Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2018

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Cover photographs: Top – Targinnie Creek site Bottom – Black Swan site

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SUMMARY

The requirements of this project were to:

1. Conduct a castnet sampling program based on the approved sampling design over the 2017-18 recruitment season.
2. Refine the data collection methods and statistical analytical methods developed in 2017 (if required).
3. Provide fish recruitment report card scores and grades for the 2018 report card.

The report is presented in 2 parts. Part 1 addresses the first objective and part of objective 2 (data collection methods). Part 2 addresses objectives 2-3.

There were no changes to the data collection methods from 2016-17 to 2017-18. There was a total of 104 surveys with 2,080 castnet casts in line with the standard survey methodology previously used. There was a slight change from 2015-16 when 103 surveys with 2,020 casts were made.

Standardised castnet surveys were undertaken monthly, around the time of the full moon, at 26 sites from Dec 2017-Mar 2018 covering the same timeframe as in previous years. The timing selected provided the maximum opportunity for recruits to distribute throughout each system. A survey involved 20 casts at each site covering the same area in each survey.

There was a total of 7,824 individuals recorded in the 104 surveys comprising 6,141 fish and 1,683 prawns. Most recorded species were Banana Prawn (21.5%), Flattail Mullet (21.3%) and Estuary Glassfish (12.2%). Pikey Bream were the 6th most caught (5.5%) and Yellowfin Bream were the 7th most caught (4.4%). Both Yellowfin and Pikey Bream were recorded at 25 of the 26 sites.

There was a total of 346 Yellowfin Bream and 429 Pikey Bream recorded. There was a total of 775 Bream (both species) in 2018 compared with 910 in 2017 and 519 in 2016.

For Yellowfin Bream there was an increase of 71.3% from 2016 to 2017 however there was a decrease of 39.7% from 2017 to 2018 bringing the total catch back to just greater than 2016. Yellowfin Bream were 64.5% of the Bream recorded in 2016 and 63.1% in 2017 however fell to 44.6% in 2018. This is the first year reporting the numbers of Pikey Bream exceeding the numbers of Yellowfin Bream.

There was a minor change in the analysis model in 2016-17 and that model was retained for 2017-18 to provide grades from A-E from scores on a 0,1 scale. All of harbour grade for 2017-18 was B which is the same grade as achieved in 2016-17. Auckland Inlet again scored A while there was an improvement in Graham Creek (2016-17 grade C-2017-18 grade B), Boat Creek (2016-17 grade D-2017-18 grade C), and Inner Harbour (2016-17 grade C-2017-18 grade B). There was a lowering of grade in The Narrows, Mid Harbour, Boyne Estuary, Colosseum Inlet and Rodds Bay which all went from B-C. All other Zones were the same grade as last year.

In previous years the Yellowfin/Pikey Bream catch ratio has been relatively stable overall however this year the balance has tipped towards Pikey and away from Yellowfin. The reasons for this switch are unknown however some information is presented in the discussion that may be relevant.

PART 1: DATA COLLECTION
1. INTRODUCTION

Building on the 2016 report card, the Gladstone Harbour Report Card 2017 has been informed by 99 measures of the four components of harbour health: environmental, social, cultural and economic.

The 2017 report card is based on data collected during the period from July 2016 to June 2017. As GHHP continues to expand and refine its monitoring programs, additional measures will become available. *Figure 1* shows the results of the 2017 Report Card and *figure 2* shows the Environmental Grades of Harbour Zones.[1]

The environmental grades of Harbour Zones are based on 3 indicator groups:

- Water and sediment quality
- Habitats
- Fish and crabs

GHHP determined that recruitment of key fish species is an appropriate fish indicator. To assist with the development of a fish recruitment indicator in 2015 it was decided to undertake an assessment of fish recruitment in the Gladstone area. The results of that assessment were in the report "Developing a fish recruitment indicator for the pilot Gladstone Healthy Harbour Report Card in 2015" (Sawynok et al 2015). Based on that assessment it was decided that recruitment of Yellowfin and Pikey Bream be used for the development of the fish indicator.

Recruitment surveys were undertaken in 2016-17 and the results were provided in the report "Developing a fish recruitment indicator for the Gladstone Harbour Report Card using data derived from castnet sampling 2017" (Sawynok and Venables 2017).

Figure 1: Indicators used in the 2017 Gladstone Harbour Health Report Card

[1] From http://ghhp.org.au/report-cards/2015

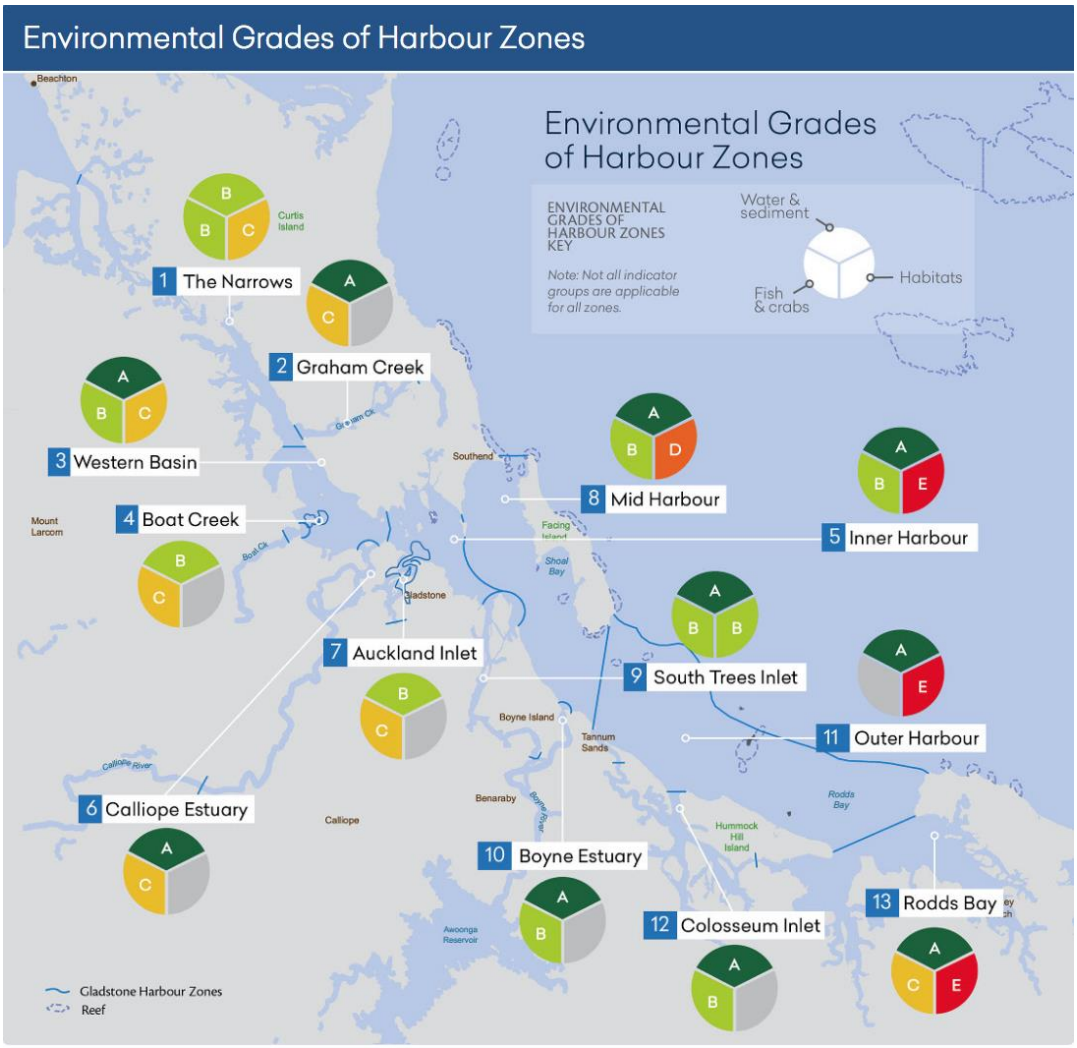

Figure 2: Environmental Grades of Harbour Zones 2017

2. OBJECTIVES

The requirements of this project were to:

1. Conduct a castnet sampling program based on the approved sampling design over the 2017-18 recruitment season.
2. Refine the data collection methods and statistical analytical methods developed in 2017 (if required).
3. Provide fish recruitment report card scores and grades for the 2018 report card.

3. GLADSTONE HARBOUR ZONES

The Gladstone Harbour has been divided into 13 reporting zones for the GHHP Report Card as shown in *figure 3*. The area includes Gladstone Harbour, Calliope River, Boyne River, the Narrows, Outer Harbour and Rodds Bay.

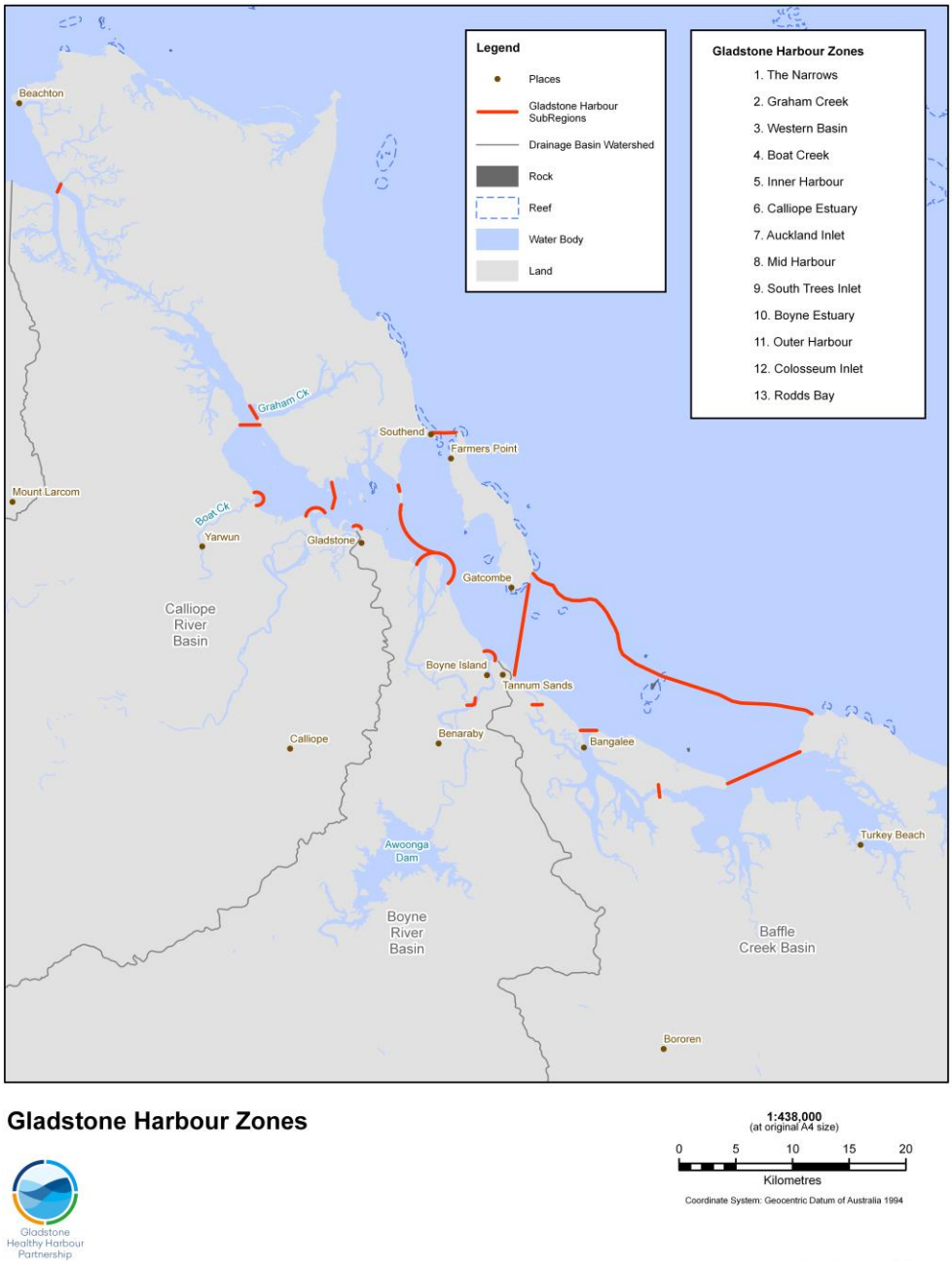

Figure 3: Gladstone reporting zones for the GHHP Report Card (from 2014 GHHP Technical Report at www.ghhp.org/publications)

The 13 Gladstone Harbour 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. METHODS

SPECIES SELECTION

1. Based on the trial recruitment surveys in 2015 Yellowfin Bream and Pikey Bream were selected as the key species.

SITE SELECTION

2. Bream recruits generally use all parts of the estuary to the top end of the tidal limit and into the freshwater reaches on occasions when conditions allow.
3. At least one site was selected in each sub-region.
4. In each reporting zone, where possible, one site was selected towards the upper tidal limit and another within the area of daily tidal influence.
5. Existing sites were used where possible to allow for comparison with historically collected data.
6. Sites were located to cover all key areas of the zones.
7. Details of sites are stored in the Infofish 2017 database. Details include site ID, Suntag map and grid, latitude, longitude, text description, type of sub-strata, vegetation, site photographs and Google Earth image of site. Site details are provided in Appendix 1.

TIMING OF SURVEYS

8. Bream spawn during the winter months however the location of spawning sites is uncertain in Gladstone Harbour. By Oct recruits are generally in the size range 30-40mm and able to be caught in a castnet.
9. Standardised surveys were undertaken at selected sites each month between Dec 2017 and Mar 2018.
10. Timing of surveys was generally around the largest spring tides as that was mostly when recruits access nursery habitat, particularly at the upper tidal reaches. Surveys were generally completed over a 2-3 week timeframe by 3 surveyors.

DEFINING BREAM RECRUITS

11. Both Yellowfin and Pikey Bream spawn at the mouths of rivers and nearshore locations (Pollock 1982a) from May-Aug (Pollock 1982b) and then recruits make their way to all parts of the estuary.
12. Yellowfin Bream are from 130-150mm after 1 year (Brown 2007, Pollock 2011, Cowden 1995). No data on growth patterns are available for Pikey Bream however is it expected that growth rates are similar to those of Yellowfin Bream and reaching a similar size after 1 year. Recruits during the survey period were fish from 0-100mm.

SURVEY METHODS

14. Survey apparatus used was a castnet. This is the same apparatus as used in previous Infofish recruitment surveys and ensured a standardised approach so that the results were comparable with other surveys. A standard castnet was a monofilament net with a drop of 2.4m, a mesh size of 20mm and a spread of 3.6m+. Photographs of the survey equipment in use were taken (*figure 4*).
15. Infofish has a current permit to undertake surveys using a castnet. Permit number is 187865 and is current to 31/8/2021.
16. The standard number of casts was 20 at all sites with 4 visits to each site.
17. Details of the number of casts and all fish including species, date, location and length (key species only) were recorded in a waterproof field record book for later transfers to a standard excel spreadsheet (Infofish 2016 trip sheet). The length of the fish was recorded to the nearest mm. For fork tailed fish the fork length was measured. For round tailed fish the total length was recorded.

Figure 4: Castnet method used for the recruitment surveys

MAXIMISING SURVIVAL OF FISH CAUGHT

18. To maximise the survival of fish on release, for casts where a small number of fish were caught these were removed quickly from the net, measured and then released. For casts where a large number of fish were caught the net was left in the water while the fish were removed.
19. Some species are hardier than others so fish that were more susceptible to mortality were removed first (eg Bony Bream). These steps maximised the survival of released fish however some mortality did occur.
20. Surveys were not undertaken when the water temperature was above 32^{o}C as survival decreases rapidly when this temperature is exceeded.

TAGGING OF FISH

21. Bream and other key species over 150mm were tagged using standard 30mm or 45mm Hallprint gun tags (*figure 5*).

Figure 5: Bream recruits from Hobble Gully

DATA MANAGEMENT

22. Data on the recruitment sites and from the recruitment surveys are stored in the Infofish 2016 online database located at http://qld.info-fish.net/infofish/. Data are also available in the GHHP DIMS system.
23. Data from the standard Microsoft Excel spreadsheet was validated by visual examination and cross checking prior to being uploaded to the database. This included spelling mistakes and any inconsistencies in fish lengths.

