

Mud Crab Indicator for the 2025 Gladstone Harbour Report Card

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The authors would like to take this opportunity to respectfully acknowledge the Traditional Owners of the land on which we live, work and learn, and pay our respects to the Elders, past, present and future for they hold the memories, the traditions, the culture and hopes of Indigenous Australia. In particular, we pay our respects to the peoples on whose Country this research was carried out.

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VERSION HISTORY

Version Number	Purpose/Changes	Authors	Date
1.1	Initial draft of interim report – to GHHP	NF, JDV, WD, GC, AA	06/08/2025
1.2	Revisions following ISP review	NF, JDV, WD, GC, AA	21/09/2025

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EXECUTIVE SUMMARY

Since 2017, the mud crab indicator for the Gladstone Harbour Report Card has provided an annual assessment of mud crab populations using standardised surveys conducted twice per year across seven Gladstone Harbour zones. Scores and grades for three measures are assessed: abundance (catch per unit effort; CPUE), prevalence of rust lesions, and sex ratio. This report presents the results of the ninth year of sampling, conducted in 2025.

Two sampling events were undertaken in February (summer, wet season) and June (winter, dry season) of 2025. Scores for each of the three measures were averaged across all zones first to give a harbour average for each measure, and then the average of the three harbour averages was calculated to provide a harbour-wide score and grade for the mud crab indicator. The table below presents the scores and grades for the 2025 sampling:

Zone	Abundance (CPUE)	Prevalence of rust lesions	Sex ratio	Zone score 2025
1. The Narrows	0.67	0.95	1.00	0.88
2. Graham Creek	0.12	0.70	0.24	0.35
4. Boat Creek	1.00	1.00	0.21	0.74
5. Inner Harbour	0.03	1.00	1.00	0.68
6. Calliope Estuary	0.21	0.59	0.00	0.27
7. Auckland Inlet	0.00	1.00	0.24	0.41
13. Rodds Bay	0.00	0.32	1.00	0.44
Harbour Average	0.29	0.80	0.53	0.54

The Harbour average was graded C in 2025 (score 0.54), slightly higher than in 2023 (grade C; score 0.51) and 2024 (grade D; score 0.46). A range of anthropogenic and environmental factors may affect the scores and grades for the mud crab indicator. These factors may include (but are not limited to) commercial and recreational fishing pressure, habitat quality, weather conditions and recruitment. Relative abundance (CPUE) was greater in 2025 compared to the past three years, although the summer catches in 2025 were lower than in 2024. Since many environmental factors can contribute to differences in catches of mud crabs over time, the decision was taken in 2018 for abundance to be scored based on the use of a 10-year moving average benchmark, using the average of the 75th percentile of scores for current and previous sampling years. This long-term adjustment to the benchmark allows for annual harbour-wide changes in catchability and abundance, which are more likely to reflect shorter term natural variations. The prevalence of rust lesions was graded A in The Narrows, Boat Creek, Inner Harbour and Auckland Inlet. Graham Creek scored marginally lower than in 2024, but received the same grade (B). Calliope Estuary (C) and Rodds Bay (D) were graded lower than in 2024. Overall, the sex ratio was higher in 2025 than in 2024, and was unusually skewed towards males during the summer catches in 2025. Changes in the sex ratio of males to females over the minimum size limit might be caused not only by harvest, but by varying factors such as habitat suitability. However, fishing pressure is generally the major driver of differences in sex ratio in fisheries where sex and size restrictions are applied.

The mud crab indicator has been successfully monitored since 2017. After the completion of 2026 sampling, a continuous 10-year data set will be available across the seven monitoring zones in Gladstone Harbour. This long-term data set in combination with findings from other mud crab research projects conducted by CQUniversity, will provide a strong basis for the interpretation and analysis of factors influencing mud crab populations within Gladstone Harbour.

As part of this report, several recommendations are provided to guide the future monitoring and development of the mud crab indicator for Gladstone Harbour. It is recommended that the current monitoring program continues, with sampling conducted twice a year at the seven long-term sites. Maintaining this schedule will ensure consistency in the dataset leading up to the planned review of ten years of monitoring data, to be undertaken after the 2026 sampling. Future changes might include expanding the monitoring program to include other estuaries, such as South Trees Inlet and the Boyne Estuary, to improve the indicator's relevance across a broader area of the harbour. If additional resources become available, establishing a reference site at Eurimbula Creek is advised, to provide important context for interpreting results from more heavily fished and industrialised areas. Further recommendations include exploring the potential for monitoring bioaccumulation of relevant metal(loid)s and continuing research into the cause of rust lesions. While implementation of some of these recommendations may be best considered after the 2026 review, they provide a clear direction for the indicator's continued development.

INTRODUCTION

In 2017, GHHP commissioned CQUniversity to develop mud crab indicator for the Gladstone Harbour Report Card (Project ISPO15-2017). The indicator focuses on a single species, the giant mud crab (*Scylla serrata*), a large, high-value decapod that is a popular fisheries resource in Australia and the wider Indo-Pacific. The mud crab fishery in Gladstone is one of the highest-catch regions in Australia. Since the development of the indicator and a long-term monitoring program in 2017, GHHP has annually commissioned CQUniversity to monitor, score and grade the mud crab indicator, and to consider and propose refinements when needed.

Biological indicators like the GHHP mud crab indicator can help to engage public interest and understanding of environmental health (Flint *et al.*, 2021). The OECD defines an environmental indicator as "[...] a parameter, or a value derived from parameters, that points to, provides information about and/or describes the state of the environment, and has a significance extending beyond that directly associated with any given parametric value. The term may encompass indicators of environmental pressures, conditions and responses." Using this definition, environmental indicators do not necessarily reflect only a single, individual environmental pressure. In the case of biological indicators, the monitored animals have been exposed to the cumulative effects of a range of pressures and conditions in their environment over time, which can result in a range of biological responses. They also provide a more comprehensive picture of the state of the environment than, for example, physicochemical parameters.

Some of the factors influencing mud crab populations in Gladstone Harbour include commercial and recreational fishing (restricted to males over 150 mm carapace width), coastal development affecting mangrove and estuarine habitat quality, changes in water quality, and local weather patterns including those associated with global climate change. The prevalence of disease is also an important consideration and in previous years rust shell lesions have been recorded in Gladstone Harbour (Andersen and Norton, 2001; Dennis *et al.*, 2016). To address the range of pressures that are present in the harbour, the GHHP mud crab indicator combines scores from three metrics: relative abundance (catch per unit effort – CPUE), the prevalence of rust lesions, and sex ratio (Flint *et al.*, 2021).

