Fish monitoring of the Pumicestone Shellfish Habitat Restoration Trial

Interim report 1 to Healthy Land and Water- June 2018

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June 2018

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Summary

Oyster reefs occurred historically throughout Pumicestone Passage, but were lost due to the cumulative effects of human pressures (Diggles 2013). Healthy oyster reefs are considered an important habitat for many species of finfish, including several species of commercial and recreational significance (Peterson et al. 2003, Gilby et al. 2018b). The Pumicestone Shellfish Habitat Restoration Trial seeks to restore oyster reefs to the lower Pumicestone Passage. The restoration project successfully deployed replicates of four different types of oyster reefs (natural/artificial mixed patch reefs, steel reef cages, and biodegradable matrix with, and without oyster shells) to Pumicestone Passage in December 2017. Whilst there are several broad aims for the project, a key aim is to enhance populations of fish across Pumicestone Passage.

This report outlines the preliminary results of fish surveys conducted at both the reef site itself, as well as more broadly throughout lower Pumicestone Passage. The principal goal is to determine the degree to which the restoration of the oyster reefs also enhances fish and fisheries across the lower Pumicestone Passage. To do this, we surveyed fish using several established videography methods both before the installation of the reefs (November and December 2017- to provide a baseline), and approximately 6 months after the reefs were installed (May 2018).

Overall, we found that the abundance of fish has increase at the reef site since the reef installations in December. Specifically, we have noted up to a doubling in the total number (in terms of total fish abundance), the number of fish species (species richness) and the number of fish that we like to catch and eat (harvestable fish abundance) at the reefs site, when compared to nearby control sites.

In order to disentangle this effect further, we found that some of the reef deployment methods appear to have an assemblage of fish congregating around them that is more abundant and diverse than the other reef types. Specifically, the two biodegradable potato starch matrix methods (BESE with, and without added oyster shells) were consistently surrounded by a higher average diversity and abundance of fish, than at the nearby control sites and at the other reef deployment methods.

Finally, we found that fish distributions across lower Pumicestone Passage have been modified slightly following the installations of the reefs. Here, it appears that some species have moved closer to the reef area; a potential drawing-in of individuals and species from around the lower Passage, to the reef location. Whilst these broader results are an interesting indication of the potential for the reefs to modify fish biodiversity and fisheries catches across the Passage, we caution that much more data is needed before we can properly analyse these broad, seascape-scale effects, and account for the major seasonal variations that take place in the system.

We conclude that whilst these results are an exciting early indication of the success of the reefs, further monitoring is required to determine; 1) whether these patterns are maintained over time and between seasons, and 2) whether these effects proliferate throughout the lower Pumicestone Passage. Monitoring will continue every 6 months for the next 2.5 years, at least, with the next report to be issued in June 2019.

1. Scientific objectives

This fish monitoring program around the Pumicestone Shellfish Habitat Restoration Trial seeks to fulfil two primary objectives;

- Objective one
    - Structured habitats, like oyster reefs, provide important habitats in which fish seek food and projection from predators (Gilby et al. 2018a). 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 four different reef deployment methods.
- Objective two
    - 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. 2018b).
    - 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

Objective one- Effects of oyster reefs on fish at the restoration site

<u>Part A-</u> Baited remote underwater video stations (BRUVS) deployed simultaneously at the 5 oyster reef deployment sites, and 10 analogous control sites (same substrate, same seascape context) in lower Pumicestone Passage.

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

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

A 'fish map' of the lower Pumicestone Passage, with RUVS deployed in a 200m 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.

Video deployment and analysis

Baited remote underwater video stations (BRUVS) are constructed from 3 kg weight, a 1 m length of 2 cm gauge PVC pipe to attach baits at a fixed distance of 50 cm from the camera, and a GoPro camera recording in high definition. Baits consisted of 500 g of pilchards (*Sardinops sagax*) placed into a 20 x 30 cm mesh bag with 0.5 cm openings. These are buoyed at the surface for easy retrieval and so that rope does not enter the video's field of view. For detailed descriptions of the method for using BRUVS in estuaries, see Gilby et al. (2017b).

Remote underwater video stations (RUVS; i.e. unbaited BRUVS) are constructed of a GoPro camera recording in high definition, fixed to a 3kg weight, which are buoyed at the surface for easy retrieval and so that rope does not enter the video's field of view (Figure 1).

