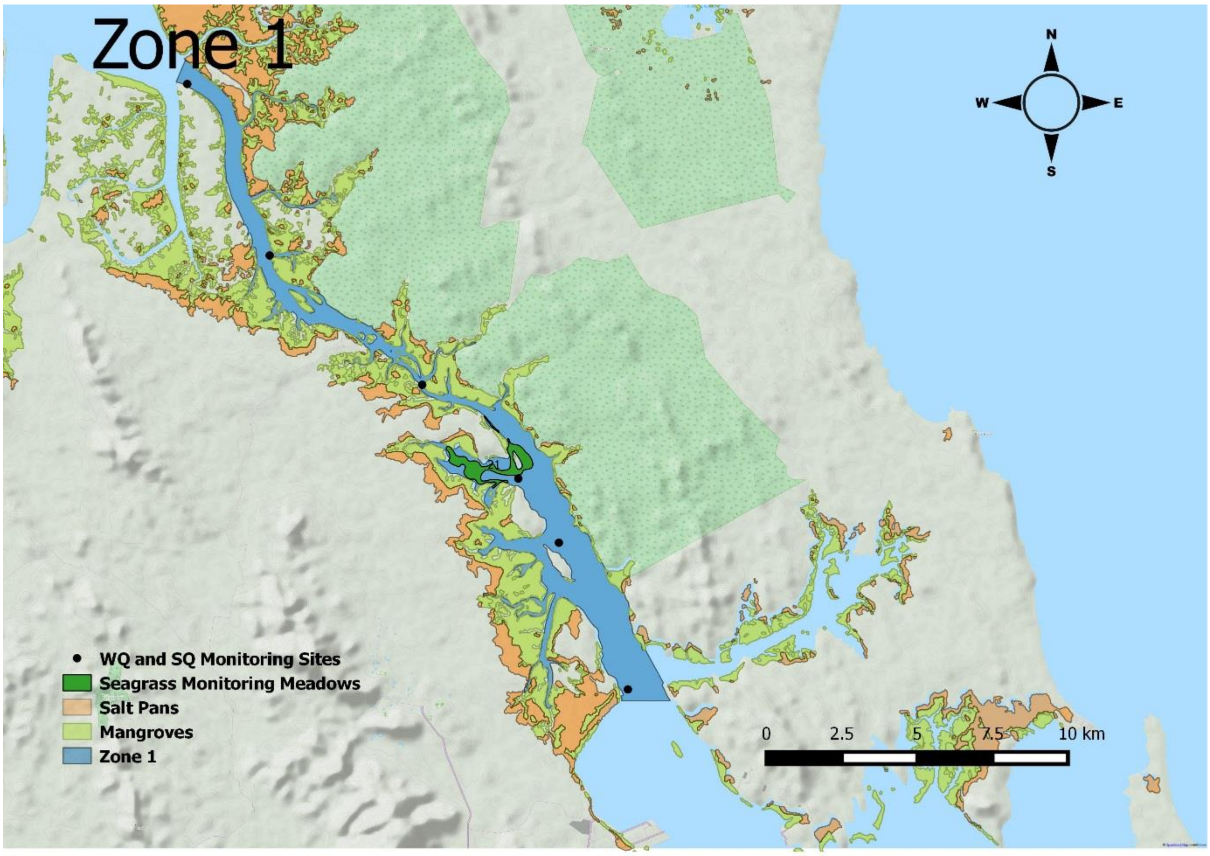


Figure 3.2: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone1: The Narrows.

Six water and sediment quality monitoring sites

One seagrass monitoring meadow

Zone area: 29.25km^2

The Narrows is the northern outlet of the 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 from the south with Keppel Bay in the distance.

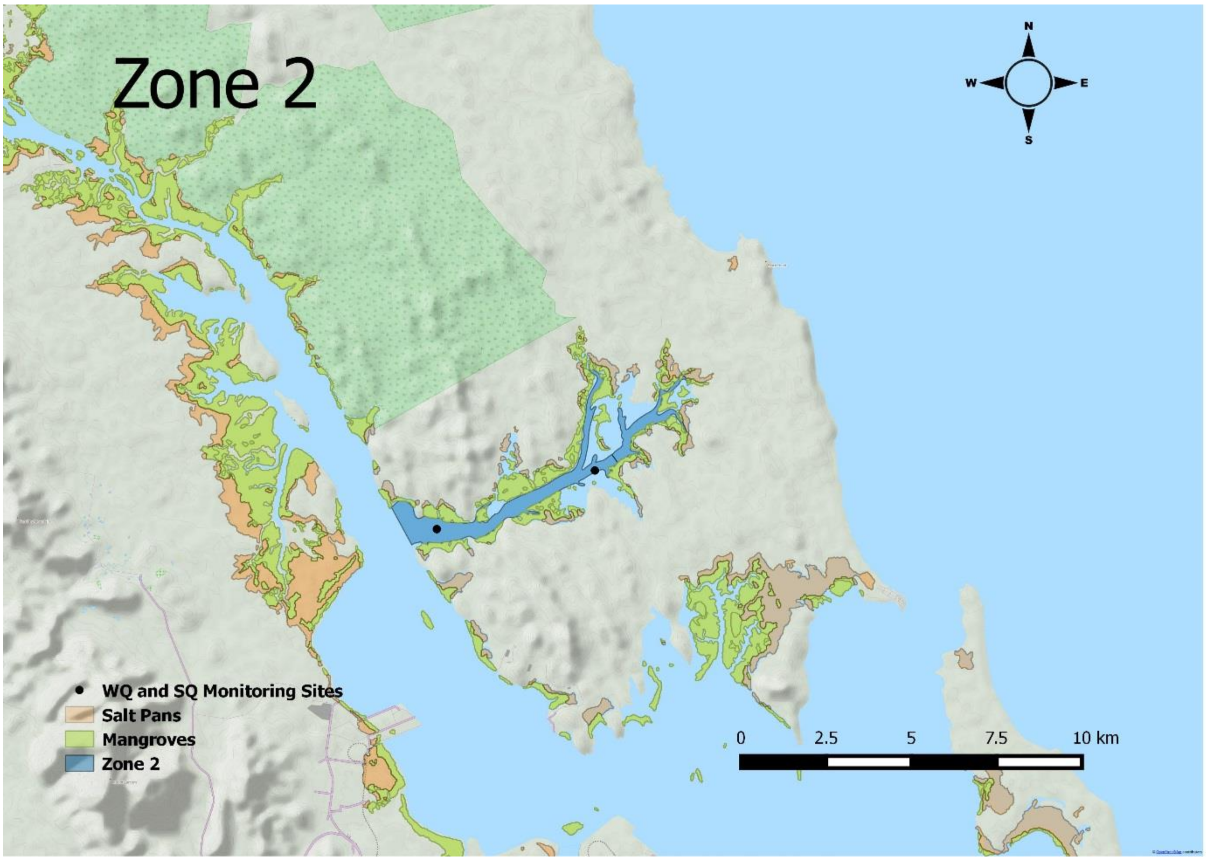


Figure 3.4: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 2: Graham Creek.

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 from the north. Graham Creek is in the middle of the picture and the Western Basin is in the distance.

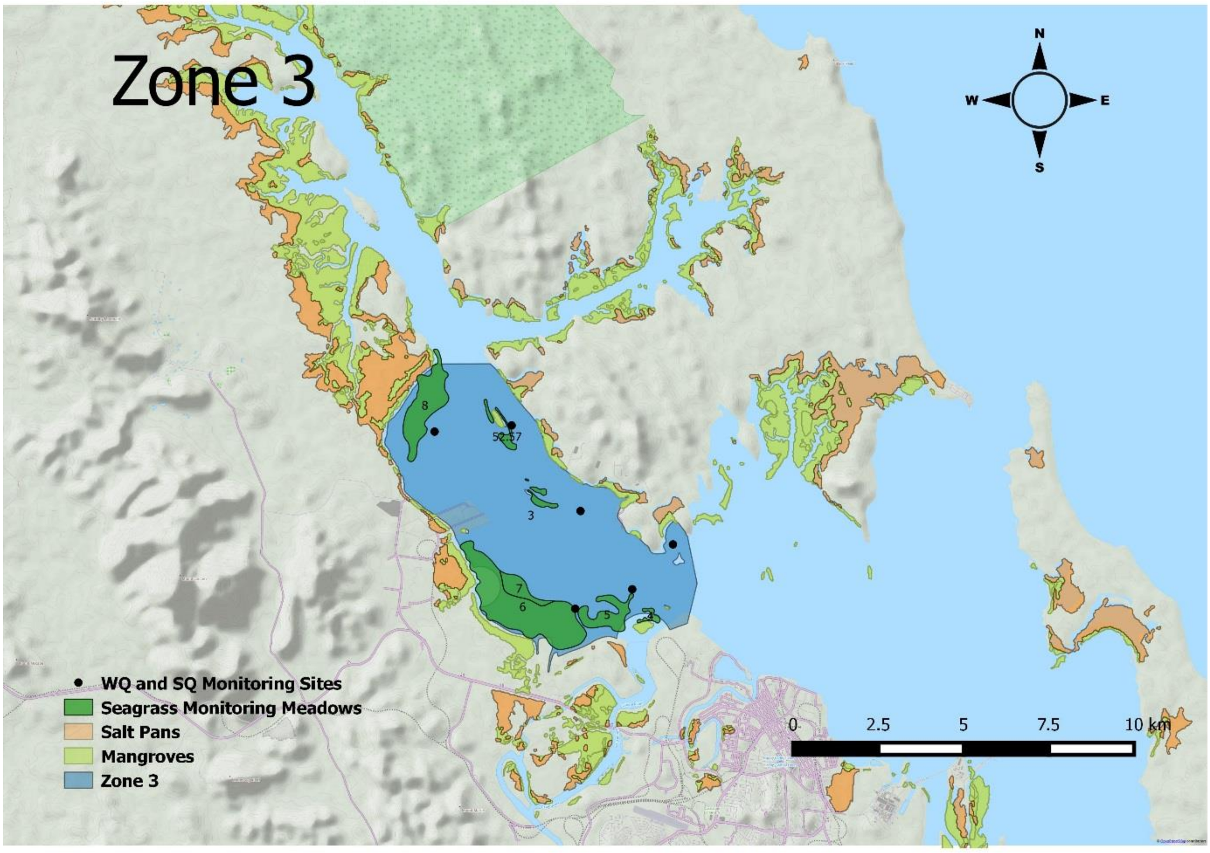


Figure 3.6: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 3: Western Basin.

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 commenced operation 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.

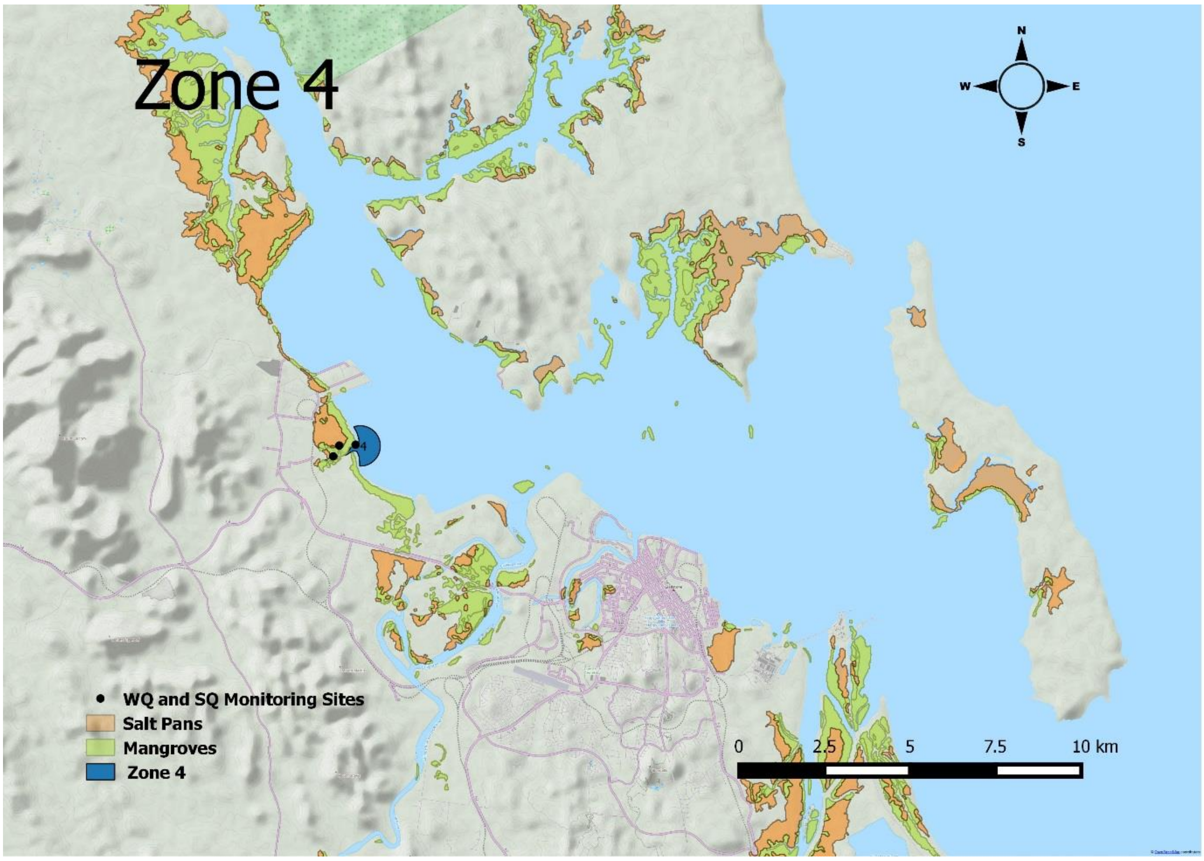


Figure 3.8: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 4: Boat Creek.

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 only includes approximately 2km of waterway and a small open harbour area near the mouth.

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

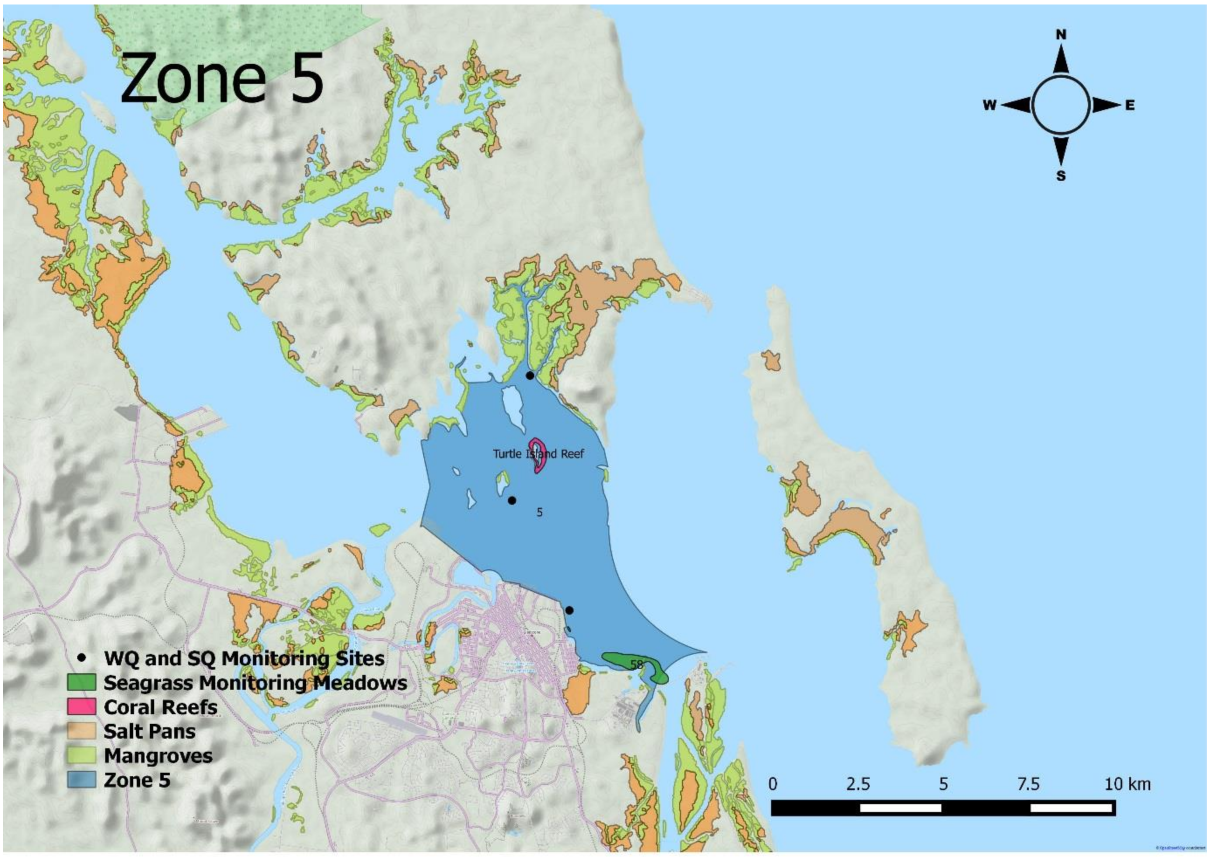


Figure 3.10: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 5: Inner Harbour.

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 monitored seagrass meadow in the north 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.

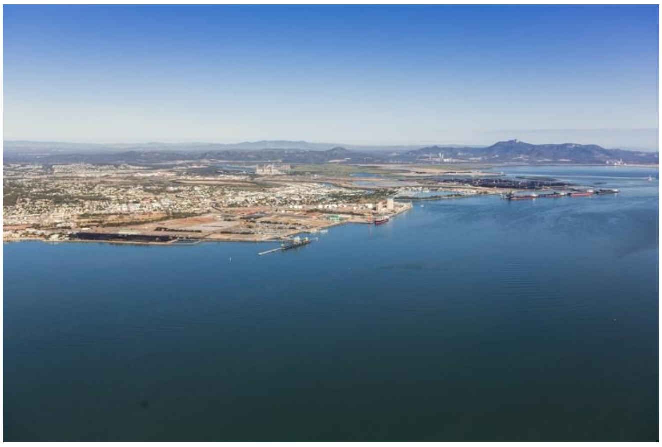


Figure 3.11: The Inner Harbour from the north-east, with Auckland Point wharves and the City of Gladstone on the left and the R.G. Tanna coal loading facility on the right.

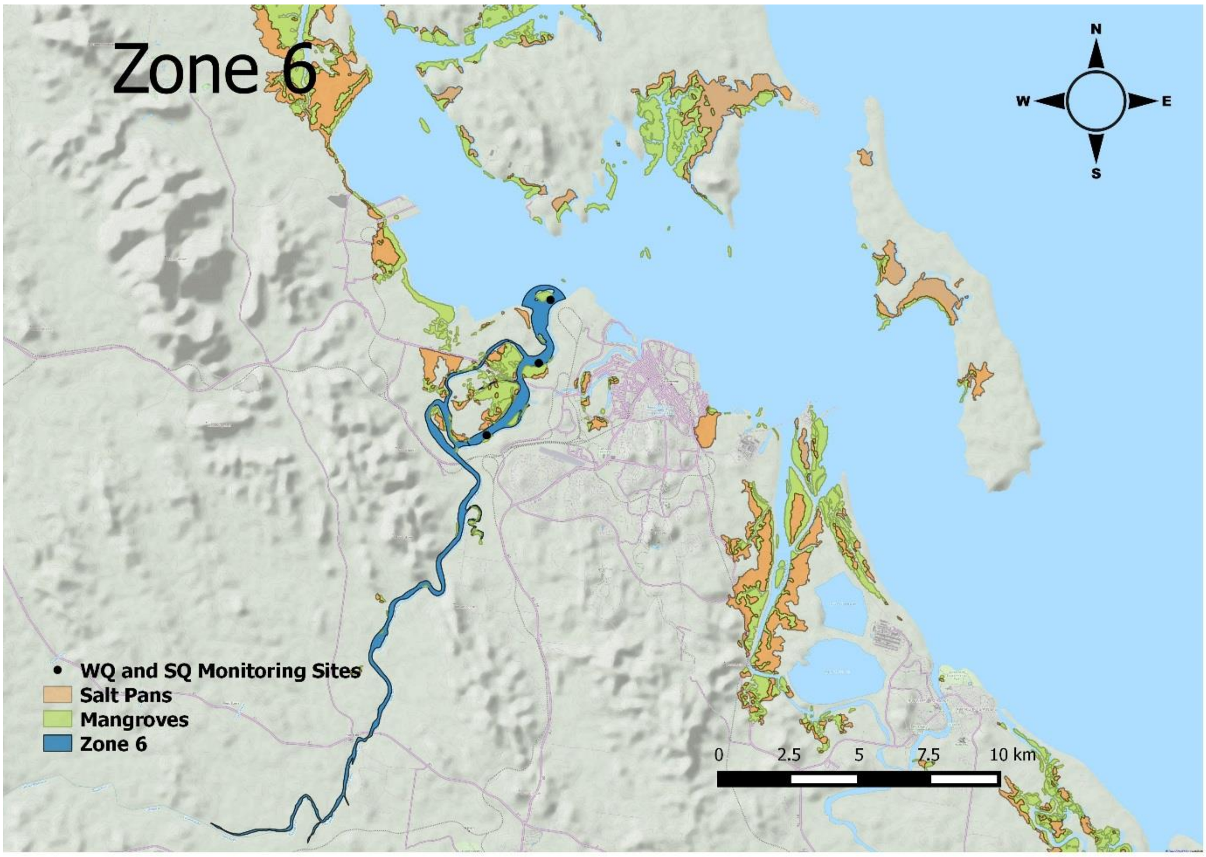


Figure 3.12: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 6: Calliope Estuary.

