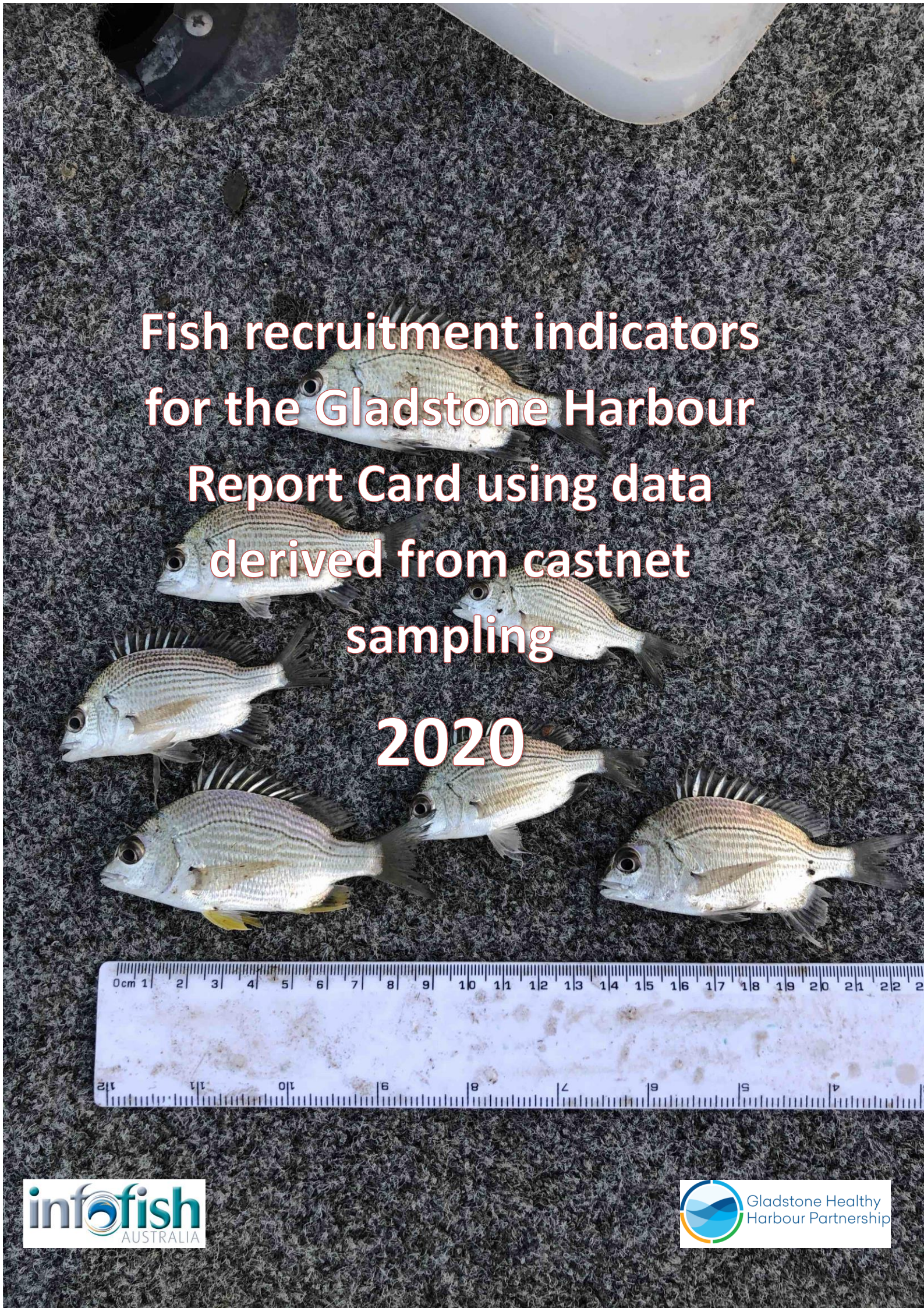
Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling

2020



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Gladstone Healthy Harbour Partnership

Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2020

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SUMMARY

The requirements of this project were to supply fish recruitment grades and scores for Yellowfin and Pikey Bream for the 2020 Gladstone Harbour Report Card, following the same methods used in the past 4 years so that results were comparable from year to year.

Castnet surveys were undertaken monthly at 26 sites from December 2019 to March 2020 covering the same timeframe as previous years. There was one change in sites with Wiggins Island (site 146) replacing Mud Island (site 96) in zone 3. The habitat at Mud Island was a poorer habitat for Bream recruits compared with Wiggins Island.

There was a total of 104 surveys with 2,080 casts in line with the standard survey methodology previously used. A survey involved 20 casts at each site covering the same area in each survey.

There was a total of 9,771 individuals recorded in the 104 surveys comprising 7,375 fish and 2,396 prawns. The highest catch rate was at Ramsay Crossing at 15.9 individuals/cast followed by Graham Creek 2 at 10.7 individuals/cast and then Callemondah at 8.6 individuals/cast. Lowest catch rates were recorded at Munduran Creek at 1.4 individuals/cast, Barney Point Pond at 1.7 individuals/cast and Beecher Creek at 1.9 individuals/cast.

Flattail Mullet (a count of 2,401 or 25% of individuals recorded), Banana Prawn (2,396 or 25%) and Goldlined Rabbitfish (782 or 13%) were the most frequently observed species. Pikey Bream (475 or 5%) was the 6th highest fish species caught and Yellowfin Bream (330 or 3%) was the 7th. Flattail Mullet were recorded at all 26 sites while Yellowfin Bream were recorded at 23 sites and Pikey Bream at 22 sites.

In 2020 total fish and prawn were up 59% compared with 2019 observations. The fish count was up 40% on 2019 and prawn count was up 172% on 2019. The 2020 counts were the highest recorded in the 5 years of surveys.

There was a total of 805 Bream (both species) in 2020 compared with 444 in 2019. Pikey Bream were 59% of the Bream catch while they were 44% in 2019. This was the second survey year that the numbers of Pikey Bream exceeded that of Yellowfin Bream. Pikey Bream tend to dominate in the northern sites while Yellowfin Bream tend to dominate in the southern sites.

The random effects model used in 2018 was used again, without modification, to determine scores and grades for each site, each zone and for all of harbour. The overall result for Gladstone Harbour was C with most zones recording a B or C. Graham Creek 2 and Wiggins Island were recorded as A. In the case of Wiggins Island this was due to moving the site from Mud Island which has provided historically poor results.

The following table provides the scores averaged over sites within zones for the last 5 years from 2016-2020, along with the grade colours for the GHHP report card used to convert scores to grades in the 2020 Gladstone Harbour Report Card for each component of harbour health.

Zone	2020	*2019*	*2018*	*2017*	*2016*
1.Narrows	0.63	*0.19*	*0.60*	*0.75*	*0.34*
2.Graham Creek	0.92	*0.14*	*0.74*	*0.58*	*0.33*
3.Western Basin	0.98	*0.07*	*0.70*	*0.56*	*0.07*
4.Boat Creek	0.38	*0.39*	*0.61*	*0.34*	*0.28*
5.Inner Harbour	0.63	*0.14*	*0.68*	*0.55*	*0.24*
6.Calliope Estuary	0.66	*0.29*	*0.68*	*0.71*	*0.29*
7.Auckland Inlet	0.80	*0.56*	*0.83*	*0.82*	*0.42*
8.Mid Harbour	0.62	*0.08*	*0.62*	*0.66*	*0.20*
9.South Trees Inlet	0.39	*0.30*	*0.74*	*0.69*	*0.39*
10.Boyne Estuary	0.51	*0.35*	*0.50*	*0.73*	*0.54*
11.Outer Harbour	NS	*NS*	*NS*	*NS*	*NS*
12.Colosseum Inlet	0.63	*0.43*	*0.55*	*0.63*	*0.37*
13.Rodds Bay	0.52	*0.39*	*0.57*	*0.72*	*0.46*
ALL OF HARBOUR	**0.64**	***0.28***	***0.65***	***0.63***	***0.33***

NS = not surveyed

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)

1. INTRODUCTION

The Gladstone Healthy Harbour Partnership (GHHP) was established in 2012 to assess the health of Gladstone Harbour. The GHHP produces an annual report on the health of the harbour that includes environmental, social, cultural and economic indicators. Fish recruitment and health were identified as important environmental indicators.

Following trial surveys in 2015 Yellowfin and Pikey Bream were selected as appropriate species to be used as fish recruitment indicators. From 2016-2019 standardised surveys were undertaken at 26 sites in the 13 environmental reporting zones to assess recruitment and provide scores and grades for the report card. Standardised surveys were again undertaken in 2020 using the same methodology as in previous years.

2. OBJECTIVES

The requirements of this project were to:

1. Conduct a castnet sampling program based on the approved sampling design over the 2019-20 recruitment season.
2. Provide fish recruitment report card scores and grades for the 2020 report card.

3. GLADSTONE HARBOUR MONITORING ZONES

The Gladstone Harbour has been divided into 13 environmental monitoring zones for the GHHP Report Card as shown in Figure 1. The area includes Gladstone Harbour, Calliope River, Boyne River, the Narrows, Outer Harbour and Rodds Bay.

Figure 1: Gladstone reporting zones for the GHHP Report Card (from 2018 Report Card Technical Report.pdf at https://dims.ghhp.org.au/repo/public/79fdb7)

The 13 Gladstone Harbour reporting zones are:

1. The Narrows
2. Graham Creek
3. Western Basin
4. Boat Creek
5. Inner Harbour
6. Calliope Estuary
7. Auckland Creek
8. Mid Harbour
9. South Trees Inlet
10. Boyne Estuary
11. Outer Harbour
12. Colosseum Inlet
13. Rodds Bay

4. SITE LOCATIONS

There were 26 survey sites surveyed in 2019-20. There was one change to sites compared with previous survey years. Site 96 Mud Island was replaced by site 146 Wiggins Island (1km to the south west). The change was made as the habitat was more suitable for Bream recruits. Site locations are shown in Figure 2. Site details for Wiggins Island are in Appendix 1.

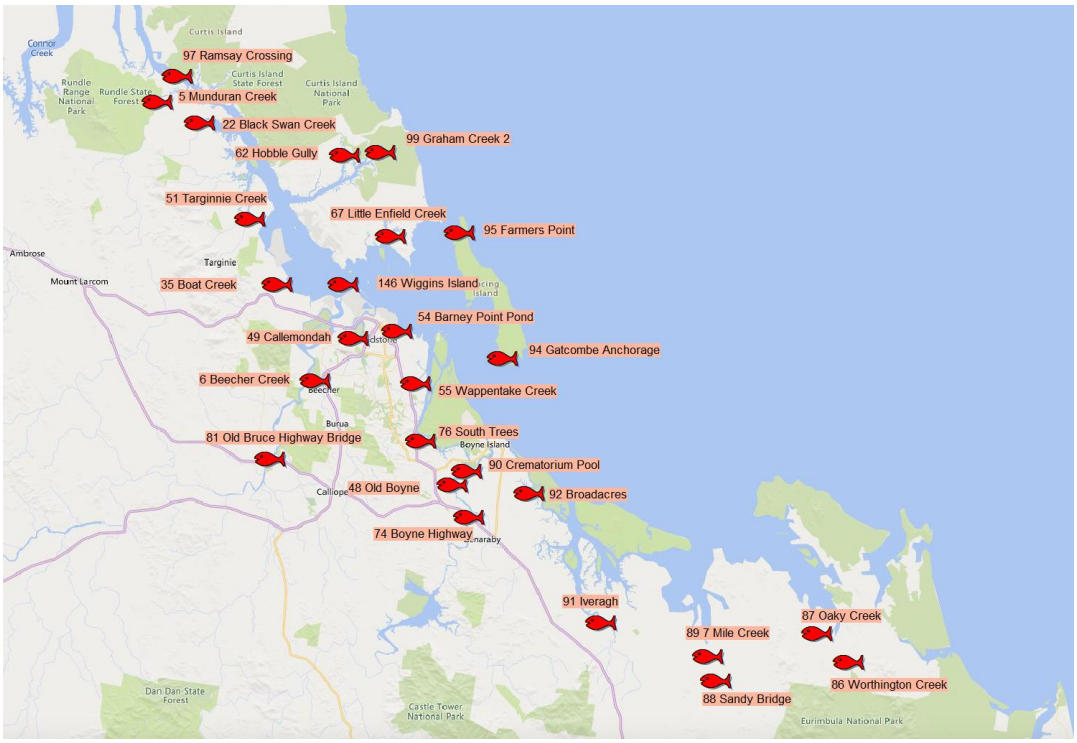


Figure 2: Site locations and site ID in the Gladstone area for Bream recruitment surveys

5. METHODS

Details of all methods are provided in "Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2018" (Sawynok et al 2018). There were no changes in 2019-20 to the methods used in 2018-19, 2017-18 and 2016-17 surveys (Sawynok and Venables 2017). In summary each survey comprised 20 casts with a castnet at each site covering the same areas as previous surveys. Surveys were conducted each month from December 2019 to March 2020. Figure 3 shows the castnet method used and Figure 4 shows the target species of Bream.

The random effects statistical model used was the same as that described in the 2018 report (Sawynok et al 2018). In summary a random effects model was used to generate scores on a 0-1 scale for each site. The scores for each site were then averaged to provide a zone score and then an all of harbour score. Scores were then converted to a grade based on the following scale:

E	D	C	B	A
0.00-0.24	0.25-0.49	0.50-0.64	0.65-0.84	0.85-1.00

Figure 3: Castnet method used for the recruitment surveys

Figure 4: Bream recruits are the target for the recruitment assessment

6. RESULTS

6.1 SUMMARY OF 2020 SURVEYS

Surveys were undertaken around and after full moon tides as these provided the maximum opportunity for Bream recruits to move to all areas subject to tidal influence. Dates for surveys were:

- 12-22 December 2019
- 11-17 January 2020
- 8-21 February 2020
- 7-22 March 2020

Table 1 provides a summary of surveys at all sites from December 2019 to March 2020. There were 104 surveys with 2,080 casts resulting in a catch of 9,771 fish and prawns.

