

2011 - 2012

Investigating ecological restoration: enhancement of fisheries due to the presence of oyster reefs in the Hudson River



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Executive Summary

Oyster reef restoration efforts have been increasing in recent years with the goal of enhancing both oyster fisheries and the ecosystem benefits provided by oyster reefs. To this end, the Hudson River Foundation (HRF) has been developing oyster reefs throughout the New York Metropolitan Region to restore ecosystem services, ranging from improving water quality (Nelson et al. 2004; Grizzle et al. 2008) to habitat provision (Wells 1961; Tolley and Volety 2005). The research objective of this project was to quantify the success of the Hudson River Foundation's Oyster Reef Restoration Program in enhancing reef resident and transient organismal abundance and diversity. To accomplish this goal a series of experiments and survey strategies were employed (colonization trays, fish traps and gill nets). Specific outcomes of this project:

1. *The abundance, diversity and biomass of the reef resident communities varied greatly among the experimental oyster reefs.*

Staten Island and Hastings were unique among the sites as they represented the two salinity extremes and the communities associated with the oyster reefs reflected that. The Staten Island reef had both the greatest abundance and diversity of organisms associated with it, followed by Soundview. Both Bay Ridge Flats and Governor's Island sites had very low organismal abundance and diversity.

2. *There was a clear difference in community composition between the experimental reefs and at individual reefs over the course of the sampling season*

Multidimensional scaling plots of the communities at each experimental oyster reef demonstrated that the communities were distinct between spring and fall.

3. *The "zone of influence" of the experimental reef did not extend beyond the physical margin of the reef structure.*

Experiments examining the "halo" effect of the experimental reefs found no evidence that the effects of the reefs extended beyond the physical structure itself. There was also no difference between large mobile crustaceans and fish on or off the reef.

Recommendations for Future Efforts

1. Increase the size of the restored oyster reefs

The habitat provision of the experimental reefs was significant for the reef resident organisms. There was a distinct difference in the abundance and diversity of resident organisms on the experimental oyster reefs than the adjacent soft sediment communities. However, the impact of

the experimental reefs on transient organisms was minimal. This is likely due to the small size of the experimental reefs. The large mobile species were as likely to be found on the reef structure as they were away.

2. Focus restoration efforts at Soundview

Only Soundview and Hastings received natural oyster spat. The dramatic fluctuation in salinity at Hastings and the wave refraction of the passing commercial boat traffic had deleterious effects on the survival of the oyster spat and the stability of the reef structure. In contrast, Soundview is moderately protected from wave activity and the natural oyster spat experience high survival. Soundview had the second greatest abundance and biomass of organisms associated with the reef.

Introduction

To measure the success of the Hudson River Foundation's Oyster Reef Restoration Program, we conducted a series of experiments and extensive field surveys designed to quantify the fisheries enhancement generated by the created oyster reefs. Specifically, we had the following objectives:

- to characterize and quantify the abundance, diversity and biomass of the reef resident community on the restored reefs
- to determine the temporal and spatial utilization of the reefs by commercial, recreational and ecologically important fishes and crustaceans
- to investigate the distance of the reef's "zone of influence" on resident and transient species
- to analyze the similarity in resident and transient fish and crustacean communities between the reefs

The central hypothesis to be tested was that the magnitude of fisheries benefits resulting from oyster reef restoration varies as a function of the location of the reefs within the Hudson River estuary. More importantly, we hypothesized that there would be an interaction between reef location and water quality.

A key expectation of many habitat restoration programs is that creation of additional habitat will lead to enhancement of local fisheries. We conducted a project designed to evaluate this expectation for oyster reefs constructed in the Hudson River estuary as part of the Hudson River Foundation's Oyster Reef Restoration Program. For oyster reefs, fisheries enhancement is expected for oysters as well as for a host of finfish and mobile invertebrate species that utilize the reefs as primary or transient habitat. A two-year assessment of faunal utilization examined the recruitment of mobile invertebrates and fish onto previously constructed reefs. The project quantified the potential fisheries enhancement of created oyster reefs and to evaluated how the reefs' location within Hudson River affects the relative magnitude of fisheries benefits.

Restoration of estuarine/marine habitats has proceeded at an accelerated pace over the last two decades and will more than likely continue to expand as societal demand to compensate for growing degradation of natural resources continues to increase (Vitousek et al. 1997, Botsford et al. 1997, Hobbs and Harris 2001). Government agencies, both federal and state, non-governmental organizations, and academic scientists routinely tout the ecological benefits associated with habitat restoration as justification for their high financial costs; however, demonstration and, more importantly, quantification of the ecological benefits associated with habitat restoration is often overlooked after engineering and construction are completed.

For most estuarine/marine habitat restoration programs (e.g., saltmarsh, seagrass, coral and oyster reefs), one key expectation is that creation of additional habitat will enhance local (i.e., on scales of m -100's km) fisheries. The provision of additional habitat can augment fisheries through both a numerical response (i.e., increased settlement, post-settlement survival), as well as through a bioenergetic response of predators to the addition of habitat-associated prey (Peterson and Powers 2003, Powers et al. 2003). For oyster reefs, the addition of reef habitat may serve to overcome a survival bottleneck in the early life history of many species whose recruitment is limited by the amount of suitable oyster reef habitat (e.g., oysters, gobies, blennies, toadfish). Because of the complex topography of oyster reefs, enhanced survival of many species may also result from provision of structural refuges from predation (Hixon 1998). Oyster reefs may also increase fisheries through production and aggregation of reef-associated prey resources (Peterson and Powers 2003). This latter functional response enhances fisheries, not by adding new fish to the system but rather, by increasing growth of individuals already present in the regional population, thereby producing gains in fish production. The results of this project in combination with those of the current monitoring program will allow a predictive relationship between reef location and expected fisheries benefits.

Methods

Utilization by resident fishes and crustaceans

To assess the resident fishes and crustaceans utilizing the reefs, we sampled replicate 0.3-m² colonization trays filled with surf shell cultch. Sampling units were plastic bakery trays (50×58×10 cm) lined with fiberglass window screen, and randomly assigned to sites (Rodney and Paynter 2006). Each colonization tray received 20L of dried cultch (Fig. 1). Two trays were placed at the crest (or center) and the base of each reef along a single axis of dominant length (Fig. 2-6). Nylon ropes linking the trays together were attached to anchor screws marked with surface and subsurface buoys at each end. After SCUBA divers excavate holes in the bottom substrate, the trays were inserted into the depressions. This preserved the reef structure created by the growing oysters and shell. Trays were allowed 6 weeks colonization time. The trays were first placed in the reef structure in May and the final retrieval was in October. In 2012, a duplicate set of collection trays were left in the reef matrix for the entire season to assess the development of a resident community over a longer duration at the Soundview site. During tray

retrieval, divers placed caps over the trays, securing them with elastic cords and lifted them to the surface for field processing. When the trays are recovered, a new set was deployed. Resident fish (gobies, blennies, toadfish) and mobile crustaceans (shrimp and crabs) settling in the shell were collected when the tray was removed. In addition, this method also quantified newly recruited oyster spat and fouling organisms (mussels, tunicates, macroalgae) that add structure and food sources to the reefs.

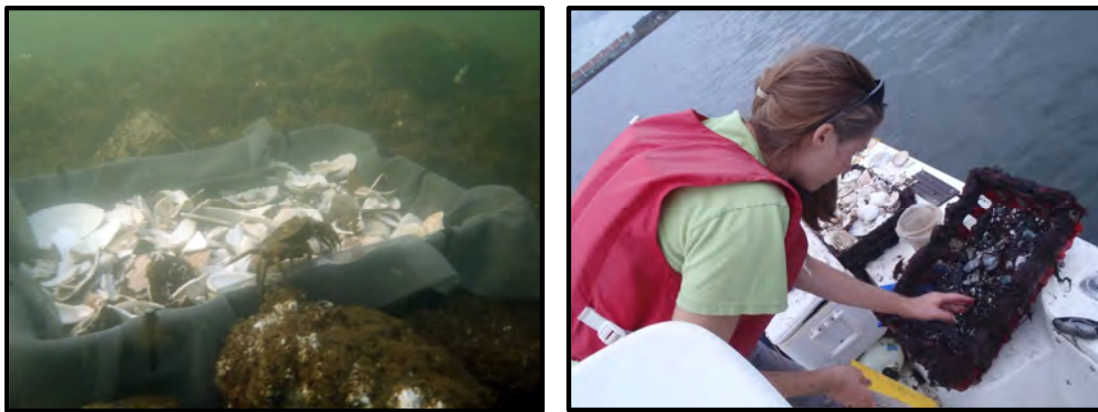


Figure 1. Colonization trays in the reef matrix (A) and being emptied for processing in the lab.

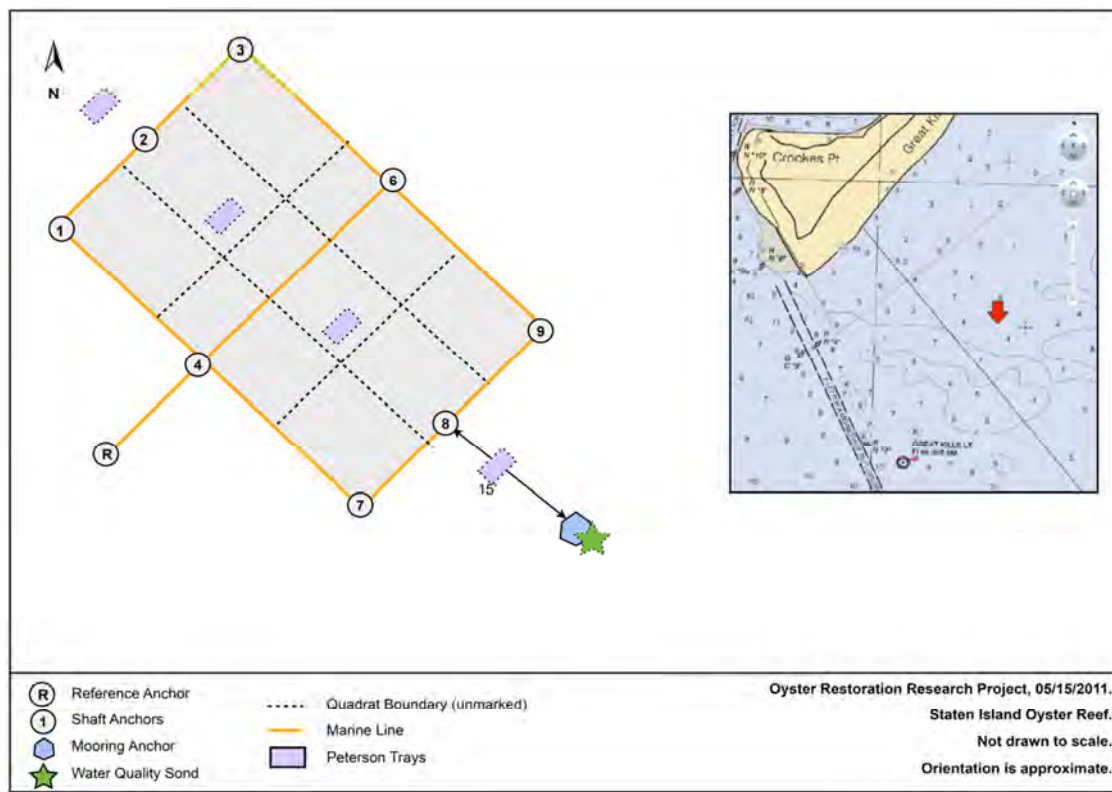


Figure 2. Staten Island Oyster reef showing the locations of the colonization trays

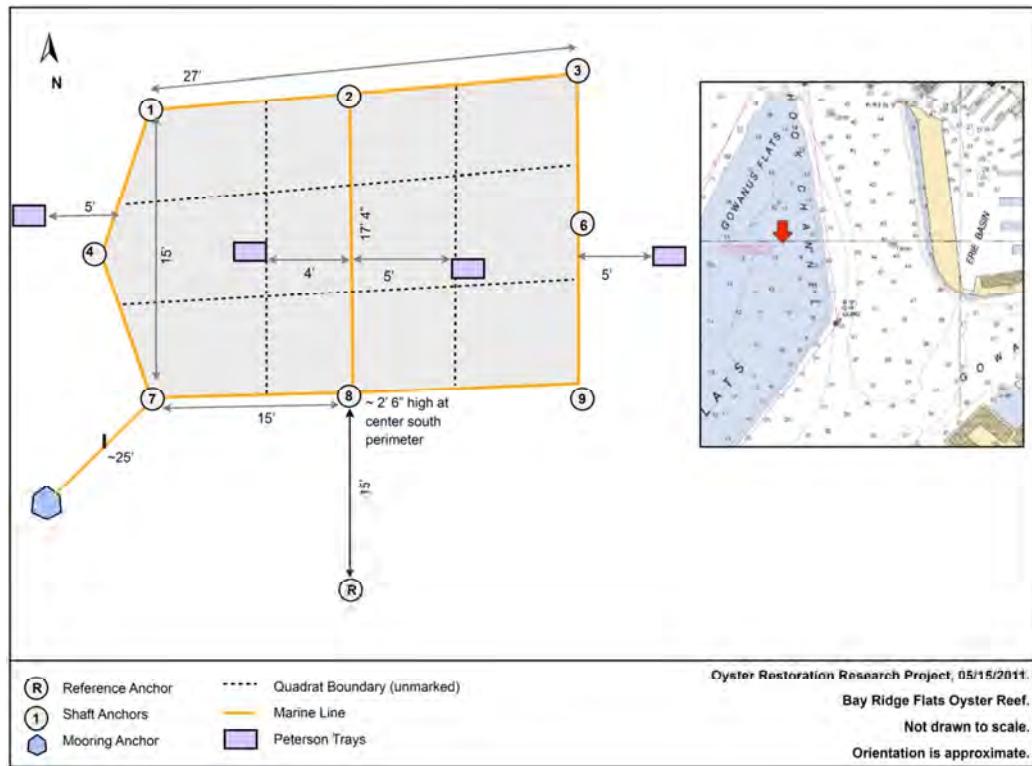


Figure 3. Bay Ridge Flats Oyster reef showing the locations of the collection trays

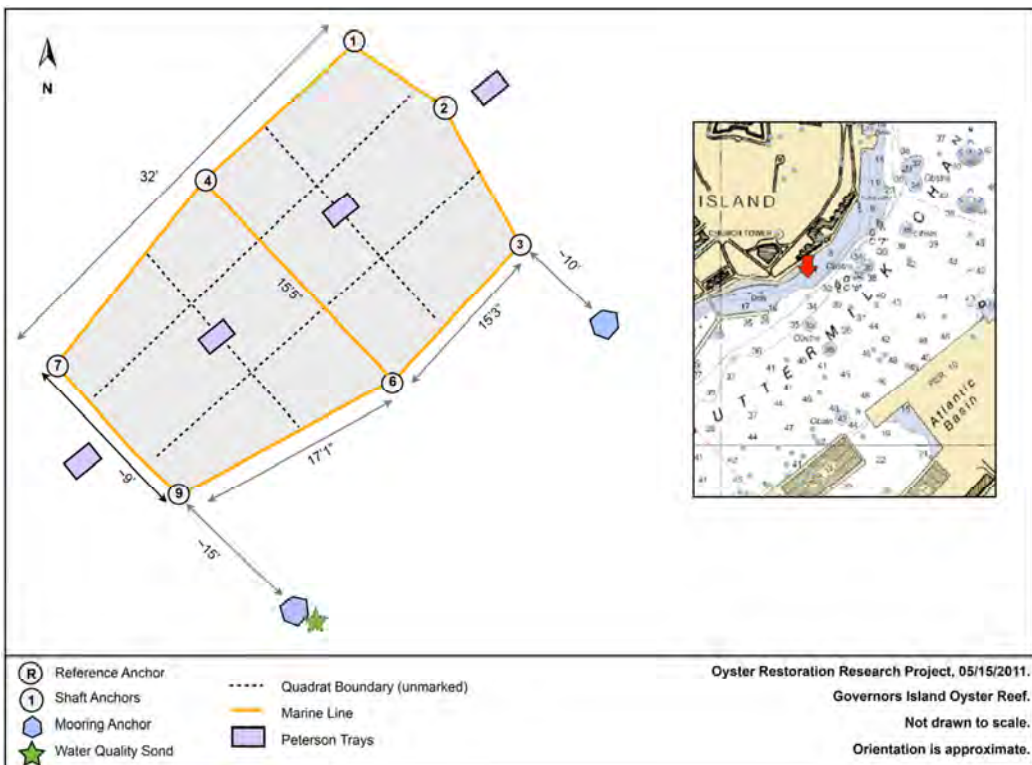


Figure 4. Governors Island Oyster reef showing the locations of the collection trays.