DATA ANALYSIS

24. This report provides a summary of the data collected. For each site the number of surveys, number of casts, total individuals in the catch and the number of Yellowfin and Pikey Bream were recorded.
25. Catch rates were calculated for each site and for each month of surveys and for fish and prawn. Data were standardised on individuals/cast.
26. Percentage of fish and prawn in the monthly surveys was calculated.
27. The number of Yellowfin and Pikey Bream surveyed in each zone was calculated.

STATISTICAL ANALYSIS

28. Statistical analysis was carried out by Stefan Sawynok and Dr Bill Venables and is appended to this report.

FISH HEALTH

29. Fish health issues were recorded during recruitment surveys however there is separate project dealing with fish health.

5. SITE LOCATIONS

The Gladstone Harbour was subdivided into 13 reporting zones and each zone was assessed for suitable sites where Bream recruits were likely to be found and where castnet surveys could be undertaken. The Outer Harbour (zone 11) was not considered to have any suitable habitat that Bream recruits were likely to use other than for transit to more suitable locations. No sites were surveyed in this zone.

For the remaining 12 zones, based on the criteria for site selection there were a total of 26 sites selected in 2015-16 where castnet surveys were undertaken (Sawynok and Venables 2016). There was at least 1 site in each zone. Existing sites were used to provide continuity with data previously collected. In 2016-17, surveys were carried out at 25 existing sites and 1 new site. The new site was Graham Creek 2 (site ID 99) which replaced Graham Creek (site ID 60). There were access difficulties for the Graham Creek site and not all surveys in 2015-16 were able to be completed.

Figure 6 shows the locations of sites with details of the sites contained in Appendix 1. Sites in sub-regions are shown in *Table 1*.

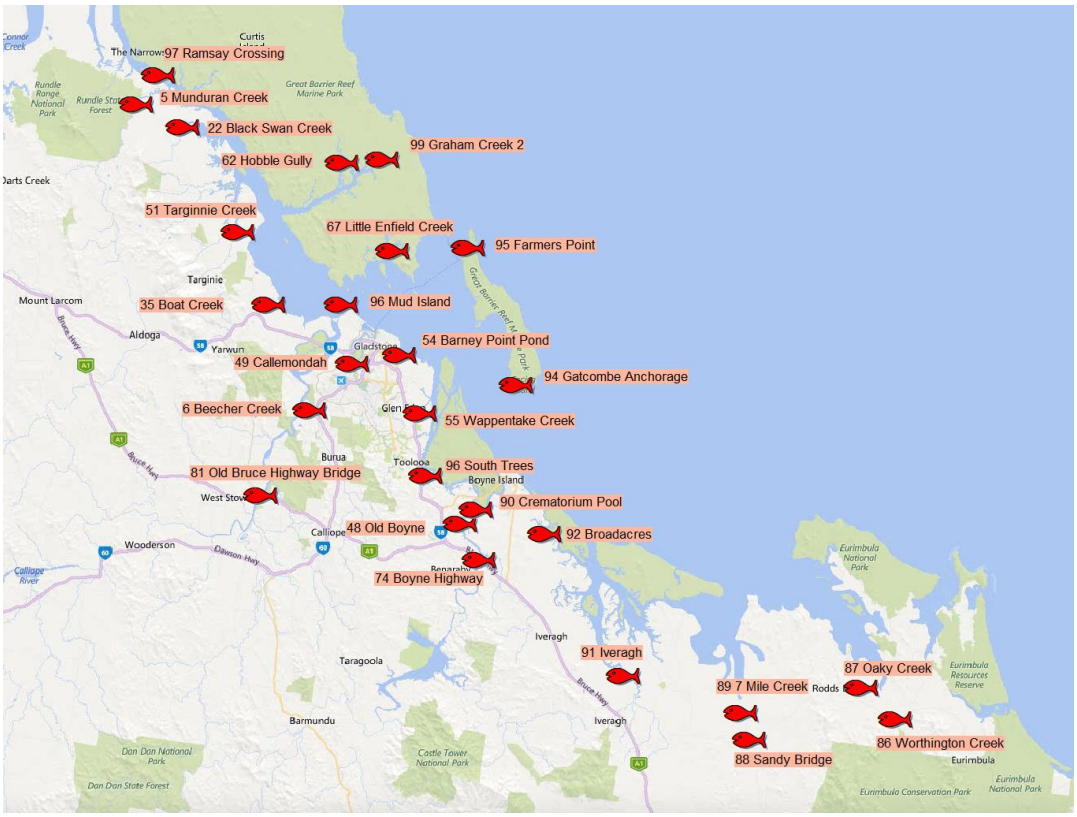

Figure 6: Site locations and site ID in the Gladstone area for Bream recruitment surveys

6. RESULTS

6.1 SUMMARY OF 2018 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:

- 11-23 Dec 2017
- 2-22 Jan 2018
- 6-23 Feb 2018
- 3-22 Mar 2018

Table 1 provides a summary of surveys at all sites from Dec 2017-Mar 2018. There were 104 surveys with 2,080 casts resulting in a catch of 7,824 individuals. A total of 623 casts (30.0%) resulted in a nil catch. The percentage of nil casts was 27.8% in 2017 and 2016.

Table 1: Summary of surveys undertaken from Dec 2017-Mar 2018

ZONE	SITE ID	SITE	SURVEYS	CASTS	CATCH	CATCH RATE
1	97	RAMSAY CROSSING	4	80	908	11.4
1	5	MUNDURAN CREEK	4	80	112	1.4
1	22	BLACK SWAN	4	80	108	1.4
1	51	TARGINNIE CREEK	4	80	107	1.3
2	62	HOBBLE GULLY	4	80	598	7.5
2	99	GRAHAM CREEK 2	4	80	292	3.7
3	96	MUD ISLAND	4	80	186	2.3
4	35	BOAT CREEK	4	80	249	3.1
5	67	LITTLE ENFIELD CREEK	4	80	345	4.3
5	54	BARNEY POINT POND	4	80	131	1.6
6	6	BEECHER CREEK	4	80	67	0.8
6	81	OLD BRUCE HWY BRIDGE	4	80	653	8.2
7	49	CALLEMONDAH	4	80	509	6.4
8	95	FARMERS POINT	4	80	147	1.8
8	94	GATCOMBE ANCHORAGE	4	80	197	2.5
9	55	WAPPENTAKE CREEK	4	80	91	1.1
9	76	SOUTH TREES	4	80	651	8.1
9	90	CREMATORIUM POOL	4	80	231	2.9
10	48	OLD BOYNE	4	80	260	3.3
10	74	BOYNE HIGHWAY	4	80	185	2.3
11	OUTER HARBOUR NO SITES					
12	92	BROADACRES	4	80	363	4.5
12	91	IVERAGH	4	80	229	2.9
13	89	7 MILE CREEK	4	80	252	3.2
13	88	SANDY BRIDGE	4	80	338	4.2
13	87	OAKY CREEK	4	80	389	4.9
13	86	WORTHINGTON CREEK	4	80	226	2.8
		TOTAL	104	2080	7824	3.8

Catch rates varied considerably between sites as shown in *table 1* and *figure 7*. The highest catch rate was at Ramsay Crossing at 11.4 individuals/cast followed by Old Bruce Highway Bridge at 8.2 and then South Trees at 8.1 individuals/cast. Lowest catch rates were recorded at Beecher Creek at 0.8 individuals/cast, Wappentake Creek at 1.1 individuals/cast and Targinnie Creek at 1.3 individuals/cast.

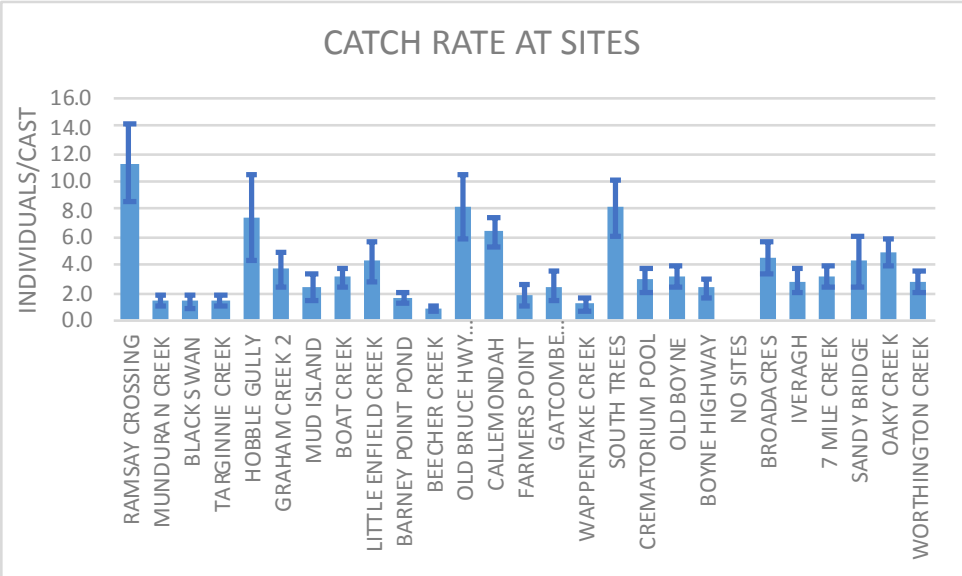

Figure 7: Catch rate at each site (mean with bars showing 95% confidence interval)

Banana Prawn (21.5%), Flattail Mullet (21.3%) and Estuary Glassfish (12.2%) were the most caught species. Pikey Bream were the 6th most caught (5.5%) and Yellowfin Bream were the 7th most caught (4.4%) as shown in *figure 8*. A list of all species including scientific names is shown in Appendix 2.

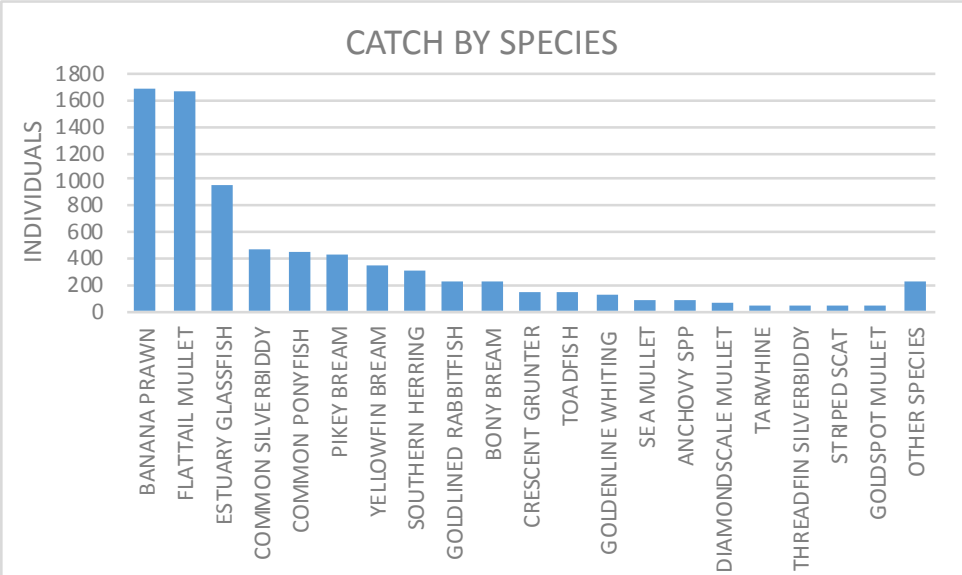

Figure 8: Percentage of individuals (fish and prawn) recorded across all sites from Dec 2017-Mar 2018

Flattail Mullet were recorded at all 26 sites, Yellowfin Bream at 25 sites and Pikey Bream also at 25 sites. *Figure 9* shows sites where the top 20 species were recorded. A full list of sites where each species were recorded is shown in Appendix 2.

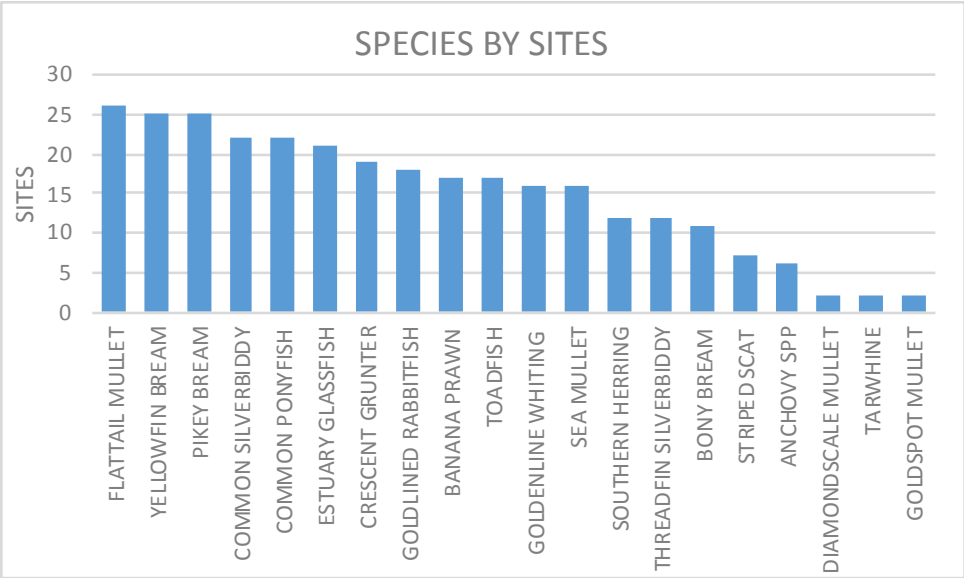

Figure 9: Mean catch rate all sites on monthly surveys from Dec 2017-Mar 2018

Surveys were undertaken over a 4 month period from Dec 2017-Mar 2018 so that comparisons could be made over time. *Figure 10* shows the number of individuals (fish and prawn) recorded at all sites each month. The highest number of individuals was recorded in Mar with 2,358 (1,744 fish and 614 prawn) while the lowest was recorded in Feb with 1,553 (1,330 fish and 223 prawn).

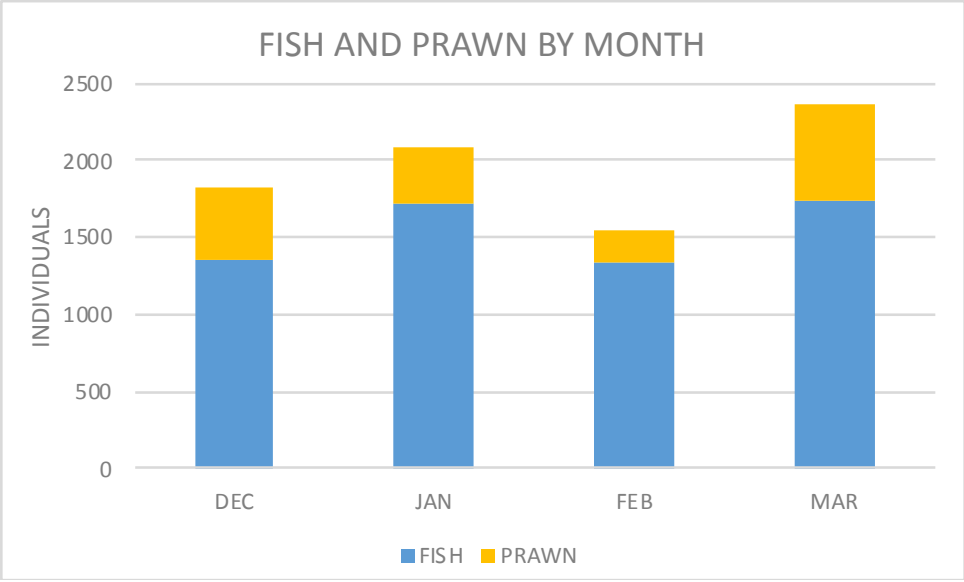

Figure 10: Numbers of individuals recorded at all sites on monthly surveys from Dec 2017-Mar 2018

Figure 11 shows the percentage of fish and prawn in the catch each month. Prawn catch rate was highest in Dec and Mar at 26.0% and was lowest in Feb at 14.4%.

The mean individuals/cast ranged from a low of 3.1 in Feb to a high of 4.5 in Mar. *Figure 12* shows the mean catch rate with bars representing the 95% confidence interval from each month's surveys.

