## Fish monitoring of the Pumicestone Shellfish Habitat Restoration Trial

### Update Report to Healthy Land and Water- June 2020

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# USC

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#### **Project Partners**

With thanks to the project partners, without whom this exciting project would not be possible



Pumicestone Passage Fish Restocking Assoc.

Kabi Kabi First Nation

#### Summary

Shellfish reefs occurred historically throughout Pumicestone Passage, but were lost due to the cumulative effects of human pressures (Diggles 2013). Healthy shellfish reefs are an important habitat for many species of finfish, including several species of commercial and recreational significance (Peterson et al. 2003, Gilby et al. 2018c). The Pumicestone Shellfish Habitat Restoration Trial seeks to restore shellfish reefs to Pumicestone Passage. The restoration project successfully deployed replicates of different types of shellfish reefs (natural/artificial mixed patch reefs, steel reef cages, and biodegradable matrix with, and without oyster shells and live oysters etc.) to Pumicestone Passage in December 2017 (i.e. stage 1). Following positive scientific results from the installation of stage 1, further reefs were installed in late 2018 and 2019 (i.e. stages 2 and 3). This included additional patch reefs, and a coir mesh bag patch reef (Diggles et al. 2018, Gilby et al. 2018a).

The purpose of this report is to detail results regarding the assemblage of fish congregating around the Pumicestone Shellfish Habitat Restoration Trial site. Our monitoring approach quantified how the restoration effort has modified fish assemblages at two spatial scales; 1) fish congregating at the shellfish reef restoration site itself, and 2) fish assemblages across the lower Pumicestone Passage from Toorbul to the Bribie Island bridge. To do this, we surveyed fish using several established underwater videography techniques both before the installation of the reefs (November and December 2017- to provide a baseline), and then every 6 months (in May-June and December) until June 2019 post the stage 1 installation. Firstly, we used baited remote underwater video stations (BRUVS) to record the number and type of fish aggregating coarsely at the reef restoration site. These baited camera approaches give a good indication of broader patterns in fish associations with coarse seascape attributes (like the reef site) as they attract fish to the camera using baits. Secondly, we used remote underwater video stations (RUVS, i.e. unbaited BRUVS) to measure the number and type of fish aggregating on individual reefs at the reef site, and to quantify patterns in fish abundance and diversity more broadly across the southern Pumicestone Passage. These unbaited camera approaches give a good indication of fish habitat associations and spatial patterns of fish assemblages as they do not attract fish to the camera, but rather record fish that passively swim by the camera.

In this report, we detail three key findings following the completion of a two additional monitoring events in December 2019 and May/June 2020 (i.e. 24 and 30 months post the initial reef installations);

- 1. The reef site contains a fish assemblage that is 3.8 times more speciose and has 16.4 and 10.7 times more harvestable fish and total fish abundance, respectively, than pre-installation surveys.
- 2. We show that the abundance of fish at the reef restoration site is so high that differences in the abundance and diversity of fish congregating around individual reef units, and therefore their contribution towards the broader fish assemblage patterns, is difficult to distinguish statistically.
- 3. We suggest that it is likely that the reef restoration action has increased the overall carrying capacity of the lower Pumicestone Passage, and therefore is unlikely to have functioned simply as a fish attracting device. This result remains preliminary, however, and will be confirmed following additional analyses that will be described in the final report.

As mentioned in the previous report, USC has recruited a doctoral student (Lucy Goodridge Gaines) to assist in completing the recent rounds of surveys and completing the upcoming final report on the project. We thank and acknowledge Lucy's contribution towards the work presented in this report. USC will submit a final report to Healthy Land and Water by September 2020. This report will focus on three key attributes of the three-year survey program- 1) the total effect of the restoration on fish assemblages (i.e. from the BRUVS data), 2) modelling the effects of the reef, seascape, and season on fish abundance and distribution across the broader southern Pumicestone Passage, and show what effect the reef restoration site has on these patterns, and 3) quantify conclusively whether the reef restoration actions increased carrying capacity in the lower Pumicestone Passage, or functioned simply as a fish attracting device.