The metric of relative abundance of mud crabs that are caught during the monitoring program provides a temporal and spatial comparison of catch rates, using a standardised and fishery-independent biannual survey. To control for potential monitoring variations that could arise due to capture technique, consistent methods are employed during each catch period. Catch rates of mud crabs can reflect a wide variety of natural and anthropogenic impacts on a population (Alberts-Hubatsch *et al.*, 2016a). Factors influencing the abundance of mud crabs may include localised and regional fishing pressure, habitat availability and habitat condition, the availability of food and proximity to suitable nursery grounds for the settlement of mud crab megalopae and metamorphosis to immature crabs (Charles *et al.*, 2024). Climate has also been shown to impact the abundance of mud crabs (Meynecke *et al.*, 2015) so there is also potential for this indicator to be used to monitor climate effects on mud crabs in the longer term.

The prevalence of rust lesions metric reports the proportion of captured crabs with rust spot shell lesions. The lesions were first recorded by commercial fishers in Gladstone Harbour in 1994 (Andersen and Norton, 2001). The disease is not infectious and it is thought to be related to inhibition of calcium uptake following sublethal copper exposure, although this has not yet been experimentally confirmed (Andersen and Norton, 2001; Flint *et al.*, 2021). Since rust spots are not continuously observed in Gladstone Harbour, their prevalence at any given time provides an indication of environmental state. Rust spot lesions impact the seafood 'grade' of mud crabs, so are a concern for local fishers. Recording the presence of rust spot is a relatively straightforward and non-destructive monitoring tool.

The third measure used in the mud crab indicator is sex ratio of male to female crabs over the minimum legal size. In Queensland, female mud crabs, and male mud crabs under 150 mm, may not be retained. Hence, the major drivers of changes in sex ratio are recreational and commercial fishing pressure on male mud crabs over 150 mm carapace width (measured across the ninth posterolateral spines, referred to as 'spine width' in this report), although other factors including habitat suitability may also influence results. Changes in the ratio of males to females in sex-based fisheries can indicate a change in fishing pressure (Pillans *et al.*, 2005; Alberts-Hubatsch *et al.*, 2016b; Charles *et al.*, unpub. data). The impacts of shifts in sex ratio are not well understood but may have implications for population dynamics of mud crabs and reproductive success and may also influence ecosystem processes due to the different burrowing behaviours and movements exhibited by male and female crabs. Reproductive biology of females, and the movement ecology of mud crabs, were the topics of two PhD student projects at CQUniversity – both PhD theses are currently under examination (Hossain, unpublished doctoral thesis; Charles, unpublished doctoral thesis).

Objectives

The overall objectives of this project were to:

1. Conduct mud crab surveys of the 7 GHHP reporting zones consistent with the survey methods used in previous years and consisting of a summer (warm, wet season) survey and a winter (cool, dry season) survey.
2. Provide mud crab scores and grades for the 2025 Gladstone Harbour Report Card. Calculate scores and grades using the methods developed in the 2017 mud crab monitoring project and revised in 2020, and using the thresholds for sex-ratio and abundance used for the calculation of the 2018, 2019, 2020, 2021, 2022, 2023 and 2024 mud crab scores.

METHODS

Permits and approvals

The following permits and approvals are in place for this research:

- General Fisheries Permit (Queensland Department of Agriculture and Fisheries; Permit Number 263226)
- Animal Ethics Approval (CQUniversity approval number 24775)
- Authorisation for research in the Great Barrier Reef Marine Park (Approval Number G17/05-027)
- Field Work Risk Assessment (CQUniversity Occupational Health and Safety Unit).

Field methods

Field methods and gears were as described in previous years (see Flint *et al.*, 2017-2024). Two mud crab surveys were undertaken in 2025 (Table 1), representing a summer (warm, wet season) and winter (cool, dry season) sample. The seven monitoring sites (Figure 1) were previously chosen through a quantitative selection process (Flint *et al.*, 2017) related to the availability of suitable habitat types and the occurrence of previous sampling sites, and have been surveyed twice annually since 2017. Eurimbula Creek was surveyed in 2018/19 as a reference site and to refine benchmarks. Details of these surveys were provided by Flint *et al.* (2019).

Table 1: Gladstone zones/sites sampled during February and June 2025.

Zone/site	Survey 1	Survey 2
Zone 1: The Narrows	07/02/2025	06/06/2025
Zone 2: Graham Creek	07/02/2025	06/06/2025
Zone 4: Boat Creek	08/02/2025	07/06/2025
Zone 5: Inner Harbour	06/02/2025	05/06/2025
Zone 6: Calliope Estuary	08/02/2025	07/06/2025
Zone 7: Auckland Inlet	06/02/2025	05/06/2025
Zone 13: Rodds Bay	09/02/2025	08/06/2025