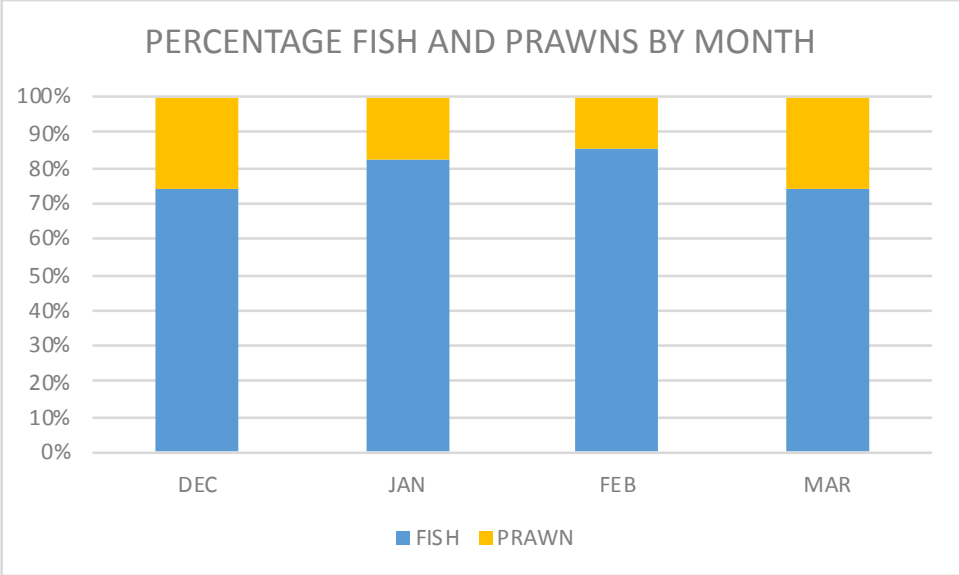

Figure 11: Percentage of fish and prawn in the catch across all sites on monthly surveys from Dec 2017-Mar 2018

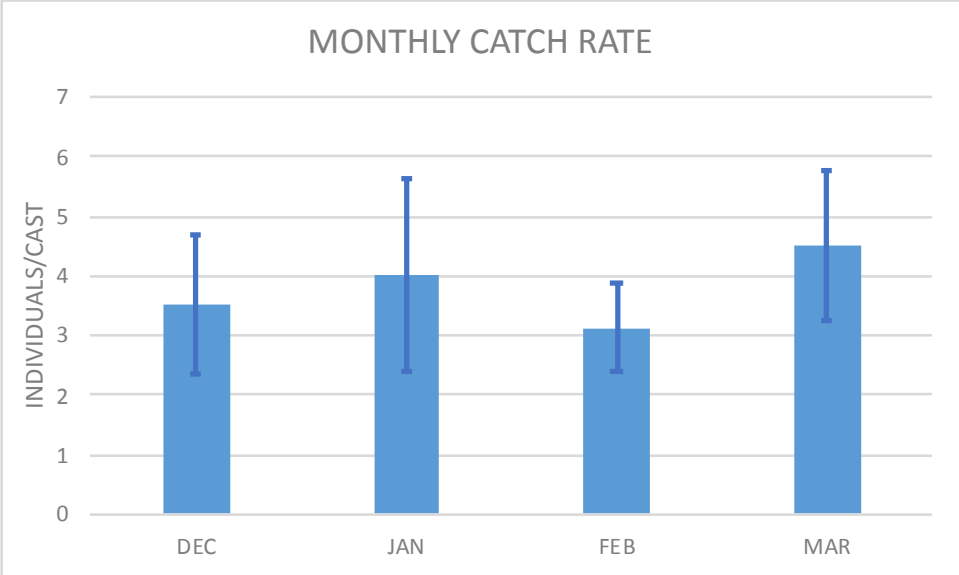

Figure 12: Catch rate for fish and prawn at all sites on monthly surveys from Dec 2017-Mar 2018 (bars show 95% confidence interval)

6.2 BREAM IN 2018

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 report card. *Table 2* shows the number of Bream recorded at each site in surveys from Dec 2017-Mar 2018.

Table 2: Bream recorded at each site in surveys from Dec 2017-Mar 2018

ZONE	SITE ID	SITE	SURVEYS	CASTS	YELLOW FIN BREAM	PIKEY BREAM
1	97	RAMSAY CROSSING	4	80	9	56
1	5	MUNDURAN CREEK	4	80	15	0
1	22	BLACK SWAN	4	80	4	22
1	51	TARGINNIE CREEK	4	80	21	6
2	62	HOBBLE GULLY	4	80	2	53
2	99	GRAHAM CREEK 2	4	80	0	24
3	96	MUD ISLAND	4	80	2	8
4	35	BOAT CREEK	4	80	4	2
5	67	LITTLE ENFIELD CREEK	4	80	1	30
5	54	BARNEY POINT POND	4	80	1	1
6	6	BEECHER CREEK	4	80	12	2
6	81	OLD BRUCE HWY BRIDGE	4	80	76	12
7	49	CALLEMONDAH	4	80	20	57
8	95	FARMERS POINT	4	80	6	3
8	94	GATCOMBE ANCHORAGE	4	80	4	1
9	55	WAPPENTAKE CREEK	4	80	10	1
9	76	SOUTH TREES	4	80	11	44
9	90	CREMATORIUM POOL	4	80	35	14
10	48	OLD BOYNE	4	80	20	6
10	74	BOYNE HIGHWAY	4	80	29	1
11	OUTER HARBOUR NO SITES					
12	92	BROADACRES	4	80	9	31
12	91	IVERAGH	4	80	8	1
13	89	7 MILE CREEK	4	80	6	35
13	88	SANDY BRIDGE	4	80	18	2
13	87	OAKY CREEK	4	80	15	4
13	86	WORTHINGTON CREEK	4	80	8	13
		TOTAL	104	2080	346	429

Figure 13 shows the sites where Bream were recorded. Yellowfin Bream were recorded at 25 (96.2%) of the 26 sites. The only site where Yellowfin Bream were not recorded was Graham Creek 2. Pikey Bream were also recorded at 25 (96.2%) sites. The only site where Pikey Bream were not recorded was Munduran Creek. There were no sites surveyed in sub-region 11 (Outer Harbour) as there was no habitat suitable for juvenile Bream in that sub-region.

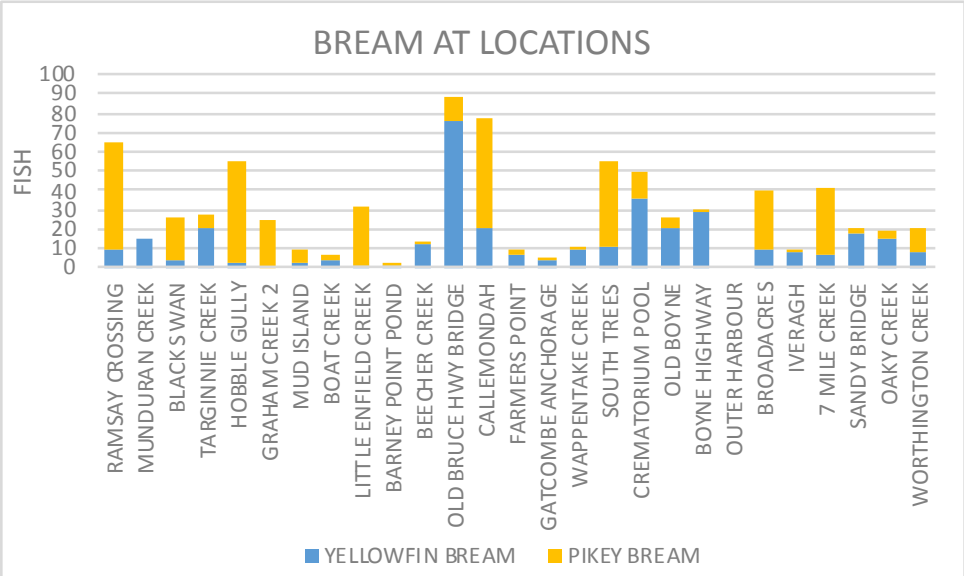

Figure 13: Numbers of Yellowfin and Pikey Bream recorded at each site in surveys from Dec 2017-Mar 2018 (no sites Outer Harbour)

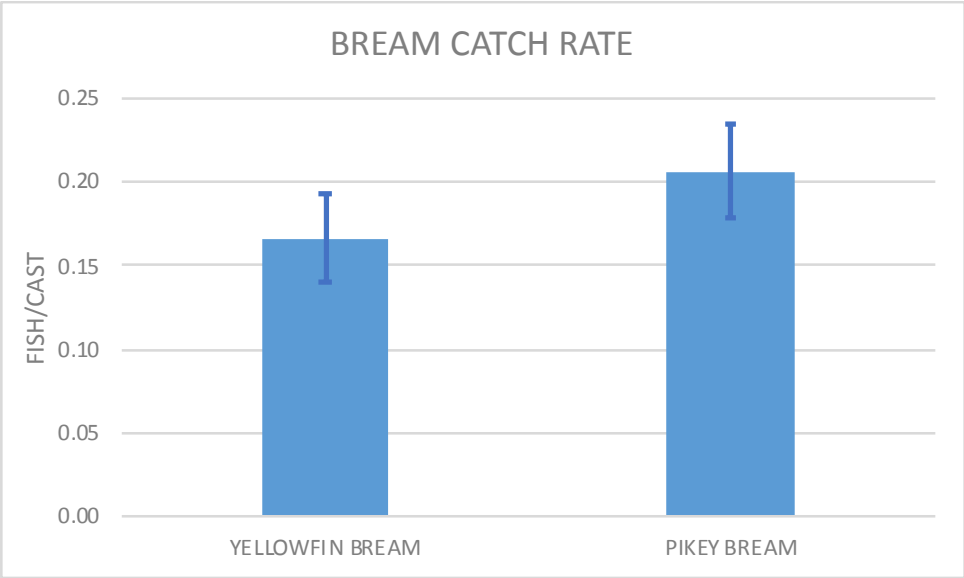

Figure 14: Mean catch rates with 95% confidence intervals for each Bream species from monthly surveys

There was a total of 346 Yellowfin Bream and 429 Pikey Bream recorded. Over the whole survey period from Dec 2017-Mar 2018 the mean catch rate for Yellowfin Bream was 0.17 fish/cast and for Pikey Bream was 0.21 fish/cast as shown in *figure 14*.

Figure 15 shows the numbers of Yellowfin and Pikey Bream recorded during the monthly surveys from Dec 2017-Mar 2018. The greatest number of Yellowfin Bream was 127 recorded in Dec while the least number was 53 in Feb. The greatest number of Pikey Bream was 133 recorded in Jan while the least number was 76 recorded in Mar.

Figure 16 shows the catch rate for each Bream species for each monthly survey. 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.

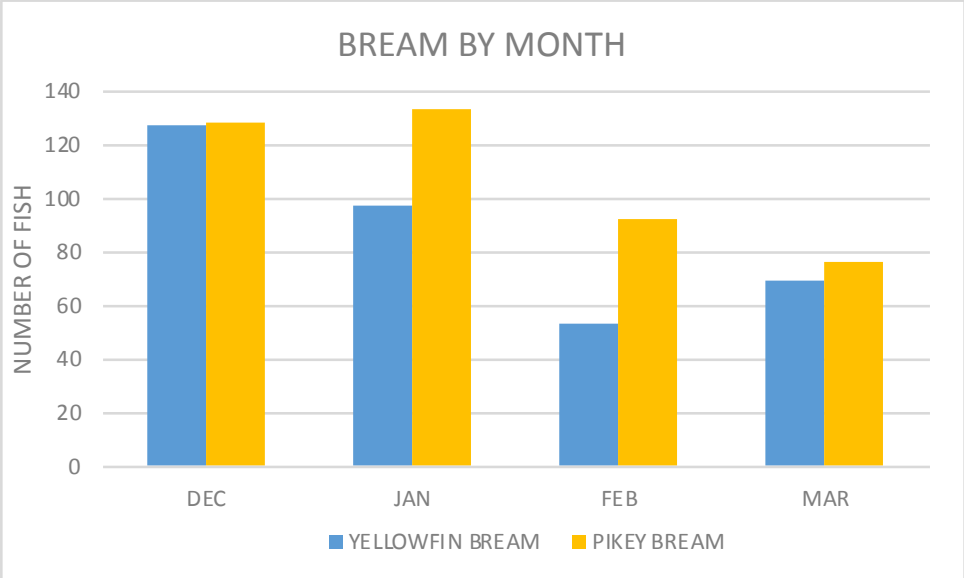

Figure 15: Numbers of Bream recorded during monthly surveys from Dec 2017-Mar 2018

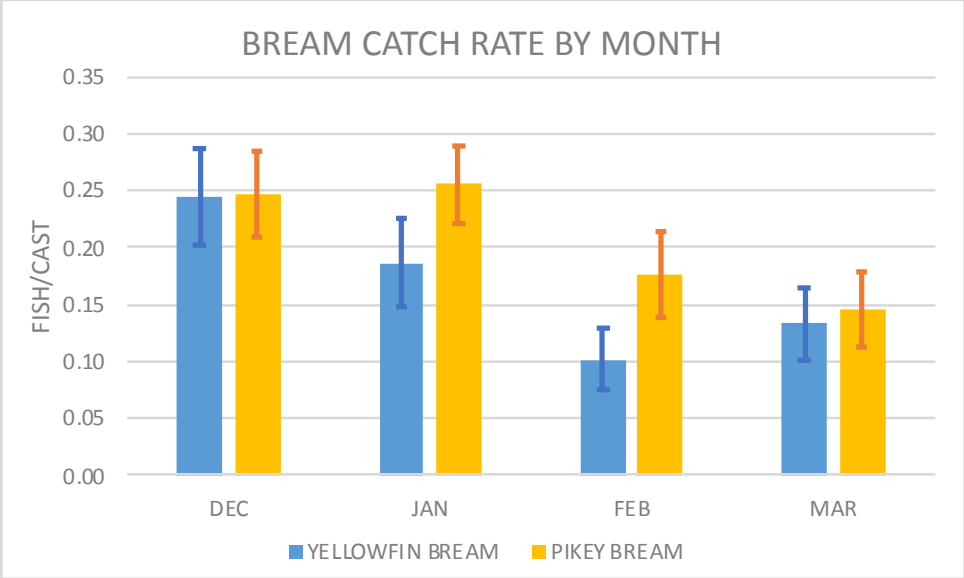

Figure 16: Mean catch rates with 95% confidence intervals for each Bream species for each of the monthly surveys

Figure 17 shows the timeline of the surveys showing fork length (mm) of Bream recorded during the monthly surveys.

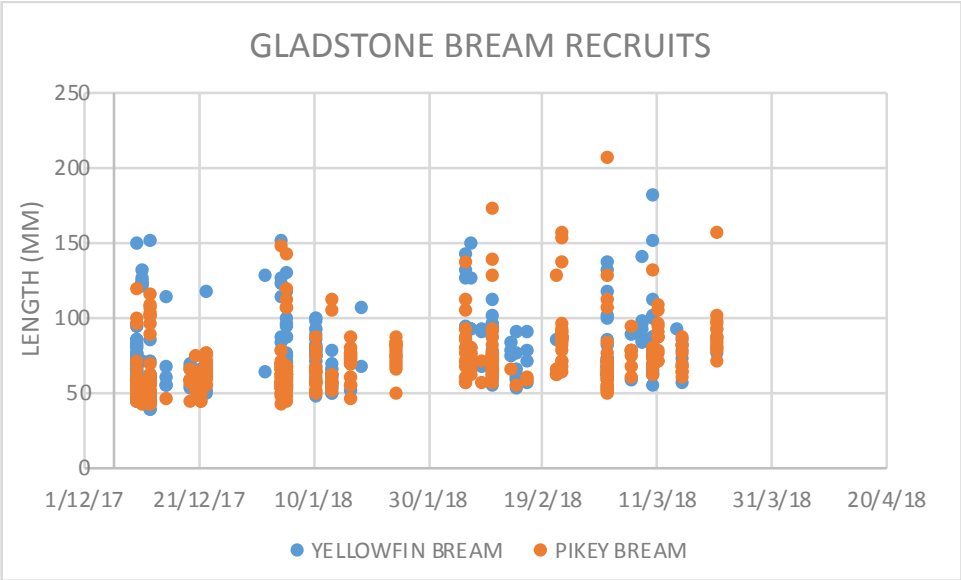

Figure 17: Timelines and fork lengths (mm) of Bream recorded during surveys

Figures 18 shows a typical Pikey Bream being measured while *figure 19* shows the sizes of Bream recorded in each of the monthly surveys. The smallest Yellowfin Bream recorded were 2 fish of 37mm (fork length) at Worthington Creek. The smallest Pikey Bream recorded were 4 fish of 40mm at Ramsay Crossing, South Trees and Broadacres.

