1-5-2015

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Publisher Citation

Zajac, R., McCarthy, A. (2015) Drift algae in New Haven Harbor and impacts on benthic communities. Report to the Quinnipiac River Fund, New Haven Foundation.

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Final Report for

Quinnipiac River Fund Grant #20120099

2012-2013

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January 5, 2015

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Introduction

The Quinnipiac River Watershed (QRW) drains into New Haven Harbor (NHH) and thus the harbor is the recipient of the many potential contaminants that enter the watershed from its varied urban, suburban and agricultural landscapes. The long history of such inputs into NHH has resulted in contaminated sediments and impaired overall ecological health. Concurrently, the harbor is the focus of extensive human development and activity which has reshaped and altered its coastline and varied sea floor habitats. However, the harbor remains an important natural resource in terms of, for example, providing habitat for both resident and migrating fish, as settlement area for oysters (which are eventually relayed to deeper waters), and as a overwintering feeding area for migrating birds. Much of the habitat value of the harbor is tied to its benthic communities and the sedimentary characteristics and features that comprise its sea floor.

In 2009 the University of New Haven initiated studies to develop a contemporary database and assessment of the benthic ecology of New Haven Harbor. Previous studies were last conducted in the 1970s and 1980s (e.g. McCusker, and Bosworth 1979, 1981, Rhoads and Germano 1982). Benthic populations and communities are excellent indicators of environmental conditions and are regularly used for environmental assessment in estuarine and coastal waters (e.g. Pearson and Rosenberg 1978, Rhoads et al. 1978, Zajac and Whitlatch 2001, Mangi 2003). Given the inherent ability of the benthos to integrate sediment and water quality, many environmental indicators and indices to assess the degree and nature of environmental change have been developed based on marine macrobenthic taxa and communities (e.g. Weisberg et al. 1997, Borja et al. 2000). Our findings have been reported to the Quinnipiac River Fund Board (Zajac and Brown 2012), and also have been presented at the Biennial Long Island Sound Research Conference that was held at the end of October 2010, and at national and regional meetings in 2011. Briefly, these studies showed that there are a diverse set of benthic (seafloor) habitats within the harbor that support a surprisingly diverse pool of species although there are areas that are impaired. Additionally, comparison to data collected in the 1980's suggest that there has been an overall shift in the benthic community characteristics in New Haven Harbor suggesting a long-term degradation due to the presence / increased abundance of organisms that are typical under disturbed conditions.

During this work, we found that there was an extensive area of drift macroalgae, mostly *Ulva* sp., commonly known as sea lettuce, covering much of the western portions of the harbor, along the intertidal area of the North Harbor (Long Wharf area) and also in pockets in other areas (Zajac and Brown 2012, Zajac 2013), one can also see examples of video data of the drift algae at: http://www.youtube.com/watch?v=lpvz4lA6BRA). Such accumulations of drift algae are known to have significant negative effects on benthic communities (e.g. Norkko and Bonsdorff 1996a,b, Thiel and Watling 1998, Norkko et al. 2000, and often can be an indicator of high nutrient loading into a coastal system (Soulsby et al. 1985, Vahteri et al 2000). These accumulations can kill off organisms living below the drift algae due to significant oxygen reduction, particularly during high respiratory demand periods during night and dawn. In turn this can reduce species richness, alter community structures and disrupt population dynamics. Interestingly though, they may actually provide temporary habitat for organisms that might not necessarily be found in the system. We know little about the dynamics of these New Haven Harbor algal beds over time; whether they break down over the winter and how long they last into the fall. Thus, it is important to determine the seasonal dynamics of the drift algal mats. Secondarily, we do not know what effects they may be having on the benthic communities, and how long-lasting those effects may be.

The macroalgae study conducted in 2011-2012 (Zajac 2013) indicated that the algal beds continue to be extensive along the western shore of NHH, and that although there is some breakdown moving into the fall, the drifting beds are present through October. The objective of this study was to continue assessing the extent and characteristics of macroalgal blooms in New Haven Harbor and determine the impacts such blooms have on benthic communities.

Methods

Sampling was conducted in October 2011, and July, August and October 2012 in several areas along the western portion New Haven Harbor where drift algal beds were most extensive in previous studies (Figure 1). A survey of the entire New Haven Harbor was also conducted in August 2012. Underwater video surveys were performed to determine the spatial extent and areal coverage of the drift algal mats. Three to five random video samples were taken within and near the mats at each sampling point in order to determine algal biomass and associated fauna. Benthic samples were taken using a modified Ponar grab sampler at each site. All the algae within the sampler was collected and returned to the laboratory where biomass was measured on a dry weight basis (biomass data from this study were presented in Zajac 2013 because they were available at the time that final report was being compiled). In the lab the algae was washed onto 0.33 mm sieves to collect any mobile animals living within the mat, and then the blades were examined to remove any attached organisms. Sub-cores (5 cm diameter) were taken in the grab sampler and processed to obtain data on benthic communities. Samples were preserved in 70% ethanol and stained with Rose Bengal. The benthic organisms were later enumerated and identified the lowest possible taxon with the aid of a dissecting microscope. All data was entered into a digital database and then analyze to determine the temporal dynamics of the algal mats, and how community structure changes both inside and outside the mat areas over the study period.

Results and Discussion

Changes in Drift Macroalgal Beds

Due to mechanical issues with the research vessel being used, sampling was not initiated until late June 2012. The drift macroalgal beds in NHH are mainly comprised of the green sea lettuce *Ulva* spp., but in 2012 a significant proportion was comprised of the red alga *Gracilaria* spp. (likely *Gracilaria tikvahiae*). Typically the macroalgal beds in NHH start increasing in extent in May and by June they are relatively well developed (Zajac 2013, and Zajac *personal observations*). This was the case in 2012, with almost 100% cover in the nearshore areas (Areas I and V, see Fig. 1) of the western harbor, and this was comparable to what was found in 2011 (Fig. 2). There was relatively sparse cover away from nearshore areas. In August 2012, The extent of the bed along the western shore expanded somewhat, but declined near the mouth of the West River in the northwest portion of the harbor (Fig. 2). During this period, little to no drift algae were found in the more west-central portion of the harbor as well as near the channel that leads from the mouth of the West River into the harbor (Areas III and III in Fig.1). Smaller accumulations were found in the transitional area from the West shore into the central harbor (Area IV, Fig. 1) during this period. By the end of October 2012 much of the study area in the Western portion of the harbor was free of drift macroalgae except at one location (Fig. 2). Interestingly, in 2011 the drift macroalgae was much more extensive in early October. This suggests that either conditions in 2012 were such that the persistence of the beds were not supported or that the beds breakdown relatively quickly as temperatures and other environmental factors shift during the fall. The algal biomass data (Zajac 2013) did indicate that the biomass was significantly lower in 2012 than in 2011, and as such that may have led to a more rapid breakdown of the beds. There may also be differences between the degree to which the different types of algae making up the beds can extend their growth into the fall.