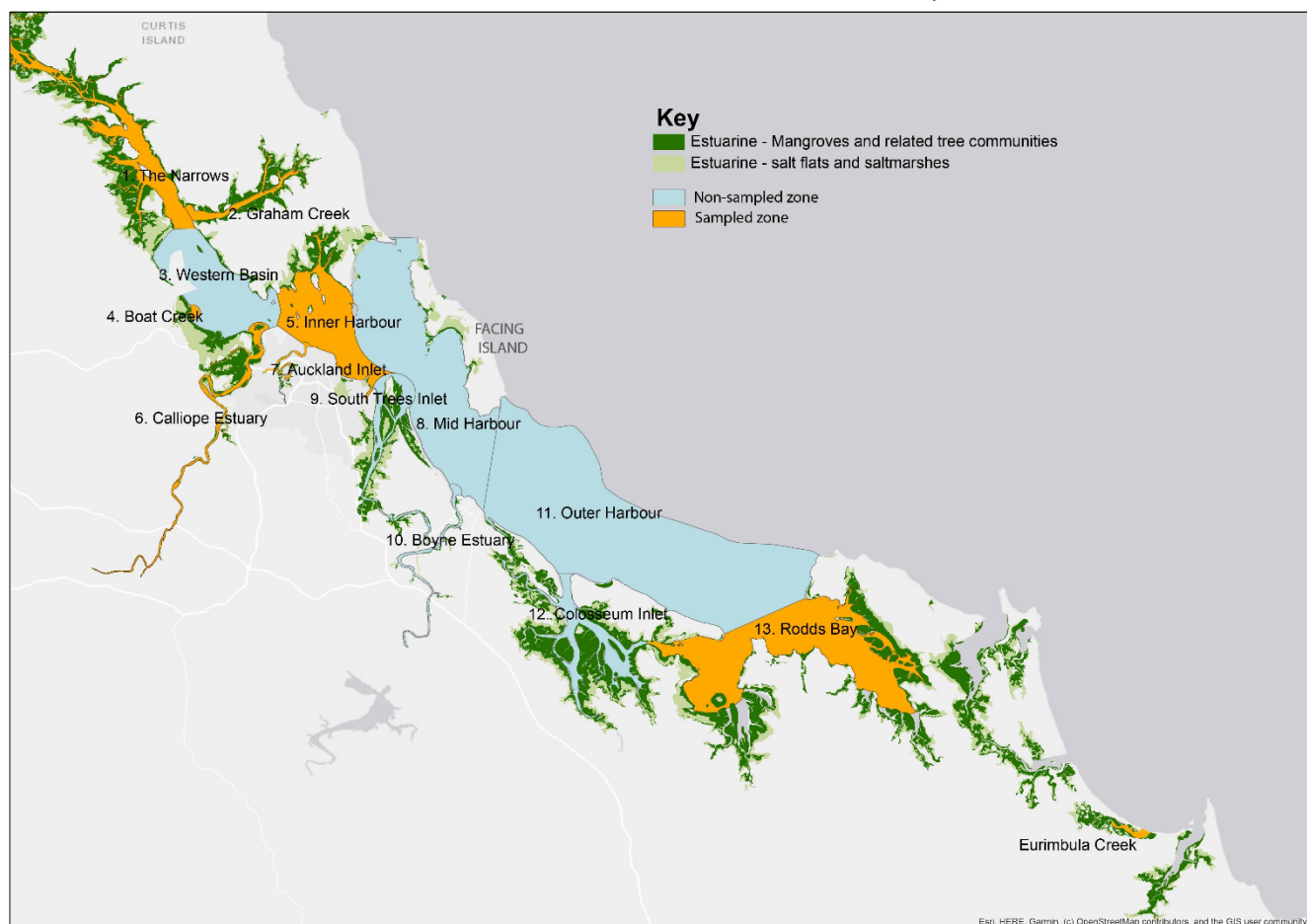


Figure 1: Map of the Gladstone Harbour zones showing long-term monitoring sites surveyed annually from 2017 through to 2025. The map also shows the location of Eurimbula Creek, a mud crab protection zone which was sampled in 2018 and 2019 as a reference site for measures including sex ratios.

At each sampling site / date, the following information was recorded:

- Zone and site name;
- GPS location;
- Date;
- Set time and retrieval time for each uniquely identified pot;
- The total number of animals of each species caught in every pot; and
- Water quality parameters (temperature, dissolved oxygen, conductivity, pH, turbidity, total dissolved solids, oxidation reduction potential and salinity) measured using a YSI ProDSS Multiparameter Sampling Instrument, recorded once before setting the first pot and once after retrieving the final pot (not reported but provided to GHHP).

For every mud crab captured at each site, the following information was recorded:

- Species;
- Sex;
- Carapace width (notch width) (mm); and

- Abnormalities: type, body location, and number, dimensions and grade of rust spot lesions (source Andersen and Norton, 2001).

All bycatch species (including blue swimmer crabs, other crabs and fish) were also recorded. Blue swimmer crabs were opportunistically weighed, measured, and checked for abnormalities before release.

Data analysis

As in previous years, the data from the two field surveys (February and June 2025) were analysed separately and then together. Exploratory analyses included descriptive statistics, for example distribution plots (kernel density), and box plots for visual comparisons of differences and variance around the mean. All analyses were conducted in R version 4.4.0 (<https://www.r-project.org/>).

Scoring, grading and aggregation

The mud crab measures were calculated for each Zone, as follows:

- **Abundance** (CPUE)
=
$$\frac{(\text{total number of mud crabs caught})}{(\text{number of pots set})}$$
- **Prevalence of rust lesions**
=
$$\frac{(\text{number of crabs with rust lesions})}{(\text{number of crabs assessed for rust lesions})}$$
- **Sex ratio** based on oversize mud crabs
=
$$\frac{(\text{number of male mud crabs} > 150 \text{ mm})}{(\text{number of female mud crabs} > 150 \text{ mm})}$$

The formulae provided in Table 2 were used to score the mud crab measures, comparing each index value against the benchmark and worst-case scenario (WCS) values. Using this method, index values worse than the WCS score a 0, while index values better than the benchmark score a 1 and all other index values range between these bounds. The method for determining benchmark and WCS values for each measure is described by Flint *et al.* (2017-2024). The Gladstone Harbour Report Card grading system is provided in Table 3.

Sex ratio of legal-sized crabs (>150 mm carapace spine width, which is equivalent to a crab with 143 mm notch width) is calculated against a 'minimally disturbed' benchmark from the literature and sampling undertaken at an unfished estuary in central Queensland of 2:1 (Eurimbula Creek, Figure 1).

The benchmark for the abundance measure is updated annually, as a 10-year moving average of the 75th percentile of scores. Each year, the moving average of the 75th percentiles is recalculated (now nine years from 2017 to 2025). Notably, the CPUE in 2017 (3.5) was much higher than in every subsequent year, so the benchmark has been gradually dropping each year since then.

Table 2: Benchmarks and scoring method for each of the three recommended measures. NC = not calculable. LTMP – long term monitoring program.

Measure	Benchmark	Worst case scenario	Method of calculation
Abundance (CPUE)	2017: 3.5 (75 th %ile of 2017 scores) 2018: 2.5 (moving average of 75 th %ile of 2017 and 2018 scores) 2019: 2.12 (moving average of 75 th %ile of 2017, 2018 and 2019 scores) 2020: 1.95 (moving average of 75 th %ile of 2017, 2018, 2019, 2020) 2021: 1.8 (moving average of 75 th %ile of 2017, 2018, 2019, 2020) 2022: 1.6 (moving average of 75 th %ile of 2017-2022) 2023: 1.5 (moving average of 75 th %ile of 2017-2023) 2024: 1.3 (moving average of 75 th %ile of 2017-2024) 2025: 1.3 (moving average of 75th %ile of 2017-2025)	0.25	The function used to calculate scores for abundance is: $1 - ((x - B) / (WCS - B))$ Where: x = recorded CPUE B = benchmark (1.3) WCS = worst case scenario (0.25)
Prevalence of rust lesions	0.04	0.35	The function used to calculate scores for prevalence is: $1 - ((x - B) / (WCS - B))$ Where: x = recorded prevalence B = benchmark (0.04) WCS = worst case scenario (0.35)
Sex ratio	2017: 3 2018+: 2	0.25	The function used to calculate scores for sex ratio is: $1 - ((x - B) / (WCS - B))$ Where: x = recorded sex ratio B = benchmark (2) WCS = worst case scenario (0.25)

Table 3: Gladstone Harbour Report Card grading scale (Source: GHHP, 2015).

Score	Grade
≥ 0.85	A
$\geq 0.65, < 0.85$	B
$\geq 0.5, < 0.65$	C
$\geq 0.25, < 0.5$	D
$0, < 0.25$	E

RESULTS

Abundance and size

The February (summer) 2025 sampling event captured 54 mud crabs across the seven monitored zones in Gladstone Harbour. This was lower than the March 2024 sampling event (79 mud crabs) but higher than February 2023 (24) and February 2022 (33). Of the 54 mud crabs caught, 20 were females and 34 were males.

The June (winter) 2025 event captured 116 mud crabs across the seven zones, which was higher than the winter catches for the past three years (83 in July 2024, 70 in June 2023, 84 in June 2022). The minimum number of mud crabs ($n = 5$ across the year) were caught in all monitored zones in 2025, so all zones were able to be scored and graded. Of the 116 mud crabs caught, 46 were females and 70 were males.

