



Fish recruitment indicators
for the Gladstone Harbour
Report Card using data
derived from castnet
sampling
2021

Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2021

Bill Sawynok and Stefan Sawynok
Infofish Australia Pty Ltd
12 Mingoola Street Murarrie Qld 4172

April 2021



This report has been prepared by Infofish Australia for the Gladstone Healthy Harbour Partnership. Infofish Australia have taken all steps to ensure the information contained in this publication is accurate at the time of publication. Readers should ensure that they make the appropriate enquiries to determine whether new information is available on a particular subject matter.

© Infofish Australia Pty Ltd

All rights reserved. No part of this publication may be reprinted, reproduced, stored in a retrieval system or transmitted, in any form or by any means, without prior permission from Infofish Australia.

Table of Contents

SUMMARY	5
1. INTRODUCTION.....	7
2. OBJECTIVES	7
3. GLADSTONE HARBOUR MONITORING ZONES.....	8
4. SITE LOCATIONS.....	9
6. RESULTS	12
6.1 SUMMARY OF 2020-21 SURVEYS.....	12
6.2 BREAM IN 2020-21	16
7. COMPARING RESULTS FROM 2015-16 TO 2020-21	20
8. OTHER SPECIES	24
9. RECRUITMENT INDEX	26
9.1 Negative binomial variance parameter	26
9.2 Variance	26
9.3 Site Main Effects	26
9.4 Aggregation to the Zone Level.....	30
10. DISCUSSION	33
11. REFERENCES.....	33
APPENDIX 1 – SURVEY SITES	34
APPENDIX 2 - SPECIES	35
APPENDIX 3 – BREAM SIZE PROFILE	37
APPENDIX 4 – CATCH AND EFFORT DATA.....	38

Figures

Figure 1: Gladstone reporting zones for the GHHP Report Card (from 2018 Report Card Technical Report.pdf at https://dms.ghhp.org.au/repo/public/79fdb7).	8
Figure 2: Site locations and site ID in the Gladstone area for Bream recruitment surveys.	9
Figure 3: Castnet method used for the recruitment surveys.	10
Figure 4: Pikey Bream recruits from Hobble Gully in February 2021.	11
Figure 5: Catch rate at each site (mean with bars showing 95% confidence interval).....	12
Figure 6: Number of individuals (fish and prawn) recorded across all sites from December 2020-February 2021.....	13
Figure 7: Number of sites where key species were recorded (dotted line total number of sites).....	13
Figure 8: Numbers of individuals recorded at all sites on monthly surveys from December 2020 to February 2021.....	14
Figure 9: Percentage of fish and prawn in the catch across all sites on monthly surveys from December 2020-February 2021.....	14
Figure 10: Catch rate for fish and prawn at all sites on monthly surveys from December 2020 to February 2021.....	15

Figure 11: Numbers of Yellowfin and Pikey Bream recorded at each site in surveys from December 2020-February 2021.	17
Figure 12: Mean catch rates with 95% confidence intervals for each Bream species.	18
Figure 13: Numbers of Bream recorded during monthly surveys from December 2020 to February 2021.	18
Figure 14: Mean catch rates with 95% confidence intervals for each Bream species for each of the monthly surveys.	19
Figure 15: Timelines and fork lengths (mm) of Bream recorded during surveys... ..	19
Figure 16: Typical Pikey Bream being measured.	20
Figure 17: Catch rate per cast for fish and prawn 2015-16* to 2020-21.	21
Figure 18: Percentage of NIL casts in each year from 2015-16* to 2020-21.	21
Figure 19: Comparison of Bream catch from 2015-16* to 2020-21.	22
Figure 20: Sites where bream were recorded 15-16 to 20-21 (dotted line is the total number of sites surveyed).....	23
Figure 21: Bream recruits from 2015-16 to 2020-21 and rainfall from November 2015.	23
Figure 22: Sites where other species were recorded 2015-16 to 2020-21 (dotted line is the total number of sites).....	24
Figure 23: Catch rate of other key species as individuals per cast recorded from 2015-16* to 2020-21.	25
Figure 24: Site random effect estimates. A comparison of BLUPs using the restricted data set with those using the full data set.....	27
Figure 25: Zone scores and corresponding bootstrap 95% confidence intervals. .	32
Figure 26: Fork Length change at the harbour level over the data collection period.....	37
Figure 27: Bream CPUE for 20-21 against CPUE for 19-20 per site partitioned into recording zones.	45

Tables

Table 1: Summary of surveys undertaken from December 2020 – February 2021.	12
Table 2: Bream recorded at each site in surveys from December 2020 to February 2021.	16
Table 3: Summary of surveys of fish and prawn recorded from 2015-16* to 2020-21.	21
Table 4: Summary of surveys of the Bream catch from 2015-16* to 2020-21.	22
Table 5: Number of sites where Bream were recorded from 2015-16 to 2020-21.	22
Table 6: Number of sites where other species were recorded 2015-16 to 2020-21.	24
Table 7: Numbers of key species recorded in surveys from 2015-16 to 2020-21..	25
Table 8: Variance component estimates (as standard deviations) for the main model using (a) only data up to year 18-19, (b) only data to year 19-20 and (c) all available data.	26

Table 9: Random effects estimates (BLUPs), <i>EY</i> + <i>EYS</i> , for the Gladstone Harbour Bream survey sites for all study years.	28
Table 10: Score estimates on a (0, 1) –scale, for the Gladstone Harbour Bream survey sites for all years.	29
Table 11: Score estimates on a (0, 1) –scale, averaged over sites within zones, and over all-of harbour.....	30
Table 12: Alphabetic grades for (unadjusted) averaged scores over sites within sub-regions, and over all of harbour.	31
Table 13: Estimates and bootstrap uncertainty intervals.	31
Table 14: Summary of site details.	34
Table 15: Number of each species recorded and number of sites where recorded.	35
Table 16: Bream size distribution summary statistics: Fork Length (mm).	37
Table 17: Numbers of casts per site for all survey years.....	38
Table 18: Total numbers of Pikey Bream caught per site per survey year.....	39
Table 19: Total numbers of Yellowfin Bream caught per site per survey year.	40
Table 20: Total numbers of Pikey Bream and Yellowfin Bream combined per site, per survey year.	41
Table 21: Pikey Bream catch per visit of 20 Casts, (CPUE), per site, per survey year.	42
Table 22: Yellowfin Bream catch per visit of 20 Casts, (CPUE), per site, per survey year.	43
Table 23: Pikey Bream plus Yellowfin Bream catch per visit of 20 Casts, (CPUE), per site, per survey year.....	44

SUMMARY

The requirements of this project were to supply fish recruitment grades and scores for Yellowfin and Pikey Bream for the 2021 Gladstone Harbour Report Card, following the same methods used in the past 5 years so that results were comparable from year to year.

This year the sampling period was reduced to 3 months instead of 4 with surveys conducted in December, January and February but not March as had been previously surveyed. The number of sites surveyed remained constant at 26. There was a total of 78 surveys with 1,560 casts compared with previous years where there was a total of 104 surveys with 2,080 casts. A survey involved 20 casts at each site in approximately the same area in each survey.

There was a total of 8,535 individuals recorded across the 78 surveys comprising 5,169 fish and 3,366 prawns. The highest catch rate was at Graham Creek 2 at 17.1 individuals/cast followed by 7 Mile Creek at 14.4 individuals/cast and then Little Enfield Creek at 12.2 individuals/cast. Lowest catch rates were recorded at Boyne Highway and Farmers Point at 1.7 individuals/cast. Last year Ramsay Crossing had the highest catch rate at 15.9 individuals/cast; this year this catch rate fell to 3.6. This was likely influenced by strong SE winds that persisted through the whole survey period, which possibly impacted the survey habitat.

This year Banana Prawn dominated the catch at 3,366 (39.4%) followed by Flattail Mullet at 1,808 (21.2%) and Common Silverbiddy at 794 (9.3%). Yellowfin Bream were the 5th most recorded species at 329 (3.9%) and Pikey Bream the 6th at 297 (3.5%). Flattail Mullet were recorded at all 26 sites while Yellowfin Bream were at 24 sites and Pikey Bream at 20 sites.

There was a total of 626 Bream observed this year compared to 805 total Bream in 2019-20 (December to March). Pikey Bream tend to dominate in the northern sites while Yellowfin Bream tend to dominate in the southern sites however habitat type is a factor in their location.

The random effects model used in 2020 was used again, without modification, to determine scores and grades for each site, each zone and for all of harbour. The only difference was the smaller sample size this year. The overall result for Gladstone Harbour was C with most zones recording a B or C. Wiggins Island scored an A, however this is likely due to moving the site in 2018-19 from Mud Island which had provided historically poor results.

The following table provides the scores averaged over sites within zones for the last 6 years from 2015-16 to 2020-21, along with the grade colours for the GHHP report card used to convert scores to grades in the 2021 Gladstone Harbour Report Card for each component of harbour health.

Zone	2021	2020	2019	2018	2017	2016
1.Narrows	0.54	0.63	0.19	0.60	0.75	0.34
2.Graham Creek	0.84	0.92	0.14	0.74	0.58	0.33
3.Western Basin	0.94	0.98	0.07	0.70	0.56	0.07
4.Boat Creek	0.35	0.38	0.39	0.61	0.34	0.28
5.Inner Harbour	0.61	0.63	0.14	0.68	0.55	0.24
6.Calliope Estuary	0.68	0.66	0.29	0.68	0.71	0.29
7.Auckland Inlet	0.63	0.80	0.56	0.83	0.82	0.42
8.Mid Harbour	0.78	0.62	0.08	0.62	0.66	0.20
9.South Trees Inlet	0.47	0.39	0.30	0.74	0.69	0.39
10.Boyne Estuary	0.53	0.51	0.35	0.50	0.73	0.54
11.Outer Harbour	NS	NS	NS	NS	NS	NS
12.Colosseum Inlet	0.56	0.63	0.43	0.55	0.63	0.37
13.Rodds Bay	0.51	0.52	0.39	0.57	0.72	0.46
ALL OF HARBOUR	0.62	0.64	0.28	0.65	0.63	0.33

Note that the zone and harbour scores calculated in 2021 are based on 3 months of sampling and that prior to that date scores were based on 4 months of sampling.

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 15-16 to 19-20 standardised surveys were undertaken from December-March 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 20-21 using the same methodology as in previous years however were only undertaken from December-February resulting in three sampling events rather than the four sampling events conducted 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 2020-21 recruitment season.
2. Provide fish recruitment report card scores and grades for the 2021 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://dms.ghhp.org.au/repo/public/79fdb7>).

The 13 Gladstone Harbour reporting zones are:

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

4. SITE LOCATIONS

There were 26 survey sites surveyed in 2020-21. Survey sites were the same as in the previous year. Site locations are shown in Figure 2.

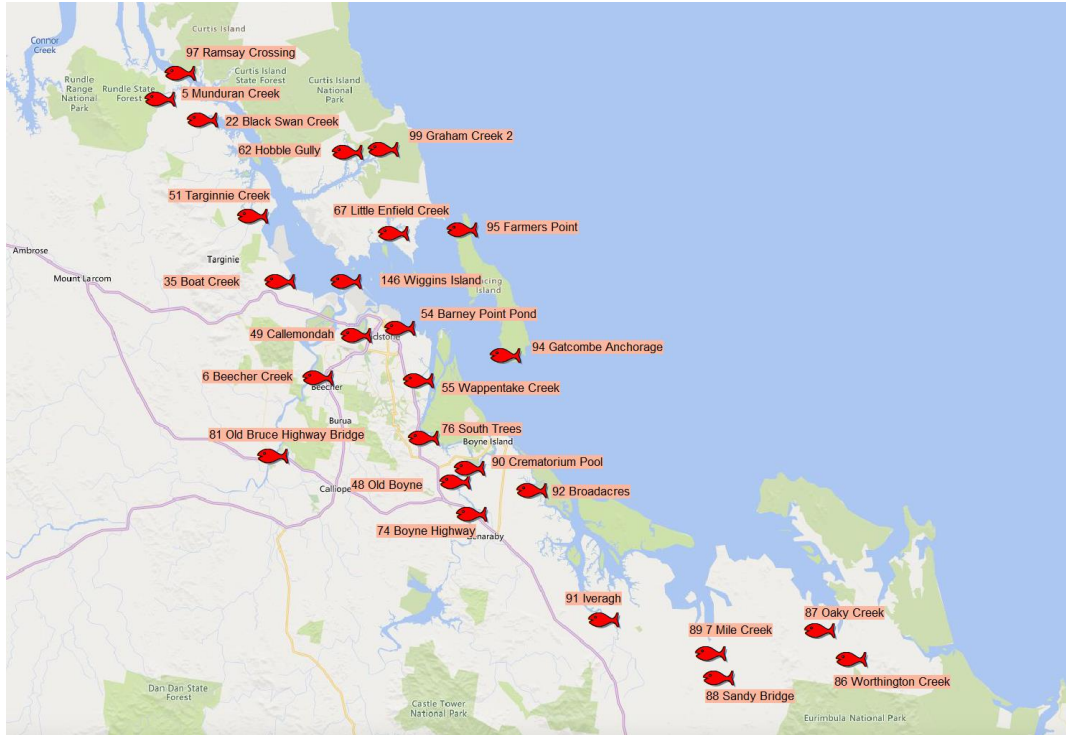


Figure 2: Site locations and site ID in the Gladstone area for Bream recruitment surveys.

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 2020-21 to the methods used in the previous 4 years 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 2020 to February 2021 a total of three surveys. In previous years surveys were conducted monthly between December and March a total of four surveys. 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). The only difference this year was the sample size was reduced from 104 to 78 surveys seeing as there were no surveys conducted in March.