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 RG Tanna's 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, from the north-east.

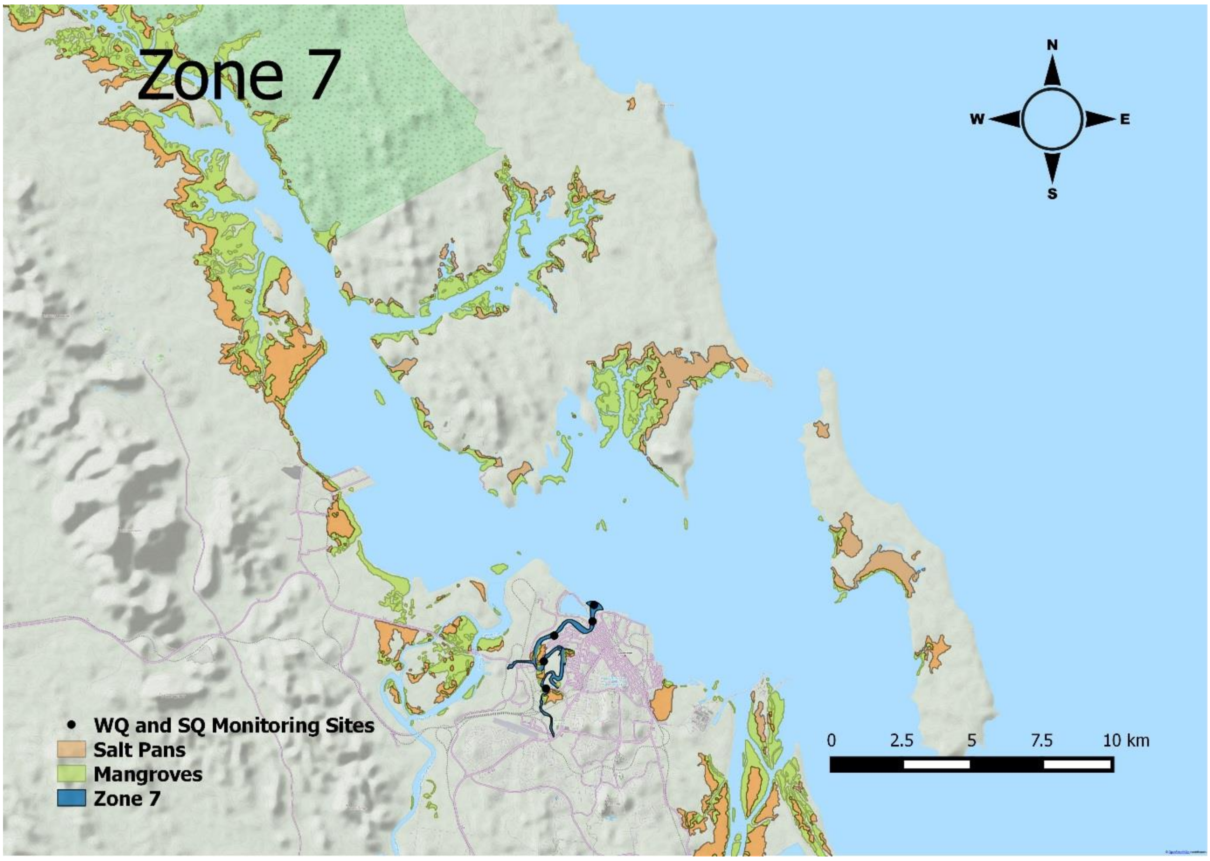


Figure 3.14: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 7: Auckland Inlet.

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

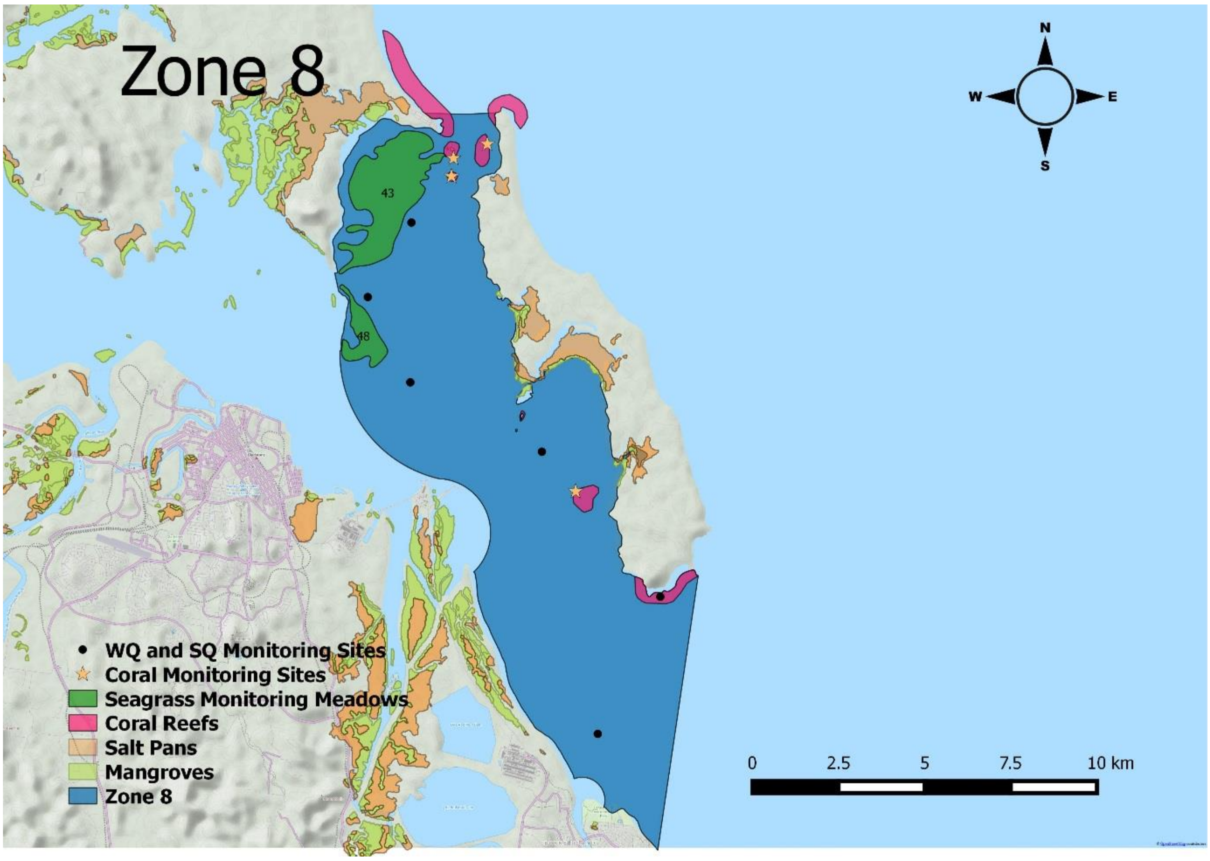


Figure 3.16: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 8: Mid Harbour.

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

Zone area: 95.73km^2

The Mid Harbour zone 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, which is adjacent to The Great Barrier Reef Marine Park.

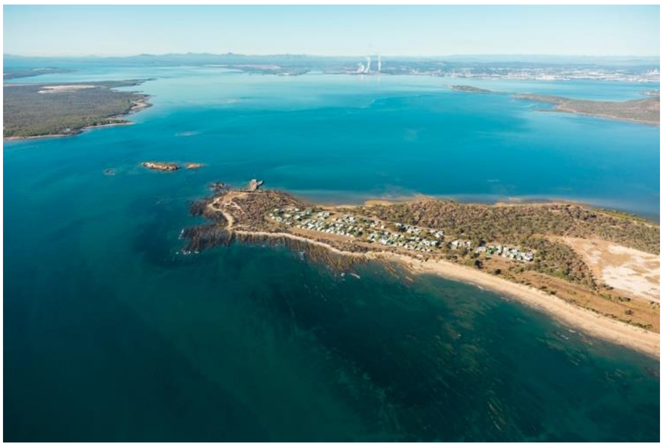


Figure 3.17: The Mid Harbour from north-east. Curtis Island is in the foreground and the Inner Harbour is in the background.

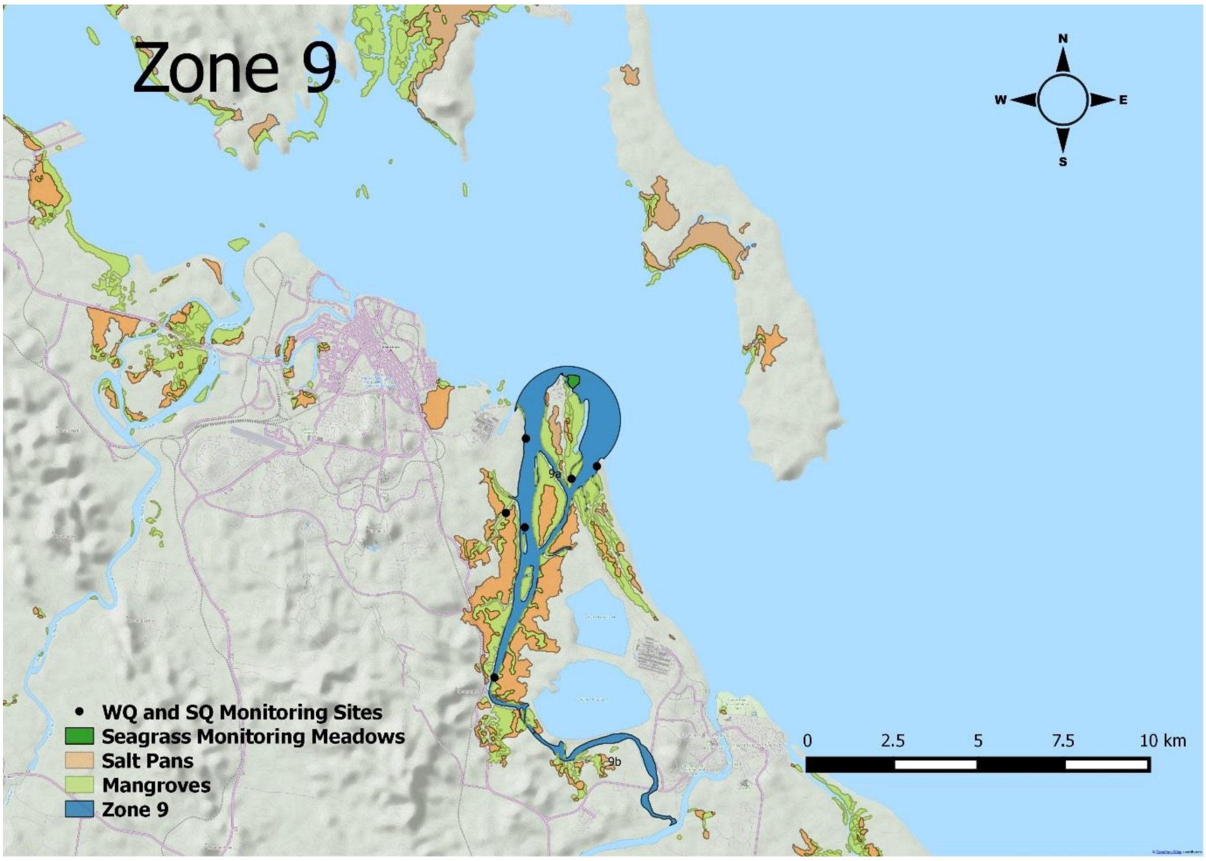


Figure 3.18: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 9: South Trees Inlet.

Six water and sediment quality monitoring sites Zone area: 9.45km^2
One seagrass monitoring meadow

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, from the north, showing South Trees Island in the foreground and Boyne Island in the background.

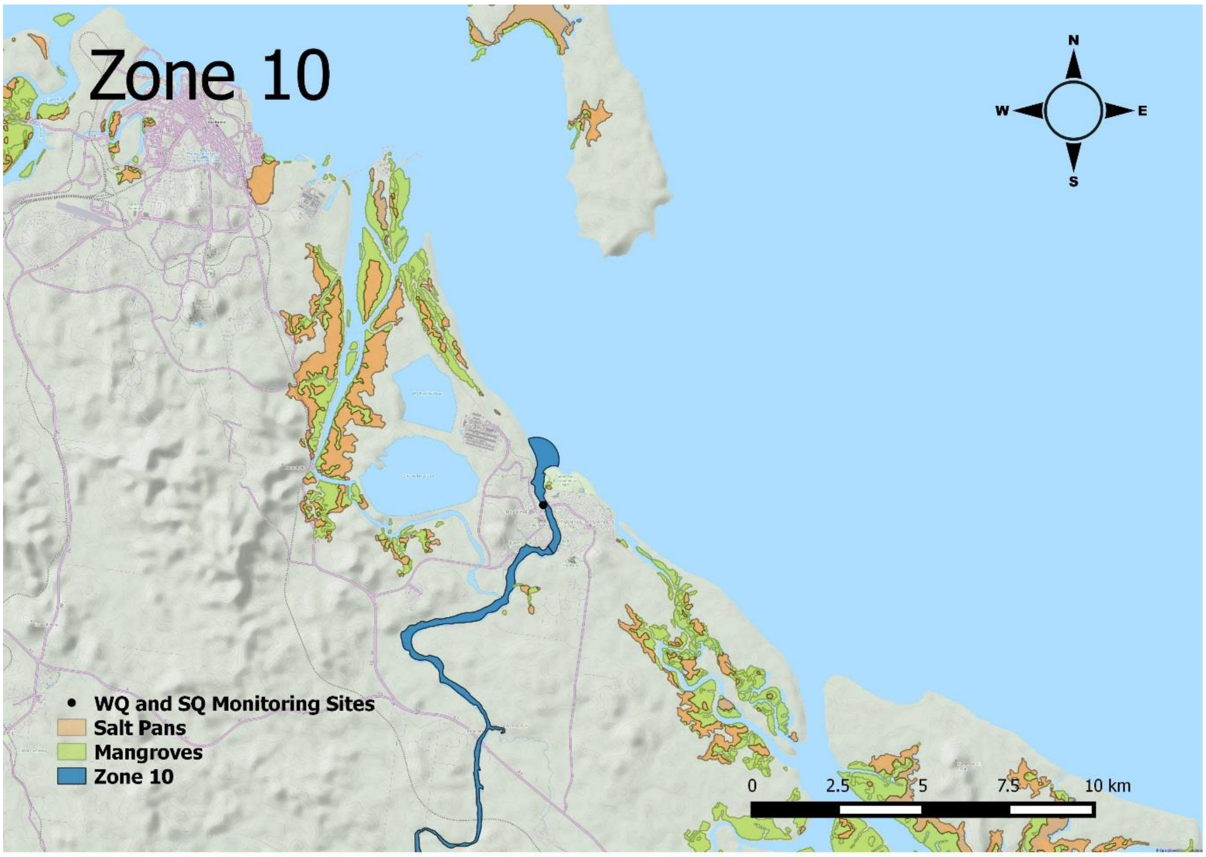


Figure 3.20: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 10: Boyne Estuary.

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 predominately 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 from the north-east. Boyne Island is on the right and Tannum Sands on the left.

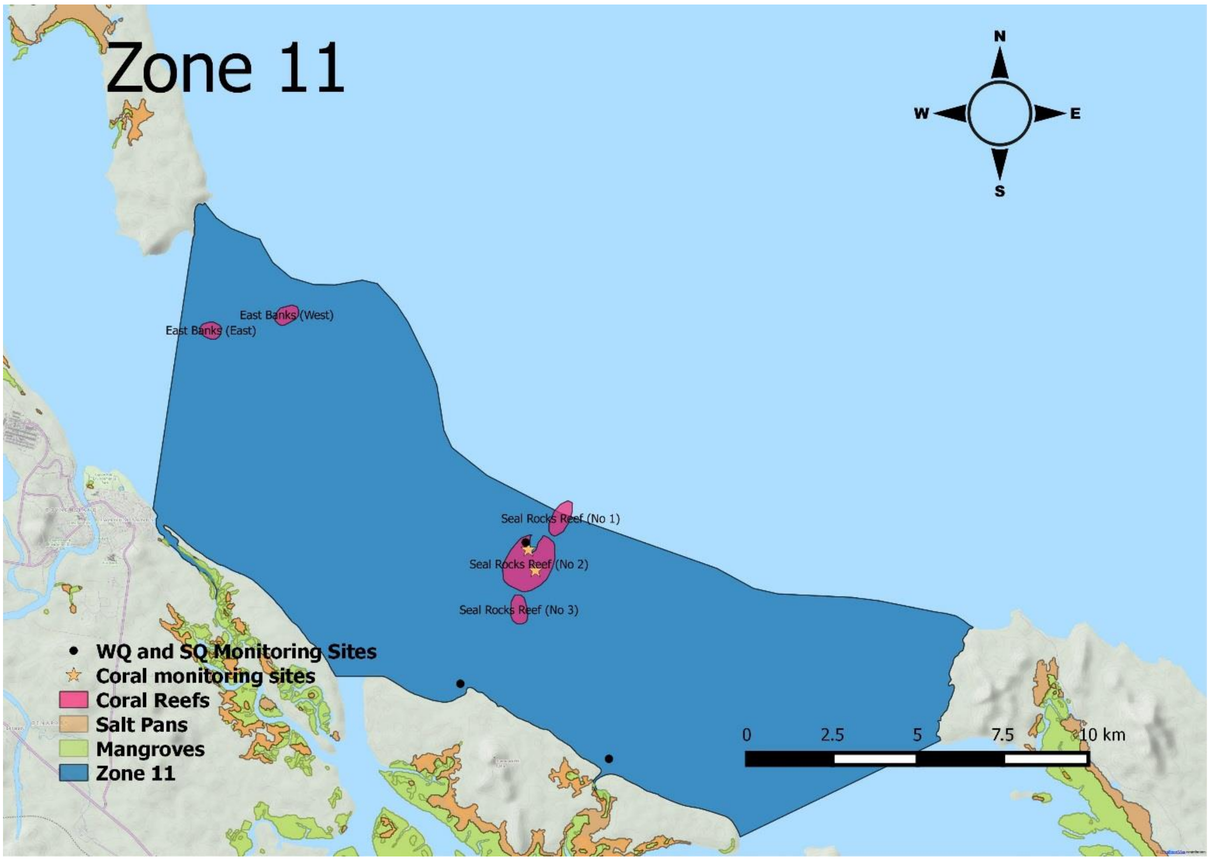


Figure 3.22: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 11: Outer Harbour.

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.