Over the full sample, the mud crabs captured in 2025 were not significantly different from those captured in 2024 ($t = -0.957$, $p = 0.339$). The average size of mud crabs caught in February 2025 was 148.3 mm carapace notch width (Table 4) and in June 2025 was 146.05 mm (Table 5). Welch's two-sample t-tests (Welch tests) were conducted to compare the 2025 data with 2024 data and with the baseline established from historical data (2001-09) (Flint *et al.* 2017). These tests assume unequal variances and unequal sample sizes across samples, which is the case here. The hypothesis being tested each time was whether this year's sample distribution (mean and variance) was equal to the distribution from the previous year and from the baseline, and if this year's sample was significant larger/smaller than last year's. The full February 2025 sample including both males and females is not significantly different from March 2024 ($p = 0.600$) or to the historical dataset ($p = 0.224$). In contrast, the June 2025 sample of both male and female mud crabs was significantly different in size to mud crabs caught in July 2024 ($p = 0.059$), and significantly smaller than in July 2024 ($p = 0.029$), but it was not significantly different to the historical dataset ($p = 0.687$).

When considered separately, male mud crabs caught in 2025 were significantly larger than in 2024 for summer ($p = 0.044$) but not for winter ($p = 0.462$). Female crabs were not significantly different in size than those female crabs caught in 2024, in either summer ($p = 0.820$) or winter ($p = 0.649$) (Table 4 and 5).

The results of the Welch's two-sample t-tests comparing males and females from each data collection event in 2025 found that females were significantly larger than males in February 2025 ($t = -1.77$, $df = 37.19$, $p = 0.085$; Figure 2), a similar result was observed in summer 2024. In June 2025, females were also significantly larger than males ($t = -3.86$, $df = 72.54$, $p\text{-value} < 0.001$; Figure 3).

The largest average mud crab size in February 2025 was recorded at Auckland Inlet but from only one crab (notch width of 172 mm) followed by Calliope Estuary (169 mm notch width). The smallest average mud crab size in February was recorded at Boat Creek (142 mm notch width). In June 2025, the largest average mud crab size sampling was again from Auckland Inlet (mean notch width of 162 mm) and the smallest again at Boat Creek (142 mm).

Table 4: Notch width (mm) of mud crabs caught in February 2025 in comparison to March 2024, March 2024 to February 2023, and February 2025 to historical data collected between 2001-2009 by Fisheries Queensland (significance level $p < 0.05$)

February 2025	FULL SAMPLE			MALES			FEMALES		
	February 2025	March 2024	Historical data (2001-2009)	February 2025	March 2024	Historical data (2001-2009)	February 2025	March 2024	Historical data (2001-2009)
N	54	79	1930	34	39	726	20	40	1204
Mean	148.30	146.63	145.45	145.21	138.41	135.12	153.55	154.65	151.67
Standard deviation	16.70	19.61	20.74	15.81	17.84	18.65	17.25	18.05	19.43
2025-24 two-tailed Welch t-test	$H_0: 2024 = 2025$	$H_0: 2023 = 2024$	$H_0: \text{baseline} = 2025$	$H_0: 2024 = 2025$	$H_0: 2023 = 2024$	$H_0: \text{baseline} = 2025$	$H_0: 2024 = 2025$	$H_0: 2023 = 2024$	$H_0: \text{baseline} = 2025$
t value	0.525	-2.279	1.228	1.725	-2.330	3.605	-0.229	-0.513	0.481
p value	0.600	0.029	0.224	0.089	0.044	9.0E-04	0.820	0.612	0.635
Signif?	H_0 NOT rejected	H_0 rejected (5% level)	H_0 NOT rejected	H_0 rejected (10% level)	H_0 rejected (5% level)	H_0 rejected (1% level)	H_0 NOT rejected	H_0 NOT rejected	H_0 NOT rejected
2025-24 One-tailed Welch t-test	$H_1: 2025 > 2024$	$H_1: 2024 < 2023$	$H_1: 2025 > \text{baseline}$	$H_1: 2025 > 2024$	$H_1: 2024 < 2023$	$H_1: 2025 > \text{baseline}$	$H_1: 2025 < 2024$	$H_1: 2024 < 2023$	$H_1: 2025 > \text{baseline}$
p value	0.300	0.014	0.112	0.044	0.022	0.000	0.410	0.306	0.318
Signif. diff.?	No	Yes, 2024 < 2023	No	Yes, 2025 > 2024	Yes, 2024 < 2023	Yes, 2025 > baseline	No	No	No

Table 5: Notch width (mm) of mud crabs caught in June 2025 in comparison to July 2024, July 2024 to June 2023, and June 2025 to historical data collected between 2001-2009 by Fisheries Queensland (significance level $p < 0.05$)

June 2025	FULL SAMPLE			MALES			FEMALES		
	June 2025	July 2024	Historical data (2001-2009)	June 2025	July 2024	Historical data (2001-2009)	June 2025	July 2024	Historical data (2001-2009)
N	116	83	1930	70	32	726	46	51	1204
Mean	146.05	150.36	145.45	141.54	143.87	135.12	152.91	154.42	151.67
Standard deviation	15.37	15.99	20.74	11.96	15.84	18.65	17.46	14.83	19.43
2025-24 two-tailed Welch t-test	$H_0: 2024 = 2025$	$H_0: 2023 = 2024$	$H_0: \text{baseline} = 2025$	$H_0: 2024 = 2025$	$H_0: 2023 = 2024$	$H_0: \text{baseline} = 2025$	$H_0: 2024 = 2025$	$H_0: 2023 = 2024$	$H_0: \text{baseline} = 2025$
t value	-1.903	-1.074	0.404	-0.741	-1.503	4.047	-0.457	-0.412	0.471
p value	0.059	0.284	0.687	0.462	0.138	9.97e-05	0.649	0.681	0.640
Signif?	H_0 rejected (10% level)	H_0 NOT rejected	H_0 NOT rejected	H_0 NOT rejected	H_0 NOT rejected	H_0 rejected (1% level)	H_0 NOT rejected	H_0 NOT rejected	H_0 NOT rejected
2025-24 One-tailed Welch t-test	$H_1: 2025 < 2024$	$H_1: 2024 < 2023$	$H_1: 2025 > \text{baseline}$	$H_1: 2025 < 2024$	$H_1: 2024 < 2023$	$H_1: 2025 > \text{baseline}$	$H_1: 2025 < 2024$	$H_1: 2024 < 2023$	$H_1: 2025 > \text{baseline}$
p value	0.029	0.142	0.343	0.231	0.0690	4.99e-05	0.324	0.341	0.320
Signif. diff.?	Yes, 2025 < 2024	No	No	No	No	Yes, 2025 < baseline	No	No	No