Table 1: Summary of surveys undertaken from Dec 2019-Mar 2020

Zone	SITE ID	SITE	SURVEYS	CASTS	FISH/ PRAWN	CATCH RATE
1	97	RAMSAY CROSSING	4	80	1274	15.9
1	5	MUNDURAN CREEK	4	80	109	1.4
1	22	BLACK SWAN	4	80	320	4.0
1	51	TARGINNIE CREEK	4	80	474	5.9
2	62	HOBBLE GULLY	4	80	609	7.6
2	99	GRAHAM CREEK 2	4	80	857	10.7
3	146	WIGGINS ISLAND	4	80	339	4.2
4	35	BOAT CREEK	4	80	215	2.7
5	67	LITTLE ENFIELD CREEK	4	80	572	7.2
5	54	BARNEY POINT POND	4	80	136	1.7
6	6	BEECHER CREEK	4	80	152	1.9
6	81	OLD BRUCE HWY BRIDGE	4	80	216	2.7
7	49	CALLEMONDAH	4	80	686	8.6
8	95	FARMERS POINT	4	80	239	3.0
8	94	GATCOMBE ANCHORAGE	4	80	288	3.6
9	55	WAPPENTAKE CREEK	4	80	316	4.0
9	76	SOUTH TREES	4	80	374	4.7
9	90	CREMATORIUM POOL	4	80	204	2.6
10	48	OLD BOYNE	4	80	307	3.8
10	74	BOYNE HIGHWAY	4	80	239	3.0
11	OUTER HARBOUR NO SITES					
12	92	BROADACRES	4	80	410	5.1
12	91	IVERAGH	4	80	241	3.0
13	89	7 MILE CREEK	4	80	327	4.1
13	88	SANDY BRIDGE	4	80	160	2.0
13	87	OAKY CREEK	4	80	474	5.9
13	86	WORTHINGTON CREEK	4	80	233	2.9
		TOTAL	104	2080	9771	4.7

Catch rates varied considerably between sites as shown in Table 1 and Figure 5. The highest catch rate was at Ramsay Crossing at 15.9 individuals/cast followed by Graham Creek 2 at 10.7 and then Callemondah at 8.6 individuals/cast. Lowest catch rates were recorded at Munduran Creek at 1.4 individuals/cast, Barney Point Pond at 1.7 individuals/cast and Beecher Creek at 1.9 individuals/cast.

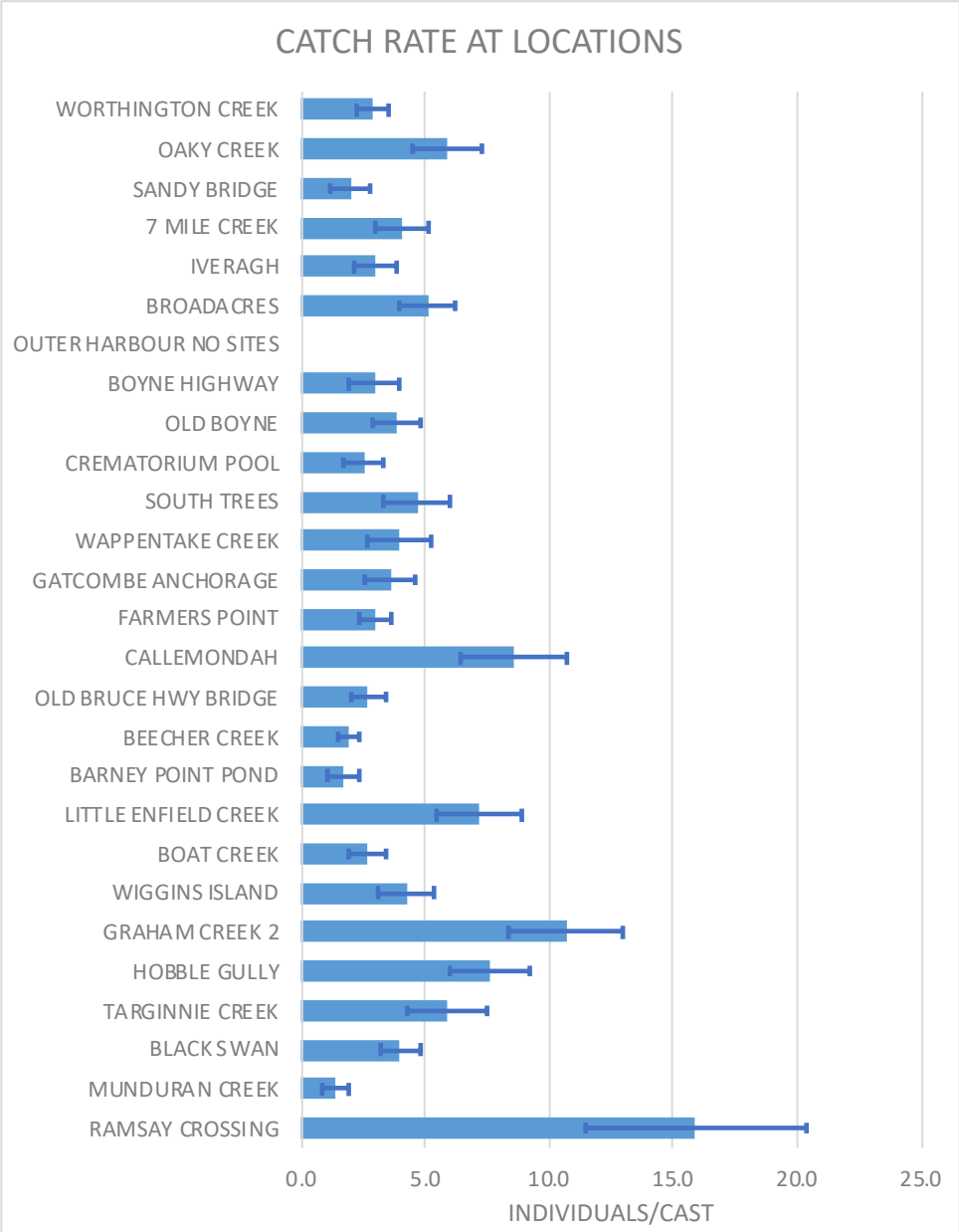


Figure 5: Catch rate at each site (mean with bars showing 95% confidence interval)

Flattail Mullet (a count of 2,401 or 25% of individuals recorded), Banana Prawn (2,396 or 25%) and Goldlined Rabbitfish (782 or 13%) were the most frequently observed species. Pikey Bream (475 or 5%) was the 6th highest fish species caught and Yellowfin Bream (330 or 3%) was the 7th as shown in Figure 6. A list of all species including scientific names and the numbers caught is shown in Appendix 2.

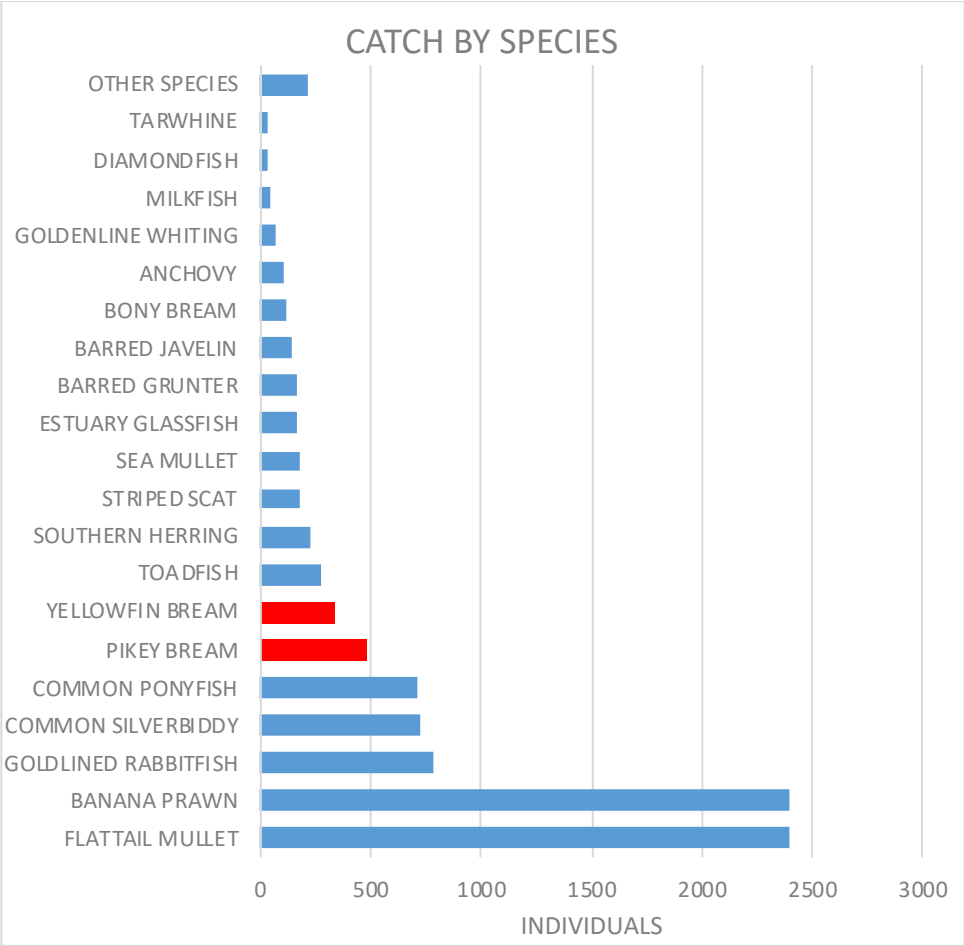


Figure 6: Number of individuals (fish and prawn) recorded across all sites from Dec 2019-Mar 2020

Figure 7: Number of sites where key species were recorded (dotted line total number of sites)

There were 12 species (or species groups) of recreational, commercial, indigenous or conservation importance that were recorded during surveys. Figure 7 shows the number of sites at which these species were recorded. The number of sites where each species was recorded is shown in Appendix 2.

Surveys were undertaken over a 4-month period from December 2019 to March 2020 so that comparisons could be made across years. Figure 8 shows the number of individuals (fish and prawn) recorded at all sites each month. The largest number of individuals was recorded in February (a total of 3,533 comprising 2,404 fish and 1,129 prawn) while the smallest was recorded in December (a total of 1,404 comprising 1,192 fish and 212 prawn).

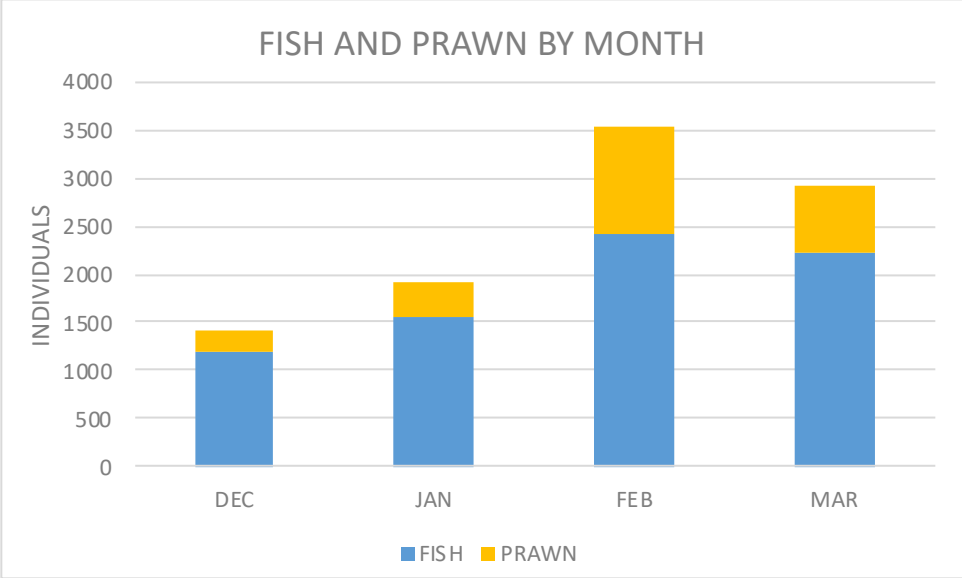


Figure 8: Numbers of individuals recorded at all sites on monthly surveys from December 2019 to March 2020

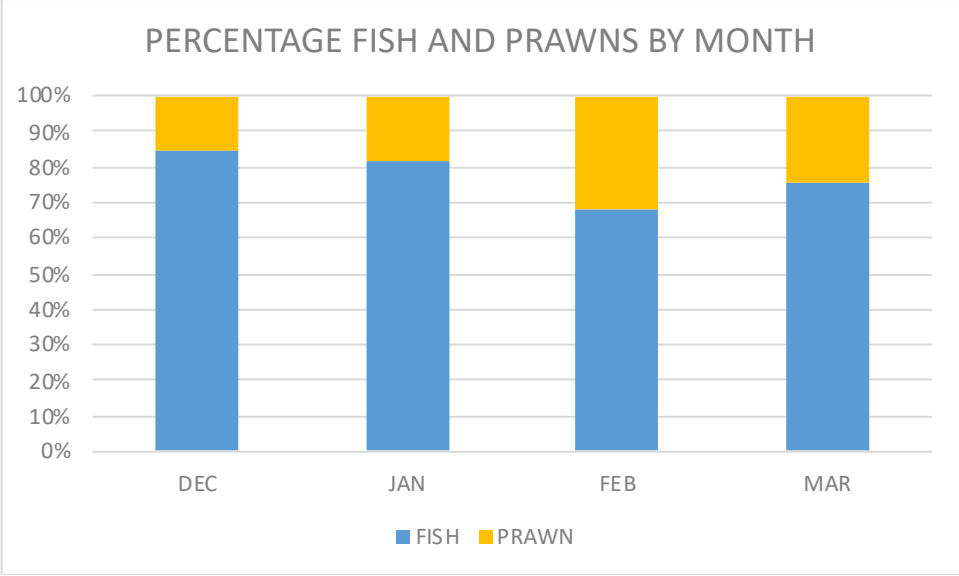


Figure 9: Percentage of fish and prawn in the catch across all sites on monthly surveys from December 2019 to March 2020

Figure 9 shows the percentage of fish and prawn in the catch each month. The percentage of prawn in the catch was highest in February at 32% and was lowest in December at 15%.

The mean individuals per cast ranged from a low of 2.6 in December to a high of 6.8 in February. Figure 10 shows the mean catch rate with bars representing the 95% confidence interval for each month's surveys.