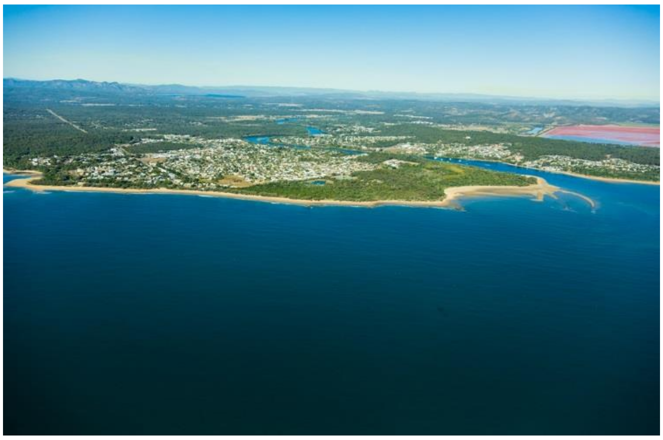


Figure 3.23: The Outer Harbour and Tannum Sands, from the north-east. Boyne Island and one of Gladstone's red mud (bauxite) dams are on the right.

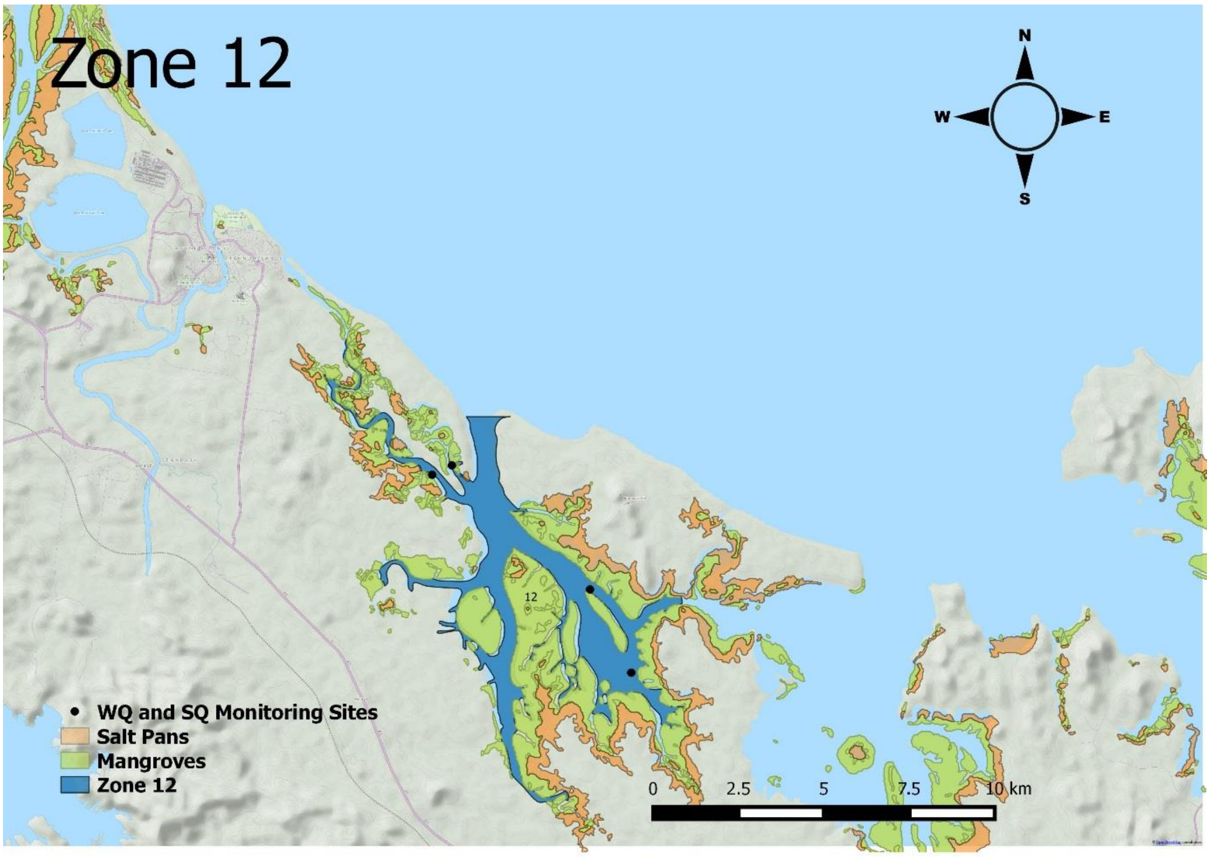


Figure 3.24: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 12: Colosseum Inlet.

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.

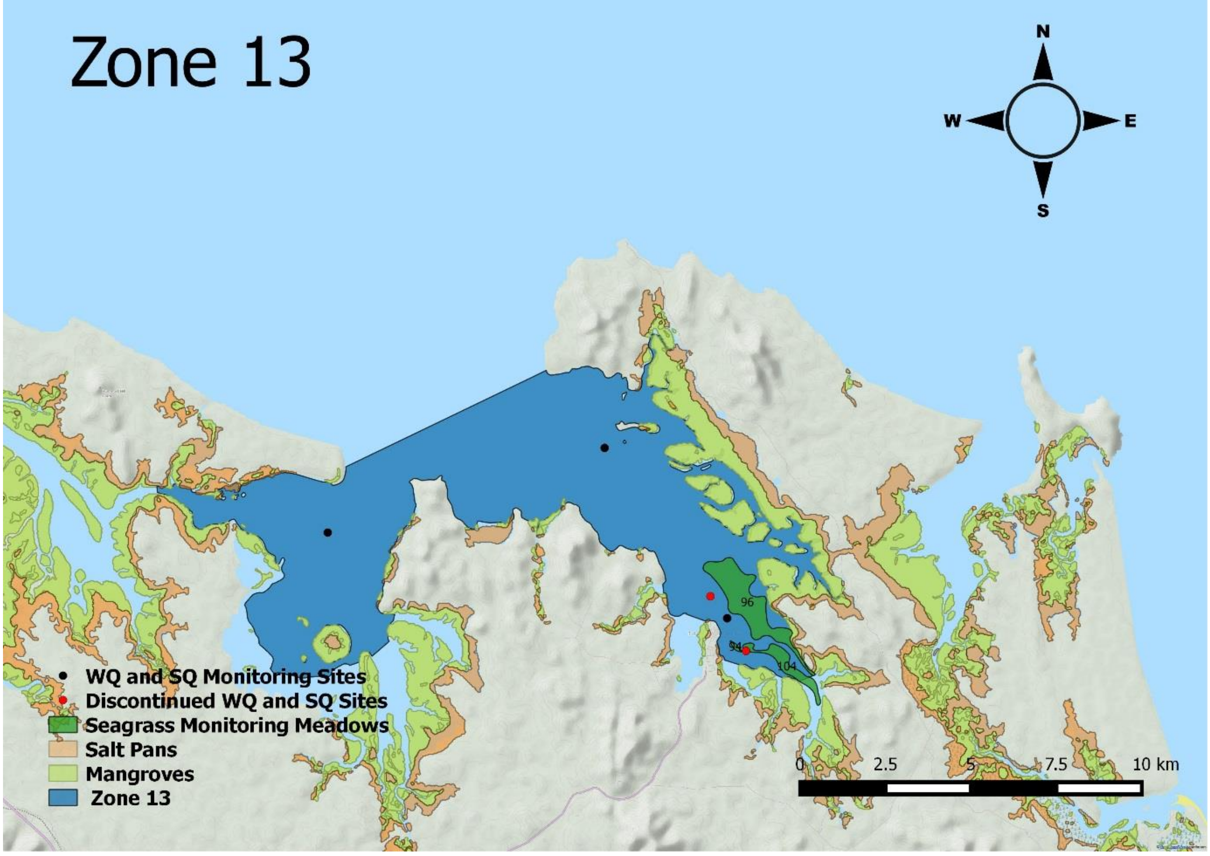


Figure 3.26: Habitat types and water and sediment quality sampling sites in Gladstone Harbour Zone 13: Rodds Bay.

Five 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. Although there were five sites in Rodds Bay, only three were sampled on each sampling occasion. This is because two sample sites were omitted in June 2015, and another two sites were added (Figure 3.14). 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, with Rodds Peninsula in the foreground.

3.2. Social, cultural and economic reporting areas

Data that contributed to the social, cultural and economic grades were collected from the Gladstone region. Participants in the Computer-Assisted Telephone Interview (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). Shipping data for the Port of Gladstone were provided by the Gladstone Ports Corporation (GPC). Commercial fishing data were collected from the area within the Queensland Fisheries S30 Grid (QFish S30). This includes Gladstone Harbour and the open coastal waters immediately adjacent to the harbour (Figure 3.29).

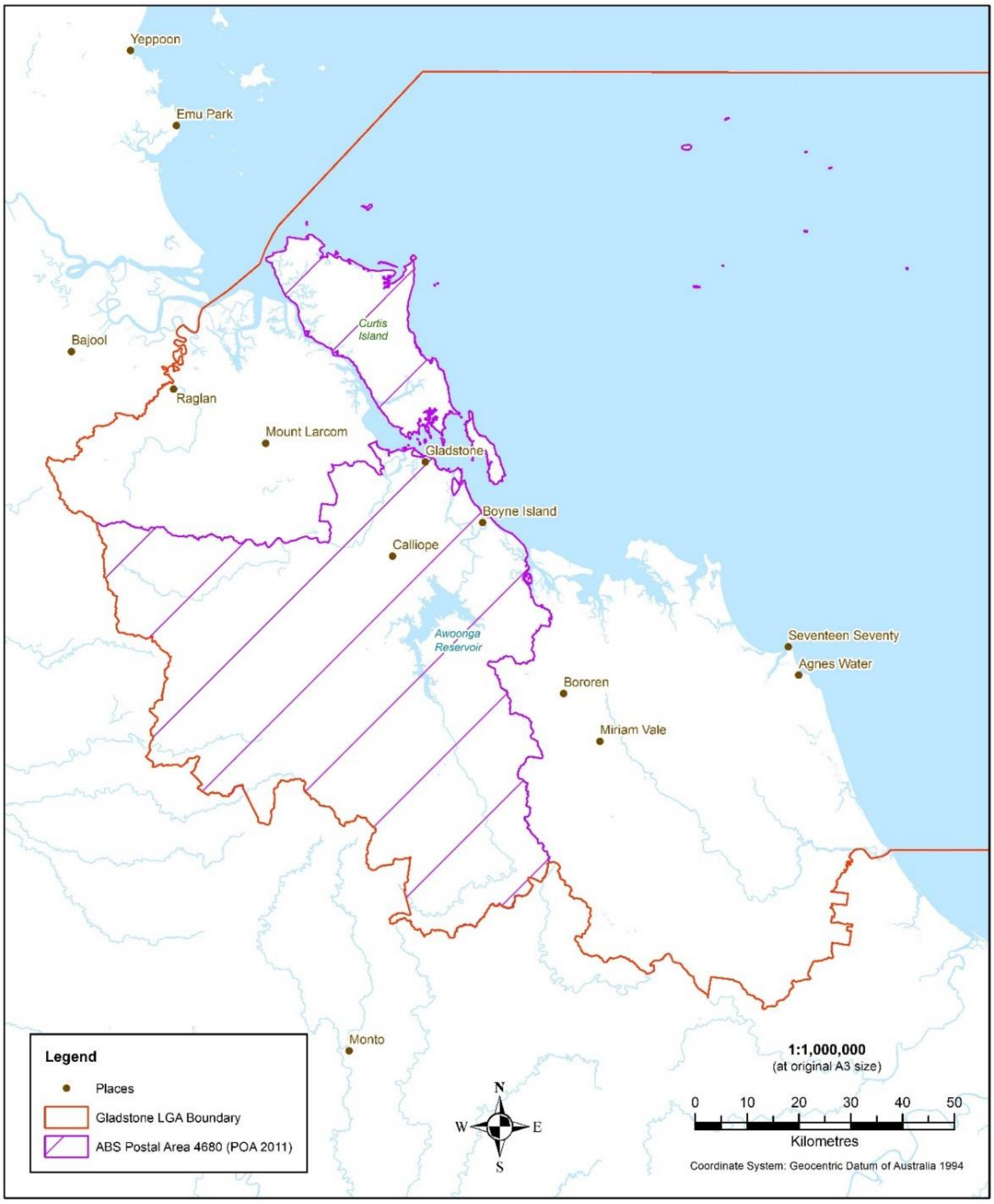


Figure 3.28: The Gladstone region showing the mainland extent of the Gladstone Local Government Area (LGA) and the Gladstone 4680 postcode area. Both were used to define areas from which some social, cultural and economic data were collected.

Gladstone Healthy Harbour Partnership

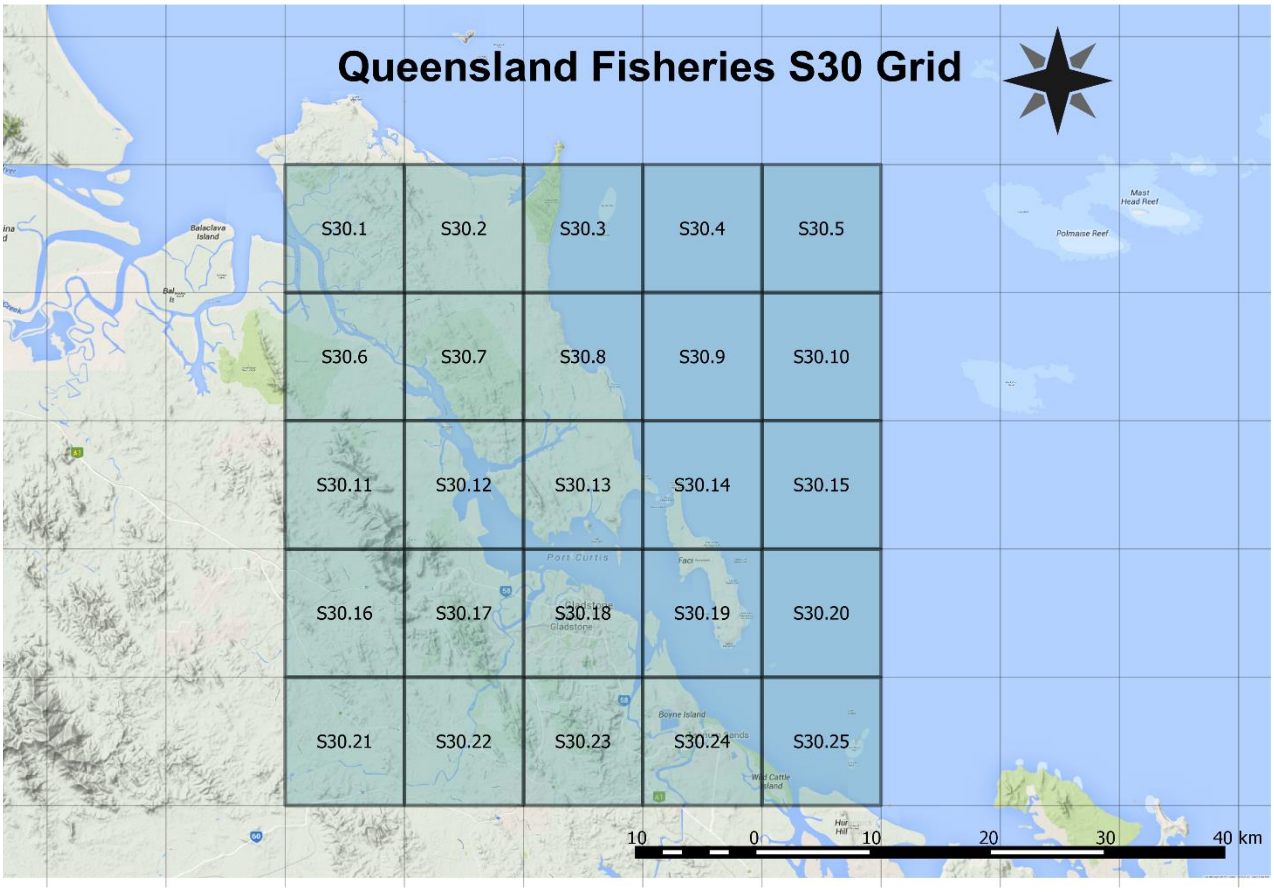


Figure 3.29: The Queensland Fisheries S30 Grid. Data from this grid are used to calculate the commercial fishing indicator.

4. The Environmental component

The Environmental component of the 2015 report card consists of three indicator groups: water and sediment quality, habitats and connectivity. A fourth indicator group, fish and crabs, is under development and will be included in the 2016 report card. The water and sediment quality and connectivity indicator groups contain their full suite of indicators and sub-indicators, however, additional measures for water and sediment quality may be included in subsequent report cards. An additional habitat indicator, mangroves, will be included from 2016 subject to data availability.

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 2015 Report Card, guideline values were provided by:

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

See Appendix 5 for further details.

Guideline values differ amongst 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., 2005)
- 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 2015 Gladstone Harbour Report Card. Those data were based on samples collected from 51 sites across the 13 harbour zones in August and November 2014 and March 2015, and from 46 of those sites and an additional 5 sites in June 2015 (Figures 3.2 to 3.27).

Ten water quality parameters were assessed for the 2015 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 throughout 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 three independent laboratories: the National Measurement Institute (NMI), Envirolab Services Pty Ltd and ALS Global. NMI is the Australian Government's peak measurement body for biological, chemical, legal, physical and trade measurement. Laboratories used to analyse PCIMP data have been accredited by the National Association of Testing Authorities, Australia to ensure compliance with relevant international and Australian standards and competency in providing consistently reliable testing, calibration, measurement, and inspection data.

Table 4.1: Water quality indicators included in the 2015 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
	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 2015 Gladstone Harbour Report Card assessed six sediment metals, one metalloid (arsenic) and total Polycyclic Aromatic Hydrocarbons (Total PAHs) (Table 4.2). Sediment nutrients were not included as there are currently no relevant national or international guidelines. They may be included in future report cards should relevant guidelines become available.

Sediment sampling to collect data for the 2015 Gladstone Harbour Report card was conducted by PCIMP between 22 and 24 June at 51 harbour sites. These were the same sites used for water quality sampling in that month (Figures 3.2 to 3.27). Separate grab samples were collected for PAH measurements and other 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 photographed. For Total PAH and total organic carbon analysis, the top 10mm of sediment was placed into a clean sample jar. Other sediment quality measurements used the top 100mm. 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
	Total polycyclic aromatic hydrocarbons (PAHs)		Simpson et al., 2013

See Appendix 6 for a full list of guidelines.

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 heavy metals. As a rule of thumb, the solubility of most toxic metals tends to increase at low pH. Plant and animal species usually tolerate a narrow pH range, outside of which there are adverse impacts on their ecology and behaviour.

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 reduces light levels reaching the seabed reducing 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

Total nitrogen 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, condensed phosphates, organically bound phosphate and particulate phosphate. The total phosphorus 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 runoff, weathering of rocks, 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 the growth of corals.

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, invertebrates, fish and other 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 anthropogenic intervention, 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 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 is toxic to all aquatic species.

Cadmium

Cadmium (Cd) is a non-essential and toxic element to plants and animals. The sources of cadmium in oceanic waters may be natural (e.g. volcanic activities, weathering of rocks) 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 levels of cadmium in aquatic systems can lead to range of toxic effects on 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 levels 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 and Anastasi 2010).

Nickel

Nickel (Ni) the 24th most abundant metal in the Earth's crust and is an essential trace metal for all organisms (Cempel and Nikel 2006). Nickel in waterways can come from sources that are industrial (e.g. industrial discharges, handling of coal) or natural (e.g. through weathering of rocks). In water, nickel is mostly adsorbed onto sediment and suspended particles. At high levels, 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 levels, zinc becomes toxic to organisms.

4.1.2.4. Polycyclic Aromatic Hydrocarbons

Polycyclic Aromatic Hydrocarbons (PAHs) are a group of complex organic compounds. PAHs are classified by source into petrogenic PAHs (from coal, oil and gas) and pyrogenic PAHs (formed by incomplete combustion of carbon-containing products such as coal, oil, gas, garbage and timber), although there are also some biogenic PAHs (formed through biological activity). PAHs associated with petroleum, creosote or coal tar in sediments may have a moderate level of bio-availability. Eighteen PAHs (as total PAHs, standardised to 1% total organic carbon) were assessed for the 2015 Report Card using the methodology described by Simpson et al. (2013).. Algae and molluscs concentrate PAHs from the environment, which may bioaccumulate up the food chain. The toxic effects of PAHs tend to be most pronounced in crustaceans.