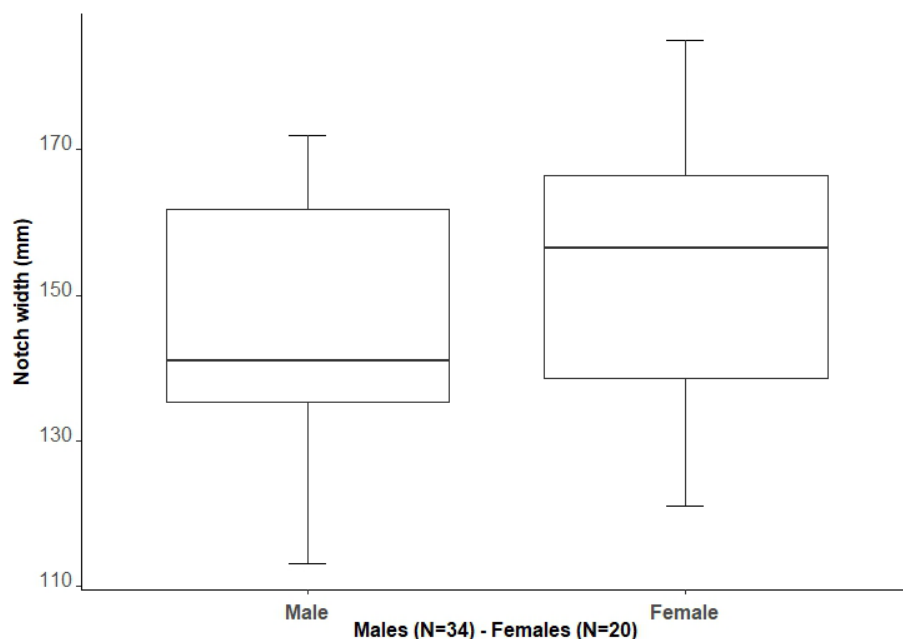


Figure 2: Notch width (mm) distribution of male and female mud crabs caught in February 2025.

The box represents the middle 50% of ordered observations. Centre line is the median and the lower and upper edges correspond to the 25th and 75th percentiles. Whiskers extend from the box to the smallest and largest values no greater than 1.5 times the interquartile range (=75th percentile of ordered observations – 25th percentile of ordered observations).

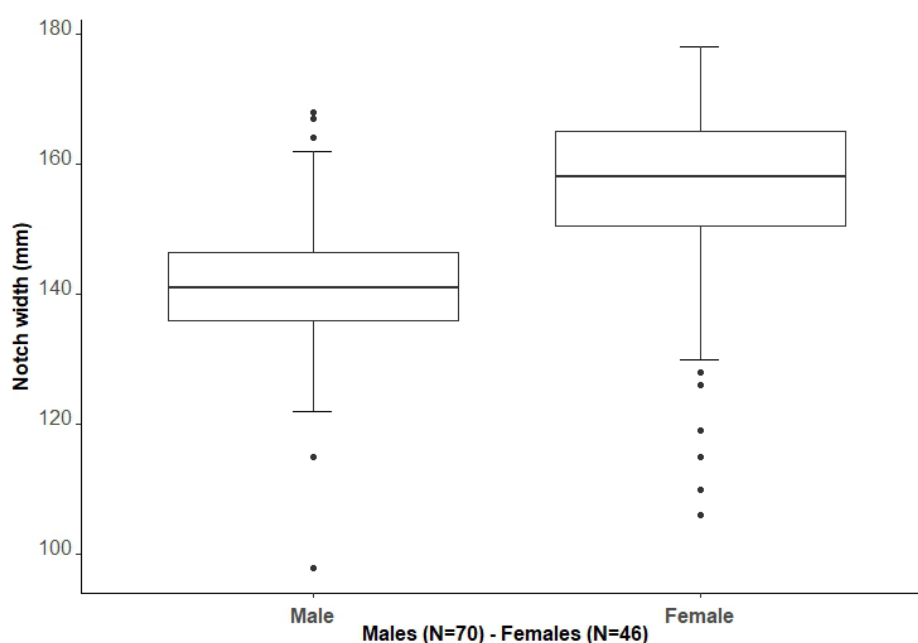


Figure 3: Notch width (mm) distribution of male and female mud crabs caught in June 2025.

The box represents the middle 50% of ordered observations. Centre line is the median and the lower and upper edges correspond to the 25th and 75th percentiles. Whiskers extend from the box to the smallest and largest values no greater than 1.5 times the interquartile range (=75th percentile of ordered observations – 25th percentile of ordered observations). Observations that are smaller/larger than the lower/upper fences of the boxplot are plotted individually as circles and deemed outliers that should be assessed for validity and impact on statistical analyses.

In February 2025, CPUE was relatively low in most zones, and was highest in Boat Creek ($n = 24$). This is the first time in nine years that the highest summer catch was not from The Narrows ($n = 14$). CPUE was lowest at Auckland Inlet with only one mud crab captured (Table 6, Figure 4). In June 2025, CPUE was again highest at Boat Creek ($n = 52$) followed by The Narrows ($n = 23$), and lowest at Rodds Bay, with only three mud crabs (Table 7, Figure 5).

Table 6: Catch (number of crabs) per unit effort (number of pots) (CPUE) in February 2025, by zone.

ZONE	ZONE NAME	# POTS	# TOTAL MUD CRABS CAUGHT	RATIO CAUGHT / POT
1	Narrows	20	14	0.7000
2	Graham Creek	20	4	0.2000
4	Boat Creek	16	24	1.5000
5	Inner Harbour	20	4	0.2000
6	Calliope Estuary	20	2	0.1000
7	Auckland Inlet	20	1	0.0500
13	Rodds Bay	20	5	0.2500

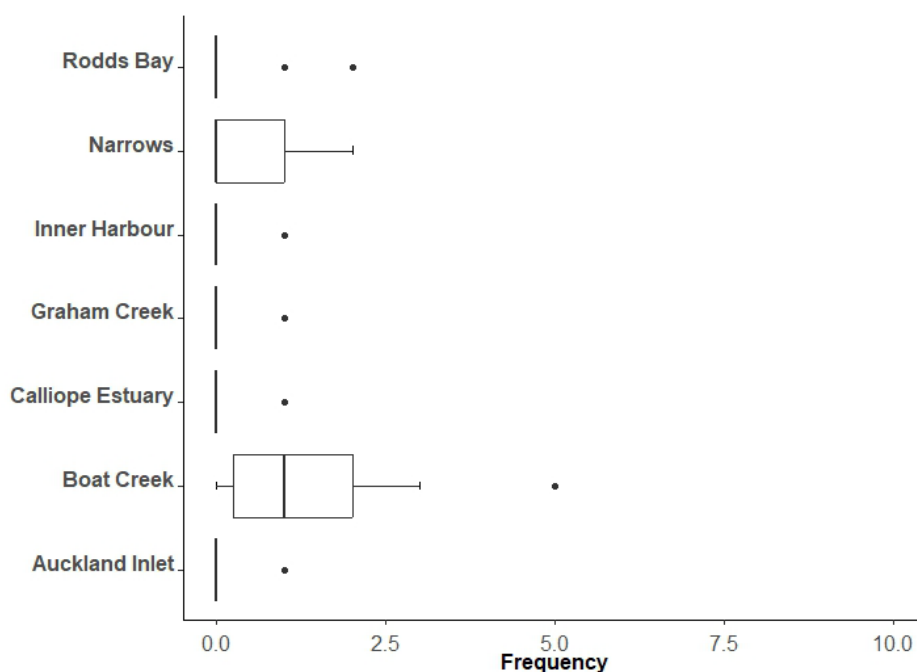


Figure 4: Number of mud crabs in each pot set in February 2025, by zone.