Because they don't attract fish using baits, and therefore avoid the confounding effects of baited cameras drawing fishes from other habitats, RUVS are used to more accurately quantify fish-habitat associations. Such approaches are increasingly used for the study of fishes and fish-habitat associations in coastal ecosystems (see Sheaves et al. 2016, Bradley et al. 2017, Gilby et al. 2018a).

Monitoring fish communities in estuaries requires a broad-brush approach, using multiple videography techniques (Gilby et al. 2017a). Whilst BRUVS are more effective in quantifying the relative abundance of species within the estuary more generally (especially large, bait-attracted species of significance to fisheries), they serve to reduce overall species richness at camera sites, likely due to the high level of activity around baits forcing fish away from cameras (Harvey et al. 2007). Conversely, using RUVS is more effective for detecting species richness in an estuary, but performs less well in terms of quantifying the relative abundance of bait-attracted species. Using multiple videography techniques, as we have done here, allows for the best spread of information across fish abundance and diversity, and allows us to tailor our videography methods to our specific research questions.

All video deployments were made two hours either side of high tide to ensure that camera units could be retrieved and so that all surrounding habitats (principally mangroves) were also submerged (see Olds et al. 2012). Fish assemblage composition was quantified from video footage using the standard *MaxN* statistic (i.e. the maximum number of individuals of a species identified within a single frame of the video for each deployment). Surveys were conducted in November 2017 (1 month before installations), December 2017 (completed the day before installations began), and May 2018 (~5-6 months post-installation). For the purposes of this report, the two 'pre-installation' surveys (November and December 2017) were pooled to give more accurate 'before installation' baseline values.

Figure 1 Deployment and design of remote underwater video stations (RUVS). BRUVS are similar in construction, but also have a length of PVC pipe which hold a crab pot bait bag containing ~500g of pilchards that attract fish to the video's field of view.

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

- 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 (BG pers. obs.), and are good indicators of overall ecosystem condition (Gilby et al. 2017c, 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

In total, we identified 20 species of fish within the footprint of the reef site, and 12 species of fish outside the reef site following installation. Further, we found that the abundance of most indicator groups was higher within the reef site's footprint following reef installation, than they were before installation (Figure 2). For example, average species richness and harvestable fish abundance was higher around the reefs sites than at adjacent control sites following installation (Figure 2A,B). The majority of these effects, however, were not statistically significantly higher than controls, so future monitoring events will be required to determine whether these trajectories continue in an upwards fashion around the reefs.

There were two key trends that require further analysis with future monitoring events. Firstly, it was apparent that the adjacent control sites consistently contained fewer fish (albeit generally not significant lower), both before and after the installations of the reefs. This is likely due to site-specific attributes of the reef site; perhaps it's positioning nearer to the mouth of the adjacent canal estate, or the selected depth profile of the site and adjacent deeper channel. With further replication over time, we will be able to further interrogate these potential effects using more powerful statistics. These analyses will be able to; 1) demonstrate how these potential seascape effects modify the effects of the reefs, and 2) use effects size analyses to show how the augmentation effect that the reefs have on fish might widen over time, especially once accounting for any seasonal variations. Secondly, it was apparent that the values of indicators potentially reduced at some control sites following the installation of the reefs. This is potentially due to the attracting of fish from surrounding area to the reefs themselves. Whilst this effect might occur early in the reef growth process, it is hypothesised that the niches left by the movement of those species or individuals will be 'infilled' over time by new individuals, thereby increasing the overall carrying capacity of the lower Pumicestone system. Objective two (fish mapping- see below) will also be critical in quantifying these effects.

