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Pumicestone Passage Shellfish Reef Habitat Restoration Project – 9 Month Invertebrate Monitoring

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Summary

Samples of oyster shells were obtained from various different types of experimental subtidal oyster reefs deployed as part of the Pumicestone Shellfish Habitat Restoration Trial. The oyster shells (n = 100 per reef module) were examined for evidence of natural spatfall of Sydney rock oysters (*Saccostrea glomerata*) and colonization by various other invertebrates. Results from the samples confirm that natural *S. glomerata* spatfall occurred subtidally in the restoration area, with an average of 56.16 spat collected from 100 shells. Spatfall was highest on shells in crate modules (mean 80.33 spat per 100 shells, range 64-98) and lower on patch reefs (mean 32 spat per 100 shells, range 28-34). Also evident was prolific colonisation by corraline algae and soft corals, which helped cement the loose shells together into a reef formation. There was evidence of users anchoring on the reefs (one lost anchor was found on a crate reef), and many of the besser blocks used as fences were dragged several meters away from the patch reefs. Observations by divers together with underwater photographs confirmed that sedimentation was also problematic along the edges of most of the reefs (particularly patch reefs). This "edge effect" problem could possibly be reduced by increasing the area and height of the shell piles (from c. 2 x 2 meters and 40 cm to >4 x 4 meters x 60-75 cm) and using a more robust "fence" system around the patch reefs to retain shell and reduce anchor damage. A 15 minute underwater video of one degraded patch reef still demonstrated use by a large number of fishes, including (in order of abundance) silver biddy, whiptail, moses perch, grass tuskfish, happy moments, Gunther's wrasse, yellowfin bream, and snapper. Patch reefs appeared to provide ready access to fish for grazing and foraging, but were also more prone to sedimentation. Overall these results are very encouraging and these observations of reef performance will be useful to inform deployment of more effective reef designs during the second summer infill deployment period (December/January 2018/19).

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1.0 Introduction

Archaeological and historical records indicate the existence of extremely abundant populations of reef forming shellfish in the coastal bays and estuaries of Pumicestone Passage, Moreton Bay and other estuaries in Southern Queensland prior to European settlement (Diggles 2015). However, today most shellfish reef habitats in Australia are functionally extinct (Beck et al. 2011), including 100% loss of subtidal shellfish reefs and around 96% loss of vertical zonation of oysters in Pumicestone Passage over the last 125 years, due mainly to ecological processes associated with catchment development (Diggles 2013). Realization of the large extent of the loss of ecosystem services historically provided by shellfish reefs in Australia has led to recent efforts to restore them (Gilles et al. 2015), with shellfish reef restoration projects now occurring in several Australian States (Gilles et al. 2018).

In Moreton Bay the historically dominant reef forming shellfish species was the Sydney rock oyster (*Saccostrea glomerata*) (see Smith 1981, Diggles 2015). Despite the extinction of subtidal shellfish reefs in Pumicestone Passage, micro-trials in 2014-16 confirmed the presence of natural subtidal recruitment of *S. glomerata* in that waterway, suggesting shellfish restoration was feasible provided clean substrate was deployed at an appropriate time of year (Diggles 2017). Armed with that knowledge, the Pumicestone Shellfish Habitat Restoration Trial was undertaken with the aim of investigating various methods for restoring lost subtidal oyster reefs to the lower Pumicestone Passage.

In early December 2017, 16 modules of six different types of experimental oyster reefs (patch reefs filled with recycled oyster shells and surrounded by artificial (concrete module) fences with and without live oysters on top, steel wire cages (crates) filled with recycled oyster shells with and without live oysters on top, and a biodegradable matrix (BESE) with and without oyster shells) were deployed into a site in southern Pumicestone Passage (Figures 1,2, Table 1). A fish monitoring study 6 months later (May 2018) found a doubling in both total fish abundance and species richness when compared to baseline data from the area (Gilby et al. 2018). The present study was undertaken 9 months post–deployment to examine the deployed shells for evidence of natural subtidal recruitment of *S. glomerata* and other invertebrates.

2.0 Method

Divers undertook sampling of the various subtidal reef modules in the study area during the low tide on 6 September 2018. Each of the reef modules was first located and marked with a marker buoy (Figure 3) before the divers inspected them and obtained a sample of shells (>100 shells per unit) which were placed in a fine mesh (3 mm) dive bag and taken to the surface. Once on board the attending boat the shells were placed into a fish bin and visually examined for recruitment of *S. glomerata* and other invertebrate symbionts. Photographs of the condition of the reefs were taken using an underwater camera (GoPro Hero3+) and a 15 minute video was taken over one of the degraded patch reefs (Reef #16, Table 1) using an unattended GoPro deployed on a brick to examine fish activity and ascertain whether the damaged patch reefs were still providing useful fisheries habitat. Water quality data was obtained using a YSI85 DO/Temp/salinity/conductivity probe and a secchi disk.

Figure 1. Location of the study area (1) in Pumicestone Passage, Northern Moreton Bay.

Table 1. Details of the locations and types of experimental oyster reefs examined.

Reef Number	GPS co ordinates Latitude	Longitude	Depth (m)	Reef type	Spatfall / 100 shells	Condition
1	27.0513 S	153.1331 E	3.5	Crate (wire cage, covered)	79	good
2	27.0511 S	153.1329 E	3.7	Patch	34	good
3	27.0514 S	153.1327 E	3.5	BESE w/Live Oysters	n/a	good
4	27.0512 S	153.1326 E	3.8	Patch w/Live Oysters	n/a	unknown
5	27.051 S	153.1326 E	3.8	BESE	n/a	good
6	27.051 S	153.1327 E	3.8	Crate (wire cage, uncovered)	64	good
7	27.0511 S	153.133 E	3.7	BESE W/Live Oysters	n/a	good
8	27.0508 S	153.1328 E	4.2	BESE	n/a	good
9	27.0506 S	153.133 E	4.5	Patch	28	poor
10	27.0505 S	153.1325 E	4.7	BESE w/Live Oysters	n/a	good
11	27.0505 S	153.1323 E	5	Crate w/Live Oysters	n/a	unknown
12	27.0503 S	153.133 E	4.8	Crate w/Live Oysters	98	good
13	27.0501 S	153.1328 E	4.9	BESE w/Live Oysters	n/a	good
14	27.0501 S	153.1327 E	4.9	BESE	n/a	good
15	27.0502 S	153.1325 E	4.9	BESE	n/a	good
16	27.0501 S	153.1324 E	5	Patch w/Live Oysters	34	poor
Total				Mean spatfall per 100 shells	56.16	