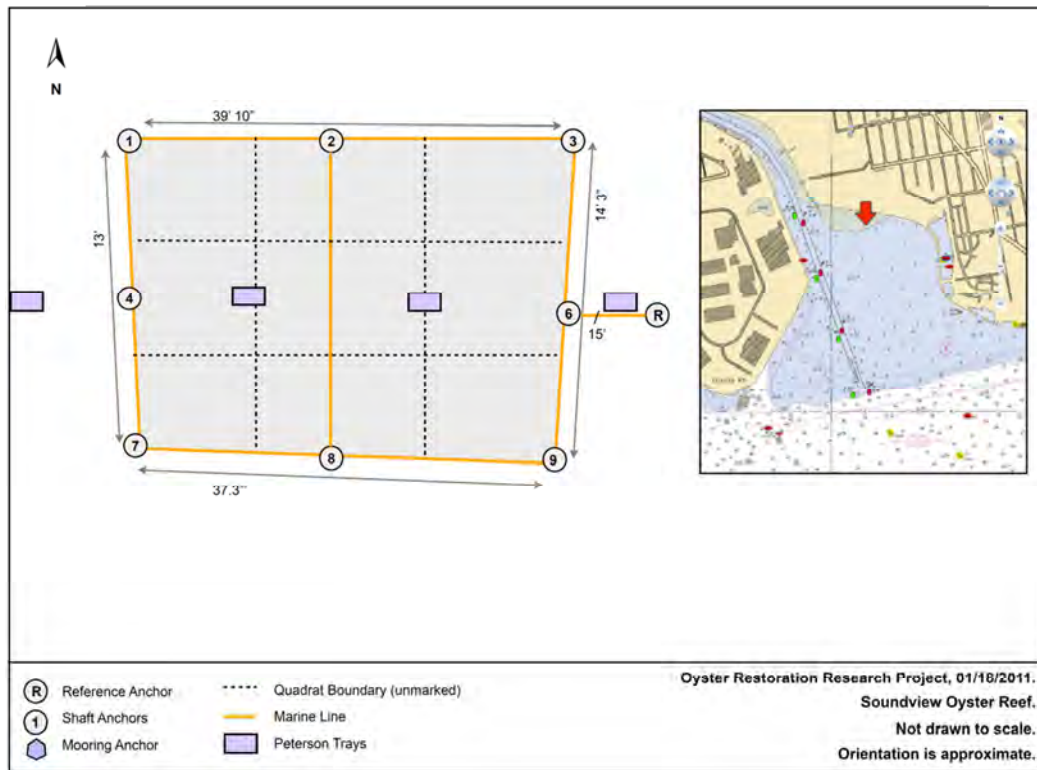


Figure 5. Soundview Oyster reef showing the locations of the collection trays.

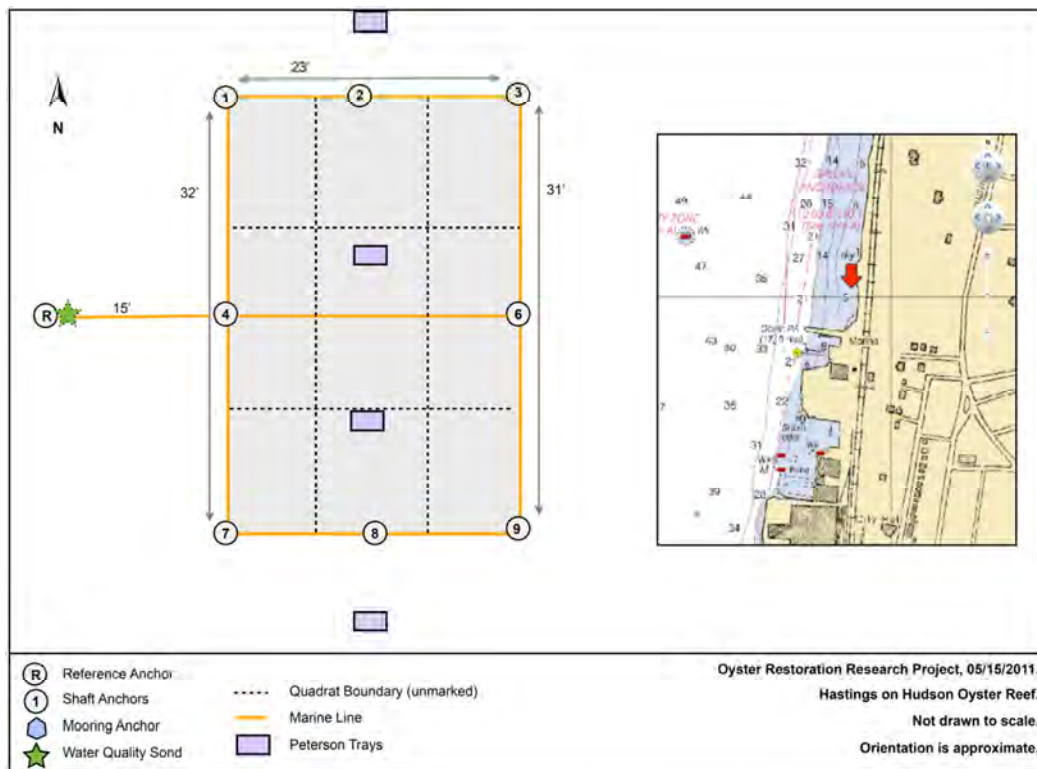


Figure 6. Hastings on Hudson Oyster reef showing the placement of the collection trays.

To collect and sort the fauna, all visible motile organisms were removed and each shell was visibly examined for oyster spat. All spat within each tray was enumerated and shell heights were measured to the nearest mm (Fig. 7). This provided the number of recruits / unit area / time interval for each experimental reef. Fishes and decapods collected in the trays were measured to the nearest 0.1 mm (shrimp: carapace length, crabs: carapace width, fishes: standard length). Density and biomass estimates for all organisms were determined for future ECOPATH modeling efforts (Frisk et al. 2010). In addition to abundance and biomass data, species richness, Pielou's evenness and Shannon-Weiner diversity were calculated for each sample using the PRIMER 6 software package.



Figure 7. Sorting the collection trays and measuring individual organisms.

Utilization by transient fishes and crustaceans

Many studies of oyster reef habitat have concentrated on the fauna residing in the shell matrix. However, use of the oyster reef by transient species such as blue crabs, panaeid shrimp and fish which visit the reefs for only limited periods is less understood. Obtaining a complete census of mobile fish and crabs within the complex matrix of a subtidal oyster reef can be logistically challenging. We therefore used a multi-pronged approach to estimating the relative magnitudes of benthic macrofaunal and semi-demersal fish utilization among the restored reefs. Catch data was collected by the monitoring program using commercially available fish and crab traps (Ketcham Supply Arrow Traps, Fig 8) adjacent to the reef and at distance (100 m away) to qualitatively measure the utilization by fish and mobile crustaceans. In addition, gill nets were used to qualitatively document presence/absence and catch per unit effort (CPU) as a comparative measure of transient fish utilization. Thirty-meter experimental multi-panel gill nets with alternating replicate 5 m (horizontal) x 2 m (vertical) panels of 50.8, 63.5 and 76.2 mm stretch square mesh monofilament were deployed over each reef. Previous studies using these mesh sizes successfully collected bluefish, spot, striped bass, flounder and weakfish (Harding and Mann 1999, 2001). These nets were deployed for 2 h during daylight at each experimental reef. All fishes collected by trap or net were identified and measured for total length.



Figure 8. Fish traps used to collect fish and crabs on the reefs and at distance.

Results and Discussion

Utilization by resident fishes and crustaceans

Over the course of both years, a total of 79 colonization trays were sampled (2011: BRF=7, Hastings = 11, SV = 15, GI= 4 and SI= 4; 2012: Hastings = 15 + 4 permanent trays and SV = 16 + 3 permanent trays). Staten Island and Governor's Island had the lowest tray recovery due to wave refraction and storm damage. A total of 23,545 individual organisms from 54 species were enumerated, measured and weighed. The abundance and species richness varied greatly between sites (Figs. 9-15)

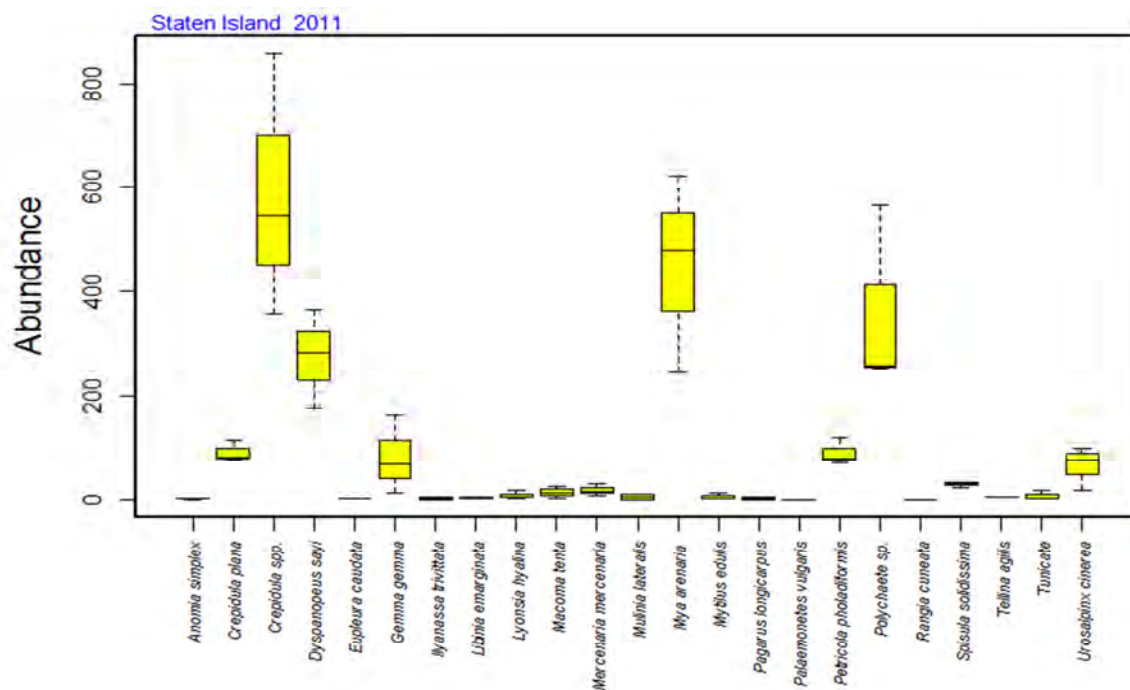


Figure 9. Abundance by species at Staten Island.

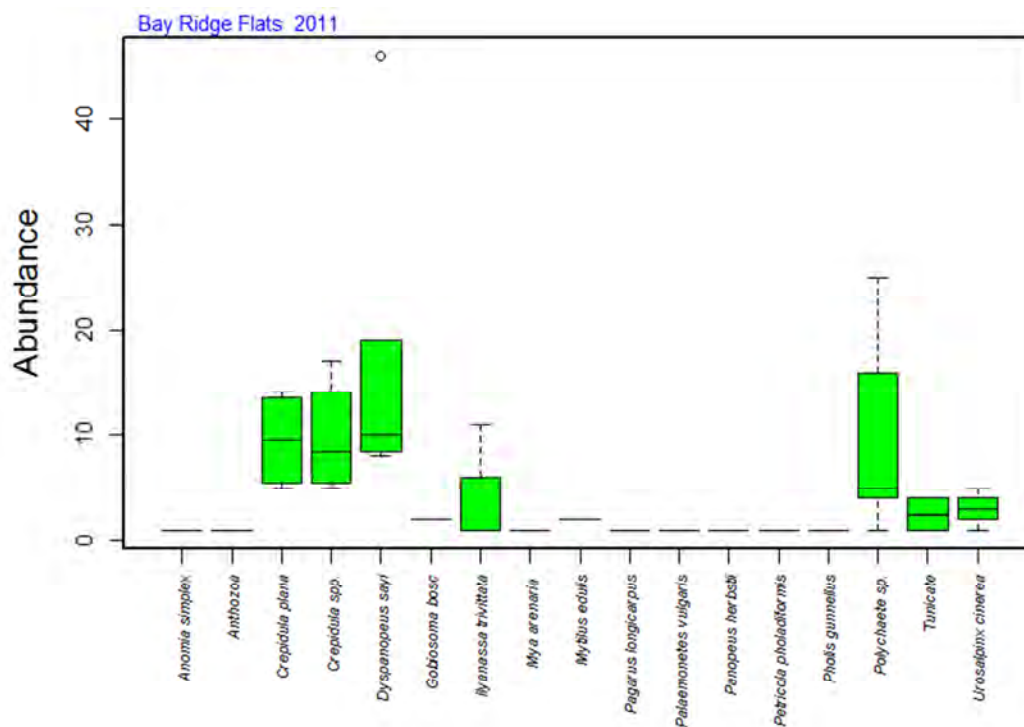


Figure 10. Abundance by species for Bay Ridge Flats.