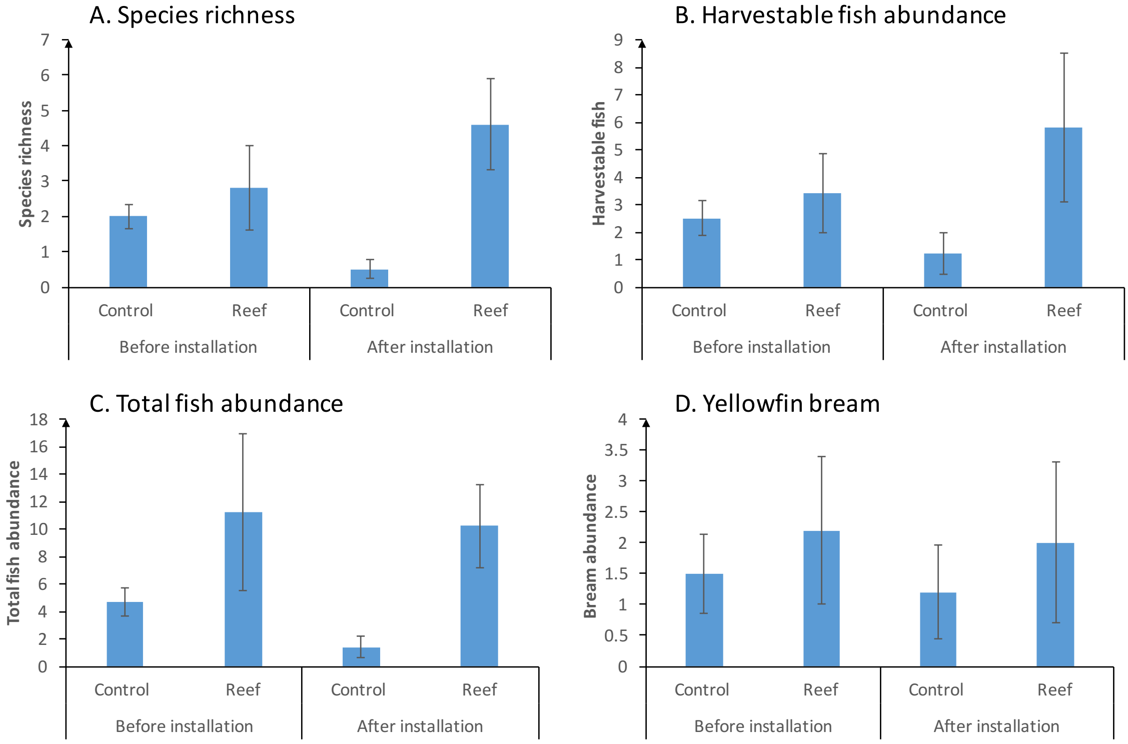

Figure 2 Average (A) species richness (i.e. the number of individual fish species), and abundance of (B) harvestable fish, (C) all fish (total fish abundance), and (D) yellowfin bream *Acanthopagrus australis* (+/- standard error) in the reef areas and at adjacent control sites before reef installations (November/December 2017), and after reef installations (May 2018).

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

Whilst the effects of the reef installations on fish assemblages within the reef site (from the BRUVS data- see above) was somewhat equivocal, there were clear trends in the ways in which the different reef types influenced fish assemblages. Across the board, BESE (a biodegradable matrix of potato starch) with added oyster shells, BESE without shells, and to a lesser extent, patch reefs with live shells (for only some indicators), were inhabited by a fish assemblage that was more diverse and had more fish (Figure 3) (note: BESE are developed by Bureau Waardenburg, Netherlands with Radboud University, Nijmegen as a partner). This corresponded to approximately a 2.5X increase in species richness, 4-8x increase in harvestable fish abundance, and 3-4x increase in total fish abundance around the BESE deployment methods, compared to the pre-installation controls. The crates with shells and crates with live shells, on the other hand, were characterised by abundances and diversity generally similar to controls. We hypothesise that this difference in habitat value is due to smaller fish being more easily able to swim into the small crevices formed by the BESE, in turn driving the abundance of larger fish around them. Conversely, the crates with shells are more tightly filled, so might not provide this same opportunity at this stage of the project. It will be important to follow how the value of the BESE for fish tracks over time as the BESE are infilled with settling invertebrates, and the potato starch begins to degrade away. This will be the topic of future analysis, and will hopefully be matched with biological information on the settlement of invertebrates and degradation of the surrounding matrix.