Table 7: Catch (number of crabs) per unit effort (number of pots) (CPUE) in June 2025, by zone.

ZONE	ZONE NAME	# POTS	# TOTAL CAUGHT	RATIO CAUGHT / POT
1	Narrows	19*	23	1.21
2	Graham Creek	20	11	0.55
4	Boat Creek	18+	52	2.89
5	Inner Harbour	19*	7	0.37
6	Calliope Estuary	19*	16	0.84
7	Auckland Inlet	20	4	0.20
13	Rodds Bay	20	3	0.15

* One pot was found to be missing on deployment, which reduced effort to 19 pots at Inner Harbour and The Narrows. The missing/stolen pot was able to be replaced by day 3, but one pot was observed to be raided while deployed at Calliope Estuary and was excluded from analysis.

+ Usually only 16 pots are set at Boat Creek, but in June 2025 effort increased to 18 pots, due to a change in research vessel that allowed greater upstream access.

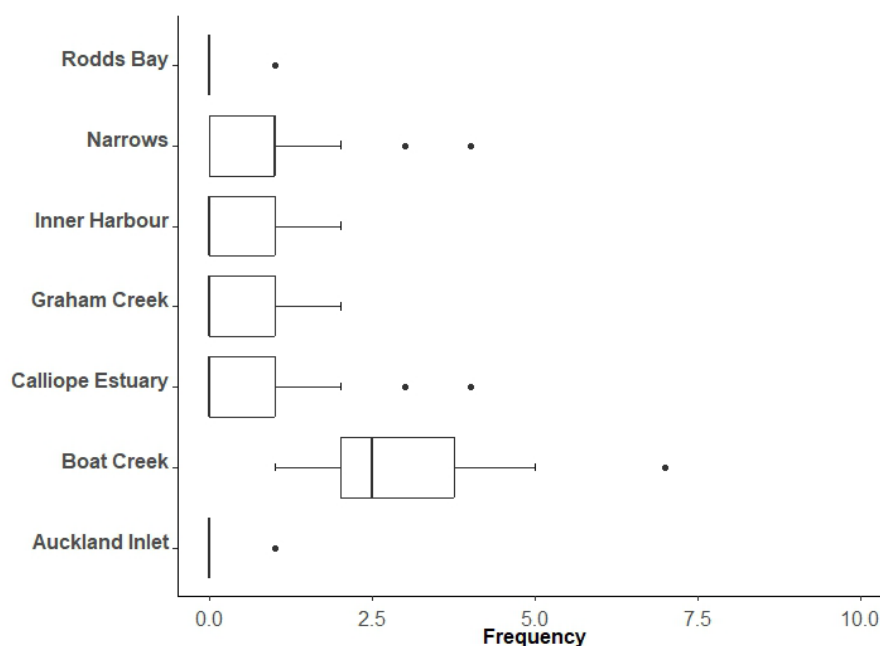


Figure 5: Number of mud crabs in each pot set in June 2025, by zone.

Sex ratio

In February 2025, unlike in previous sampling events, more oversized male crabs than female crabs were caught in Gladstone Harbour. In June 2025 more oversized females than males were caught, but the margin was somewhat lower than usual. A total of 96 mud crabs over the legal-size limit of 150 mm carapace width (equivalent to 143 mm notch width) were caught in 2025, of which 46 were male. Sex ratios remained low in most zones, however at The Narrows and Inner Harbour they were similar to the sex ratios commonly recorded at the mud crab protection area, Eurimbula Creek (Table 8).

Table 8: Sex ratios of mud crabs with notch width > 143 mm, in February and June 2025, by zone. / = no data as no mud crabs of the relevant size/sex were captured.

ZONE	ZONE NAME	FEBRUARY 2025 DATA			JUNE 2025 DATA		
		Males	Females	Sex ratio	Males	Females	Sex ratio
1	The Narrows	5	3	1.7	11	2	5.5
2	Graham Creek	0	1	0.0	4	5	0.8
4	Boat Creek	5	5	1.0	8	16	0.5
5	Inner Harbour	2	1	2.0	3	1	3.0
6	Calliope Estuary	1	1	1.0	1	10	0.1
7	Auckland Inlet	/	1	/	2	2	1.0
13	Rodds Bay	3	1	3.0	1	1	1.0

Rust lesions

Only three of the 54 mud crabs captured in February 2025 had rust lesions, one at The Narrows and two at Graham Creek. There were eight mud crabs with rust lesions encountered in June 2025 (of the 117 mud crabs caught), one from The Narrows, two from Boat Creek, three from Calliope Estuary and two from Rodds Bay (Table 9). Small capture numbers at Calliope Estuary and Rodds Bay meant the percentage of crabs with lesions was relatively high despite low incidence.

Table 9: Number and percentage of mud crabs with rust spot lesions caught in February and June 2025, by zone.

ZONE	ZONE NAME	FEBRUARY 2025 DATA			JUNE 2025 DATA		
		# caught	# with lesions	% with lesions	# caught	# with lesions	% with lesions
1	The Narrows	14	1	7.14	23	1	4.35
2	Graham Creek	4	2	50.00	11	0	0.00
4	Boat Creek	24	0	0.00	52	2	3.85
5	Inner Harbour	4	0	0.00	7	0	0.00
6	Calliope Estuary	2	0	0.00	16	3	18.75
7	Auckland Inlet	1	0	0.00	4	0	0.00
13	Rodds Bay	5	0	0.00	3	2	66.67

Mud crab measure results by Zone

The mud crab data set used to score each selected zone for the 2025 Gladstone Harbour Report Card included combined data from two monitoring events conducted in February and June 2025. Results for each measure are provided by zone in Table 10.

Table 10: Calculated index values for 2025, for each of the three measures in each of the seven long-term monitoring zones.

Zone	Zone name	Abundance (CPUE)	Prevalence of rust lesions	Sex ratio
1	The Narrows	0.955	0.054	3.200
2	Graham Creek	0.375	0.133	0.667
4	Boat Creek	2.194	0.026	0.619
5	Inner Harbour	0.284	0.000	2.500
6	Calliope Estuary	0.471	0.167	0.182
7	Auckland Inlet	0.125	0.000	0.667
13	Rodds Bay	0.200	0.250	2.000

Indicator scores and grades

Scores and grades for the mud crab measures for the 2025 Report Card are provided in Table 11. An overall score for the Mud Crab Indicator of 0.54 (C) has been calculated as the average of the three "Harbour Average" measure scores, and an overall grade is provided for each zone. This year, five or more mud crabs were caught in every zone, so scores and grades could be calculated for each zone.