The harbor wide survey in August 2012 indicated significant accumulations along the western portion of New Haven Harbor as well as along the shore in the Long Wharf area (Fig. 3). Very little macroalgae was observed along the eastern shore of the harbor nor in the south-central area just off Sandy Point. From the data collected both in 2011 and 2012, and observations during the surveys, we can extrapolate the areas that are most prone to accumulations of drift macroalgae (Fig. 3). In addition to the areas noted above, there are also relatively heavy accumulations all along the shore at Long Wharf and also on the inside harbor portions of Sandy Point. In the deeper water portions of the central harbor (~> 8 ft / 2.5 m), there is little evidence of drift macroalgal beds, as well as in the deeper waters of Morris Cove and along the navigation channels leading into the harbor. Although the significant drift macroalgal beds are confined to certain portions of New Haven Harbor they do comprise a significant area of the intertidal in shallow subtidal habitats of the harbor. These are significant habitats with regards to organisms that feed on benthic fauna, such as wading birds and small fish. The significant growth of macroalgae that occurs in these areas is likely due to a combination of warm waters between spring and early fall, ample sunlight and also significant inputs of nutrients from rivers, combined sewer outfalls and direct runoff from the highly developed shoreline of the harbor.

Effects on Benthic Communities

The patterns of spatial extent and areal coverage of the drift macroalgal beds in the harbor indicate that Areas I and V have the highest accumulations, that Area IV is transitional with moderate to low accumulations, whereas Areas II and III have little to no accumulation (Figs. 1 and 2). Based on this pattern the benthic data was sorted based on these areas and analyzed to see the effects that different levels of macroalgal that development can have on various benthic community characteristics. The total abundance of organisms was significantly different among the five areas (Table 1), with very low abundance in Areas I and V during the summer and late summer in Area I (Fig. 4). Higher abundances were generally found in Areas II and III during much of the year. In late fall, total abundance in all areas was relatively high with a significant recovery in Area I which was a intertidal/shallow subtidal habitat.

Taxonomic (species) richness was significantly different among the sampling areas as well as seasonally (Table 1), with lower numbers of species found in the areas most impacted by the macroalgal beds (I and V), and higher numbers of different taxa in areas that were less impacted, and overall more taxa in the fall after the algae had died back (Fig. 5). The diversity organisms can also be assessed using several other metrics including a diversity index such as Shannon's index and also rarefaction techniques that estimate the number of species based on a fixed sample size. For both measures there was a significant difference among areas and seasons (Table 1). Shannon Diversity was generally higher in areas that had low to no macroalgae (IV, II and II; Fig. 6) and lowest in Area V during the summer and in Area I in the late summer. Similar differences were found for the estimated number of species (Fig. 7), although low numbers were found in Area IV in late summer, perhaps due to the macroalgal beds extending into this area as the summer progressed.

Several general patterns emerge from these analyses. Both the abundance and the diversity of benthic organisms was lower in the areas where accumulations and expansion of drift macroalgae was the greatest, suggesting that conditions within these beds were having negative effects on the benthic community. These negative effects appear to be occurring only during the late spring through early fall as community characteristics rebounded to higher levels by the late fall. Such negative impacts have been found in other studies as noted above in the introduction. In New Haven Harbor, the affected areas may represent impacted habitats which do not allow the establishment of certain suites of species that may be important within the estuarine food web, such as small worms and crustaceans that juvenile flatfish the on, and or species such as oysters and large bivalves that can not only be harvested (depending on water quality) but also can help filter near shore waters.

Coupled with our previous studies (Zajac and Brown 2012, Zajac 2013) this work expands the contemporary assessment of the harbor's benthic ecology that can be useful for addressing a variety of environmental issues and providing an assessment of long-term changes that may be occurring in the harbor. This type of information is useful to a number of groups interested in the well-being of the Quinnipiac River watershed and New Haven Harbor, including environmental managers, educators, the public and other researchers. Most importantly it helps build a contemporary baseline by which to measure future changes in conditions in the harbor, both with regard to its estuarine-related dynamics and the potential impacts of inputs from the Quinnipiac River watershed. Tracking the year-to-year changes in the extent and biomass of the drift macroalgae may provide a metric by which to measure conditions within the harbor and also riverine inputs of nutrients, leading to an overall measure of water quality within the harbor.

Literature Cited

Borja, A., J. Franco and V. Perez. 2000. A marine biotic index to establish the ecological quality of soft bottom benthos within European estuaries and coastal environments. Mar. Poll. Bull. 40: 1100-1114.

Buchanan, J.B., Kain, J.B., 1971. Measurement of the physical and chemical environment. In: Holme, N.A., McIntyre, A.D. (Eds.), Methods for the Study of Marine Benthos. Blackwell Scientific Publications, Oxford, pp. 30-58.

Magni P (2003) Biological benthic tools as indicators of coastal marine ecosystems health. Chemistry and Ecology 19:363-3

McCusker, A. J., Bosworth, W. S. (1979). New Haven Harbor ecological studies summary report 1970-1977. Prepared for the United Illuminating Company, New Haven, Connecticut. Normandeau Associates, Inc, Bedford, New Hampshire

McCusker, A. J., Bosworth, W. S. (1981). New Haven Harbor ecological studies summary report 1980. Prepared for the United Illuminating Company, New Haven, Connecticut. Normandeau Associates, Inc., Bedford, New Hampshire

Norkko, A. and E. Bonsdorff. 1996. Population responses of coastal zoobenthos to stress induced by drifting algal mats. Marine ecology progress series. Oldendorf 140:141-151.