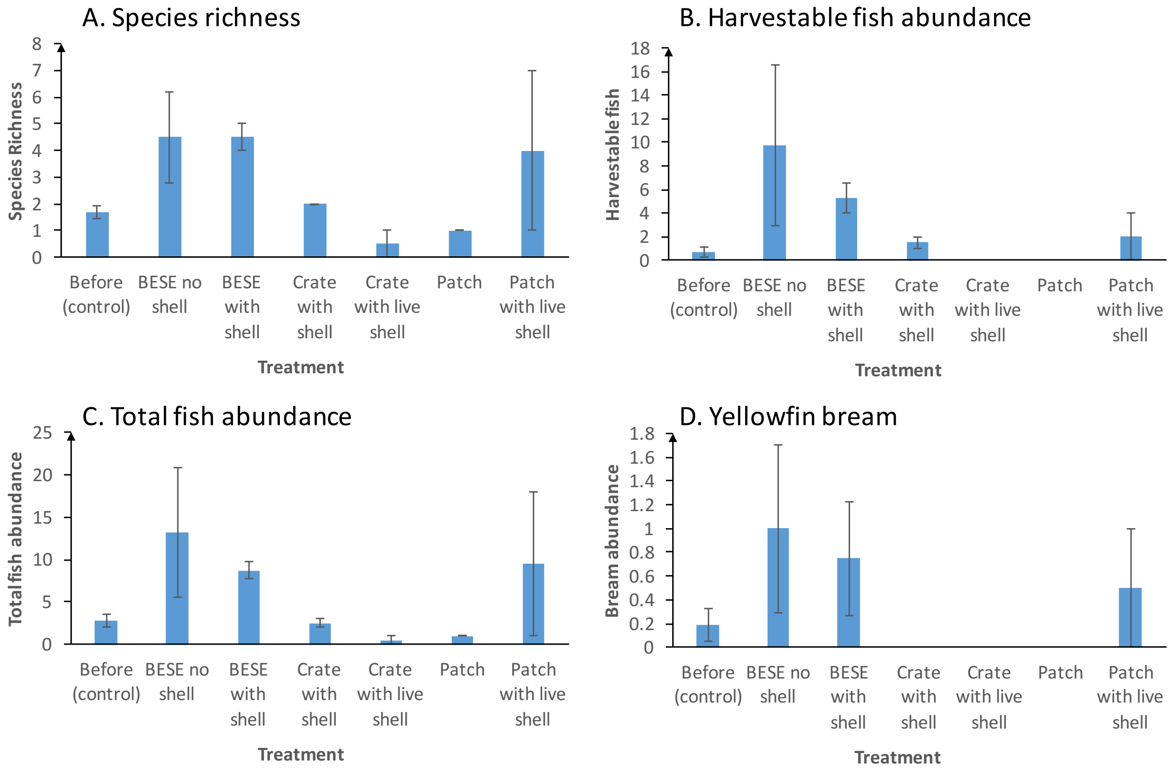

Figure 3 Average (A) species richness (i.e. the number of individual fish species), and abundance of (B) harvestable fish, (C) all fish (total fish abundance), and (D) yellowfin bream *Acanthopagrus australis* (+/- standard error) before reef installations (far left column; November/December 2017), and on each of the reef deployment types post installation (in May 2018).

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 2017), are used to quantify the distribution of fishes across the lower Pumicestone passage before and after reef installation. This allows us to track 1) how the installation of the reef 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.

Preliminary 'fish maps' indicate that the effect of the reefs has been to draw fish in from the surrounding areas (compare pre- and post-installation 'hotspots' in figure 4). We caution that this is a very early result (~6 months), that these effects will need to be studied over the longer term, and that we need to be careful to encompass any seasonal variations into our understandings (this is only one post-installation surveys in late autumn). We hypothesise that if the reefs are functioning to enhance fish at a seascape-scale, then the 'hotspots' that have reduced in extent following reef installations will become 'hot again' down the track as new fish fill available niches and the carrying capacity of the system is reached.