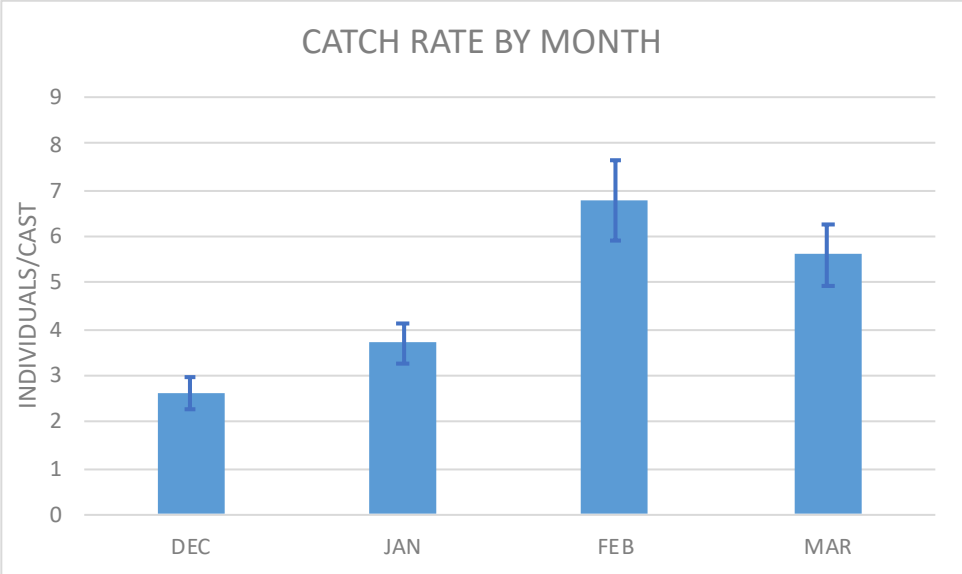


Figure 10: Catch rate for fish and prawn at all sites on monthly surveys from December 2019 to March 2020

6.2 BREAM IN 2020

Bream (Yellowfin and Pikey) were the most caught species by recreational fishers in the Gladstone area comprising 20% of the catch and 20% of the kept catch from 2006-2014 (Sawynok et al 2015). Bream recruitment is important for maintaining fish stocks and is being used as a key fish indicator for the Gladstone Harbour report card. Table 2 shows the number of Bream recorded at each site in surveys from December 2019 to March 2020.

Table 2: Bream recorded at each site in surveys from December 2019 to March 2020

SUB-REGION	SITE ID	SITE	SURVEYS	CASTS	YELLOW FIN BREAM	PIKEY BREAM
1	97	RAMSAY CROSSING	4	80	7	74
1	5	MUNDURAN CREEK	4	80	6	1
1	22	BLACK SWAN	4	80	2	33
1	51	TARGINNIE CREEK	4	80	25	20
2	62	HOBBLE GULLY	4	80	2	84
2	99	GRAHAM CREEK 2	4	80	0	60
3	146	WIGGINS ISLAND	4	80	25	15
4	35	BOAT CREEK	4	80	0	2
5	67	LITTLE ENFIELD CREEK	4	80	9	39
5	54	BARNEY POINT POND	4	80	0	0
6	6	BEECHER CREEK	4	80	13	9
6	81	OLD BRUCE HWY BRIDGE	4	80	23	18
7	49	CALLEMONDAH	4	80	30	37
8	95	FARMERS POINT	4	80	1	0
8	94	GATCOMBE ANCHORAGE	4	80	6	12
9	55	WAPPENTAKE CREEK	4	80	2	1
9	76	SOUTH TREES	4	80	10	13
9	90	CREMATORIUM POOL	4	80	14	7
10	48	OLD BOYNE	4	80	15	5
10	74	BOYNE HIGHWAY	4	80	40	0
11	OUTER HARBOUR NO SITES					
12	92	BROADACRES	4	80	16	14
12	91	IVERAGH	4	80	19	2
13	89	7 MILE CREEK	4	80	7	15
13	88	SANDY BRIDGE	4	80	8	0
13	87	OAKY CREEK	4	80	30	12
13	86	WORTHINGTON CREEK	4	80	20	2
		TOTAL	104	2080	330	475

Figure 11 shows the sites where Bream were recorded. Yellowfin Bream were recorded at 23 (89%) of the 26 sites. Pikey Bream were recorded at 22 (85%) sites. There were no sites surveyed in zone 11 (Outer Harbour) as there was no habitat suitable for juvenile Bream in that zone. Pikey Bream tend to dominate in the northern sites while Yellowfin Bream tend to dominate in the southern sites.

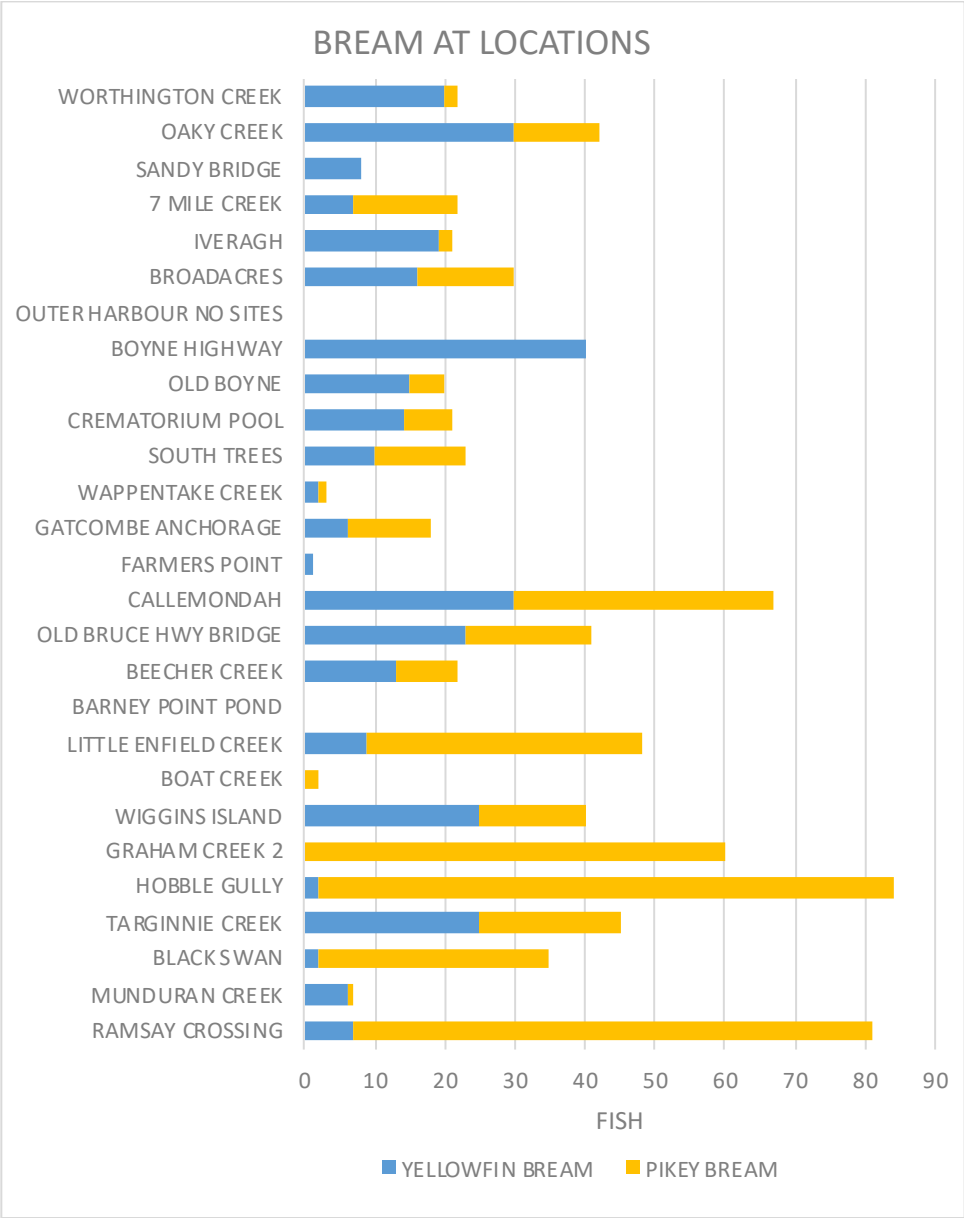


Figure 11: Numbers of Yellowfin and Pikey Bream recorded at each site in surveys from December 2019 to March 2020

There was a total of 330 Yellowfin Bream and 475 Pikey Bream recorded. Over the whole survey period the mean catch rate for Yellowfin Bream was 0.16 fish/cast and for Pikey Bream was 0.23 fish per cast as shown in Figure 12.

Figure 13 shows the numbers of Yellowfin and Pikey Bream recorded during the monthly surveys. The greatest number of Yellowfin Bream was 116 recorded in December while the least number was 46 in February. The greatest number of Pikey Bream was 140 recorded in February while the least number was 64 recorded in March.

Figure 14 shows the catch rate for each Bream species for each month's surveys. Surveys were undertaken around full moon tides as these provided the maximum opportunity for Bream recruits to move to all areas subject to tidal influence.

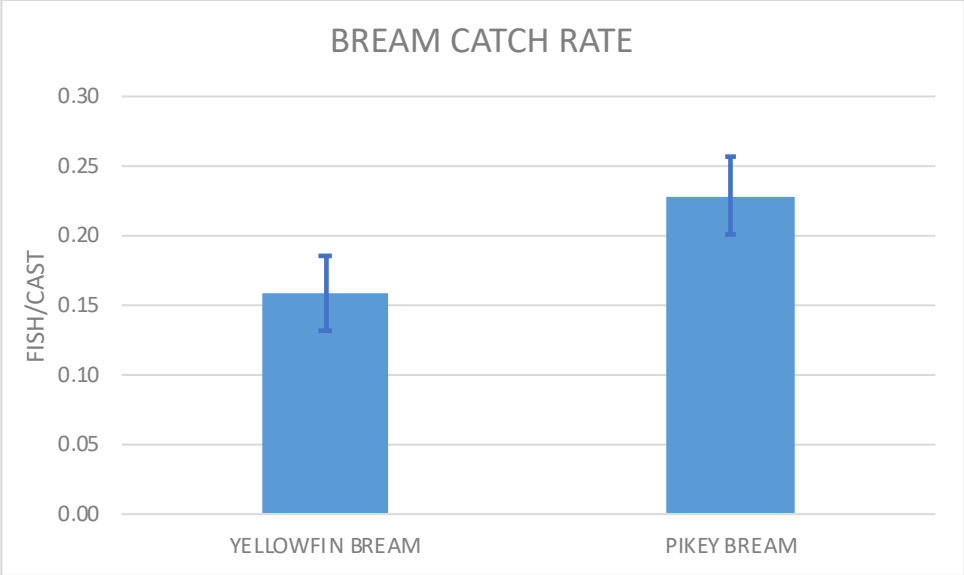


Figure 12: Mean catch rates with 95% confidence intervals for each Bream species

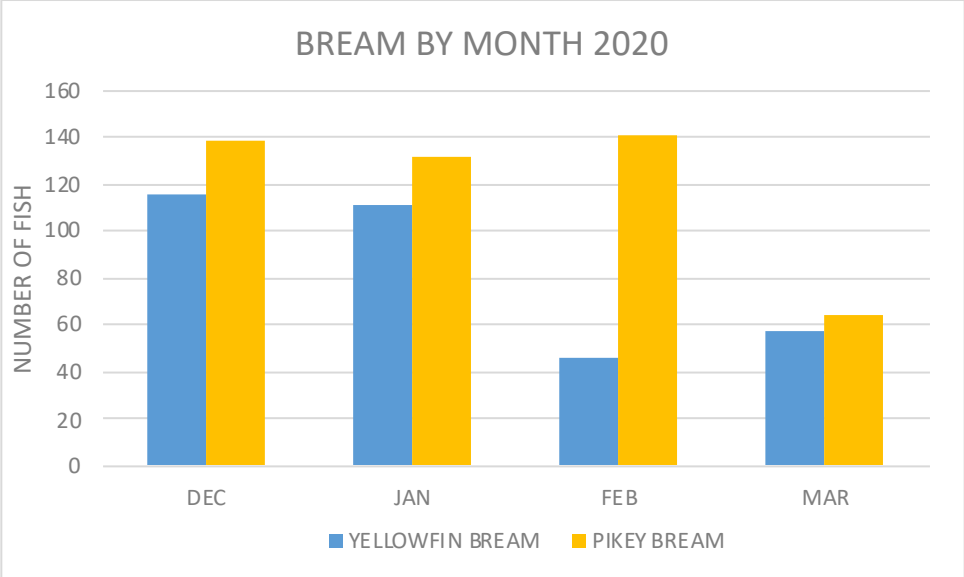


Figure 13: Numbers of Bream recorded during monthly surveys from December 2019 to March 2020

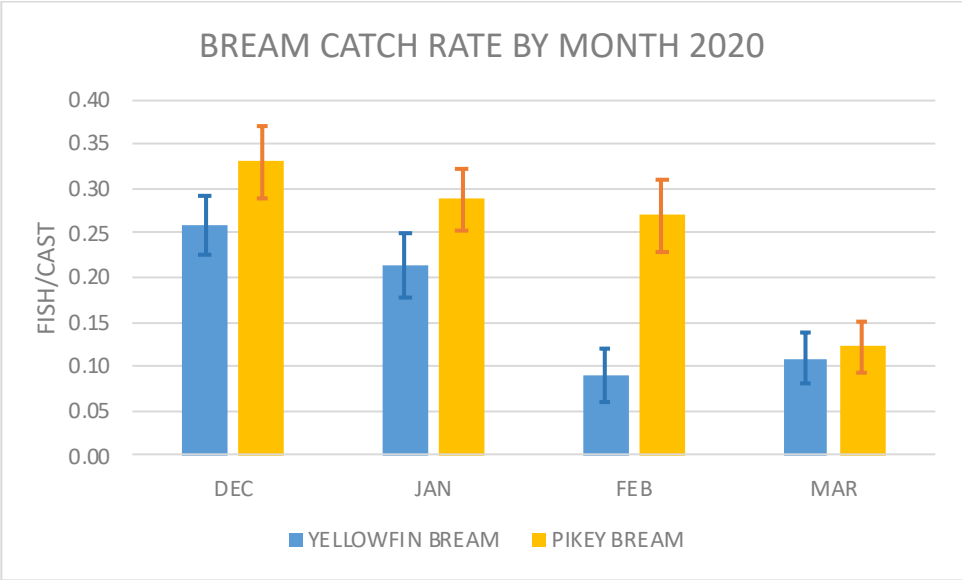


Figure 14: Mean catch rates with 95% confidence intervals for each Bream species for each of the monthly surveys

Figure 15 shows the timeline of the surveys showing fork length (mm) of Bream recorded during the monthly surveys.