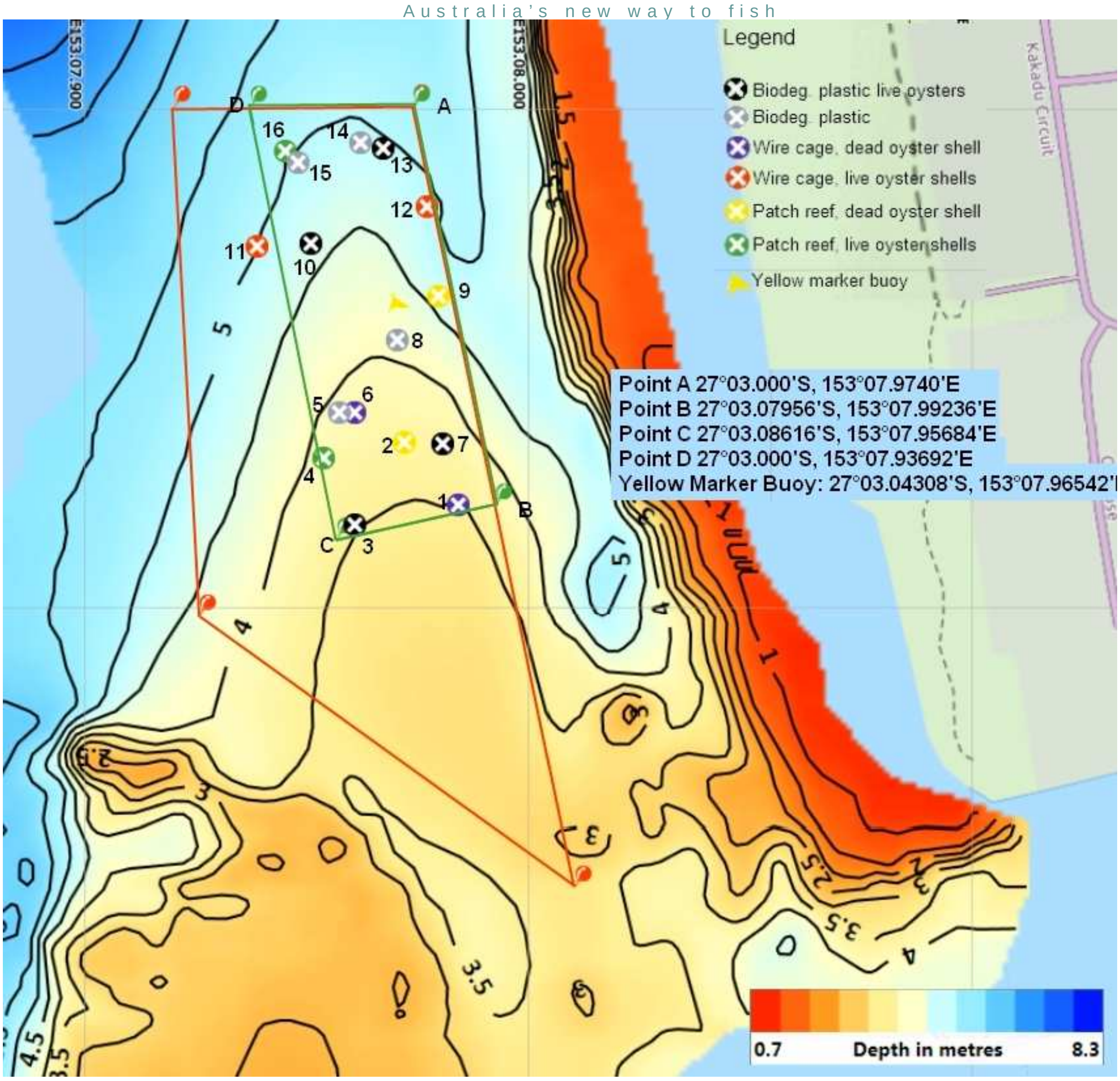


Figure 2. Detailed map of the project area showing bathymetry and layout of the experimental reef modules. Description of reef numbers as per Table 1.

Figure 3. Each module was marked with a temporary marker buoy before being dived upon for sampling. All marker buoys were removed upon completion of sampling.

3.0 Results

3.1 Water quality

Water quality data obtained on the day (Temperature 18.6°C, salinity 36 ppt, DO 7.8 mg/L (102% saturation), secchi depth >2.5 meters) showed that conditions were suitable for oyster growth.

3.2 Sydney rock oyster spatfall

Strong currents prevented divers from having sufficient bottom time to sample shell from all the available crate and patch reef modules (n = 8 in total). There was insufficient time to locate reefs 4 and 11, however, samples of 100 shell were obtained from the other six reef modules, namely module #'s 1,2,6,9,12, and 16. Shells were not available from the BESE modules and these were inspected for general condition only. Spat of *S. glomerata* were observed in samples taken from all modules examined at an average of 56.16 spat counted per 100 shells sampled (Table 1). The mean spatfall from the crate modules examined (crates 1, 6 and 12) was 80.33 spat per 100 shells (range 64-98 spat per 100 shells). In contrast, the average spatfall for the patch reefs examined was much lower at 32 spat per 100 shells (range 28-34, see Table 1, Figure 4).

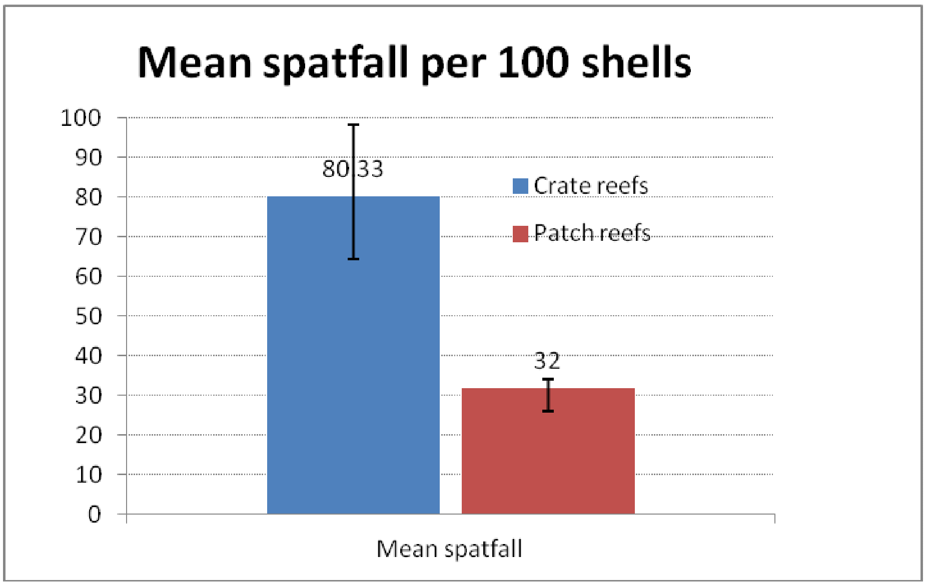


Figure 4. Results for natural *S. glomerata* spatfall on oyster shells collected from crate reef modules and patch reefs after 9 months subtidal deployment in Pumicestone Passage. Spatfall was higher on crate reefs.

The mean size of live *S. glomerata* spat obtained from reef modules supplied with dead shell was between 10 and 14 mm (Table 2) which is considered typical and representative of natural spatfall less than 9 months old (Figure 5). The live oysters sampled from modules originally supplied with live shell had a higher average size, probably due to divers sampling of some of the live oysters originally laid over the modules during deployment. Samples of shells also found evidence of abundant recruitment of other reef forming organisms binding the shells together into a reef matrix, including several species of corraline algae, colonial tunicates (Figure 6), and soft corals.

Figure 5. Evidence of natural *S. glomerata* spatfall on oyster shells collected 9 months post-deployment from a subtidal reef module in Pumicestone Passage.

Figure 6. Colonisation of an oyster shell by colonial tunicates, corraline algae and barnacles after 9 months deployment on a subtidal reef module in Pumicestone Passage.

Table 2. Details of *S. glomerata* spatfall and other bivalves and invertebrates found in samples of 100 shells obtained from the sampled reef modules.