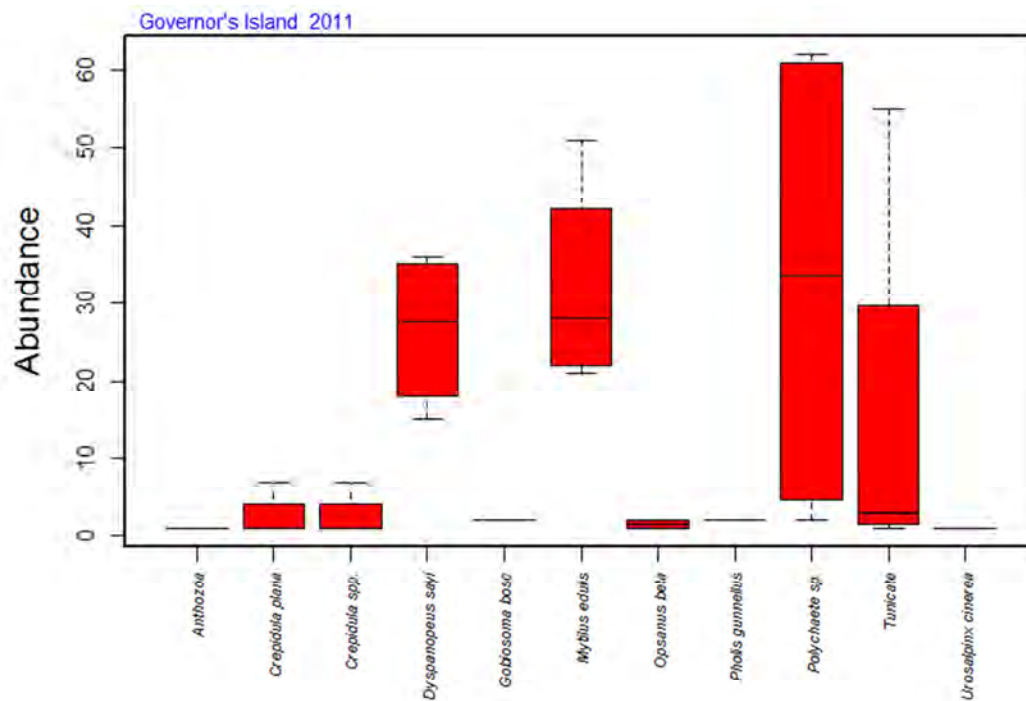


Figure 11. Abundance by species for Governor's Island.

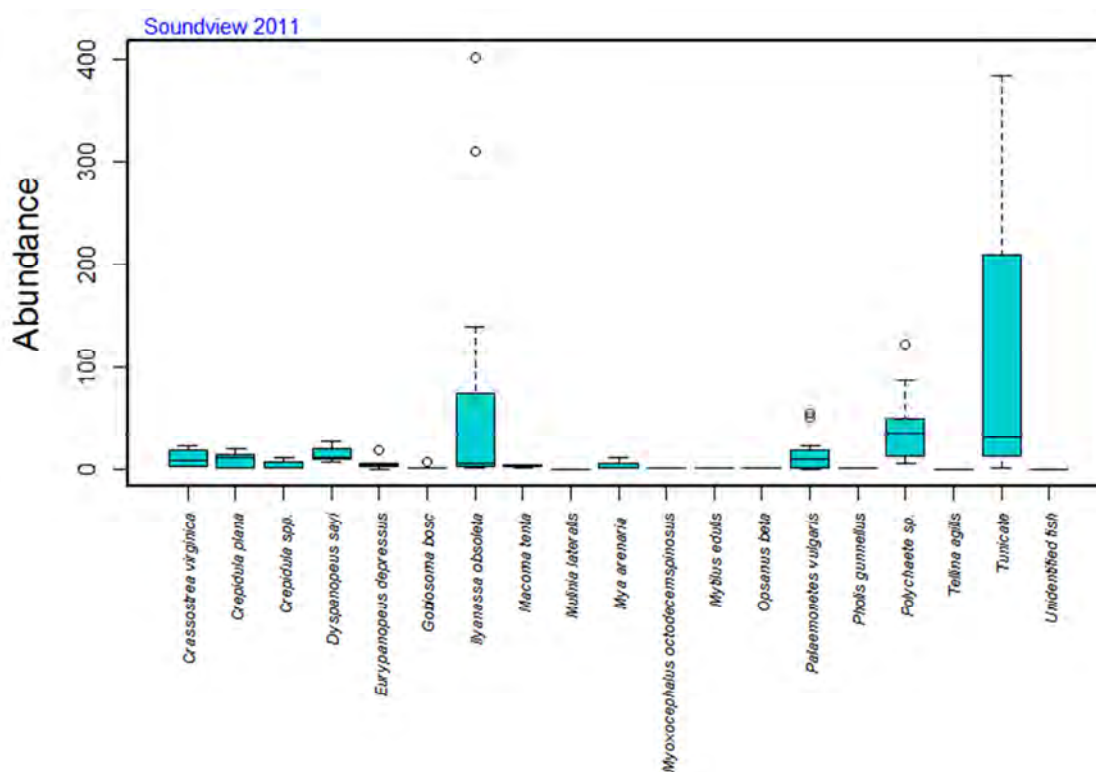


Figure 12. Abundance by species for Soundview.

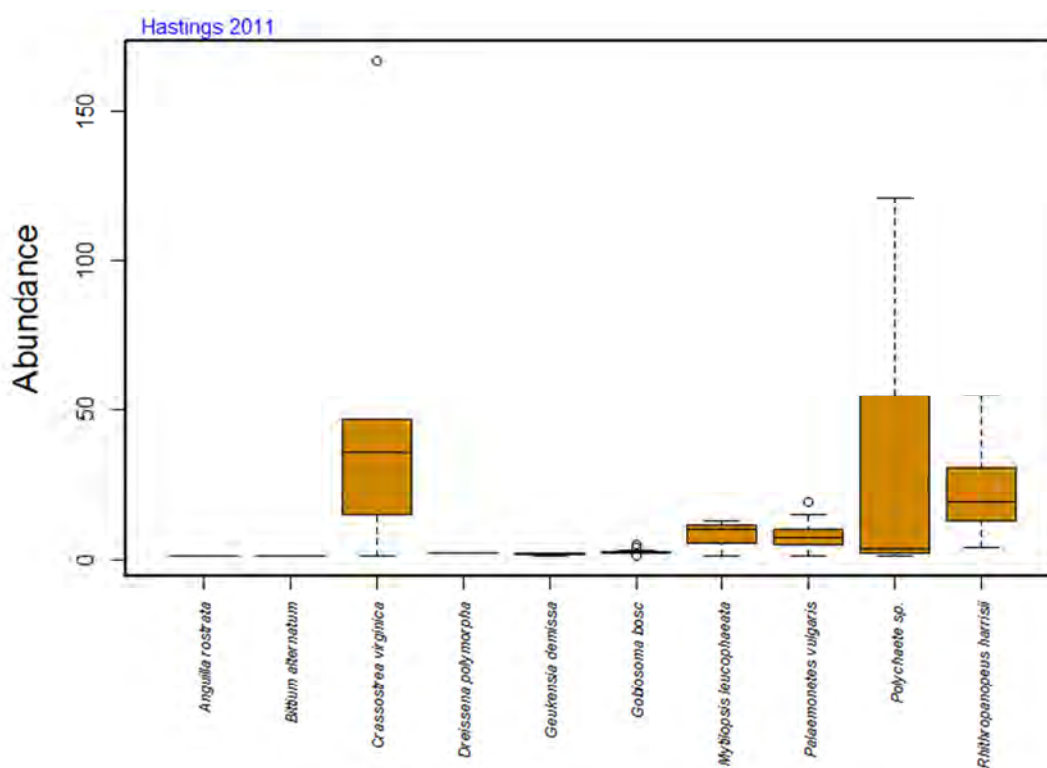


Figure 13. Abundance by species for Hastings on the Hudson.

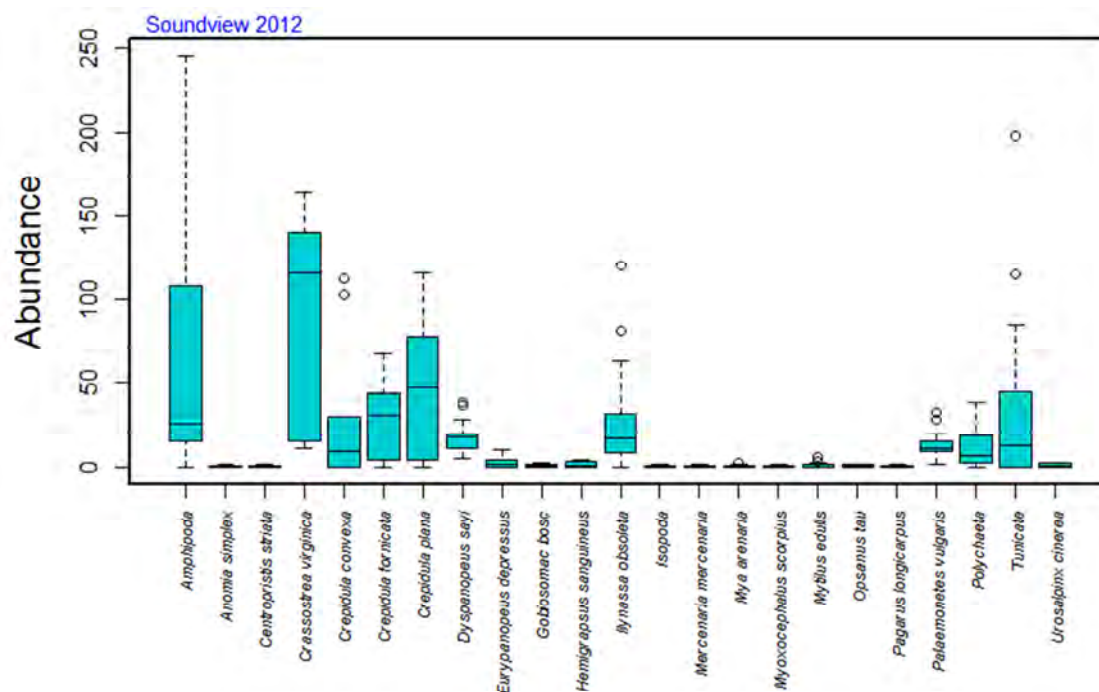


Figure 14. Abundance by species for Soundview.

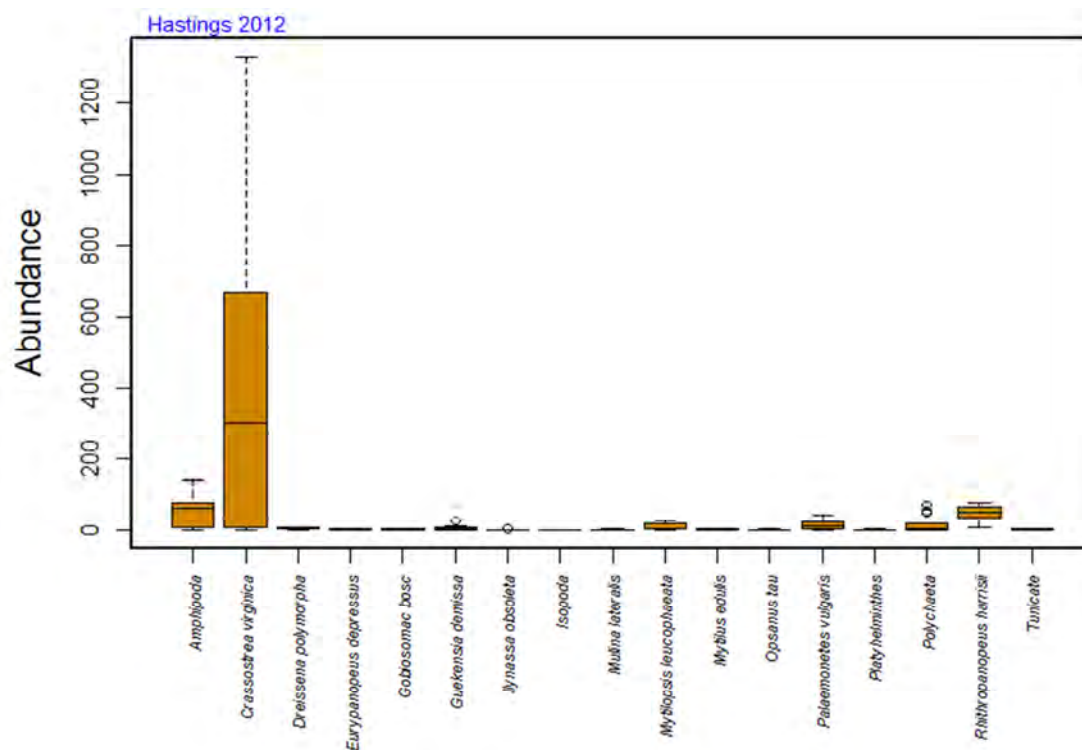


Figure 15. Abundance by species for Hastings on the Hudson.

Despite this great variation in abundance, there were similarities in the presence and trophic groups of the most abundant species across the sites. The most abundance species at each site were suspension feeding organisms (*Crepidula plana*, *Crepidula fornicata*, *Mytilus edulis*, *Crassostrea virginica*, *Mya arenaria* and *tunicates*) as well as small predatory crabs (*Dyspanopeus sayi* and *Rhithropanopeus harrisii*). Comparing the total organismal abundance at each site, the highest abundance occurred at the Staten Island site (Fig. 16). This was driven by the very high abundances of *Crepidula* spp., *Mya arenaria* and *Dyspanopeus sayi*.

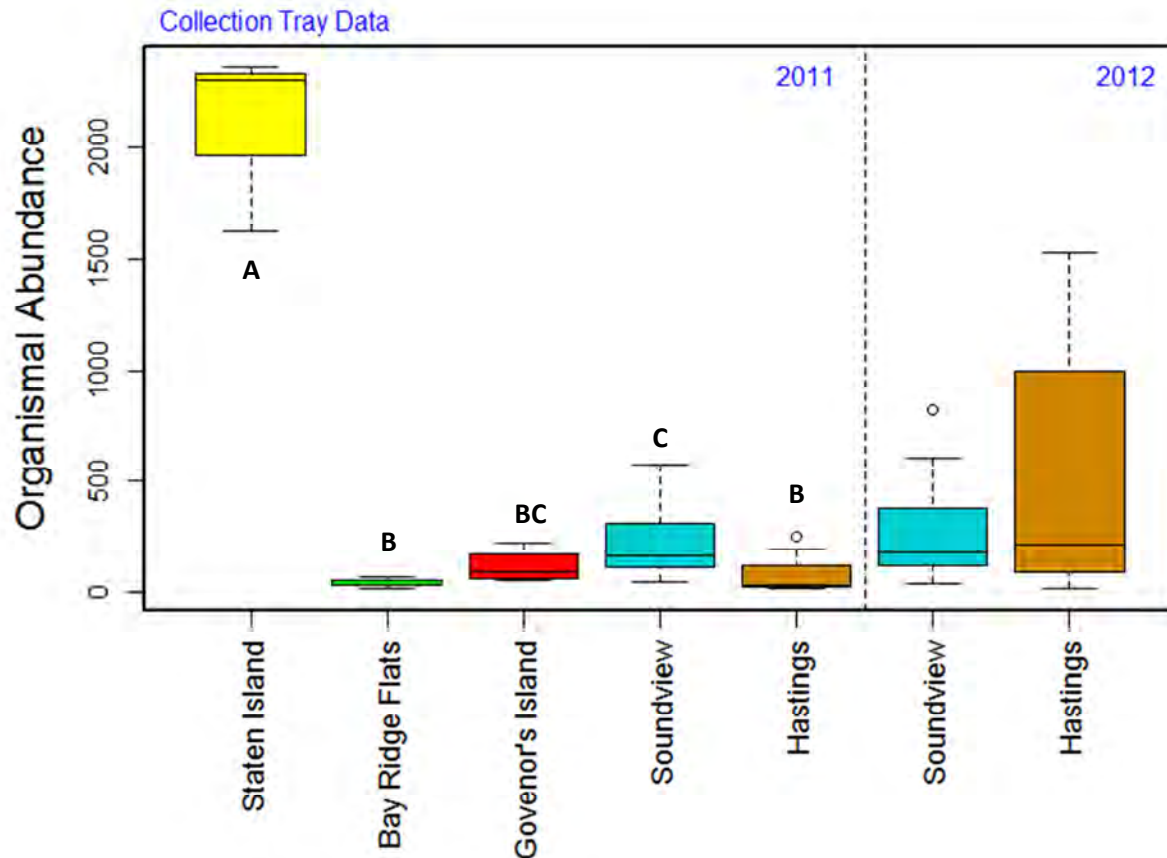


Figure 16. Organismal abundance by site; letter indicate statistically significant differences between sites in 2011. There were no differences between Soundview and Hastings in 2012.