Norkko, A. and E. Bonsdorff. 1996. Rapid zoobenthic community responses to accumulations of drifting algae. Marine ecology progress series. Oldendorf 131:143-157.

Norkko, J., E. Bonsdorff, and A. Norkko. 2000. Drifting algal mats as an alternative habitat for benthic invertebrates::: Species specific responses to a transient resource. Journal of Experimental Marine Biology and Ecology 248:79-104.

Pearson, T.H. and R. Rosenberg (1978) Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr. Mar. Biol., Ann. Rev. 16: 229-311.

Rhoads D, Germano J (1982) Characterization of organism-sediment relations using sediment profile imaging: An efficient method of remote ecological monitoring of the seafloor(REMOTS(TM) System). Marine Ecology Progress Series 8:115-128

Rhoads, D.C., P.L. McCall and J.Y. Yingst. (1978) Production and disturbance on the estuarine seafloor. Amer. Sci. 66: 577-586.

Soulsby, P., D. Lowthion, M. Houston, and H. Montgomery. 1985. The role of sewage effluent in the accumulation of macroalgal mats on intertidal mudflats in two basins in southern England. Netherlands Journal of Sea Research 19:257-263.

Thiel, M. and L. Watling. 1998. Effects of green algal mats on infaunal colonization of a New England mud flat–long-lasting but highly localized effects. Hydrobiologia 375:177-189.

Vahteri, P., A. MÃ¤kinen, S. Salovius, and I. Vuorinen. 2000. Are Drifting Algal Mats Conquering the Bottom of the Archipelago Sea, SW Finland? AMBIO: A Journal of the Human Environment 29:338-343.

Weisberg, S.B., J.A. Ranasinghe, D.D. Dauer, L.C. Schnaffer, R.J. Diaz and J.B. Frithsen. 1997. An estuarine benthic index of biotic integrity (B-IBI) for Chesapeake Bay. Estuaries and Coasts 20:149-158.

Zajac, R.N. 2013. Assessment of Drift Macroalgal Accumulations in New Haven Harbor.

Zajac R, Whitlatch R (2001) Response of macrobenthic communities to restoration efforts in a New England estuary. Estuaries and Coasts 24:167-183. Final Report Quinnipiac River Fund Grant 20110106 (2011-2012).

Zajac, R.N. and Brown, D.S. 2012. An assessment of the ecological condition of benthic communities in New Haven Harbor in relation to selected environmental factors and habitat structure. Quinnipiac River Fund Project Final Report, 2009-2011.

Figure 1. Sampling locations in the western portion of New Haven Harbor for the drft macroalgal surveys and benthic samples. Areas I and V are where extensive accumulations of macroalgae were found in previous studies; Area IV is a transitional area where some accumulations were found; Areas II and III had little to no drift macroalge.