Reef Number	Reef type	Spatfall /100 shells	Mean (range) spat size (mm)	Other bivalves	Crabs, shrimp	Other invertebrates
1	Crate (wire cage, covered)	79	10.55 (5-25)	1 glory scallop	9	1 gastropod +++ corraline algae
2	Patch	34	10.11 (5-20)	2 hammer shells 2 glory scallops	11	1 gastropod 1 flatworm 6 seasquirts
6	Crate (wire cage, uncovered)	64	11.81 (5-25)	-	15	1 flatworm amphipods +++ corraline algae
9	Patch	28	14.17 (9-17)	2 *Hyotissa*	-	Brittle starfish
12	Crate w/Live Oysters	98	13.94 (5-30)	15 Leaf oysters 1 pearl oyster 67 hairy mussels	5	+++ corraline algae
16	Patch w/Live Oysters	34	35.57 (6-60)	2 hammer shells 2 glory scallops 1 *Dendostrea*	-	-
Total	Mean	56.16				
9	Besser block removed by anchor damage	9 (66% dead)	46.7	-	10	28 sea squirts 2 nudibranchs +++ corraline algae +++ barnacles

3.3 Reef condition

There was evidence of users anchoring in the reef area as one lost anchor was found on crate reef #1, and many of the besser blocks used as fences for patch reefs 9 and 16 were dragged several meters away and scattered over the bottom. All of the besser blocks observed had heavy growth from barnacles and reef forming invertebrates. For example, a single besser block found isolated on the bottom several meters away from its presumed original location on patch reef#9 was retrieved and examined (Figure 7). The exterior was heavily fouled with barnacles, corraline algae, and several types of brown and green macroalgae, while the interior of the block contained 9 Sydney rock oysters, 3 of which were alive and 6 dead (33% survival). Inside and adjacent to the oysters were 2 Palaemonid shrimp (*Palaemon serenus*) (Figure 8), Caridean snapping shrimp (*Alpheus* sp.) 7 small (10 mm carapace width) black crabs (Xanthidae), 1 larger portunid crab (*Charybdis* sp., 70 mm carapace width, Figure 9), and 2 nudibranchs amongst 28 sea squirts (*Pyura* sp.) and dense corraline algae. The concrete besser blocks used as fences around two of the three patch reefs thus provided additional valuable reef substrate, but because of anchor damage they appear too small to effectively fulfill their primary role as fences to retain shell. The oyster reef balls used around the third patch reef (#2) remained in place.

The condition of the 2 patch reefs that used besser blocks was rated as poor. Only patch reef #2 (the only patch reef surrounded by the heavier, more stable oyster reef balls) was rated in good condition (Table 1, Appendix 1). For patch reefs #9 and 16, there was evidence of sedimentation along the edges especially where besser blocks had been displaced by anchors (Figure 10, Appendix 1). The condition of patch reef #4 is currently unknown as it could not be located in the time available.

Figure 7. Condition of a single besser block found isolated on the bottom several meters away from patch reef#9. Dense growth of barnacles barnacles, corraline algae, and several types of brown and green macroalgae are evident externally.

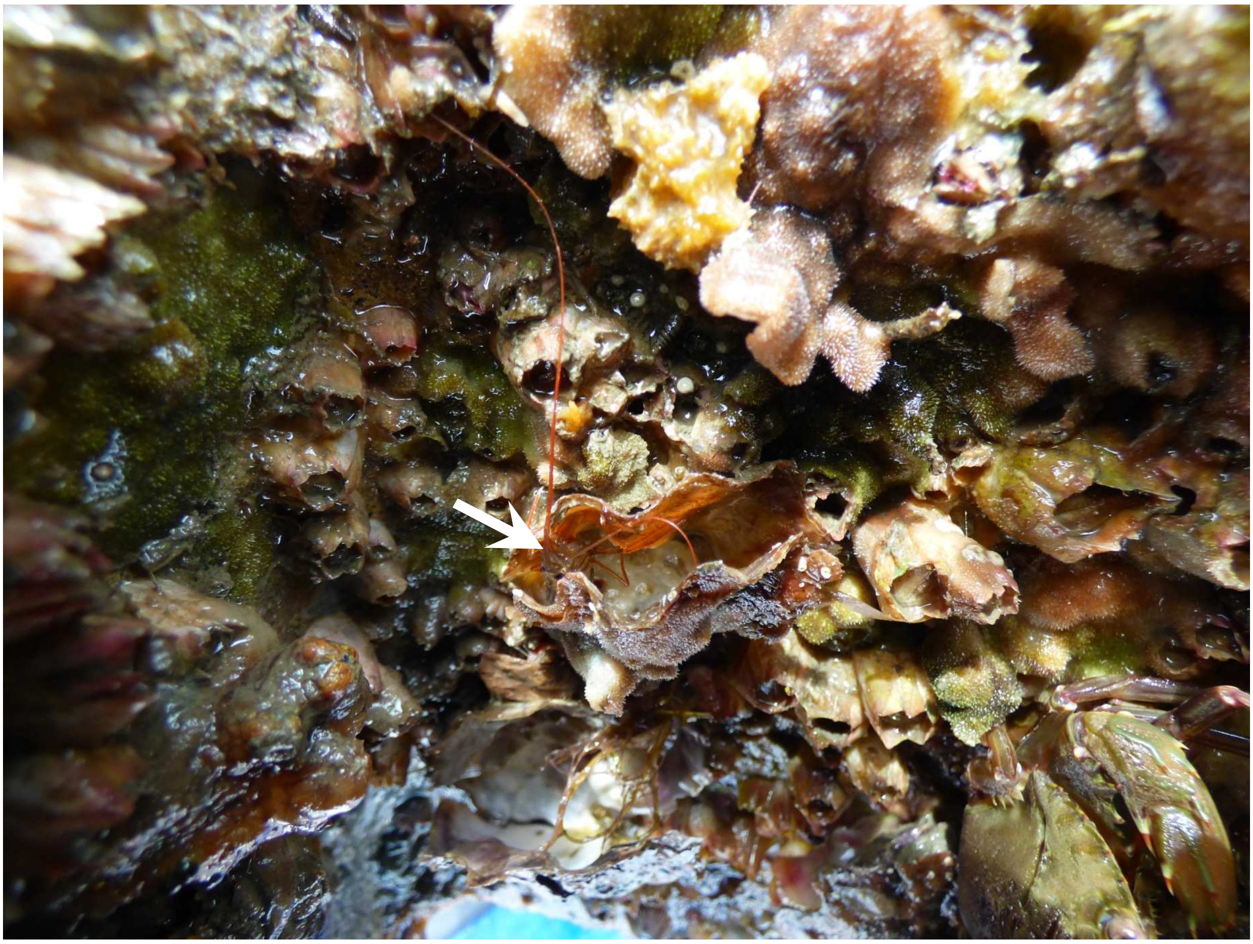


Figure 8. Palaemonid shrimp (arrow) hiding inside a dead oyster shell inside the besser block shown in figure 5. A portunid crab is also visible in the bottom right of the photo.

Figure 9. A portunid crab (*Charybdis* sp.) hiding amongst dead and live Sydney rock oyster (*S. glomerata*) shells (arrows) recruited inside the besser block shown in figure 5.