The increase in abundance at the Hastings site in 2012 is due exclusively to the large spat set of *Crassostrea virginica*. Not only did the organismal abundance vary between sites, but there was also a large variation between collection times (Fig. 17). While there was no clear pattern across sites, the greatest abundances of organisms were collected in the late summer (August and September).

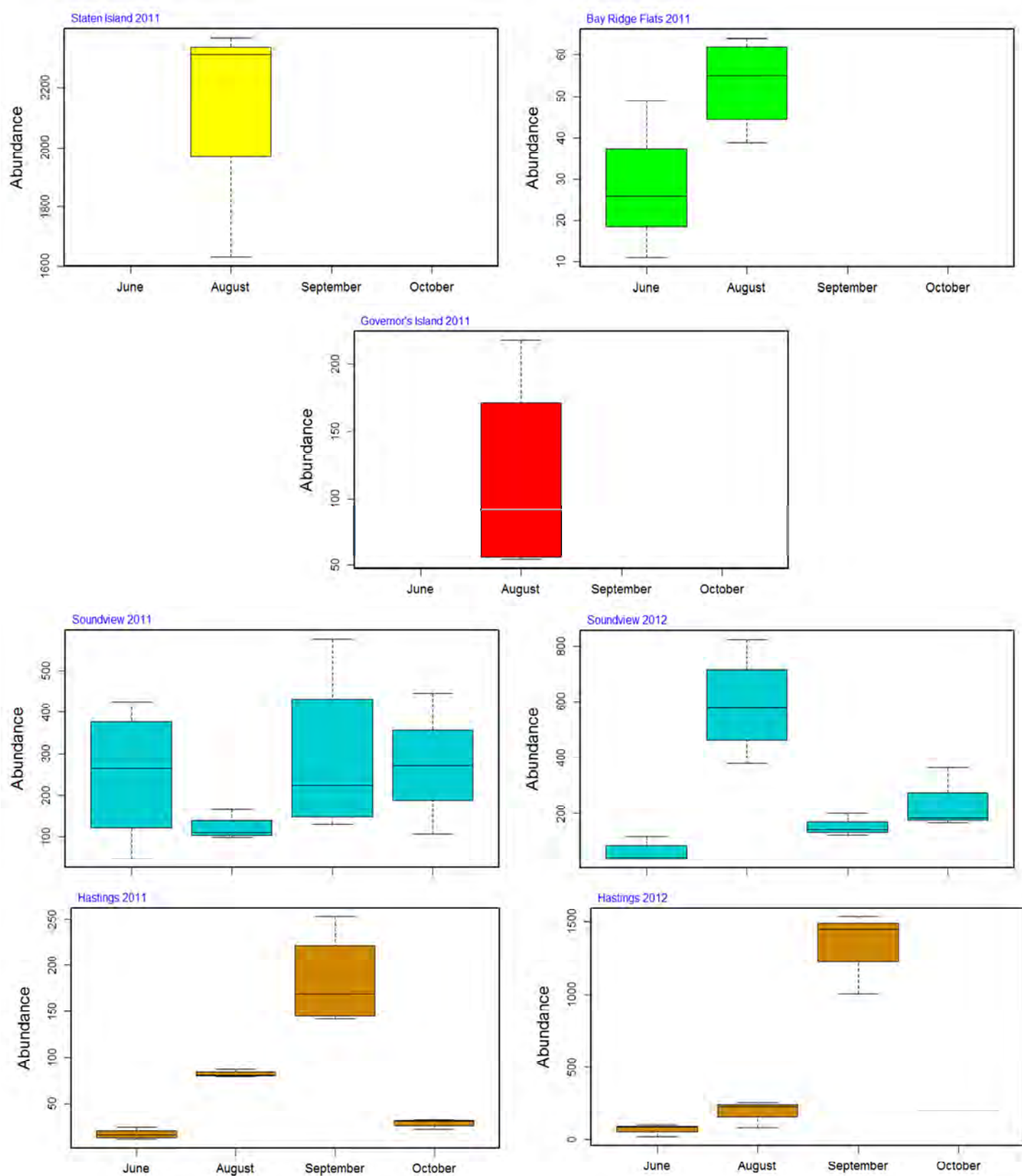


Figure 17. Abundance by month at each site.

In 2012, the total abundance of organisms was compared between the temporary trays and those that were left in place over the entire summer. While the abundance was greater in temporary trays at the Hastings site (Fig. 18), that was the result of a large oyster set that had not yet been consumed by predators. When the oysters were removed from the analysis, it was apparent that there was no difference in the abundance of other organisms between the temporary tray abundance of organisms and that of the permanent trays (Fig. 19).

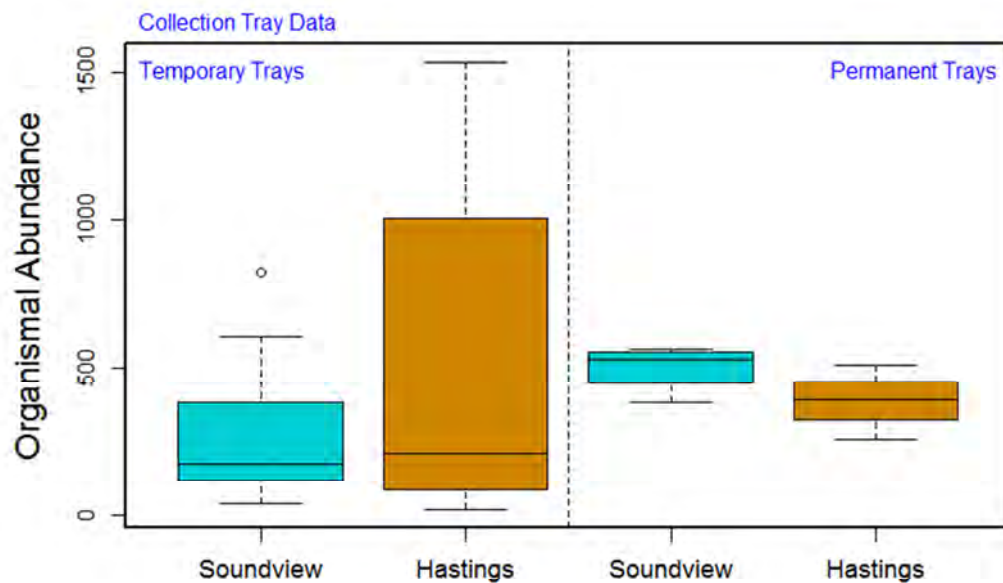


Figure 18. Comparison of the organismal abundance of the temporary versus permanent trays at Soundview and Hastings sites.

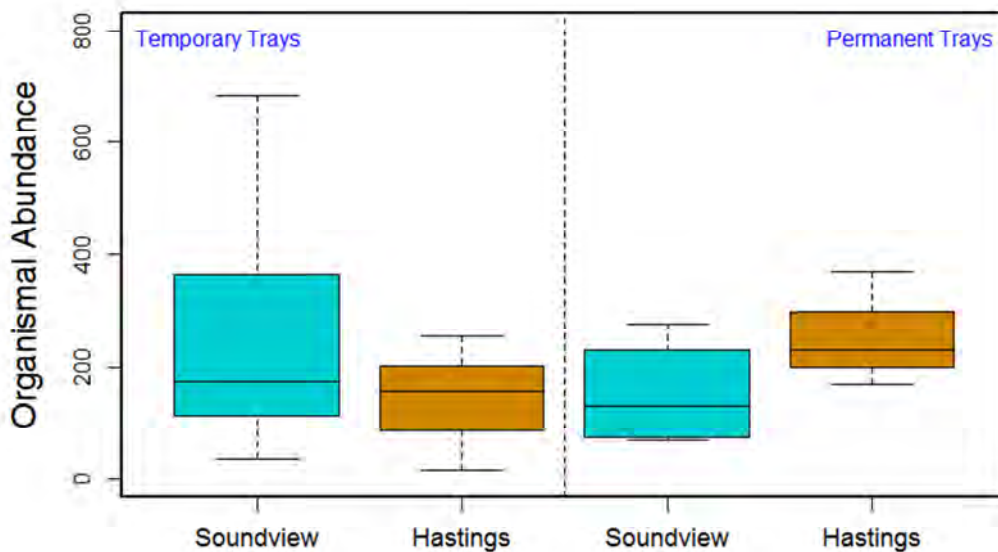


Figure 19. Comparison of the abundance of the temporary versus permanent trays with the oysters removed at Soundview and Hastings sites.

Abundance data can mask the importance of various species due to their size. Therefore, we contrasted the abundance data presented above with species biomass in the collection trays at each site (Figs. 20-26).

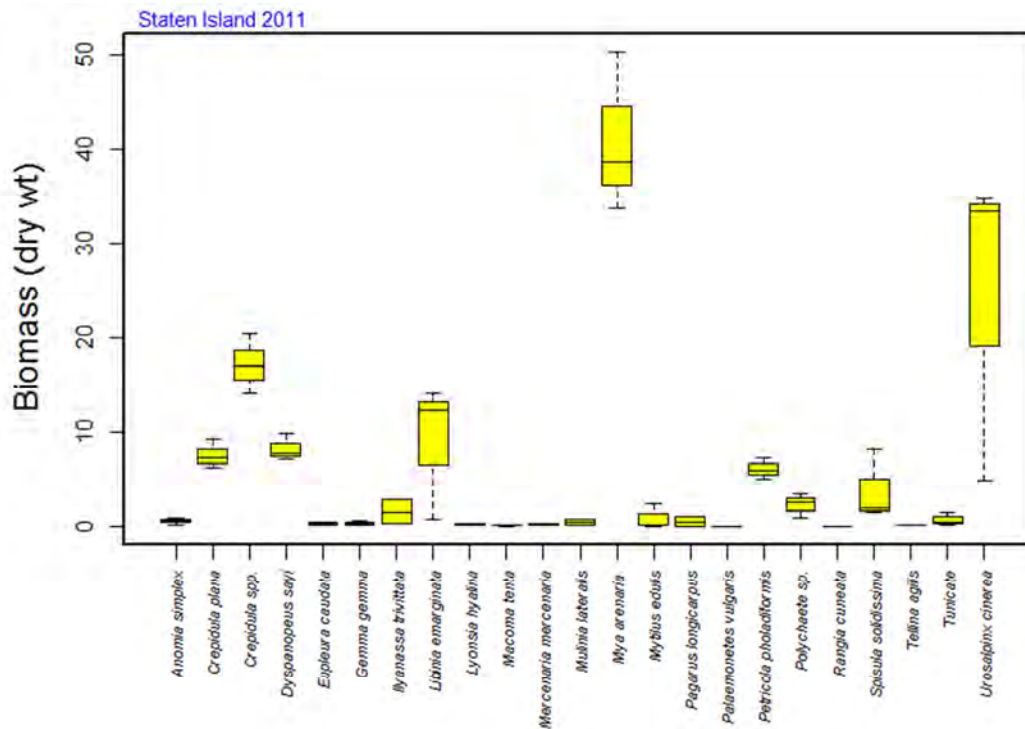


Figure 20. Biomass by species at Staten Island.

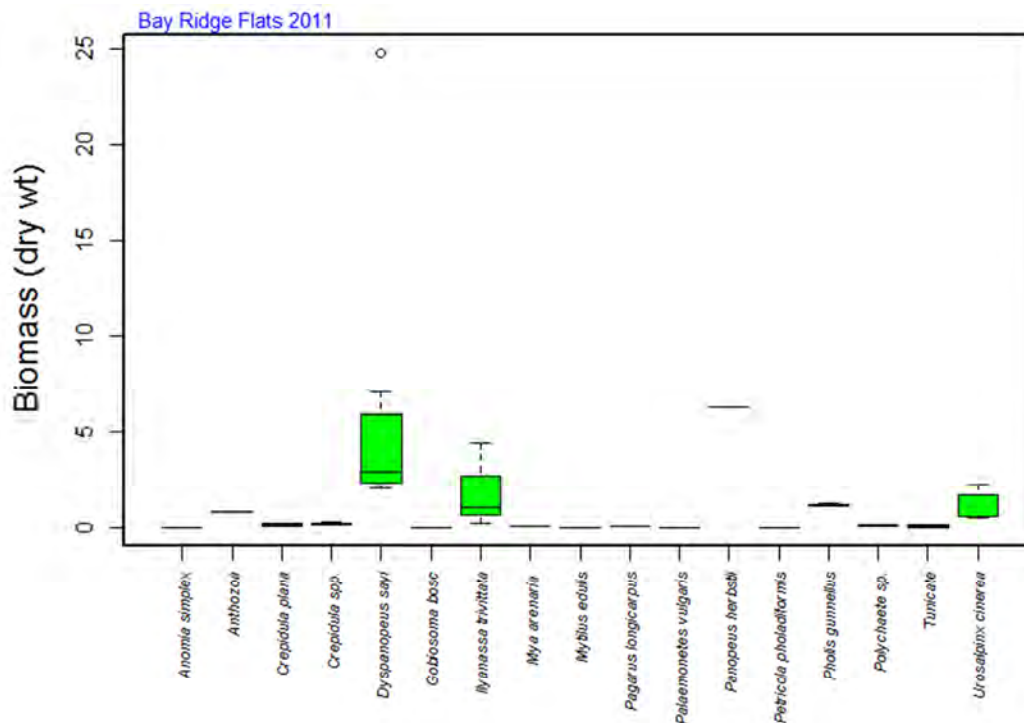


Figure 21. Biomass by species at Bay Ridge Flats.