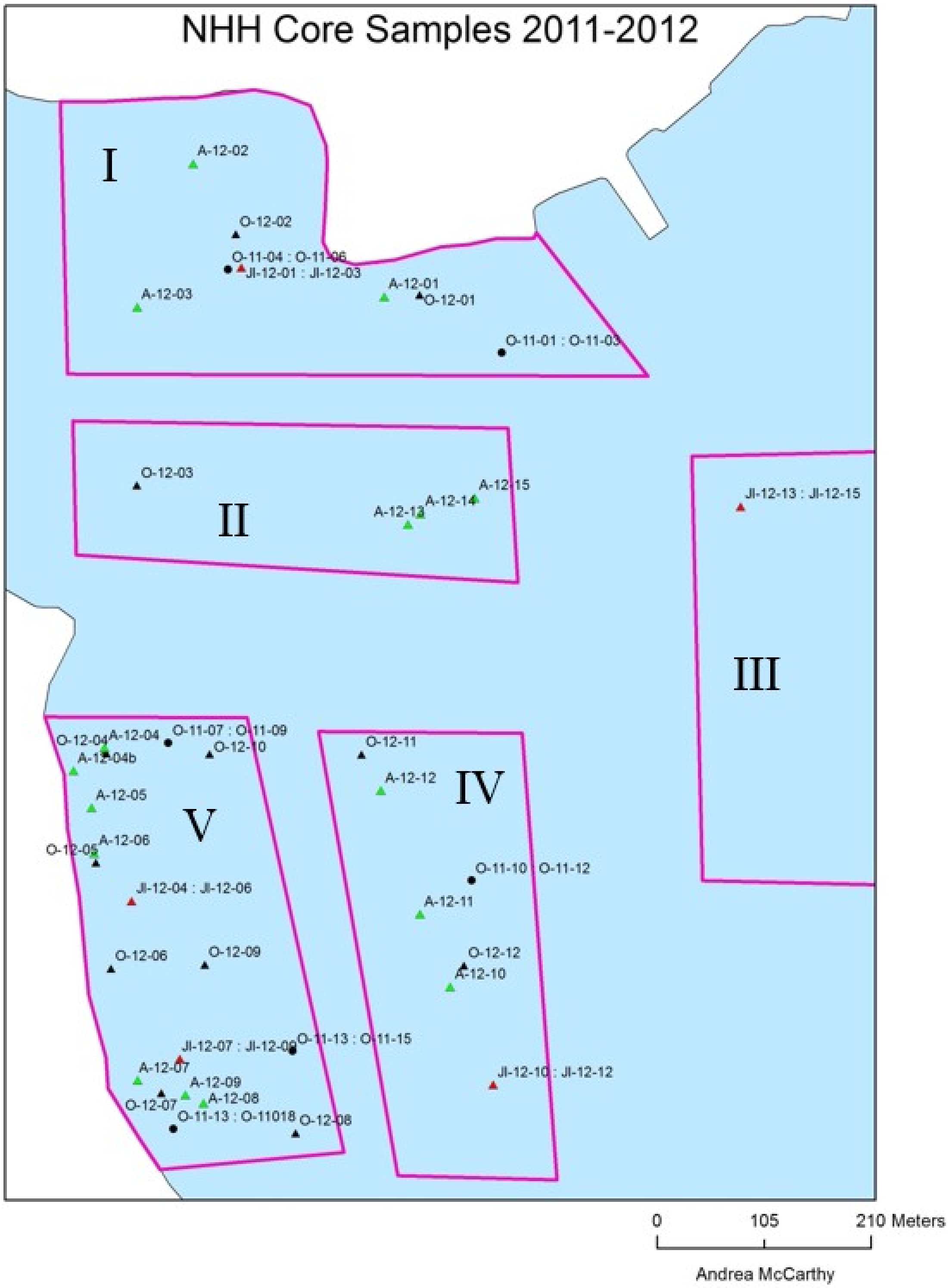
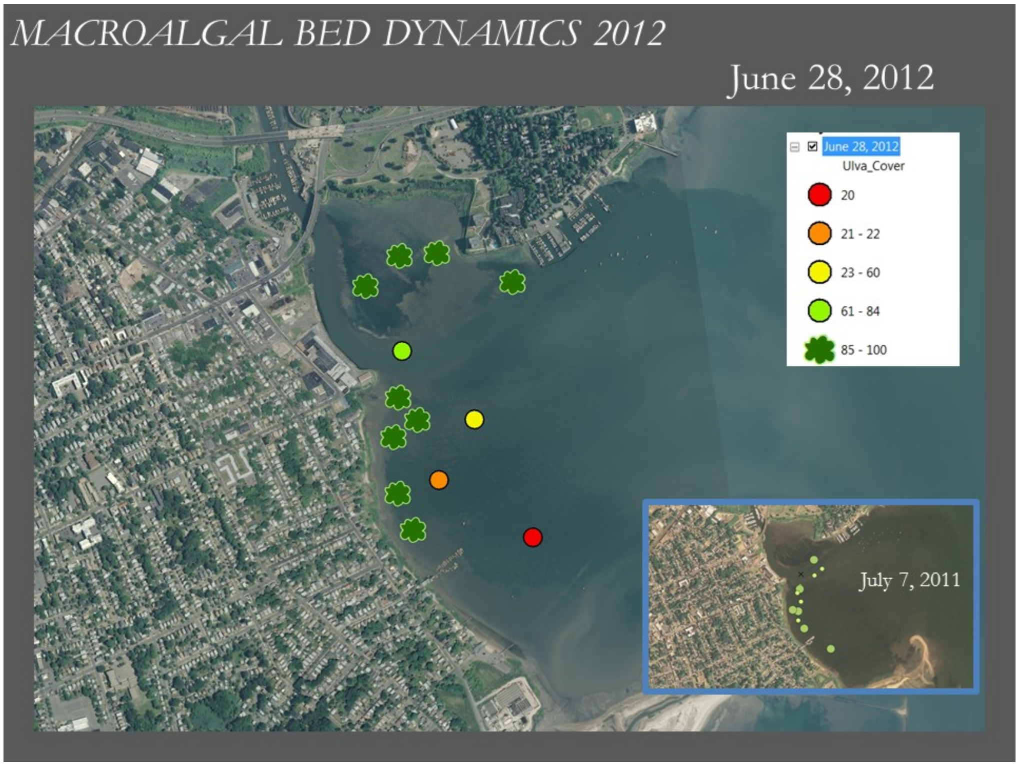
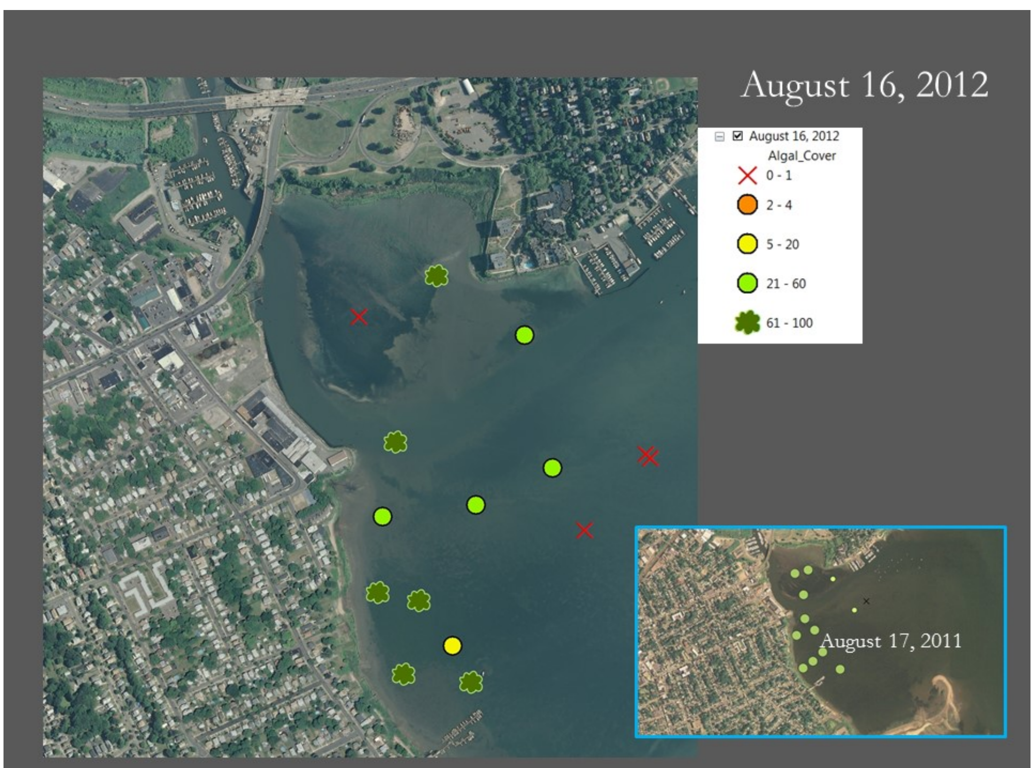


Figure 2. Location and extent of drift macroalgae beds in New Haven Harbor in 2012.Insets show comparison to 2011. Key is in Percent cover in ~ 8 x 6 cm frame three of replicate video samples taken at each sampling site.