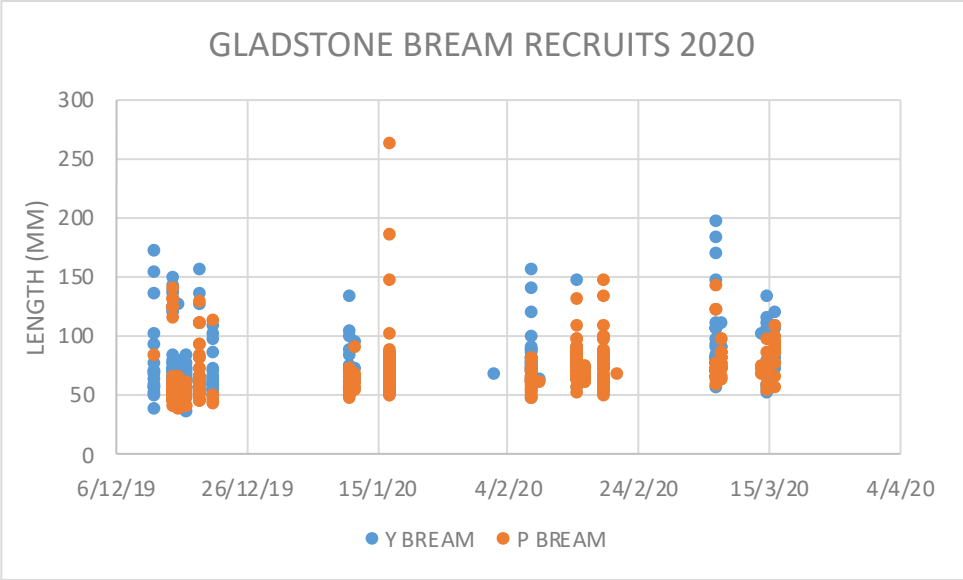


Figure 15: Timelines and fork lengths (mm) of Bream recorded during surveys

Figure 16 shows a typical Pikey Bream being measured. The smallest Yellowfin Bream recorded was a fish of 35mm (fork length) at Callemondah in December 2019. The smallest Pikey Bream recorded was a fish of 37mm (fork length) at Beecher Creek in December 2019. A summary of Bream sizes is presented in Appendix 3.

Figure 16: Typical Pikey Bream being measured

7. COMPARING RESULTS FROM 2016-2020

Table 3 and Figure 17 provide a numerical and visual summary of the surveys and catch from 2016-2020. In 2017, 2018, 2019 and 2020 there were 104 surveys with 2,080 casts while in 2016 there were only 103 surveys with 2,020 casts - 60 fewer than in subsequent years. The figures (*) for 2016 were adjusted by proportional scaling to 104 surveys with 2,080 casts to make the data across the 5 survey years comparable.

In Table 3, the percentage of the total fish and prawn recorded each year compared with the previous year has been provided. For 2020 the total catch of fish and prawn was up 59% compared with the 2019 total.

In 2020 the number of fish in the catch was 7,375, which is the largest count observed across the 5 survey years. The percentage of prawn in the catch has remained reasonably stable over the past 5 years ranging from 22-25% except for 2019 when it was much less at 14%.

Table 3: Summary of surveys of fish and prawn recorded from 2016-2020

YEAR	SURVEYS	CASTS	FISH	PRAWN	TOTAL	PREVIOUS YEAR	PRAWN PERCENT
2020	104	2080	7375	2396	9771	+59%	25%
2019	104	2080	5271	880	6151	-21%	14%
2018	104	2080	6142	1682	7824	-12%	22%
2017	104	2080	6774	2102	8876	*-0.4%*	24%
2016	103	2020	6786	1867	8653		22%
2016*	*104*	*2080*	*6988*	*1922*	*8910*		

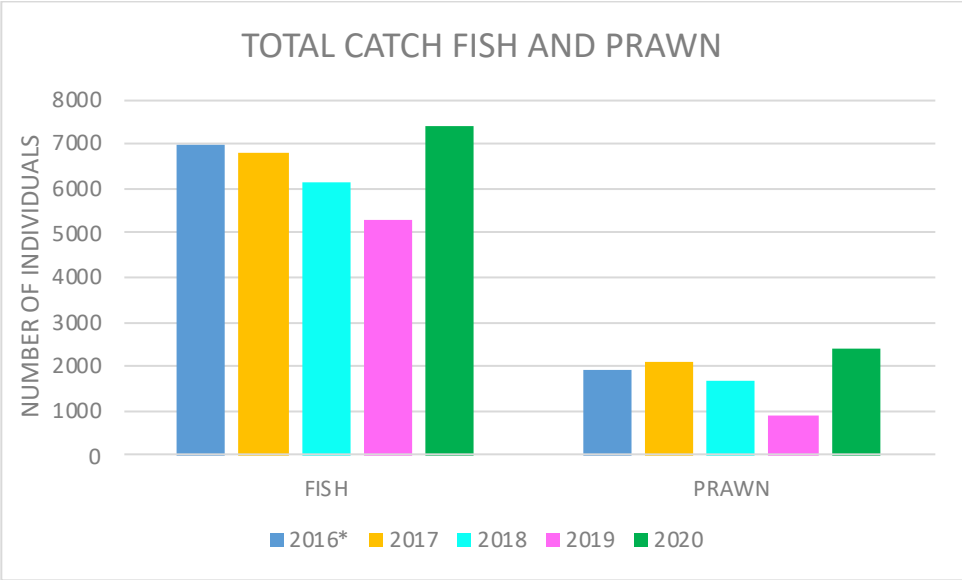


Figure 17: Comparison of total catch from 2016*-2020

The increase in the catch is reflected in the reduction of the number of "NIL" casts (no catch). The number of NIL casts in each of the survey years is shown in Figure 18. In 2020 the NIL casts were the lowest across the 5 years at 23%, with the highest of 39% occurring in 2019.

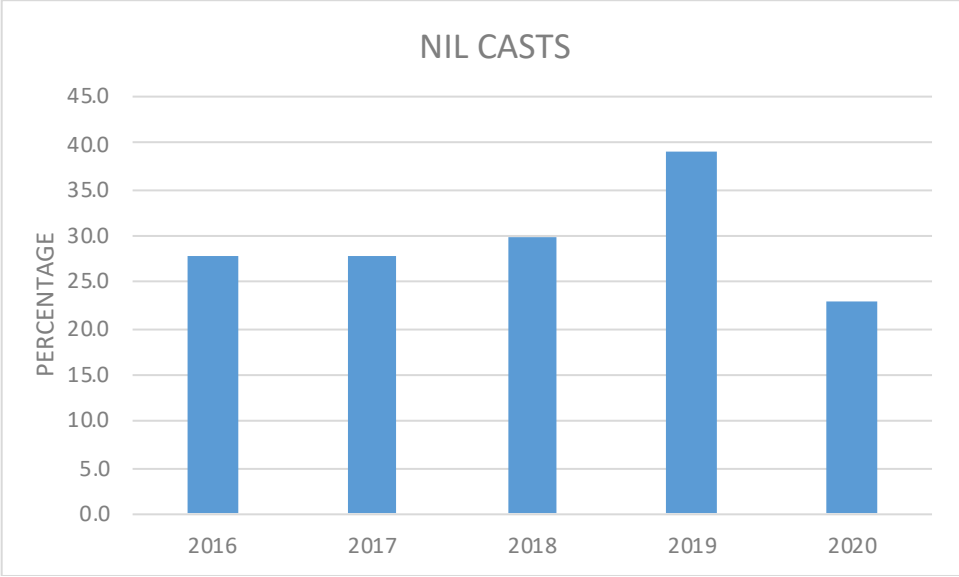


Figure 18: Percentage of NIL casts in each year from 2016-2020

Table 4 and Figure 19 provide a numerical and visual summary of the Bream catch in surveys from 2016-2020. There was a total of 805 Bream (both species) in 2020 compared with 444 in 2019 which is an 81% increase. Yellowfin Bream were 41% of the Bream catch in 2020 which is the lowest percentage in the 5 years. Apart from 2019 there has been a steady increase in the proportion of Pikey Bream in the catch with the highest number recorded in 2020.

Table 4: Summary of surveys and the Bream catch from 2016-2020

YEAR	SURVEYS	CASTS	Y'FIN	PIKEY	TOTAL	PREVIOUS YEAR	Y'FIN PERCENT
2020	104	2080	330	475	805	+81%	41%
2019	104	2080	248	196	444	-43%	56%
2018	104	2080	346	429	775	-15%	45%
2017	104	2080	574	336	910	+75%	63%
2016	103	2020	325	179	504		65%
2016*	*104*	*2080*	*335*	*184*	*519*		

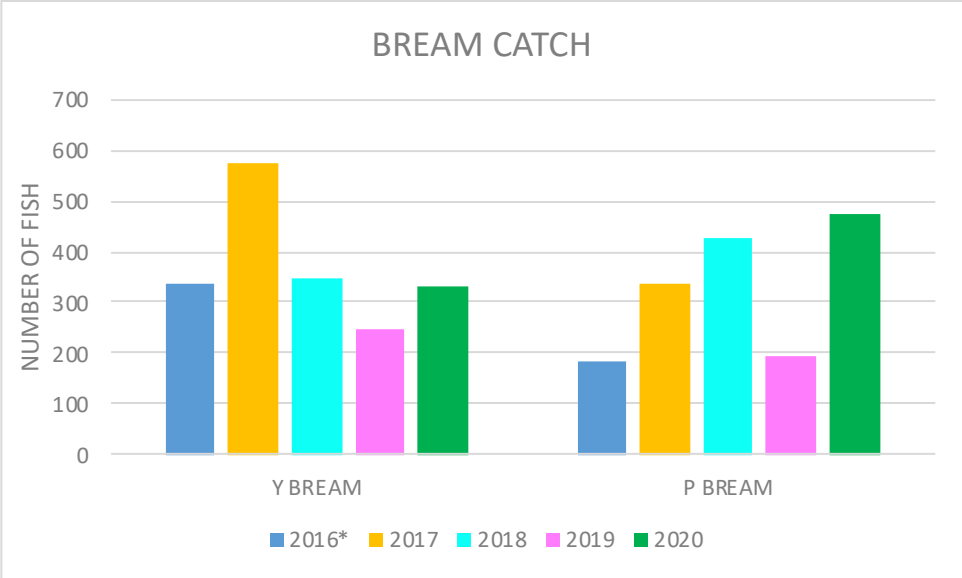


Figure 19: Comparison of Bream catch from 2016*-2020

Table 5 and Figure 20 show the number of sites where Bream were recorded each year. In 2020 Yellowfin Bream were recorded at 23 of the 26 sites while Pikey Bream were recorded at 22 sites. Bream continue to be recorded at most of the sites. Over the 5 years of surveys Bream have been recorded at all 26 sites indicating their wide distribution throughout the Gladstone area.

Table 5: Number of sites where Bream were recorded from 2016-2020

SPECIES	2016	2017	2018	2019	2020
YELLOWFIN BREAM	22	21	25	22	23
PIKEY BREAM	19	20	23	19	22

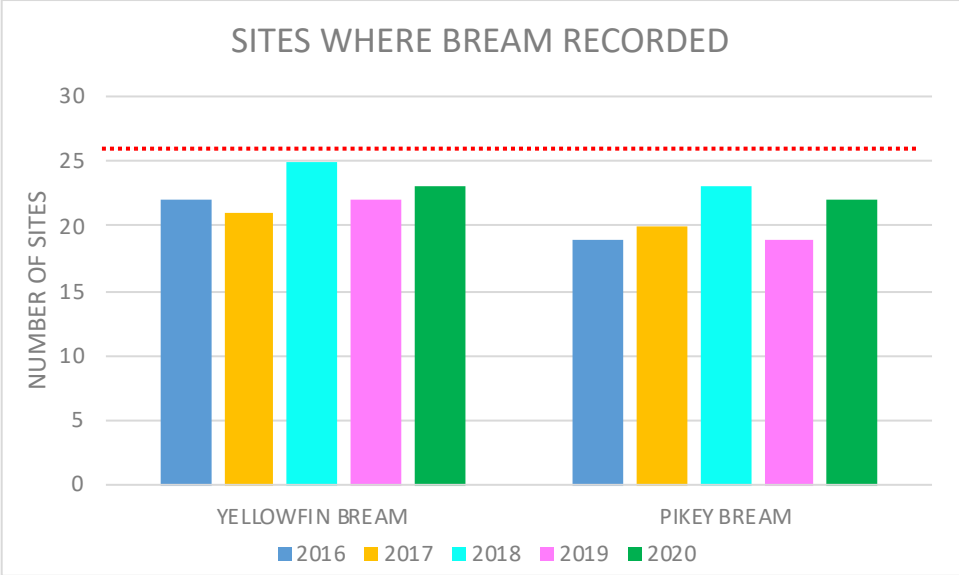


Figure 20: Sites where Bream were recorded 2016-2020 (dotted line total number of sites)

Figure 21 shows the Bream recruits recorded each year and the total rainfall (mm) recorded at the Gladstone Radar station 039123. Total rainfall from 1 December 2019 to 31 March 2020 was 398.6mm. For 1 January to 29 February the rainfall was 249mm and flows were observed at all sites in February and March resulting in sites being fresh or brackish.