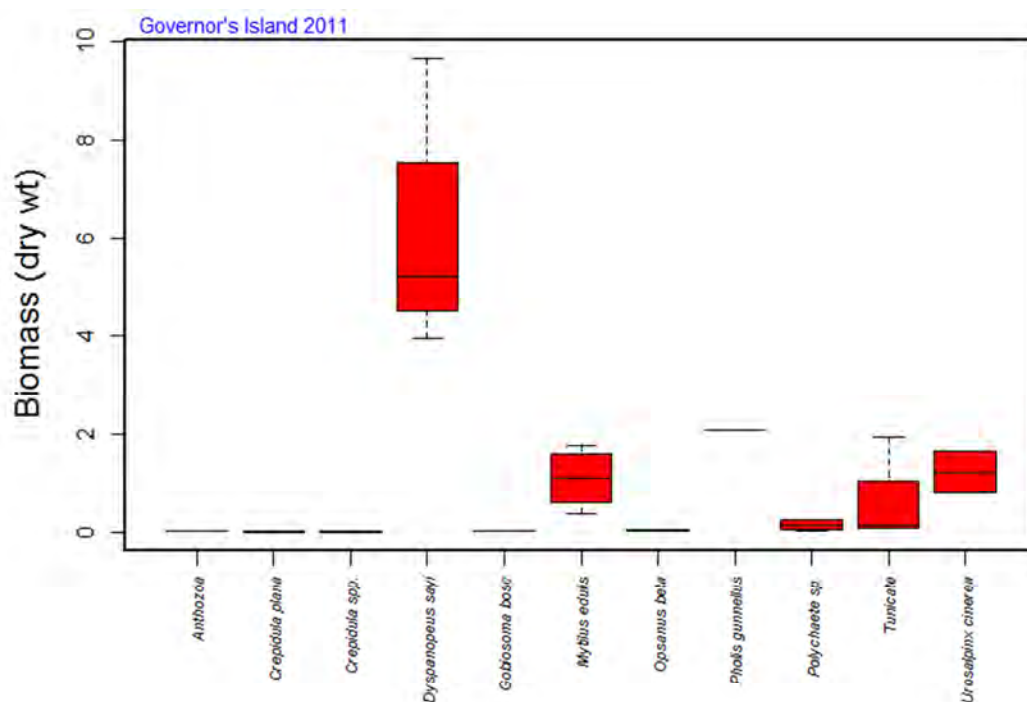


Figure 22. Biomass by species at Governor's Island.

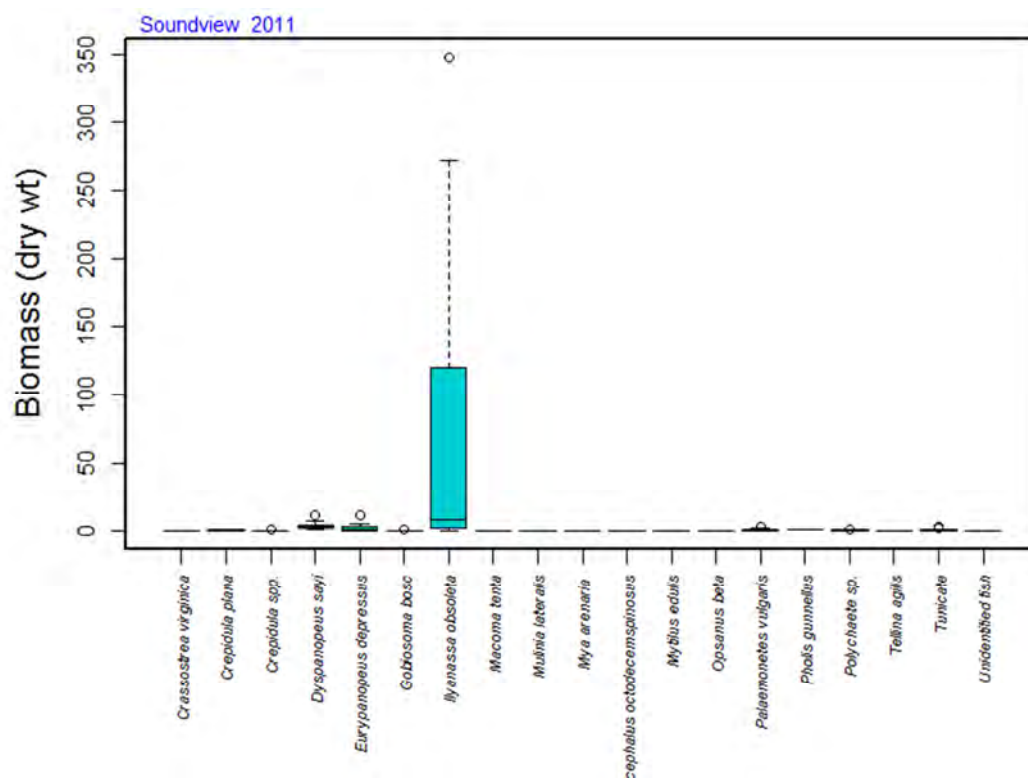


Figure 23. Biomass by species at Soundview.

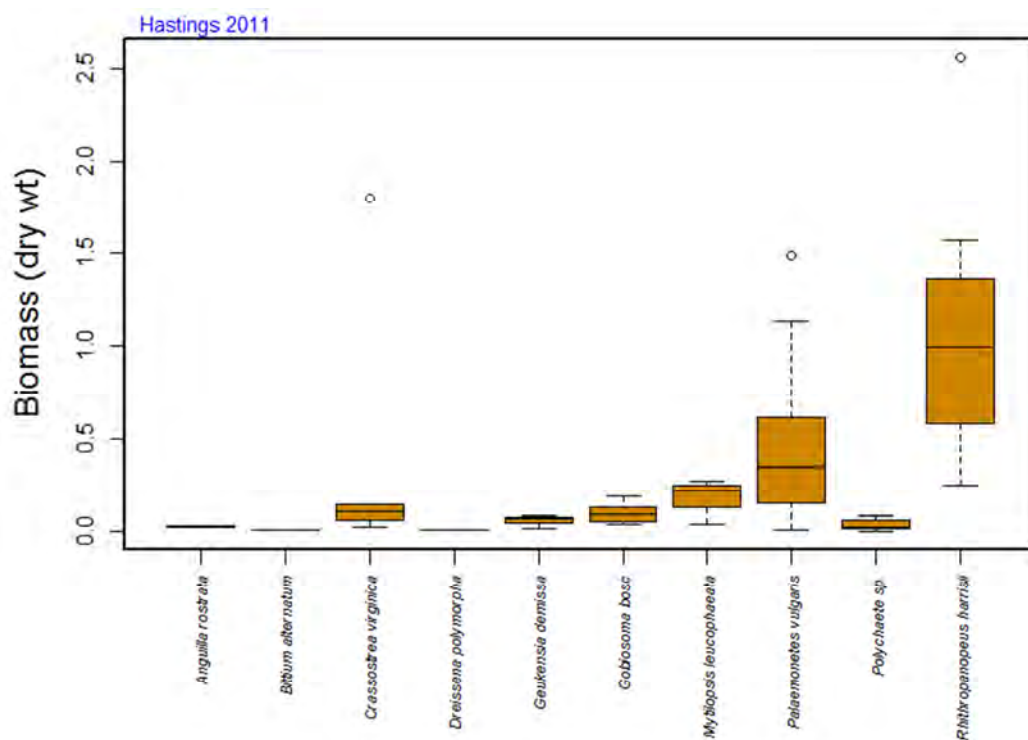


Figure 23. Biomass by species at Hastings.

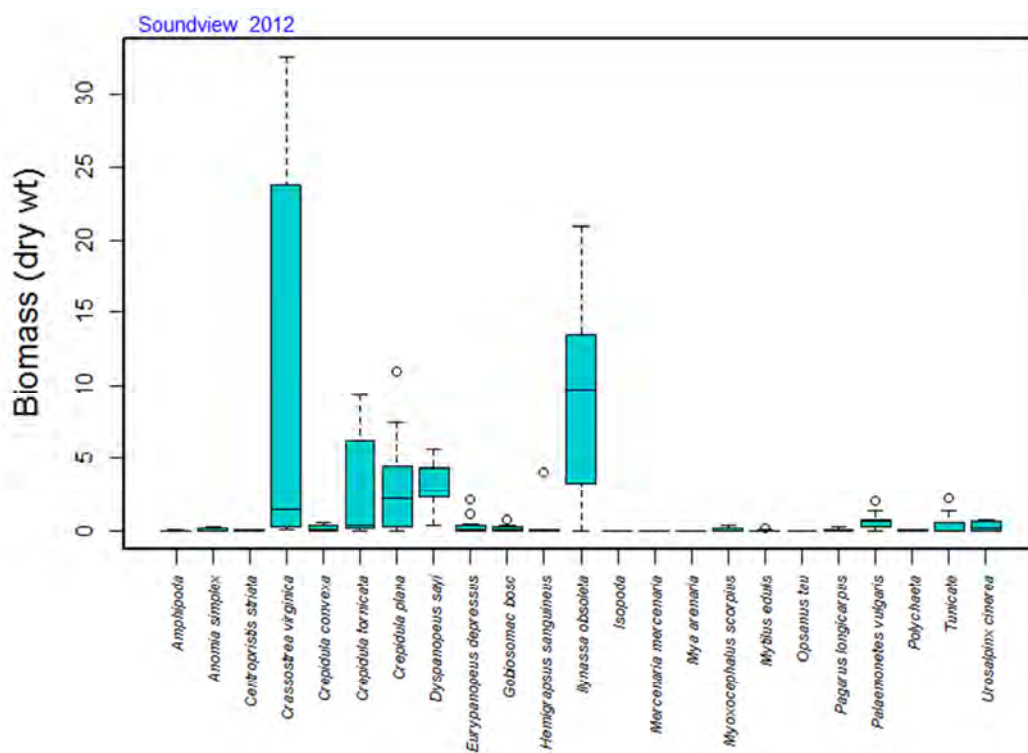


Figure 24. Biomass by species at Soundview.

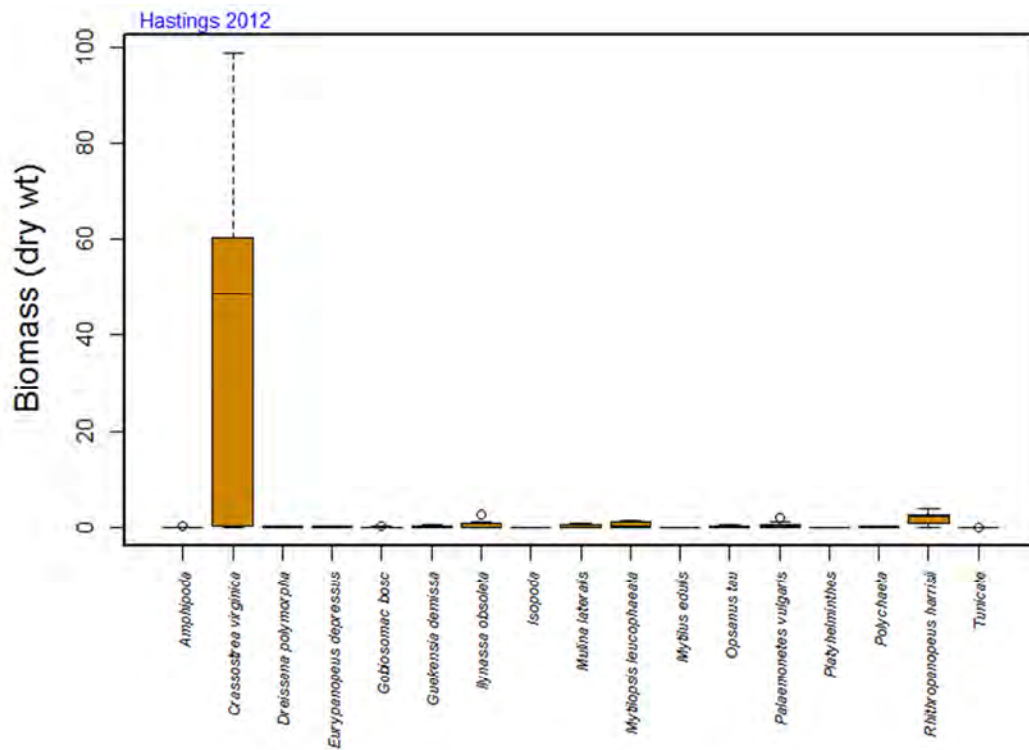


Figure 25. Biomass by species at Hastings.

The greatest amount of organismal biomass was found at the Staten Island site, while the least was found at the Hastings site in 2011. At Staten Island, the biomass was dominated by the suspension feeding bivalve *Mya arenaria* and the predatory oyster drill, *Urosalpinx cinerea*. Other species of note based on biomass were the predatory mud crab, *Dyspanopeus sayi* and the spider crab, *Libinia emarginata*. At the Bay Ridge Flats site, both the abundance and biomass was dominated by the mud crab, *D. sayi*. Again, the mud crab composed the greatest biomass at Governor's Island. At Soundview, the biomass was dominated by the mud snail, *Ilyanassa obsoleta* in 2011 and by *I. obsoleta* and *Crassostrea virginica* in 2012. However, the biomass of *I. obsoleta* in 2012 was only 10% of what was present in 2011. As the abundance was similar, we know that the size of the mud snails on the reef were significantly smaller in 2012 than the previous year. Finally, at Hastings, organismal biomass was dominated by the small predatory crab, *Rhithropanopeus harrisii* in 2011. In 2012, *C. virginica* dominated both the abundance and biomass in the colonization trays.

Comparing the biomass of the organisms collected in the colonization trays across the sampling periods, the greatest biomass was collected in June and August and then decreased into the fall (Fig. 26). The only exception to this was observed at Hastings in 2012 and this was the result of a large oyster spat set in the trays that dominated both the abundance and the biomass at that site in September.