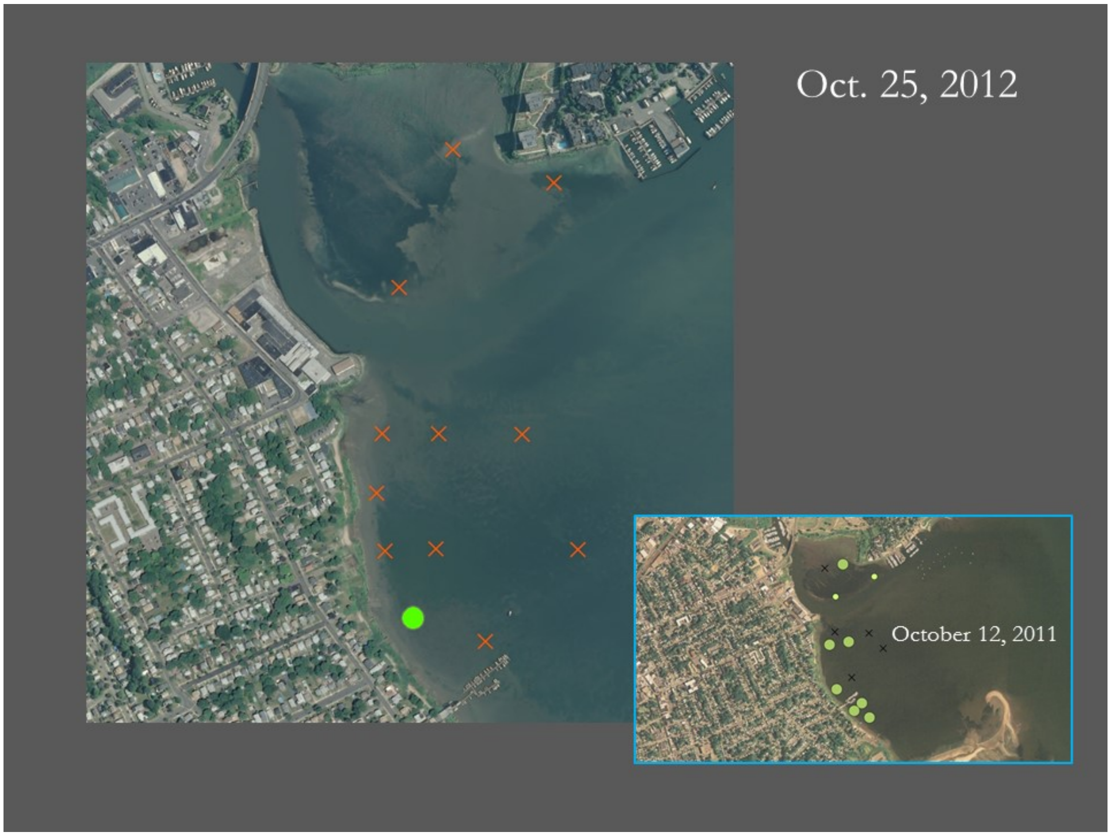

Oct. 25, 2012
October 12, 2011

Figure 3. TOP: Results of Harbor-wide survey of drift macroalgae conducted in August 2012. BOTTOM: Extrapolated distribution and density of beds based on direct sampling and also observations from shore and boat.

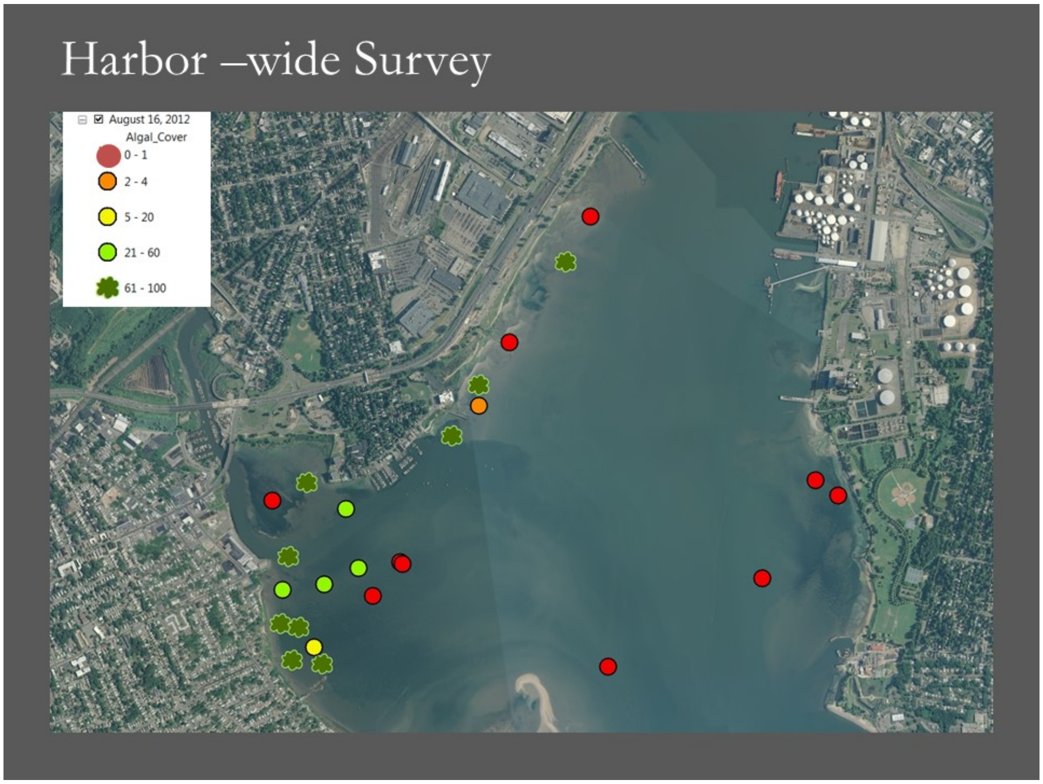


Figure 4. Seasonal differences in benthic community mean abundance (+ 1 standard error, per 20 cm^2) among the different sampling areas in New Haven Harbor. Areas I and V are where extensive accumulations of macroalgae were found in previous studies; Area IV is a transitional area where some accumulations were found; Areas II and III had little to no drift macroalgae.

