Assessment of Drift Macroalgal Accumulations in New Haven Harbor

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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. Surprisingly, very little quantitative research has been done on assessing the ecological health of benthic communities in NHH. Surveys were done in the 1970's as a part of the monitoring program for United Illuminating (McCusker, and Bosworth 1979, 1981) and a spatially limited study by Rhoads and Germano (1982) that was related to these surveys. There have also been some consultant reports related to specific projects and a few scatted sampling efforts by researchers and students at the University of New Haven and Yale University in the 1990's and early 2000's. As such, we have a very limited knowledge of this critical component of the NHH ecosystem.

In 2009 Roman Zajac and studnets working in his lab initiated studies to develop a contemporary database and assessment of the benthic ecology of New Haven Harbor. 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). Often community and/or population data are combined with other ecologic metrics such as dissolved oxygen in an index of ecological health. Given their inherent ability 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 (see Zajac and Brown 2012 Final report to QRF Fund for the results of these studies) have been reported to the Quinnipiac River Fund board, and also have been presented at the biennial Long Island Sound Research Conference that was held at the end of October 2010. Briefly, the study showed that there are a diverse set of benthic (seafloor) habitats within the harbor, and these support a surprisingly diverse pool of species. 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 and also in pockets in other areas (Figure 1, 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 trip to 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 do not know the dynamics of these algal beds over time; whether they break down over the winter and how long they last into the fall. Our information to date indicates that extensive beds in the western portion of the harbor continue to be present into late September, although there are indications of the breakdown of the algal fronds to some extent. 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 objectives of this study were to continue assessing habitat structure and species diversity in New Harbor by starting to investigate in greater detail the dynamics and potential impacts of extensive drift algal mats that have been found in portions of the harbor. Coupled with our previous studies this work was meant to add to 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.

Figure 1. Map of New Haven Harbor; the box indicates the study area.

Methods

The project comprised both field and laboratory components. Sampling was conducted between May and October 2011 in the western portion of New Haven Harbor (Figure 1). Sampling generally occurred over two days, one day for collecting video data on algal bed location and conditions and another for collecting sediment samples to assess algal biomass and the community characteristics of organisms living in the sediments both within and outside areas where algal mats were present. On each set of each sampling dates underwater video surveys were conducted to determine the spatial extent and areal coverage of the drift algal mats and 9 - 12 random benthic samples were taken in order to determine algal biomass and associated fauna using a modified 0.25 m^2 quadrat benthic grab. For the video data collection, the frame holding the video camera and the light would be lowered slowly so as to not disturb the sediments until it rested on the bottom. A 30 to 60 second video was recorded digitally and the percent cover of algae was estimated visually off of the digital monitor. This was repeated from three sides of the vessel on which the sampling was taking place. For the grab sampling, all the algae within the grab was collected in all and returned to the laboratory. The locations of all underwater video sample locations as well as where benthic

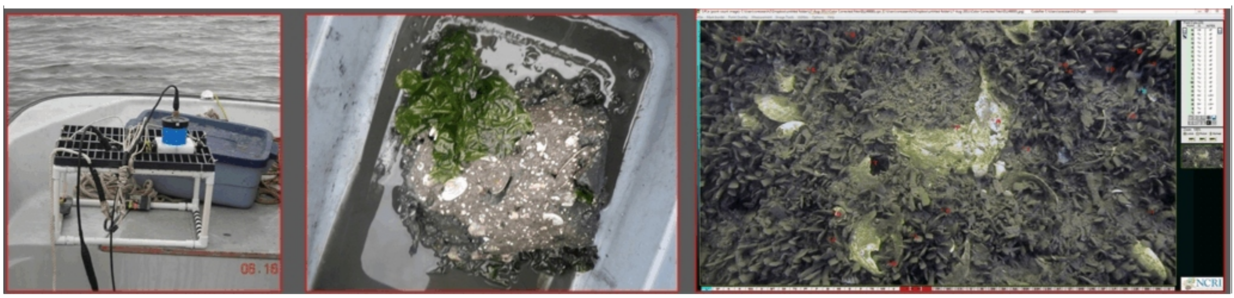

Figure 2. Left: Underwater video equipment; Middle: Benthic sample with macroalgae; Right: Amphipod mat in underwater video.

wraps were collected were recorded using a GPS and then later transferred into a GIS in order to assess the spatial distribution and extent of the algal beds. Figure 2 shows examples of the field equipment and collection techniques.