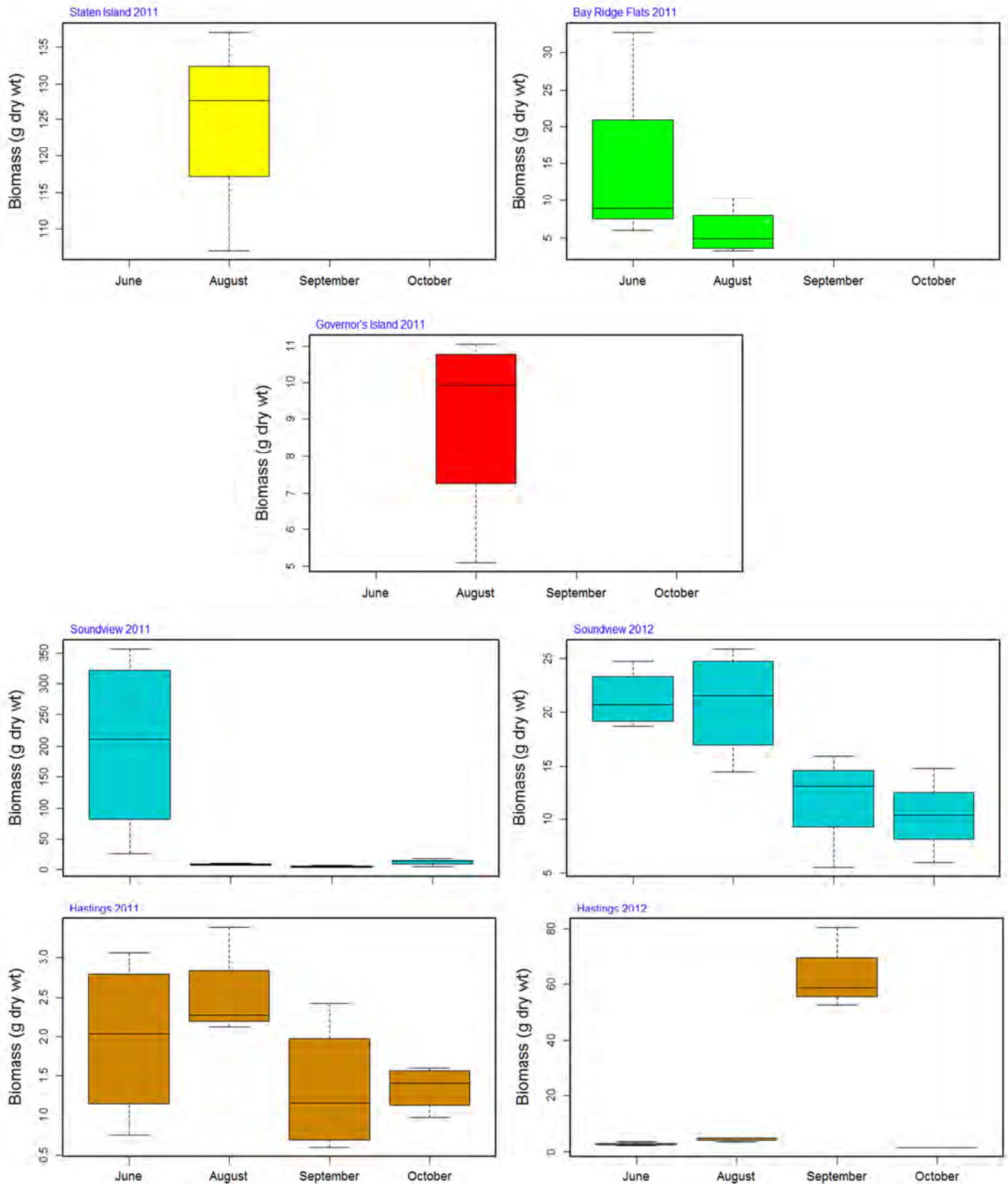


Figure 26. Organismal biomass in the collection trays at each site for each collection.

Comparing the biomass across the sites, we see that the Staten Island site had the greatest amount collected followed by Soundview. Again we see the impact of the oyster recruitment event at Hastings in 2012 (Fig. 27).

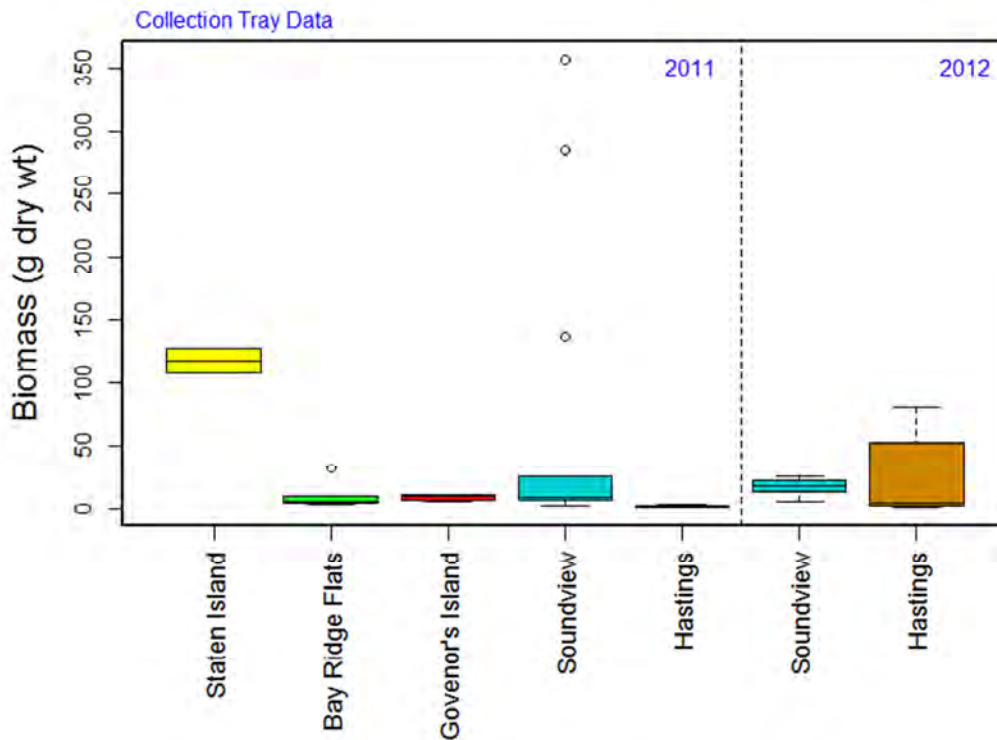


Figure 27. Organismal biomass at each site.

At Soundview and Hastings, it was possible to contrast the accumulation of biomass in the temporary and permanent collection trays (Fig. 28). Unlike abundance where there was no distinct difference between the temporary and permanent trays, organismal biomass was significantly greater in the permanent trays. This was even more dramatic when the oyster spat were removed from the analysis in the temporary trays (Fig. 29). Combining the comparison of organismal abundance and biomass, it appears that although the density of organisms did not change, those organisms present had grown in size in the permanent trays leading to a greater biomass in these trays. This suggests that once the organisms recruited to the trays they remained there throughout the season.

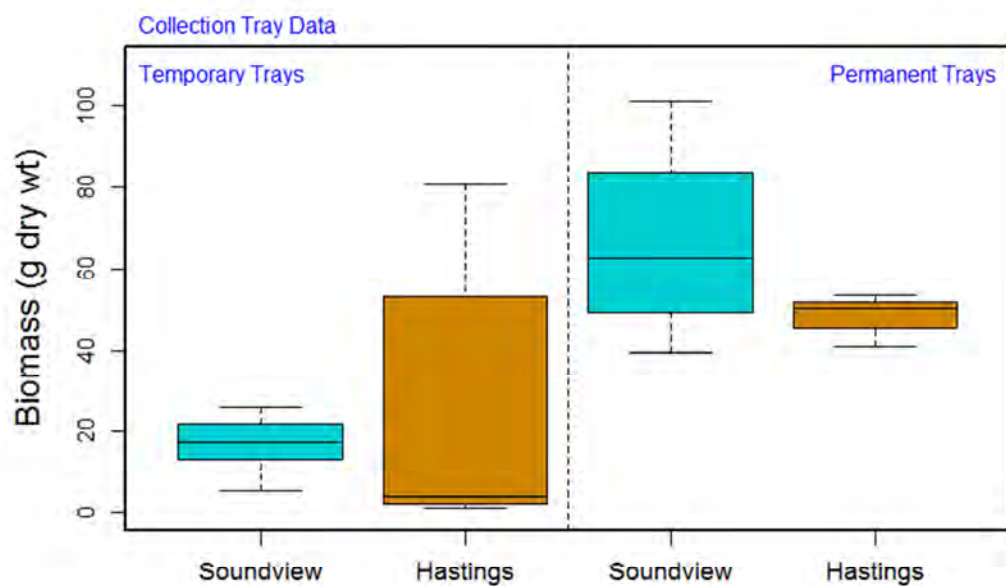


Figure 28. Comparison of the temporary and permanent trays at Soundview and Hastings in 2012.

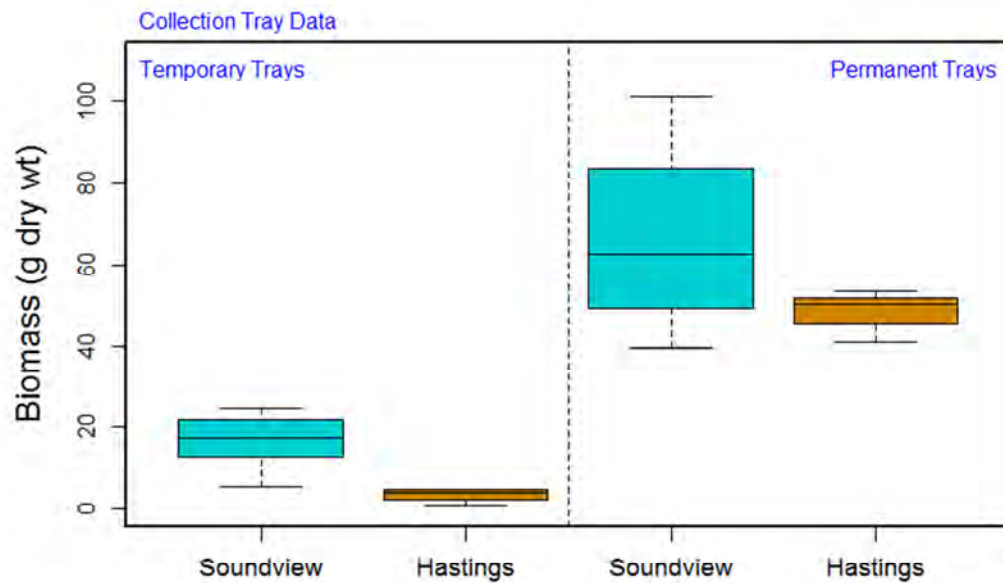


Figure 29. Comparison of the temporary and permanent trays at Soundview and Hastings in 2012 with the oyster spat removed.

Abundance and biomass statistical analysis

Comparing the abundance of organisms between the sites, there was a significant difference ($p < 0.001$; Fig. 16). Tukey's multiple comparison analysis identified that Staten Island has significantly more abundant organisms in the trays than the other sites followed by Soundview that was significantly more abundant than Hastings and Bay Ridge Flats sites. There was no difference in the abundance of the organisms in the collection trays between Bay Ridge Flats, Governor's Island and Hastings. Comparing Soundview and Hastings alone, revealed a significant difference between sites ($p = 0.03$) and years ($p = 0.001$). There were significantly greater abundances found in the colonization trays in 2012 and at the Soundview site. There was no significant difference between the abundance of organisms between the temporary and permanent colonization trays.

The differences between sites were not as significant when comparing the biomass ($p = 0.01$). In 2012, there was no difference between Soundview and Hastings ($p = 0.32$) but was there a significant difference between the temporary and permanent trays ($p < 0.001$). This demonstrates that although there were not a greater abundance of organisms in the permanent trays, those organisms present were of a larger size.

Species Diversity

In addition to assessing the organismal abundance and biomass of the experimental oyster reefs, understanding the impact these reefs have on species diversity is critical to quantifying the ecosystem services they provide. Comparing across the five experimental reefs in 2011, Staten Island had the highest level of taxa richness (Table 1). Species diversity increased from May through August and declined in the fall.

Table 1. Taxa richness by site for each month in 2012.

	2011			
	Taxa Richness			
	June	August	September	October
Staten Island	-	24	-	
Bay Ridge Flats	8	15	-	-
Governor's Island	-	12	-	
Soundview	8	15	12	10
Hastings	5	7	7	4

The same pattern of increasing species diversity was observed in 2012 (Table 2). There also appeared to be increasing accumulation of species in the permanent trays compared to the temporary ones in October.

Table 2. Taxa richness by site for each month in 2012 and comparing the temporary and permanent trays.

	2012				
	Taxa Richness				
	Temporary				Permanent
	June	July	September	October	October
Soundview	9	17	12	9	17
Hastings	5	7	12	7	13

Table 3. Mollusc species collected in the colonization trays at each of the sites.

Staten Island	Bay Ridge Flats	Governor's Island	Soundview	Hastings
<i>Anomia simplex</i>	<i>A. simplex</i>			
<i>Crepidula plana</i>	<i>C. plana</i>	<i>C. plana</i>	<i>C. plana</i>	
<i>Crepidula convexa</i>	<i>C. convexa</i>	<i>C. convexa</i>	<i>C. convexa</i>	
<i>Crepidula fornicata</i>	<i>C. fornicata</i>	<i>C. fornicata</i>	<i>C. fornicata</i>	
<i>Mytilus edulis</i>	<i>M. edulis</i>	<i>M. edulis</i>	<i>M. edulis</i>	
<i>Mya arenaria</i>	<i>M. arenaria</i>	<i>M. arenaria</i>		
<i>Urosalpinx cinerea</i>	<i>U. cinerea</i>	<i>U. cinerea</i>		
<i>Ilyanassa trivittata</i>	<i>Ilyanassa trivittata</i>			
<i>Petricola pholadiformis</i>	<i>P. pholadiformis</i>			
<i>Mulinia lateralis</i>			<i>M. lateralis</i>	
<i>Macoma tenta</i>			<i>M. tenta</i>	
<i>Tellina agilis</i>			<i>Tellina agilis</i>	
			<i>Crassostrea virginica</i>	<i>C. virginica</i>
<i>Gemma gemma</i>				
<i>Lyonsia hyalina</i>				
<i>Mercenaria mercenaria</i>				
<i>Rangia cuneata</i>				
<i>Spisula solidissima</i>				
<i>Eupleura caudata</i>				
			<i>Ilyanassa obsoleta</i>	
				<i>Mytilopsis leucophaeata</i>
				<i>Dreissena polymorpha</i>
				<i>Geukensia demissa</i>

The colonization trays collected 54 species over the course of the sampling. There were several unique mollusc species at both the Staten Island and the Hastings sites (Table 3). These differences reflect the two extremes in salinity that these sites represent. Three gastropod species (*Crepidula plana*, *C. convexa*, *C. fornicata*) and one bivalve species (*Mytilus edulis*) were present at all but the Hastings site where salinities dropped to zero during heavy rain events. One gastropod species, *Ilyanassa obsoleta*, was only found at the Soundview site. This organism, the mud snail, favors higher organic sediments such as those found at Soundview and Hastings, but requires the higher salinities found only at the Soundview site. The hard clam, *Mercenaria mercenaria*, was only collected at Staten Island. Importantly, the only two sites that collected wild spat in the colonization trays were Soundview and Hastings.

All sites had predatory crustaceans present (Table 4). The mud crab, *Dyspanopeus sayi*, was found at all sites with salinities higher than those at Hastings. Although *D. sayi* wasn't present there, the brackish water predatory crab, *Rhithropanopeus harrisii* was present. Soundview has the greatest number of reef resident fish in the colonization trays. The naked goby, *Gobiosoma bosc*, and the rock gunnel, *Pholis gunnellus*, was present at most of the sites. The toad fish, *Opsanus beta*, was present at Governor's Island and Soundview. Hastings was the only site where the American eel, *Angilla rostrata* was collected.

Table 4. Other taxonomic groups collected in the colonization trays at each site.