4.1.3. Development of indicators and grades

The initial list of candidate measures was established to address report card objectives developed from the community vision statements. The ISP short-listed those measures further by following the recommendations of the qualitative modelling work undertaken by Dambacher et al. (2013). A subset of six of those measures was piloted in 2014 and this subset was expanded and refined for the 2015 Report Card based on the following factors:

- relevance as a measure of water or sediment quality in Gladstone Harbour
- availability of relevant guidelines
- availability of relevant data

4.1.4. Results

4.1.4.1 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 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 2015 Report Card was a B (0.81) and all harbour zones received good or very good scores for overall water quality (Table 4.3).

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

Water quality	Physicochemical	Nutrients	Dissolved metals	Overall
1. The Narrows	0.81	0.48	0.95	0.82
2. Graham Creek	0.88	0.58	0.95	0.86
3. Western Basin	0.85	0.44	0.94	0.82
4. Boat Creek	0.69	0.23	0.86	0.69
5. Inner Harbour	0.92	0.60	0.95	0.88
6. Calliope Estuary	0.97	0.49	0.89	0.88
7. Auckland Inlet	0.71	0.45	0.94	0.77
8. Mid Harbour	0.76	0.55	0.92	0.80
9. South Trees Inlet	0.89	0.42	0.95	0.85
10. Boyne Estuary	0.68	0.11	0.93	0.70
11. Outer Harbour	0.80	0.59	0.95	0.84
12. Colosseum Inlet	0.78	0.32	0.95	0.78
13. Rodds Bay	0.78	0.45	0.93	0.80

Of the two physicochemical measures, turbidity received poor or very poor scores (Table 4.4). Three harbour zones (Boat Creek, Auckland Inlet and Boyne Estuary) received turbidity scores between 0.38 and 0.42 which indicates relatively high turbidity levels. The very high scores for pH in all zones indicates that this measure was good or very good.

Scores for the nutrients sub-indicator group were generally low across all harbour zones (Table 4.3). Two zones received very poor nutrient scores: Boyne River Estuary (0.11) and Boat Creek (0.23) (Table 4.3). The other zones received scores ranging between 0.32 (Colosseum Inlet) and 0.60 (Inner Harbour). Scores for total nitrogen ranged from 0.00 (Boyne Estuary) to 0.60 (Mid Harbour), with nine zones receiving scores of less than 0.50 and four zones receiving scores of between 0.50 and 0.60. Scores for total phosphorus ranged from 0.05 (Boat Creek) to 0.72 (Outer Harbour) (Table 4.4).

Low levels of dissolved metals were recorded across all 13 zones. Very good scores (> 0.85) were recorded for lead, nickel and zinc across all zones, and for aluminium and manganese in all zones except for Boat Creek (Table 4.4), which received 0.76 for aluminium and 0.77 for manganese. Copper scores ranged from 0.42 (Calliope Estuary) to 0.69 in three zones (Table 4.4).

Table 4.4: Scores for water quality measures for each of the 13 zones in the 2015 Gladstone Harbour Report Card.

Zone	Physicochemical		Nutrients		Metals					
	pH	Turbidity	Total nitrogen	Total phosphorus	Aluminium	Copper	Lead	Manganese	Nickel	Zinc
1. The Narrows	1.00	0.62	0.50	0.45	1.00	0.67	1.00	1.00	1.00	1.00
2. Graham Creek	1.00	0.76	0.47	0.69	1.00	0.69	1.00	1.00	1.00	1.00
3. Western Basin	1.00	0.69	0.48	0.41	1.00	0.62	1.00	1.00	1.00	1.00
4. Boat Creek	1.00	0.39	0.40	0.05	0.76	0.61	1.00	0.77	1.00	1.00
5. Inner Harbour	1.00	0.84	0.58	0.62	1.00	0.67	1.00	1.00	1.00	1.00
6. Calliope Estuary	1.00	0.93	0.46	0.53	1.00	0.42	0.96	1.00	1.00	1.00
7. Auckland Inlet	1.00	0.42	0.52	0.38	1.00	0.62	1.00	1.00	1.00	0.99
8. Mid Harbour	1.00	0.53	0.60	0.50	0.89	0.67	1.00	1.00	0.99	0.97
9. South Trees Inlet	1.00	0.78	0.48	0.35	1.00	0.68	1.00	1.00	1.00	1.00
10. Boyne Estuary	1.00	0.38	0.00	0.21	1.00	0.56	1.00	1.00	1.00	1.00
11. Outer Harbour	0.99	0.64	0.46	0.72	1.00	0.69	1.00	1.00	1.00	1.00
12. Colosseum Inlet	1.00	0.55	0.29	0.35	1.00	0.69	1.00	1.00	1.00	1.00
13. Rodds Bay	1.00	0.56	0.37	0.53	1.00	0.69	0.87	1.00	1.00	1.00

4.1.4.2. Sediment quality

The overall sediment quality score was derived from two sub-indicator groups: metals and metalloids, and total PAHs. Five metals (cadmium, copper, lead, nickel and zinc), and the metalloid arsenic were assessed. Eighteen PAHs were measured and used to calculate total PAHs (normalised to 1% total organic carbon) as per the method of Simpson et al. (2013) (Table 4.5).

The overall grade for sediment quality was an A (0.98). Both sub-indicator groups received very good scores (0.85–1.0) indicating levels that were well within the guideline values for all measures assessed.

Zone scores for sediment quality ranged from 0.94 in The Narrows to 1.00 in Boyne Estuary and Colosseum Inlet (Table 4.6). Low levels of metals and metalloids were reported across all harbour zones. Copper, lead and zinc received very good scores (0.85 to 1.0) in all zones. Cadmium received very good scores in all zones except The Narrows where it received a score of 0.84. Arsenic received very good scores in 9 of the 13 zones; good scores in the Mid Harbour (0.82), South Trees Inlet (0.83) and Rodds Bay (0.80); and a satisfactory score in the Outer Harbour (0.50). Nickel received very good scores in seven harbour zones; good scores in Graham Creek (0.81), Boat Creek (0.70), the Inner Harbour (0.83) and South Trees Inlet (0.82); and satisfactory scores in The Narrows (0.53) and Auckland Inlet (0.64). Total PAHs received a score of 1.00 in each harbour zone.

The scores for these two sub-indicator groups are presented in Table 4.7.

Table 4.5: List of the 18 individual polycyclic aromatic hydrocarbons (PAHs) that were measured to derive the measure for total PAHs for the 2015 Gladstone Harbour Report Card.

Acenaphthalene	Benzo(e)pyrene	Fluorene
Acenaphthene	Benzo(g,h,i)perylene	Indeno(1,2,3-cd)pyrene
Anthracene	Benzo(k)fluoranthene	Naphthalene
Benzo(a)anthracene	Chrysene	Perylene
Benzo(a)pyrene	Dibenzo(a,h)anthracene	Phenanthrene
Benzo(b)fluoranthene	Fluoranthene	Pyrene

Table 4.6: Overall sediment quality, metal and metalloids and total PAH scores for each of the 13 zones for the 2015 Gladstone Harbour Report Card.

Sediment quality	Metals and metalloids	Total PAH	Overall
1. The Narrows	0.87	1.00	0.94
2. Graham Creek	0.96	1.00	0.98
3. Western Basin	0.98	1.00	0.99
4. Boat Creek	0.92	1.00	0.96
5. Inner Harbour	0.95	1.00	0.98
6. Calliope Estuary	0.97	1.00	0.98
7. Auckland Inlet	0.91	1.00	0.95
8. Mid Harbour	0.97	1.00	0.99
9. South Trees Inlet	0.94	1.00	0.97
10. Boyne Estuary	0.99	1.00	1.00
11. Outer Harbour	0.92	1.00	0.96
12. Colosseum Inlet	1.00	1.00	1.00
13. Rodds Bay	0.96	1.00	0.98

Table 4.7: Scores for sediment quality measures for each of the 13 zones in the 2015 Gladstone Harbour Report Card.

Zone	Metals and metalloids						Total PAHs
	Arsenic	Cadmium	Copper	Lead	Nickel	Zinc	
1. The Narrows	0.86	0.84	1.00	1.00	0.53	1.00	1.00
2. Graham Creek	0.94	1.00	1.00	1.00	0.81	1.00	1.00
3. Western Basin	0.90	1.00	1.00	1.00	0.96	1.00	1.00
4. Boat Creek	0.87	1.00	0.96	1.00	0.70	1.00	1.00
5. Inner harbour	0.90	1.00	1.00	1.00	0.83	1.00	1.00
6. Calliope Estuary	1.00	1.00	0.86	1.00	0.93	1.00	1.00
7.Auckland Inlet	0.88	1.00	0.90	1.00	0.64	1.00	1.00
8. Mid Harbour	0.82	1.00	1.00	1.00	1.00	1.00	1.00
9. South Trees Inlet	0.83	1.00	1.00	1.00	0.82	1.00	1.00
10. Boyne Estuary	1.00	1.00	1.00	1.00	0.97	1.00	1.00
11. Outer Harbour	0.50	1.00	1.00	1.00	1.00	1.00	1.00
12. Colosseum Inlet	1.00	1.00	1.00	1.00	1.00	1.00	1.00
13. Rodds Bay	0.80	1.00	1.00	1.00	0.99	1.00	1.00

4.1.5. Water and sediment quality conclusions

Water quality

Water quality was relatively uniform across the harbour with all zones receiving good overall scores (Table 4.3). Nutrients (nitrogen and phosphorus) received poor to very poor scores, whereas dissolved metals (aluminium, copper, lead, manganese, nickel and zinc) and physicochemical indicators (pH, turbidity) generally received good to very good scores (Table 4.4). The reasons for nutrient levels generally exceeding guidelines are unclear and require further investigation.

Five measures of water quality can be compared between 2014 and 2015: scores for turbidity, nitrogen, phosphorus and aluminium improved, whereas the score for copper declined.

The causes and sources of the high levels of total nitrogen and total phosphorus throughout most of the harbour, relative to the DEHP guidelines, are not known.

Sediment quality

Sediment quality scores were uniformly very good across all zones of Gladstone Harbour due to low levels of metals (cadmium, copper, lead, nickel and zinc) and total PAHs.

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,

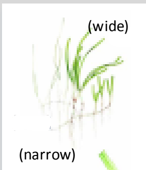
Zostera muelleri
Halophila ovalis
Halophila decipiens
Halophila spinulosa
Halodule uninervis

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. While the area and distribution of the seagrass meadows can vary annually, 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, with the most extensive seagrass beds occurring 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 effect light penetration. High nutrient levels caused by agricultural or urban run-off can cause algal blooms that shade seagrass. Increases in water turbidity from suspended sediments can reduce seagrass growth and reduce the size and extent of extant seagrass meadows 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 has been monitored in Gladstone Harbour since 2002 enabling 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:

1. Biomass: changes in average above-ground biomass within a monitoring meadow
2. Area: changes in the total area of a monitoring meadow
3. 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 a fine-scale survey of seagrass within the Gladstone Port Limits was commissioned by GPC (Rasheed et al., 2003). This baseline survey identified large areas of seagrass within the Gladstone Port Limits.

The annual seagrass monitoring program commenced 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/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 photos 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 employed (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 2015 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 recorded historical variability within each meadow
- expert knowledge of the different meadow types
- testing of a range of thresholds to determine which ranges best fit 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.

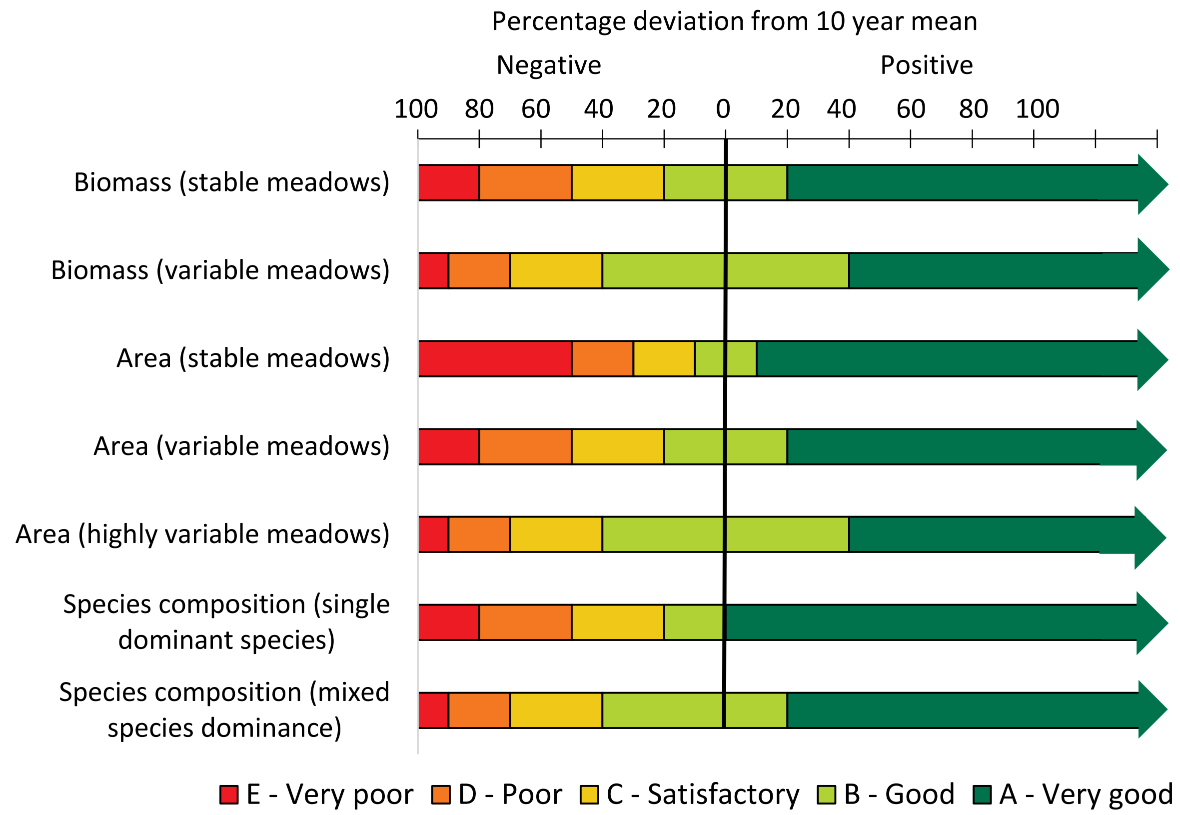


Figure 4.1: Threshold values between grades A to E varied for different seagrass meadow types for each of the three seagrass indicators (biomass, area and species composition). Each grade was determined by the percentage difference from a baseline of the 10-year mean.

4.2.3. Results

The overall score for seagrass in 2015 of 0.43 (D) indicates that seagrass meadows in Gladstone Harbour were in poor condition overall. The Narrows received the lowest zone score (0.15) due to a low biomass score. The Inner Harbour (0.41) and Rodds Bay (0.45) received scores within the 0.25–0.50 range which indicates poor condition. In both instances this resulted from a low biomass score. The remaining three zones were in satisfactory condition receiving scores within the 0.50 to 0.65 range —Western Basin (0.51), Mid Harbour (0.56) and South Trees Inlet (0.52) (Table 4.9).

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

Zone	Meadow	Biomass	Area	Species composition	Overall meadow score	Overall zone score
1. The Narrows	21	0.15	0.74	0.62	0.15	0.15
3. Western Basin	4	0.85	0.42	0.85	0.42	0.51
	5	0.53	0.41	0.66	0.41	
	6	0.67	0.83	0.67	0.67	
	7	0.53	0.68	1.00	0.53	
	8	0.66	0.60	0.35	0.35	
	52–57	0.67	0.94	0.88	0.67	
5. Inner Harbour	58	0.41	0.96	0.75	0.41	0.41
8. Mid Harbour	43	0.58	0.69	0.85	0.58	0.56
	48	0.58	0.54	0.61	0.54	
9. South Trees Inlet	60	0.52	0.96	1.00	0.52	0.52
13. Rodds Bay	94	0.42	0.92	0.84	0.42	0.45
	96	0.38	0.71	0.56	0.38	
	104	0.55	0.96	0.68	0.55	
Harbour score						0.43

Zone results

Zone 1 – The Narrows

This zone has one monitored seagrass meadow. The overall condition of this meadow has declined from very good in 2009 to very poor in the 2014–15 reporting year (Table 4.10). Biomass has declined from 21g dry weight (DW) m^{-2} in the 2013–14 reporting year to 0.5gDWm^{-2} in 2014–15. Meadow area has remained close to the long-term average. Species composition data showed that *Zostera muelleri* comprised 56% of the mean biomass and *Halophila ovalis* comprised 44%.

Zone 3 – The Western Basin

The Western Basin has six monitored seagrass meadows. The biomass score for Meadow 6 (0.67), Meadow 8 (0.66) and Meadow 52–57 (0.67) resulted in a good biomass score for those meadows, while the score of 0.53 resulted in a moderate grade for that zone. Meadows 4 and 5 received scores of 0.42 and 0.41 respectively due to low area which gave them a poor grade overall. Meadow 8 also received a poor grade which was the result of a low score for species composition (Table 4.13).

Zone 5 – The Inner Harbour

As the Inner Harbour has only one monitored meadow, the zone score was determined by the lowest indicator scores for the zone which were for biomass (Table 4.10). Since 2010 this has remained low at <1gDWm^{-2} following biomass peaks of ~5gDWm^{-2} recorded between 2007 and 2009 (Table 4.14). Species composition showed some shift from *Z. muelleri* to *H. uninervis*, but this was not sufficient to indicate a decline in overall meadow health. Area received the highest score (0.96) which indicates a large but sparse meadow.

Zone 8 – The Mid Harbour

The Mid Harbour zone has two seagrass meadows and received an overall zone score of 0.56 (Table 4.13). Both meadows received scores for biomass of 0.58. Meadow 43 received a score of 0.69 for area, while Meadow 48 received a score of 0.54. Both meadows received their highest scores for species composition of 0.85 and 0.54 respectively. Hence Meadow 43 was in satisfactory condition due to biomass score and Meadow 48 was in satisfactory condition due to its area score.

Zone 9 – South Trees Inlet

South Trees Inlet received an overall zone score of 0.51 for the 2014–15 reporting year (Table 4.10). Biomass was ~1.3gDWm^{-2} which was 40–70% below the baseline of 3.7gDWm^{-2}. The species composition grade was 1.00 owing to the absence of *Halophila* spp. Meadow area was 0.96 as it was >20% above the baseline.

Zone 13 – Rodds Bay

Rodds Bay received an overall zone score of 0.45 (Table 4.10). All three of this zone's meadows received their lowest scores for biomass. Meadows 94 and 96 received very good scores for area, 0.92 and 0.96 respectively. The overall meadow area for Meadow 104 (~70ha) was approximately double the baseline value for this meadow. Meadow 96 (0.71) received a good score for area and also returned an area above the baseline value. Both meadows 94 (0.84) and 104 (0.68) received good scores for species composition as *Z. muelleri* was close to the baseline value in both instances. Meadow 96 (0.56) was considered to be in a satisfactory condition as *Z. muelleri* only accounted for 59% of mean biomass.

4.2.4. Seagrass conclusions

Seagrasses in the Gladstone region underwent 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 either correspond with (2010–2013) or directly follow (2004, 2014) flooding and major rain or storm activity in the region. Declines in monitoring meadow condition were indicative of wider declines in seagrasses across the Port Curtis region. Between November 2009 and 2013 reductions in meadow area of ~75% and ~50% occurred for deep-water and coastal seagrasses respectively (Carter et al., 2015b). Reductions in coastal seagrasses were mostly concentrated in The Narrows and Western Basin zones; these meadows are closest to the source of episodic flooding from the Calliope River and potential impacts from Western Basin dredging operations.

Declines in seagrass biomass and area generally occurred in 2009 and 2010, before the commencement of the Western Basin Capital Dredging and Disposal Project on 20 May 2011, with observed declines also occurring at Rodds Bay. This monitoring zone, originally established as a reference site, sits entirely outside of the Gladstone Port Limits and just over 50km from the Western Basin. Declines in seagrass biomass were also associated with high flows in the Calliope River; the strongest associations occurred at 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 commencement of the capital dredging program makes it difficult to ascertain what additional impacts dredging may have had on seagrass condition and subsequent rate of recovery. However, monitoring of light levels during the Western Basin Dredging and Disposal Project indicates that light levels were maintained above locally derived guidelines at seagrass meadows outside of the dredging locations.