In summary the 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 zone scores were averaged to give an all-of-harbour score. Scores were then converted to a grade based on the following scale:

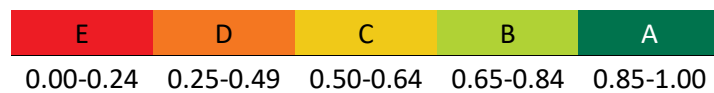


Figure 3: Castnet method used for the recruitment surveys.



Figure 4: Pikey Bream recruits from Hobble Gully in February 2021.

6. RESULTS

6.1 SUMMARY OF 2020-21 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:

- 5-11 December 2020
- 7-22 January 2021
- 7-17 February 2021

Table 1 provides a summary of surveys at all sites from December 2020 to February 2021. There were 78 surveys with 1,560 casts resulting in a catch of 8,535 fish and prawns.

Table 1: Summary of surveys undertaken from December 2020 – February 2021.

Zone	SITE ID	SITE	SURVEYS	CASTS	FISH/PRAWN	CATCH RATE
1	97	RAMSAY CROSSING	3	60	216	3.6
1	5	MUNDURAN CREEK	3	60	201	3.4
1	22	BLACK SWAN	3	60	230	3.8
1	51	TARGINNIE CREEK	3	60	356	5.9
2	62	HOBBLE GULLY	3	60	528	8.8
2	99	GRAHAM CREEK 2	3	60	1023	17.1
3	146	WIGGINS ISLAND	3	60	224	3.7
4	35	BOAT CREEK	3	60	162	2.7
5	67	LITTLE ENFIELD CREEK	3	60	734	12.2
5	54	BARNEY POINT POND	3	60	136	2.3
6	6	BEECHER CREEK	3	60	113	1.9
6	81	OLD BRUCE HWY BRIDGE	3	60	315	5.3
7	49	CALLEMONDAH	3	60	338	5.6
8	95	FARMERS POINT	3	60	100	1.7
8	94	GATCOMBE ANCHORAGE	3	60	122	2.0
9	55	WAPPENTAKE CREEK	3	60	223	3.7
9	76	SOUTH TREES	3	60	517	8.6
9	90	CREMATORIUM POOL	3	60	105	1.8
10	48	OLD BOYNE	3	60	181	3.0
10	74	BOYNE HIGHWAY	3	60	104	1.7
11	OUTER HARBOUR NO SITES					
12	92	BROADACRES	3	60	478	8.0
12	91	IVERAGH	3	60	397	6.6
13	89	7 MILE CREEK	3	60	862	14.4
13	88	SANDY BRIDGE	3	60	247	4.1
13	87	OAKY CREEK	3	60	316	5.3
13	86	WORTHINGTON CREEK	3	60	307	5.1
		TOTAL	78	1560	8535	5.5

Catch rates varied considerably between sites as shown in Table 1 and Figure 5. The highest catch rate was at Graham Creek 2 at 17.1 individuals/cast followed by 7 Mile Creek at 14.4 and then Little Enfield Creek at 12.2. Lowest catch rates were recorded at Farmers Point and Boyne Highway at 1.7 individuals/cast and Crematorium Pool at 1.8. Last year Ramsay Crossing had the highest catch rate at 15.9 individuals/cast; this year the catch rate fell to 3.6. This was likely influenced by strong SE winds that persisted through the whole survey period impacting the habitat.

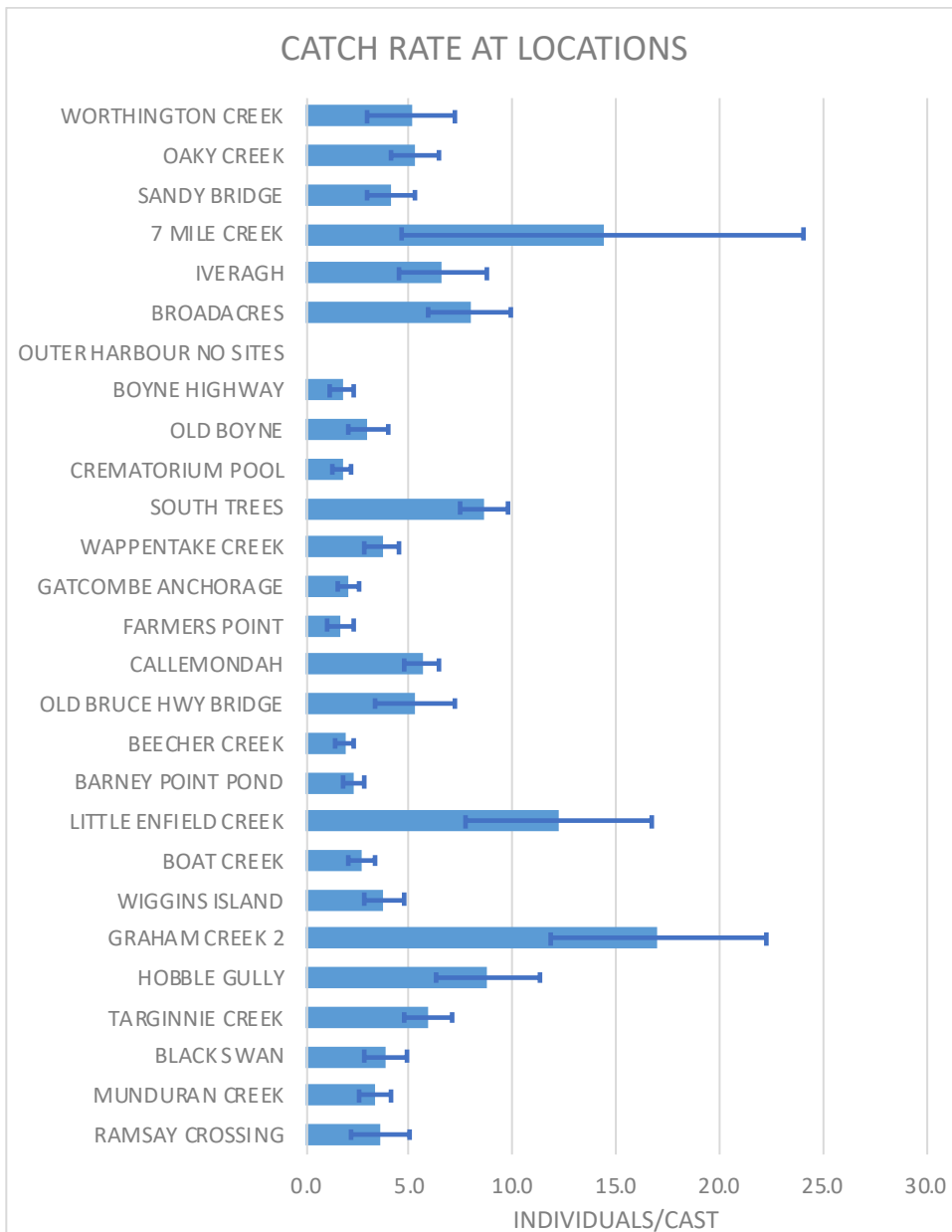


Figure 5: Catch rate at each site (mean with bars showing 95% confidence interval)

This year Banana Prawn were the most prevalent species caught (3,366 or 39.1%) with Flattail Mullet (1,808 or 21.2%) being the most prevalent fish species caught. Yellowfin Bream (329 or 3.9%) was the 5th highest fish species caught and Pikey Bream (297 or 3.5%) was the 6th as shown in Figure 6. A list of all species including scientific names and the numbers caught is shown in Appendix 2.

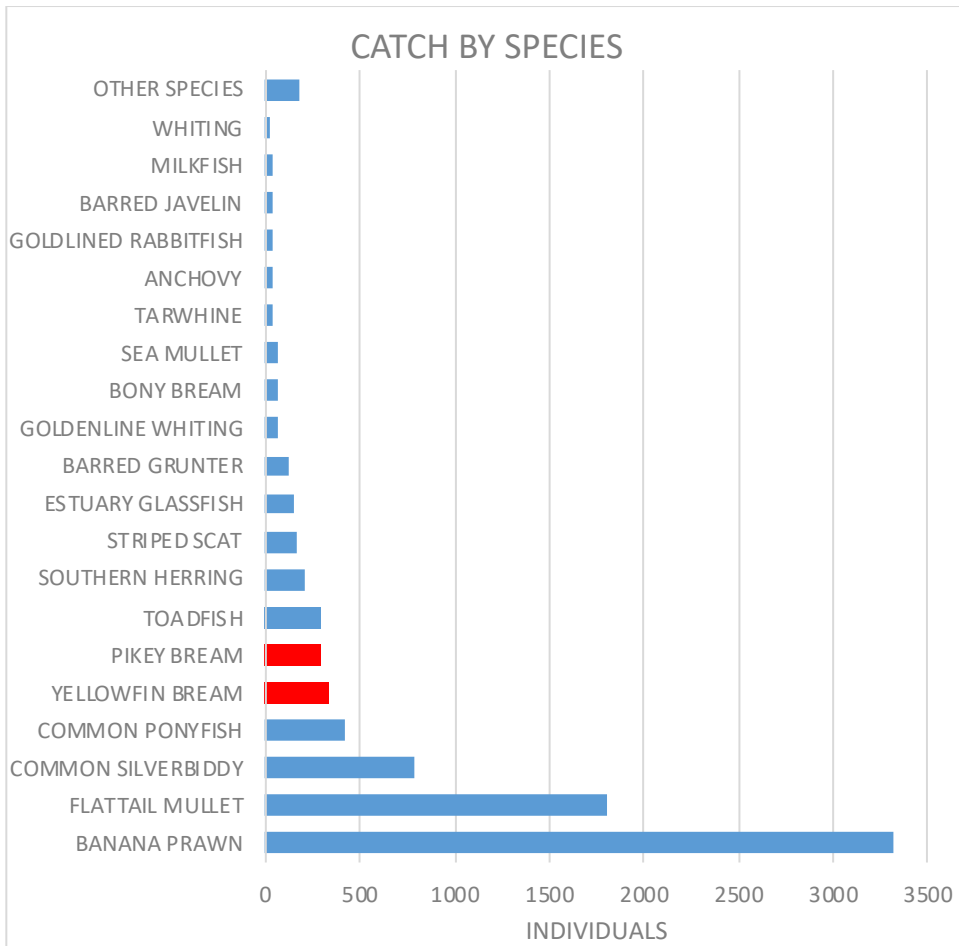


Figure 6: Number of individuals (fish and prawn) recorded across all sites from December 2020-February 2021.

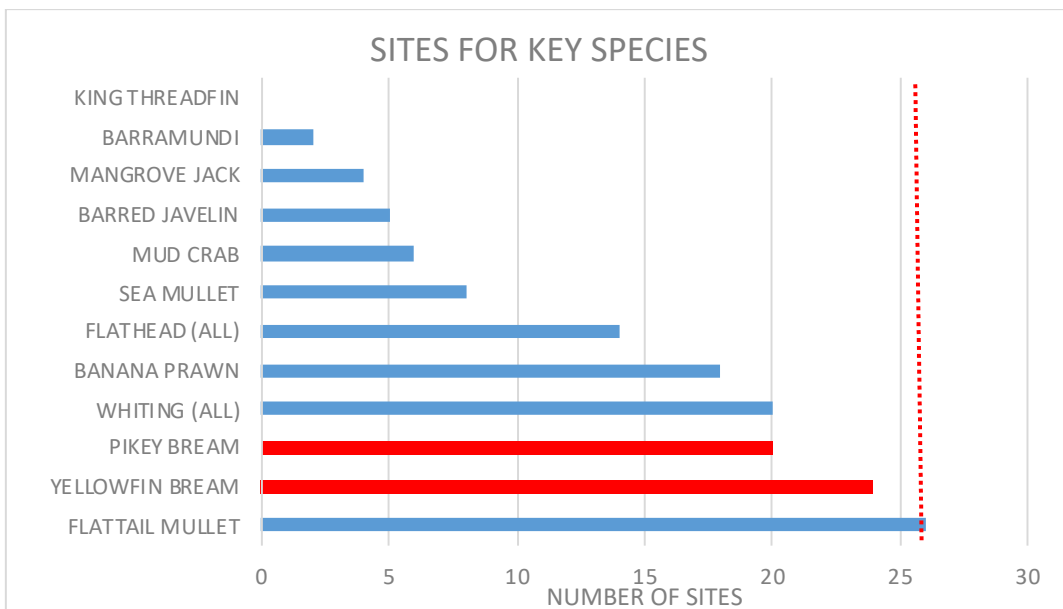


Figure 7: Number of sites where key species were recorded (dotted line total number of sites).

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 3-month period from December 2020 to February 2021. 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 3,344 comprising 2,112 fish and 1,232 prawn) while the smallest was recorded in December (a total of 1,879 comprising 1,723 fish and 156 prawn).

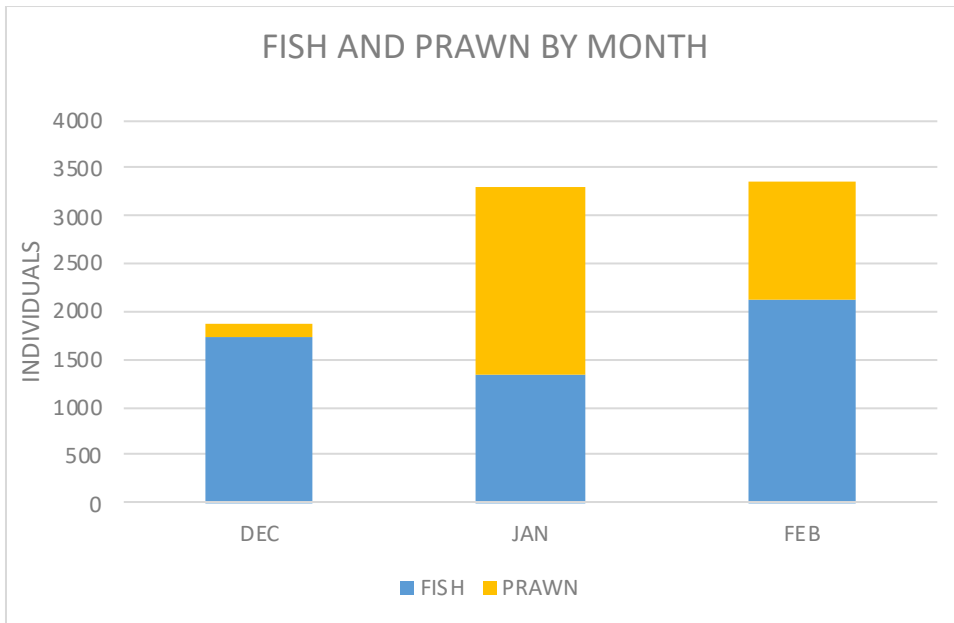


Figure 8: Numbers of individuals recorded at all sites on monthly surveys from December 2020 to February 2021.