#### **1. Scientific objectives**

The scientific objectives and aims of our monitoring have not changed to those listed in the initial proposal, and those detailed in the previous reports. The fish monitoring program around the Pumicestone Shellfish Habitat Restoration Trial seeks to fulfil two primary objectives;

- Objective one- Effects of shellfish reef restoration on fish at the restoration site
  - Structured habitats, like oyster reefs, provide important habitats in which fish seek food and projection from predators (Gilby et al. 2018b). Therefore, the oyster restoration site will likely contain significantly higher abundance and diversity of fish that adjacent control sites following restoration.
  - Objective one therefore seeks to determine how the abundance and diversity of fish changes at the restoration site, and whether there are any differences in the habitat values of the different reef unit types.
- Objective two- Effects of shellfish reef restoration on fish communities of the lower Pumicestone Passage
  - Because most coastal fish species require multiple habitats, and move between these throughout their lifecycle, the benefits of restoring oyster reefs are not restricted only to the restoration site itself (Gilby et al. 2018c).
  - Objective two therefore seeks to determine how the diversity and abundance of fish changes across the lower Pumicestone Passage following restoration.

#### 2. Methods and research plan

The monitoring methods used to survey fish around the shellfish reef restoration area have not been modified from the proposal or those used in previous interim reports. We detail them briefly below. Further details on the construction methods of the different survey apparatuses are available in interim report one (Gilby et al. 2018a), or from USC.

To date, seven surveys have been conducted around the restoration sites; in November 2017, and December 2017 (both pre-installation), and then again every 6 months to May/June 2020 (i.e. post initial installation). For the purpose of this report, both 'before' samplings have been pooled.

## Methods for objective one- Effects of shellfish reef restoration on fish at the restoration site

<u>Part A-</u> Baited remote underwater video stations (BRUVS) deployed simultaneously at 5 sites within the shellfish reef restoration area (on each of the 4 corners, and in the centre), and 10 control sites (same substrate, same seascape context) placed at least 200m from each other across the lower Pumicestone Passage on the southern bank of Bribie Island.

<u>Part B-</u> Remote underwater video stations (RUVS, essentially unbaited BRUVS which help to better determine fish-habitat associations) deployed at each of the shellfish reef restoration units, along with 16 control sites, to determine which reef restoration method supports the most diverse and abundant fish assemblages.

# Methods for objective two- Effects of shellfish reef restoration on fish communities of the lower Pumicestone Passage

A 'fish map' of the lower Pumicestone Passage, with RUVS deployed in a 200 m grid around the reef sites and throughout the lower Pumicestone Passage to determine the distribution and habitat associations of fish broadly in the Passage. This data will also be used to quantify if the reefs are simply aggregating fish (i.e. drawing them in from the surrounding seascape), or serving to increase the overall carrying capacity of the lower Pumicestone system.

From this data, we pool the abundance of the different species into three globally recognised, and key indicators of estuarine fish assemblages (Gilby et al. 2017a, Gilby et al. 2018b)-

- Species richness- the total number of individual species identified from each camera deployment,
- Harvestable fish abundance- the sum of *MaxN* values for all species harvested commercially or recreationally in southeast Queensland, and;
- Total fish abundance- the sum of *MaxN* values for all species identified from each camera deployment.

In addition, we used the abundance of yellowfin bream *Acanthopagrus australis* as an indicator species. Bream are a commonly targeted species both commercially and recreationally, are often the first species to respond to the addition of structure in southeast Queensland (Gilby et al. 2019), and are good indicators of overall ecosystem condition (Gilby et al. 2017b, Olds et al. 2018).

#### 3. Preliminary results and discussion

## *Objective one, Part A- effects of reef installation on fish communities at the reef site broadly*

We have identified 42 species of fish within the footprint of the reef site, 14 of which are harvested in commercial and/or recreational fisheries, and 55 species of fish outside the reef site, 20 of which are harvested in commercial and/or recreational fisheries during BRUVS surveys. During the pre-installation surveys, the reef site had fish assemblages averaging 2.8 species, 3.4 harvested fish, and 11.2 fish in total per BRUVS deployment. In the most recent surveys (i.e. 30 months post-installation of the first reef units), these numbers have simply exploded. Now, the reef site contains a fish assemblage that is 3.8 times more speciose and has 16.4 and 10.7 times more harvestable fish and total fish abundance, respectively, than during pre-installation surveys. This constitutes a clear statistically significant increase in the abundance and diversity of fish assemblages congregating at the reef site.