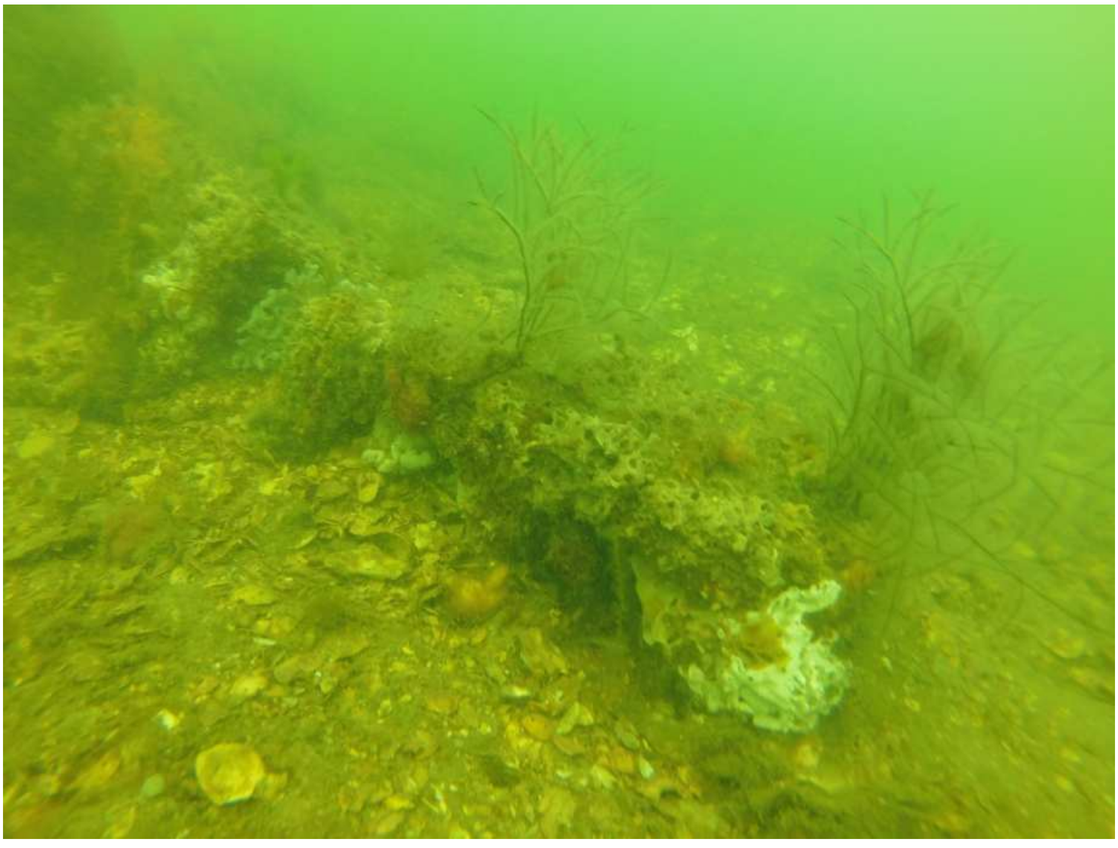


Figure 10. Besser block fence surrounding patch reef #16, showing sediment infilling around the edge of the reef where the integrity of the fence was disturbed by anchors.

In contrast to the patch reefs, the BESE modules and crate reefs appeared in relatively good condition, exhibiting dense fouling with barnacles, corraline algae, macroalgae, colonial tunicates and soft corals (Table 1, Appendix 1). There was little evidence of oyster shells being displaced from crate reefs that remained uncovered by wire mesh, however it was evident that wire mesh on crate reef #1 did reduce access to the shellfish by larger fish (Appendix 1).

3.4 Gopro footage of Reef unit16 (patch reef with live shell)

To ascertain whether patch reefs degraded by anchor damage still provided useful fish habitat, a GoPro camera was deployed on a brick on patch reef #16 for 15 min from around 1.30 pm to 1.45 pm. The resulting video has been uploaded on the internet at:

https://youtu.be/lBuN0dCKjb4

The video revealed extensive use of the patch reef by at least 9 species of finfish (Table 3). In order of greatest to least abundance, the species observed included silver biddy, whiptail, moses perch, grass tuskfish, happy moments, Gunther's wrasse, yellowfin bream, and snapper (Table 3). Activities observed included direct grazing on the reef (silver biddy, whiptail, grass tuskfish, happy moment), or swim bys (yellowfin bream, snapper, moses perch).

Table 3. Species of fish observed associating with degraded patch reef #16 in a 15 minute video taken at 1.30 pm on 6 September 2018.

Fish name	Latin name	Approx # views	Activity
silver biddy	*Gerres subfasciatus*	>50	grazing on reef
whiptail	*Pentapodus paradiseus*	30-40	grazing on reef
moses perch	*Lutjanus russelli*	10-20	swim by
grass tuskfish	*Choerodon cephalotes*	10-20	grazing on reef
happy moment	*Siganus fuscescens*	10-20	grazing on reef
Gunthers wrasse	*Pseudolabrus guentheri*	<10	swim by
blacksaddle goatfish	*Parupeneus spilurus*	3-4	swim by
yellowfin bream	*Acanthopagrus australis*	3-4	swim by
snapper	*Chrysophrys auratus*	1-2	swim by

The previous underwater footage we have of this area is at the end of the video transects #1 and #3 from the pre-project monitoring for site 1, available at:

https://www.youtube.com/watch?v=H58T2xrK12g&list=PLqVK7e16TgMFgi8QgTp28heGe71ZPH3Sd&index=1

https://www.youtube.com/watch?v=SAsPtwZ6xhw&t=413s&list=PLqVK7e16TgMFgi8QgTp28heGe71ZPH3Sd&index=4

The "before and after" comparisons are stark (Figures 11, 12, 13, 14). Observations using depth sounders also show fish concentrating and browsing directly above the patch reefs in particular (Figures 15, 16). These changes following deployment of the tiny experimental subtidal shellfish reefs suggest that restoration of subtidal shellfish reef habitat potentially could provide significant biodiversity benefits for degraded areas in Pumicestone Passage and Moreton Bay if they were deployed on a larger scale.

Figures 11 and 12. Before and after comparison of benthic condition**. Figure 11** (above) shows muddy bottom near end of Transect #1, in Jan 2017. Figure 12 (below) Patch reef #16, near same location, 6 Sept 2018, large numbers of fish are evident browsing on the oyster shell substrate.

Figures 13 and 14. Before and after comparison of patch reef #2**.** **Figure 13** (above) photo taken immediately after deployment, Dec 2017. **Figure 14** (below), photo on 6 Sept 2018, note prolific sponge/soft coral growth on oyster reef balls and also over shells.

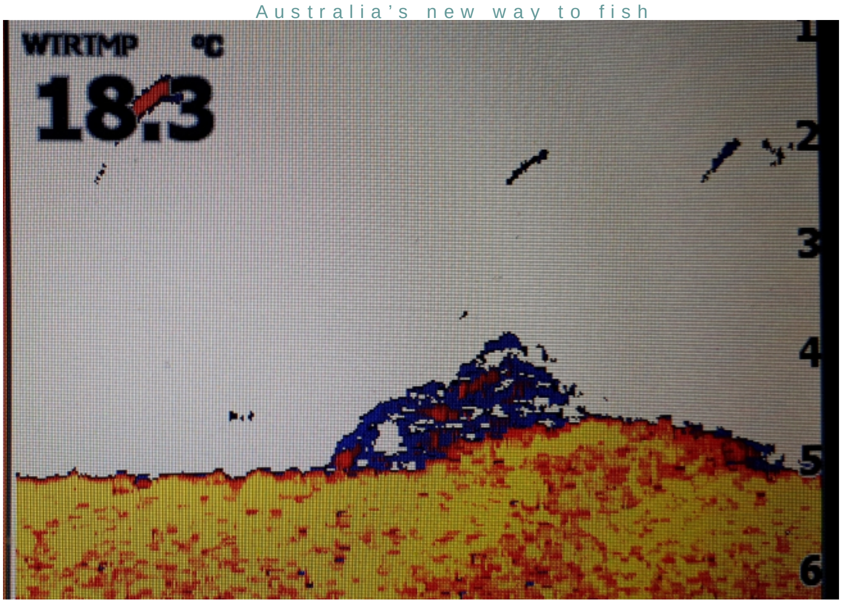


Figure 15. Sounder screenshot in May 2018 of patch reef #9 with browsing fish evident.