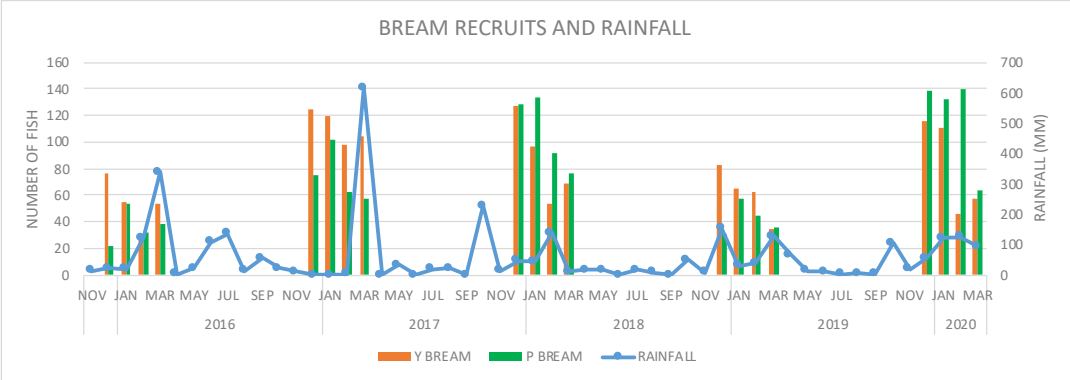


Figure 21: Bream recruits from 2016-2018 and rainfall from November 2015

8. OTHER SPECIES

There were 12 species of recreational, commercial, indigenous or conservation importance that were recorded during surveys (Table 6). Figure 22 shows the number of sites where the top 3 other species were recorded. Flattail Mullet was the only species recorded at all 26 sites each year. Banana Prawn was recorded at 17 sites in 2020 and Sea Mullet was recorded at 10 sites.

Table 6: Number of sites where other species recorded 2016-2020

SPECIES	2016	2017	2018	2019	2020
FLATTAIL MULLET	26	26	26	26	26
BANANA PRAWN	18	17	17	12	17
SEA MULLET	23	12	16	9	10
GOLDENLINE WHITING	13	13	16	11	15
BARRED JAVELIN	10	7	8	5	10
DUSKY FLATHEAD	6	10	9	8	7
BARTAIL FLATHEAD	1	4	7	1	7
MUD CRAB	4	7	4	5	4
MANGROVE JACK	5	6	8	5	3
MUD CRAB	4	7	4	7	3
BARRAMUNDI	2	0	1	1	1
KING THREADFIN	0	0	2	1	0

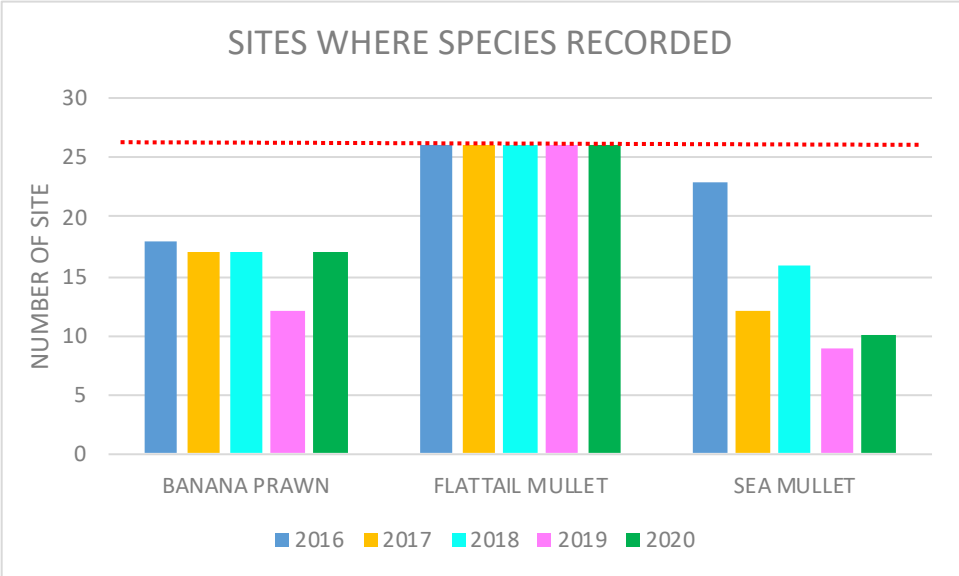


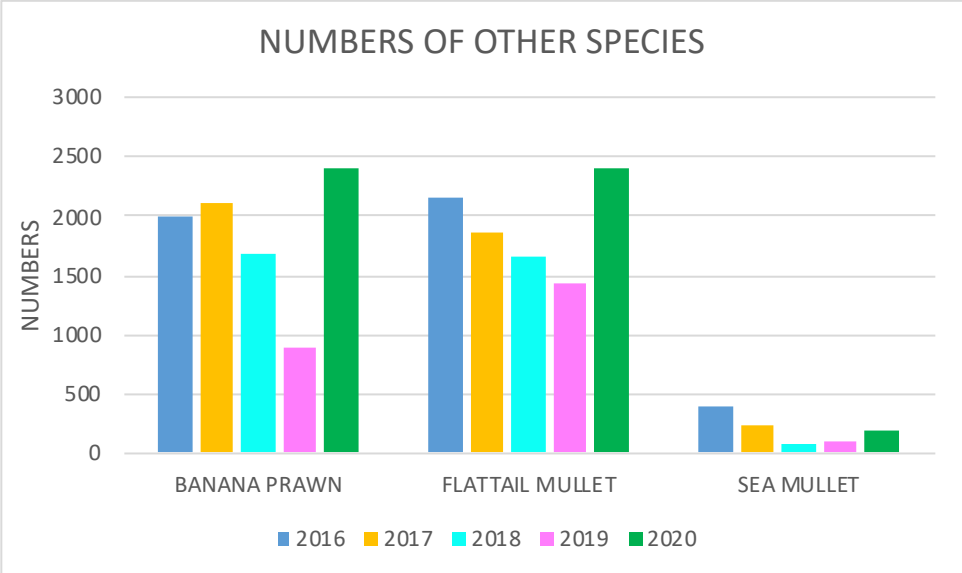
Figure 22: Sites where other species were recorded 2016-2020 (dotted line is the total number of sites)

For the other key species, the numbers recorded each year are shown in Table 7. Banana Prawn ranged from 2,102 in 2017 to 2,396 in 2020. Flattail Mullet ranged from 2,150 in 2016 to 2,401 in 2020. Sea Mullet ranged from 401 in 2016 to 82 in 2018. Figure 23 shows the numbers of key species recorded each year.

Table 7: Numbers of key species recorded in surveys from 2016-2020

SPECIES	2016	2017	2018	2019	2020
BANANA PRAWN	1992	2102	1682	880	2396
FLATTAIL MULLET	2150	1859	1665	1449	2401
SEA MULLET	401	233	82	104	181
GOLDENLINE WHITING	168	130	120	57	74
BARRED JAVELIN	42	47	25	19	145
DUSKY FLATHEAD	9	23	13	15	12
BARTAIL FLATHEAD	2	5	26	7	10
MANGROVE JACK	8	15	20	8	7
MUD CRAB	6	31	10	18	9
SAND WHITING	3	11	8	4	1
KING THREADFIN	0	0	4	2	0
BARRAMUNDI	4	0	1	1	2

Figure 23: Numbers of other key species recorded from 2016*-2020



9. DEVELOPING A RECRUITMENT INDEX

A negative binomial random effects statistical model (Sawynok B, Sawynok S and Venables B (2018)) has been applied to the pooled data commencing in 2011-12. The model predicts the catch rate of Bream species by a number of independent variables, including sites and years. The random coefficients from this model for the sites are known as "Best Linear Unbiased Parameters" or BLUPs, and it is these that provide the basis for the calculation of a recruitment index.

The model specification was the same as that used in 2018-19 however there was one change in site location. The Mud Island site was replaced by a Wiggins Island site as this was considered to be more suitable habitat for recording Bream recruits.

9.1 Negative binomial variance parameter

The estimated negative binomial θ parameters are very stable close to $\theta = 2$. Re-estimating them from the final fitted model, for the restricted and full data sets, yields

- $\hat{\theta}$ = 2 for the model fitted with data up to year 17-18 only, and
- $\hat{\theta}$ = 2 when the further data for year 18-19 is included and
- $\hat{\theta}$ = 2 when the further data for year 19-20 is included.

Fixing this parameter at $\theta = 2$ confers a degree of stability on the process, but leaves the crucial estimates, and the scores and grades, relatively unaffected.

9.2 Variance

The variance component estimates were relatively unchanged, as shown in Table 8, when additional data was added into the pool.

Table 8: Variance component estimates (as standard deviations) for the main model using (a) data up to year 17-18, (b) data to year 18-19 and (c) all available data

	(a) data to 17-18	(b) data to 18-19	(c) data to 19-20
Site	0.7773	0.8482	0.7961
Year	0.2767	0.3275	0.2935
Year x Site	0.3366	0.3582	0.4861

The quantity required to standardize the BLUPs, $E_Y + E_{YS}$, leading to the scores is the standard deviation:

$$\begin{aligned}\hat{\sigma}_{\text{BLUP}} &= \sqrt{\hat{\sigma}_Y^2 + \hat{\sigma}_{YS}^2} \\ &= \sqrt{0.2935^2 + 0.4861^2} \\ &= 0.5679\end{aligned}$$

9.3 Site Main Effects

The site main effects, $E_S \sim \mathrm{N}(0, \sigma_S^2)$, indicate how different sites are in Bream abundance. These are on a log scale so comparisons are in a proportional rather than a difference sense. Sites with naturally low average Bream abundance have a low capacity to show small proportional differences, whereas those with higher natural abundance have a

greater capacity. It is making justifiable allowance for these natural differences between sampling sites that is a key challenge of this analysis.

In order to show the relative stability of the site main effects with the addition of new data Figure 24 shows the BLUPs using data up to 18-19 (horizontal scale) and estimates using the full data set (vertical scale). The diagram is partitioned into sub-region cells to show the high degree of heterogeneity even within sub-regions. It is this heterogeneity that complicates the production of fully justifiable scores at the sub-region level. The diagonal line in each panel indicates where the two estimates would be equal. Points relatively distant from the line had the greatest change.

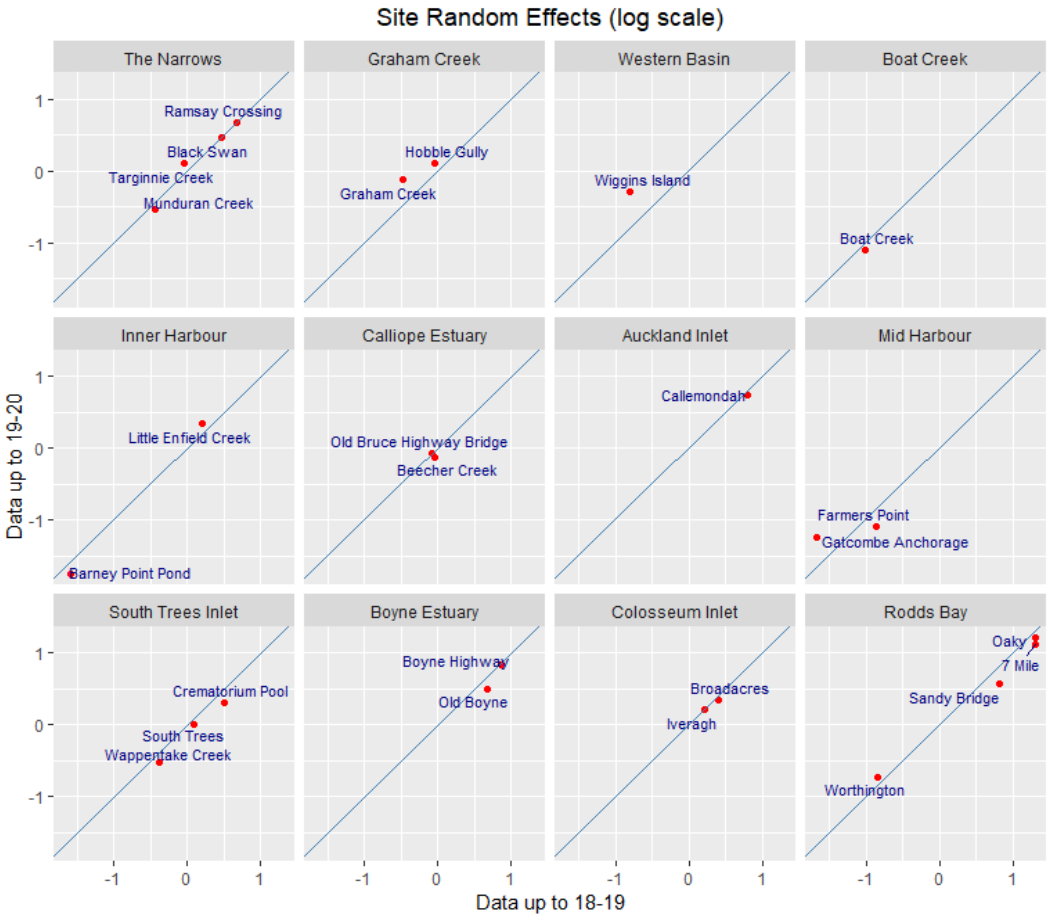


Figure 24: Site random effect estimates. A comparison of BLUPs using the restricted data set with those using the full data set.

Table 9 shows the combined year and year by site BLUP estimates, that is $E_Y + E_{YS}$, for all years in the study. The year BLUP, E_Y, is the representation of how much each year differs in aggregate from a conceptual long-term mean in catch rate, and the year by site BLUP, E_{YS}, represents the deviation of each site from its year aggregate. Both of these are *after the allowance* for aggregate site differences, as encapsulated by the site BLUPs, E_S.