Staten Island	Bay Ridge Flats	Governor's Island	Soundview	Hastings
<u>Crustacean</u>	<u>Crustacean</u>	<u>Crustacean</u>	<u>Crustacean</u>	<u>Crustacean</u>
<i>Dyspanopeus sayi</i>	<i>D. sayi</i>	<i>D. sayi</i>	<i>D. sayi</i>	
<i>Palaemonetes vulgaris</i>	<i>P. vulgaris</i>		<i>P. vulgaris</i>	<i>P. vulgaris</i>
<i>Pagrus longicarpus</i>	<i>P. longicarpus</i>			
<i>Libinia emarginata</i>				
	<i>Panopeus herbstii</i>			
			<i>Eurypanopeus depressus</i>	
				<i>Rhithropanopeus harrisii</i>
<u>Fish</u>	<u>Fish</u>	<u>Fish</u>	<u>Fish</u>	<u>Fish</u>
	<i>Gobiosoma bosc</i>	<i>G. bosc</i>	<i>G. bosc</i>	<i>G. bosc</i>
	<i>Pholis gunnellus</i>	<i>P. gunnellus</i>	<i>P. gunnellus</i>	
		<i>Opsanus beta</i>	<i>O. beta</i>	
			<i>Myoxocephalus octodecemspinosus</i>	
				<i>Anguilla rostrata</i>
<u>Other</u>	<u>Other</u>	<u>Other</u>	<u>Other</u>	<u>Other</u>
Polychaete sp.	Polychaete spp.	Polychaete spp.	Polychaete spp.	Polychaete spp.
Tunicate	Tunicate	Tunicate	Tunicate	
	Anthozoa	Anthozoa		

Polychaete worms were found at all sites and the higher salinity sites all had tunicates recruit to the trays as well. Comparing the species within the trays between the temporary and permanent trays, there were some species that were only present in the permanent trays. The bivalve, *Anomia simplex* and the long clawed hermit crab, *Pagurus longicarpus*, were only found in the permanent trays at Soundview. The dwarf surf clam, *Mulina lateralis*, flatback mud crab, *Eurypanopeus depressus*, flatworms and isopods were only found within the permanent trays at Hastings.

Multivariate analysis of resident organisms was made using the PRIMER 6 software for analysis of similarities (ANOSIM) and similarity percentages (SIMPER). The multidimensional scaling (MDS) of community composition and related parameters among treatments were based on resemblance matrices of fourth-root transformed Bray-Curtis similarities (Fig. 30). Global R statistics were assessed for significant treatment effects at $p = 0.05$, whereas pair-wise comparisons were interpreted using the value of R itself (due to the limitations of permutation analysis in constructing consistent distributions). The PRIMER routine, BIO-ENV, assessed agreement between community composition and abiotic parameters using a Spearman rank correlation coefficient.

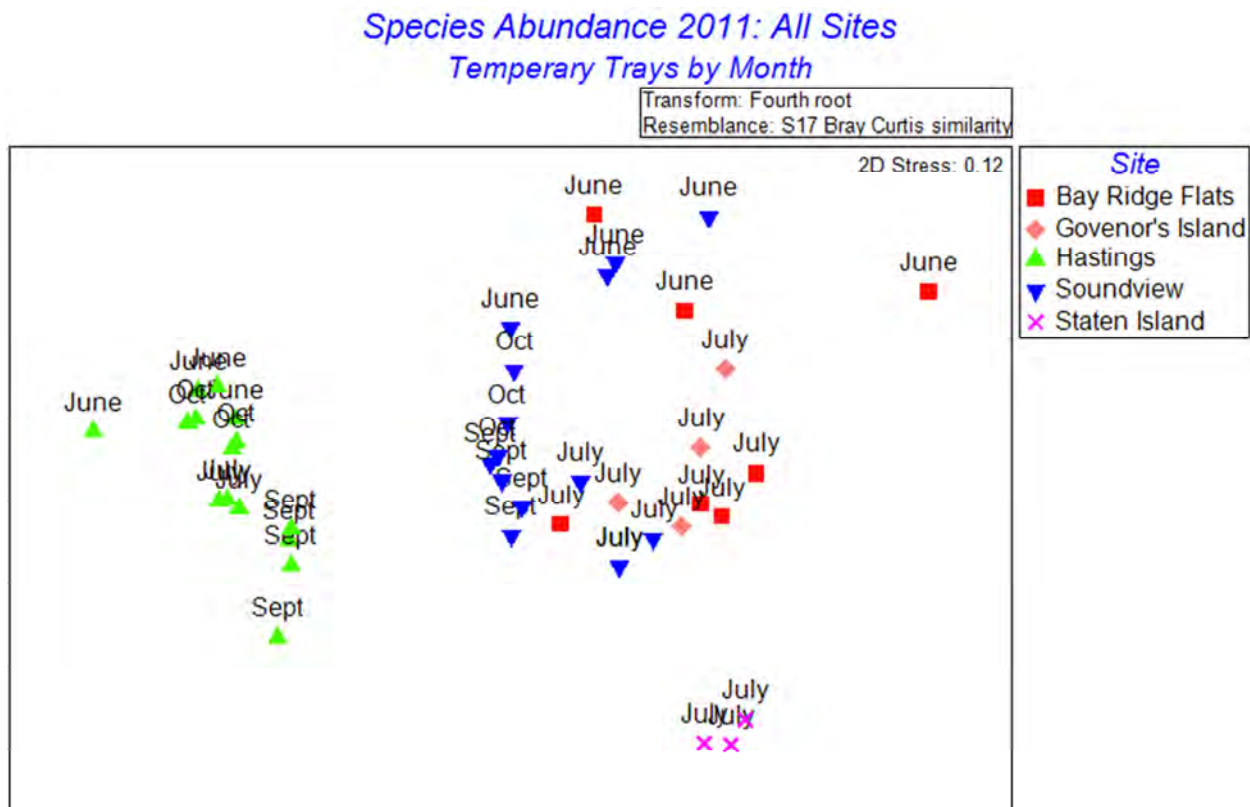


Figure 30. Multidimensional Scaling (MDS) plots comparing the community similarity between the experimental oyster reef sites and collection months.

Staten Island and Hastings reef resident communities were significantly different from the other sites. This again is driven by these sites representing the extremes in salinity (marine – freshwater). The communities also demonstrated a seasonal separation as species composition changed over the course of the sampling duration. These patterns were the same when assessed using biomass instead of abundance.

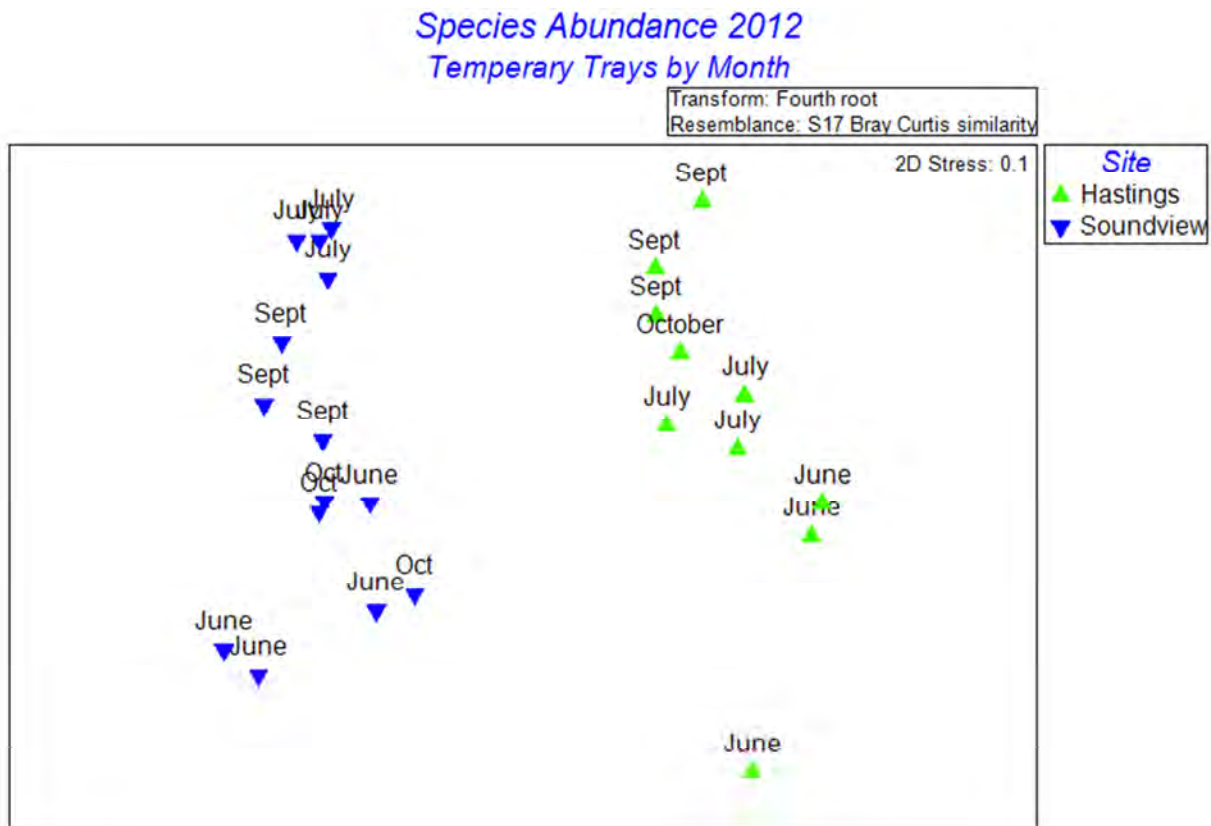


Figure 31. Multidimensional Scaling (MDS) plots comparing the community similarity between Soundview and Hastings sites and collection months in 2012.

In 2012, the MDS plots revealed a distinct separation between the two sites and the collections times during the season (Fig. 31). Finally, multivariate analysis was used to compare the species collected in the temporary versus permanent trays at both Soundview and Hastings in 2012 (Fig. 32). There was a clear separation of the temporary and permanent trays at Soundview, but not at Hastings. This illustrates that the communities between these two tray treatments were distinct when assessed via biomass.

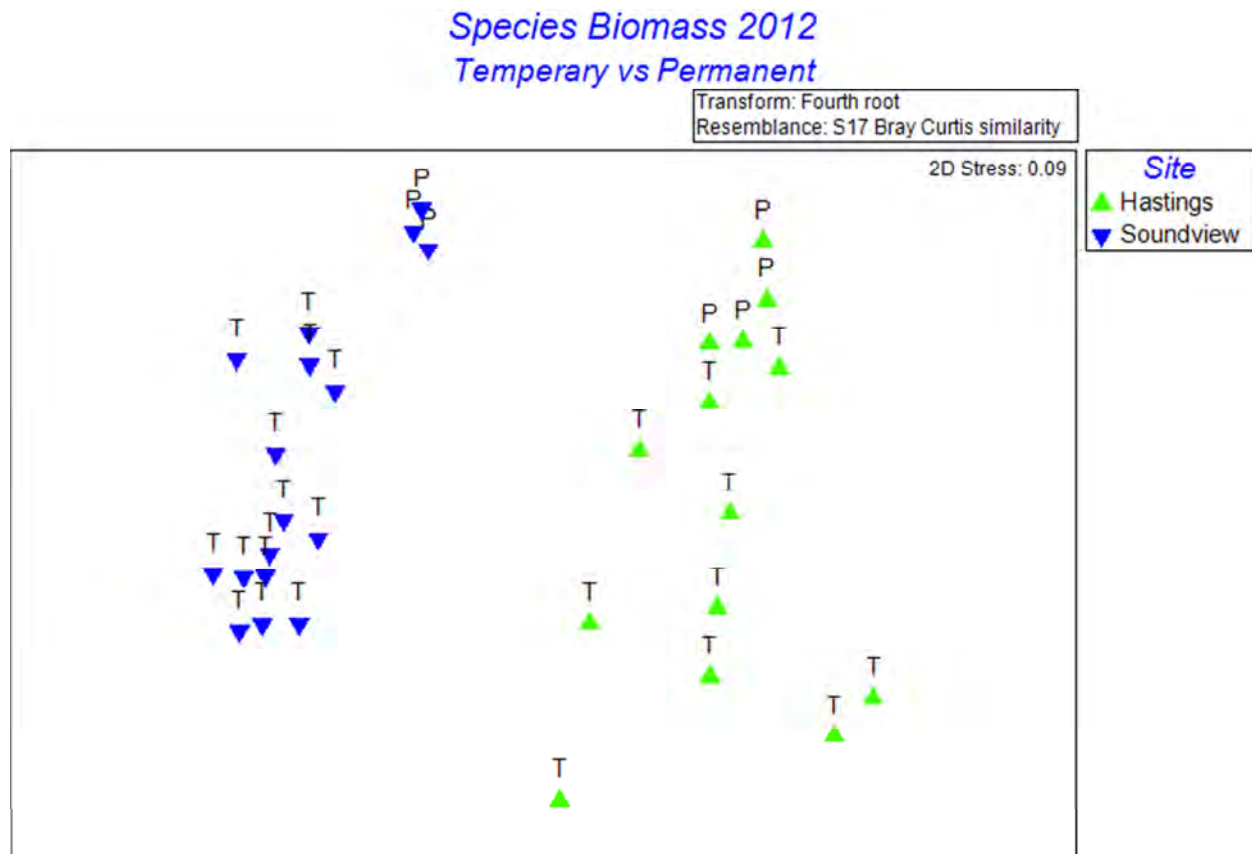


Figure 32. Multidimensional Scaling (MDS) plots comparing the community similarity between the temporary and permanent colonization trays at Soundview and Hastings in 2012.

Fish Traps and Gill Nets

Over the course of the two years there were 70 fish traps sampled which were placed either on or at distance from the reef. These traps collected a total of 112 organisms from 16 different species. The most abundant organisms caught in the traps were spider crabs (*Libinia spp.*) and blue crabs (*Callinectes sapidus*). The most abundance fish caught was the white perch (*Morone americana*) which occurred exclusively at Hastings. Staten Island had the greatest abundance of organisms captured in the Fish Traps (Fig. 33). This was followed by Soundview. Both Bay Ridge Flats and Governor's Island had the least number of organisms caught. While it appeared that there were more organisms caught on the reef, there was not a significant difference in the abundance of fish and crustaceans caught on the reef than at distance. The Gill Nets were deployed for a total of 35 sampling periods representing over 70 hrs in the water and collected 24 individuals from 7 species. The greatest number of organisms caught in the Gill Net occurred at Hastings and were the white perch (*Monrone americana*). The second most numerous organisms captured in the Gill Net was the blue crab (*Callinectes sapidus*).