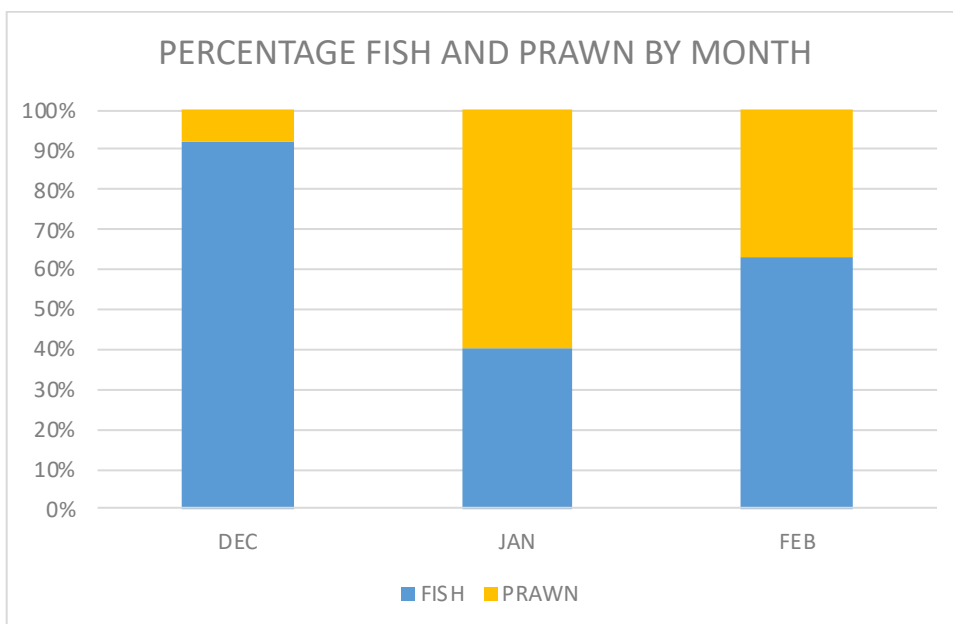


Figure 9: Percentage of fish and prawn in the catch across all sites on monthly surveys from December 2020-February 2021.

Figure 9 shows the percentage of fish and prawn in the catch each month. The percentage of prawn in the catch was highest in January at 59.7% and was lowest in December at 8.3%.

The mean individuals per cast ranged from a low of 3.6 in December to a high of 6.4 in January and February. Figure 10 shows the mean catch rate with bars representing the 95% confidence interval for each month's surveys.

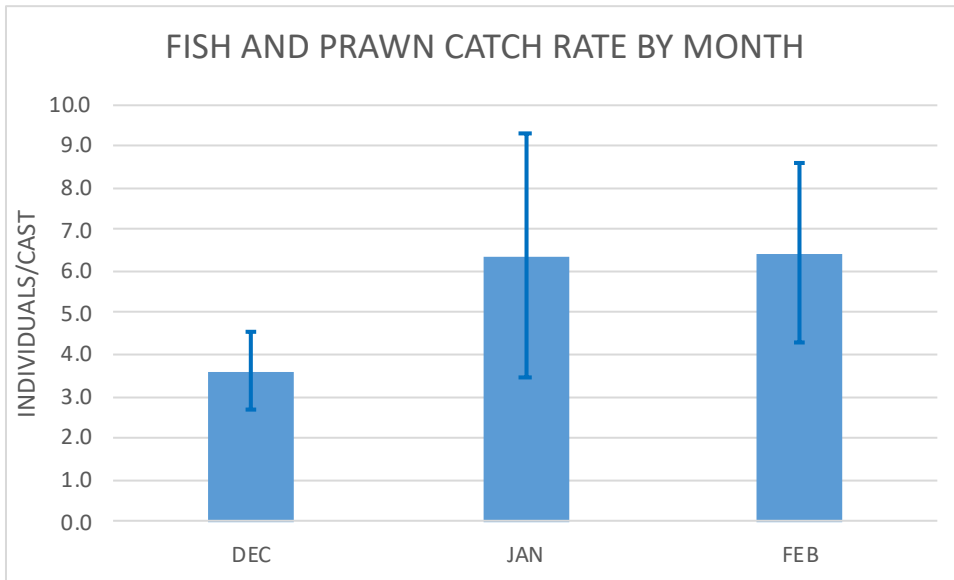


Figure 10: Catch rate for fish and prawn at all sites on monthly surveys from December 2020 to February 2021.

6.2 BREAM IN 2020-21

Bream (Yellowfin and Pikey) were the most caught species by recreational fishers in the Gladstone area comprising 20.7% of the catch and 20.3% 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 2020 to February 2021.

Table 2: Bream recorded at each site in surveys from December 2020 to February 2021.

ZONE	SITE ID	SITE	SURVEYS	CASTS	YELLOW FIN BREAM	PIKEY BREAM
1	97	RAMSAY CROSSING	3	60	1	1
1	5	MUNDURAN CREEK	3	60	17	1
1	22	BLACK SWAN	3	60	4	21
1	51	TARGINNIE CREEK	3	60	32	8
2	62	HOBBLE GULLY	3	60	5	83
2	99	GRAHAM CREEK 2	3	60	0	28
3	146	WIGGINS ISLAND	3	60	21	8
4	35	BOAT CREEK	3	60	1	0
5	67	LITTLE ENFIELD CREEK	3	60	4	33
5	54	BARNEY POINT POND	3	60	0	0
6	6	BEECHER CREEK	3	60	7	5
6	81	OLD BRUCE HWY BRIDGE	3	60	47	11
7	49	CALLEMONDAH	3	60	9	28
8	95	FARMERS POINT	3	60	6	0
8	94	GATCOMBE ANCHORAGE	3	60	2	18
9	55	WAPPENTAKE CREEK	3	60	2	1
9	76	SOUTH TREES	3	60	5	7
9	90	CREMATORIUM POOL	3	60	23	11
10	48	OLD BOYNE	3	60	23	4
10	74	BOYNE HIGHWAY	3	60	23	0
11	OUTER HARBOUR NO SITES					
12	92	BROADACRES	3	60	8	8
12	91	IVERAGH	3	60	21	0
13	89	7 MILE CREEK	3	60	26	17
13	88	SANDY BRIDGE	3	60	13	0
13	87	OAKY CREEK	3	60	19	3
13	86	WORTHINGTON CREEK	3	60	10	1
	TOTAL		78	1560	329	297

Figure 11 shows the sites where Bream were recorded. Yellowfin Bream were recorded at 24 (88.5%) of the 26 sites. Pikey Bream were recorded at 20 (84.6%) 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.

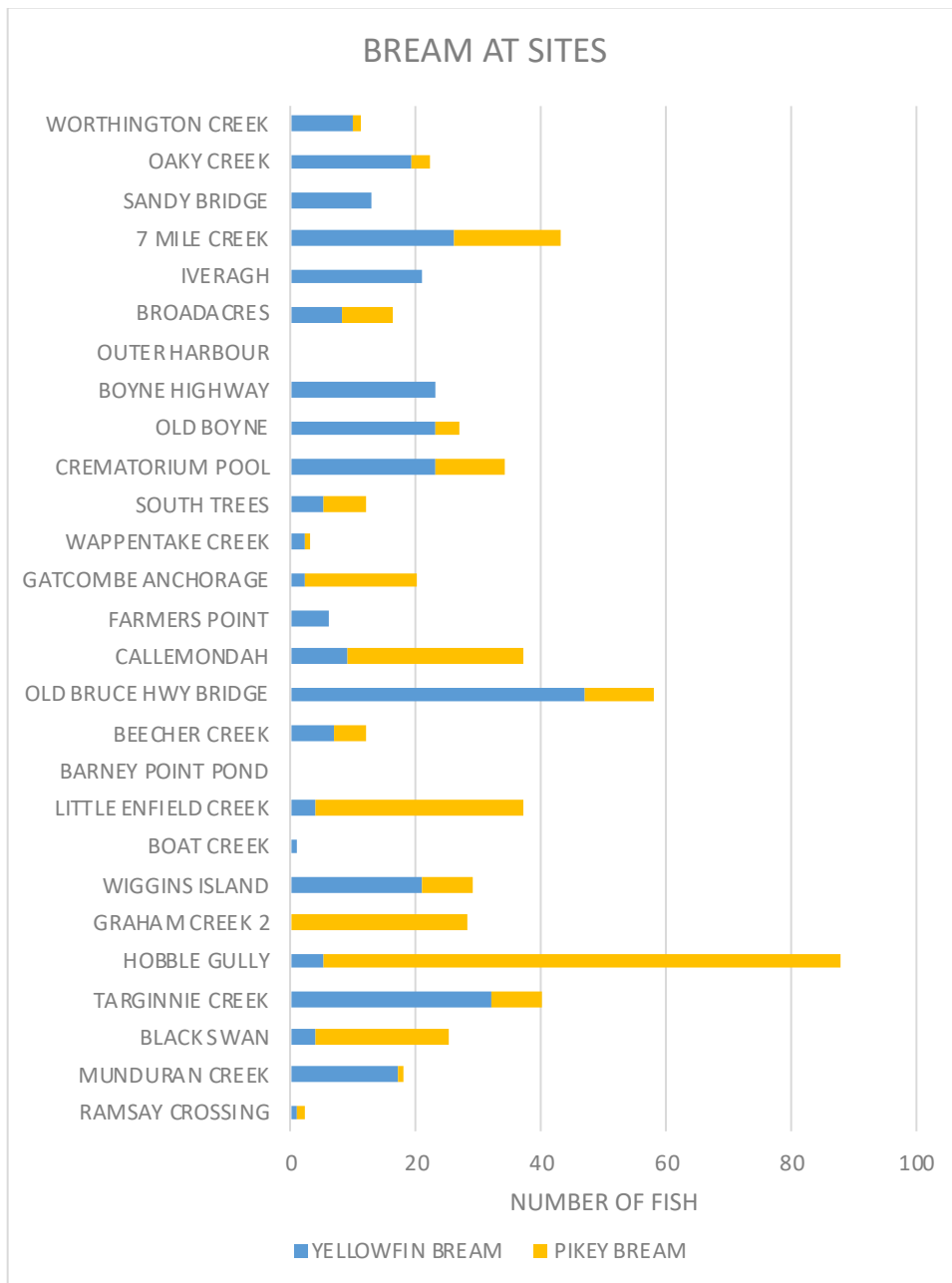


Figure 11: Numbers of Yellowfin and Pikey Bream recorded at each site in surveys from December 2020-February 2021.

There was a total of 329 Yellowfin Bream and 297 Pikey Bream recorded. Over the whole survey period the mean catch rate for Yellowfin Bream was 0.21 fish/cast and for Pikey Bream was 0.19 fish/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 121 recorded in December while the least number was 104 in both January and February. The greatest number of Pikey Bream was 118 recorded in February while the least number was 80 recorded in December.

Figure 14 shows the catch rate for each Bream species for each month's surveys.

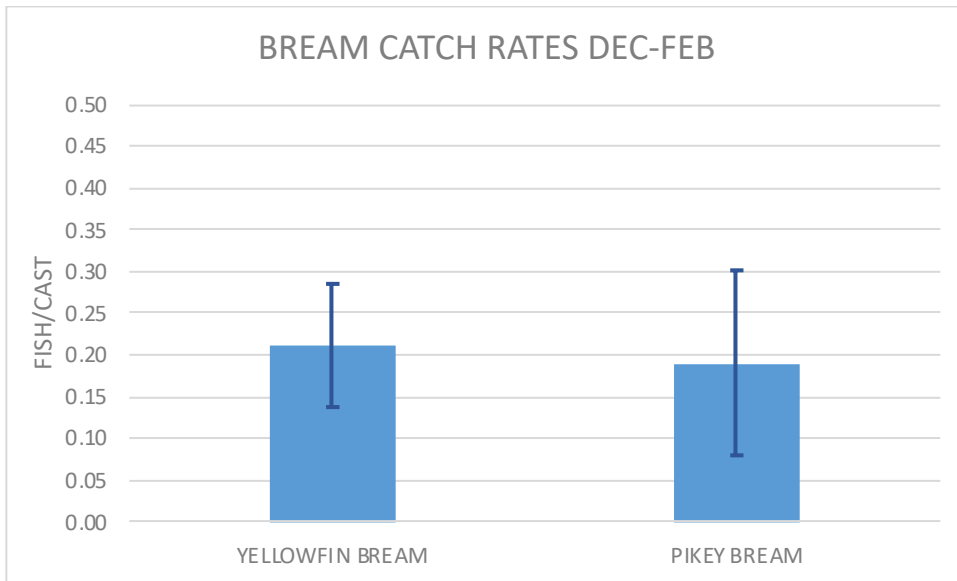


Figure 12: Mean catch rates with 95% confidence intervals for each Bream species.