Figure 16. Typical undersized snapper captured by a young angler over patch reef #9 in May 2018. This fish was released after the photo was taken.

Discussion

Results from these samples confirm that natural *S. glomerata* spatfall occurred subtidally in the restoration area, with an overall mean of 56 spat per 100 shells sampled from crate and patch reefs (maximum 98 spat per 100 shell sample from a crate reef overlaid with live shell). Spatfall was greater on average on shells obtained from crates (mean 80.33 spat per 100 shells) compared to shells on patch reefs (mean 32 spat per 100 shells). It is hypothesised that shells placed in the top layers of the crates (i.e. in places 60-70 cm above the bottom most easily accessible to divers) may be better protected from sedimentation compared to shells on patch reefs, which appeared more susceptible to sedimentation once the besser block fences had been disturbed (Figure 10, and photos of individual reefs in Appendix 1). It was encouraging, however, to observe that the one patch reef which used oyster reef balls as a fence remained in good condition. Also evident on reefs of all types was prolific colonisation by corraline algae, colonial tunicates and soft corals. These epibionts probably would contribute to a smothering situation that would prevent oyster spatfall to a certain extent, however on the other hand these invertebrates also helped bind the loose shells together into a monolithic reef formation. The abundance of various different invertebrates clearly demonstrated a significant increase in biodiversity had occurred compared to the shelly mud bottom previously present in the restoration area.

Observations by divers together with underwater photographs (see Appendix 1) confirmed that anchor damage and sedimentation were both problematic, especially in patch reefs which used besser blocks as fence material. Anchor damage is likely to be greatly reduced if boating users in the immediate vicinity of the reefs could be warned by signage not to anchor in the restoration area. Sedimentation effects were evident along the edges of most of the reefs regardless of configuration. For the patch reefs, this "edge effect" problem could possibly be reduced by increasing the area and height of the shell piles (from c. 2 x 2 meters and 40-50 cm to at least 4 x 4 meters and 60-75 cm high) and using a more robust "fence" system around the patch reefs to retain shell and help reduce anchor damage.

A 15 minute underwater video of one degraded patch reef (reef #16) still demonstrated use by a large number of fishes, including (in order of abundance) silver biddy, whiptail, moses perch, grass tuskfish, happy moments, Gunther's wrasse, yellowfin bream, and snapper. Patch reefs appeared to provide superior access to fish for grazing and foraging compared to BESE and crate reefs (Figure 15, GoPro video of reef module #16), however the downside of the patch reef formation was they appeared more prone to anchor damage (if properly designed reef fencing modules were not used) and subsequent sedimentation. Overall these results are very encouraging and these observations of reef performance will be useful to inform deployment of more effective reef designs during the second summer infill deployment period (December/January 2018/19).

References

Beck MW and 14 other co-authors (2011). Oyster reefs at risk and recommendations for conservation, restoration, and management. *Bioscience* 61: 107-116.

Diggles BK (2013). Historical epidemiology indicates water quality decline drives loss of oyster (*Saccostrea glomerata*) reefs in Moreton Bay, Australia. *New Zealand Journal of Marine and Freshwater Research* 47: 561-581.

Diggles BK (2015). Protection and repair of Australia's shellfish reefs – Southern Queensland Report. DigsFish Services Client Report DF15-01. September 2015. 27 pgs. http://restorepumicestonepassage.org/wp-content/uploads/2014/04/NESP-Project-Southern-Queensland-Report-DigsFish.pdf

Diggles BK (2017). Annual pattern of settlement of Sydney rock oyster (*Saccostrea glomerata*) spat in Pumicestone Passage, Moreton Bay. *Proceedings of the Royal Society of Queensland*, 122: 17-33.

Gilby B, Brook T, Duncan C, Ortodossi N, Henderson C, Olds A, Schlacher T (2018). Fish monitoring of the Pumicestone Shellfish Habitat Restoration Trial. Interim report 1 to Healthy Land and Water- June 2018.

Gilles CL and 22 other co-authors (2015). Scaling up marine restoration efforts in Australia. *Ecological Management and Restoration* 16(2): 84-85.

Gilles CL, McLeod IM, Alleway HK, Cook P, Crawford C, Creighton C, Diggles BK, Ford J, Hamer P, Heller-Wagner G, Lebrault E, Le Port A, Russell K, Sheaves M, Warnock B (2018). Australian shellfish habitats: past distribution, current status and future direction. *PLOS One* http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0190914

Smith G (1981). Southern Queensland's oyster industry. *Journal of the Royal Historical Society of Queensland* 11: 45-58.

Project partners

The various partners involved with this project are listed below. Many thanks to all partners together with Bribie's oyster gardeners and the broader community for their efforts and support as we continue our journey towards restoration of the lost shellfish reefs in Pumicestone Passage and Moreton Bay.