Table 9: Random effects estimates (BLUPs), $E_Y + E_{YS}$, for the Gladstone Harbour Bream survey sites for all study years

Zone	Site	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20
The Narrows	Ramsay Crossing					0.32	0.20	0.06	-0.55	0.26
	Munduran Creek	0.61	-0.16	-0.15	0.03	-0.03	0.34	0.01	-0.50	-0.35
	Black Swan				0.21	-1.05	0.98	0.16	-0.23	0.29
	Targinnie Creek	0.17	-0.43		0.65	-0.62	0.28	0.34	-0.96	0.68
Graham Creek	Graham Creek				0.34	-0.36	-0.16	0.37	-1.07	1.01
	Hobble Gully				-0.16	-0.15	-0.10	0.36	-0.39	0.65
Western Basin	Wiggins Island					-0.83	0.09	0.31	-0.85	1.22
Boat Creek	Boat Creek		-0.35	-0.04	0.51	-0.33	-0.24	0.16	-0.16	-0.17
Inner Harbour	Little Enfield Creek				0.31	-0.35	0.19	0.31	-0.70	0.53
	Barney Point Pond		-0.28	0.00	0.31	-0.44	-0.05	0.23	-0.55	-0.09
Calliope Estuary	Beecher Creek	0.52	-0.66	-0.14	0.16	-0.32	0.29	-0.06	-0.09	0.25
	Old Bruce Highway Bridge				-0.28	-0.29	0.34	0.75	-0.60	0.24
Auckland Inlet	Callemondah	-0.05	-0.91	-0.31	0.04	-0.11	0.52	0.53	0.09	0.49
Mid Harbour	Farmers Point					-0.73	1.11	0.33	-0.79	-0.28
	Gatcombe Anchorage					-0.30	-0.23	0.02	-0.78	0.86
South Trees Inlet	Wappentake Creek		-0.39	-0.01	-0.03	-0.33	0.07	0.51	-0.15	-0.07
	South Trees					-0.07	0.13	0.40	-0.34	-0.08
	Crematorium Pool					-0.10	0.79	0.22	-0.43	-0.33
Boyne Estuary	Old Boyne	0.31	-0.08		0.26	0.10	0.37	0.03	-0.58	-0.14
	Boyne Highway				-0.07	0.02	0.32	-0.03	0.08	0.16

Colosseum Inlet	Broadacres	-0.35	0.09	0.39	-0.20	0.24
	Iveragh	-0.05	0.27	-0.24	-0.01	0.14
Rodds Bay	Oaky	-0.09	0.21	0.10	0.00	0.27
	7 Mile	0.00	0.26	0.40	-0.17	-0.03
	Worthington	-0.30	0.24	-0.02	-0.46	0.32
	Sandy Bridge	0.15	0.68	-0.05	-0.05	-0.48

The BLUPs are transformed into *scores* by dividing by their standard deviation and finding the cumulative probability in the standard normal distribution. In symbols:

$$Z_{YS} = \frac{E_Y + E_{YS}}{\sqrt{\sigma_Y^2 + \sigma_{YS}^2}}, \qquad \text{Score}_{YS} = \Phi(Z_{YS})$$

Where $\Phi(z)$ is the standard normal (cumulative) distribution function. The resulting scores are shown in Table 10.

Table 10: Score estimates on a $(\mathbf{0}, \mathbf{1})$ –scale, for the Gladstone Harbour Bream survey sites for all years

Zone	Site	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20
The Narrows	Ramsay Crossing					0.71	0.64	0.55	0.17	0.67
	Munduran Creek	0.86	0.39	0.40	0.52	0.48	0.73	0.51	0.19	0.27
	Black Swan				0.64	0.03	0.96	0.61	0.34	0.70
	Targinnie Creek	0.62	0.22		0.87	0.14	0.69	0.72	0.05	0.89
Graham Creek	Graham Creek				0.73	0.26	0.39	0.74	0.03	0.96
	Hobble Gully				0.39	0.40	0.43	0.74	0.25	0.87
Western Basin	Wiggins Island					0.07	0.56	0.70	0.07	0.98
Boat Creek	Boat Creek		0.27	0.47	0.82	0.28	0.34	0.61	0.39	0.38
Inner Harbour	Little Enfield Creek				0.71	0.27	0.63	0.71	0.11	0.82

	Barney Point Pond		0.31	0.50	0.71	0.22	0.47	0.66	0.17	0.44
Calliope Estuary	Beecher Creek	0.82	0.12	0.40	0.61	0.29	0.70	0.46	0.44	0.67
	Old Bruce Highway Bridge				0.31	0.30	0.72	0.91	0.14	0.66
Auckland Inlet	Callemondah	0.47	0.05	0.29	0.53	0.42	0.82	0.83	0.56	0.80
Mid Harbour	Farmers Point					0.10	0.97	0.72	0.08	0.31
	Gatcombe Anchorage					0.30	0.35	0.51	0.09	0.94
South Trees Inlet	Wappentake Creek		0.25	0.49	0.48	0.28	0.55	0.81	0.40	0.45
	South Trees					0.45	0.59	0.76	0.28	0.44
	Crematorium Pool					0.43	0.92	0.65	0.23	0.28
Boyne Estuary	Old Boyne	0.70	0.45		0.68	0.57	0.74	0.52	0.15	0.40
	Boyne Highway				0.45	0.51	0.72	0.48	0.56	0.61
Colosseum Inlet	Broadacres					0.27	0.56	0.75	0.37	0.66
	Iveragh					0.47	0.69	0.34	0.49	0.60
Rodds Bay	Oaky					0.44	0.64	0.57	0.50	0.68
	7 Mile					0.50	0.68	0.76	0.38	0.48
	Worthington					0.30	0.66	0.49	0.21	0.71
	Sandy Bridge					0.61	0.88	0.46	0.47	0.20

9.4 Aggregation to the Zone Level

Scores are aggregated to the sub-region level within years and further aggregated to all of harbour. Aggregation is by simple averaging over sites within zones (i.e. equally weighted) and simple averaging over zones to all of harbour.

The results of this averaging process are shown in Table 11, and the resulting grades are shown in Table 12.

Table 11: Score estimates on a $(\mathbf{0}, \mathbf{1})$ –scale, averaged over sites within sub-regions, and over all of harbour

Sub-region	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20
The Narrows	0.74	0.30	0.40	0.68	0.34	0.75	0.60	0.19	0.63
Graham Creek				0.56	0.33	0.41	0.74	0.14	0.92
Western Basin					0.07	0.56	0.70	0.07	0.98
Boat Creek		0.27	0.47	0.82	0.28	0.34	0.61	0.39	0.38
Inner Harbour		0.31	0.50	0.71	0.24	0.55	0.68	0.14	0.63
Calliope Estuary	0.82	0.12	0.40	0.46	0.29	0.71	0.68	0.29	0.66
Auckland Inlet	0.47	0.05	0.29	0.53	0.42	0.82	0.83	0.56	0.80
Mid Harbour					0.20	0.66	0.62	0.08	0.62
South Trees Inlet		0.25	0.49	0.48	0.39	0.69	0.74	0.30	0.39
Boyne Estuary	0.70	0.45		0.57	0.54	0.73	0.50	0.35	0.51
Colosseum Inlet					0.37	0.63	0.55	0.43	0.63
Rodds Bay					0.46	0.72	0.57	0.39	0.52
All of Gladstone Harbour	0.68	0.25	0.43	0.60	0.33	0.63	0.65	0.28	0.64

Table 12: Alphabetic grades for (unadjusted) averaged scores over sites within sub-regions, and over all of harbour

Sub-region	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20
The Narrows	B	D	D	B	D	B	C	E	C
Graham Creek				C	D	D	B	E	A
Western Basin					E	C	B	E	A
Boat Creek		D	D	B	D	D	C	D	D
Inner Harbour		D	C	B	E	C	B	E	C
Calliope Estuary	B	E	D	D	D	B	B	D	B
Auckland Inlet	D	E	D	C	D	B	B	C	B
Mid Harbour					E	B	C	E	C
South Trees Inlet		E	D	D	D	B	B	D	D
Boyne Estuary	B	D		C	C	B	C	D	C
Colosseum Inlet					D	C	C	D	C
Rodds Bay					D	B	C	D	C
All of Gladstone Harbour	B	D	D	C	D	C	B	D	C

To provide uncertainty measures for the scores standard bootstrapping techniques were used as described in Sawynok et al 2018. Bootstrap simulations were used in the aggregation process to incorporate zone- and harbour-level scores into higher levels of the GHHP report card.

Table 13 and Figure 25 show the original scores for the 12 zones, and all of harbour, together with their lower and upper uncertainty limits as calculated by the bootstrap simulation method.

Table 13: Estimates and bootstrap uncertainty intervals

Zone	Score	2.5%	97.5%
The Narrows	0.6309	0.5257	0.7344
Graham Creek	0.9186	0.8147	0.9675
Western Basin	0.9843	0.9467	0.9963
Boat Creek	0.3820	0.1907	0.5882
Inner Harbour	0.6325	0.4421	0.7418
Calliope Estuary	0.6649	0.4141	0.8269
Auckland Inlet	0.8043	0.6300	0.8928
Mid Harbour	0.6230	0.4932	0.7591
South Trees Inlet	0.3909	0.2757	0.5277
Boyne Estuary	0.5065	0.3702	0.6473
Colosseum Inlet	0.6288	0.4881	0.7448
Rodds Bay	0.5183	0.3961	0.6267
All of Harbour	0.6404	0.5802	0.7043

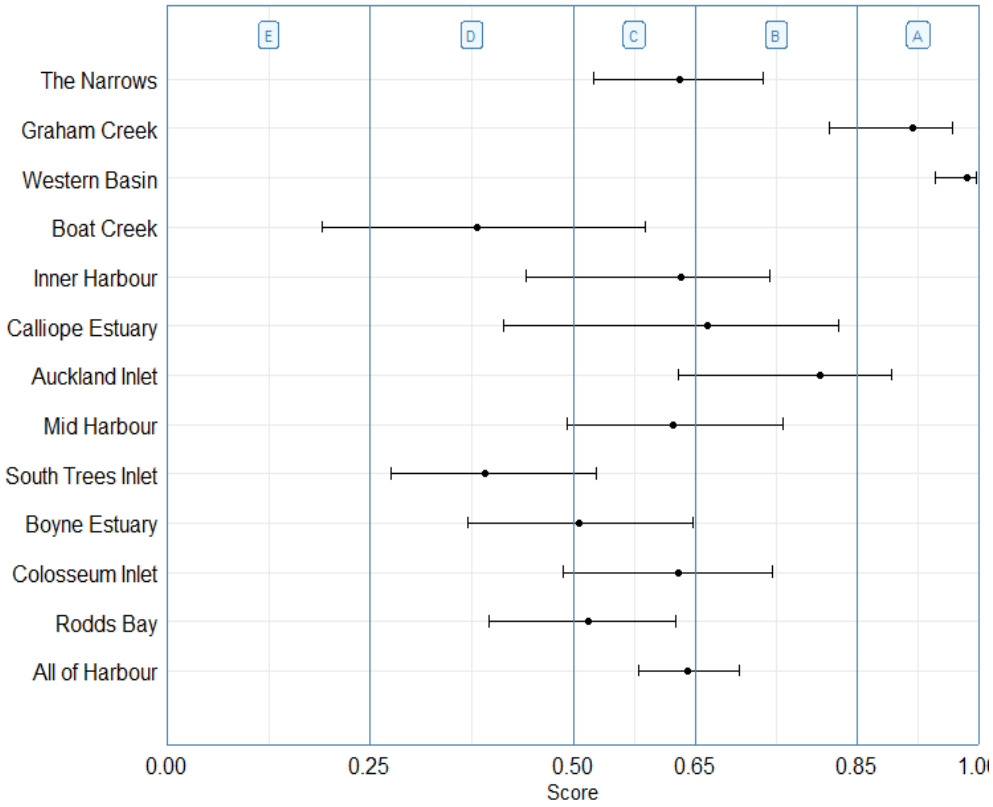


Figure 25: Estimates and bootstrap uncertainty intervals

10. DISCUSSION

The overall result for Gladstone Harbour was C with most zones recording a B or C. Graham Creek 2 and Wiggins Island were recorded as A. In the case of Wiggins Island this was due to moving the site from Mud Island which historically has provided poor results.

For December and January conditions were extremely dry through to late January. Conditions changed significantly from late January with frequent storms and showers throughout the whole survey area. The rainfall total for February and March was 249mm at Gladstone Airport. There were significant differences at some sites compared with previous years and the earlier surveys. This was likely due to the extremely dry conditions leading up to February and the changes in conditions since then. However further investigations are required to determine the extent of the relationship between prevailing climatic conditions and bream recruitment.

Some sites did not receive a freshwater flush or had limited input in February. Beecher Creek did not have any input. In March all sites had experienced freshwater flows and most sites were either fresh or brackish. This resulted in lower numbers of Bream recorded in March, compared to February which was likely due to the fish being dispersed by the flows.

The change in conditions resulted in changes in species composition and numbers at many of the sites depending on the extent of the freshwater flow and timing. At the Old Bruce Highway Bridge site on the Calliope River the water level was very low with no freshwater input for the January survey. The survey resulted in 84 individual fish and prawn including 15 Bream. The February survey was delayed due to a strong freshwater flow and when undertaken later in the month resulted in 21 individual fish with no Bream recorded.

In the February surveys there were 527 Goldlined Rabbitfish at all sites which is the highest number recorded in any month over the past 5 years. This had fallen to 129 in the March surveys. At Callemondah in February there were 113 fish recorded in Feb while there were none recorded in March. There were similar changes recorded at a number of other sites.

In 2018 there were more Pikey Bream recorded than Yellowfin Bream. This was different to 2016 and 2017 when Yellowfin exceed the number of Pikey Bream. In 2019 more Yellowfin Bream were recorded again. This year Pikey Bream dominated at sites north of Gladstone while Yellowfin Bream dominated at sites to the south. This may be influenced by Rockhampton[1] historically being the southern limit of the range of Pikey Bream.

[1] From https://www.daf.qld.gov.au/fish-identification-information/fish-species-guide/fish-species-id-info/profile?fish-id=pikey-bream

11. REFERENCES

Sawynok B and Venables B (2016): Developing a fish recruitment indicator for the Gladstone Harbour Report Card using data derived from castnet sampling: http://infofishaustralia.com.au/gladstone/

Sawynok B and Venables B (2017): Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2017 http://infofishaustralia.com.au/gladstone

Sawynok B, Sawynok S and Venables B (2018): Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2018 http://infofishaustralia.com.au/gladstone

Sawynok, W., W. N. Venables, and U. Pinto. (2017). "Incorporating a Fish Recruitment Indicator into the Gladstone Harbour Report Card." Journal of Ecological Indicators, (Submitted)

APPENDIX 1 – SURVEY SITES

A summary of sites and site details, as stored in the Infofish 2020 database, along with a more detailed description of the habitat. Details for each site are available in the report "Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2018" (Sawynok et al 2018). Details of site 146 Wiggins Island that replaced site 96 Mud Island are in Figure 26.