Table 11: Scores and grades for mud crab measures and the 2025 mud crab indicator by Zone.

Zone	Abundance (CPUE)	Prevalence of rust lesions	Sex ratio	Zone score 2025
1. The Narrows	0.67	0.95	1.00	0.88
2. Graham Creek	0.12	0.70	0.24	0.35
4. Boat Creek	1.00	1.00	0.21	0.74
5. Inner Harbour	0.03	1.00	1.00	0.68
6. Calliope Estuary	0.21	0.59	0.00	0.27
7. Auckland Inlet	0.00	1.00	0.24	0.41
13. Rodds Bay	0.00	0.32	1.00	0.44
Harbour Average	0.29	0.80	0.53	0.54

DISCUSSION

The Harbour Average was graded C in 2025, with a slightly higher score than in 2024 when it was graded D (0.46) and 2023 when it was also graded C (0.51). The overall grades for the Mud Crab Indicator for each zone are provided in Table 12. The full set of scores and grades from previous years (2017 to 2024) are provided in Appendix 1 for comparison to the 2025 results. The data collection and scoring methods used in 2025 were identical to those used in the last five years.

Table 12: Summary of Zone results by grade for 2025.

Grade	Zones
A	Zone 1 – The Narrows
B	Zone 4 – Boat Creek Zone 5 – Inner Harbour
C	None
D	Zone 2 – Graham Creek Zone 6 – Calliope Estuary Zone 7 – Auckland Inlet Zone 13 – Rodds Bay
E	None

Catches have been improving over the last two years, following several low-catch years. Similar to 2024, no zones were graded E in 2025, and all zones were able to be graded this year since the minimum catch rule ($n \geq 5$) was met. As detailed in the CQUniversity reports from previous years, the catch of mud crabs in baited pots can vary in response to a range of natural and anthropogenic factors, including weather variations such as rainfall and temperature, and lag effects of weather and environmental conditions. The use of a 10-year moving average benchmark was adopted to eventually help to allow for natural variations in catch, but still allow any long-term declining trends (e.g., linked to extraction rates or recruitment limitation) to be identified.

The first year of sampling (2017) appears to have been an abnormally high catch year in comparison to the 8 years that followed. Next year, 2026, will be the 10th year of data collections and beyond that year the unusual result from 2017 will no longer be included in the benchmark calculation.

Mud crab populations rely on the presence of suitable habitat and on sufficient reproduction and recruitment from breeding populations. Recruitment of larval and juvenile mud crabs is difficult to monitor; mud crabs only start to enter baited pots as subadults. It is also possible that the times of year that adult crabs are active, and reproducing, could change in response to climatological factors. Recent research suggests that large male mud crabs prefer muddy, mangrove-lined habitats to sandy or unvegetated areas (Charles, unpublished doctoral thesis). The role of salinity and temperature in female mud crab ecology and reproductive biomarkers have also recently been investigated at CQUniversity, and the results are also currently under review (Hossain, unpublished doctoral thesis). Both studies will be published within the next year and available to assist with interpretation of the monitoring results seen in Gladstone Harbour.

Unusual patterns in sex ratios were observed in 2025, with a shift towards more oversized male crabs during the February sampling. This reversed in June, when females again outnumbered males, though by a smaller margin than in previous years. Across both 2025 sampling periods, 96 legal-sized crabs were recorded, with males making up just under half of the total. While most zones still showed low male-to-female ratios typical of Gladstone Harbour, The Narrows and Inner Harbour had higher ratios of males, approaching those typically recorded at the protected reference site, Eurimbula Creek. These variations may reflect localised ecological changes, natural variability or changes in localised fishing pressure, and ongoing monitoring will be important for interpretation.

The prevalence of rust lesions measure was graded A in four zones in 2025, with lower grades reported at Graham Creek, Calliope River and Rodds Bay. However, this was in part due to lower sample sizes at those sites. Eleven mud crabs had rust lesions out of the total of 171 mud crabs caught in 2025, which is a higher proportion than in 2024 but unlikely to indicate a systemic issue. As per previous reports, this measure is based on a moderately-high confidence benchmark and WCS developed

using research data published by Andersen and Norton (2001) and Dennis *et al.* (2016), and data collected in June 2017 (Flint *et al.*, 2017, later published in Flint *et al.*, 2021). However, the exact reasons for changes in prevalence of rust shell lesions in Gladstone (and elsewhere in Queensland) has not yet been definitively explained. This represents a knowledge gap that should ideally be addressed. In particular, further research at sites where rust lesions are more often encountered during monitoring, including Auckland Inlet, Rodds Bay, Inner Harbour and Calliope Estuary, may be beneficial.

In addition to the two CQUniversity PhD studies (Charles and Hossain), from 2020-2025 CQUniversity collaborated with the Queensland Department of Primary Industries on a research project funded by the Fisheries Research and Development Corporation (FRDC), to improve knowledge and assessment of Queensland mud crabs. The final report from this intensive research effort has been approved by FRDC and will become publicly available in early 2026. Some of the findings may assist in interpreting the longer-term patterns that have been observed through the Gladstone Harbour Report Card since 2017 and inform future directions. An example of an unusual result of the biannual monitoring program is the consistently low mud crab catches and scores at Rodds Bay. This is surprising because Rodds Bay, situated in the northern part of the Baffle Basin, is often viewed as a reference site for Gladstone Harbour. The region is characterised by an abundance of the healthy mangrove forests and deep muddy channels favoured by mud crabs. However, mud crab catch at Rodds Bay (specifically, Seven Mile Creek) is consistently low relative to other zones. Auckland Inlet has also shown consistently low catches, following a relatively higher catch in 2017. This creek is highly urbanised with reduced mangrove habitat which may be a contributing factor, but this would require further investigation to confirm.

After the completion of 2026 sampling, a 10-year data set will be available from the seven monitoring zones in Gladstone Harbour. We anticipate our 10-year review of this data set in combination with findings of the other mud crab research projects conducted by CQU, will provide a strong basis for interpretation and analysis of the factors influencing mud crab populations in Gladstone Harbour.

Recommendations

The mud crab indicator has been successfully monitored in Gladstone Harbour twice a year since 2017, with some revisions to the scoring and grading methods made over time as more information became available. On the basis of this long-term monitoring and the results of other mud crab research projects conducted at CQU, we plan to conduct a review of the 10 years of monitoring data that will have been collected following completion of 2026 sampling. We also provide the following recommendations for GHHP to contemplate, noting that 2026 might be a better time to consider implementing any changes:

Recommendation 1: Continue to monitor the mud crab indicator, using the established monitoring methods, twice a year at the seven long term monitoring sites. Seasonal sampling should continue at a minimum, and more frequently if this becomes possible in future.

Recommendation 2: Consider increasing the number of zones sampled to include other estuaries in Gladstone Harbour (in particular, South Trees Inlet and Boyne Estuary). This would expand the dataset and increase the relevance of the indicator to additional portside industries.