We have re-run the multivariate analyses that we first conducted in the previous report with the two additional survey points (Figure 1). We found a significant interaction between treatment (i.e. reef site versus control) and sampling period (i.e. before surveys, and every 6 months subsequent), thereby indicating that the assemblage of fish has changed significantly between the reef and control sites, and that this effect varies across time (Table 1). These results are highly encouraging, as the trajectory of the relationship in Figure 1 clearly shows a development of the fish assemblage on the reef away from the before survey assemblages, and towards an assemblage to the right of the figure which is highly distinct from the control sites (which are predominantly positioned to the top left of the figure). Fish assemblages on the reef were best explained by abundance of threadfin bream Pentapodus paradiseus (23.6% of variation), black trevally Siganus fusescens (17.64% of variation) and black trevally Siganus fusescens (16.8% of variation). Conversely, assemblages at control sites were best explained by the abundance of yellowfin bream (16.8% of variation) and sand whiting Sillago cilliata (15.26% of variation). Overall, 50% of the difference in fish assemblages between reefs and control sites were explained by the abundance of 7 key species. Black trevally (10.7% of variation), threadfin bream (9.7% of variation), yellowfin bream (9.3% of variation), eastern striped grunter *Pelates sexlineatus* (6.8% of variation), yellowfin tripodfish Tripodichthys angustrifrons (6.8% of variation) and silver biddy Gerres subfasciatus (5.9% of variation) were higher in abundance on the reef than at control sites. Conversely, sand whiting (5.9% of variation) were higher in abundance at control sites than on the reef.

The fish assemblages aggregating on the restoration site are now strongly reflective of coral and rocky reefs in broader Moreton Bay (Gilby et al. 2016). Further surveys could be conducted on reefs in Moreton Bay in similar coastal contexts (e.g. Scarborough or Woody Point) to determine how closely the fish assemblage at the restoration site reflects a fully developed, self-sustaining, and self-regulating fish assemblage on similar natural habitats elsewhere. This self-regulating and self-sustaining nature of restoration sites is a key focus of global restoration guidelines (McDonald et al. 2016).

Main test						
Source	df	SS	MS	Pseudo-F	Р	Unique permutations
Treatment (Tr)	1	13740	13740	4.71	<0.0001	
Sampling period (Sa)	3	59277	11855	4.06	<0.0001	
Tr x Sa	3	35019	7003	2.4	<0.0001	
Res	52	2.27x10⁵	2918			
Total	59	3.44x10⁵				
Pairwise tests (reefs vs control sites)						
Source	t		P(perm)	Unique permutations		
Before	0.9		0.6396		2226	
6 months	2.66		<0.001	<0.001		
12 months	1.49		0.0175		2223	
18 months	1.87	7	<0.01		2887	
24 months	1.35	5	0.06		2894	
30 months	1.71	1	0.01		2886	

**Table 1** Permutational multivariate analysis of variance (PERMANOVA) output testing for differences in fish assemblage structure between treatments and sampling events (before reef installation, and 6, 12 and 18 months post installation). PERMANOVA was calculated on square root transformed Bray Curtis dissimilarly measures. Results are visualised in Figure 1. P values in **bold** are significant at alpha=0.05.



**Figure 1** Non-metric multidimensional scaling (nMDS) ordination of centroids of fish assemblages across both treatments (reef site versus control) and sampling periods (thereby reflecting the significant interaction found in PERMANOVA; see table 1). nMDS was calculated on square root transformed Bray Curtis dissimilarity measures. In this figure, points that are closer together have a more similar fish assemblage than those that are further apart. Points within the grey ellipses are statistically similar to each other (all other points are statistically different). Arrows denote trajectory of change between monitoring events.

Patterns in our various fish indicator metrics have shown very interesting trajectories throughout the life of the project. During the 'before' installation surveys, species richness, harvestable fish abundance, and yellowfin bream abundance were not significantly different between the control and reef sites (Figure 2). Now, however, there is usually a statistically higher abundance and diversity of fish at the reef site than at control sites (Figure 2). Total fish abundance was significantly higher at the reef site during the 'before installation' surveys, but the scale of this difference has increased dramatically in the time since (Figure 2). The exception to these patterns of increasing difference between controls and reef sites was, however, the 24 month survey, when there was no significant difference between the reef and control sites for harvestable fish abundance, total fish abundance, and yellowfin bream abundance, and a significantly higher species richness at control sites than on the reef. This is a tremendously surprising result, and we will more thoroughly investigate the reasons for this result in the final report, which will include in-depth analysis of spatial patterns in fish assemblages by matching fish and time data with spatio-temporal variables that are known to drive fish abundance and diversity across coastal seascapes in southeast Queensland (e.g. salinity, proximity to mangroves, seagrass, and reefs). In figure two, it is obvious that the scale of difference between reef sites and controls is greater during the winter period surveys (i.e. 6, 18 and 30 months), as opposed to the summer surveys (i.e. 12 and 24 months). Consequently, whilst there is an overall trajectory of increasing difference between reefs and control sites throughout the project, the scale of these differences doesn't increase as expected during summer; this will also be a focus of subsequent analyses.