Table 14: Summary of site details

Sub-Region	Site ID	Site Name	Latitude	Longitude	Map	Grid
1	97	RAMSAY CROSSING	-23.641	151.066	CIS	S31
1	5	MUNDURAN CREEK	-23.658	151.048	CISG	R33
1	22	BLACK SWAN	-23.679	151.089	CISG	V35
1	51	TARGINNIE CREEK	-23.762	151.13	GLD	HZ1
2	62	HOBBLE GULLY	-23.71	151.222	GLD	NZ10
2	99	GRAHAM CREEK 2	-23.712	151.24	GLD	MZ12
3	146	WIGGINS ISLAND	-23.821	151.218	GLD	AZ10
4	35	BOAT CREEK	-23.814	151.162	GLD	BZ4
5	67	LITTLE ENFIELD CREEK	-23.775	151.266	GLD	FZ15
5	54	BARNEY POINT POND	-23.86	151.275	GLD	D16
6	6	BEECHER CREEK	-23.923	151.207	CR02	I9
6	81	OLD BRUCE HIGHWAY BRIDGE	-23.964	151.154	CR02	P4
7	49	CALLEMONDAH	-23.862	151.232	GLD	D12
8	95	FARMERS POINT	-23.774	151.33	GLD	GZ22
8	94	GATCOMBE ANCHORAGE	-23.876	151.365	GLD	F25
9	55	WAPPENTAKE CREEK	-23.89	151.282	BRG	H17
9	76	SOUTH TREES	-23.951	151.291	BRG	N17
9	90	CREMATORIUM POOL	-23.972	151.334	BRG	Q22
10	48	OLD BOYNE	-23.981	151.33	BRG	R21
10	74	BOYNE HIGHWAY	-24.01	151.338	BRG	U22
11		OUTER HARBOUR NO SITES				
12	92	BROADACRES	-23.991	151.392	BRG	S28
12	91	IVERAGH	-24.103	151.46	RBT	H17
13	89	7 MILE CREEK	-24.131	151.561	RBT	R21
13	88	SANDY BRIDGE	-24.15	151.567	RBT	R23
13	87	OAKY CREEK	-24.11	151.663	RBT	AB18
13	86	WORTHINGTON CREEK	-24.135	151.689	RBT	AE21

Site Id:	146
Site Name:	WIGGINS ISLAND
Waterway:	CALLIOPE RIVER
Sub-Region:	3
Map:	GLD
Grid:	AZ10
Lat:	-23.821
Long:	151.218
Tidal Influence:	Tidal
Depth:	1
Access:	Water
Distance to Mouth:	
Substrate:	☑ Sand ☑ Mud ☑ Gravel ☐ Rock
Description	SOUTH EAST END OF WIGGINS ISLAND ADJACENT TO THE CALLIOPE RIVER
Vegetation	MANGROVES
Image:	 Image
Second Image:	 Image

Figure 26: Site details for new site 146 Wiggins Island

APPENDIX 2 - SPECIES

List of species recorded using standard name, scientific name, number of sites, and number of fish recorded in surveys from Dec-Mar. Species with a question mark are those where the identification was uncertain.

Table 15: Number of each species recorded and number of sites where recorded

STANDARD NAME	SCIENTIFIC NAME	SITES	NUMBER
Mullet – Flattail	*Liza dussumieri*	26	2401
Prawn – Banana	*Fenneropenaeus indicus*	17	2396
Rabbitfish – Goldlined	*Siganus lineatus*	25	782
Silverbiddy – Common	*Gerres subfasciatus*	24	723
Ponyfish – Common	*Leiognathus equulus*	20	706
Bream – Pikey	*Acanthopagrus berda*	22	475
Bream – Yellowfin	*Acanthopagrus australis*	23	330
Toadfish – Common	*Tetractenos hamiltoni*	20	279
Herring – Southern	*Herklotsichthys castelnaui*	18	223
Mullet – Sea	*Mugil cephalus*	10	181
Scat – Striped	*Selenotoca multifasciata*	11	180
Glassfish – Estuary	*Ambassis marianus*	19	163
Grunter – Barred	*Terapon jarbua*	21	163
Javelin – Barred	*Pomadasys kaakan*	10	145
Bream – Bony	*Nematalosa erebi*	14	112
Anchovy spp		4	110
Whiting – Goldenline	*Sillago analis*	15	74
Milkfish	*Chanos chanos*	6	40
Diamondfish	*Monodactylus argenteus*	9	37
Tarwhine	*Rhabdosargus sarba*	6	34
Silverbiddy – Threadfin	*Gerres filamentosus*	5	21
Forktail Catfish	*Neoarius graeffei*	1	21
Snapper – Moses	*Lutjanus russellii*	6	17
Mullet - Diamondscale	*Liza vaigiensis*	4	15
Whiting spp	*Sillago spp*	2	13
Flathead – Dusky	*Platycephalus fuscus*	7	12
Whiting – Winter	*Sillago maculata*	1	11
Flathead – Bartail	*Platycephalus indicus*	7	10
Herring – Hairback	*Nematalosa come*	1	10
Crab – Mud	*Scylla serrata*	4	9
Sole – Black?	*Brachinus nigra*	3	7
Mangrove Jack	*Lutjanus argentimaculatus*	3	7
Herring – Giant	*Elops machnata*	2	6
Hardyhead – Common	*Atherinomorus vaigiensis*	2	6
Garfish – Snubnose	*Arrhamphus scleolepis*	4	6

Goby – Greenspotted	*Acentrogobius viridipunctatus*	3	5
Scat – Spotted	*Scatophagus argus*	4	4
Garfish spp		3	4
Queenfish – Giant	*Scomeroides commersonnianus*	2	3
Flathead – Rock	*Cymbacephalus staigeri*	1	2
Sicklefish		2	2
Tarpon	*Magalops cyprinoides*	1	2
Wrasse spp		1	2
Freshwater Eel	*Anguilla reinhardtii*	1	2
Blackspotted Rockcod	*Epinephelus malabaricus*	2	2
Bullrout	*Notesthes robusta*	2	2
Barracuda	*Sphyraena spp*	2	2
Barramundi	*Lates calcarifer*	1	2
Crab – Blue Swimmer	*Portunis armatus*	1	1
Rainbowfish – Eastern	*Melanotaenia splendida*	1	1
Crab spp		1	1
Grinner – Painted	*Trachinocephalus trachinus*	1	1
Blubberlips – Brown	*Plectorhinchus gibbosus*	1	1
Gudgeon spp		1	1
Longtom		1	1
Trevally spp		1	1
Whiting – Sand	*Sillago ciliata*	1	1
Blue Threadfin	*Eleutheronema tetradactylum*	1	1
Permit	*Trachinotus blochii*	1	1
Tiger Prawn	*Penaeus monodon*	1	1
Blackspot Stripey Snapper	*Lutjanus fulviflamma*	1	1

APPENDIX 3 – BREAM SIZE PROFILE

Figure 27 and Table 16 show the size distribution of the Bream catch, by species, for each of the four months of the survey and for all of harbour.

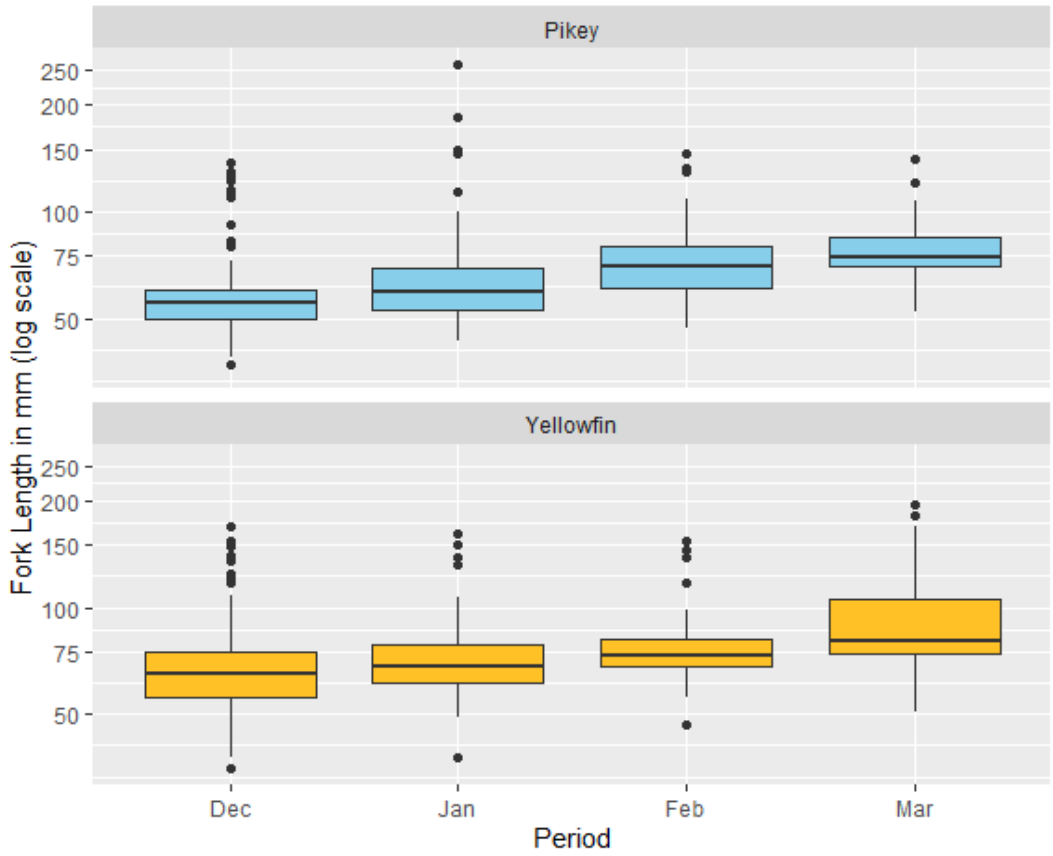


Figure 27: Fork Length change at the harbour level over the data collection period

Table 16: Bream size distribution summary statistics: Fork Length (mm)

Species	Month	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Pikey Bream	Dec	40	48	55.0	58.12	62.00	118
	Feb	54	64	71.5	79.14	85.00	171
	Jan	40	55	60.0	65.76	71.00	245
	Mar	48	62	70.0	75.65	80.75	205
Yellowfin Bream	Dec	37	51	58.0	64.83	70.75	150
	Feb	52	64	72.0	79.40	91.00	148
	Jan	46	60	68.0	72.74	80.00	150
	Mar	54	65	79.0	82.49	91.00	180

APPENDIX 4 – CATCH AND EFFORT DATA

Table 17: Numbers of casts per site for all survey years

Sub-region	Site	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20
The Narrows	Ramsay Crossing					50	80	80	80	80
	Munduran Creek	60	60	80	100	100	80	80	80	80
	Black Swan				80	80	80	80	80	80
	Targinnie Creek	10	10		80	80	80	80	80	80
Graham Creek	Graham Creek				20	60	80	80	80	80
	Hobble Gully				80	80	80	80	80	80
Western Basin	Wiggins Island					100	80	80	80	80
Boat Creek	Boat Creek		10	80	75	80	80	80	80	80
Inner Harbour	Little Enfield Creek				100	80	80	80	80	80
	Barney Point Pond		80	100	100	80	80	80	80	80
Calliope Estuary	Beecher Creek	50	70	80	100	80	80	80	80	80
	Old Bruce Highway Bridge				50	80	80	80	80	80
Auckland Inlet	Callemondah	50	70	100	100	80	80	80	80	80
Mid Harbour	Farmers Point					90	80	80	80	80
	Gatcombe Anchorage					100	80	80	80	80
South Trees Inlet	Wappentake Creek		70	60	100	80	80	80	80	80
	South Trees					90	80	80	80	80
	Crematorium Pool					100	80	80	80	80
Boyne Estuary	Old Boyne	20	20		100	80	80	80	80	80
	Boyne Highway				40	80	80	80	80	80
Colosseum Inlet	Broadacres					100	80	80	80	80

	Iveragh				100	80	80	80	80
Rodds Bay	Oaky				100	80	80	80	80
	7 Mile				100	80	80	80	80
	Worthington				100	80	80	80	80
	Sandy Bridge				100	80	80	80	80

Table 18: Total numbers of Pikey Bream caught per site per survey year

Sub-region	Site	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20
The Narrows	Ramsay Crossing					56	48	56	26	74
	Munduran Creek	0	0	2	0	0	0	0	1	1
	Black Swan				25	1	77	22	21	33
	Targinnie Creek	0	0		0	0	2	6	0	20
Graham Creek	Graham Creek				3	2	8	24	0	60
	Hobble Gully				21	30	24	53	20	84
Western Basin	Wiggins Island					0	3	8	0	15
Boat Creek	Boat Creek		0	0	5	2	1	2	3	2
Inner Harbour	Little Enfield Creek				30	13	24	30	6	39
	Barney Point Pond		0	2	1	0	0	1	0	0
Calliope Estuary	Beecher Creek	0	0	0	1	1	2	0	10	9
	Old Bruce Highway Bridge				0	10	37	12	12	18
Auckland Inlet	Callemondah	2	0	12	17	15	43	57	34	37
Mid Harbour	Farmers Point					0	0	3	0	0
	Gatcombe Anchorage					2	1	0	0	12
South Trees Inlet	Wappentake Creek		0	1	1	1	1	1	1	1
	South Trees					11	16	44	11	13
	Crematorium Pool					1	0	14	9	7
Boyne Estuary	Old Boyne	2	0		4	1	0	6	3	5

	Boyne Highway			0	1	0	1	0	0
Colosseum Inlet	Broadacres				2	12	31	8	14
	Iveragh				2	3	1	5	2
Rodds Bay	Oaky				13	12	13	10	12
	7 Mile				23	16	35	9	15
	Worthington				1	4	5	2	2
	Sandy Bridge				0	2	4	5	0