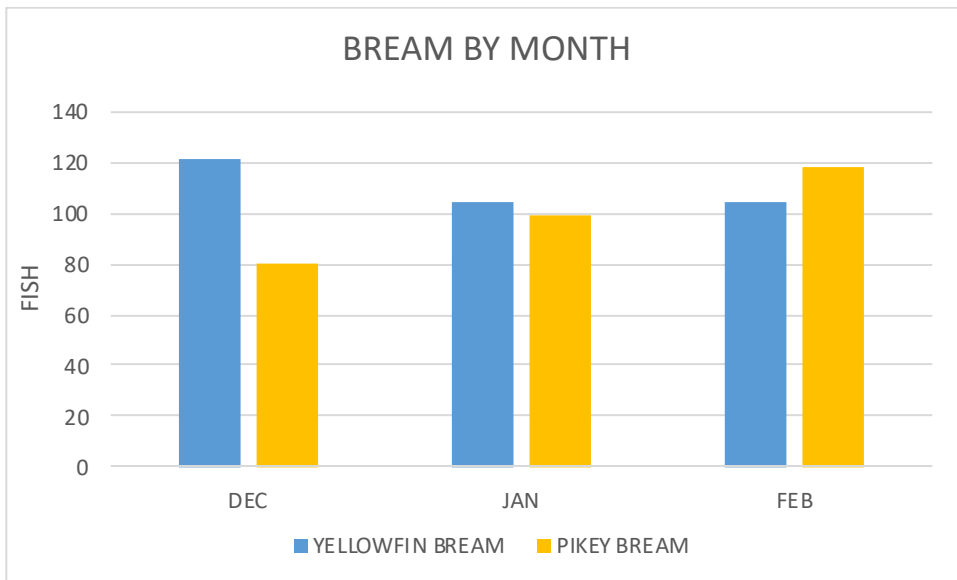


Figure 13: Numbers of Bream recorded during monthly surveys from December 2020 to February 2021.

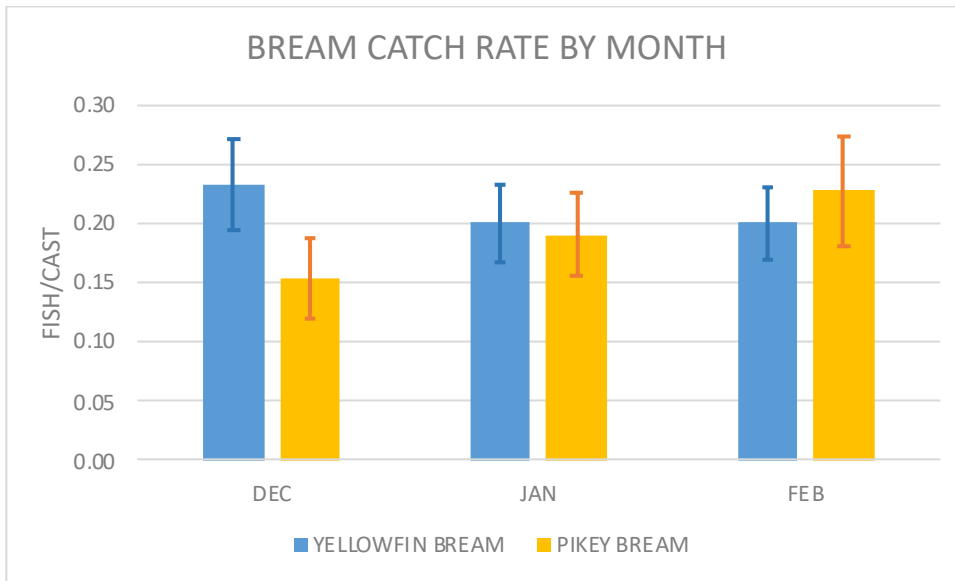


Figure 14: Mean catch rates with 95% confidence intervals for each Bream species for each of the monthly surveys.

Figure 15 shows the timeline of the surveys showing fork length (mm) of Bream recorded during the monthly surveys. Crosses show the average length while the horizontal line shows the median length.

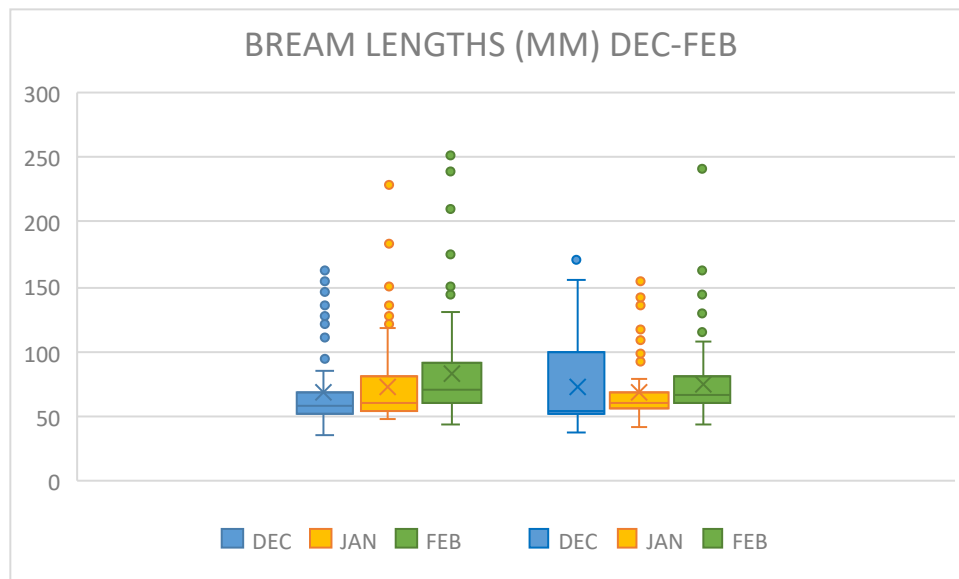


Figure 15: Timelines and fork lengths (mm) of Bream recorded during surveys.

Figure 16 shows a typical Pikey Bream being measured. The smallest Yellowfin Bream recorded was a fish of 34mm (fork length) at Old Boyne in December 2020. The smallest Pikey Bream recorded was a fish of 36mm (fork length) at Targinnie Creek in December 2020. A summary of Bream sizes is presented in Appendix 3.



Figure 16: Typical Pikey Bream being measured.

7. COMPARING RESULTS FROM 2015-16 TO 2020-21

Table 3 provides a summary of the surveys and catch from 2015-16 to 2020-21. In 2016-17, 2017-18, 2018-19 and 2019-20 there were 104 surveys with 2,080 casts while in 2015-16 there were 103 surveys with 2,020 casts, 60 fewer than in subsequent years. The statistics for 2015-16 that are marked with an asterisk have been adjusted by proportional scaling to 104 surveys with 2,080 casts to make the statistics comparable across the 5 survey years. In 2020-21 there were 78 surveys with 1,560 casts.

Figure 17 shows the catch rate per cast for fish and prawn in each of the years. The catch rate for fish in 2020-21 was 3.31 and just below the highest rate of 3.55 in 2019-20. The catch rate for prawn was 2.16 being the highest across all survey years and well above the 1.15 in 2019-20. The overall catch rate of 5.48 individuals/cast (see Table 1) was the highest recorded in the 6 years of surveys.

The increase in the catch rate is reflected in the reduction of the number of “NIL” casts (no catch). The percentage of NIL casts in each of the survey years is shown in Figure 18. In 2020-21 the NIL casts were the lowest across the 6 years at 15.7%, with the highest at 39.1% occurring in 2018-19.

Table 3: Summary of surveys of fish and prawn recorded from 2015-16* to 2020-21.

YEAR	SURVEYS	CASTS	FISH	PRAWN	TOTAL	FISH/ CAST	PRAWN /CAST
20-21	78	1560	5169	3366	8535	3.31	2.16
19-20	104	2080	7375	2396	9771	3.55	1.15
18-19	104	2080	5271	880	6151	2.53	0.42
17-18	104	2080	6142	1682	7824	2.95	0.81
16-17	104	2080	6774	2102	8876	3.26	1.01
15-16*	104	2080	6988	1922	8910	3.36	0.92
15-16	103	2020	6786	1867	8653		

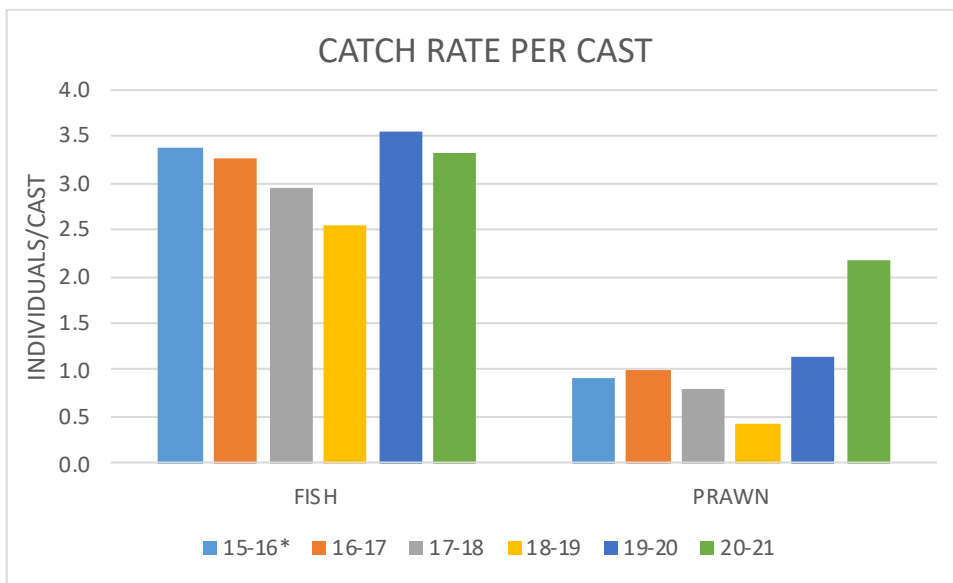


Figure 17: Catch rate per cast for fish and prawn 2015-16* to 2020-21.

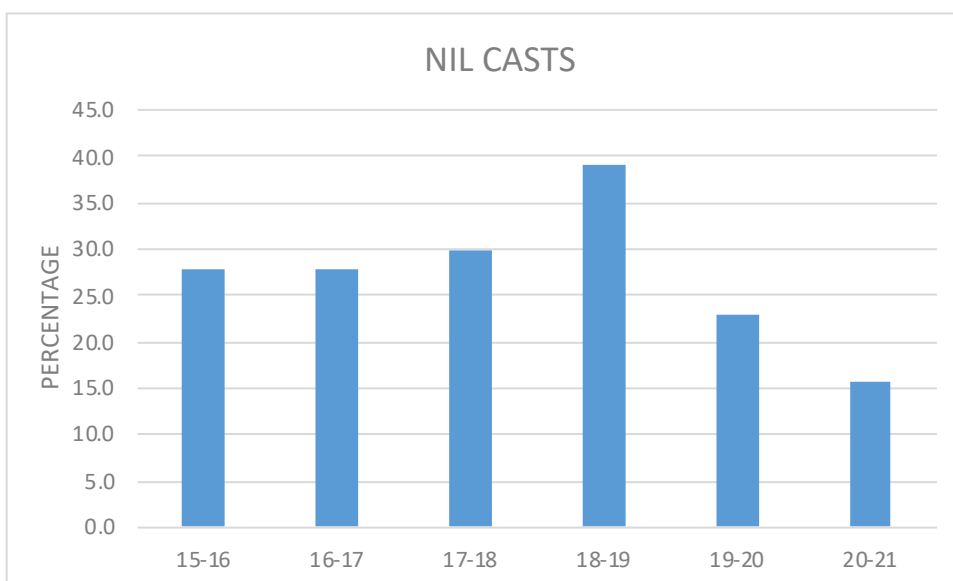


Figure 18: Percentage of NIL casts in each year from 2015-16* to 2020-21.

Table 4 provides a summary of the Bream catch in surveys from 2015-16* to 2020-21 while Figure 19 provides the catch rate as Bream per cast. In 2020-21 the catch rate for Yellowfin Bream was 0.21 while it was highest in 2016-17 at 0.28. The catch rate for Pikey Bream was 0.19 compared with the highest rate of 0.23 in 2019-20.

Table 4: Summary of surveys of the Bream catch from 2015-16* to 2020-21.

YEAR	SURVEYS	CASTS	Y'FIN	PIKEY	TOTAL	Y'FIN/CAST	PIKEY/CAST
20-21	78	1560	329	297	626	0.21	0.19
19-20	104	2080	330	475	805	0.16	0.23
18-19	104	2080	248	196	444	0.12	0.09
17-18	104	2080	346	429	775	0.17	0.21
16-17	104	2080	574	336	910	0.28	0.16
15-16*	104	2080	335	184	519	0.16	0.09
15-16	103	2020	325	179	504		

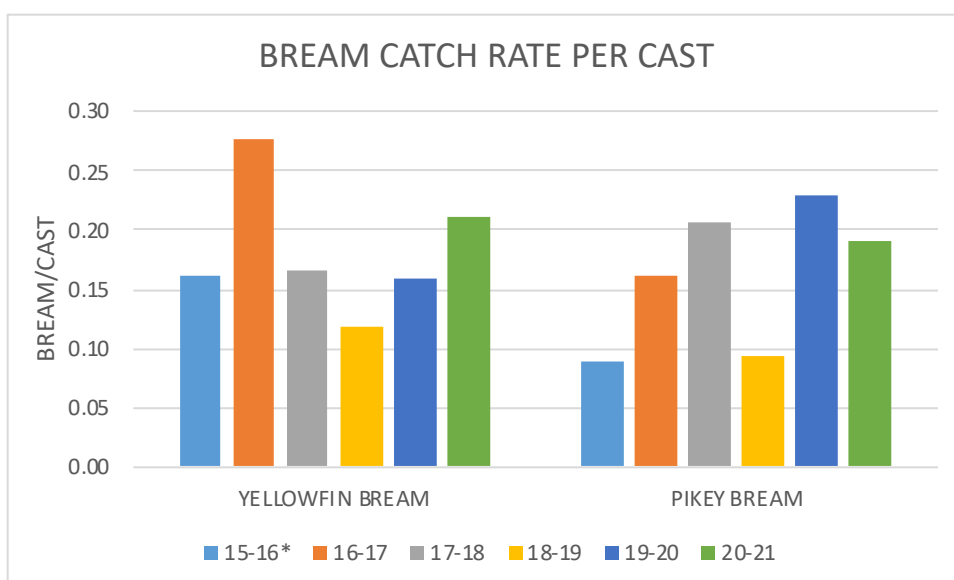


Figure 19: Comparison of Bream catch from 2015-16* to 2020-21.