Species composition grades below very good (0.85–1.0) were mostly a result of a shift from the more stable species *Z. muelleri* to meadows dominated by colonising *H. ovalis* between 2009 and 2014. Shifts back to *Z. muelleri* dominance in some meadows indicate both propagule availability and suitable conditions for recruitment of this species. Seed banks for this species have been detected during monitoring in Gladstone Harbour (McCormack et al., 2013), and TropWATER is investigating the viability of these seedbanks.

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, 2002–2014 (source Carter et al., 2015a).

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

4.3. Corals

Coral communities are iconic components of marine ecosystems in Northern 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 (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 with 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 macro-algal 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 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.

4.3.1. Coral data collection

Site search

Coral surveys to identify suitable sites for long-term monitoring and then to collect field data were conducted between 6 and 8 July 2015. Prior to starting the surveys, potential sites for long-term coral monitoring were identified using existing reports on coral community locations (BMT WBM, 2013; DHI, 2014) in the Inner Harbour, Mid Harbour and Outer Harbour zones. Three islands within the Inner Harbour had been identified as possible locations for coral monitoring sites: Quoin, Turtle and Diamantina Islands. However, searches 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 2015 Report Card occurred concurrently with site selection 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. The majority of hard and soft corals were identified to the genus level.

Juvenile corals

Juvenile coral colonies, up to 10cm 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 which was based 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 4.7). The lowest score of 0.00 was set to represent the worst condition that could be expected in the local environment (Table 4.7). 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 2.2). A baseline of 14% macroalgal cover was set at the C/D threshold for coral communities in Gladstone Harbour (Table 4.7).

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 elevated concentrations of nutrients, 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).

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)
Coral cover	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%
Macroalgae cover	14%	5%	20% of hard substrate area
Juvenile 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 grade for coral in the 2015 Report Card was an E. This was a result of a low cover of living corals, low abundance of juvenile corals and high macroalgal cover at most of the surveyed reefs (Tables 4.9). Both zones surveyed received very poor scores. All but one indicator received poor to very poor scores at all surveyed sites; the exception was macroalgal cover at Farmers Reef which received a very good score of 1.00 (Table 4.12).

Table 4.12: Coral indicator scores for the two surveyed harbour zones and overall zone and harbour scores (Thompson et al., 2015).

Zone	Coral cover	Macroalgal cover	Juvenile density	Overall score
8. Mid Harbour	0.08	0.37	0.23	0.23
11. Outer Harbour	0.05	0.00	0.33	0.13
Harbour score				0.18

Table 4.13: Individual coral indicator scores within the two surveyed harbour zones (Thompson et al., 2015).

Zone/Reef	Coral cover		Macroalgal cover		Juvenile density	
	Value	Score	Value	Score	Value	Score
8. Mid Harbour						
Facing Island 2	13.1	0.16	24.8	0.00	5.0	0.41
Farmers Reef	4.8	0.06	4.1	1.00	3.5	0.26
Manning Reef	0.0	0.00	32.0	0.00	2.1	0.12
Rat Island	6.6	0.08	14.0	0.50	2.1	0.11
11. Outer Harbour						
Seal Rocks North	0.0	0.00	28.0	0.00	5.0	0.42
Seal Rocks South	8.3	0.10	58.2	0.00	3.4	0.25

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 is 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 also Facing Island 2, the high cover of macroalgae is dominated by the large brown algae genera *Sargassum* and *Lobophora*. In other areas of the inshore Great Barrier Reef, both taxa form persistent communities following declines in coral cover.

Scores for juvenile coral density were poor for four of the surveyed reefs and very poor in the remaining two reefs (Table 4.13). However, an assessment of the size class data for this indicator suggests that these scores may underestimate the recovery of Gladstone Harbour's coral communities. The size class 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 class 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. Very low numbers of juvenile coral colonies in the 5–10cm class (Table 4.14) suggests a lack of settlement or survival of juveniles spawned in late 2012. Higher numbers of very small colonies suggest that a higher settlement of juveniles occurred following the 2014 spawning event than in previous spawning events, or that juveniles that settled after previous spawning events had low survival rates.

Table 4.14: Proportion of juvenile hard corals in three size classes (Thompson et al., 2015).

8. Mid Harbour

Zone/ Reef	<2cm (%)	2–5cm (%)	5–10cm (%)
Facing Island 2	79.3	20.7	0.0
Farmers Reef	59.3	31.5	9.3
Manning Reef	86.7	10.0	3.3
Rat Island	38.0	46.0	16.0

11. Outer Harbour

Zone/ Reef	<2cm (%)	2–5cm (%)	5–10cm (%)
Seal Rocks North	7.6	21.7	0.7
Seal Rocks South	61.2	35.3	3.5
Overall Average	67.0	27.5	5.5

4.3.4. Coral conclusions

The coral communities in Gladstone Harbour are in very poor condition. The available information strongly suggests that the floods of 2011 and 2013 have impacted the coral communities across the harbour.

Freshwater run-off in flood plumes is a recognised cause of coral mortality owing to reduced salinity levels. 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 to 29 January 2013 during which salinity levels remained below 20psu at a depth of 0.75m in the Mid Harbour. A minimum level of less than 5psu was reached on 28 January. These sustained low levels are likely to have caused high levels of coral mortality within the harbour. Berkelmans et al. (2012) reported a salinity threshold for *Acropora* (e.g. staghorn and elkhorn corals) of 22psu for three days, beyond this mortality can be expected.

The loss of coral cover caused by freshwater plumes from flooding was not limited to Gladstone Harbour. Flooding in the Fitzroy River caused severe mortality of corals in Keppel Bay in 1991 and 2011 (van Woesik, 1991; Thompson et al., 2011).

The very low proportion of juvenile coral colonies in the 5–10cm size class (> 2 years old) across the surveyed reefs indicated low settlement and/or survival of juveniles spawned in late 2012. Conversely, the high number of juvenile coral colonies in the <2cm and 2–5 cm classes (Table 4.11) indicated that conditions for the settlement and survival of juveniles may have improved since then.

The flooding in 2011 and 2013 almost certainly had a severe effect on Gladstone's coral communities, but this does not preclude the possibility that other factors may have also contributed to the current condition of corals in Gladstone Harbour. The Great Barrier Reef Report Card 2014 reports that coral reefs in the Fitzroy region have remained in very poor condition since 2011–12 following multiple disturbances.

4.4. Connectivity

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 score for the Gladstone Harbour Report Card (Figure 4.2):

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.

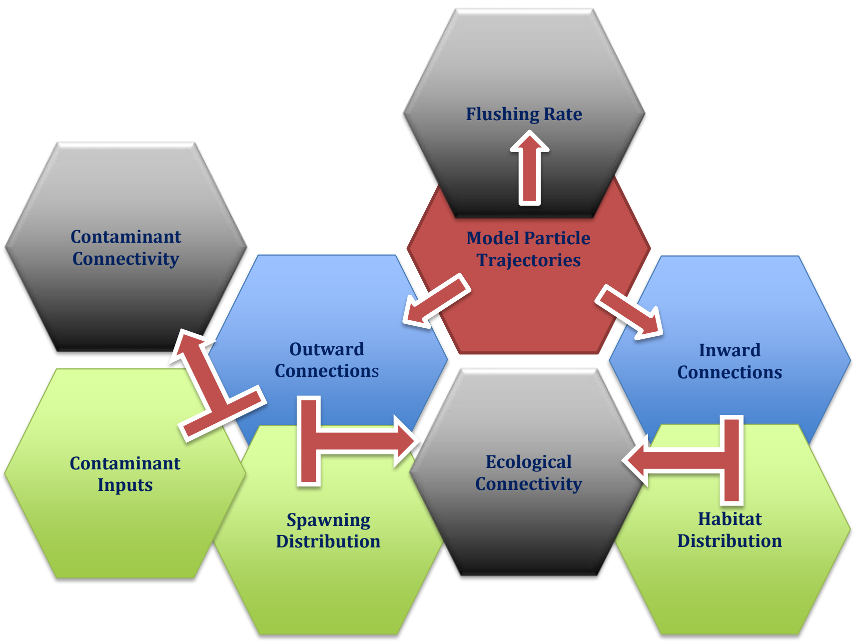


Figure 4.2: The three connectivity indicators calculated from the trajectories of virtual particles within the hydrodynamic model.

4.4.1. Data collection

A three-dimensional hydrodynamic computer model of Gladstone Harbour developed by CSIRO for GHHP generated the data used to calculate 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 4.3). The resolution is variable over the grid and ranges from 100–250m within Gladstone Harbour to approximately 1000m 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 in the model to include tidal movement.

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 (ACCES 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).

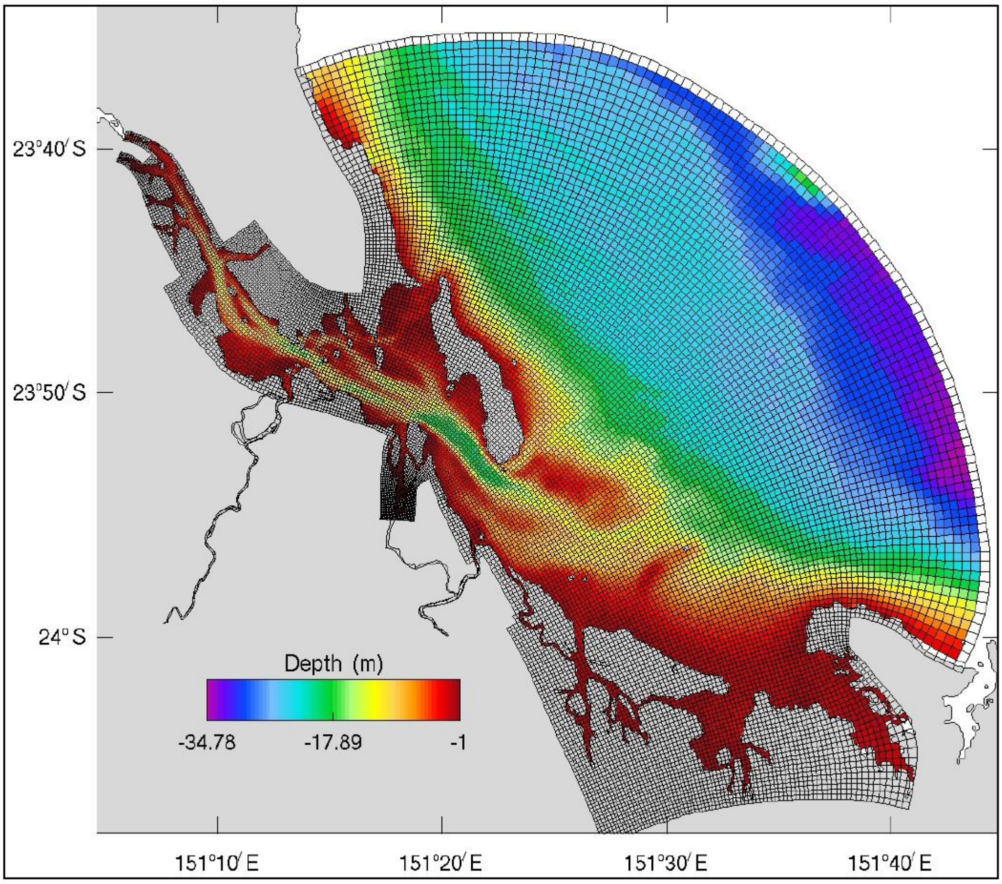


Figure 4.3: The Gladstone Harbour hydrodynamic model's curvilinear grid overlayed on harbour bathymetry (Source: Condie et al., 2015).

Two model runs covering the period September 2010 to August 2014 generated the data for determining baseline conditions. A third model run from September 2014 to June 2015 generated report card grades and scores for the 2015 Report Card. The 2010 to 2014 period was required to generate a sufficient baseline for calculating report card grades and scores. As the Western Basin Dredging and Disposal Project resulted in changes to the harbour bathymetry and coastline, separate model runs were required for the periods before and after capital dredging to allow these changes to be incorporated (Table 4.15.)

Table 4.15: Hydrodynamic model runs used to determine a connectivity baseline and report card grades and scores for the 2015 Gladstone Harbour Report Card.

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: September 2014–June 2015	2015 report card grades 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, 2000 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 4.15). 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 4.15). 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: the Western Basin, Inner Harbour, Calliope Estuary and South Trees Inlet (Table 4.16). While 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 4.16: 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 4.17: Relative aquatic ecotoxicology (Wright et al., 1998) and 4-years of annual loads from some industrial facilities as reported to the National Pollution Inventory (www.npi.gov.au) (Source: Condie et al. 2015).

Substance (including compounds)		Relative aquatic ecotoxicology	Annual loads (kg)															
			Calliope Estuary				Western Basin				Inner Harbour				South Trees Inlet			
			2010-2011	2011-2012	2012-2013	2013-2014	2010-2011	2011-2012	2012-2013	2013-2014	2010-2011	2011-2012	2012-2013	2013-2014	2010-2011	2011-2012	2012-2013	2013-2014
Metals	Arsenic	0.20			10.0	2.7	91.5	93.5	208	257					560	568	543	270
	Beryllium	1.0						17.6	40.3									
	Cadmium	2.0	0.84				8.61			11.9					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				
	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										
	Nickel	0.17		15.6				11.7			0.16	0.01	0.02			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 tetrachloride	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					134000	129240	239500	111000
	Formaldehyde	1.0																
	Hexochlorobenzene	167																
	Hexochlorobutadiene	50																
	Methylenechloride	0.50																
	Nitrobenzene	0.25																
	Nitrophenol	0.50																
	Tetrachloroethylene	0.50																
	Toluene	0.13									0.01	0.01	0.52	0.02				
	Trichloroethylene	0.50																
	Xylene	0.17									0.01	0.01	0.28	0.01				

4.4.2. Development of indicators and grades

Connectivity grades and scores for the 2015 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 dredging 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. While 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 4.4) to which the 2014–15 flushing time statistics were compared to derive the flushing rate scores.

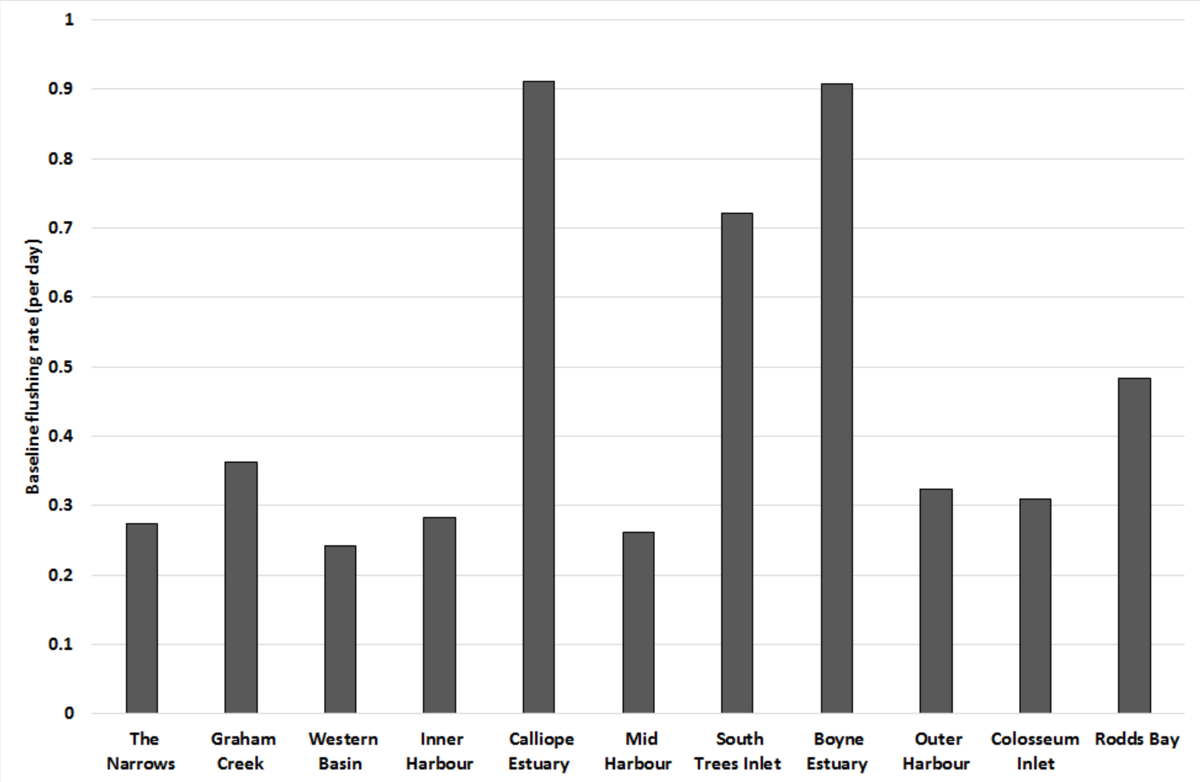


Figure 4.4: Baseline four-year average flushing rates in each of the modelled harbour zones.

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 4.5).

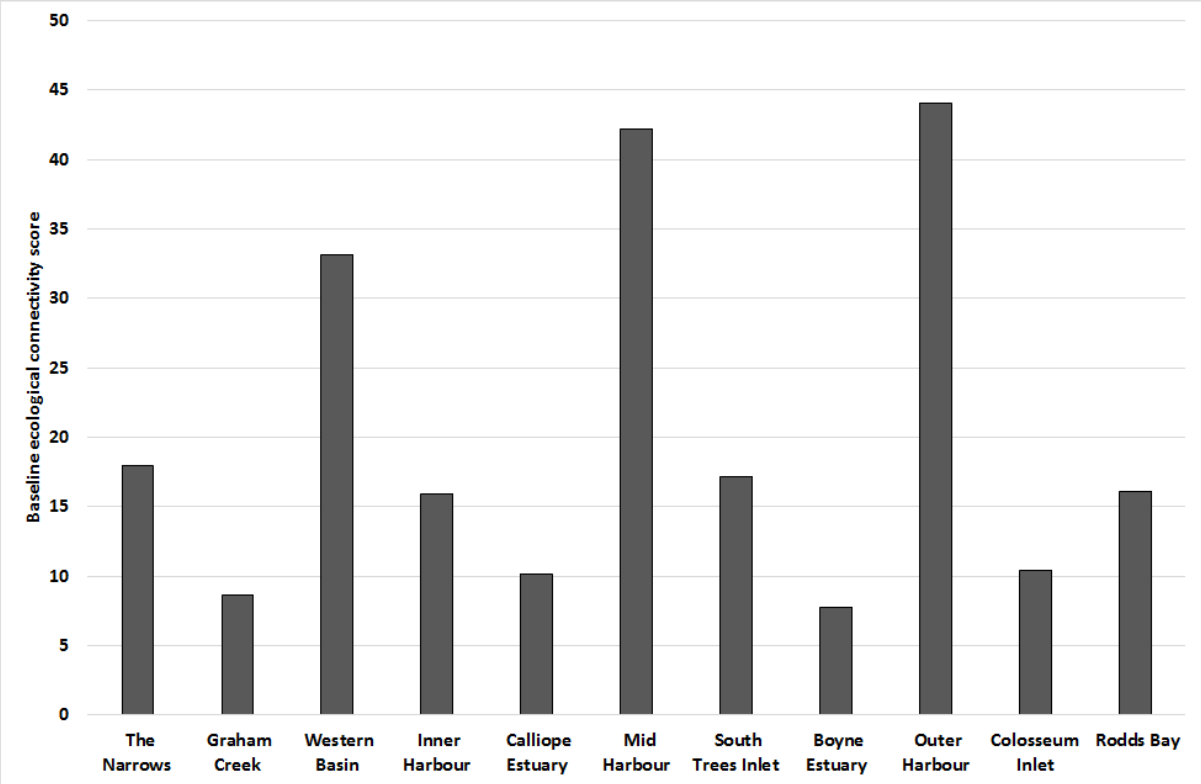


Figure 4.5: Baseline four-year average ecological connectivity in each of the modelled harbour zones.

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 2015 Report Card score for this indicator (Figure 4.6).