Figure 18: Typical Pikey Bream being measured

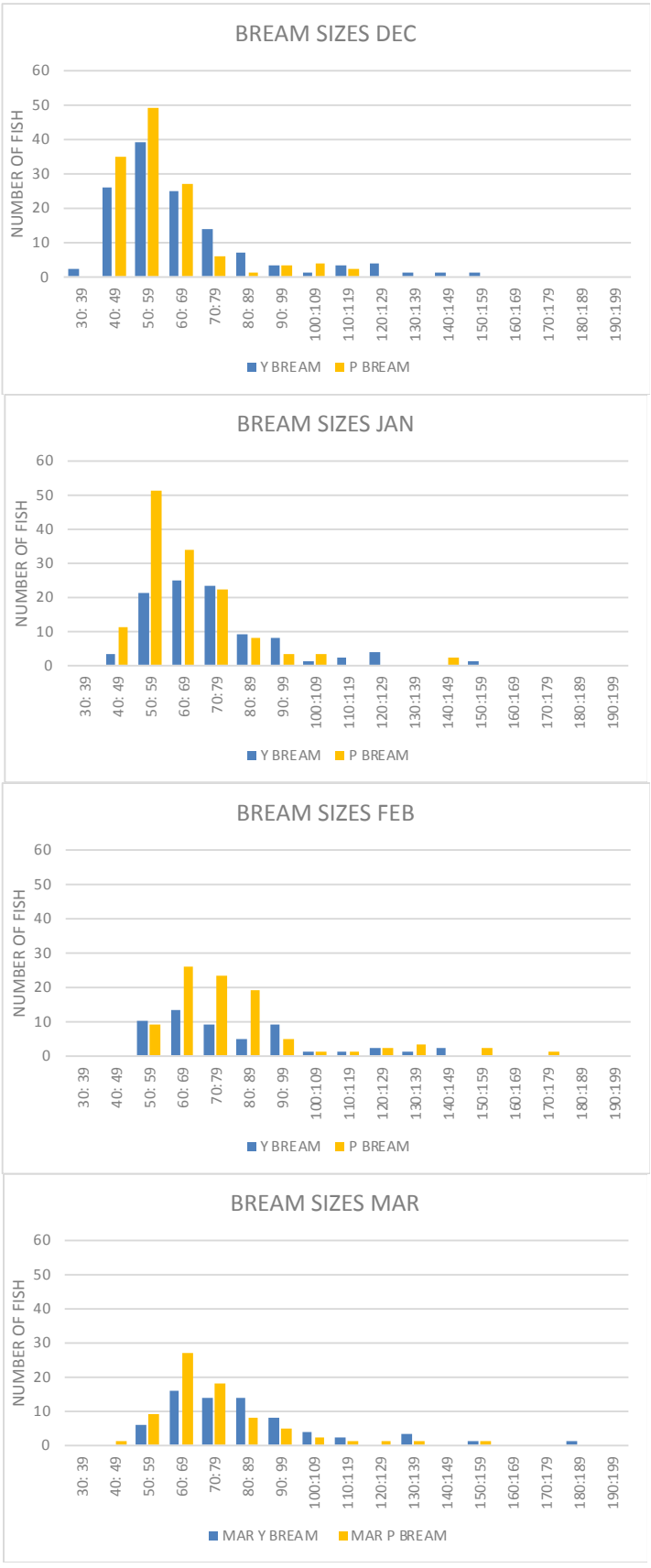

Figure 19: Bream fork lengths (mm) from Dec 2017-Mar 2018 surveys

7. COMPARING RESULTS FROM 2016-2018

Table 3 provides a summary of the surveys and catch from 2016-2018. In 2017 and 2018 there were 104 surveys with 2,080 casts while in 2016 there were 103 surveys with 2,020 casts, 60 less than in the last 2 years. The figures (*) for 2016 were adjusted to 104 surveys with 2,080 casts to make the 3 years comparable.

The previous year shows the percentage of the total fish and prawn recorded each year compared with the previous year. For 2017 the total fish and prawn were down 0.4% compared with the 2016 adjusted total. For 2018 the total fish and prawn were down 11.4% compared with 2017. *Figure 20* shows the total catch of fish and prawn for the 3 years with the percentage change to the previous year and the percentage of prawn in the catch.

The percentage of prawn in the catch has remained fairly stable ranging from 21.5% in 2018 to 23.8% in 2017.

Table 3: Summary of surveys of fish and prawn recorded from 2016-2018

YEAR	SURVEYS	CASTS	FISH	PRAWN	TOTAL FISH AND PRAWN	FISH PREVIOUS YEAR	PRAWN PERCENT OF TOTAL CATCH
2018	104	2080	6142	1682	7824	-11.4%	21.5%
2017	104	2080	6774	2102	8876	*-0.4%*	23.8%
2016	103	2020	6786	1867	8653		21.6%
2016*	*104*	*2080*	*6988*	*1922*	*8910*		

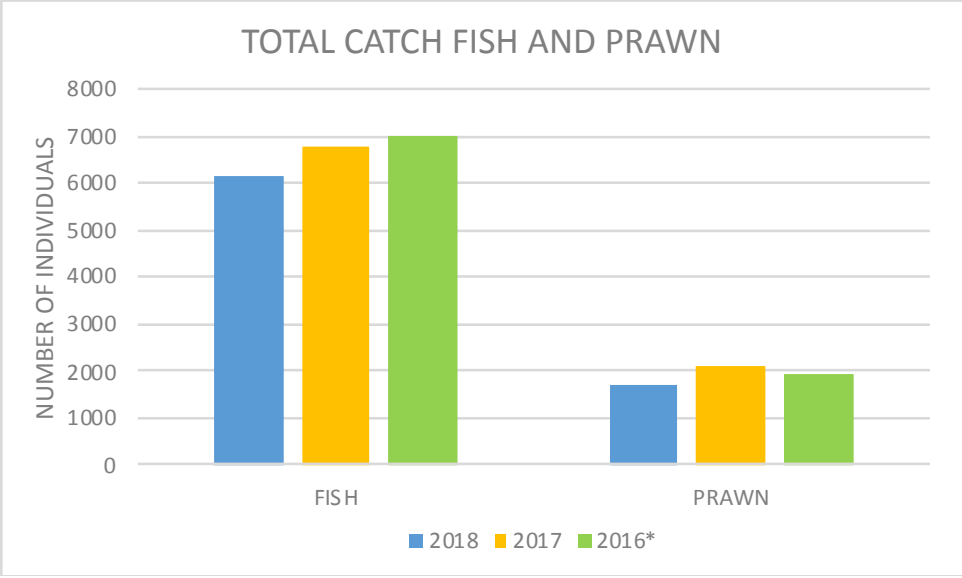

Figure 20: Comparison of total catch from 2016*-2018

Table 4 provides a summary of the surveys and Bream catch from 2016-2018. There was a total of 775 Bream (both species) in 2018 compared with 910 in 2017 and 519 in 2016*. Yellowfin Bream were 44.8% of the Bream catch in 2018 while they were 63.1% in 2017 and 64.5% in 2016. *Figure 21* shows the numbers of Bream in each year's surveys with the percentage change to the previous year and the percentage of Yellowfin Bream in the catch.

Table 4: Summary of surveys and the Bream catch from 2016-2018

YEAR	SURVEYS	CASTS	Y'FIN	PIKEY	TOTAL BREAM	BREAM COMPARED TO PREVIOUS YEAR	Y'FIN PERCENT BREAM TOTAL
2018	104	2080	346	429	775	-14.8%	44.6%
2017	104	2080	574	336	910	*+75.3%*	63.1%
2016	103	2020	325	179	504		64.5%
2016*	*104*	*2080*	*335*	*184*	*519*		

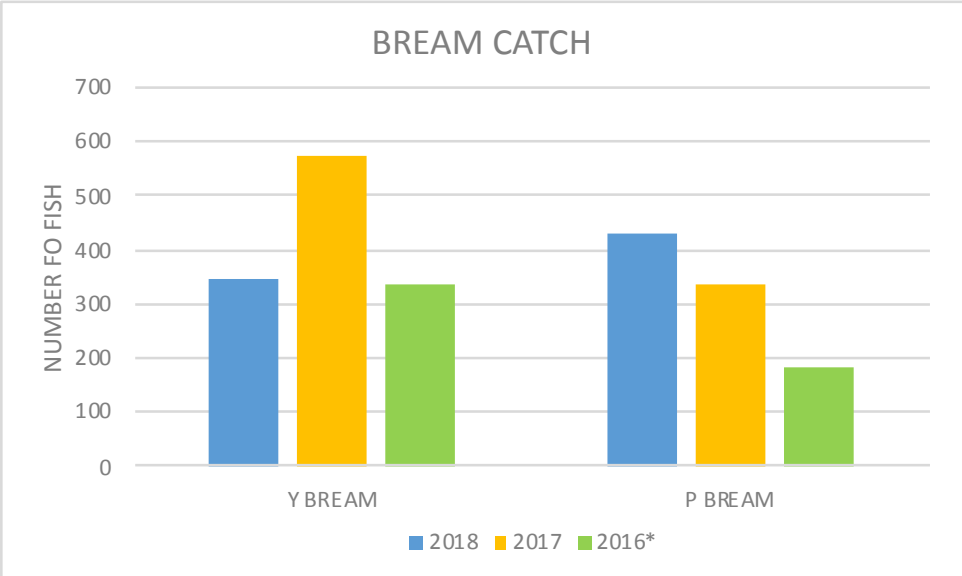

Figure 21: Comparison of Bream catch from 2016*-2018

While the total number of Bream for 2018 was down by 14.8% there was a considerable change in the proportion of each species. The numbers of Pikey Bream have increased over the 3 years with a 133.2% increase from 2016* to 2018.

For Yellowfin Bream there was an increase of 71.3% from 2016* to 2017 however there was a decrease of 39.7% from 2017 to 2018 bringing the number to just greater than for 2016*. Yellowfin Bream were 64.5% of the Bream recorded in 2016 and 63.1% in 2017 however fell to 44.6% in 2018. This is the first year where the numbers of Pikey Bream have exceeded the numbers of Yellowfin Bream.

Figure 22 shows the Bream recruits recorded each year and the total rainfall (mm) recorded at the Gladstone Radar station 039123.

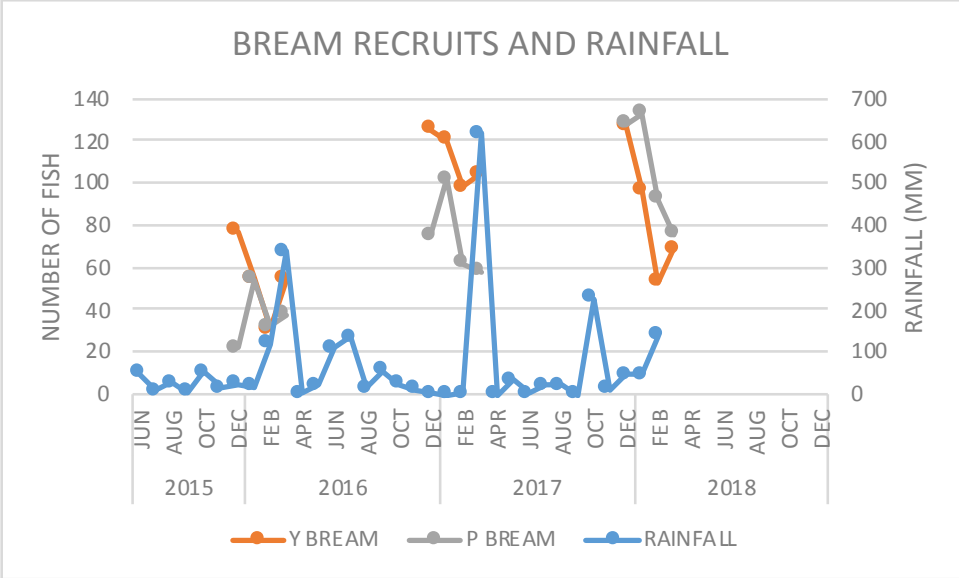

Figure 22: Bream recruits from 2016-2018 and rainfall from Jun 2015

8. OTHER SPECIES

There were 12 other species of recreational, commercial, indigenous or conservation importance that were recorded during recruitment surveys as shown in *table 5*. Of those species Flattail Mullet were recorded at all 26 sites, Banana Prawn at 17 sites and Goldenline Whiting at 16 sites. Banana Prawn and Flattail Mullet were the most recorded of those species. A complete list of all species is contained in Appendix 2.

Table 5: Other species of recreational, commercial, indigenous or conservation importance

SPECIES	SITES	NUMBER
PRAWN - BANANA	17	1682
MULLET- FLATTAIL	26	1665
WHITING – GOLDENLINE	16	120
MULLET – SEA	16	82
FLATHEAD – BARTAIL	7	26
JAVELIN – BARRED	8	25
MANGROVE JACK	8	20
FLATHEAD – DUSKY	9	13
CRAB – MUD	4	10
WHITING - SAND	3	8
THREADFIN – KING	2	4
BARRAMUNDI	1	1

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APPENDIX 1 – SURVEY SITES

A summary of sites and site details, as stored in the Infofish 2016 database, along with a more detailed description of the habitat. Details of each site as stored in the database are included in this appendix.

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	Q33
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	96	MUD ISLAND	-23.815	151.22	GLD	BZ10
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	I8
6	81	OLD BRUCE HIGHWAY BRIDGE	-23.964	151.154	CR02	P4
7	49	CALLEMONDAH	-23.862	151.232	GLD	D11
8	95	FARMERS POINT	-23.774	151.33	GLD	FZ21
8	94	GATCOMBE ANCHORAGE	-23.876	151.365	GLD	F25
9	55	WAPPENTAKE CREEK	-23.89	151.282	BRG	H16
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	H18
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	AD21

SITE DETAILS – RAMSAY CROSSING

Site Id:	97
Site Name:	RAMSAY CROSSING
Waterway:	NARROWS
Sub-Region:	1
Map:	CIS
Grid:	S31
Lat:	-23.641
Long:	151.066
Tidal Influence:	Tidal
Depth:	1
Access:	Land
Distance to Mouth:	11
Substrate:	☐ Sand ☑ Mud ☑ Gravel ☑ Rock
Description	ADJACENT TO NORTHERN RAMSAY CROSSING BOAT RAMP/SURVEY AROUND LOW TIDE
Vegetation	MANGROVES
Image:	 Image
Second Image:	 Image

SITE DETAILS – MUNDURAN CREEK

Site Id:	5
Site Name:	MUNDURAN CREEK
Waterway:	MUNDURAN CREEK
Sub-Region:	1
Map:	CISG
Grid:	Q33
Lat:	-23.658
Long:	151.048
Tidal Influence:	Intermittent Tidal
Depth:	1
Access:	Land
Distance to Mouth:	16
Substrate:	☐ Sand ☐ Mud ☑ Gravel ☑ Rock
Description	POOL AT TOP END OF TIDAL LIMIT OF MUNDURAN CREEK/ACCESS BY NARROWS ROAD
Vegetation	SMALL SCATTERED MANGROVES WITH MIXED FOREST ON BANKS
Image:	 Image
Second Image:	 Image

SITE DETAILS – BLACK SWAN

Site Id:	22
Site Name:	BLACK SWAN
Waterway:	BLACK SWAN CREEK
Sub-Region:	1
Map:	CISG
Grid:	V35
Lat:	-23.679
Long:	151.089
Tidal Influence:	Intermittent Tidal
Depth:	1
Access:	Water
Distance to Mouth:	14
Substrate:	☑ Sand ☑ Mud ☐ Gravel ☐ Rock
Description	TIDAL POOL AT TOP END OF BLACK SWAN CREEK
Vegetation	MANGROVES ALONG BANKS AND ON TIDAL FLAT
Image:	 Image
Second Image:	 Image

SITE DETAILS – TARGINNIE CREEK

Site Id:	51
Site Name:	TARGINNIE CREEK
Waterway:	TARGINNIE CREEK
Sub-Region:	3
Map:	GLD
Grid:	HZ1
Lat:	-23.762
Long:	151.13
Tidal Influence:	Tidal
Depth:	1
Access:	Water
Distance to Mouth:	9
Substrate:	☐ Sand ☑ Mud ☑ Gravel ☐ Rock
Description	TIDAL LIMIT AT TOP END OF TARGINNIE CREEK
Vegetation	LOW MANGROVES WITH EUCALPYT FOREST ON BANKS
Image:	 Image
Second Image:	 Image