Joondoburri Land Trust

Sebastiani Oyster Farm

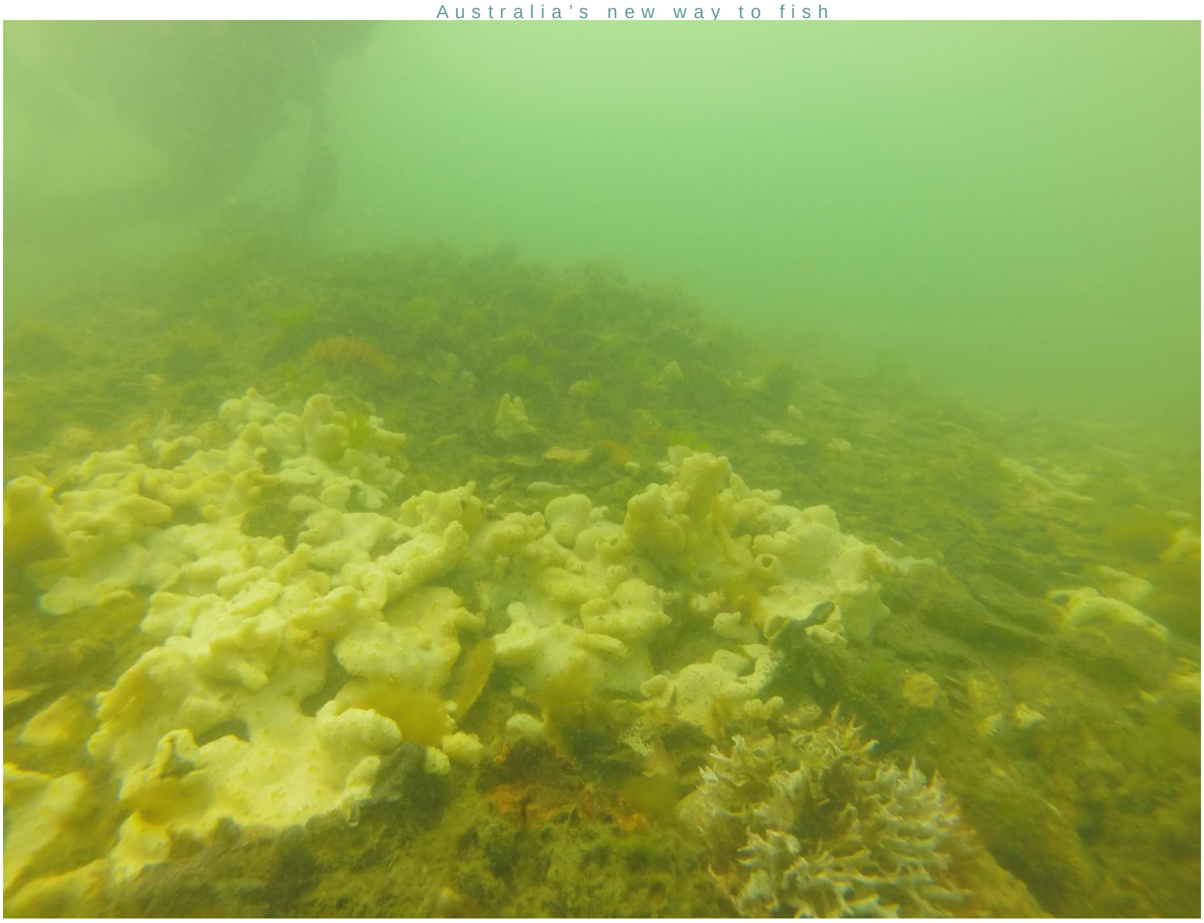
Pumicestone Passage Fish Restocking Assoc.

Kabi Kabi First Nation

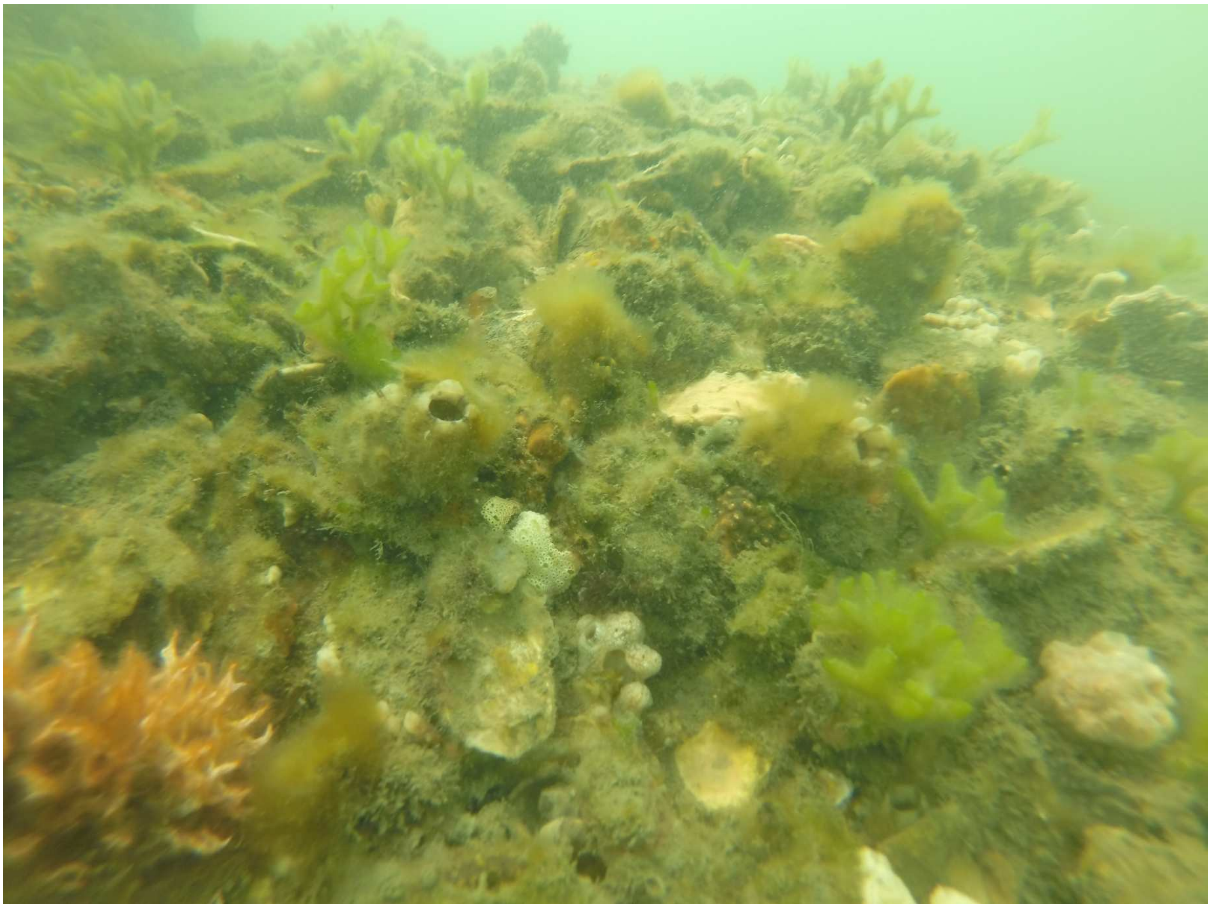
Appendix 1. Photographs of module condition

Reef Module #1 – Crate (wire cage) with dead shell (covered with mesh). Side 1.

Reef Module #1 – Crate (wire cage) with dead shell (covered). Note sedimentation (right). 2.