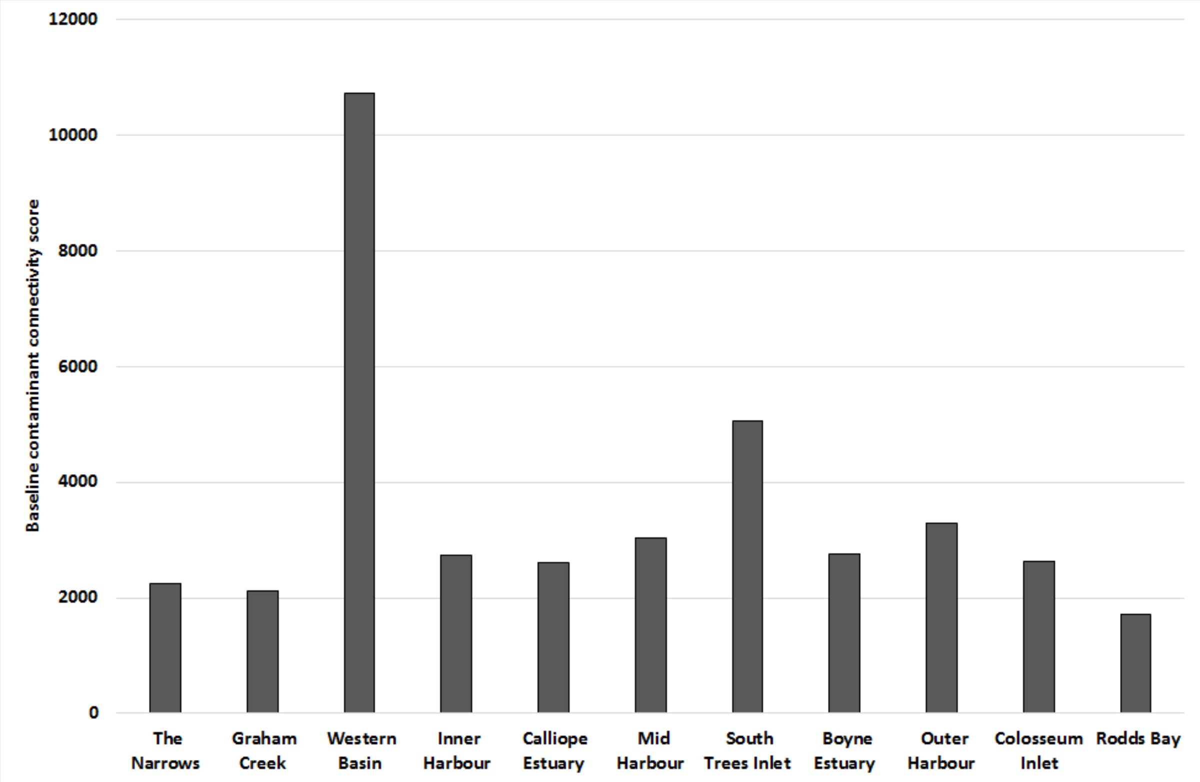


Figure 4.6: Baseline four-year average contaminant connectivity in each of the modelled harbour zones.

Report card scores for each indicator were calculated by comparing the means and variability in the 2014–15 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 (Figure 2.2) was derived by applying a linear transformation to the t-statistics.

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

4.4.3. Results

The overall grade for connectivity in the 2014–15 report card of 0.61 (C) indicates a satisfactory condition for connectivity. The overall score for the flushing rate of 0.77 indicates a good condition for this indicator. Ten of the eleven zones received scores that were higher than the four-year flushing rate baseline, C or above (Table 4.18). Only one zone, Calliope Estuary (0.43), received a poor score for connectivity.

Ecological connectivity was low compared to the baseline. Graham Creek (0.81) was the only zone to receive a good score owing to a high import of particles in the 2014–15 model run. Mid Harbour (0.59) received a satisfactory score. Three zones—The Western Basin (0.27), The Outer Harbour (0.49) and Rodds Bay (0.41)—received poor scores, and the remaining six zones received very poor scores (0.00–0.25) (Table 4.18).

The overall score for contaminant connectivity of 0.78 (good) indicates a low export of contaminants to other zones relative to the four-year baseline. Only two zones received less than a good or very good score. These were Graham Creek with a very poor score of 0.0 and South Trees Inlet with a satisfactory score of 0.59 (Table 4.18).

Connectivity scores for the 2015 Gladstone Harbour Report Card were calculated using a statistical technique known as bootstrapping. This method provides scores that approximate the arithmetic mean score and provides estimates of the variability in the data. The scores calculated by bootstrapping will frequently differ from the arithmetic mean scores, as presented in Condie et al. (2015).

Table 4.18: Connectivity scores for each zone and harbour-wide averages for 2014–15.

Zone	Flushing Rate	Ecological connectivity	Contaminant connectivity	Average connectivity
1. The Narrows	1.00	0.00	1.00	0.65
2. Graham Creek	1.00	0.81	0.00	0.61
3. Western Basin	0.95	0.27	0.81	0.68
4. Boat Creek	Not modelled owing to insufficient model resolution			
5. Inner Harbour	0.78	0.13	1.00	0.64
6. Calliope Estuary	0.34	0.23	0.73	0.43
7. Auckland Inlet	Not modelled owing to insufficient model resolution			
8. Mid Harbour	0.16	0.59	0.95	0.57
9. South Trees Inlet	1.00	0.11	0.59	0.57
10. Boyne Estuary	0.72	0.00	1.00	0.56
11. Outer Harbour	0.59	0.49	0.79	0.62
12. Colosseum Inlet	1.00	0.13	1.00	0.71
13. Rodds Bay	1.00	0.41	0.66	0.69
Harbour score	0.77	0.29	0.78	0.61

4.4.4. Connectivity conclusions

In the 2014–15 reporting year, flushing rate received very good scores (0.85–1.00) in six harbour zones. This resulted in an overall harbour grade of B (0.65–0.85) for flushing rate compared to grades of C (0.50–0.65) in all baseline years (Condie et al., 2015). Although flushing rates in estuary zones can be linked to rainfall, the relationship is dependent on how rainfall is distributed during the year. While the annual rainfall in 2014–15 was close to the annual average for Gladstone, it is probable that more consistent rainfall across months contributed to the high scores for this indicator.

Contaminant connectivity scores were also above the baseline; all but two zones received very good (0.85–1.00) or good scores (0.65–0.85). This resulted in an overall harbour average of B (0.65–0.85).

A very poor score (0.00–0.25) was recorded in Graham Creek. This was associated with a high export from this zone rather than an increase in contaminant load.

In 2014–15, flushing rate and contaminant connectivity both tended to score high, whereas ecological connectivity tended to score low. This combination indicates that particles were rapidly flushed out of their starting zone and then either contained within a small number of neighbouring zones or (more likely) transported quite rapidly out of the harbour. Such a scenario provides less opportunity for both contamination of other zones and larval recruitment to nursery areas in other zones. Therefore, the wide range of scores achieved in 2014–15 was largely due to changes in water circulation rather than changes in contaminant loads or habitat distributions.

4.5. Environmental component and indicator groups results

The overall Environmental component score for the 2015 Report Card was 0.59 (C) this score was derived from the aggregation of the three environmental indicator groups (water and sediment quality, habitats and connectivity) using the bootstrapping methodology (AIMS, 2015).

The indicator group score for water and sediment quality was derived from the aggregation of the water and sediment quality indicator scores, that for habitats was derived from the aggregation of the seagrass and coral indicator scores and that for connectivity was derived from the aggregation of the three connectivity sub-indicators: flushing rate, contaminant connectivity and ecological connectivity. The overall harbour scores for these three indicator groups were: water and sediment quality 0.90 (A), habitats 0.30 (D) and connectivity 0.61 (C).

Individual zone scores were calculated by aggregating the indicator groups present in each zone (Table 4.19). Although Auckland Inlet received the highest overall zone score 0.87 (A), this was based solely on the water and sediment quality score as there were no habitat or connectivity scores for this zone. Similarly Boat Creek received the second highest environmental score 0.84 (B), but this was also based solely on the water and sediment quality scores. A total of nine zones including Boat Creek received scores between 0.65 and 0.85 (B).For five of those zones this result was based on the aggregation of water and sediment quality and connectivity only as those zones contained no habitat monitoring sites. Three zones: The Narrows, Mid Harbour and Outer Harbour received scores between 0.50 and 0.65 (C), with all of those scores being based on the full suite of indicator groups.

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

Zone	Indicator groups			
	Water and sediment quality	Habitats (Seagrass and corals)	Connectivity	Overall zone score
1. The Narrows	0.88	0.15	0.65	0.54
2. Graham Creek	0.93	NA	0.61	0.75
3. Western Basin	0.91	0.51	0.68	0.69
4. Boat Creek	0.84	NA	NA	0.84
5. Inner Harbour	0.93	0.41	0.64	0.65
6. Calliope Estuary	0.94	NA	0.43	0.67
7. Auckland Inlet	0.87	NA	NA	0.87
8. Mid Harbour	0.90	0.39	0.57	0.60
9. South Trees Inlet	0.92	0.52	0.57	0.66
10. Boyne Estuary	0.86	NA	0.56	0.69
11. Outer Harbour	0.91	0.13	0.62	0.54
12. Colosseum Inlet	0.91	NA	0.71	0.79
13. Rodds Bay	0.90	0.45	0.69	0.67
Harbour score	0.90	0.30	0.61	0.59

5. The Social component

Report cards have become an increasingly popular way to document environmental condition. The 2015 Gladstone Harbour Report Card also reports on the social, cultural and economic condition of the harbour. Eight indicators that have been 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 2015 report card (Source: Cannard et al., 2015).

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 usage	Marine safety incidents	Marine safety incidents: Department of Transport and Main Roads (2015) Marine incidents in Queensland, 2014	Comparison to a baseline: Rate of incidents in Gladstone as compared to other Queensland ports from 2005–2014 (calendar year)
		Oil spills	Oil spills and marine pollution data: Marine Safety Queensland 2014	Comparison to a baseline: Rate of oil spills in Gladstone as compared to other Queensland ports from 2005–2014 (calendar year)
		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 2015 report card (Source: Cannard et al., 2015).

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
	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). The appropriateness of each measure was determined based on its relationship with the indicator/indicator group and its measurability.

A Computer-Assisted Telephone Interview (CATI) survey interviewed 400 residents from the Gladstone 4680 postcode area in September 2015 (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 quality control and quality assurance. The project team and the ISP reviewed the survey questionnaire. Prior to being administered, a focus group discussion with eight Gladstone residents pre-tested and fine-tuned the questionnaire. The 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, and elicit trends over time and to facilitate translation into the A–E report card grades (Pascoe et al., 2014).

The survey questionnaire used for the 2015 Report Card was slightly modified from that used to collect data for the 2014 Pilot Report Card (Gladstone Healthy Harbour Partnership, 2014). Data on marine safety incidents (which includes collision between ships, collision with an object, capsizing and groundings) and oil spills that are provided by Maritime Safety Queensland (MSQ) are now aligned to Commonwealth rather than Queensland state criteria. Under the Commonwealth criteria, incidents that involve domestic commercial vessels only are reported under the *Navigation Act 2012* and incidents involving internationally registered commercial vessels are reported under the *Transport Operation (Marine Safety) Act 1994*. As the data that contribute to the report card are those reported under *Transport Operation (Marine Safety) Act*, incidents involving domestic commercial vessels only are no longer included in the report card scores. As a consequence, there has been a decline in the number of reported incidents.

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 based on data from a pilot phase in 2014. The pilot comprised online surveys of 218 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 producing 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.

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 survey questions in the CATI survey were based on a range of questions such as 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 overall grade for the Social component of the 2015 Gladstone Harbour Report Card was 0.64 (C). In 2014 Pilot Report Card, the score was 0.58 (C). Of the three indicator groups, harbour usability received a score of 0.75 (B), harbour access a score of 0.62 (C), and liveability and wellbeing received a score of 0.64 (C) (Figure 5.1). The scores for harbour access and liveability and wellbeing were about the same as they were in 2014, but the score for harbour usability increased from 0.60. This was due to the changes in the way that oil spills and other marine safety incidents are reported, as described above, rather than to an actual change in harbour usability.

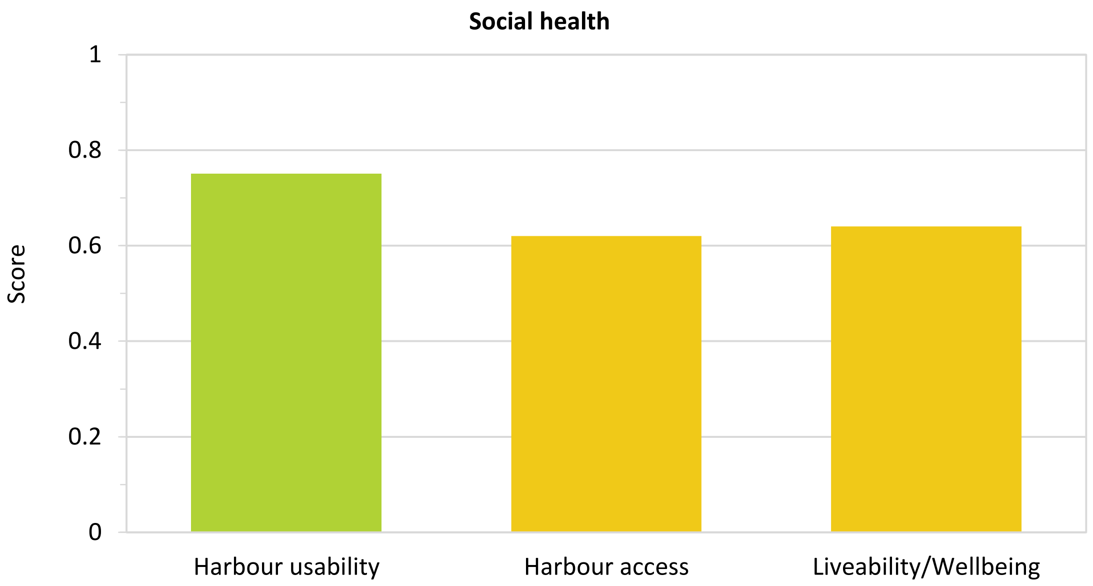


Figure 5.1: Indicator group scores within the Social component of harbour health in the 2015 Gladstone Harbour Report Card.

Harbour usability

The scores for the three indicators of harbour usability ranged from 0.52 (C) for perceptions of air and water quality up to 0.69 (C) and 0.72 (B) for harbour recreational activities and perceptions of harbour safety respectively (Figure 5.2).

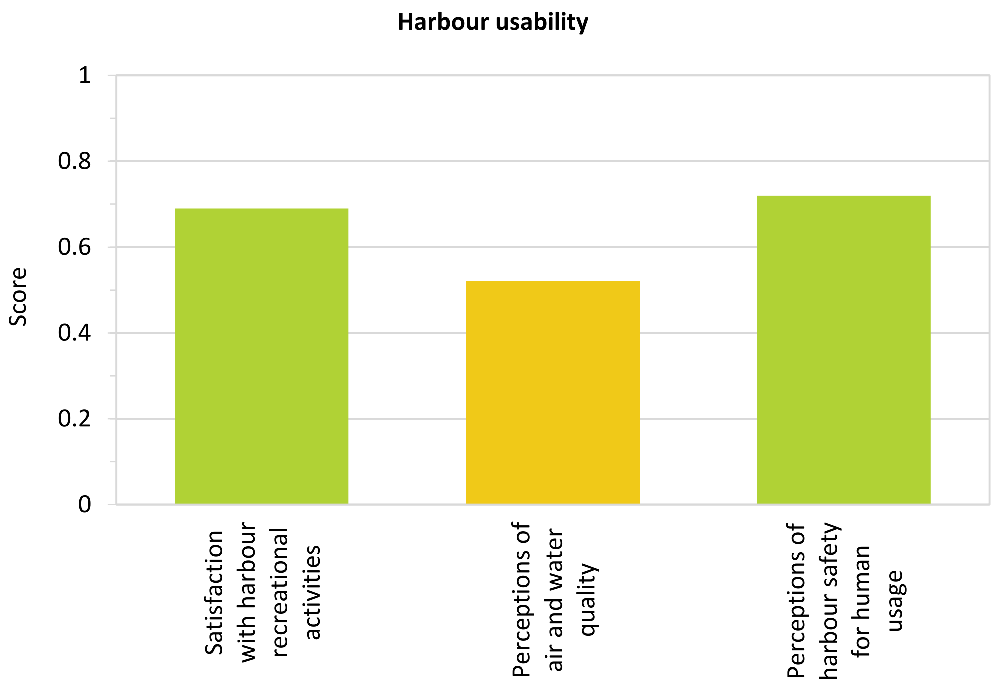


Figure 5.2: Scores for the three indicators of harbour usability in the 2015 Gladstone Harbour Report Card.

Of the survey respondents who had visited the Gladstone Harbour area for recreation, most (87%) were satisfied with the trip. However, perceptions of the usability and condition of the harbour were more diverse. Most participants (73%) were satisfied with the quality of boat ramps, but just under half of the respondents (48%) were not concerned about marine debris and litter. Almost half (49%) of the respondents agreed that the water quality was satisfactory, but only 36% thought the air quality was satisfactory in the harbour area. A majority of respondents (61%) were happy to eat seafood caught in the harbour area and 63% felt safe being in the harbour area at night.

Harbour access

The scores for the four indicators of harbour access ranged from 0.58 for perceptions of harbour health to 0.68 for satisfaction with harbour access (Figure 5.3).

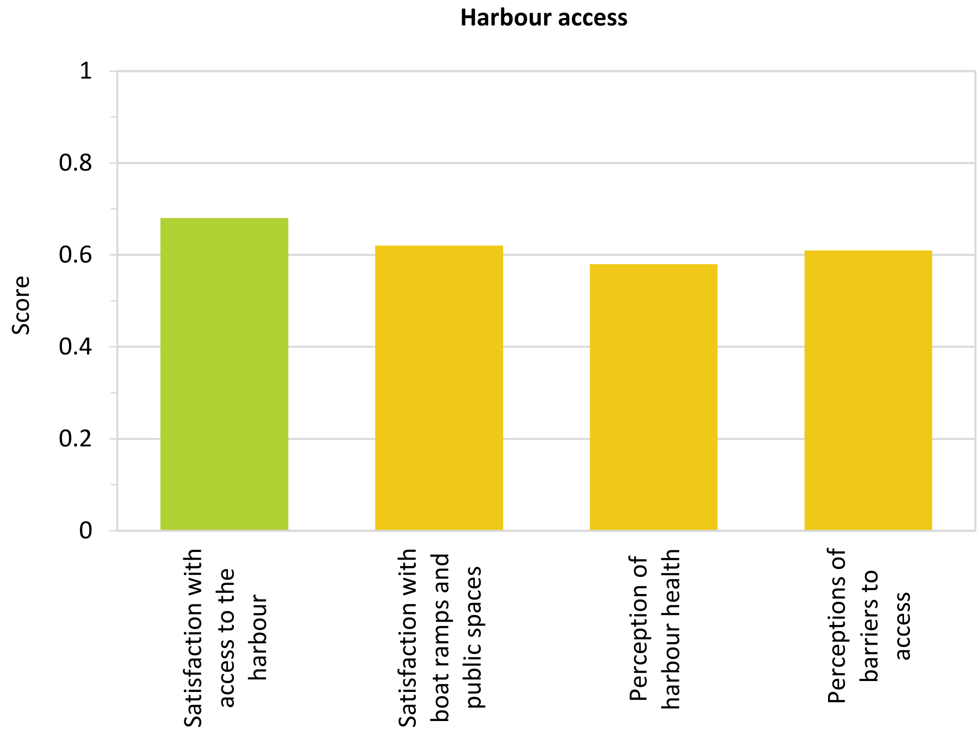


Figure 5.3: Scores for the four indicators of harbour access in the 2015 Gladstone Harbour Report Card.