SITE DETAILS – HOBBLE GULLY

Site Id:	62
Site Name:	HOBBLE GULLY
Waterway:	GRAHAM CREEK
Sub-Region:	2
Map:	GLD
Grid:	NZ10
Lat:	-23.71
Long:	151.222
Tidal Influence:	Tidal
Depth:	1
Access:	Water
Distance to Mouth:	8
Substrate:	☐ Sand ☑ Mud ☐ Gravel ☑ Rock
Description	TIDAL REACH OF HOBBLE GULLY BELOW ROCK HOLE
Vegetation	MANGROVES ALONG BANK
Image:	 Image
Second Image:	 Image

SITE DETAILS – GRAHAM CREEK 2

Site Id:	99
Site Name:	GRAHAM CREEK 2
Waterway:	GRAHAM CREEK
Sub-Region:	2
Map:	GLD
Grid:	MZ12
Lat:	-23.712
Long:	151.24
Tidal Influence:	Tidal
Depth:	1
Access:	Water
Distance to Mouth:	9
Substrate:	☐ Sand ☑ Mud ☐ Gravel ☐ Rock
Description	TIDAL GUTTERS AT UPPER END OF GRAHAM CREEK
Vegetation	MANGROVES
Image:	 Image
Second Image:	 Image

SITE DETAILS – MUD ISLAND

Site Id:	96
Site Name:	MUD ISLAND
Waterway:	GLADSTONE HARBOUR
Sub-Region:	3
Map:	GLD
Grid:	BZ10
Lat:	-23.815
Long:	151.22
Tidal Influence:	Tidal
Depth:	2
Access:	Water
Distance to Mouth:	0
Substrate:	☑ Sand ☑ Mud ☑ Gravel ☐ Rock
Description	TIDAL GUTTERS ON WESTERN SIDE OF MUD ISLAND
Vegetation	NIL
Image:	 Image
Second Image:	 Image

SITE DETAILS – BOAT CREEK

Site Id:	35
Site Name:	BOAT CREEK
Waterway:	BOAT CREEK
Sub-Region:	4
Map:	GLD
Grid:	BZ4
Lat:	-23.814
Long:	151.162
Tidal Influence:	Intermittent Tidal
Depth:	1
Access:	Land
Distance to Mouth:	4
Substrate:	☑ Sand ☑ Mud ☐ Gravel ☐ Rock
Description	Top end of tidal limit in Boat Creek above railway line and near overhead conveyor
Vegetation	SPARSE MANGROVE WITH EUCALYPTS BACK FROM CREEK
Image:	 Image
Second Image:	 Image

SITE DETAILS – LITTLE ENFIELD CREEK

Site Id:	67
Site Name:	LITTLE ENFIELD CREEK
Waterway:	ENFIELD CREEK
Sub-Region:	5
Map:	GLD
Grid:	FZ15
Lat:	-23.775
Long:	151.266
Tidal Influence:	Tidal
Depth:	1
Access:	Water
Distance to Mouth:	1
Substrate:	☐ Sand ☑ Mud ☐ Gravel ☐ Rock
Description	DRAINS IN LITTLE ENFIELD CREEK/SURVEY AT LOW TIDE
Vegetation	DENSE MANGROVES ALONG BANKS
Image:	 Image
Second Image:	 Image

SITE DETAILS – BARNEY POINT POND

Site Id:	54
Site Name:	BARNEY POINT
Waterway:	GLADSTONE HARBOUR
Sub-Region:	6
Map:	GLD
Grid:	D16
Lat:	-23.86
Long:	151.275
Tidal Influence:	Intermittent Tidal
Depth:	2
Access:	Land
Distance to Mouth:	1
Substrate:	☐ Sand ☑ Mud ☐ Gravel ☐ Rock
Description	TIDAL POOL AT THE END OF TIDAL FLAT AT BARNEY POINT
Vegetation	SPARSE LOW SCATTERED MANGROVES
Image:	 Image
Second Image:	 Image

SITE DETAILS – BEECHER CREEK

Site Id:	6
Site Name:	BEECHER CREEK
Waterway:	CALLIOPE RIVER
Sub-Region:	6
Map:	CR02
Grid:	I8
Lat:	-23.923
Long:	151.207
Tidal Influence:	Intermittent Tidal
Depth:	2
Access:	Land
Distance to Mouth:	15
Substrate:	☑ Sand ☐ Mud ☑ Gravel ☑ Rock
Description	POOLS AT TIDAL LIMIT OF BEECHER CREEK ABOVE AND BELOW CAUSEWAY/ACCESS BY JEFFERIS ROAD OFF DAWSON HIGHWAY
Vegetation	SPARSE MANGROVES AND EUCALYPT FOREST ALONG BANKS
Image:	 Image
Second Image:	 Image

SITE DETAILS – OLD BRUCE HIGHWAY BRIDGE

Site Id:	81
Site Name:	OLD BRUCE HIGHWAY BRIDGE
Waterway:	CALLIOPE RIVER
Sub-Region:	6
Map:	CR02
Grid:	P4
Lat:	-23.964
Long:	151.154
Tidal Influence:	Intermittent Tidal
Depth:	1
Access:	Land
Distance to Mouth:	22
Substrate:	☐ Sand ☐ Mud ☑ Gravel ☑ Rock
Description	Below old Bruce Highway bridge on Calliope River
Vegetation	
Image:	 Image
Second Image:	 Image

SITE DETAILS – CALLEMONDAH

Site Id:	49
Site Name:	CALLEMONDAH
Waterway:	AUCKLAND INLET
Sub-Region:	7
Map:	GLD
Grid:	D11
Lat:	-23.862
Long:	151.232
Tidal Influence:	Tidal
Depth:	2
Access:	Land
Distance to Mouth:	5
Substrate:	☐ Sand ☑ Mud ☑ Gravel ☑ Rock
Description	TIDAL POOL BELOW CALLEMONDAH DAM WALL/ACCESS FROM BLAIN DRIVE
Vegetation	SPARSE MANGROVES
Image:	 Image
Second Image:	 Image

SITE DETAILS – FARMERS POINT

Site Id:	95
Site Name:	FARMERS POINT
Waterway:	FACING ISLAND
Sub-Region:	8
Map:	GLD
Grid:	FZ21
Lat:	-23.774
Long:	151.33
Tidal Influence:	Intermittent Tidal
Depth:	1
Access:	Water
Distance to Mouth:	0
Substrate:	☑ Sand ☐ Mud ☐ Gravel ☐ Rock
Description	SMALL TIDAL CREEK POOLS NORTH OF FARMERS POINT ON FACING ISLAND
Vegetation	SPARSE MANGROVES WITH CASUARINAS ON SAND DUNES
Image:	 Image
Second Image:	 Image

SITE DETAILS – GATCOMBE ANCHORAGE

Site Id:	94
Site Name:	GATCOMBE ANCHORAGE
Waterway:	FACING ISLAND
Sub-Region:	8
Map:	GLD
Grid:	F25
Lat:	-23.876
Long:	151.365
Tidal Influence:	Tidal
Depth:	2
Access:	Water
Distance to Mouth:	0
Substrate:	☑ Sand ☑ Mud ☐ Gravel ☑ Rock
Description	SMALL ANCHORAGE AT GATCOMBE HEAD ON FACING ISLAND
Vegetation	SPARSE SMALL MANGROVES
Image:	 Image
Second Image:	 Image

SITE DETAILS – WAPPENTAKE CREEK

Site Id:	55
Site Name:	WAPPENTAKE CREEK
Waterway:	SOUTH TREES INLET
Sub-Region:	9
Map:	BRG
Grid:	H16
Lat:	-23.89
Long:	151.282
Tidal Influence:	Intermittent Tidal
Depth:	2
Access:	Land
Distance to Mouth:	6
Substrate:	☑ Sand ☑ Mud ☑ Gravel ☐ Rock
Description	POOLS AT TIDAL LIMIT AT TOP END OF WAPPENTAKE CREEK
Vegetation	SPARSE MANGROVE WITH EUCALYPT FOREST ALONG BANKS
Image:	 Image
Second Image:	 Image

SITE DETAILS – SOUTH TREES

Site Id:	98
Site Name:	SOUTH TREES
Waterway:	SOUTH TREES INLET
Sub-Region:	9
Map:	BRG
Grid:	N17
Lat:	-23.951
Long:	151.291
Tidal Influence:	Tidal
Depth:	1
Access:	Land
Distance to Mouth:	11
Substrate:	☐ Sand ☑ Mud ☑ Gravel ☑ Rock
Description	ROCKY SECTION OF SIDE ARM OF SOUTH TREES INLET TO EAST OF GLADSTONE - BENARABY ROAD
Vegetation	LIGHT MANGROVES WITH EUCALYPT FOREST BACK FROM BANKS
Image:	 Image
Second Image:	 Image

SITE DETAILS – CREMATORIUM POOL

Site Id:	90
Site Name:	CREMATORIUM POOL
Waterway:	SOUTH TREES INLET
Sub-Region:	9
Map:	BRG
Grid:	Q22
Lat:	-23.972
Long:	151.334
Tidal Influence:	Tidal
Depth:	1
Access:	Land
Distance to Mouth:	7
Substrate:	☐ Sand ☐ Mud ☑ Gravel ☑ Rock
Description	TIDAL POOL NEAR BOYNE ISLAND CREMATORIUM/ACCESS VIA PIONEER DRIVE OFF BOYNE ISLAND ROAD
Vegetation	MANGROVES BELOW TRACK CROSSING WITH SPARSE MANGROVES AROUND POOL
Image:	 Image
Second Image:	 Image

SITE DETAILS – OLD BOYNE

Site Id:	48
Site Name:	OLD BOYNE
Waterway:	BOYNE RIVER
Sub-Region:	10
Map:	BRG
Grid:	R21
Lat:	-23.981
Long:	151.33
Tidal Influence:	Intermittent Tidal
Depth:	2
Access:	Water
Distance to Mouth:	7
Substrate:	☐ Sand ☐ Mud ☑ Gravel ☑ Rock
Description	TIDAL POOLS AT LOWER END ON OLD BOYNE RIVER CHANNEL
Vegetation	LIMITED VEGETATION WITH MOSTLY SPARSE MANGROVES
Image:	 Image
Second Image:	 Image

SITE DETAILS – BOYNE HIGHWAY

Site Id:	74
Site Name:	BOYNE HIGHWAY
Waterway:	BOYNE RIVER
Sub-Region:	10
Map:	BRG
Grid:	U22
Lat:	-24.01
Long:	151.338
Tidal Influence:	Tidal
Depth:	1
Access:	Land
Distance to Mouth:	13
Substrate:	☐ Sand ☐ Mud ☑ Gravel ☐ Rock
Description	BOYNE RIVER AT BRUCE HIGHWAY BRIDGE AT BENARABY/SURVEY AT LOW TIDE
Vegetation	SPARSE MANGROVES WITH EUCALPYT FOREST ALONG BANKS
Image:	 Image
Second Image:	 Image

SITE DETAILS – BROADACRES

Site Id:	92
Site Name:	BROADACRES
Waterway:	WILD CATTLE CREEK
Sub-Region:	12
Map:	BRG
Grid:	S28
Lat:	-23.991
Long:	151.392
Tidal Influence:	Tidal
Depth:	2
Access:	Land
Distance to Mouth:	6
Substrate:	☑ Sand ☑ Mud ☐ Gravel ☑ Rock
Description	AT BROADACRES LAUNCH SITE/ACCESSED FROM YACHT ROAD OFF BROADACRES ROAD/SURVEY AROUND LOW TIDE
Vegetation	MANGROVES ALONG BANKS BUT CLEARED AREA AROUND LAUNCH SITE
Image:	 Image
Second Image:	 Image

SITE DETAILS – IVERAGH

Site Id:	91
Site Name:	IVERAGH
Waterway:	12 MILE CREEK
Sub-Region:	12
Map:	RBT
Grid:	H18
Lat:	-24.103
Long:	151.46
Tidal Influence:	Intermittent Tidal
Depth:	1
Access:	Land
Distance to Mouth:	14
Substrate:	☑ Sand ☑ Mud ☐ Gravel ☐ Rock
Description	SIDE ARM OF 12 MILE CREEK UNDER POWER LINE/ACCESSED THROUGH CHRISTIE'S PRIVATE PROPERTY
Vegetation	LOW MANGROVES ALONG BANKS AND SALT FLATS
Image:	 Image
Second Image:	 Image

SITE DETAILS – 7 MILE CREEK

Site Id:	89
Site Name:	7 MILE
Waterway:	7 MILE CREEK
Sub-Region:	13
Map:	RBT
Grid:	R21
Lat:	-24.131
Long:	151.561
Tidal Influence:	Tidal
Depth:	2
Access:	Land
Distance to Mouth:	6
Substrate:	☑ Sand ☑ Mud ☐ Gravel ☐ Rock
Description	SCRUBBY CREEK AT JUNCTION WITH SANDY CREEK NEAR 7 MILE BOAT RAMP/ACCESSED BY DYCKHOFFS ROAD OFF TURKEY BEACH ROAD/SURVEY AT LOW TIDE
Vegetation	MANGROVES ALONG BANK AND MUD FLATS WITH ADJACENT EUCALYPT FOREST
Image:	 Image
Second Image:	 Image

SITE DETAILS – SANDY BRIDGE

Site Id:	88
Site Name:	SANDY BRIDGE
Waterway:	SANDY CREEK
Sub-Region:	13
Map:	RBT
Grid:	R23
Lat:	-24.15
Long:	151.567
Tidal Influence:	Intermittent Tidal
Depth:	1
Access:	Land
Distance to Mouth:	9
Substrate:	☑ Sand ☐ Mud ☑ Gravel ☐ Rock
Description	POOLS ABOVE AND BELOW ROAD BRIDGE ON TURKEY BEACH ROAD/THIS IS THE SAME LOCATION AS SITE 7 BUT WITH THE REMOVAL OF CAUSEWAY HAS BEEN SIGNIFICANTLY
Vegetation	EUCALYPT FOREST ALONG BOTH BANKS WITH VERY FEW MANGROVES
Image:	 Image
Second Image:	 Image

SITE DETAILS – OAKY CREEK

Site Id:	87
Site Name:	OAKY
Waterway:	OAKY CREEK
Sub-Region:	13
Map:	RBT
Grid:	AB18
Lat:	-24.11
Long:	151.663
Tidal Influence:	Intermittent Tidal
Depth:	2
Access:	Land
Distance to Mouth:	3
Substrate:	☐ Sand ☑ Mud ☑ Gravel ☐ Rock
Description	Pools below upper junction on Oaky Creek
Vegetation	EUCALYPT AND WATTLE ALONG BANKS WITH VERY FEW MANGROVES
Image:	 Image
Second Image:	 Image

SITE DETAILS – WORTHINGTON CREEK

Site Id:	86
Site Name:	WORTHINGTON
Waterway:	WORTHINGTON CREEK
Sub-Region:	13
Map:	RBT
Grid:	AD21
Lat:	-24.135
Long:	151.689
Tidal Influence:	Tidal
Depth:	1
Access:	Land
Distance to Mouth:	1
Substrate:	☐ Sand ☐ Mud ☑ Gravel ☑ Rock
Description	Pools below and above road crossing on Worthington Creek
Vegetation	EUCALYPT FOREST ALONG BOTH BANKS WITH FEW MANGROVES
Image:	 Image
Second Image:	 Image

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.