In the lab, the algae were washed on a 0.33 mm sieves to collect any mobile animals living within the mat, and then the blades examined to remove any attached organisms. Both wet and dry weights of the algae were collected. Dry weights were collected after warming the algae at 60° C for two hours and then placing algal samples in a desiccator for at least one week. Sediment samples for infauna were preserved whole in 70% ethanol and stained with Rise Bengal. Later they were washed on a 300 µm seive and residues returned to 70% ethanol until the sample was sorted. Samples are in the process of being sorted and species identified. [Although the funding received was less than that requested, we collected full sets of benthic samples in order to be able to do a comprehensive analysis. Due to this, changes in graduate personnel, the extensive amount of time it takes to sort samples (i.e. remove the organisms from the sediments) and identify the organisms, this portion of the project is still in progress. A graduate student at University of New Haven has decided to take on this portion of the study as her thesis project with an anticipated completion date of spring 2013.] Field data on macroalgal cover were converted to estimates have or will make smelly of approximate cover and entered into a geographic information system mapped based on the GPS positions collected in the field. Maps depicting the extent of coverage were produced to show trends in macroalgal cover.

Results and Discussion

Macroalgal beds in the western portion of New Haven harbor exhibited a seasonal pattern of expansion and decline in their spatial extent and degree of development (Figures 3 & 4). In early May, macroalgae was found in only 50% of the sites surveyed, and most of these had low areal cover (~ 5 - 50% within each video sample location). However, it is clear that drift macroalge have established have established populations by mid-spring. In two weeks, 75% of the sites sampled had drift macroalgae, mostly in the 5 to 50% cover range although one area just southeast of the mouth of the West River had a well-developed algal bed with 50 to 100% cover (Figure 3). This indicates a relatively rapid expansion of the macroalgal beds as spring progresses. The next set of samples were taken approximately 1 month later in early July and by that time drift macroalgae was covering approximately 90% of the western portion of New Haven Harbor and the aerial coverage within most sites was between 50 and 100%, and many of these had 100% cover.

By late July and August, the drift algal mats had reached their greatest development in terms of coverage at the sampling locations, with effectively all locations having 100% cover (Figure 4). At these times algal growth was very luxuriant, with *Ulva* sheets that reached up into the water column so that the height of the drifting algae was approximately 20- 40 cm above the sediment/water interface (see insets in Figure 4). The top inset images on the July 27th map in Figure 4 shows a case of 100% cover of a well developed Ulva mat; the bottom inset shows an area that had no drift algae and the sediment is covered with a mat of amphipod tubes. Amphipods (small crustaceans) are an important food source for a variety of fish and other benthic organisms. This particular image was taken adjacent to the boat channel that runs through the study site that allows passage from the West River into the main section of New Haven Harbor (depicted as a set of dashed lines in Fig. 1). Marcoalgal beds were generally absent or gad very low areal cover in the vicinity of the boat channel, suggesting that increased water flow and perhaps boat traffic, as well as greater depths along and in the channel limit the development of mats in this area. The inset in the August 17th map shows the edge of an algal mat and numerous mud snails (*Ilyanasa obsoleta*) grazing on the sediments under the map. Mud snails and other snail spcecies graze on the algal mats and are found in very high densities in and under the mats.

The drift macroalgal mats in New Haven Harbor appear to start breaking down in late summer and into the fall, although 62% of the sampling sites still had 50-100% algal cover (Figure 4). Interestingly the other sampling locations had no living algae, suggesting localized senescence of mats in some areas while mats continued to be relatively extensive in other parts of the study area. The insets for the October 12 map show the progression of algal mat breakdown. In the bottom inset image, the algal sheets are riddled with holes and there are large numbers of snails grazing on the algae. The top inset image shows the broken down algal sheets being incorporate into the sediments by collapsing onto the sediments and then being sedimented over as microbial degradation and grazing by macrofauna continues. This breakdown likely causes a significant infusion of organic material into the sediments, which may affect sedimentary oxygen demand. Analyses of how algal mats (both when at full growth and upon senescence) affect the biota in the study area are still underway, but results from the survey we conducted in New Haven

Harbor prior to this study (Zajac and Brown 2012) and thesis work by Steven Brown, a graduate student in the Zajac Lab) indicate that generally there are negative impacts on organisms that live in the sediments, but there may short-term positive effects on organisms that live within the algal mat itself. Similar findings have been made by other researchers working on hoe drift algal mats may affect the ecology of benthic organisms (see Introduction).

The biomass of drift macroalgae was very high in July 2011 and then dropped significantly by October 2011 (Figure 5). In terms of the maximum biomass found, the New Haven Harbor maximum in July 2011, 948 gm dry wt. gm^{-2}, far exceeded that found in other studies from a variety of locations. This suggests that conditions in this portion of the Harbor are very conducive to macroalgal growth during the primary growing period (likely April - August). Interestingly, sparse algal accumulations were observed along the transition from the study area and the central harbor, and no macroalgal mats were observed beyond that in the central harbor (Figures 3 and 4). This suggest that the extensive coverage and biomass in the western portion of New Haven Harbor is not due to accumulation of macroalgae drifting in from this area of the harbor.