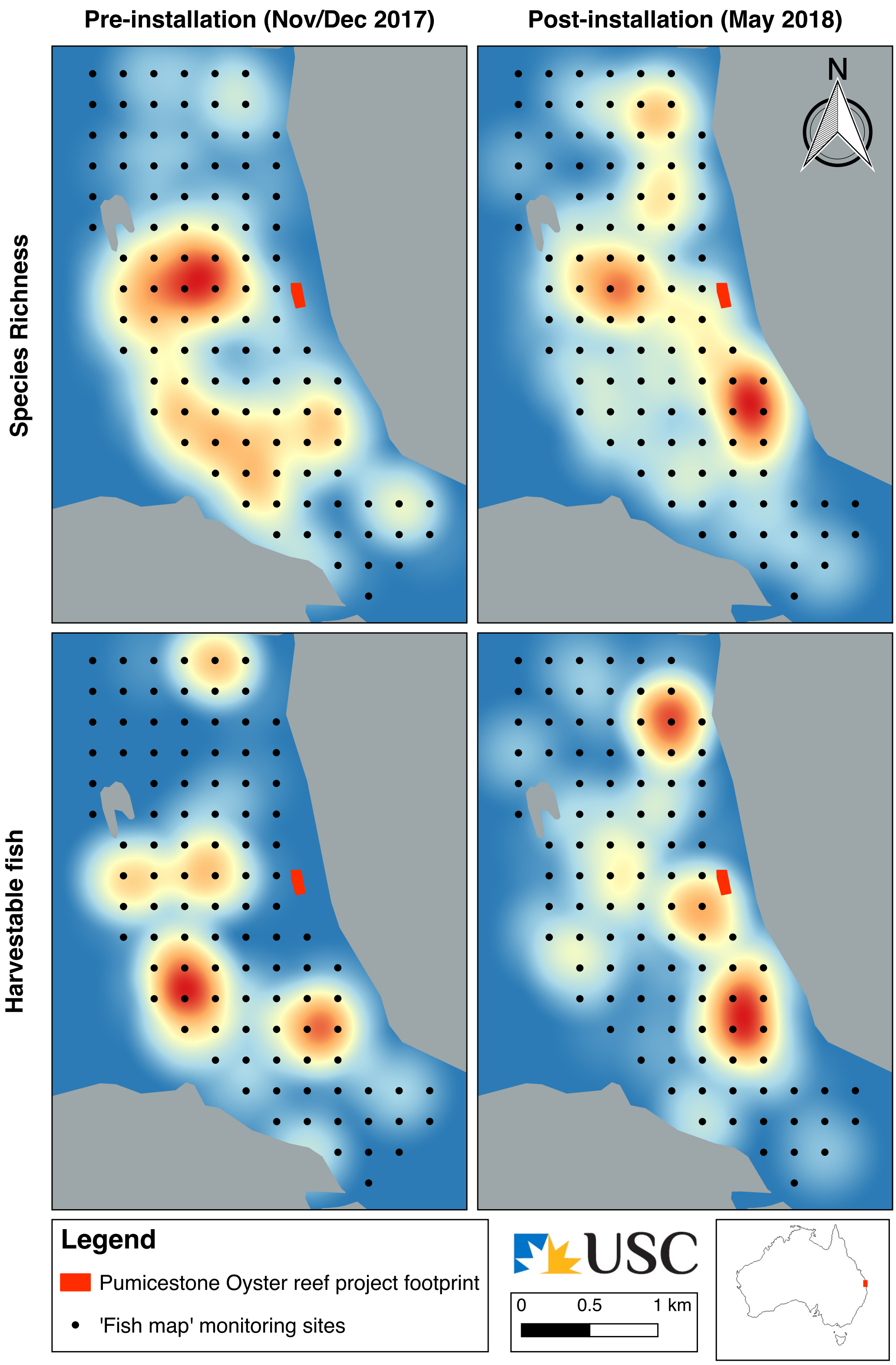

Figure 4 Fish 'heat maps' of the distribution of species richness (top two maps) and harvestable fish (bottom two baps, both before (left column) and after (right column) reef installation in Pumicestone Passage. Shading in the background scales from blue (low values), to orange, then red (highest values). 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.

Preliminary heat maps for bream and total fish abundance were inconclusive and showed little effect of the installation of the reefs, and so will be reanalysed when additional data becomes available after future monitoring events. Again, we caution that these maps should be considered in the context of likely seasonal variations (for example bream often migrate to the mouthes of estuaries to spawn in winter; Pollock 1982).

Key conclusions and future directions

Key results from this monitoring event

- We detected an increase in the number of species and number of harvestable fish congregating within the oyster reef restoration site's footprint using BRUVS. Whilst these effects were generally not significantly higher than controls, we expect that this augmentation effect will continue into the future.
- We identified that the BESE elements installations are currently tracking as the habitat installed with the best values for fish. It is important to monitor how this pattern changes over time as the BESE elements are infilled by invertebrates, and the matrix degrades away.
- We detected some changes in the distributions of fish in the lower Pumicestone Passage region following oyster reef installations. Whilst this might be an initial effect of fish being attracted to new structure, we caution that more data is required to support this effect, and to account for seasonal variations in fish movements.

Key scientific questions to be addressed with additional monitoring data

- Do the observed patterns of fish enhancement at the oyster reef restoration site maintain over time and between seasons?
- Does the 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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