Ninety-three percent of people surveyed had visited Gladstone Harbour in the previous 12 months and most of those people (86%) had visited the harbour for recreation. About 68% of respondents had visited at about the same frequency as in 2014 (15% had visited more frequently, 17% less frequently). Most survey respondents (79%) believed they had fair access to the harbour, 82% were satisfied with the level of access to public spaces and 71% were satisfied with the number of boat ramps. A majority (66%) believed that the harbour was in good condition and about 63% were optimistic about the future health of the harbour. A slight majority (57%) believed that the health of the harbour had improved in the past year (an increase from 48% who believed that same thing in 2014). A slight majority of respondents (57%) agreed that the amount of shipping had reduced their access (a decrease from 71% in 2014). Most (72%) agreed the amount of recreational boating had not reduced their use of the harbour area. Further, most (79%) respondents agreed that marine debris did not affect their access or frequency of harbour use. However, less than half of the people surveyed (45%) felt that they were able to have input into the management of Gladstone Harbour if they chose to.

Liveability and wellbeing

The contribution of Gladstone Harbour to the liveability of Gladstone and wellbeing was scored at 0.64 (C) (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).

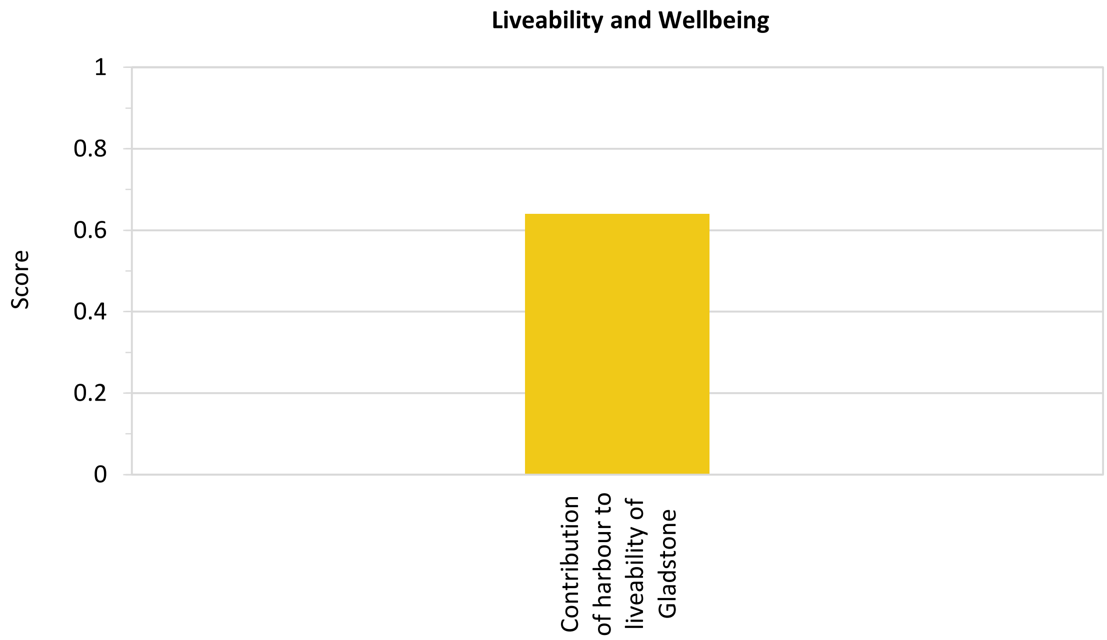


Figure 5.4: Score for the contribution of Gladstone Harbour to the liveability and wellbeing of Gladstone in the 2015 Gladstone Harbour Report Card.

Seventy percent of people surveyed agreed that Gladstone Harbour makes living in Gladstone a better experience, and just over half (53%) of the respondents regularly participated in community events in the harbour area.

5.4. Social indicator conclusions

The majority of the community view the harbour area as a place providing recreational facilities and an environment for leisure activities. The harbour area is seen as a producer of healthy food and a safe place to enjoy day and night. Concerns continue around pollutants (air and water) and marine debris and litter, but these do not appear to impede the community's view on the 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.

Gladstone Harbour remains a key area for residents to visit and recreation levels remain similar to 2014 levels. Residents' recreation experience is not affected by public space access or the quality of boating facilities. Shipping activity in the harbour continues to be seen as a factor impacting on people's harbour access.

The harbour environment is viewed positively by many residents and they hold strong beliefs of this continuing into the future. In terms of the community contributing to public management decisions about the harbour, not all residents feel such an opportunity is available to them.

Generally, people living in the Gladstone region find Gladstone Harbour provides them with a positive living experience and quality of life. Many residents participate in community events that are held in and around the harbour area (e.g. The Gladstone Harbour Festival, Ecofest and the Botanic to Bridge fun run) and their involvement supports the physical and mental health of the community.

6. The Cultural component

To assess the cultural health of the harbour, the 2015 report card reports on six sense of place indicators, with cultural heritage indicators being developed for future report cards. These indicators were developed from the GHHP vision. The cultural indicators in the 2015 Gladstone Harbour Report Card address the following report card objective:

- The Gladstone community's sense of identity and satisfaction with the condition of the harbour is increased.

6.1. Data collection

All data for the sense of place indicator group were collected through the CATI survey. 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 provide a useful basis for exploring community stewardship.

Definition of 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 reflects 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 fulfilment or has restorative capacity.

Table 6.1: Indicator groups, indicators and measures used to determine cultural grades and scores for the 2015 Gladstone Harbour Report Card.

Indicator group	Indicators	Measures	Data source	How grades determined
Sense of place	Measure of 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

6.2. Development of indicators and grades

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 cultural indicator was given a weighting that was developed during the pilot phase in 2014 via online surveys as described in section 5.2. A BBN was used to aggregate indicator scores into indicator groups and component scores.

6.3. Results

The overall score for the cultural health of Gladstone Harbour for 2015 was 0.65 (B). This comprised the six indicator scores for sense of place (Figure 6.1). In future years, cultural health will also include an assessment of the status of Indigenous cultural heritage sites.

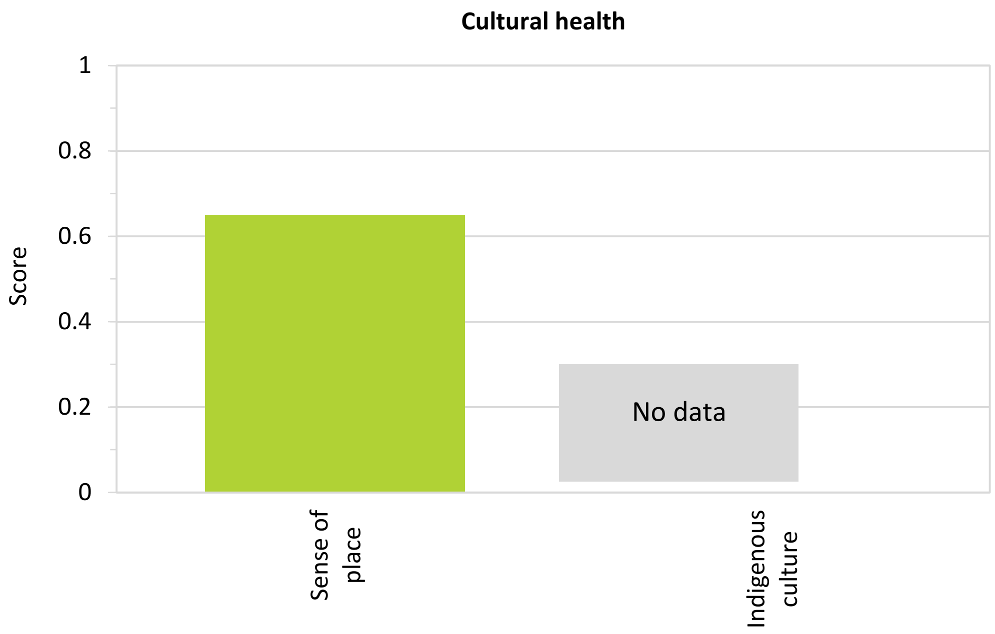


Figure 6.1: Results of the September 2015 CATI survey for the sense of place indicator group.

The overall grade for the cultural component of the 2015 Gladstone Harbour report card was a B. This grade was determined based on the sense of place related indicators. The sense of place indicator was assessed through a community survey of 400 people which was conducted in September 2015.

Sense of place

The sense of place indicator scores ranged from 0.55 (C) for distinctiveness to 0.80 (B) for attitudes to the harbour (Figure 6.2).

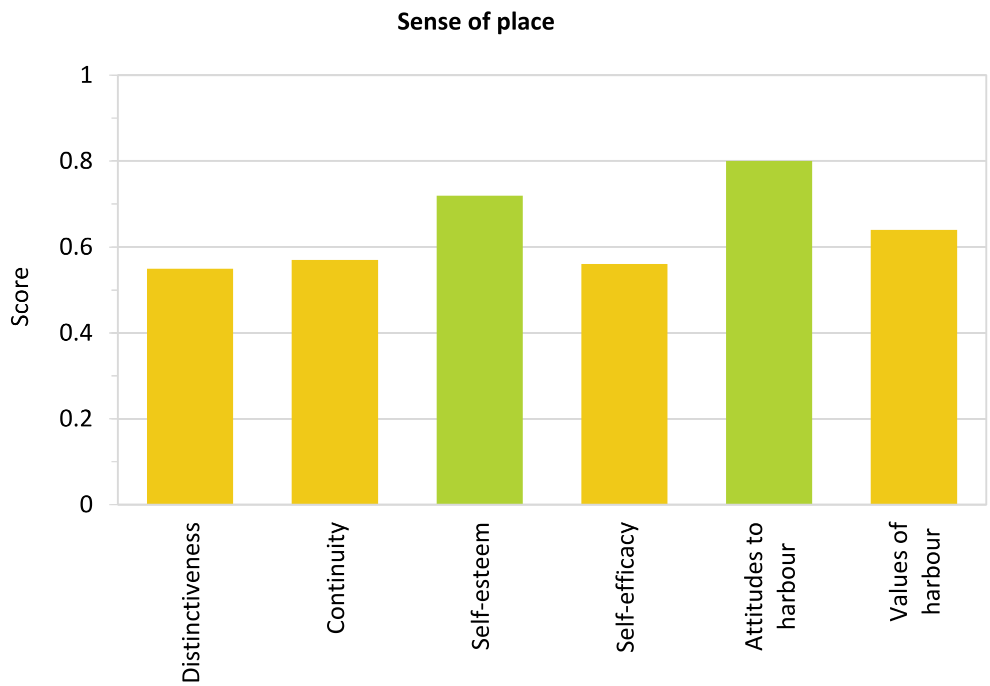


Figure 6.2: Indicator scores for sense of place, the only indicator group used for Cultural health in the 2015 Gladstone Harbour Report Card.

The only cultural indicator reported in 2015 is sense of place; its score of 0.65 makes the overall grade a B. The highest value was recorded for attitudes to harbour measure (0.80) and the lowest was recorded for measures of distinctiveness (0.55).

Continuity (0.57) and self-efficacy (0.56) received similar scores; self-esteem (0.72) and values of harbour (0.64) received slightly increased scores.

6.4. Cultural indicator conclusions

All six measures of sense of place fall in or above the satisfactory grade (C). This suggests that the community's expectations of Gladstone Harbour area are being met. However, some place-related identity measures (distinctiveness, continuity, self-efficacy) were lower than others.

The lower score for the distinctiveness measure suggests that at first glance people may only moderately identify with the harbour. Similarly, people's continuity with the harbour area is only moderate which suggests that many people don't have an enduring attachment to the place. It is more likely that there is some discontinuity, possibly due to changed demographics in the region following recent periods of development and change around the harbour area. An increase in the proportion of short-term or 'new' residents may be contributing to these scores. The self-efficacy score further supports this explanation as the harbour is not seen by most people to be a place that offers opportunities and supports their chosen lifestyle.

The harbour is viewed with pride and this is reflected in the higher self-esteem measure. Nevertheless, the attitudes to the harbour and the values for the scores show that people have a positive outlook about the harbour area and what it provides to the community.

7. The Economic component

To assess the economic health of harbour, this report card uses eight indicators aggregated into three indicator groups: economic performance, economic stimulus and economic value. 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 a diversity of industries.
- Economic activity in the Gladstone Harbour continues to generate social and economic benefits to the regional community.
- Enhance the values of Gladstone Harbor's recreational and environmental assets.

7.1. Data collection

The Gladstone Local Government Area (LGA) was used as the broader geographic scope 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)
- hotel occupancy data: collected from the Gladstone LGA
- 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:

- 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

Further information on these methods is provided in the grey box on p. 93.

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 2015 Gladstone Harbour Report Card.

Indicator group	Indicator	Measure	Data source	Baseline
Economic performance	Commercial fishing	Productivity of line, net, trawl and pot fisheries estimated as total value of fish and crustaceans harvested from QFish S30 in four fishery sectors: line, net, trawl and pot	Fisheries Queensland, Queensland Department of Agriculture and Fisheries	Time series data from 1990–1991 to 2014–2015
	Shipping activity	Shipping activity productivity calculated from monthly shipping movements by cargo type (2014–15 financial year)	Gladstone Ports Corporation	Time series data from 2007 to 2014–2015
	Tourism expenditure	Expenditure on hotel accommodation and food (2013–14 financial year) Numbers visiting Gladstone Visitor Information Centre	Expenditure on hotel accommodation and food (2013–14 financial year) Gladstone Visitor Information Centre Gladstone Regional Council Economic Profile (www.economicprofile.com.au/gladstone) Australian Bureau of Statistics Satellite Accounts 2013–14 Expenditure on hotel accommodation (for 2003–04 to 2012–13 financial year)	Last 10 years average for 2013–14

Table 7.1 (Cont.): Data sources and baselines employed to derive the economic scores and grades for the 2015 Gladstone Harbour Report Card.

Indicator group	Indicator	Measure	Data source	Baseline
Economic stimulus	Employment	Australian Bureau of Statistics (ABS) 2015: Unemployment statistics for the Gladstone Local Government Area (2015 March quarter)	Queensland Office of Economic and Statistical Research (via the Queensland Government Statistician's Office, Queensland Treasury)	Queens-land 2015 distribution
	Socio-economic status	Index of economic resources derived from 2011 ABS census and updated using the community CATI survey	CATI survey, 2011 ABS census	Australian 2011 distribution
Economic value (Recreation)	Beach recreation	Beach creation satisfaction* – travel Cost questions in the CATI survey	Travel cost data derived from CATI survey	10-point scale
	Recreational fishing	Recreational fishing satisfaction * – travel Cost questions in the CATI survey	Travel cost data derived from CATI survey	10-point scale
	Land-based recreation	Land based recreation satisfaction* – travel Cost questions in the CATI survey	Travel cost data derived from CATI survey	10-point scale

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

7.2. Development of indicators and grades

7.2.1. 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 2014–15 financial year were used in this report card. Shipping activity from 2006–07 to 2014–15 and potential future shipping activity related to developments on Curtis Island and at Fisherman's Landing were the basis for comparison.

Tourism

The report card grade for tourism was based on estimated expenditure on hotel accommodation, food and other local services in the Gladstone region, as well as the number of visitors to the Gladstone Visitor Information Centre. Data for 2014–15 were compared with 10-year averages (2003–04 to 2012–13). Expenditure data were derived from the Australian Bureau of Statistics Tourism Satellite Accounts.

This method is different to that used for the 2014 Pilot Report Card in which the value of tourism was based on accommodation expenditure only. This change also resulted in tourism having a greater weighting in the overall economic performance category (with the conditional probability tables re-estimated given the values for each of the components).

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 2015 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 take 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 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 from QFish S30. Commercial fishers operating in Queensland's state-managed fisheries are required to complete daily catch and effort logbooks. These logbooks enable fishers to record roughly 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 only provide a very general indication of where the fishing activity occurred. Data for the 2014–15 financial year were collected from the area within QFish S30 only.

Fishing data collected from within Grid S30 over the period 1990–91 to 2014–15 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 2014–15 was estimated based on catch data by fishing method from the QFish database and average prices for different species derived from the Australian Bureau of Agricultural and Resource Economics and Sciences fisheries statistics (Skirtun, Sahlgvist, & Vieira, 2013). These prices are based on the most recent prices available which were from 2012–13.

7.2.2. 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 rates across all Queensland LGAs. This comparison used the most recent Australian Bureau of Statistics (ABS) data available which were for the 2015 March quarter.

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

Most information on the economic values (recreation) of harbour-based recreational activities was collected through the CATI survey. Travel cost data were collected for the activity the survey respondent did most frequently.

7.2.3. 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 measures of economic value (recreation) combined the average economic value per type of trip (which was used to weight the contributions of each component), and the level of satisfaction experienced by those who did the activity. The study this year focused on estimating a value for recreational fishing, which was under-represented in the 2014 survey.

Information on the non-market economic value (recreation) of harbour area activities was collected through a community survey of 400 people within the Gladstone region and conducted in September 2015. 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. Full travel cost information was only collected for recreational fishing and details were provided about the last trip 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.

As for social and cultural indicators, economic indicators were weighted based on surveys of 40 community leaders, and 19 social scientists and economists. The survey of social scientists and economists was also used to develop the relationships between measures, indicators and indicator groups. 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), contributing to an overall score for the economic component of the 2015 Gladstone Harbour Report Card of 0.77 (B). Of those indicator groups, economic stimulus received the highest score of 0.82 (B) (a slight decrease from 0.87 in 2014), economic performance received a score of 0.79 (B) and economic value of recreation received a score of 0.72 (B) (Figure 7.1). These scores were close to those for these indicator groups in the 2014 Pilot Report Card, although all three have decreased slightly.

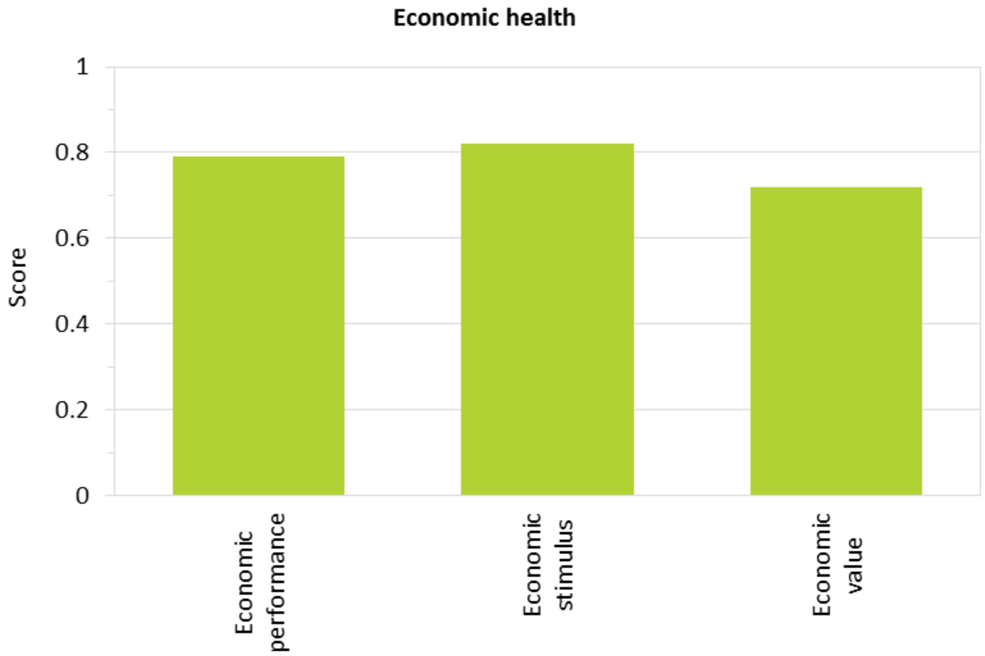


Figure 7.1: The scores for each of the three economic indicator groups in the 2015 Gladstone Harbour Report Card were high.

7.3.1. Economic performance

The highest score was received by shipping activity (0.82) which was followed by tourism (0.64) and commercial fishing (0.63). The economic performance score of 0.79 (B) was strongly influenced by the high score of 0.82 for shipping activity. However, the overall score for economic performance was reduced slightly by the relatively moderate scores for tourism (0.64) and commercial fishing (0.63) (Figure 7.2). Note that shipping activity is weighted more highly than the other two sectors due to its greater economic contribution.