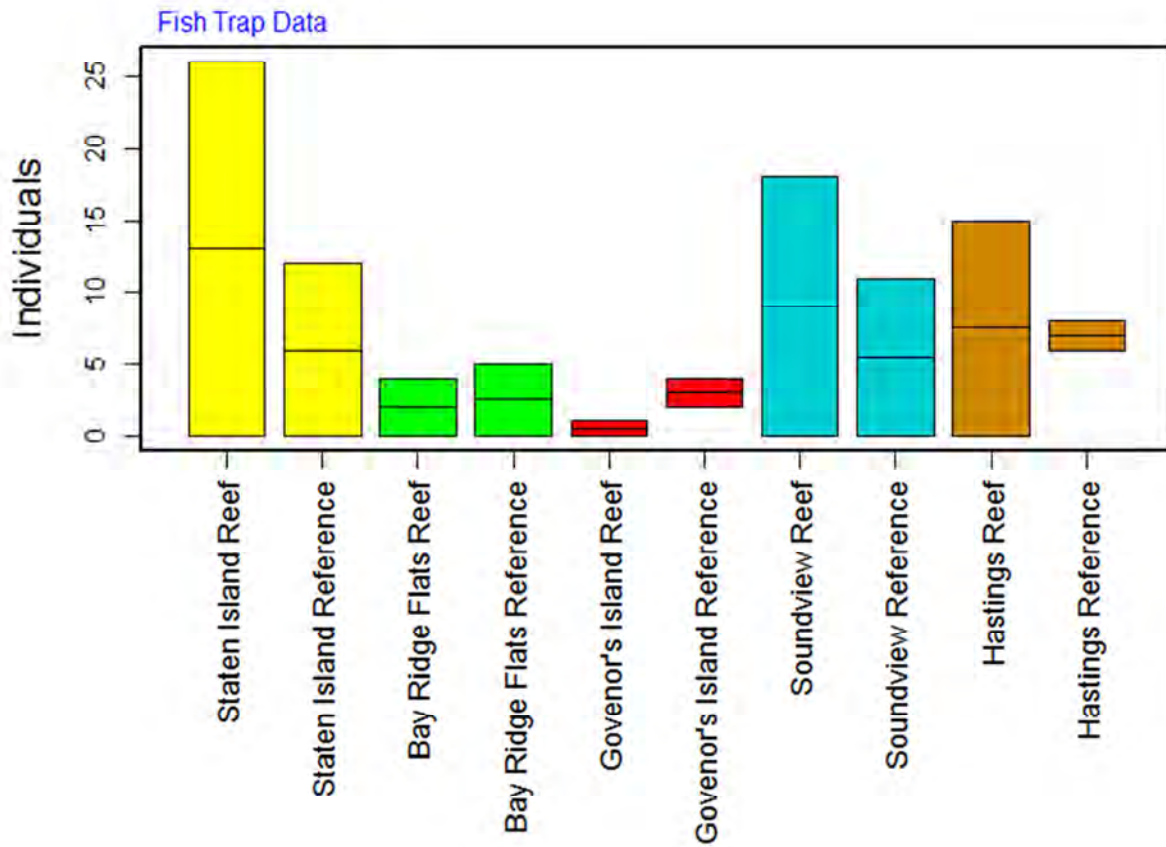


Figure 33. The total abundance of organisms caught in the Fish Traps at each site over the course of the survey.

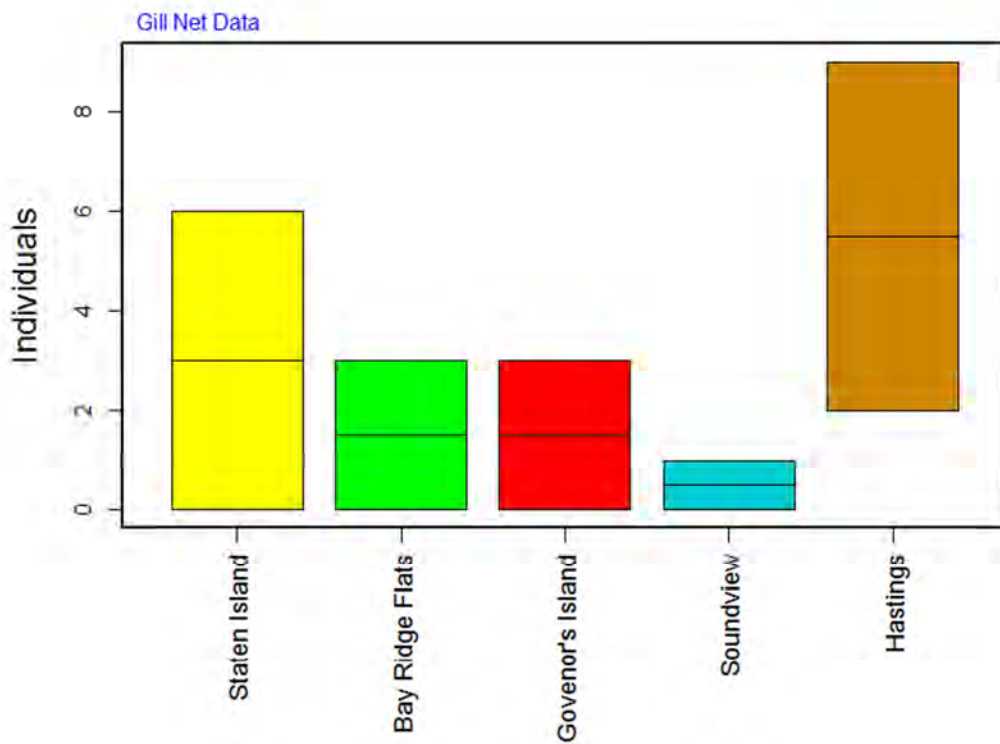


Figure 34. The total abundance of organisms caught in the Gill Nets at each site over the course of the survey.

Presentations and Publications

Data have been sufficiently analyzed to draw publishable conclusions and in the following months Ms. Kulp will undertake the task of completing a manuscript reporting the habitat usage by resident and transient species in the highly eutrophied Hudson River.

There were three presentations of this project's data by Rebecca Kulp. The first presentation was at the 2011 Marine Science Consortium, the second was at the 2012 Benthic Ecology meetings and the final presentation was at the 2013 Benthic Ecology meetings. The posters and abstracts of these oral presentations have been attached.

Ecosystem Services of Restored Hudson River Oyster Reefs

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Restoring oyster populations is not just beneficial for oyster fisheries, but can also enhance several ecosystem services. These services have started to be used to quantify and evaluate the success of restored oyster reefs. In 2010, the Hudson River Foundation constructed five preliminary oyster reefs with the goal of creating sustainable oyster populations. One ecosystem service, species colonization was used to evaluate the five oyster reefs during the summer and fall of 2011. At six-week intervals, four trays filled with surf clam shells were inserted and retrieved from each reef. Species richness, abundance and biomass were measured. Two of the five sites, Hastings and Soundview, were examined to determine spatial and temporal patterns, as well as whether the benthic communities were responding to the reef structure. Using a multivariate analysis, communities were distinctive between sites (72% dissimilar; SIMPER) and retrieval time points (global $R = 0.853$, $p < 0.001$; ANOSIM). Site differences were mainly attributed to the different mud crab species found at the two sites (contributes 35.5% to dissimilarity; SIMPER). While results suggested developing oyster reef communities in the Hudson, future monitoring needs to be performed before restoration success can be determined.

Strength in numbers? Evaluating the role of mesopredators in the NY Metropolitan Region

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Predation of newly settled juvenile *Crassostrea virginica* (spat) often dominates post-settlement mortality. Mesopredators such as the Xanthid mud crabs are abundant (ca. 200 m⁻²) on the newly constructed oyster reefs in the NY Metropolitan Region at both Hastings and Soundview Park, and due to their high abundances can potentially control spat post-settlement mortality. Predator-exclusion studies were conducted at both sites from June to August 2012 using glued hatchery-reared oyster singles and naturally recruited oysters. This study examined the effects of spat predator size class (all sizes, <25 mm, and <5 mm) and oyster reef structure. We hypothesized that mesopredators (<25 mm) would contribute significantly to spat mortality and

reef structure would enhance predation. Glued oysters experienced significant site and cage treatment effects on mortality, but not a reef structure effect. Naturally recruited tiles showed no differences between treatments, regardless of settlement time period and site. Results indicate that mesopredators are not the dominant predators of newly settled spat at Hastings or Soundview Park. Further research should evaluate whether results are unique to the newly restored Hudson Estuary and eastern Long Island Sound reefs or if prior studies have been overestimating the consumptive abilities of Xanthid mud crabs on oyster reefs.

In addition, this project facilitated a Tibor T. Polar Fellowship for Rebecca Kulp. The citation of the final report and the abstract of this project is below.

Kulp, R.E. and B.J. Peterson. 2012. Who controls whom? Linking the predator-prey dynamics between mud crabs and juvenile Eastern oysters to restoration efforts in the New York Metropolitan Region. Section IV: 1-31 pp. In S.H. Fernald, D.J. Yozzo and H. Andreyko (eds.), Final Reports of the Tibor T. Polgar Fellowship Program, 2012. Hudson River Foundation.

Abstract: Predation of newly settled juvenile Eastern oysters (*Crassostrea virginica*; spat) often dominates post-settlement mortality. Mesopredators such as the flat mud crab (*Eurypanopeus depressus*), Say mud crab (*Dyspanopeus sayi*) and white-fingered mud crab (*Rhithropanopeus harrisi*) are abundant on the newly constructed oyster reefs in the New York Metropolitan Region at both Hastings and Soundview Park, and potentially control spat post-settlement mortality. Predator-exclusion studies were conducted at both sites over the summer using glued hatchery-reared oyster singles and naturally recruited oysters. The study not only separated the effect of spat predators by size classes (all sizes, <25 mm, and <5 mm), but also examined the role oyster reefs have in enhancing or decreasing predation pressure. While there was a site and cage treatment interaction ($P < 0.001$), there was not a reef structure effect. The naturally recruited tiles showed no difference between 25 mm and exposed cage treatments, regardless of settlement time period and site ($P < 0.05$). Results indicate that mesopredators are not important in spat post-settlement mortality at Hastings or Soundview Park.

Since the cage field study could not measure mud crab predation directly, an additional pilot study was performed to test the plausibility of using stable isotope signatures for species-specific interactions. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ signatures were compared between oyster spat, *D. sayi* fed an all-spat diet, and control *D. sayi* not fed oyster spat. While control *D. sayi* had significantly enriched $\delta^{13}\text{C}$ signatures compared to laboratory *D. sayi* ($P < 0.001$), the $\delta^{15}\text{N}$ values did not differ ($P > 0.05$). Further research is needed to evaluate whether filter feeders are an important food resource for *D. sayi*, as results suggest *D. sayi* may depend on benthic and not pelagic carbon fixation.

References Cited

Aronson, R. B., Precht W. F. (1995) Landscape patterns of reef coral diversity: A test of the intermediate disturbance hypothesis. *J. Exp. Mar. Biol. Ecol.* 192:1-14.

Botsford, L. W., Castilla, J. C., Peterson, C. H. (1997) The management of fisheries and marine ecosystems. *Science* 277:509-515

- Carpenter, S. R., Kitchell, J. F. (1993) The trophic cascade in lakes. Cambridge University Press, London England.
- Coen, L. D., Luckenbach, M. W. (2000) Developing success criteria and goals for evaluating oyster reef restoration: ecological functioning or resource exploitation? *Ecol. Engineer.* 15:323-343
- Coen, L. D., Luckenbach, M. W., Breitburg, D. L. (1999) The role of oyster reefs as essential fish habitat: a review of current knowledge and some new perspectives. In: Benaka LR (ed) Fish habitat: essential fish habitat and restoration, *Am. Fish. Soc. Symp.* 22:438-454.
- Frisk, M. G., Miller, T. J., Latour, R. J., Martell, S. J. D. (2010) Assessing biomass gains from marsh restoration in Delaware Bay using Ecopath with Ecosim. *Ecol. Modeling* 222: 190-200.
- Gomelyuk, V. E. (2009) Fish assemblages composition and structure in three shallow habitats in north Australian tropical bay, Garig Gunak Barlu National Park, Northern Territory, Australia. *J. Mar. Biol. Ass. UK* 89: 449-460.
- Harding J. M., Mann, R. (1999) Fish species richness in relation to restored oyster reefs, Piankatank River, Virginia. *Bull. Mar. Sci.* 65:289-300.
- Harding J. M., Mann, R. (2001) Oyster reefs as fish habitat: opportunistic use of restored reefs by transient fishes. *J. Shell. Res.* 20: 951-959.
- Heyman, W. D., Ecochard, J. B., Biasi, F. B. (2007) Low-cost bathymetric mapping for tropical marine conservation – a focus on reef fish spawning aggregation sites. *Marine Geodesy* 30: 37-50.
- Hixon, M. A. (1998) Population dynamics of coral-reef fishes: controversial concepts and hypotheses. *Aust. J. Ecol.* 23: 192-201.
- Hobbs, R. J., Harris, J. A. (2001) Restoration ecology: repairing earth's ecosystems in the new millennium. *Restor. Ecol.* 9: 239-246.
- Lawton, J. H. (1996) Corncake pie and prediction in ecology. *Oikos* 76: 3-4.
- Lotz, J. Zurk, L. M., McNames, J., Ellis, T., Ecochard, J. L. (2007) Coral fish shoal detection from acoustic echograms. *IEEE OCEANS 2007*: 1-7.
- Peterson, C. H., Powers, S. P. (2003). Quantitative enhancement of fish production by oyster reef habitat: restoration valuation. *Mar. Ecol. Prog. Ser.* 264: 249-264.
- Powers, S. P., Grabowski, J.H., Peterson, C. H., Lindberg, W. J.(2003) Estimating enhancement of fish production by offshore artificial reefs: uncertainty exhibited by divergent scenarios. *Mar. Ecol. Prog. Ser.* 264: 265-277.
- Rodney, W.S., Paynter, K.T. (2006) Comparisons of macrofaunal assemblages on restored and non-restored oyster reefs in mesohaline regions of Chesapeake Bay in Maryland. *J. Exp. Mar. Biol. Ecol.* 335: 39-51.
- Rogers, C. S., M. Gilnack & H. C. Fitz. 1983. Monitoring of coral reefs with linear transects: A study of storm damage. *J. Exp. Mar. Biol. Ecol.* 66:285-300.
- Rossi, R. E., Mulla, D. J., Journel, A. G., Franz, E. H. (1992) Geostatistical tools for modeling and interpreting ecological spatial dependence. *Ecol. Monogr.* 62: 277-314.

Thompson, S.K. (2002) Sampling, 2nd ed. John Wiley & Sons Inc, New York NY.

Valentine, J. F., Heck, K. L., Peterson, B. J., Blackmon, D., Christian, J., Goecker, M., Kroutil, R. M., Vanderklift, M., Beck, M. (2008) Exploited species impacts on trophic linkages along reef-seagrass interfaces in the Florida keys. *Ecol. Applications* 18: 1501-1515.

Valentine, J. F., Heck, K. L., Peterson, B. J., Blackmon, D., Christian, J., Goecker, M., Kroutil, R. M., Vanderklift, M., Beck, M. (2007) Food web interactions along seagrass-coral reef boundaries: effects of piscivore reductions on cross-habitat energy exchange. *Mar.Ecol.Progr. Ser.* 333: 37-50.

Vitousek, P. M., Mooney, H. A., Lubchenco, J., Mellilo, J. (1997) Human domination of earth's ecosystems. *Science* 277: 494-499.