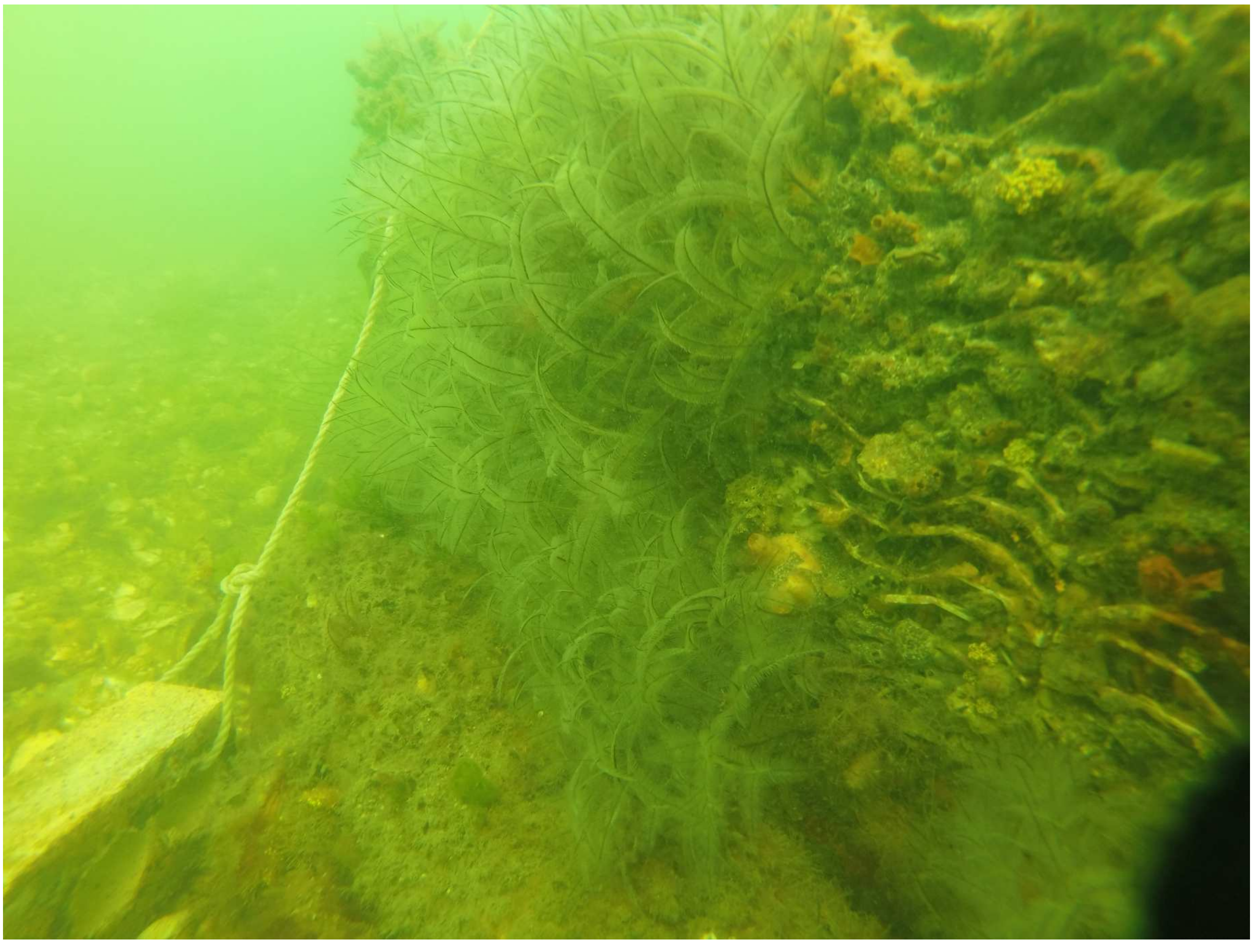


Reef Module #2 – Patch reef with dead shell. Note lack of sedimentation.



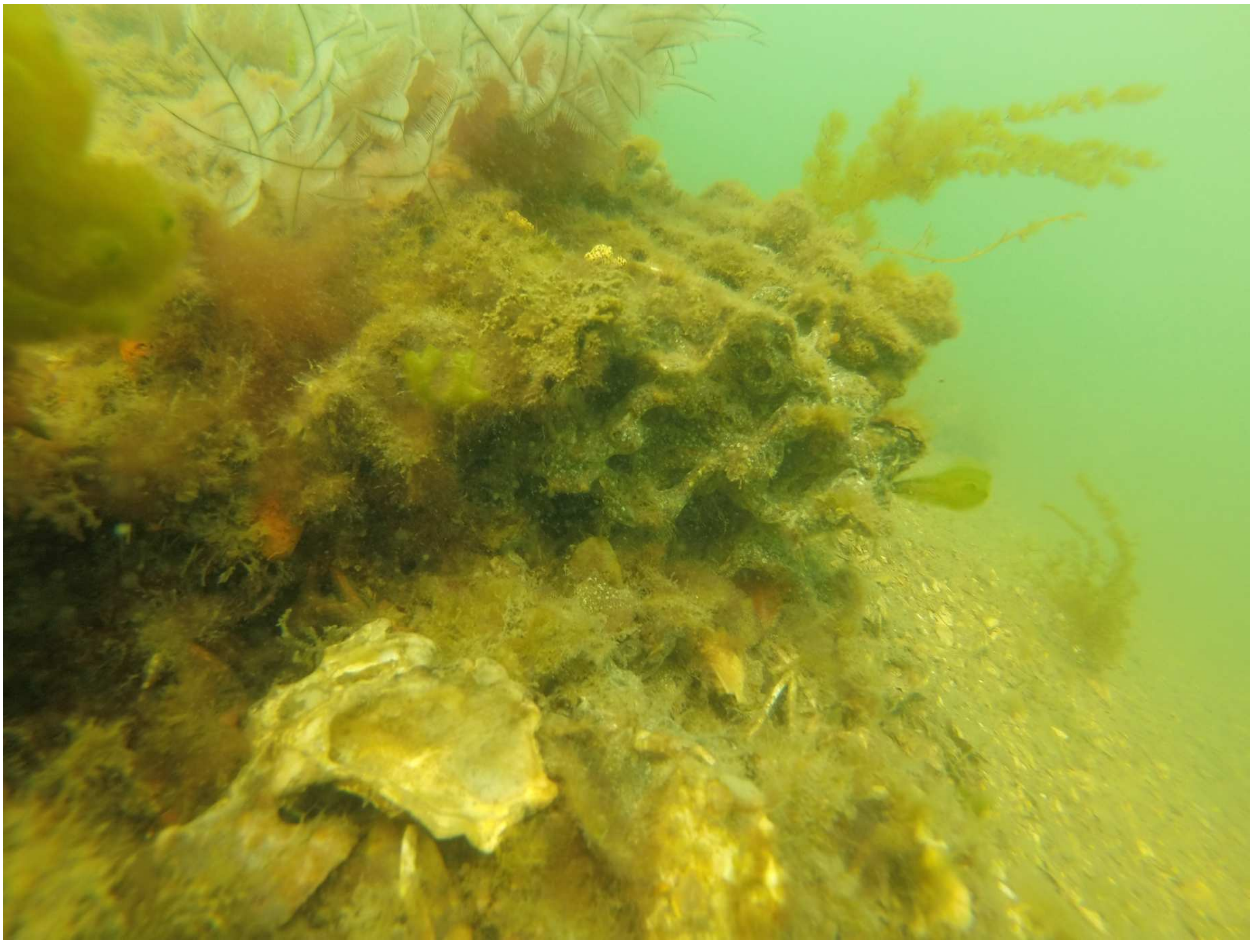
Reef Module #2 – Patch reef with dead shell. Closeup of invertebrate colonization of shells.

Reef Module #5 – BESE module. Top of module showing macroalgal/invertebrate growth.