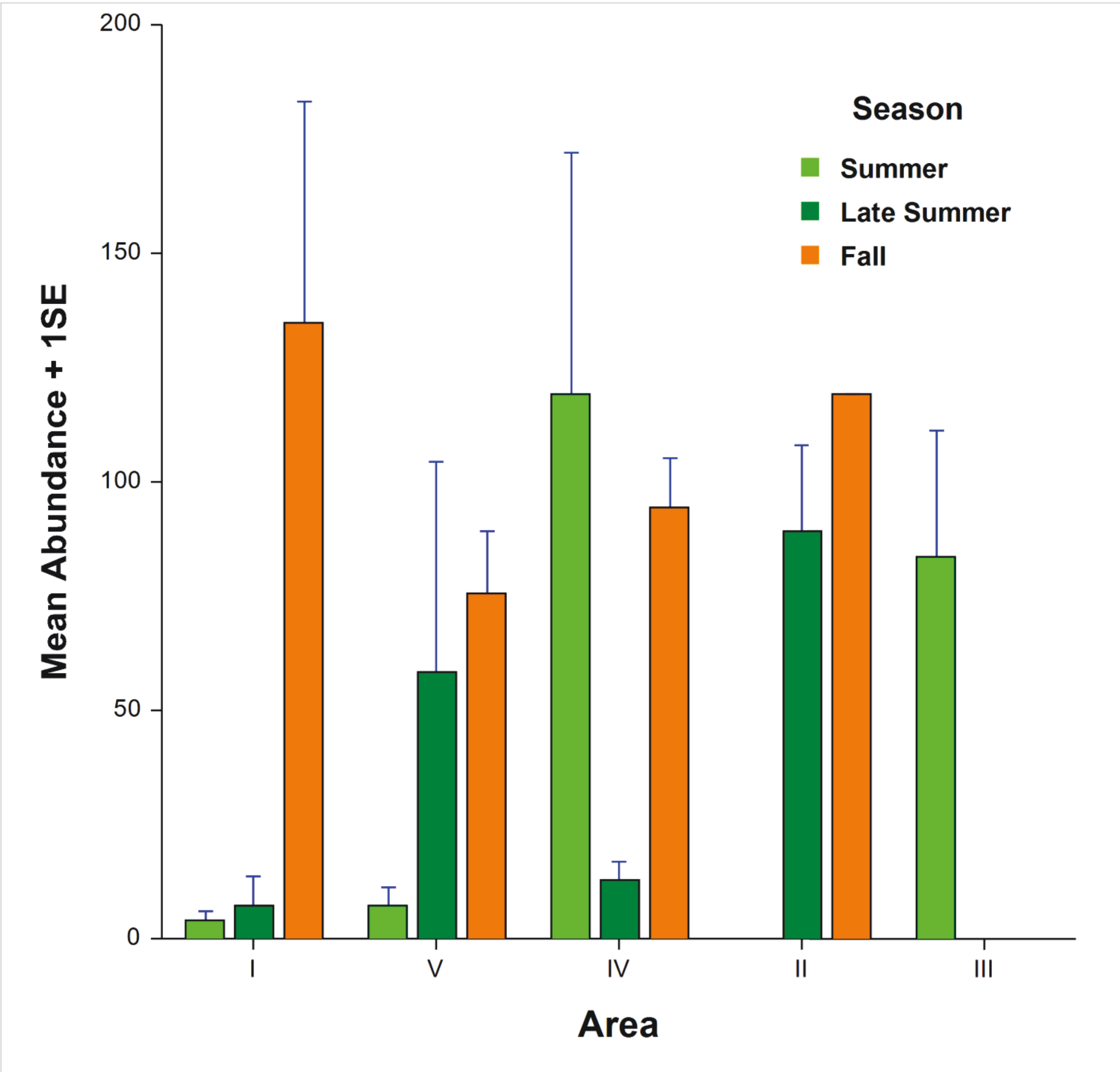


Figure 5. Seasonal differences in benthic community mean taxonomic richness (+ 1 standard error, per 20 cm^2) among the different sampling areas in New Haven Harbor. Areas I and V are where extensive accumulations of macroalgae were found in previous studies; Area IV is a transitional area where some accumulations were found; Areas II and III had little to no drift macroalgae.