Table 5 and Figure 20 show the number of sites where Bream were recorded each year. In 2020-21 Yellowfin Bream were recorded at 24 of the 26 sites while Pikey Bream were recorded at 20 sites. Bream continue to be recorded at most of the sites. Over the 6 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 2015-16 to 2020-21.

SPECIES	15-16	16-17	17-18	18-19	19-20	20-21
YELLOWFIN BREAM	22	21	25	22	23	24
PIKEY BREAM	19	20	23	19	22	20

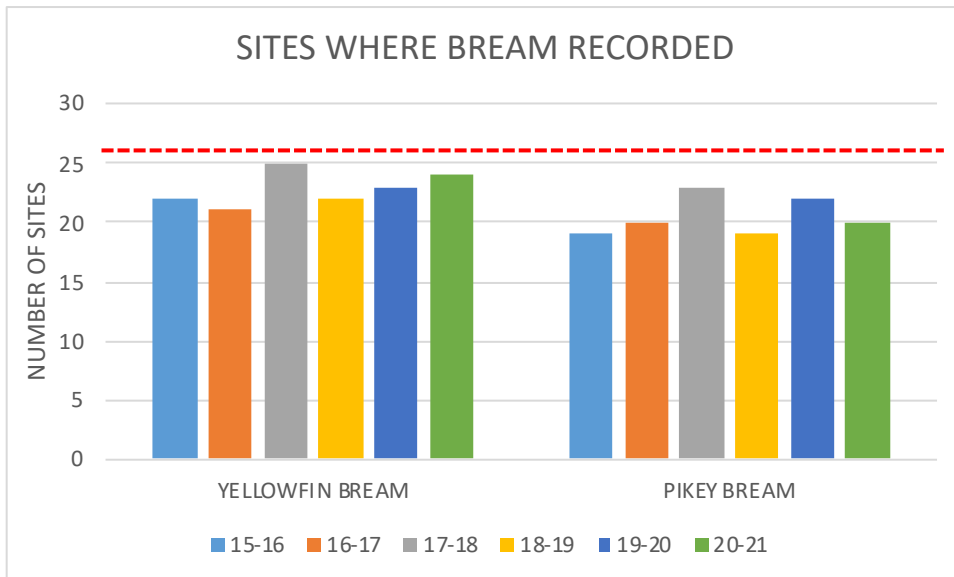


Figure 20: Sites where bream were recorded 15-16 to 20-21 (dotted line is the total number of sites surveyed).

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 November 2020 to 28 February 2021 was 162.2mm. For 1 January to 28 February the rainfall was just 5.6mm making those the driest months since 2017 when 2.2mm was recorded. Rainfall of 143.6mm in December is likely to have contributed to the boost in prawn numbers.

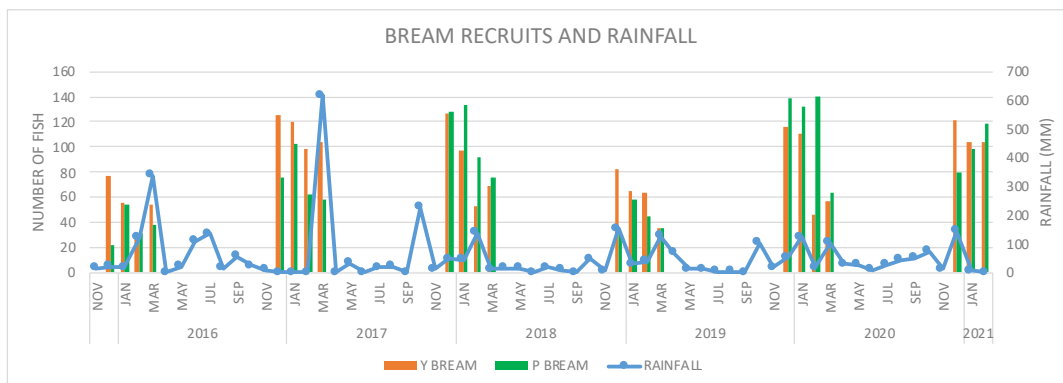


Figure 21: Bream recruits from 2015-16 to 2020-21 and rainfall from November 2015.

8. OTHER SPECIES

Apart from Bream there were 10 species or specie groups 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 18 sites in 20-21 and Sea Mullet was recorded at 8 sites.

Table 6: Number of sites where other species were recorded 2015-16 to 2020-21.

SPECIES	15-16	16-17	17-18	18-19	19-20	20-21
FLATTAIL MULLET	26	26	26	26	26	26
BANANA PRAWN	16	16	15	11	17	18
SEA MULLET	21	11	15	7	10	8
WHITING (ALL)	16	16	16	16	18	20
BARRED JAVELIN	7	7	5	5	10	5
FLATHEAD (ALL)	6	9	12	8	11	14
MUD CRAB	3	6	4	6	4	6
MANGROVE JACK	5	6	6	4	3	4
BARRAMUNDI	2	0	0	0	0	2
KING THREADFIN	0	1	1	1	0	0

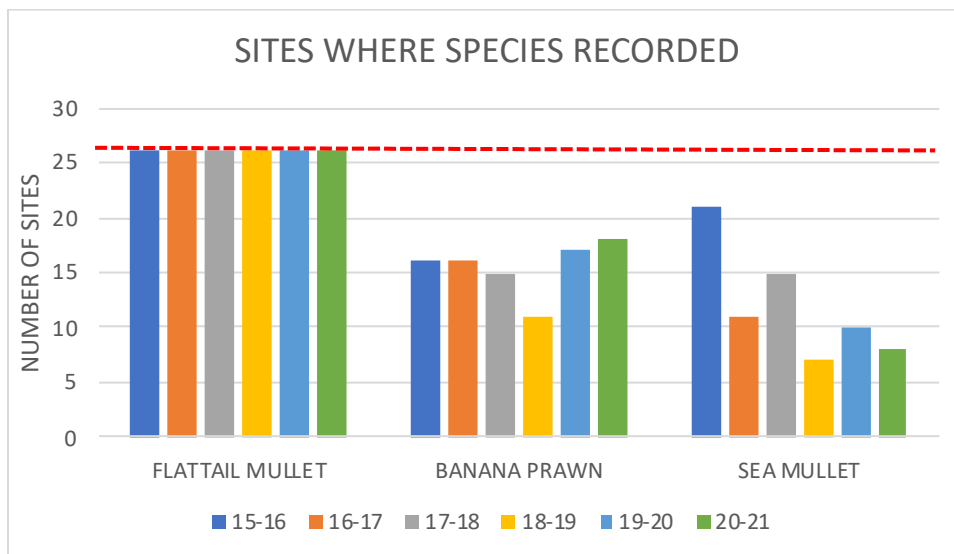


Figure 22: Sites where other species were recorded 2015-16 to 2020-21 (dotted line is the total number of sites).

For the other key species, the numbers recorded each year are shown in Table 7. Banana Prawn ranged from 516 in 2018-19 to 3,366 in 2020-21 which is significantly higher than any other year. Flattail Mullet ranged from 1,134 in 2018-19 to 1,808 in 2020-21. Figure 23 shows the numbers of the top 3 key species recorded each year.

Table 7: Numbers of key species recorded in surveys from 2015-16 to 2020-21.

SPECIES	15-16	16-17	17-18	18-19	19-20	20-21
BANANA PRAWN	1992	2102	1682	880	2396	3366
FLATTAIL MULLET	2150	1859	1665	1449	2401	1808
SEA MULLET	401	233	82	104	181	65
WHITING (ALL)	171	141	121	61	75	98
BARRED JAVELIN	42	47	25	19	145	35
FLATHEAD (ALL)	11	28	39	15	22	22
MUD CRAB	6	31	10	18	9	14
MANGROVE JACK	8	15	20	8	7	6
BARRAMUNDI	4	0	1	1	2	2
KING THREADFIN	0	0	4	2	0	0

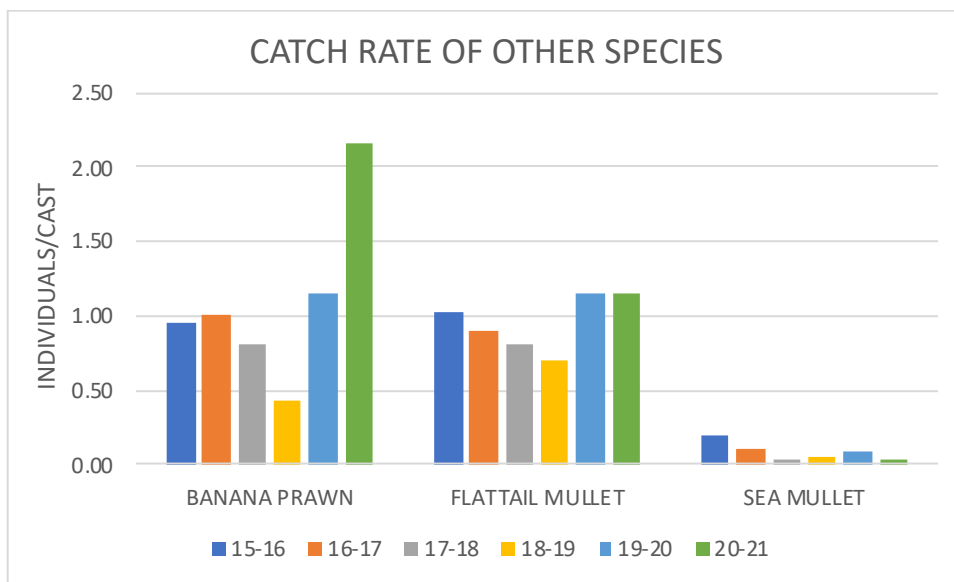


Figure 23: Catch rate of other key species as individuals per cast recorded from 2015-16* to 2020-21.

9. 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 using 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 2019-20 however the number of samples was 1,560 down from 2,080 in previous years.

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 2018-19 only, and
- $\hat{\theta} = 2$ when the further data for year 2019-20 is included and
- $\hat{\theta} = 2$ when the further data for year 2020-21 is included.

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

9.2 Variance

The additional data gained in the 2020-21 surveys shows little change between last year and this year as those variance component estimates are relatively the same, as shown in Table 8.

Table 8: Variance component estimates (as standard deviations) for the main model using (a) only data up to year 18-19, (b) only data to year 19-20 and (c) all available data.

	(a) data to 18-19	(b) data to 19-20	(c) data to 20-21
Site	0.8482	0.7961	0.7750
Year	0.3275	0.2935	0.2656
Year x Site	0.3582	0.4861	0.5077

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

$$\begin{aligned}\hat{\sigma}_{\text{BLUP}} &= \sqrt{\hat{\sigma}_Y^2 + \hat{\sigma}_{YS}^2} \\ &= \sqrt{0.2656^2 + 0.5077^2} \\ &= 0.573\end{aligned}$$

9.3 Site Main Effects

The site main effects, $E_S \sim N(0, \sigma_S^2)$, 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 19-20 (horizontal scale) and estimates using the full data set up to 20-21 (vertical scale). The diagram is partitioned into zones to show the high degree of heterogeneity between and within zones. It is this heterogeneity that complicates the production of fully justifiable scores. The diagonal line in each panel indicates where the two estimates would be equal. Points relatively distant from the line had the greatest change.

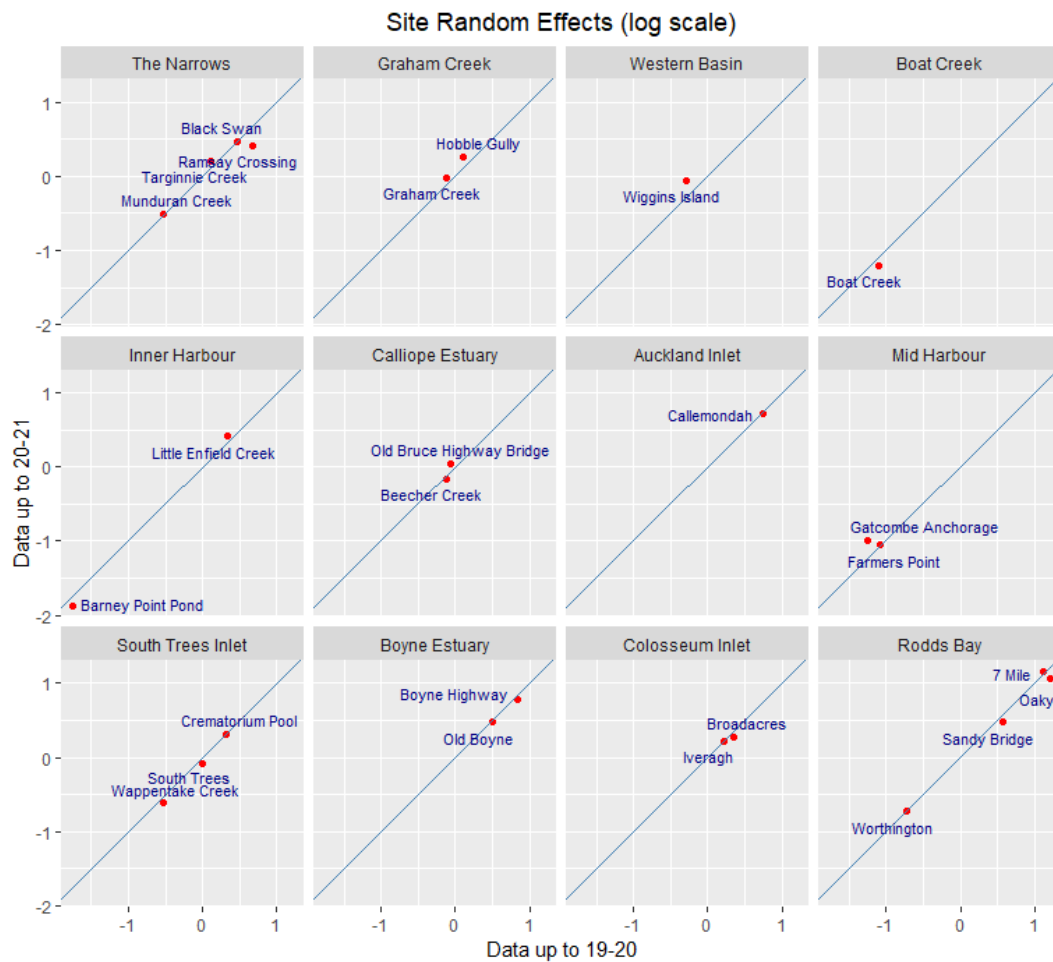


Figure 24: Site random effect estimates. A comparison of BLUPs using the restricted data set with those using the full data set.