Overall, however, it is apparent from the results that the addition of the reef units every year adds to the overall carrying capacity of the reef restoration area, that there continues to be an accumulation of fish abundance from a variety of trophic groups at the site, and

that the restored ecosystem is functioning as an excellent fish habitat in southern Pumicestone Passage. Whether these effects are as a result of fish being attracted to the reef (i.e. the reef acts simply as a fish aggregating device), or that the reef acts to increase the overall carrying capacity of the lower Pumicestone Passage system as a whole, will be addressed using the fish map data and spatial modelling techniques in the final report (see, however, our preliminary conclusions below for objective 2).

We continue to see no significant difference in the abundance of yellowfin bream on the reef site relative to control sites (Figure 2D). Previous studies have shown that yellowfin bream are an excellent indicator of ecosystem condition and estuarine functioning in southeast Queensland estuaries (Olds et al. 2018, Henderson et al. 2019), and that their abundance is typically one of the first indicators of shellfish reef restoration success in the region (Duncan et al. 2019, Gilby et al. 2019). Further, we found a significant influence of the abundance and prevalence of yellowfin bream on our above multivariate analyses. Therefore, the continued lack of a statistical pattern for yellowfin bream here is surprising. Differences in patterns with yellowfin bream between these results and other studies may be due to differences in focal seascapes; other studies have focused more strongly on shallower estuaries, that are less flushed by tides than the lower Pumicestone Passage, which may result in a greater abundance of yellowfin bream congregating on subtidal structures (Gilby et al. 2018b, Olds et al. 2018, Henderson et al. 2019), especially during nonbreeding months (Pollock 1982a, b). We will continue to monitor the abundance of this important species over time and will identify additional indicator species with future monitoring events should the inconclusive results for yellowfin bream continue (likely those identified as driving multivariate patterns above).

## *Objective one, Part B- effects of different reefs types on the number and type of fish at the reef site*

There continues to be very little difference in the assemblages of fish congregating in the vicinity of individual reef units. All values for species richness (Figure 3A), harvestable fish abundance (Figure 3B) and total fish abundance (Figure 3C) were significantly higher at these sites during the 30 month surveys, than the pre-installation surveys, and all were either the highest, or second highest values recorded for each indicator at each reef installation type. For some reef types (e.g. crate live shell), these effects constitute nearly a doubling of the previous highest values for these metrics. These results align well with the results from objective one, part A, where we showed a significant increase in these metrics at the reef site overall, relative to controls, and a significantly greater augmentation effect of the reefs relative to previous monitoring (Figure 2). It is likely that the significant influx of fish to the reef restoration site means that fish can no longer make strategic decisions regarding which reef units to settle on.



**Figure 2** Average (A) species richness (i.e. the number of individual fish species), and abundance of (B) harvestable fish, (C) all fish (total fish abundance), and (D) yellowfin bream *Acanthopagrus australis* (+/- standard error) in the reef areas and at adjacent control sites before reef installations (November/December 2017), and then every 6 months subsequent. Stars above columns indicate significant differences between controls and reef sites for that time point at α=0.05.



#### Treatment

Treatment

**Figure 3** Average (A) species richness (i.e. the number of individual fish species), and abundance of (B) harvestable fish, (C) all fish (total fish abundance), and (D) yellowfin bream *Acanthopagrus australis* (+/- standard error) before reef installations (far left column; November/December 2017), and then every 6 months subsequent. Stars above columns indicate significant differences between that column and the before control sites at  $\alpha$ =0.05.

#### Objective two- Effects of oyster reefs on fish communities of the lower Pumicestone

'Fish maps', a gridded (200 m) camera array (for further details, see Brook et al. 2018), are used to quantify the distribution of fishes across the lower Pumicestone Passage before and after reef installation (Figure 4). This allows us to monitor 1) how the installation of the shellfish reefs enhances fish and fisheries at broader spatial scales across Pumicestone Passage, and 2) to determine whether the reefs are simply 'attracting' fish from other parts of the system, as opposed to fully augmenting fisheries and increasing overall carrying capacity across the Passage. We have now deployed over 700 cameras across southern Pumicestone Passage during the monitoring for this project, and have identified 83 different species of fish inhabiting the region, including 31 species that are targeted by recreational and/or commercial fishers.