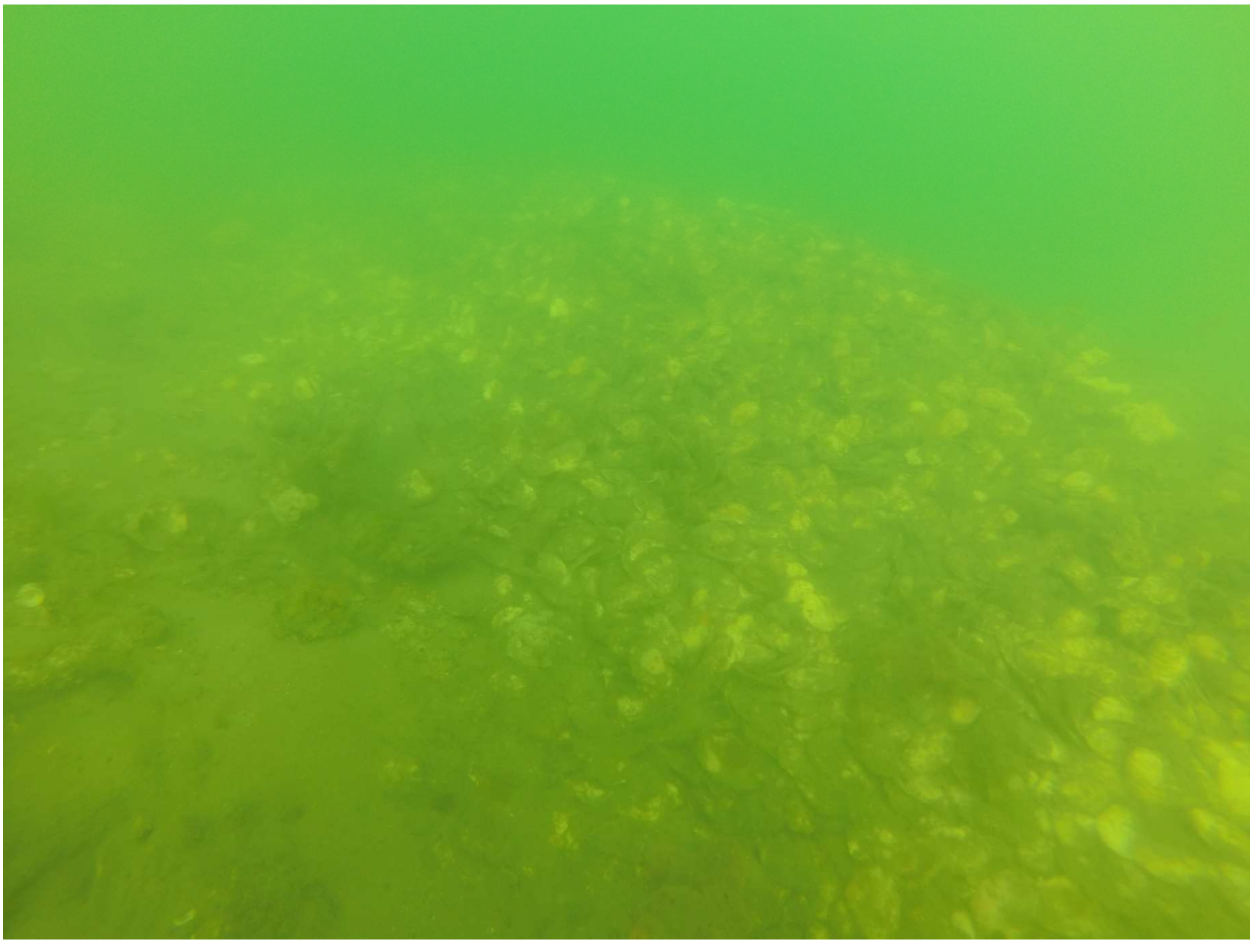
Reef Module #5 – BESE module. Edge showing temporary marker anchor and reef growth.

Reef Module #7 – BESE module with shell. Top of module showing macroalgal growth



Reef Module #7 – BESE module with shell. Detail showing edge sedimentation and shells.

Reef Module #9 – Patch reef with dead shell. Note macroalgal overgrowth and loss of fence.

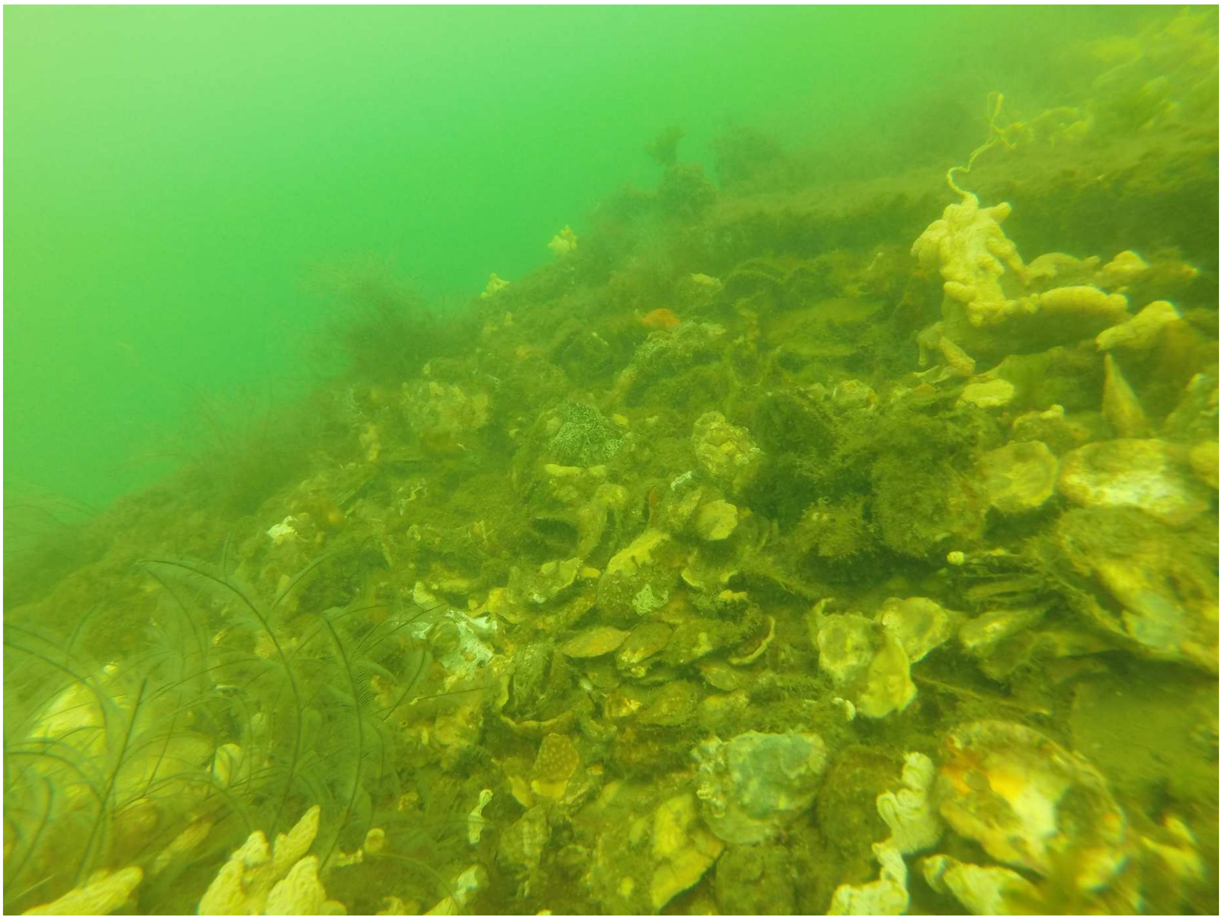


Reef Module #9 – Patch reef with dead shell. Note edge sedimentation to left of photo.

Reef Module #10 – BESE module with live oysters. Note reef growth along vertical sides.

Reef Module #10 – BESE module with live oysters. Note edge sedimentation to left of photo.

Reef Module #12 – Crate (wire cage) with live shell (uncovered). Note reef growth and fish.



Reef Module #12 – Crate (wire cage) with live shell (uncovered). Note fish (absent as were scared away by the diver) have full access to the shell/live shellfish mix on top of cage.

Reef Module #14 – BESE module. Note edge sedimentation to left and concrete mooring.

Reef Module #14 – BESE module. Note mix of macroalgal and reef growth.

Reef Module #16 – Patch reef with live shell. Note sedimentation of edge (left) due to damage to besser block fence (see also Figure 10), and apparent lack of fish due to diver presence (compare to fish evident in video presented in Section 3.4).