Table 19: Total numbers of Yellowfin Bream caught per site per survey year

Sub-region	Site	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20
The Narrows	Ramsay Crossing					6	22	9	4	7
	Munduran Creek	33	13	10	20	23	29	15	8	6
	Black Swan				4	0	17	4	2	2
	Targinnie Creek	2	0		38	5	21	21	2	25
Graham Creek	Graham Creek				4	5	0	0	0	0
	Hobble Gully				1	2	0	2	0	2
Western Basin	Wiggins Island					0	3	2	0	25
Boat Creek	Boat Creek		0	5	4	1	0	4	3	0
Inner Harbour	Little Enfield Creek				7	1	4	1	2	9
	Barney Point Pond		1	0	2	0	0	1	0	0
Calliope Estuary	Beecher Creek	18	3	11	18	9	20	12	7	13
	Old Bruce Highway Bridge				9	11	8	76	1	23
Auckland Inlet	Callemondah	9	5	13	25	16	35	20	15	30
Mid Harbour	Farmers Point					0	26	6	0	1
	Gatcombe Anchorage					2	0	4	0	6
South Trees Inlet	Wappentake Creek		2	2	3	2	3	10	5	2
	South Trees					17	15	11	13	10
	Crematorium Pool					50	123	35	16	14

Boyne Estuary	Old Boyne	8	6		35	34	42	20	10	15
	Boyne Highway				10	42	49	29	51	40
Colosseum Inlet	Broadacres					17	11	9	13	16
	Iveragh					23	20	8	18	19
Rodds Bay	Oaky					23	25	15	27	30
	7 Mile					15	19	6	17	7
	Worthington					11	14	8	7	20
	Sandy Bridge					47	68	18	27	8

Table 20: Total numbers of Pikey Bream and Yellowfin Bream combined per site, per survey year

Sub-region	Site	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20
The Narrows	Ramsay Crossing					62	70	65	30	81
"	Munduran Creek	33	13	12	20	23	29	15	9	7
	Black Swan				29	1	94	26	23	35
	Targinnie Creek	2	0		38	5	23	27	2	45
Graham Creek	Graham Creek				7	7	8	24	0	60
	Hobble Gully				22	32	24	55	20	86
Western Basin	Wiggins Island					0	6	10	0	40
Boat Creek	Boat Creek		0	5	9	3	1	6	6	2
Inner Harbour	Little Enfield Creek				37	14	28	31	8	48
	Barney Point Pond		1	2	3	0	0	2	0	0
Calliope Estuary	Beecher Creek	18	3	11	19	10	22	12	17	22
	Old Bruce Highway Bridge				9	21	45	88	13	41
Auckland Inlet	Callemondah	11	5	25	42	31	78	77	49	67
Mid Harbour	Farmers Point					0	26	9	0	1
	Gatcombe Anchorage					4	1	4	0	18
South Trees Inlet	Wappentake Creek		2	3	4	3	4	11	6	3
	South Trees					28	31	55	24	23

	Crematorium Pool				51	123	49	25	21
Boyne Estuary	Old Boyne	10	6	39	35	42	26	13	20
	Boyne Highway			10	43	49	30	51	40
Colosseum Inlet	Broadacres				19	23	40	21	30
	Iveragh				25	23	9	23	21
Rodds Bay	Oaky				36	37	28	37	42
	7 Mile				38	35	41	26	22
	Worthington				12	18	13	9	22
	Sandy Bridge				47	70	22	32	8

Table 21: Pikey Bream catch per visit of 20 Casts, (CPUE), per site, per survey year

Sub-region	Site	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20
The Narrows	Ramsay Crossing					22.40	12.00	14.00	6.50	18.50
	Munduran Creek	0.0	0	0.50	0.00	0.00	0.00	0.00	0.25	0.25
	Black Swan				6.25	0.25	19.25	5.50	5.25	8.25
	Targinnie Creek	0.0	0		0.00	0.00	0.50	1.50	0.00	5.00
Graham Creek	Graham Creek				3.00	0.67	2.00	6.00	0.00	15.00
	Hobble Gully				5.25	7.50	6.00	13.25	5.00	21.00
Western Basin	Wiggins Island					0.00	0.75	2.00	0.00	3.75
Boat Creek	Boat Creek		0	0.00	1.33	0.50	0.25	0.50	0.75	0.50
Inner Harbour	Little Enfield Creek				6.00	3.25	6.00	7.50	1.50	9.75
	Barney Point Pond		0	0.40	0.20	0.00	0.00	0.25	0.00	0.00
Calliope Estuary	Beecher Creek	0.0	0	0.00	0.20	0.25	0.50	0.00	2.50	2.25
	Old Bruce Highway Bridge				0.00	2.50	9.25	3.00	3.00	4.50
Auckland Inlet	Callemondah	0.8	0	2.40	3.40	3.75	10.75	14.25	8.50	9.25

Mid Harbour	Farmers Point					0.00	0.00	0.75	0.00	0.00
	Gatcombe Anchorage					0.40	0.25	0.00	0.00	3.00
South Trees Inlet	Wappentake Creek		0	0.33	0.20	0.25	0.25	0.25	0.25	0.25
	South Trees					2.44	4.00	11.00	2.75	3.25
	Crematorium Pool					0.20	0.00	3.50	2.25	1.75
Boyne Estuary	Old Boyne	2.0	0		0.80	0.25	0.00	1.50	0.75	1.25
	Boyne Highway				0.00	0.25	0.00	0.25	0.00	0.00
Colosseum Inlet	Broadacres					0.40	3.00	7.75	2.00	3.50
	Iveragh					0.40	0.75	0.25	1.25	0.50
Rodds Bay	Oaky					2.60	3.00	3.25	2.50	3.00
	7 Mile					4.60	4.00	8.75	2.25	3.75
	Worthington					0.20	1.00	1.25	0.50	0.50
	Sandy Bridge					0.00	0.50	1.00	1.25	0.00

Table 22: Yellowfin Bream catch per visit of 20 Casts, (CPUE), per site, per survey year

Sub-region	Site	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20
The Narrows	Ramsay Crossing					2.40	5.50	2.25	1.00	1.75
	Munduran Creek	11.0	4.33	2.50	4.00	4.60	7.25	3.75	2.00	1.50
	Black Swan				1.00	0.00	4.25	1.00	0.50	0.50
	Targinnie Creek	4.0	0.00		9.50	1.25	5.25	5.25	0.50	6.25
Graham Creek	Graham Creek				4.00	1.67	0.00	0.00	0.00	0.00
	Hobble Gully				0.25	0.50	0.00	0.50	0.00	0.50

Western Basin	Wiggins Island					0.00	0.75	0.50	0.00	6.25
Boat Creek	Boat Creek		0.00	1.25	1.07	0.25	0.00	1.00	0.75	0.00
Inner Harbour	Little Enfield Creek				1.40	0.25	1.00	0.25	0.50	2.25
	Barney Point Pond		0.25	0.00	0.40	0.00	0.00	0.25	0.00	0.00
Calliope Estuary	Beecher Creek	7.2	0.86	2.75	3.60	2.25	5.00	3.00	1.75	3.25
	Old Bruce Highway Bridge				3.60	2.75	2.00	19.00	0.25	5.75
Auckland Inlet	Callemondah	3.6	1.43	2.60	5.00	4.00	8.75	5.00	3.75	7.50
Mid Harbour	Farmers Point					0.00	6.50	1.50	0.00	0.25
	Gatcombe Anchorage					0.40	0.00	1.00	0.00	1.50
South Trees Inlet	Wappentake Creek		0.57	0.67	0.60	0.50	0.75	2.50	1.25	0.50
	South Trees					3.78	3.75	2.75	3.25	2.50
	Crematorium Pool					10.00	30.75	8.75	4.00	3.50
Boyne Estuary	Old Boyne	8.0	6.00		7.00	8.50	10.50	5.00	2.50	3.75
	Boyne Highway				5.00	10.50	12.25	7.25	12.75	10.00
Colosseum Inlet	Broadacres					3.40	2.75	2.25	3.25	4.00
	Iveragh					4.60	5.00	2.00	4.50	4.75
Rodds Bay	Oaky					4.60	6.25	3.75	6.75	7.50
	7 Mile					3.00	4.75	1.50	4.25	1.75
	Worthington					2.20	3.50	2.00	1.75	5.00
	Sandy Bridge					9.40	17.00	4.50	6.75	2.00

Table 23: Pikey Bream plus Yellowfin Bream catch per visit of 20 Casts, (CPUE), per site, per survey year

Sub-region	Site	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20
The Narrows	Ramsay Crossing					24.80	17.50	16.25	7.50	20.25
	Munduran Creek	11.0	4.33	3.00	4.00	4.60	7.25	3.75	2.25	1.75
	Black Swan				7.25	0.25	23.50	6.50	5.75	8.75
	Targinnie Creek	4.0	0.00		9.50	1.25	5.75	6.75	0.50	11.25
Graham Creek	Graham Creek				7.00	2.33	2.00	6.00	0.00	15.00
	Hobble Gully				5.50	8.00	6.00	13.75	5.00	21.50
Western Basin	Wiggins Island					0.00	1.50	2.50	0.00	10.00
Boat Creek	Boat Creek		0.00	1.25	2.40	0.75	0.25	1.50	1.50	0.50
Inner Harbour	Little Enfield Creek				7.40	3.50	7.00	7.75	2.00	12.00
	Barney Point Pond		0.25	0.40	0.60	0.00	0.00	0.50	0.00	0.00
Calliope Estuary	Beecher Creek	7.2	0.86	2.75	3.80	2.50	5.50	3.00	4.25	5.50
	Old Bruce Highway Bridge				3.60	5.25	11.25	22.00	3.25	10.25
Auckland Inlet	Callemondah	4.4	1.43	5.00	8.40	7.75	19.50	19.25	12.25	16.75
Mid Harbour	Farmers Point					0.00	6.50	2.25	0.00	0.25
	Gatcombe Anchorage					0.80	0.25	1.00	0.00	4.50
South Trees Inlet	Wappentake Creek		0.57	1.00	0.80	0.75	1.00	2.75	1.50	0.75
	South Trees					6.22	7.75	13.75	6.00	5.75
	Crematorium Pool					10.20	30.75	12.25	6.25	5.25

Boyne Estuary	Old Boyne	10.0	6.00	7.80	8.75	10.50	6.50	3.25	5.00
	Boyne Highway			5.00	10.75	12.25	7.50	12.75	10.00
Colosseum Inlet	Broadacres				3.80	5.75	10.00	5.25	7.50
	Iveragh				5.00	5.75	2.25	5.75	5.25
Rodds Bay	Oaky				7.20	9.25	7.00	9.25	10.50
	7 Mile				7.60	8.75	10.25	6.50	5.50
	Worthington				2.40	4.50	3.25	2.25	5.50
	Sandy Bridge				9.40	17.50	5.50	8.00	2.00

Figure 28 shows the total Bream CPUE per site for survey year 2019-20 plotted against the same total Bream CPUE per site for survey year 2018-19, partitioned into recording zones. Points above the diagonal line correspond to sites whose CPUE increased in 2019-20 from what it was in 2018-19, and points below the line to those for which CPUE decreased.

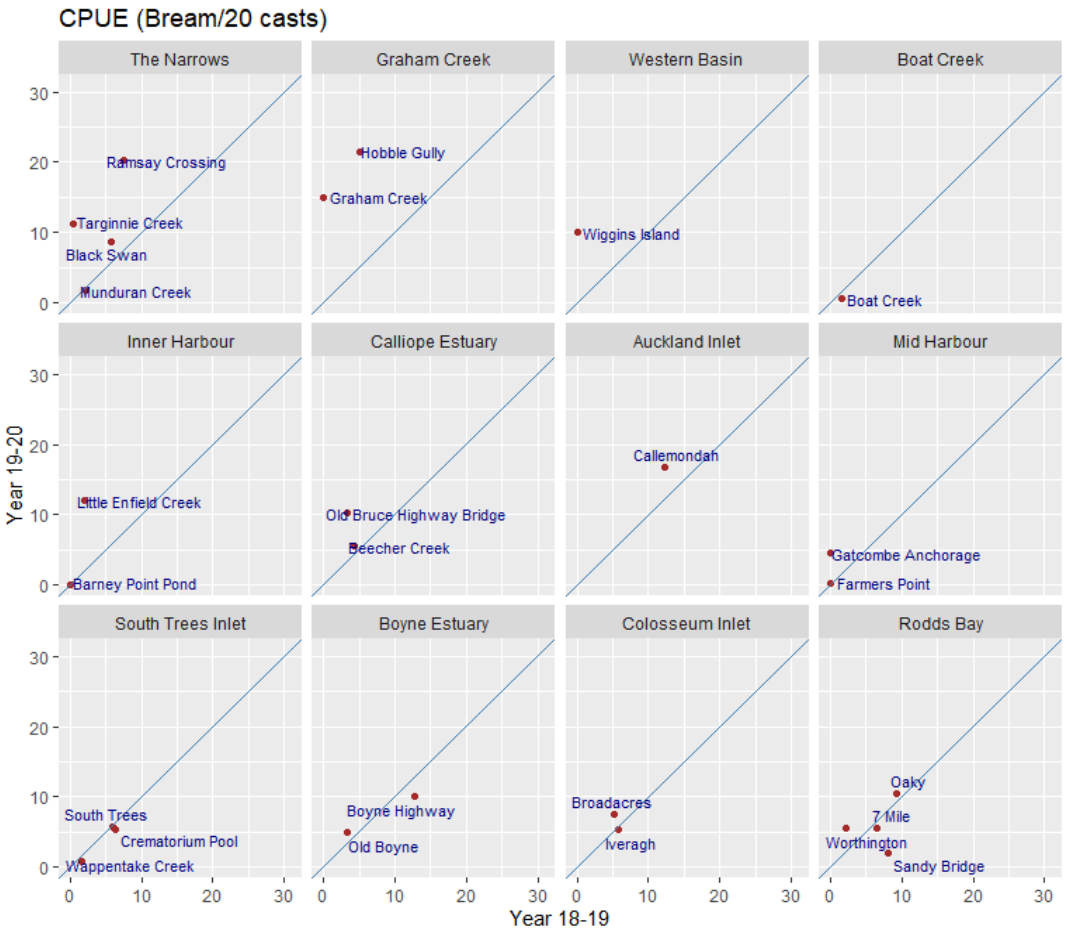


Figure 28: Bream CPUE for 2019-20 against CPUE for 2018-19 per site partitioned into recording zones