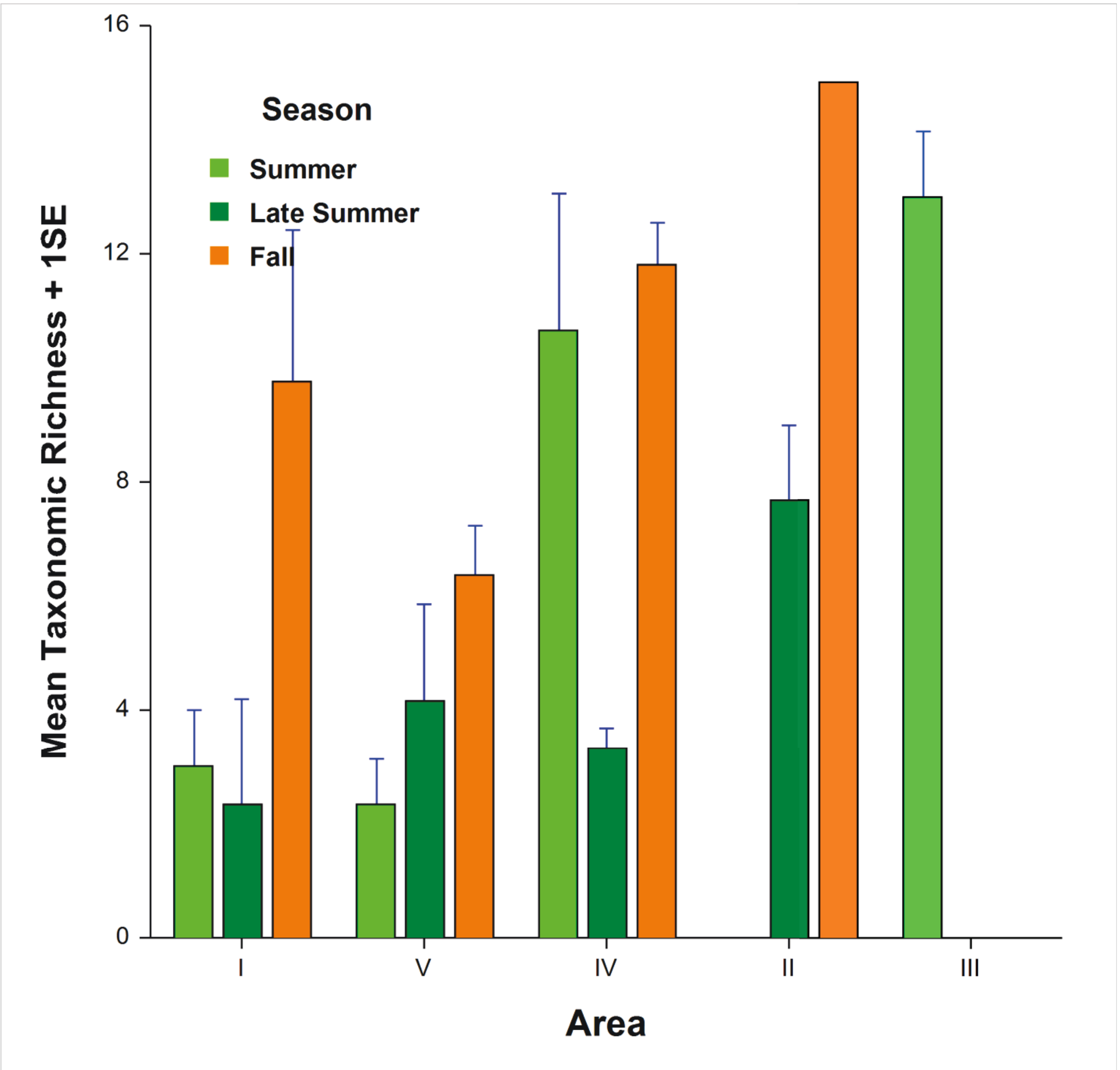


Figure 6. Seasonal differences in benthic community mean Shannon diversity (+ 1 standard error, per 20 cm^2) among the different sampling areas in New Haven Harbor. Shannon Diversity considers both the number of species and their relative abundances in each sample. Areas I and V are where extensive accumulations of macroalgae were found in previous studies; Area IV is a transitional area where some accumulations were found; Areas II and III had little to no drift macroalgae.

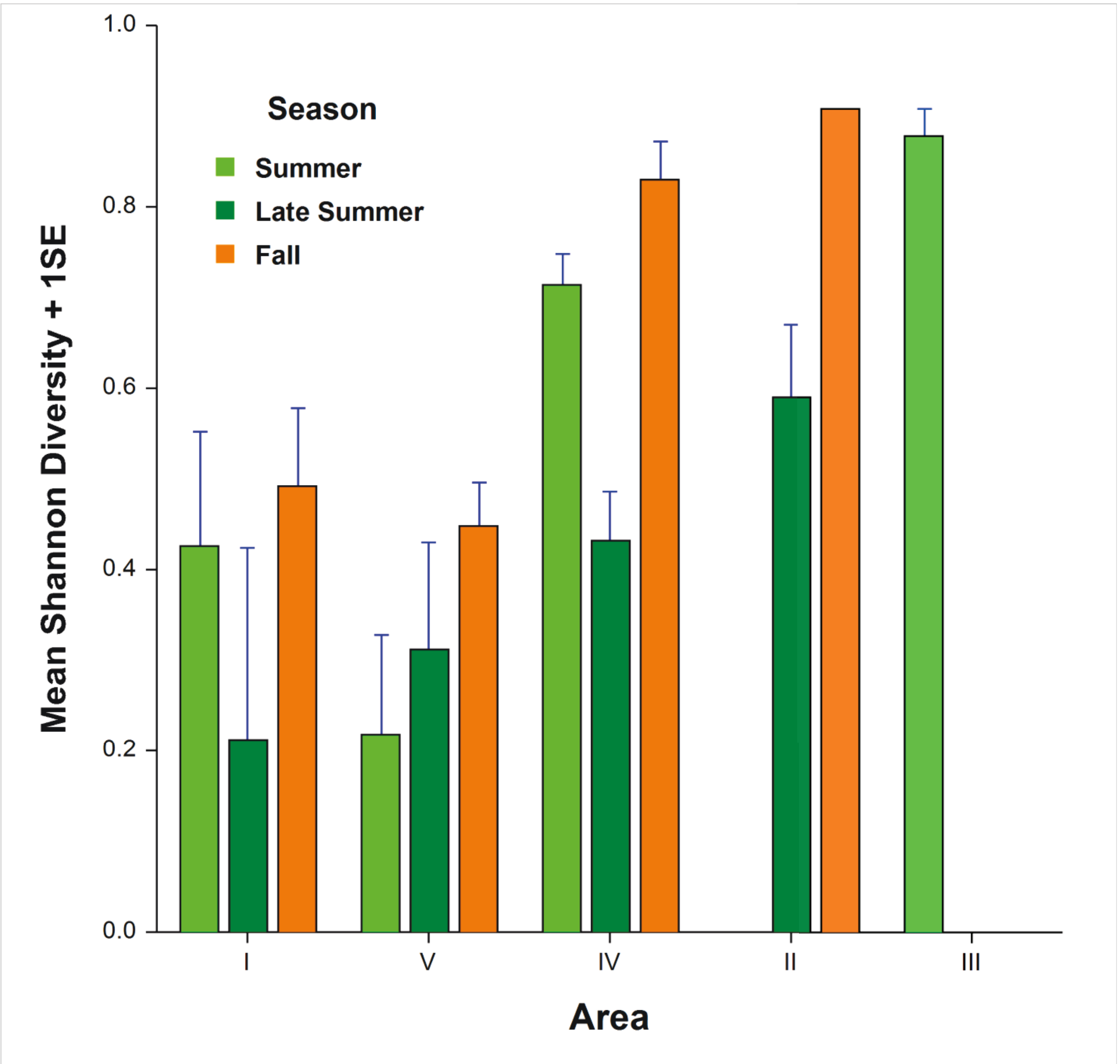


Figure 7. Seasonal differences in benthic community diversity measured using the mean estimated number of species in a random sampling of 50 individuals (+ 1 standard error, per 20 $cm^{2)}$ among the different sampling areas in New Haven Harbor. Areas I and V are where extensive accumulations of macroalgae were found in previous studies; Area IV is a transitional area where some accumulations were found; Areas II and III had little to no drift macroalgae.