Recommendation 3: If additional budget is available, initiate monitoring at Eurimbula Creek, a reference site and protection area for mud crabs with minimal environmental disturbance.

Recommendation 4: Bioaccumulation of relevant metal(loid)s in Gladstone Harbour could be considered as a possible additional measure for future monitoring.

Recommendation 5: Further research to determine the cause of rust lesions is recommended.

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APPENDIX 1: PREVIOUS SCORES AND GRADES, FROM 2017 – 2024

Scores and grades for mud crab measures and the mud crab indicator by GHHP Zone for 2017.

Zone	Abundance (CPUE)	Prevalence of rust lesions	Sex ratio*	Zone score (grade) 2017
1. The Narrows	1.00 (A)	1.00 (A)	0.00 (E)	0.67 (B)
2. Graham Creek	0.52 (C)	0.95 (A)	0.36 (D)	0.61 (C)
4. Boat Creek	1.00 (A)	1.00 (A)	0.11 (E)	0.70 (B)
5. Inner Harbour	1.00 (A)	0.89 (A)	0.71 (B)	0.87 (A)
6. Calliope Estuary	0.14 (E)	0.90 (A)	0.36 (D)	0.47 (D)
7. Auckland Inlet	0.12 (E)	0.63 (C)	0.00 (E)	0.25 (D)
13. Rodds Bay	0.03 (E)	0.67 (B)	0.39 (D)	0.36 (D)
Harbour Average				0.56 (C)

* Note the benchmark for sex ratio from 2017 was 3:1, and refined to be 2:1 in subsequent years when more information became available.

Scores and grades for mud crab measures and the mud crab indicator by Zone for 2018.

Zone	Abundance (CPUE)	Prevalence of rust lesions	Sex ratio	Zone score (grade) 2018
1. The Narrows	1 (A)	1 (A)	0 (E)	0.67 (B)
2. Graham Creek	0.3 (D)	1 (A)	0.03 (E)	0.44 (D)
4. Boat Creek	0.25 (D)	1 (A)	0.29 (D)	0.51 (C)
5. Inner Harbour	0.52 (C)	1 (A)	0.02 (E)	0.52 (C)
6. Calliope Estuary	0.47 (D)	1 (A)	0.11 (E)	0.52 (C)
7. Auckland Inlet	0 (E)	NC	NC	NC
13. Rodds Bay	0.2 (E)	0.90 (A)	0.06 (E)	0.39 (D)
Harbour Average				0.51 (C)

Scores and grades for mud crab measures and the mud crab indicator by GHHP Zone for 2019.

Zone	Abundance (CPUE)	Prevalence of rust lesions	Sex ratio	Zone score (grade) 2019
1. The Narrows	1 (A)	0.90 (A)	0 (E)	0.63 (C)
2. Graham Creek	0.12 (E)	1 (A)	0.24 (E)	0.45 (D)
4. Boat Creek	0.46 (D)	0.94 (A)	0.05 (E)	0.49 (D)
5. Inner Harbour	0.67 (B)	0.70 (B)	0.08 (E)	0.48 (D)
6. Calliope Estuary	0.29 (D)	1 (A)	0 (E)	0.43 (D)
7. Auckland Inlet	0 (E)	NC	NC	NC
13. Rodds Bay	0.27 (D)	0.70 (B)	0.12 (E)	0.36 (D)
Harbour Average				0.47 (D)

Scores and grades for mud crab measures and the mud crab indicator by Zone for 2020.

Zone	Abundance (CPUE)	Prevalence of rust lesions	Sex ratio	Zone score 2020
1. The Narrows	1 (A)	0.80 (B)	0 (E)	0.60 (C)
2. Graham Creek	0.18 (E)	0.84 (B)	0(E)	0.34 (D)
4. Boat Creek	1 (A)	0.84 (B)	0.29 (D)	0.71 (B)
5. Inner Harbour	0.19 (E)	0.99 (A)	0(E)	0.39 (D)
6. Calliope Estuary	0.13(E)	0.45 (D)	0(E)	0.19 (E)
7. Auckland Inlet	0(E)	NC	NC	NC
13. Rodds Bay	0.13(E)	0.45 (D)	0.06(E)	0.22 (D)
Harbour Average	0.38 (D)	0.73 (B)	0.06(E)	0.39 (D)

Scores and grades for mud crab measures and the mud crab indicator by Zone for 2021.

Zone	Abundance (CPUE)	Prevalence of rust lesions	Sex ratio	Zone score 2021
1. The Narrows	1	0.92	0	0.64
2. Graham Creek	0.27	0.89	0	0.39
4. Boat Creek	0.83	0.94	0.03	0.60
5. Inner Harbour	0.63	0.47	0.07	0.39
6. Calliope Estuary	0.26	1.0	0.14	0.47
7. Auckland Inlet	0	NC	NC	NC
13. Rodds Bay	0.16	0.96	0.57	0.56
Harbour Average	0.45	0.86	0.14	0.48

Scores and grades for mud crab measures and the mud crab indicator by Zone for 2022.

Zone	Abundance (CPUE)	Prevalence of rust lesions	Sex ratio	Zone score 2022
1. The Narrows	0.85	0.90	0.00	0.58
2. Graham Creek	0.00	1.00	0.00	0.33
4. Boat Creek	0.32	0.98	0.43	0.58
5. Inner Harbour	0.11	0.32	0.00	0.14
6. Calliope Estuary	0.00	1.00	0.29	0.43
7. Auckland Inlet	0.00	NC	NC	NC
13. Rodds Bay	0.00	NC	NC	NC
Harbour Average	0.18	0.84	0.14	0.39

Scores and grades for mud crab measures and the mud crab indicator by Zone for 2023.

Zone	Abundance (CPUE)	Prevalence of rust lesions	Sex ratio	Zone score 2023
1. The Narrows	0.58	0.88	0.03	0.50
2. Graham Creek	0.00	1.00	0.09	0.36
4. Boat Creek	0.31	1.00	0.71	0.67
5. Inner Harbour	0.00	NC	NC	NC
6. Calliope Estuary	0.00	1.00	0.62	0.54
7. Auckland Inlet	0.00	1.00	0.00	0.33
13. Rodds Bay	0.00	1.00	1.00	0.67
Harbour Average	0.13	0.98	0.41	0.51

Scores and grades for mud crab measures and the mud crab indicator by Zone for 2024.

Zone	Abundance (CPUE)	Prevalence of rust lesions	Sex ratio	Zone score 2024
1. The Narrows	0.88	1.00	0.06	0.65
2. Graham Creek	0.00	0.73	0.20	0.31
4. Boat Creek	1.00	1.00	0.25	0.75
5. Inner Harbour	0.21	0.96	0.09	0.42
6. Calliope Estuary	0.14	1.00	0.00	0.38
7. Auckland Inlet	0.00	1.00	0.05	0.35
13. Rodds Bay	0.04	1.00	0.00	0.35
Harbour Average	0.32	0.96	0.09	0.46