STANDARD NAME	SCIENTIFIC NAME	SITES	NUMBER
BANANA PRAWN	*Fenneropenaeus indicus*	17	1682
MULLET - FLATTAIL	*Liza dussumieri*	26	1665
GLASSFISH -ESTUARY	*Ambassis marianus*	21	955
SILVERBIDDY - COMMON	*Gerres subfasciatus*	22	471
PONYFISH - COMMON	*Leiognathus equulus*	22	452
BREAM - PIKEY	*Acanthopagrus berda*	25	429
BREAM - YELLOWFIN	*Acanthopagrus australis*	25	346
HERRING - SOUTHERN	*Herklotsichthys castelnaui*	12	307
RABBITFISH - GOLDLINED	*Siganus lineatus*	18	233
BREAM – BONY	*Nematalosa erebi*	11	224
GRUNTER - CRESCENT	*Terapon jarbua*	9	82
TOADFISH - COMMON	*Tetractenos hamiltoni*	17	155
WHITING – GOLDENLINE	*Sillago analis*	16	120
MULLET - SEA	*Mugil cephalus*	16	82
ANCHOVY SPP		6	80
MULLET – DIAMONDSCALE	*Liza vaigiensis*	2	68
TARWHINE	*Rhabdosargus sarba*	2	51
SILVERBIDDY - THREADFIN	*Gerres filamentosus*	12	47
SCAT - STRIPED	*Selenotoca multifasciata*	7	44
MULLET – GOLDSPOT	*Liza argentea*	2	36
FLATHEAD – BARTAIL	*Platycephalus indicus*	7	26
JAVELIN - BARRED	*Pomadasys kaakan*	8	25
MANGROVE JACK	*Lutjanus argentimaculatus*	8	20
SNAPPER - MOSES	*Lutjanus russellii*	6	18
DIAMONDFISH	*Monodactylus argenteus*	6	14
SOLE SPP		2	14
FLATHEAD - DUSKY	*Platycephalus fuscus*	9	13
SHRIMP – FRESHWATER	*Macrobrachium spp*	2	13
MULLET – SAND	*Valamugil seheli*	3	12
GARFISH SPP		5	11
CRAB – MUD	*Scylla serrata*	4	10
WHITING - SAND	*Sillago ciliata*	3	8
GARFISH - SNUBNOSE	*Arrhamphus sclerolepis*	3	8
SCAT - SPOTTED	*Scatophagus argus*	2	5
CATFISH – BLUE	*Arius graffei*	1	5
THREADFIN – KING	*Polydactylus macrochir*	2	4

STEELBACK	*Leptobrama mulleri*	3	4
GARFISH – RIVER	*Hyporhamphus regularis*	2	2
CRAB – SAND	*Portunus pelagicus*	1	2
TREVALLY SPP		1	1
WHITING – WINTER	*Sillago maculata*	1	1
LONGTOM SPP		1	1
MILKFISH	*Chanos chanos*	1	1
PRAWN SPP		1	1
HERRING – GIANT	*Elops machnata*	1	1
ROCKCOD – GOLDSOTTED	*Epinephelus coioides*	1	1
GRINNER SPP		1	1
THREADFIN – BLUE	*Eleutheronema tetradactylum*	1	1
BARRAMUNDI	*Lates calcarifer*	1	1
GOBY – FLATHEAD		1	1
CRAB SPP		1	1

PART 2: ANALYSIS AND INDEX CALCULATION

10. Introduction

This Part 2 of the report contains details of the analysis of the Bream catch data, up to and including the survey data from 2017-18.

10.1 Background

In Project ISP013-2015[2], which included the 2015-16 survey, the authors detailed a strategy for using the Bream catch data to arrive at suitable health indices for the Gladstone Harbour reporting zones, together with an all-of-harbour index. The proposed strategy was based on some partial survey data from 2011-12 to 2014-15, together with a survey of 26 sites, 4 visits to each, in 2015-16, which included visits to all previously surveyed sites.

The present report focuses on data collected in the 2017-18 survey when compared to 2016-17 and prior, and should be read in conjunction with *Incorporating a fish recruitment indicator into a health report card: A case study from Gladstone Harbour, Australia* which provides full details on the refined model used in this report.

Note that the terminology we use in this report differs in some respects from that used in Part II of ISP013-2016[3]. These minor changes are designed to make the language of this report more standard within the GHHP. They are detailed in Appendix A.

10.2 The statistical model

Changes to sampling sites at Graham Creek in year 2016-17 forced a minor change to the model details. The model derived in 2016-17 has been retained for year 2017-18 as the sample sites and number of samples remained the same as 2016-17.

- The response variable, denoted by Y, is again taken as the total Bream catch, Pikey Bream plus Yellowfin Bream, in fish numbers for each visit. Catch counts for the two bream species separately, as well as effort denoted by E, and the catch per unit of effort (CPUE) data are reported below in Appendix C.
- Catch per visit conforms to a Negative Binomial generalized linear mixed model, with log link and fixed variance parameter, θ. In conventional algebraic terms, for a single observation:

[2] See Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2015, Sawynok and Venables

[3] See Fish recruitment indicators for the Gladstone Harbour Report Card using data derived from castnet sampling 2016, Sawynok and Venables

$$\begin{aligned} Y|E &\sim \text{Negative Binomial}, \\ \log\mathrm{E}[Y|E] &= \log\mu = x^{\mathrm{T}}\beta + z^{\mathrm{T}}E + \log c, \\ \mathrm{Var}[Y|E] &= \mu + \mu^2/\theta \end{aligned}$$

Where the row vectors x^{T} and z^{T} specify the fixed and random effects respectively, so the fixed effect coefficient vector is β. Marginally the random effect terms are considered to have a Normal distribution, that is, $E \sim \mathrm{N}(0, \Sigma)$.[4] The precise form for the variance, Σ, is detailed below.

The final offset term, $\log c$, is the logged number of casts involved in the particular visit and allows for variations in cast numbers from the usual 20 casts per visit.

The random effects, E, are modelled as Normal (Gaussian) random variables with mean zero. The variances involved are the *variance components* used later in the discussion.

For simplicity, the model is estimated with fixed parameter $\theta = 2$, which also enhances stability. We show later that this assumed fixed value is very close to the maximum likelihood estimate and the assumption has no material effect on the parameters of interest.

- The candidates for fixed effect terms included all available and relevant spatial and temporal environmental predictors.

On model refinement the only retained fixed effect terms were:

  - A **Month** term, allowing for systematically different catch rates within the survey year,
  - A **Depth** term and a **Rock** presence/absence term as the only environmental predictors shown to be effective.

- The random effect terms included
  - A **Site** random effect, allowing for productivity differences between sites not explained by the fixed effects. This is a "blocking" term; the variance component is σ_S^2.
  - A **Year** random main effect, with variance component σ_Y^2.
  - **Year**×**Site** random interaction, with variance component σ_{YS}^2.

The proposed method for generating scores and grades from the model outputs begins with a score, on the $(0,1)$ range at the site rather than the zone level. If E_Y is the random effect estimate, (which is usually referred to as a "BLUP", an acronym for "Best Linear Unbiased Predictor"), for a particular year and E_{YS} the random interaction BLUP for a site within the year, then their sum, $E_Y + E_{YS}$ is the combined BLUP which forms the basis for the corresponding site level score.

[4] Notice that whereas a normal linear regression model would have an additional error term added to the mean formula, no such normal error term is added here. That additional component of variation is covered by (conditional) Negative Binomial distributed ascribed to the response; it is not additive in the usual sense. In a sense, though, the random effect terms *are* very like normal additive "error" terms.

10.3 Software

Data manipulation and analyses were done using the R software environment, (R Core Team 2018). The main package used for model fitting and post hoc manipulation of fitted model objects was **lme4**, which is described in Bates et al. (2015).

10.4 Score estimation and aggregation

As per ISP013-2017 we propose that these site scores then aggregated to the reporting levels:

- The zone score for a year is the simple average of the site scores within that zone. In some cases there is just one site within a zone, (and in one case, , there are none).
- The score for All of Harbour is then the simple average of the zone scores.
- Grades are generated from scores by finding the interval to which they belong, as per the GHHP standard:

Table 6: Grade definitions from [0, 1] scores

E	D	C	B	A
0.00-0.25	0.25-0.50	0.50-0.65	0.65-0.85	0.85-1.00

We note here that the scores, particularly at the site level, have a meaning in terms of the assumed statistical model and form an objective scaling of the sites. Whether this scaling, and the resulting scaling of the zones and harbour coincides precisely with the intuitive meaning given to the grades is an issue for resolution.

11. Data manipulation and cleaning

The data as recorded had a few inconsistencies, most of which were reconcilable through inbuilt redundancy.

There was some inconsistency in the way site names were recorded and these were resolved as in the following table:

Table 7: Resolution of minor place-name inconsistencies in the originally recorded data

Recorded Name	Analysis Name
7 Mile Creek	7 Mile
Black Swan Creek	Black Swan
Oakey Creek	Oaky
Oaky Creek	Oaky
Graham Creek 2	Graham Creek
Worthington Creek	Worthington

Most of these are recording glitches but it is important to note that *Graham Creek 2* is technically a different site from *Graham Creek*. The former is a site new to the study chosen to replace the latter for easier access, but remaining as close to it as possible. **In the analysis only**, we have chosen to identify it with the original site to simplify and strengthen the process.

12.Results

In this section we present the results of the analysis. The main results are the scores and grades for the current survey year, 2017-18, but to do so requires the model to be fitted using the historical data as well.

One of the important concerns is the stability of the process itself. To examine this we will present the results for two cases, namely for the data set up to last year only, that is for 2011-12 to 2015-16 inclusive, and compare that with the results up to 2016-17 and finally for the entire data record, including 2017-18 as well. In this way we can show the result for last year as if we had used the method now suggested, and the effect on it of adding this year's additional data.

12.1 Negative binomial variance parameter, θ

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

- $\hat{\theta}$ = 2.0683 for the model fitted with data up to year 15-16 only, and
- $\hat{\theta}$ = 2.1084 when the further data for year 16-17 is included and
- $\hat{\theta}$ = 2.0381 when the further data for year 17-18 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.

12.2 Variance Component

The additional data gained in the 17-18 surveys also leaves the variance component estimates relatively unaffected, as shown in Table 8.

Table 8: Variance component estimates (as standard deviations) for the main model using (a) only data up to year 15-16 and (b) only data to year 16-17 and (c) all available data. A stability check.

	(a) data to 15-16	(b) data to 16-17	(c) data to 17-18
Site	0.8676	0.8292	0.7773
Year	0.3240	0.3111	0.2767
Year x Site	0.3291	0.3577	0.3366

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

$$\begin{aligned}\hat{\sigma}_{\text{BLUP}} &= \sqrt{\hat{\sigma}_Y^2 + \hat{\sigma}_{YS}^2} \\ &= \sqrt{0.2767^2 + 0.3366^2} \\ &= 0.4357\end{aligned}$$

12.3 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 23 shows the BLUPs using data up to 2016-17, (horizontal scale) and estimates using the full data set (vertical scale). The diagram is partitioned into zone cells to show the high degree of heterogeneity even within zones. It is this heterogeneity that complicates the production of fully justifiable scores at the zone level, of course. The diagonal line in each panel indicates where the two estimates would be equal. Points relatively distant from the line had the greatest change.

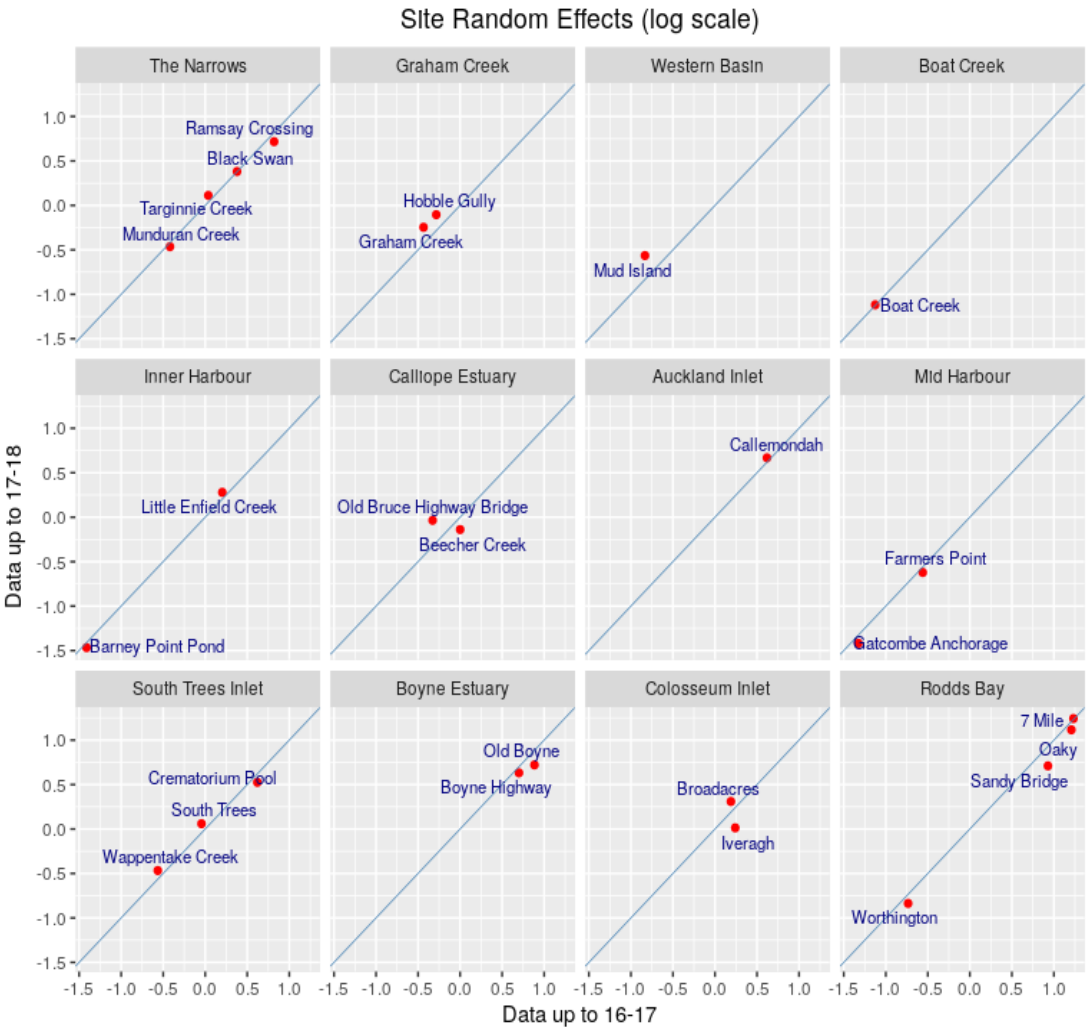

Figure 23: Site random effect estimates. A comparison of BLUPs using the restricted data set with those using the full data set.

12.4 Site main effects

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 as detailed in section 3.3.

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
The Narrows	Ramsay Crossing					0.10	0.15	0.03
	Munduran Creek	0.42	-0.30	-0.20	-0.04	-0.18	0.23	-0.01
	Black Swan				0.15	-0.73	0.76	0.13

	Targinnie Creek	0.18	-0.41		0.42	-0.52	0.22	0.23
Graham Creek	Graham Creek				0.23	-0.32	-0.03	0.31
	Hobble Gully				-0.03	-0.13	0.04	0.35
Western Basin	Mud Island					-0.53	0.21	0.35
Boat Creek	Boat Creek		-0.37	-0.10	0.32	-0.33	-0.07	0.13
Inner Harbour	Little Enfield Creek				0.23	-0.34	0.17	0.23
	Barney Point Pond		-0.35	-0.10	0.16	-0.38	0.04	0.15
Calliope Estuary	Beecher Creek	0.45	-0.53	-0.12	0.16	-0.29	0.28	0.02
	Old Bruce Highway Bridge				-0.19	-0.34	0.25	0.52
Auckland Inlet	Callemondah	0.07	-0.68	-0.21	0.10	-0.13	0.49	0.48
Mid Harbour	Farmers Point					-0.64	0.59	0.07
	Gatcombe Anchorage					-0.24	-0.01	0.11
South Trees Inlet	Wappentake Creek		-0.39	-0.07	0.00	-0.31	0.11	0.37
	South Trees					-0.19	0.09	0.25
	Crematorium Pool					-0.30	0.48	0.05
Boyne Estuary	Old Boyne	0.23	-0.23		0.11	-0.09	0.24	-0.01
	Boyne Highway				0.01	-0.03	0.33	0.05
Colosseum Inlet	Broadacres					-0.30	0.15	0.34
	Iveragh					-0.07	0.29	-0.08
Rodds Bay	Oaky					-0.08	0.26	0.16
	7 Mile					-0.12	0.20	0.28
	Worthington					-0.29	0.23	0.04
	Sandy Bridge					-0.08	0.43	-0.08

The BLUPs are transformed into *scores* by dividing by their standard deviation for 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
The Narrows	Ramsay Crossing					0.59	0.63	0.53
	Munduran Creek	0.83	0.24	0.32	0.46	0.34	0.70	0.49

	Black Swan				0.64	0.05	0.96	0.61
	Targinnie Creek	0.66	0.17		0.83	0.12	0.69	0.70
Graham Creek	Graham Creek				0.70	0.23	0.48	0.76
	Hobble Gully				0.47	0.38	0.54	0.79
Western Basin	Mud Island					0.11	0.69	0.79
Boat Creek	Boat Creek		0.20	0.40	0.77	0.23	0.44	0.61
Inner Harbour	Little Enfield Creek				0.70	0.22	0.65	0.70
	Barney Point Pond		0.21	0.41	0.64	0.19	0.54	0.63
Calliope Estuary	Beecher Creek	0.85	0.11	0.39	0.64	0.25	0.74	0.52
	Old Bruce Highway Bridge				0.33	0.22	0.71	0.89
Auckland Inlet	Callemondah	0.57	0.06	0.31	0.59	0.38	0.87	0.87
Mid Harbour	Farmers Point					0.07	0.91	0.57
	Gatcombe Anchorage					0.29	0.50	0.60
South Trees Inlet	Wappentake Creek		0.19	0.44	0.50	0.24	0.60	0.80
	South Trees					0.33	0.59	0.71
	Crematorium Pool					0.25	0.86	0.55
Boyne Estuary	Old Boyne	0.70	0.30		0.60	0.41	0.71	0.49
	Boyne Highway				0.51	0.47	0.78	0.55
Colosseum Inlet	Broadacres					0.24	0.64	0.78
	Iveragh					0.44	0.74	0.43
Rodds Bay	Oaky					0.43	0.72	0.65
	7 Mile					0.39	0.68	0.74
	Worthington					0.25	0.70	0.54
	Sandy Bridge					0.43	0.84	0.42

12.5 Aggregation to the Zone Level

The present project proposes a rather simple method for aggregating scores to the zone level within years, as required for reporting purposes, and further aggregating to all of harbour. As described previously, we use 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 Table11, and the resulting grades are shown in Table 12.