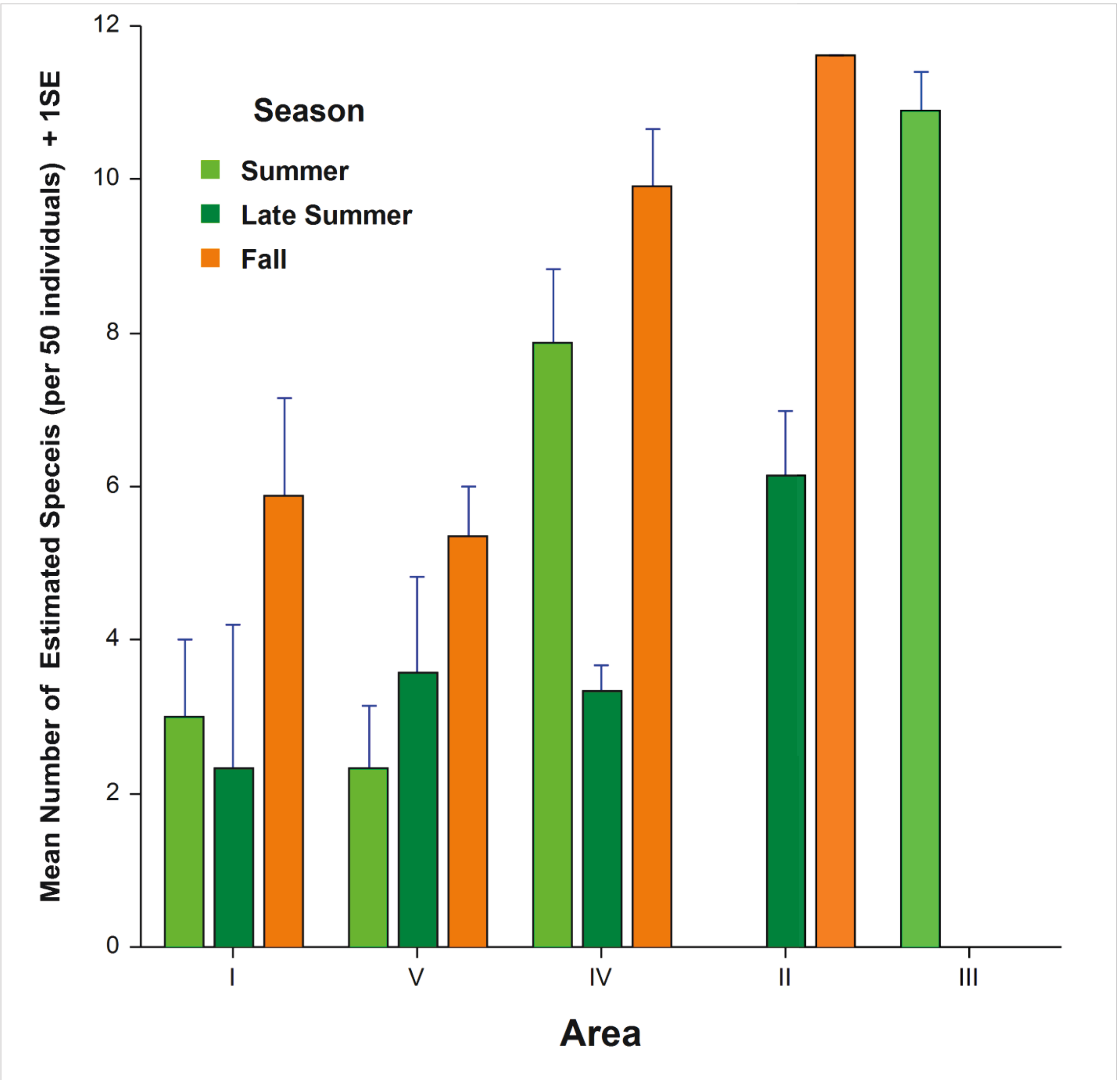


Table 1. Results of two-way analysis of variance testing differences in community characteristic among sampling areas and seasons in New Haven Harbor. Abundance data were log x +1 transformed to meet assumptions. * Term significant at alpha = 0.05

Total Abundance

Source Term	**DF**	**Sum of Squares**	**Mean Square**	**F-Ratio**	**Prob Level**	**Power (Alpha=0.05)**
A: Area	4	6.844061	1.711015	3.91	0.008228*	0.868902
B: Season	2	1.460388	0.7301939	1.67	0.199592	0.333562
AB	8	2.003466	0.2504333	0.57	0.794394	0.231813
S	45	19.66895	0.4370879			
Total (Adjusted)	59	33.17645				
Total	60					

Taxonomic Richness

Source Term	**DF**	**Sum of Squares**	**Mean Square**	**F-Ratio**	**Prob Level**	**Power (Alpha=0.05)**
A: Area	4	290.706	72.67651	4.22	0.005503*	0.895458
B: Season	2	174.069	87.03452	5.05	0.010467*	0.791829
AB	8	124.0187	15.50234	0.90	0.524502	0.364130
S	45	774.8834	17.21963			
Total (Adjusted)	59	1502.183				
Total	60					

Estimated Number of Species

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Area	4	172.6649	43.16624	6.34	0.000392*	0.981545
B: Season	2	88.61491	44.30745	6.50	0.003301*	0.887466
AB	8	43.65364	5.456706	0.80	0.604818	0.323361
S	45	306.5346	6.811879			
Total (Adjusted)	59	694.2244				
Total	60					

Shannon Diversity

Source Term	**DF**	**Sum of Squares**	**Mean Square**	**F-Ratio**	**Prob Level**	**Power (Alpha=0.05)**
A: Area	4	1.331417	0.3328542	6.64	0.000275*	0.985858
B: Season	2	0.3219536	0.1609768	3.21	0.049756*	0.584346
AB	8	0.1960822	0.02451027	0.49	0.857738	0.199674
S	45	2.256743	0.05014985			
Total (Adjusted)	59	4.561065				
Total	60					

* Term significant at alpha = 0.05