Our studies, coupled with previous surveys, indicate that extensive macroalgal mats are a common occurrence from spring through fall in the western portion of New Haven Harbor. The algal mats show a seasonal pattern of expansion and contraction, reaching greatest development in late July and August. It is likely that the shallow depths of this portion of the harbor are contributing to conditions that allow for the extensive mats to develop. In addition to that, nutrient inputs from the Quinnipiac, Mill and West Rivers into New Haven Harbor likely provide the nutrients necessary to fuel the high production that occurs. Our observations also show that relatively extensive macroalgal mats and accumulations can occur along the intertidal and shallow subtidal areas of the Long Wharf portion of New Haven Harbor. The likely impacts of all these accumulations are likely to be complex, having both short-term positive and negative effects on the benthic organisms of the harbor. However the organic material that is incorporated into sediments following the breakdown of these mats likely increases sedimentary nutrient levels which may fuel macroalgal production in subsequent years as nutrients are released into the water column as sediments are disturbed (as during winter storms). This potential dynamic, in addition to continual nutrient inputs from the rivers emptying into the harbor as well as from surrounding lands and storm water outlets, will likely contribute to the long-term persistence of the macroalgal mats during summer months in the harbor. What the long-term impacts on the ecology of the areas of the harbor where the algal mats accumulate is not known. Once the analyses of the benthic samples that we collected both in 2011 and 2012 during a follow-up study are completed, these may provide some insights as to what the short-term and long-term impacts may be.

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Figure 3. Spatial extent and cover of drift macroalgal beds in the western portion of New Haven Harbor between May and early July 2011. An X indicates that no algae were observed in underwater video; small circles indicate that algae covered ~5 - 50% of the area of the video image; large circles indicate that algae covered ~50 - 100% of the area of the video image.

Figure 4. Spatial extent and cover of drift macroalgal beds in the western portion of New Haven Harbor between late July and early October 2011. An X indicates that no algae were observed in underwater video; small circles indicate that algae covered ~5 - 50% of the area of the video image; large circles indicate that algae covered ~50 - 100% of the area of the video image. Insets show video capture images of drift macroalgae (*Ulva* spp.) and are explained in the text.

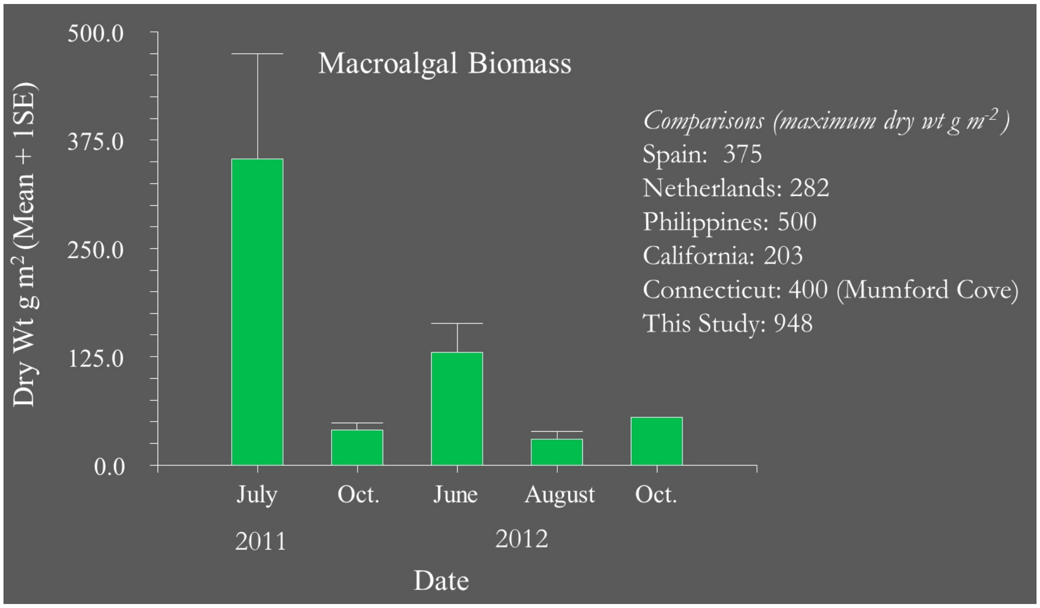

Figure 5. Changes in macroalgal biomass in the New Haven Harbor study area. Note that data from an ongoing project conducted in 2012 are also included. Comparisons are also given to the maximum biomass found in other studies compared to this one.

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