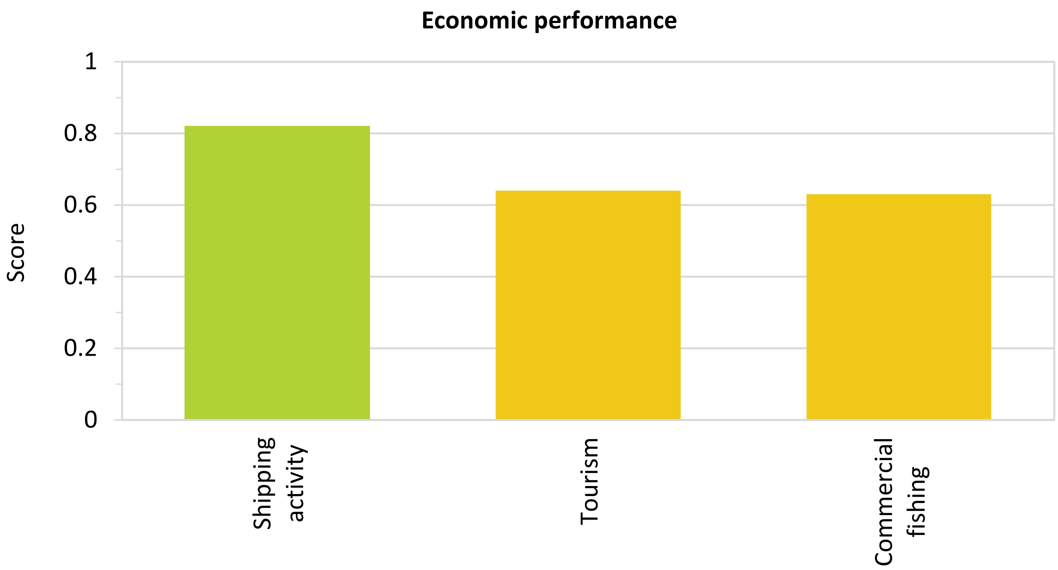


Figure 7.2: Scores for the three indicators of economic performance in the 2015 Gladstone Harbour Report Card.

Shipping

In 2014–15, the GPC generated $453 million in income, down from $691 million in the previous year (GPC, 2015). As in previous years, coal exports accounted for around two-thirds of export shipping and bauxite imports for the aluminium industry provided around half of the import shipping. The amount of ship movement information provided by GPC for the study was slightly lower in 2014–15 than in the previous year, although capacity utilisation remained high relative to past years. The underused capacity for shipping from the Curtis Island LNG plants and the expansion of Fisherman's Landing meant that the port was not at full capacity, thereby limiting the shipping score to 0.82 (down slightly from the 2013–14 Pilot Report Card score of 0.83).

Tourism

Expenditure on tourism (accommodation, food and other local services) in the Gladstone region was $266.7 million in 2014–15. Although this was $77 million higher than in 2013, the previous data included expenditure on accommodation only. The number of people signing the visitor's book at the Gladstone Visitor Information Centre was about the same in both years. This suggests that total tourism numbers were similar.

Commercial fishing

The calculated gross value of production (GVP) for Gladstone Harbour fisheries in 2014–15 was $3.5 million, well below the 2013–14 figure of $4.5 million. The sector, however, remained relatively strong compared with neighbouring regions with similar fisheries. In general economic terms, the line and net sectors performed very poorly because the line sector was effectively no longer active in the region. Net fishing production in 2014–15 declined slightly from the previous year and remained at about half of the long-term average for this sector. The crab (pot) fishery production was reported to be at about the same high level as the previous year, although as stated above, these data are considered unreliable. Production in the trawl sector decreased by around 17% from the previous year. Combining the fishing effort and productivity data for the four sectors (weighted by their relative contribution to GVP) yielded a score of 0.63 for this indicator (0.66 in 2014).

7.3.2. Economic stimulus

The score for economic stimulus of 0.82 (B) was aggregated from the scores of two sub-indicators: unemployment 0.64 (C) and socio-economic status 0.95 (A) (Figure 7.3).

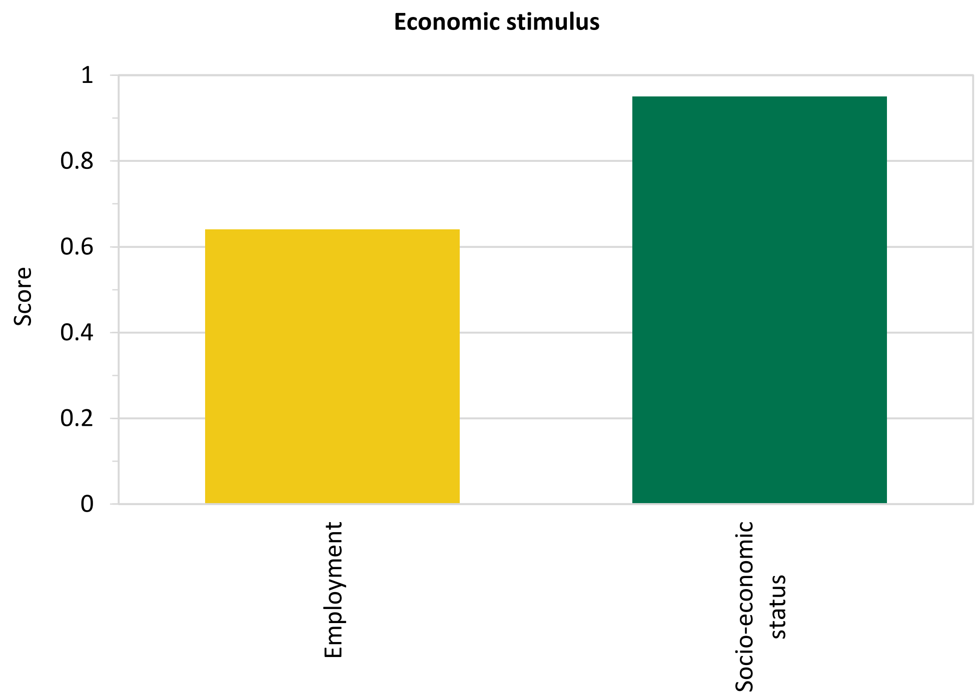


Figure 7.3: Scores for economic stimulus in the 2014–15 reporting year.

The unemployment rate of 4.7% was within the top 40% within the state; this gave a score of 0.64 for the employment indicator. Although unemployment fell slightly from the previous year's level of 4.8%, many other regions experienced greater declines in unemployment. This mean that the relative position of Gladstone deteriorated slightly compared to other LGAs in Queensland.

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.

7.3.3. Economic value (Recreation)

All three indicators of the economic value of recreation received similar scores. Land-based recreation received 0.73, recreational fishing 0.71 and beach recreation 0.70 (Figure 7.4).

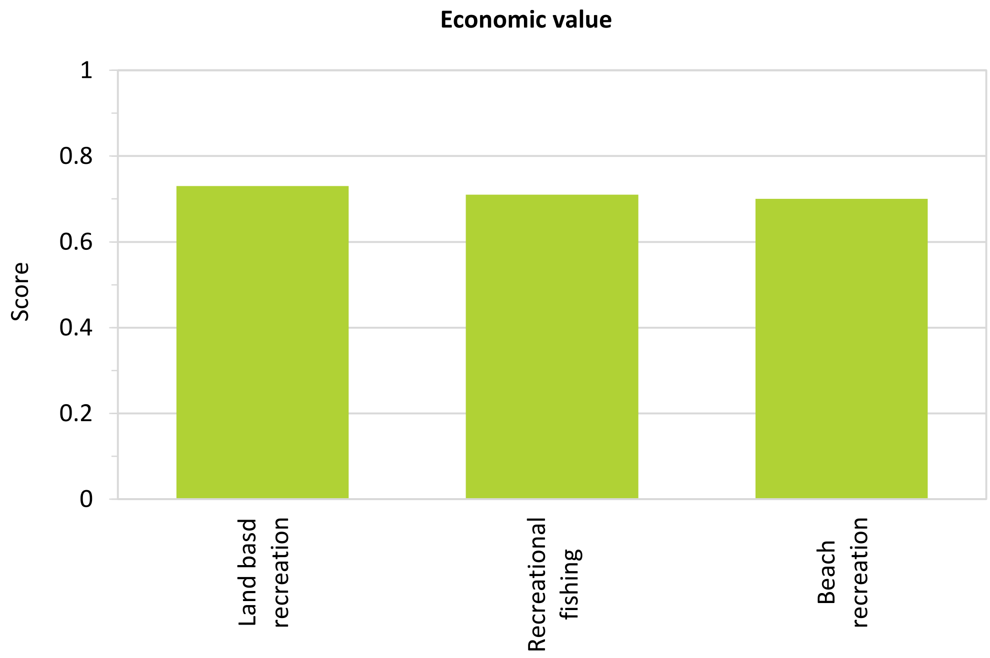


Figure 7.4: Scores for the three indicators of economic value (recreation) in the 2015 Gladstone Harbour Report Card.

About 97% of respondents (based on 154 participants from the CATI survey) reached the harbour by car and a small percentage of (3%) walked. According to the CATI survey, the most popular land-based activities along the shores of Gladstone Harbour are walking, picnicking/barbecuing and relaxing by the water. The most popular beach visited by the survey participants 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 95% of respondents had participated in land-based and beach recreation, but only 38% had undertaken recreational fishing.

The beach recreation indicator score was similar in both years (0.71 in 2013–14 and 0.70 in 2014–15). Land-based recreation satisfaction declined from 0.76 to 0.73, whereas recreational fishing satisfaction increased from 0.67 to 0.71 on average. As a result of these changes, and the adjusted weights based on the better estimates of recreational fishing benefits, the score for economic value declined from 0.75 to 0.72.

The mean value of a recreational fishing trip is estimated at $143.16 per trip and ranged from $73 to over $4,000 per trip. On average each trip was for 2.37 adults and the average trip cost per adult was $60.40. The average annual value of recreation trips for the Gladstone population is estimated at $21.34 million.

7.4. Economic indicator conclusions

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

Shipping activity provides a proxy for economic activity in key exports such as coal, 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 into the local economy. Tourism is an important sector for the harbour-based city. Fishing is an important sector for the harbour-based city, although activity is lower than in the previous year.

Economic stimulus captures the potential stimulus from economic activities that may flow through to the community. The low unemployment rate indicates that the economic stimulus from harbour-based industries is having a positive effect on the local economy and creating jobs.

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 providing better access to economic resources such as housing.

Economic value (recreation) assesses how the community generates economic values from the harbour through recreation. Economic activity in Gladstone generates income and wealth to the local community; the importance of the harbour is then assessed by how much of that wealth is spent on recreation in the harbour.

Land-based recreation was the most important activity with the average annual value for the Gladstone population estimated at $45.43 million.

Beach recreation was estimated to have an annual value of at $27.98 million.

Recreational fishing had a higher per trip value compared to beach and land-based recreation activity, but had a lower frequency across the population. The annual value was estimated at $21.34 million.

8. Iconic species of Gladstone Harbour

Gladstone Harbour and its associated water bodies and islands provides 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 indictors of harbour health year to year. 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 reduced sightings are detected in marine turtles or dugongs within the harbour. Additionally the range of most of these 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 portions of their flyways.

Although these species may not be suitable for 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 (EPBC Act) there are also legislative requirements requiring the protection and mitigation of anthropogenic impacts on these species.

Dolphins

The Indo-Pacific humpback dolphin *Sousa chinensis*, the Bottlenose dolphin *Tursiops truncatus* 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 population and Port Curtis and population were estimated to be 115 individuals 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 markinsg 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). While not directly comparable to the results of previous surveys these results indicate that Indo-Pacific humpback dolphins continue to utilize wide 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 1992. 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 predominately associated with the *Halophila ovalis* seagrass meadows, which form 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 a component of the Ecosystem Research and Monitoring Program (ERMP) funded by Gladstone Ports Corporation (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 anthropogenic impacts 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 area (Cagnazzi 2015). However while 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 turtles 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):

- 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 on an annual basis.
- Flatback turtle *Natator depressus*: EPBC status: endangered, marine and migratory. The flatback turtles is the dominant species of turtle recorded to nest on the beaches of Port Curtis. Most nesting occurs on the south 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 on an annual basis.
- 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 green turtles would move into shallower areas, which generally contained more food than the deeper areas of the harbour, during high tide 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 at five locations in the Gladstone area since 2011 as a component of the ERMP. In

In the February 2015 surveys a total of 13,752 migratory shorebirds of 21 species were counted in three areas, two of which are in the GHHP's area of interest: Port Curtis and Colosseum Inlet - Rodds Bay. This was an increase of 18.7% from the February 2014 counts and the highest total recorded since the counts commenced in 2011. However this variation is well within the magnitude expected for migratory shorebirds (Wildlife Unlimited 2015). The ten most abundant species accounted for 99% of 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. Guide to the infrastructure supporting the GHHP 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 a DIMS from 2016. Given the large volumes of data in the social, cultural and economic monitoring datasets used to inform a report card, this system will help to systematically and consistently manage the data. The DIMS will also act as a data source for the website, and will collate and analyse different data types and produce graphical outputs and tables. When completed this system will:

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

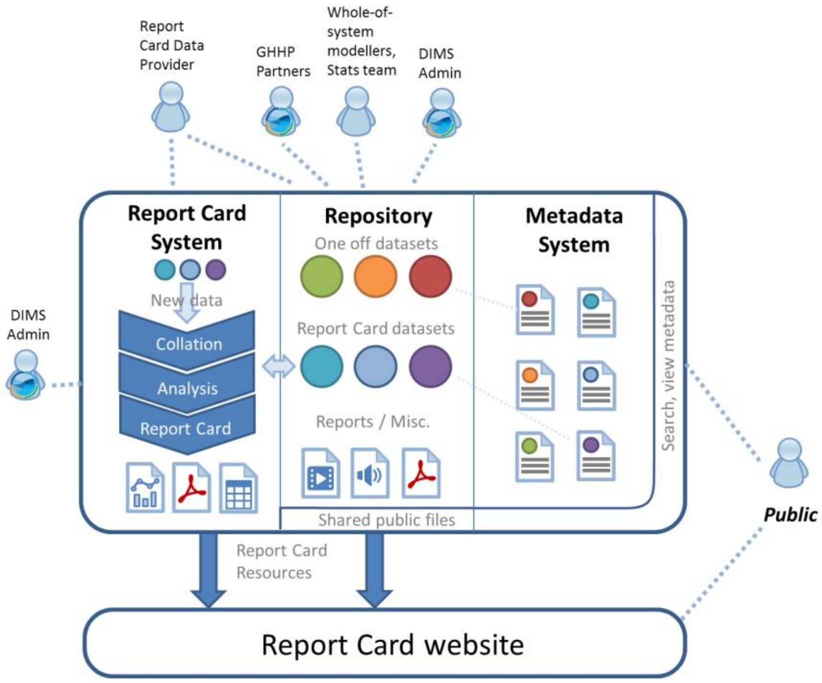


Figure 9.1: Conceptual model of the links between the report card website and the DIMS to illustrate major components and primary inputs and outputs.

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11. 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	digital information management system
ecosystem health	An ecosystem which 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)
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
indicator	Indicators are numerical values which 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 etc.
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 as scenario analysis tools to support management 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 and correct where necessary (QC). Raw data may have errors or may be in formats that are not suitable for

	further analysis, so appropriate quality control needs to be applied to assess and correct data.
raw data	Raw data or primary data are defined as data that have not been subjected to processing or any other manipulation 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, publically 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. The ability of a report card program to support management decisions concerning ecosystem health and the synthesis and communication of monitoring results and other scientific information was also considered. 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) flexibility in 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 upon the experience of 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, yellow 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 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), and the long-term predictions from the qualitative models will be tested against data from the monitoring program to provide a sound platform for increasing 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.

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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 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 to 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 report on progress towards social, cultural and economic goals for the Gladstone Harbour region. These goals developed by the 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 the 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 and 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 (To be completed June 2016)

CSIRO Wealth from Oceans Flagship, Hobart

When completed this full system model will comprise a suite of models which 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 provide advice on how the GHHP should respond to annual report card results while providing 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 the development and running of management scenarios 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 communications, shipping and ports, mining, heavy industry, the environment and education.

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

- the human behavioral drivers that explain the occurrence of 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 behavior
- where the social, economic and stewardship indicators sit in the broader social and economic system context of Gladstone Harbour.

The models developed from this process will be used as a basis for defining 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 by December 2015.

The final stage of this project is the development of the Gladstone Harbour Model. This model will be used to improve our understanding of the potential outcomes of an increasingly 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 also be conducted in order to compile an inventory of the key drivers of change in and around Gladstone Harbour. 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 future modifications required as new information becomes available.

A workshop will be conducted with the GHHP MC in early 2016 to formulate 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 by June 2016.

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 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. These are: assessing the indicators and reference conditions, and developing the report card scoring methodologies. This includes assisting in the determination of reference conditions for each report card indicator, statistical support required 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 (QA/QC) 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 and 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 of this project will be made available through the GHHP website after the review process has been completed.

ISP009 Development of a data and information management system for the Gladstone Harbour Report Card monitoring data (To be completed March 2016)

Australian Institute of Marine Science

To facilitate knowledge transfer across the monitoring and project areas and to the broader community, a digital 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 modelers 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 including 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 systems and the linkages between system administrator's data providers and user groups are illustrated in Figure 9.1 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 and 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 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*, yellow fin bream *Acanthropagus australis* and pikey bream *Acanthopagrus 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. In addition, as their range will usually extend beyond the limits of Gladstone Harbour it may be 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.

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. While 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 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 enabled the identification of baseline conditions 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 report (below) and a summary of the project 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.

ISP012 Cultural indicators pilot project (To be completed in 2015)

Terra Rosa Consulting

The cultural component of the report card consists of two indicator groups: the sense of place and cultural heritage indicators. The sense of place indicator group was assessed through 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
- develop indicator option(s) to annually assess the 'number of registered cultural heritage sites protected along the waterways and harbour' for use in the GHHP Report Card.

ISP013-2015 fish recruitment study (To be completed in 2016)

Infofish Australia and Dr Bill Venables

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

In 2014, 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 yellowfin 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 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 yellowfin 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 intends that it be 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

Venables, W. N. (2015). *GHHP barramundi recruitment index project final report*. Gladstone Health Harbour Partnership. Retrieved from: http://dims.ghhp.org.au/repo/data/public/7d9e4c.php

ISP014 Coral indicator pilot project (Completed)

Australian Institute of Marine Science (AIMS), Townsville

Coral communities are iconic components of marine ecosystems in northern Australia. In addition to their high biodiversity values, coral reefs can 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.

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, which measures changes in coral cover from the previous year 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.

ISP015: Developing an indicator for mud crab (*Scylla serrata*) abundance in Gladstone Harbour. (To be completed in 2016)

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.

GHHP Gladstone fish health research program

GHHP, Fisheries Research and Development, Canberra

The Gladstone Healthy Harbour Partnership MC has asked the ISP to develop priority research areas for identifying the causality of recent fish health issues observed within Gladstone Harbour and to develop approaches to enhance early detection of fish health issues in the future.

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 be 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 contribute in the future to the annual Gladstone Harbour Report Card.

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

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

ISP017: Additional PAH monitoring 2015

The GHP 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 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

Results of the PAH sampling will be included with existing sediment monitoring data and will be reported in the annual Gladstone Harbour Report Card, GHHP Report Card Website and annual report card technical report.

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

The role of the ISP is to ensure environmental, social and economic challenges of policy, planning and actions to achieve the vision of Gladstone Healthy Harbour Partnership (GHHP) are supported by credible science that provides independent scientific advice, review and direction. 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-offico 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 Convenor. 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 review of scientific reports commissioned by the GHHP and 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 provision of effective communication of results and recommendations to the wider community as required.

Appendix 3: Stewardship

View HERE:
http://ghhp.org.au/uploads/reports/GHHP%20Stewarship%20Reporting%20Project%20Report_v2%20FINAL.pdf


eco logical AUSTRALIA

ADAPTIVE STRATEGIES

Gladstone Healthy Harbour Partnership Stewardship Reporting Project

Prepared for
Gladstone Healthy Harbour Partnership (GHHP)

20 August 2015

Appendix 4: Citizen Science

View HERE:

Summary - http://ghhp.org.au/uploads/reports/Creekwatch_Summary%20Report.pdf

Full Report - http://ghhp.org.au/uploads/reports/CreekWatch_FinalReport.pdf

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)[a]	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 measure were not included in 2014–15 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 in the calculation of 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