The most numerically dominant species across the entire dataset are eastern striped grunter (25.9% of total fish abundance), silver biddy (12.3% of total fish abundance), black trevally (11.4% of total fish abundance) threadfin bream (5.3% of total fish abundance) and yellowfin bream (4.4% of total fish abundance). Overall, 41% of individuals observed on camera deployments are of species targeted by recreational fisheries in southeast Queensland (Webley et al. 2015, Froese and Pauly 2019); a significant increase in this proportion since the last report in June 2019.

Patterns in fish abundance and distribution across southern Pumicestone Passage continue to show change through time (Figure 4). Whilst initial surveys indicated that there was likely an initial 'attraction' effect of the reef on fish abundance and diversity, results since have indicated 1) a more even spreading of fish abundance and diversity across southern Pumicestone Passage, and 2) variation in the position of highest abundance of fish depending on time since installation, and season (Figure 4). In this sense, hotspots in fish abundance and diversity have consistently occurred to the north and to the south west of the reef restoration site in the passage (Figure 4). These hotspots from the 24- and 30-month surveys now reflect the position of hotspots from the 'before' installation surveys, thereby potentially indicating that fish have redistributed throughout the lower estuary following the initial 'attraction' effect that we observed (Figure 4). These patterns are further supported by the patterns shown in Figure 5. Here, whilst there was a spike in average total fish abundance and harvestable fish abundance in 18- and 30month surveys, respectively, the evidence suggests that the abundance of fish across the lower Pumicestone passage has remained fairly consistent through time (Figure 5A, C). Similarly, when pooled together, there is little to no slope in the relationship between fish abundance and distance to the oyster reef site, thereby indicating a statistically non-significant effect of proximity to reef on fish assemblages following reef installation (P>0.05) (Figure 5 B, D). Considering these results (i.e. little change in the abundance and distribution of fish assemblages through time and space across southern Pumicestone Passage) in the context of the results we found above for Objective 1 (i.e. significant increases in fish abundance at the restoration site), this indicates that the reef is likely functioning to increase the overall carrying capacity of southern Pumicestone Passage, and not simply act as an attracting device for fish already present. Whilst these results require further analysis using full spatial analytical methods, these more simply analysed patterns are an excellent indication of the potential for the reef to have enhanced fish abundance and carrying capacity broadly across the Pumicestone Passage



**Figure 4** Fish 'heat maps' of the distribution of species richness, harvestable fish abundance, and total fish abundance before (left column) and for the three monitoring events following reef installations (6, 12, 18, 24 and 30 months post installation; remaining columns) in Pumicestone Passage. Shading in the background scales from blue (low values), to orange, then red (highest values). For example, blue shading indicates very low abundance of fish (<2 individuals, or <2 species), whereas the red shaded areas indicate very high (>10 individuals, or >5 species) abundance around these sites.



Figure 5 Effects of time (A and C) and distance to reef restoration site (B and D) on total fish abundance (A and B) and harvestable fish abundance (C and D) from the 'FishMap' data. These analyses show a significant change in the effect of proximity to reef over time, depending on time since installation. Further analyses will be conducted on these patterns through time in the final report.

#### **Key conclusions and future directions**

#### Key results from this monitoring event

- Results from surveys continue to show that the abundance and diversity of fish congregating at the reef restoration site is significantly higher than at nearby control sites.
- Individual reef units continue to be difficult to statistically distinguish from other reef units. This is likely due to the very high abundance of fish congregating at the reef restoration site more broadly.
- We suggest that the combined significant increase in abundance of fish on the reef, matched with little change over time in the abundance and distribution of fish more broadly throughout the estuary indicates that the reef restoration action has increased the overall carrying capacity of southern Pumicestone Passage, and therefore has not functioned simply as a fish attracting device. This remains, however, a preliminary result, and must be confirmed further via thorough statistical analysis in the final report (see below).

#### Key scientific questions to be addressed in the final report

We will complete a final report on these initial surveys for Healthy Land and Water in the coming months. In this report we will;

- Quantify whether environmental variables relating to 1) the position of the reef sites, and 2) the position of individual monitoring sites affect fish assemblages, and how the addition of reef units to the restoration site over time modifies this affects, and;
- related to the above point, confirm whether installation of the reef simply attract fishes, or does it eventually increase the carrying capacity of the system by supplying additional habitat?

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