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	20- 21
The Narrows	Ramsay Crossing					0.52	0.35	0.21	-	0.41	-
									0.41		0.85
	Munduram Creek	0.60	-	-	0.00	-	0.32	-	-	-	0.17
			0.15	0.16		0.05		0.03	0.52	0.41	
	Black Swan				0.20	-	0.98	0.13	-	0.26	0.16
						1.12			0.24		
	Targinnie Creek	0.10	-		0.58	-	0.19	0.25	-	0.60	0.60
			0.42			0.71			1.04		
Graham Creek	Graham Creek				0.29	-	-	0.29	-	0.93	0.48
						0.42	0.26		1.15		
	Hobble Gully				-	-	-	0.25	-	0.55	0.69
					0.27	0.24	0.21		0.49		
Western Basin	Wiggins Island					-	-	0.14	-	1.03	0.89
						0.97	0.08		0.97		
Boat Creek	Boat Creek		-	0.01	0.55	-	-	0.18	-	-	-
			0.32			0.31	0.26		0.11	0.19	0.22
Inner Harbour	Little Enfield Creek				0.24	-	0.12	0.24	-	0.46	0.44
						0.42			0.76		
	Barney Point Pond		-	0.04	0.31	-	-	0.22	-	-	-
			0.24			0.45	0.08		0.56	0.13	0.09
Calliope Estuary	Beecher Creek	0.52	-	-	0.14	-	0.28	-	-	0.23	0.04
			0.66	0.13		0.33		0.08	0.08		
	Old Bruce Highway Bridge				-	-	0.25	0.68	-	0.15	0.53
					0.37	0.37			0.68		
Auckland Inlet	Callemondah	-	-	-	0.00	-	0.50	0.52	0.09	0.47	0.20
		0.09	0.93	0.32		0.13					
Mid Harbour	Farmers Point					-	1.09	0.30	-	-	0.20
						0.79			0.84	0.35	
	Gatcombe Anchorage					-	-	-	-	0.67	0.81
						0.44	0.38	0.14	0.89		
South Trees Inlet	Wappentake Creek		-	0.01	-	-	0.05	0.52	-	-	-
			0.36		0.05	0.33			0.13	0.11	0.02
	South Trees					-	0.15	0.45	-	-	-
						0.01			0.29	0.07	0.21
	Crematorium Pool					-	0.80	0.21	-	-	0.09
						0.09			0.43	0.37	
Boyne Estuary	Old Boyne	0.28	-		0.24	0.09	0.34	0.01	-	-	0.13
			0.04						0.60	0.19	
	Boyne Highway				-	0.04	0.33	-	0.11	0.17	-
					0.09			0.03			0.03
Colosseum Inlet	Broadacres					-	0.09	0.40	-	0.24	-
						0.34			0.18		0.02
	Iveragh					-	0.24	-	-	0.10	0.20
						0.07		0.29	0.02		
Rodds Bay	Oaky					-	0.25	0.13	0.07	0.31	-
						0.03					0.20
	7 Mile					-	0.19	0.32	-	-	0.44
						0.05			0.22	0.12	

Worthington	-	0.22	-	-	0.31	0.03
	0.31		0.04	0.47		
Sandy Bridge	0.22	0.73	-	0.01	-	-
			0.03		0.49	0.17

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

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

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

Table 10: Score estimates on a (0, 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	20- 21
The Narrows	Ramsay Crossing					0.82	0.73	0.65	0.24	0.76	0.07
	Mundurran Creek	0.85	0.40	0.39	0.50	0.47	0.71	0.48	0.18	0.24	0.62
	Black Swan				0.63	0.03	0.96	0.59	0.34	0.68	0.61
Graham Creek	Targinnie Creek	0.57	0.23		0.84	0.11	0.63	0.67	0.03	0.85	0.85
	Graham Creek				0.70	0.23	0.32	0.69	0.02	0.95	0.80
Western Basin	Hobble Gully				0.32	0.34	0.35	0.67	0.20	0.83	0.88
	Wiggins Island					0.05	0.45	0.59	0.05	0.96	0.94
Boat Creek	Boat Creek		0.29	0.51	0.83	0.29	0.32	0.62	0.42	0.37	0.35
Inner Harbour	Little Enfield Creek				0.66	0.23	0.59	0.66	0.09	0.79	0.78
	Barney Point Pond		0.34	0.53	0.71	0.22	0.44	0.65	0.17	0.41	0.44
Calliope Estuary	Beecher Creek	0.82	0.13	0.41	0.60	0.28	0.69	0.44	0.44	0.66	0.53
	Old Bruce Highway Bridge				0.26	0.26	0.67	0.88	0.12	0.60	0.82
Auckland Inlet	Callemondah	0.44	0.05	0.29	0.50	0.41	0.81	0.82	0.56	0.79	0.63
Mid Harbour	Farmers Point					0.08	0.97	0.70	0.07	0.27	0.64
	Gatcombe Anchorage					0.22	0.25	0.41	0.06	0.88	0.92
South Trees Inlet	Wappentake Creek		0.27	0.50	0.47	0.28	0.53	0.82	0.41	0.43	0.49
	South Trees					0.49	0.61	0.79	0.31	0.45	0.36
	Crematorium Pool					0.43	0.92	0.64	0.22	0.26	0.56
Boyne Estuary	Old Boyne	0.69	0.47		0.67	0.56	0.73	0.50	0.15	0.37	0.59
	Boyne Highway				0.44	0.53	0.72	0.48	0.58	0.61	0.48

Colosseum Inlet	Broadacres	0.27	0.56	0.76	0.38	0.66	0.48
	Iveragh	0.45	0.66	0.31	0.49	0.57	0.64
Rodds Bay	Oaky	0.48	0.67	0.59	0.55	0.70	0.37
	7 Mile	0.46	0.63	0.71	0.35	0.42	0.78
	Worthington	0.30	0.65	0.47	0.21	0.71	0.52
	Sandy Bridge	0.65	0.90	0.48	0.51	0.20	0.38

9.4 Aggregation to the Zone Level

Scores are aggregated to the zone level within years by averaging over sites. Zone scores are then averaged to produce an all-of-harbour score.

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 (0, 1) –scale, averaged over sites within zones, and over all-of harbour.

Zone	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21
The Narrows	0.71	0.31	0.39	0.66	0.35	0.76	0.60	0.20	0.63	0.54
Graham Creek				0.51	0.28	0.34	0.68	0.11	0.89	0.84
Western Basin					0.05	0.45	0.59	0.05	0.96	0.94
Boat Creek		0.29	0.51	0.83	0.29	0.32	0.62	0.42	0.37	0.35
Inner Harbour		0.34	0.53	0.69	0.22	0.51	0.66	0.13	0.60	0.61
Calliope Estuary	0.82	0.13	0.41	0.43	0.27	0.68	0.66	0.28	0.63	0.68
Auckland Inlet	0.44	0.05	0.29	0.50	0.41	0.81	0.82	0.56	0.79	0.63
Mid Harbour					0.15	0.61	0.55	0.07	0.57	0.78
South Trees Inlet		0.27	0.50	0.47	0.40	0.69	0.75	0.31	0.38	0.47
Boyne Estuary	0.69	0.47		0.55	0.55	0.72	0.49	0.36	0.49	0.53
Colosseum Inlet					0.36	0.61	0.53	0.43	0.61	0.56
Rodds Bay					0.47	0.71	0.56	0.40	0.51	0.51
All of Gladstone Harbour	0.66	0.26	0.44	0.58	0.32	0.60	0.63	0.28	0.62	0.62

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

Zone	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21
The Narrows	B	D	D	B	D	B	C	E	C	C
Graham Creek				C	D	D	B	E	A	B
Western Basin					E	D	C	E	A	A
Boat Creek		D	C	B	D	D	C	D	D	D
Inner Harbour		D	C	B	E	C	B	E	C	C
Calliope Estuary	B	E	D	D	D	B	B	D	C	B
Auckland Inlet	D	E	D	C	D	B	B	C	B	C
Mid Harbour					E	C	C	E	C	B
South Trees Inlet		D	C	D	D	B	B	D	D	D
Boyne Estuary	B	D		C	C	B	D	D	D	C
Colosseum Inlet					D	C	C	D	C	C
Rodds Bay					D	B	C	D	C	C
All of Gladstone Harbour	B	D	D	C	D	C	C	D	C	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	0.5370	0.4532	0.6197
Graham Creek	0.8425	0.6029	0.9349
Western Basin	0.9394	0.8268	0.9896
Boat Creek	0.3485	0.1633	0.5495
Inner Harbour	0.6100	0.4899	0.7098
Calliope Estuary	0.6766	0.5424	0.7900
Auckland Inlet	0.6342	0.4546	0.7638
Mid Harbour	0.7798	0.6139	0.8985
South Trees Inlet	0.4673	0.3152	0.6166
Boyne Estuary	0.5342	0.3919	0.6775
Colosseum Inlet	0.5602	0.4712	0.6510
Rodds Bay	0.5122	0.3953	0.6222
All of Harbour	0.6202	0.5568	0.6812

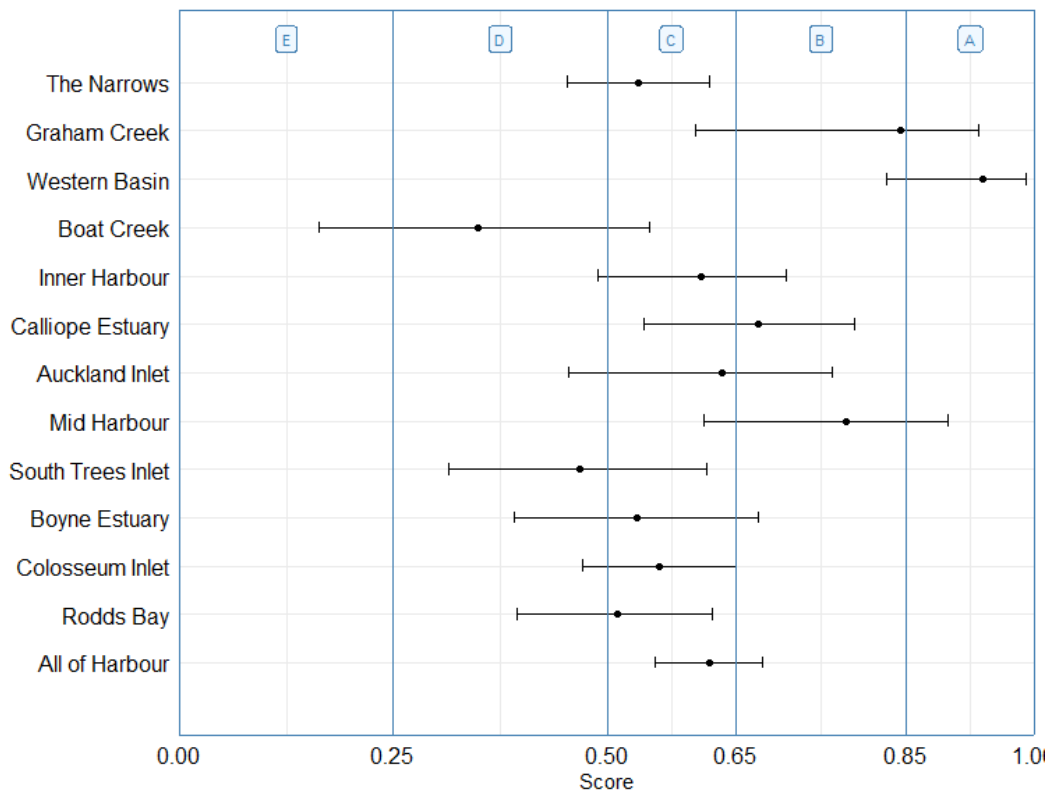


Figure 25: Zone scores and corresponding bootstrap 95% confidence intervals.

10. DISCUSSION

For 20-21 the number of surveys conducted was reduced from 104 to 78 with surveys in December, January and February and none in March as in previous years. The reduction in the number of surveys has had little effect on the overall results. In the recalculation of the historical scores using the binomial model there were minor changes to some zone scores however this had little or no effect on the grades and the scores in the previous report were maintained.