Table 11: Score estimates on a $(\mathbf{0}, \mathbf{1})$ −scale, averaged over sites within zones, and over all of harbour, using the revised system developed in this report

Zone	11-12	12-13	13-14	14-15	15-16	16-17	17-18
The Narrows	0.75	0.21	0.32	0.64	0.27	0.75	0.58
Graham Creek				0.58	0.31	0.51	0.77
Western Basin					0.11	0.69	0.79
Boat Creek		0.20	0.40	0.77	0.23	0.44	0.61
Inner Harbour		0.21	0.41	0.67	0.20	0.60	0.67

Calliope Estuary	0.85	0.11	0.39	0.48	0.24	0.73	0.70
Auckland Inlet	0.57	0.06	0.31	0.59	0.38	0.87	0.87
Mid Harbour					0.18	0.70	0.58
South Trees Inlet		0.19	0.44	0.50	0.27	0.68	0.69
Boyne Estuary	0.70	0.30		0.55	0.44	0.74	0.52
Colosseum Inlet					0.34	0.69	0.61
Rodds Bay					0.38	0.74	0.59
All of Gladstone Harbour	0.72	0.18	0.38	0.60	0.28	0.68	0.66

Table 12: Alphabetic grades for (unadjusted) averaged scores over sites within zones, and over all of harbour, using the revised system developed in this report

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

13.Bootstrap simulations and uncertainty estimates

To provide uncertainty measures for the scores we use standard bootstrapping techniques, with two minor adaptations, as described below. Bootstrap simulations are also needed for use in the aggregation process used to incorporate zone- and harbour-level scores into higher levels of the GHHP report card. This section will outline the method used and show the key results.

Note that his process differs from that presented in past reports, and is much more in line with normal statistical practice. The method was developed in connection with a publication on the Bream recruitment project, currently in review.[5]

Previous bootstrap simulations used the SE of Random Effects Estimates. After application of a guarded bootstrap sample, the previous method was found to be too pessimistic, with the revised sample providing narrower confidence intervals. The guarded bootstrap sample uses the Random Effects Estimate for all Site+Year

[5] see Sawynok, Venables, and Pinto (2017)

combinations including all parameters, which accounts for uncertainty including variance.

In outline, the process is as follows:

- Generate a guarded bootstrap sample of the full data set, as normally defined.
- If the bootstrap sample does not contain, separately, a) entries for each **Site**, b) entries for each **Year** and c) entries for each **Year**×**Site** that occurred in the original data set, reject the sample and start again. This step is required to ensure consistency of historical scores as not all sites were sampled. From 2016-17 on this is not needed as all sites are always sampled.
- Generate **Site** scores as defined in the score process above.
- Repeat a large number, say $B = 1000$ times to produce a bootstrap sample of **Site** scores.
- Adjust the simulated scores for each **Site** so that their mean agrees with the original estimate. (See below.)
- For each set of **Site** scores in the bootstrap sample, compute **Zone** and **All of Harbour** scores in the normal way.
- For an uncertainty interval at the **Site**, **Zone** or **All of Harbour** level, compute the lower and upper **2.5%** quantiles of the bootstrap simulated distribution for that quantity.
- For aggregation to higher levels in the GHHP hierarchy, the **Site** scores are used directly. Only the scores for the current year are required.

13.1 Mean correction of bootstrap simulated scores

When the simulated **Site** scores are generated they are corrected using a mild power transformation so that they agree *in mean* with the original scores. This is a declared requirement for them to be used in the hierarchical aggregation process, and a useful minor enhancement for the uncertainty estimation in any case.

The form of the adjustment is as follows:
Let S_s be the score for **Site S**, and let $\tilde{S}_{s,i}, i = 1,2,\dots,B$ be the B *unadjusted* bootstrap scores. The *adjusted* scores are then $\tilde{S}^{\star}_{s,i} = \tilde{S}^{\alpha}_{s,i}$ where the exponent α is chosen so that $\frac{1}{B}\sum_{i=1}^{B} \tilde{S}^{\alpha}_{s,i} = S_s$ In practice the adjustment is minor with $\alpha \approx 1$, but any positive for α will leave the adjusted score within the required $(0,1)$ range.

13.2 Uncertainty intervals

The following Table 13 shows the original scores for the 12 scores zones, and all of harbour, together with their lower and upper uncertainty limits as calculated by the bootstrap simulation method. The same information is displayed in Figure 24 below.

Table 13: Estimates and bootstrap uncertainty intervals

Zone	Score 17-18	2.5%	97.5%
The Narrows	0.5828	0.3949	0.7302
Graham Creek	0.7747	0.6340	0.8756
Western Basin	0.7905	0.5548	0.9188
Boat Creek	0.6136	0.4490	0.7720
Inner Harbour	0.6657	0.5260	0.7906
Calliope Estuary	0.7034	0.5478	0.8246
Auckland Inlet	0.8661	0.7062	0.9609
Mid Harbour	0.5847	0.3591	0.7824
South Trees Inlet	0.6868	0.5583	0.8032
Boyne Estuary	0.5173	0.3563	0.6717
Colosseum Inlet	0.6058	0.4456	0.7550
Rodds Bay	0.5872	0.4525	0.7043
All of Harbour	0.6649	0.5779	0.7499

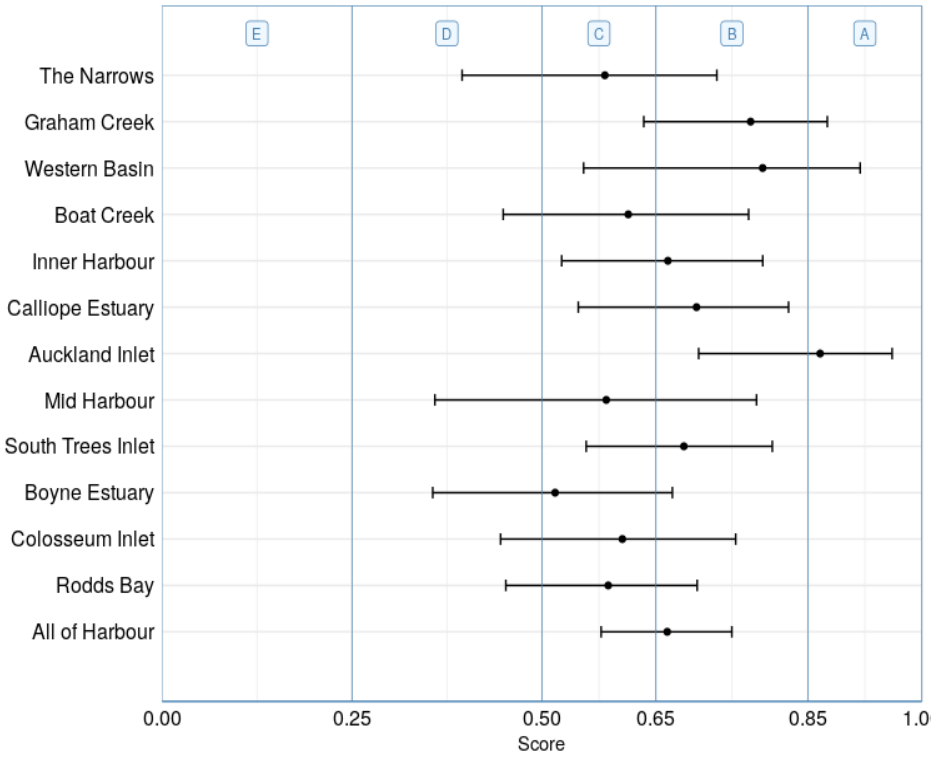

Figure 24: Estimates and bootstrap uncertainty intervals

14. Discussion

14.1 Changes from the previous methodology

A third season in which the 26 survey sites have been visited a further four times over the December-March period has been assessed using the model updated from 2017.

As previously, the model specifies a negative binomial distribution for the *total bream catch* per visit, generally of 20 casts. It has a log link, meaning that the log of the mean of the distribution is linearly related both to the predictors and the random effects. This in turn implies that influences on the mean due to predictors and random effects are represented as *proportional* rather than absolute changes in the natural scale. The parent negative binomial distribution has a fixed dispersion parameter of $\theta = 2$, for stability purposes, but in any case as we shall see, is in line with an estimated value.

Consistent site differences in catch rates are partially explained by fixed effects and partly by a random effect **Site** term. Both of these remain fairly stable with the introduction of the current year's survey data. The stability of the random effect component is shown in Table 8 and Figure 23. Allowing for small regular differences in catch rates *within a season* is done using a **Month** fixed effect term.

The index is then based on the combination of two random effect terms through their BLUP estimates, namely a **Year** random effect and a **Year**×**Site** random interaction. The sum of these two terms is then referred to its distribution, as inferred by the estimated variance components, to produce scores on the required $(0,1)$ scale.

In line with the process adopted in previous reports, and with standard GHHP practice, Zone scores are then the simple average of the scores of the Sites within each Zone, (where the Zone itself has been surveyed), and the All of Harbour score is the average *of the Zone scores*.

Given that the zone has to be the reporting level, this simple averaging process appears unavoidable, but it should be noted that it conceals two potential flaws:

- Firstly, the numbers of sites within zones are unequal. Some zones have more sites suitable for sampling than others, so the zone attracts more sites.
- Secondly, in some cases the sites within a zone are distinctly heterogeneous, and averaging will smooth over these possibly important features.

14.2 Notes on the uncertainty assessments and bootstrap simulations

As noted in the previous section, further work on assessing uncertainties since the last report has been done leading up to the submitted publication on the scoring

procedure Sawynok, Venables, and Pinto (2017). This improved process uses a slightly modified, but much more standard bootstrapping process where all free parameters are incorporated. The modifications, as described in detail above (and in the submitted publication) are mainly to ensure that the model fitting process employed during the bootstrap simulations provides estimates for all needed parameters. With unrestricted bootstrap sampling failures happen typically in about 5-10% of cases.

The result is a much improved uncertainty assessment process, somewhat surprisingly leading to shorter uncertainty intervals and hence winding back some of the implicit pessimism in the previous process. The input into the aggregation process should also carry some of this improvement through to higher levels in the hierarchy. The cost, however, is a much heavier computational load.

14.3 Unresolved issues

Site differences

The indices we have produced here are based on the assumption that the sites themselves have fairly consistent differences in potential catch rates for bream, effectively due to natural differences in their environment. These different "baseline" catch rates for the sites are reflected partly by the fixed effect terms (apart from the temporal term, **Month**) but mainly by the **Site** random main effect, which is used to capture the large unexplained remaining variations.

Figure 24 provides some evidence that these notional "baseline" catch rates, in a relative sense, can be reasonably well estimated from the data, as the BLUPs involved remain fairly stable when the additional data for the present survey is included. (This brings the number of site visit records up to 441 from 337 in 2016-17.)

Intrinsic meaning of scores

In any year site catch rates will vary up or down from this notional baseline, and such (proportional) changes are the target of the indices. These are based, at the site level, on the sum of the **Year** random main effect BLUP and the **Year**×**Site** random interaction BLUP. To produce indices on the $(0,1)$ scale, these are referred to the conceptual normal distribution from which according to the model they are drawn. The conceptual distribution is, in turn, determined by the variance component estimates which, as shown in Table 11, are also reasonably stable.

The two issues to which we draw attention here are the following:

- The baseline site differences in catch rates will clearly be partly natural and partly anthropogenic. There is no way in the data to isolate these. It may be useful to report these baseline site catch rates, at least in some relative sense, (even more explicitly than in Figure 24), so that the users of the indices are aware that an allowance for them has been made for them in arriving at the indices. The issue of to what extent such baseline differences are natural or anthropogenic has to remain unresolved in the absence of usable data.

- Currently the grades, A–E, are simply assigned according to the automatic way the $(0,1)$ scores are computed, that is by reference to their conceptual random effect distribution, using the GHHP standard. There is no particular reason, however, for a score in the range 0.50–0.65 to be allocated a C grade, for example. Just what any grade is intended to imply for users and how the scores we generate should be related to such an implication is, for want of an explicit definition, unresolved.

Put another way, it is conceivable that expert opinion could, from the scores we produce, arrive at different cut-off levels to reflect the true situation given the understood meaning of the grades. In this case a simple re-scaling of the scores could be done to ensure conformity with the GHHP standard. Now that we have two years' data, it may be possible, and appropriate, for this issue to be considered and explicitly resolved by environmental professionals.

Relative catch rates of *Pikey* and *Yellowfin* Bream

The index used the *total bream catch* as the only response from the data. This is a convenience, but also partly inevitable given that a single bream recruitment index is required. As noted in previous reports, however, it is then incumbent on stakeholders to monitor the two species separately for good management.

In previous years the Pikey/Yellowfin catch ratio has been relatively stable overall, though varying widely between sites, of course. This year the balance seems to have tipped towards Pikey and away from Yellowfin.

Additional data collected in separate projects have also indicated a change in the ratio of Pikey Bream to Yellowfin Bream. The Boyne Tannum Hookup reported that 57.7% of the Bream Catch were Yellowfin Bream, the lowest in 18 years of reported catches and well down on the long term average of 74.9%. During structured sampling for assessing new technology for fish health Yellowfin Bream were only 26.2% of the total bream catch.

The reasons for the change in reported presence of the species is unknown, but needs to be independently investigated. We feel a need to draw this to the attention of the Gladstone Healthy Harbour Partnership.

Appendix A - Terminology

This report will use some different names for various entities from those used in report, ISP013-2015. The new terms we use are more in line with those used in other parts of the GHHP project, and hence hopefully less open to misunderstanding.

- **Site:** A section of the harbour where cast net samples are taken on a regular basis. (The previous term used was *Location*.)
- **Visit:** A time and site where a survey sample is taken. A site visit generally uses 20 casts for the sample. (The previous term used was **Trip**.)
- **Zone:** A section of the harbour for which local indices are required. That is, a reporting region of the harbour. (The previous term used was **Sub-region**.)
- **Month:** A period of the calendar year within which all, or most, sites are surveyed at least once. These are generally the calendar months December, January, February and March, though in the historical data other periods of the calendar have been used. (The previous term used was **Period**.)
- **Year:** A 12 month period notionally beginning on 1 October and extending to 30 September in the following calendar year. (The previous term used was **Season**.)
- **Score:** A numerical result on a $(0,1)$ scale. This is consistent with previous usage, but repeated here for convenience.
- **Grade:** A letter, A, B, C, D, or E, got by translating a score into an ordinal scale. This is also consistent with previous usage.

Appendix B - Size Profiles

Figure 25 and Table 14 show the size distribution of the Bream catch, by species, for each of the four months of the survey, for all of harbour.