The reduction in the sampling months from 4 to 3 does not appear to have a significant effect on the catch rate. The March catch rate for Bream was down on the December to February catch rate in each of the previous 4 years by 0.21 fish/cast in 2019-20 to 0.08 fish/cast in 2018-19. This suggests that by March there is a greater dispersal of the fish or their numbers have been reduced by predation.

In 4 of the 6 years there were more Yellowfin recorded than Pikey Bream. In 2017-18 and 2019-20 there were more Pikey Bream.

Rainfall of 143.6mm in December was likely to have boosted the prawn catch which was highest in the past 6 years. However, the total rainfall of 5.6mm in Gladstone for January and February resulted in very dry and poor conditions at most sites. This would likely have limited the opportunity for recruits to access some sites and reduce fish dispersal at others.

Persistent strong winds at the time of surveys had a marked effect at Ramsay Crossing where the results were the poorest of any year and were not reflective of the potential recruitment in that area. There were just 2 recruits recorded at the site compared with 75 from surveys conducted there in the previous year.

This year saw a large fluctuation in the number of Goldlined Rabbitfish. From 2015-16 to 2018-19 the total number of fish recorded from December to March was 75-163. This rose to 634 in 2019-20 and fell again to 39 in 2020-21. This suggest that 2019-20 was a strong recruitment year however the drivers of recruitment for this species are unknown.

11. REFERENCES

Bates, D. M., M. Mächler, B. Bolker, and S. Walker. 2015. "Fitting Linear Mixed-Effects Models Using lme4." *Journal of Statistical Software* 67 (1): 1–48.

<https://doi.org/10.18637/jss.v067.i01>.

R Core Team. 2018. *R: A Language and Environment for Statistical Computing*.

Vienna, Austria: R Foundation for Statistical Computing. <https://www.R-project.org/>

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. (2020). "Incorporating a Fish Recruitment Indicator into the Gladstone Harbour Report Card." *Journal of Ecological Indicators*, (Submitted)

Sawynok B and Sawynok S (2019): Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2019
<http://infofishaustralia.com.au/gladstone>

Sawynok B and Sawynok S (2020): Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2020
<http://infofishaustralia.com.au/gladstone>

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).

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

APPENDIX 2 - SPECIES

List of species recorded using standard name, scientific name, number of sites, and number of fish recorded in surveys from December to February. 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
Prawn – Banana	<i>Fenneropenaeus indicus</i>	18	3366
Mullet – Flattail	<i>Liza dussumieri</i>	26	1808
Silverbiddy – Common	<i>Gerres subfasciatus</i>	23	803
Ponyfish – Common	<i>Leiognathus equulus</i>	23	417
Bream – Yellowfin	<i>Acanthopagrus australis</i>	24	329
Bream – Pikey	<i>Acanthopagrus berda</i>	20	297
Toadfish – Common	<i>Tetractenos hamiltoni</i>	19	295
Herring – Southern	<i>Herklotsichthys castelnaui</i>	14	205
Scat – Striped	<i>Selenotoca multifasciata</i>	11	162
Glassfish – Estuary	<i>Ambassis marianus</i>	14	161
Grunter – Barred	<i>Terapon jarbua</i>	18	124
Whiting – Goldenline	<i>Sillago analis</i>	15	75
Bream – Bony	<i>Nematalosa erebi</i>	7	72
Mullet – Sea	<i>Mugil cephalus</i>	8	66
Tarwhine	<i>Rhabdosargus sarba</i>	6	43
Anchovy spp		4	41
Rabbitfish – Goldlined	<i>Siganus lineatus</i>	16	41
Javelin – Barred	<i>Pomadasys kaakan</i>	5	35
Milkfish	<i>Chanos chanos</i>	5	31
Snapper – Moses	<i>Lutjanus russellii</i>	9	17
Whiting spp	<i>Sillago spp</i>	4	17
Flathead – Bartail	<i>Platycephalus indicus</i>	8	15
Crab – Mud	<i>Scylla serrata</i>	6	14
Diamondfish	<i>Monodactylus argenteus</i>	5	12
Silverbiddy – Threadfin	<i>Gerres filamentosus</i>	3	9
Mullet - Diamondscales	<i>Liza vaigiensis</i>	2	9
Flathead – Dusky	<i>Platycephalus fuscus</i>	6	7
Scat – Spotted	<i>Scatophagus argus</i>	2	7
Sole – Black?	<i>Brachinus nigra</i>	4	6
Crab – Blue Swimmer	<i>Portunis armatus</i>	3	6
Mangrove Jack	<i>Lutjanus argentimaculatus</i>	4	6
Whiting – Winter	<i>Sillago maculata</i>	2	6
Garfish		2	4
Gudgeon spp		3	4
Australian Stripey	<i>Microcanthus strigatus</i>	2	3

Queenfish – Giant	<i>Scomeroides commersonianus</i>	2	3
Rabbitfish - Whitespotted	<i>Siganus canaliculatus</i>	1	10
Barramundi	<i>Lates calcarifer</i>	2	2
Filefish		1	2
Herring – Giant	<i>Elops machnata</i>	1	1
Bullrout	<i>Notesthes robusta</i>	1	1
Blackspotted Rockcod	<i>Epinephelus malabaricus</i>	1	1
Gudgeon – Spangled	<i>Ophiocara porocephala</i>	1	1
Flounder - Largetooth	<i>Pseudoohombus arsius</i>	1	1
Barracuda	<i>Sphyraena spp</i>	2	2
Blubberlips – Brown	<i>Plectorhinchus gibbosus</i>	1	1
Whiting – Sand	<i>Sillago ciliata</i>	1	1
Trevally – Giant	<i>Caranx ignobilis</i>	1	1
Shrimp – Freshwater	<i>Macrobrchium spp</i>	1	1
Tarpon	<i>Magalops cyprinoides</i>	1	1
Stingray		1	1

APPENDIX 3 – BREAM SIZE PROFILE

Figure 26 and Table 16 show the size distribution of the Bream catch, by species, for each of the 3 months of the surveys and for all of harbour.

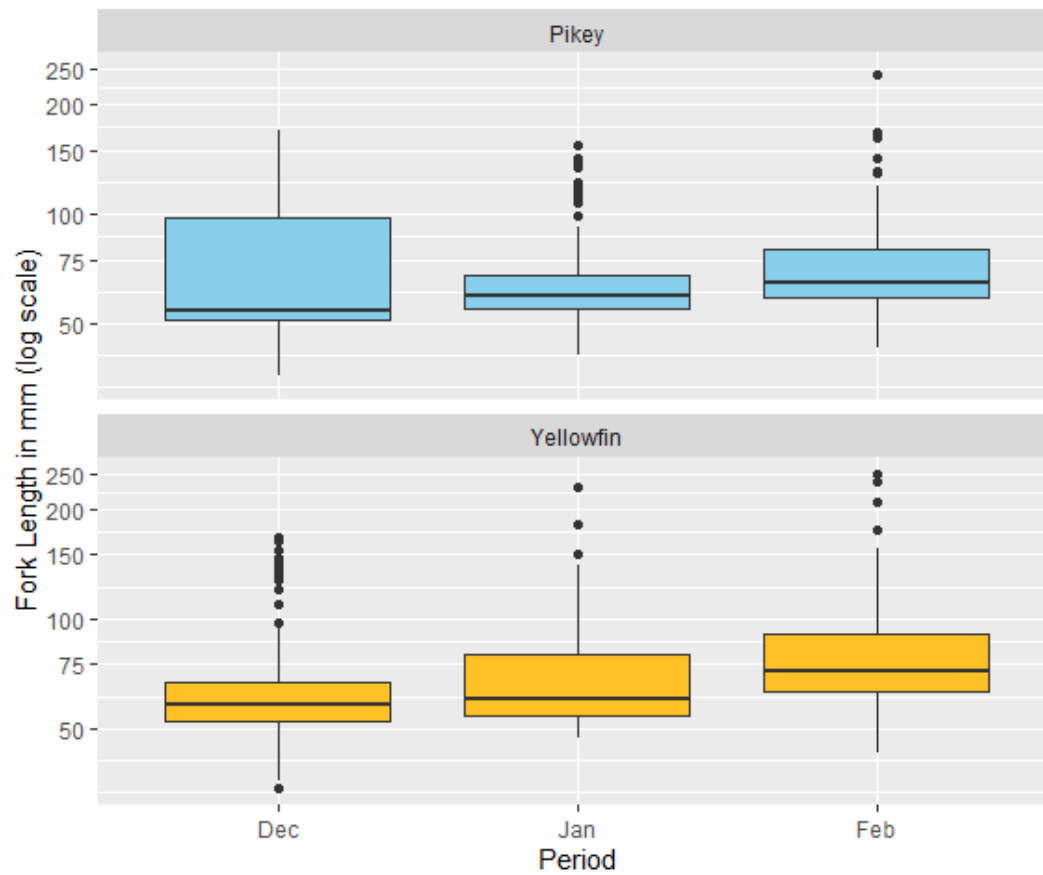


Figure 26: Fork Length change at the harbour level over the data collection period.

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

Species	Month	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Pikey Bream	Dec	36	51	54.0	72.73750	98.25	171
	Jan	41	55	60.0	68.43434	68.00	155
	Feb	43	59	65.0	73.98305	80.00	241
Yellowfin Bream	Dec	34	52	58.0	67.48760	67.00	168
	Jan	47	54	60.0	73.00980	80.00	230
	Feb	43	63	71.5	83.79787	91.00	251

APPENDIX 4 – CATCH AND EFFORT DATA

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

Zone	Site	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21
The Narrows	Ramsay Crossing					50	80	80	80	80	60
	Munduram Creek	60	60	80	100	100	80	80	80	80	60
	Black Swan				80	80	80	80	80	80	60
	Targinnie Creek	10	10		80	80	80	80	80	80	60
Graham Creek	Graham Creek				20	60	80	80	80	80	60
	Hobble Gully				80	80	80	80	80	80	60
Western Basin	Wiggins Island					100	80	80	80	80	60
Boat Creek	Boat Creek		10	80	75	80	80	80	80	80	60
Inner Harbour	Little Enfield Creek				100	80	80	80	80	80	60
	Barney Point Pond		80	100	100	80	80	80	80	80	60
Calliope Estuary	Beecher Creek	50	70	80	100	80	80	80	80	80	60
	Old Bruce Highway Bridge				50	80	80	80	80	80	60
Auckland Inlet	Callemondah	50	70	100	100	80	80	80	80	80	60
Mid Harbour	Farmers Point					90	80	80	80	80	60
	Gatcombe Anchorage					100	80	80	80	80	60
South Trees Inlet	Wappentake Creek		70	60	100	80	80	80	80	80	60
	South Trees					90	80	80	80	80	60
	Crematorium Pool					100	80	80	80	80	60
Boyne Estuary	Old Boyne	20	20		100	80	80	80	80	80	60
	Boyne Highway				40	80	80	80	80	80	60
Colosseum Inlet	Broadacres					100	80	80	80	80	60
	Iveragh					100	80	80	80	80	60
Rodds Bay	Oaky					100	80	80	80	80	60
	7 Mile					100	80	80	80	80	60
	Worthington					100	80	80	80	80	60
	Sandy Bridge					100	80	80	80	80	60

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

Zone	Site	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21
The Narrows	Ramsay Crossing					56	48	56	26	74	1
"	Munduram Creek	0	0	2	0	0	0	0	1	1	1
	Black Swan				25	1	77	22	21	33	21
	Targinnie Creek	0	0		0	0	2	6	0	20	8
Graham Creek	Graham Creek				3	2	8	24	0	60	28
	Hobble Gully				21	30	24	53	20	84	83
Western Basin	Wiggins Island					0	3	8	0	15	8
Boat Creek	Boat Creek		0	0	5	2	1	2	3	2	0
Inner Harbour	Little Enfield Creek				30	13	24	30	6	39	33
	Barney Point Pond		0	2	1	0	0	1	0	0	0
Calliope Estuary	Beecher Creek	0	0	0	1	1	2	0	10	9	5
	Old Bruce Highway Bridge				0	10	37	12	12	18	11
Auckland Inlet	Callemondah	2	0	12	17	15	43	57	34	37	28
Mid Harbour	Farmers Point					0	0	3	0	0	0
	Gatcombe Anchorage					2	1	0	0	12	18
South Trees Inlet	Wappentake Creek		0	1	1	1	1	1	1	1	1
	South Trees Crematorium Pool					11	16	44	11	13	7
						1	0	14	9	7	11
Boyne Estuary	Old Boyne	2	0		4	1	0	6	3	5	4
	Boyne Highway				0	1	0	1	0	0	0
Colosseum Inlet	Broadacres					2	12	31	8	14	8
	Iveragh					2	3	1	5	2	0
Rodds Bay	Oaky					13	12	13	10	12	3
	7 Mile					23	16	35	9	15	17
	Worthington					1	4	5	2	2	1
	Sandy Bridge					0	2	4	5	0	0

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

Zone	Site	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21
The Narrows	Ramsay Crossing					6	22	9	4	7	1
	Munduran Creek	33	13	10	20	23	29	15	8	6	17
	Black Swan				4	0	17	4	2	2	4
	Targinnie Creek	2	0		38	5	21	21	2	25	32
Graham Creek	Graham Creek				4	5	0	0	0	0	0
	Hobble Gully				1	2	0	2	0	2	2
Western Basin	Wiggins Island					0	3	2	0	25	21
Boat Creek	Boat Creek		0	5	4	1	0	4	3	0	1
Inner Harbour	Little Enfield Creek				7	1	4	1	2	9	4
	Barney Point Pond		1	0	2	0	0	1	0	0	0
Calliope Estuary	Beecher Creek	18	3	11	18	9	20	12	7	13	7
	Old Bruce Highway Bridge				9	11	8	76	1	23	47
Auckland Inlet	Callemondah	9	5	13	25	16	35	20	15	30	9
Mid Harbour	Farmers Point					0	26	6	0	1	6
	Gatcombe Anchorage					2	0	4	0	6	2
South Trees Inlet	Wappentake Creek		2	2	3	2	3	10	5	2	2
	South Trees					17	15	11	13	10	5
	Crematorium Pool					50	123	35	16	14	23
Boyne Estuary	Old Boyne	8	6		35	34	42	20	10	15	23
	Boyne Highway				10	42	49	29	51	40	23
Colosseum Inlet	Broadacres					17	11	9	13	16	8
	Iveragh					23	20	8	18	19	21
Rodds Bay	Oaky					23	25	15	27	30	10
	7 Mile					15	19	6	17	7	26
	Worthington					11	14	8	7	20	10
	Sandy Bridge					47	68	18	27	8	13

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

Zone	Site	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21
The Narrows	Ramsay Crossing					62	70	65	30	81	2
"	Munduram Creek	33	13	12	20	23	29	15	9	7	18
	Black Swan				29	1	94	26	23	35	25
	Targinnie Creek	2	0		38	5	23	27	2	45	40
Graham Creek	Graham Creek				7	7	8	24	0	60	28
	Hobble Gully				22	32	24	55	20	86	85
Western Basin	Wiggins Island					0	6	10	0	40	29
Boat Creek	Boat Creek		0	5	9	3	1	6	6	2	1
Inner Harbour	Little Enfield Creek				37	14	28	31	8	48	37
	Barney Point Pond		1	2	3	0	0	2	0	0	0
Calliope Estuary	Beecher Creek	18	3	11	19	10	22	12	17	22	12
	Old Bruce Highway Bridge				9	21	45	88	13	41	58
Auckland Inlet	Callemondah	11	5	25	42	31	78	77	49	67	37
Mid Harbour	Farmers Point					0	26	9	0	1	6
	Gatcombe Anchorage					4	1	4	0	18	20
South Trees Inlet	Wappentake Creek		2	3	4	3	4	11	6	3	3
	South Trees					28	31	55	24	23	12
	Crematorium Pool					51	123	49	25	21	34
Boyne Estuary	Old Boyne	10	6		39	35	42	26	13	20	27
	Boyne Highway				10	43	49	30	51	40	23
Colosseum Inlet	Broadacres					19	23	40	21	30	16
	Iveragh					25	23	9	23	21	21
Rodds Bay	Oaky					36	37	28	37	42	13
	7 Mile					38	35	41	26	22	43
	Worthington					12	18	13	9	22	11
	Sandy Bridge					47	70	22	32	8	13

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

Zone	Site	11- 12	12- 13	13- 14	14- 15	15- 16	16- 17	17- 18	18- 19	19- 20	20- 21
The Narrows	Ramsay Crossing					22.40	12.00	14.00	6.50	18.50	0.33
	Munduran Creek	0.0	0	0.50	0.00	0.00	0.00	0.00	0.25	0.25	0.33
	Black Swan				6.25	0.25	19.25	5.50	5.25	8.25	7.00
	Targinnie Creek	0.0	0		0.00	0.00	0.50	1.50	0.00	5.00	2.67
Graham Creek	Graham Creek				3.00	0.67	2.00	6.00	0.00	15.00	9.33
	Hobble Gully				5.25	7.50	6.00	13.25	5.00	21.00	27.67
Western Basin	Wiggins Island					0.00	0.75	2.00	0.00	3.75	2.67
Boat Creek	Boat Creek		0	0.00	1.33	0.50	0.25	0.50	0.75	0.50	0.00
Inner Harbour	Little Enfield Creek				6.00	3.25	6.00	7.50	1.50	9.75	11.00
	Barney Point Pond		0	0.40	0.20	0.00	0.00	0.25	0.00	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	1.67
	Old Bruce Highway Bridge				0.00	2.50	9.25	3.00	3.00	4.50	3.67
Auckland Inlet	Callemondah	0.8	0	2.40	3.40	3.75	10.75	14.25	8.50	9.25	9.33
Mid Harbour	Farmers Point					0.00	0.00	0.75	0.00	0.00	0.00
	Gatcombe Anchorage					0.40	0.25	0.00	0.00	3.00	6.00
South Trees Inlet	Wappentake Creek		0	0.33	0.20	0.25	0.25	0.25	0.25	0.25	0.33
	South Trees					2.44	4.00	11.00	2.75	3.25	2.33
	Crematorium Pool					0.20	0.00	3.50	2.25	1.75	3.67
Boyne Estuary	Old Boyne	2.0	0		0.80	0.25	0.00	1.50	0.75	1.25	1.33
	Boyne Highway				0.00	0.25	0.00	0.25	0.00	0.00	0.00
Colosseum Inlet	Broadacres					0.40	3.00	7.75	2.00	3.50	2.67
	Iveragh					0.40	0.75	0.25	1.25	0.50	0.00
Rodds Bay	Oaky					2.60	3.00	3.25	2.50	3.00	1.00
	7 Mile					4.60	4.00	8.75	2.25	3.75	5.67
	Worthington					0.20	1.00	1.25	0.50	0.50	0.33
	Sandy Bridge					0.00	0.50	1.00	1.25	0.00	0.00

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

Zone	Site	11- 12	12- 13	13- 14	14- 15	15- 16	16- 17	17- 18	18- 19	19- 20	20- 21
The Narrows	Ramsay Crossing					2.40	5.50	2.25	1.00	1.75	0.33
	Mundurran Creek	11.0	4.33	2.50	4.00	4.60	7.25	3.75	2.00	1.50	5.67
	Black Swan				1.00	0.00	4.25	1.00	0.50	0.50	1.33
	Targinnie Creek	4.0	0.00		9.50	1.25	5.25	5.25	0.50	6.25	10.67
Graham Creek	Graham Creek				4.00	1.67	0.00	0.00	0.00	0.00	0.00
	Hobble Gully				0.25	0.50	0.00	0.50	0.00	0.50	0.67
Western Basin	Wiggins Island					0.00	0.75	0.50	0.00	6.25	7.00
Boat Creek	Boat Creek		0.00	1.25	1.07	0.25	0.00	1.00	0.75	0.00	0.33
Inner Harbour	Little Enfield Creek				1.40	0.25	1.00	0.25	0.50	2.25	1.33
	Barney Point Pond		0.25	0.00	0.40	0.00	0.00	0.25	0.00	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	2.33
	Old Bruce Highway Bridge				3.60	2.75	2.00	19.00	0.25	5.75	15.67
Auckland Inlet	Callemondah	3.6	1.43	2.60	5.00	4.00	8.75	5.00	3.75	7.50	3.00
Mid Harbour	Farmers Point					0.00	6.50	1.50	0.00	0.25	2.00
	Gatcombe Anchorage					0.40	0.00	1.00	0.00	1.50	0.67
South Trees Inlet	Wappentake Creek		0.57	0.67	0.60	0.50	0.75	2.50	1.25	0.50	0.67
	South Trees					3.78	3.75	2.75	3.25	2.50	1.67
	Crematorium Pool					10.00	30.75	8.75	4.00	3.50	7.67
Boyne Estuary	Old Boyne	8.0	6.00		7.00	8.50	10.50	5.00	2.50	3.75	7.67
	Boyne Highway				5.00	10.50	12.25	7.25	12.75	10.00	7.67
Colosseum Inlet	Broadacres					3.40	2.75	2.25	3.25	4.00	2.67
	Iveragh					4.60	5.00	2.00	4.50	4.75	7.00
Rodds Bay	Oaky					4.60	6.25	3.75	6.75	7.50	3.33
	7 Mile					3.00	4.75	1.50	4.25	1.75	8.67
	Worthington					2.20	3.50	2.00	1.75	5.00	3.33
	Sandy Bridge					9.40	17.00	4.50	6.75	2.00	4.33

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

Zone	Site	11- 12	12- 13	13- 14	14- 15	15- 16	16- 17	17- 18	18- 19	19- 20	20- 21
The Narrows	Ramsay Crossing					24.80	17.50	16.25	7.50	20.25	0.67
	Mundurran Creek	11.0	4.33	3.00	4.00	4.60	7.25	3.75	2.25	1.75	6.00
	Black Swan				7.25	0.25	23.50	6.50	5.75	8.75	8.33
	Targinnie Creek	4.0	0.00		9.50	1.25	5.75	6.75	0.50	11.25	13.33
Graham Creek	Graham Creek				7.00	2.33	2.00	6.00	0.00	15.00	9.33
	Hobble Gully				5.50	8.00	6.00	13.75	5.00	21.50	28.33
Western Basin	Wiggins Island					0.00	1.50	2.50	0.00	10.00	9.67
Boat Creek	Boat Creek		0.00	1.25	2.40	0.75	0.25	1.50	1.50	0.50	0.33
Inner Harbour	Little Enfield Creek				7.40	3.50	7.00	7.75	2.00	12.00	12.33
	Barney Point Pond		0.25	0.40	0.60	0.00	0.00	0.50	0.00	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	4.00
	Old Bruce Highway Bridge				3.60	5.25	11.25	22.00	3.25	10.25	19.33
Auckland Inlet	Callemondah	4.4	1.43	5.00	8.40	7.75	19.50	19.25	12.25	16.75	12.33
Mid Harbour	Farmers Point					0.00	6.50	2.25	0.00	0.25	2.00
	Gatcombe Anchorage					0.80	0.25	1.00	0.00	4.50	6.67
South Trees Inlet	Wappentake Creek		0.57	1.00	0.80	0.75	1.00	2.75	1.50	0.75	1.00
	South Trees					6.22	7.75	13.75	6.00	5.75	4.00
	Crematorium Pool					10.20	30.75	12.25	6.25	5.25	11.33
Boyne Estuary	Old Boyne	10.0	6.00		7.80	8.75	10.50	6.50	3.25	5.00	9.00
	Boyne Highway				5.00	10.75	12.25	7.50	12.75	10.00	7.67
Colosseum Inlet	Broadacres					3.80	5.75	10.00	5.25	7.50	5.33
	Iveragh					5.00	5.75	2.25	5.75	5.25	7.00
Rodds Bay	Oaky					7.20	9.25	7.00	9.25	10.50	4.33
	7 Mile					7.60	8.75	10.25	6.50	5.50	14.33
	Worthington					2.40	4.50	3.25	2.25	5.50	3.67
	Sandy Bridge					9.40	17.50	5.50	8.00	2.00	4.33

Figure 27 shows the total Bream CPUE per site for survey year 20-21 plotted against the same total Bream CPUE per site for survey year 19-20, partitioned into recording zones. Points above the diagonal line correspond to sites whose CPUE increased in 20-21 from what it was in 19-20, and points below the line to those for which CPUE decreased.

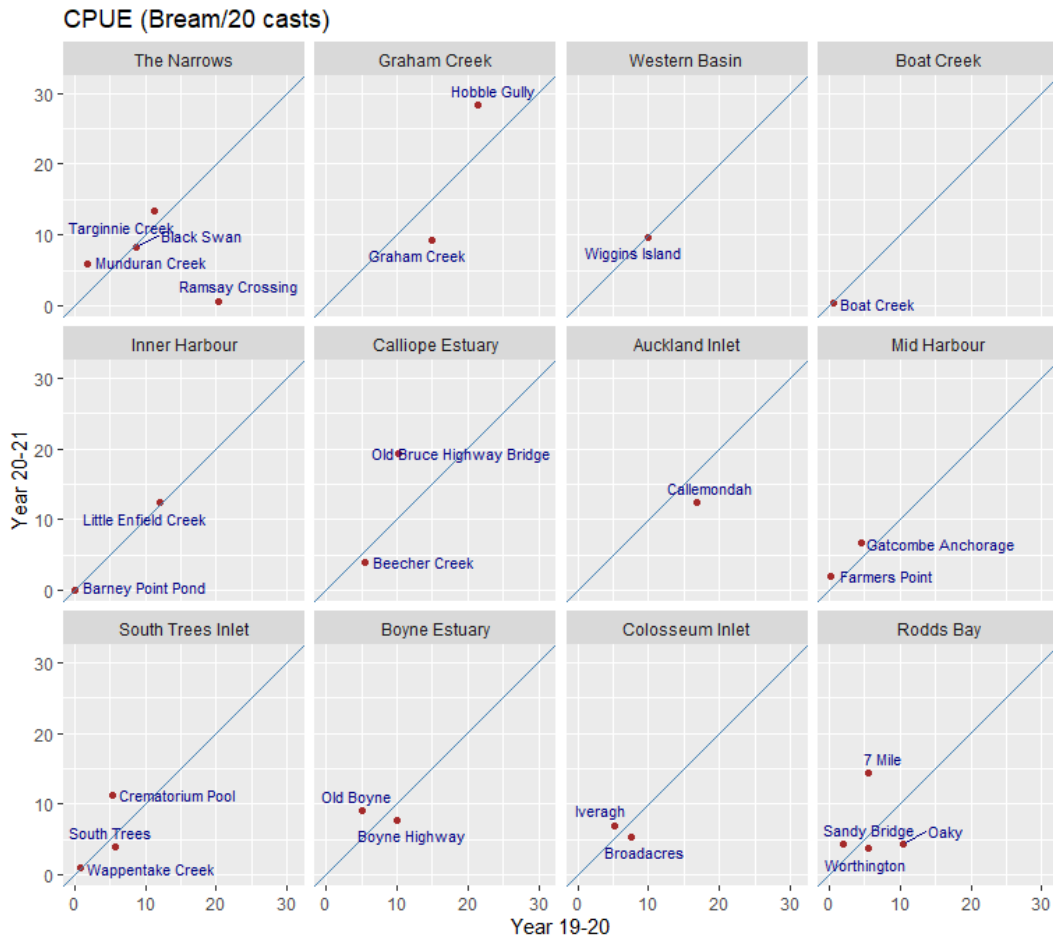


Figure 27: Bream CPUE for 20-21 against CPUE for 19-20 per site partitioned into recording zones.