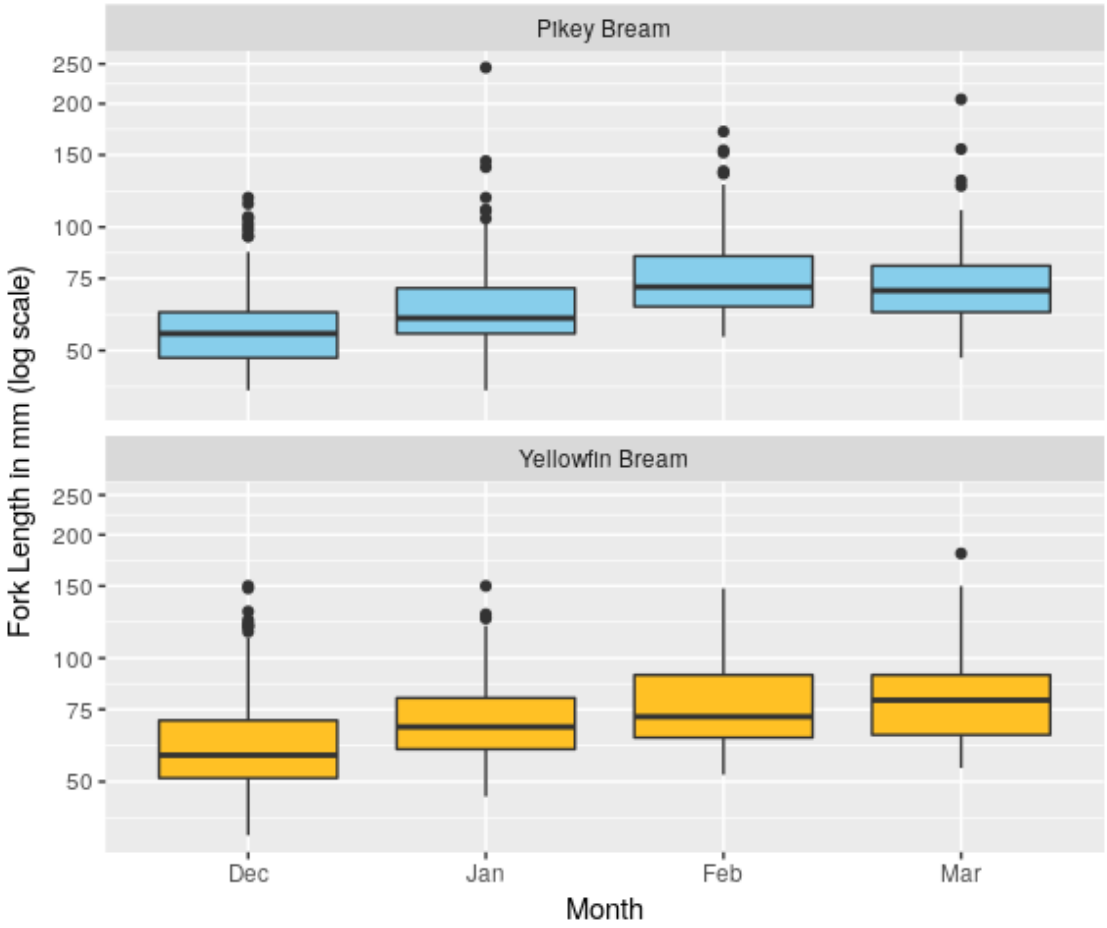

Figure 25: Fork Length change at the harbour level over the data collection period

Table 14: Bream size distribution summary statistics: Fork Length (in mm)

Species	Month	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Pikey Bream	Dec	40	48	55.0	58.12	62.0	118
	Feb	54	64	71.5	79.14	85.0	171
	Jan	40	55	60.0	65.76	71.0	245
	Mar	48	62	70.0	75.65	80.5	205
Yellowfin Bream	Dec	37	51	58.0	64.83	70.5	150
	Feb	52	64	72.0	79.40	91.0	148
	Jan	46	60	68.0	72.74	80.0	150
	Mar	54	65	79.0	82.49	91.0	180

Appendix C - Basic Catch and Effort Data

In this section we present catch and effort data as a reference for discussion.

C.1 Casts

Table 15: Numbers of casts per site, per survey year, for all surveys included in the study

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

C.2 Pikey Bream

Table 16: Total numbers of Pikey Bream caught per site per survey

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

C.3 Yellowfin Bream

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

C.4 Bream Total

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

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

C.5 Pikey Bream catch per site visit of 20 casts

Table 19: 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
The Narrows	Ramsay Crossing					22.40	12.00	14.00
	Munduran Creek	0.0	0	0.50	0.00	0.00	0.00	0.00
	Black Swan				6.25	0.25	19.25	5.50
	Targinnie Creek	0.0	0		0.00	0.00	0.50	1.50
Graham Creek	Graham Creek				3.00	0.67	2.00	6.00
	Hobble Gully				5.25	7.50	6.00	13.25
Western Basin	Mud Island					0.00	0.75	2.00
Boat Creek	Boat Creek		0	0.00	1.33	0.50	0.25	0.50
Inner Harbour	Little Enfield Creek				6.00	3.25	6.00	7.50
	Barney Point Pond		0	0.40	0.20	0.00	0.00	0.25
Calliope Estuary	Beecher Creek	0.0	0	0.00	0.20	0.25	0.50	0.00
	Old Bruce Highway Bridge				0.00	2.50	9.25	3.00
Auckland Inlet	Callemondah	0.8	0	2.40	3.40	3.75	10.75	14.25
Mid Harbour	Farmers Point					0.00	0.00	0.75
	Gatcombe Anchorage					0.40	0.25	0.00
South Trees Inlet	Wappentake Creek		0	0.33	0.20	0.25	0.25	0.25
	South Trees					2.44	4.00	11.00
	Crematorium Pool					0.20	0.00	3.50
Boyne Estuary	Old Boyne	2.0	0		0.80	0.25	0.00	1.50
	Boyne Highway				0.00	0.25	0.00	0.25
Colosseum Inlet	Broadacres					0.40	3.00	7.75
	Iveragh					0.40	0.75	0.25
Rodds Bay	Oaky					2.60	3.00	3.25
	7 Mile					4.60	4.00	8.75
	Worthington					0.20	1.00	1.25
	Sandy Bridge					0.00	0.50	1.00

C.6 Yellowfin Bream catch per site visit of 20 casts

Table 20: 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
The Narrows	Ramsay Crossing					2.40	5.50	2.25
	Munduran Creek	11.0	4.33	2.50	4.00	4.60	7.25	3.75
	Black Swan				1.00	0.00	4.25	1.00
	Targinnie Creek	4.0	0.00		9.50	1.25	5.25	5.25
Graham Creek	Graham Creek				4.00	1.67	0.00	0.00
	Hobble Gully				0.25	0.50	0.00	0.50
Western Basin	Mud Island					0.00	0.75	0.50
Boat Creek	Boat Creek		0.00	1.25	1.07	0.25	0.00	1.00
Inner Harbour	Little Enfield Creek				1.40	0.25	1.00	0.25
	Barney Point Pond		0.25	0.00	0.40	0.00	0.00	0.25
Calliope Estuary	Beecher Creek	7.2	0.86	2.75	3.60	2.25	5.00	3.00
	Old Bruce Highway Bridge				3.60	2.75	2.00	19.00
Auckland Inlet	Callemondah	3.6	1.43	2.60	5.00	4.00	8.75	5.00
Mid Harbour	Farmers Point					0.00	6.50	1.50
	Gatcombe Anchorage					0.40	0.00	1.00
South Trees Inlet	Wappentake Creek		0.57	0.67	0.60	0.50	0.75	2.50
	South Trees					3.78	3.75	2.75
	Crematorium Pool					10.00	30.75	8.75
Boyne Estuary	Old Boyne	8.0	6.00		7.00	8.50	10.50	5.00
	Boyne Highway				5.00	10.50	12.25	7.25
Colosseum Inlet	Broadacres					3.40	2.75	2.25
	Iveragh					4.60	5.00	2.00
Rodds Bay	Oaky					4.60	6.25	3.75
	7 Mile					3.00	4.75	1.50
	Worthington					2.20	3.50	2.00
	Sandy Bridge					9.40	17.00	4.50

C.7 Total Bream catch per site visit of 20 casts

Table 21: Total Bream, 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
The Narrows	Ramsay Crossing					24.80	17.50	16.25
	Munduran Creek	11.0	4.33	3.00	4.00	4.60	7.25	3.75
	Black Swan				7.25	0.25	23.50	6.50
	Targinnie Creek	4.0	0.00		9.50	1.25	5.75	6.75
Graham Creek	Graham Creek				7.00	2.33	2.00	6.00
	Hobble Gully				5.50	8.00	6.00	13.75
Western Basin	Mud Island					0.00	1.50	2.50
Boat Creek	Boat Creek		0.00	1.25	2.40	0.75	0.25	1.50
Inner Harbour	Little Enfield Creek				7.40	3.50	7.00	7.75
	Barney Point Pond		0.25	0.40	0.60	0.00	0.00	0.50
Calliope Estuary	Beecher Creek	7.2	0.86	2.75	3.80	2.50	5.50	3.00
	Old Bruce Highway Bridge				3.60	5.25	11.25	22.00
Auckland Inlet	Callemondah	4.4	1.43	5.00	8.40	7.75	19.50	19.25
Mid Harbour	Farmers Point					0.00	6.50	2.25
	Gatcombe Anchorage					0.80	0.25	1.00
South Trees Inlet	Wappentake Creek		0.57	1.00	0.80	0.75	1.00	2.75
	South Trees					6.22	7.75	13.75
	Crematorium Pool					10.20	30.75	12.25
Boyne Estuary	Old Boyne	10.0	6.00		7.80	8.75	10.50	6.50
	Boyne Highway				5.00	10.75	12.25	7.50
Colosseum Inlet	Broadacres					3.80	5.75	10.00
	Iveragh					5.00	5.75	2.25
Rodds Bay	Oaky					7.20	9.25	7.00
	7 Mile					7.60	8.75	10.25
	Worthington					2.40	4.50	3.25
	Sandy Bridge					9.40	17.50	5.50

C.8 Catch per site visit of 20 casts 2016-17 versus 2017-18

The following diagram shows the total Bream CPUE per site for survey year 2017-18 plotted against the same total Bream CPUE per site for survey year 2016-17, partitioned into recording zones. Points above the diagonal line correspond to sites whose CPUE increased in 2017-18 from what it was in 2017-18, and points below the line to those for which CPUE decreased.

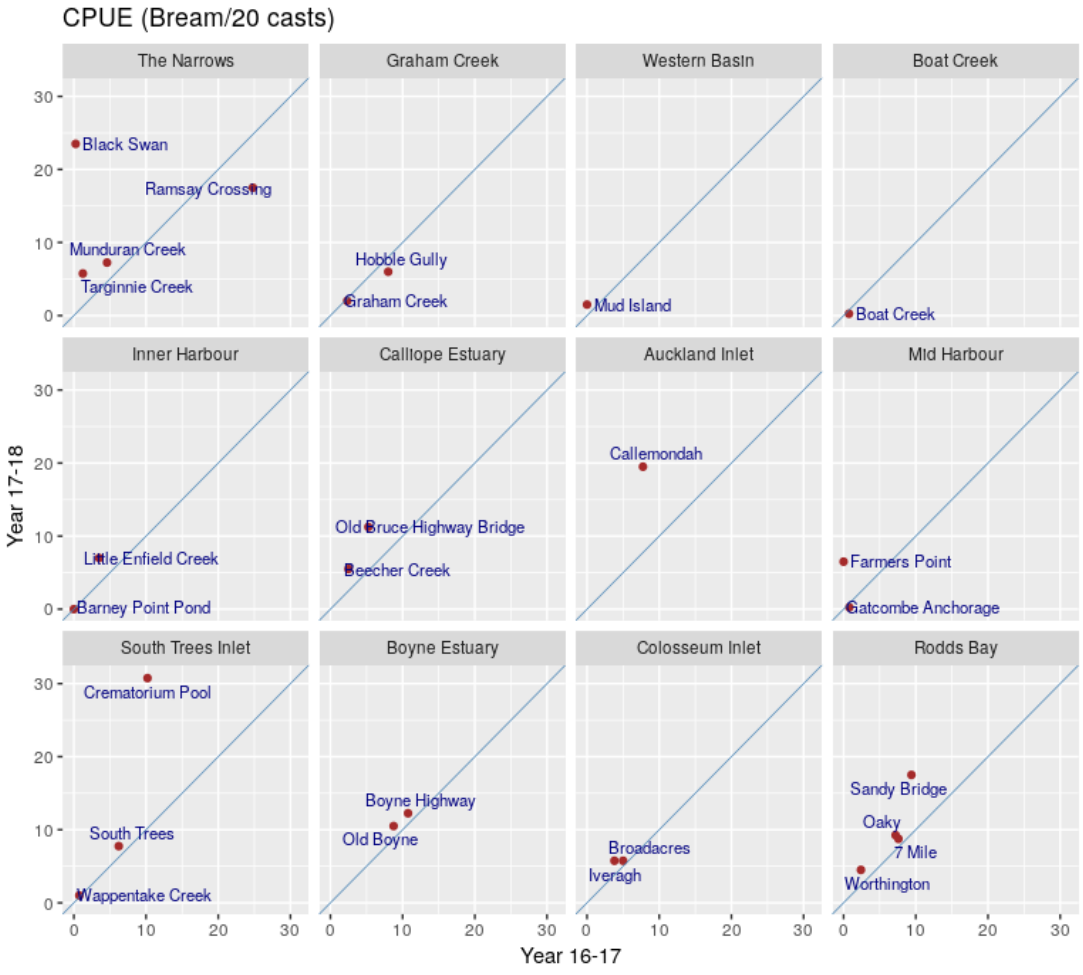

Figure 26: Bream CPUE for 2015-16 against CPUE for 2016-17 per site portioned into recording zones

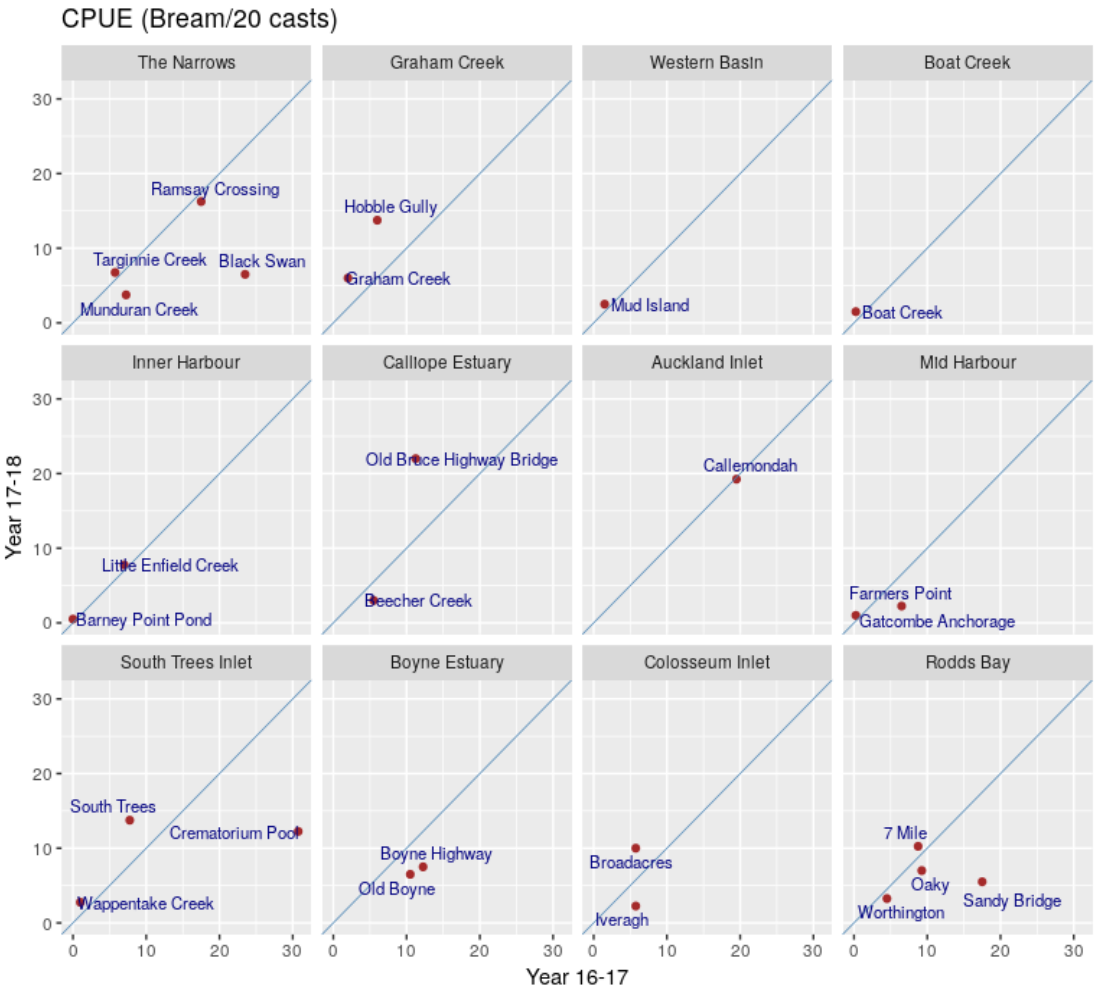

Figure 27: Bream CPUE for 2017-18 against CPUE for 2016-17 per site partitioned into recording zones

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