Urbanization in Coastal Environments:
Are there Consequences Associated to Pier Density along Child's River?

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Abstract

Urbanization along coastal environments is causing a wide assortment of negative affects in the aquatic ecosystem, considering that humans and animals alike rely on the water as a source of life and livelihood, it is crucial to understand all forms of anthropogenic influence humans inflict. I investigated the affects pier density has on an already urbanized and highly trafficked coastal shoreline, Child's River. I examined how the three stage effects associated to pier structures can impact surficial sediments and sedimentation rates to see if any negative trends observed in pelagic algae and benthic microbial communities could be correlated to pier density. Four sites were examined ranging from a pier density of 0 to a pier density of one pier every 17 meters. The current metallic concentrations within the sediments across the pier density gradient were below normal, uncontaminated coastal areas, leaving me to conclude that the metallic poisoning is not affecting Child's River. Higher pier densities were found to result in sedimentation of finer, nutrient rich materials when compared to the control site. Side effects from this type of deposition are limited due to the resuspension of surficial sediments from boat motors. The pelagic and microbial community did not show any negative trends associated with pier density. The lack of any trends could be masked by the time of year the samples were conducted, with the colder temperatures reducing algae growth and microbial activities. The results of this study suggest that isolating the affects of pier density is difficult in urbanized and heavily traffic areas and the seasonal affects mask potential trends that could be associated with pier density.

Introduction:

Past civilizations have developed along sources of water with minimal influences like the Mesopotamians along the Fertile Crescent, the Egyptians along the Nile River, and the French and Native American fur traders transporting their goods into Hudson Bay, relying on the water as a source of life. Today, we develop in close proximity to the shorelines of these waters without regard to the consequences to the environment. Land-use and development leads to changes in the quality of water overlaying aquatic sediments which is contributing to the loss of sediment-dwelling species in freshwater ecosystems (Palmer et al. 2000). The question is this; is there a limit to the amount of urbanization a waterway can take? Sala et al. (2000) predicts that biodiversity will be lost the in aquatic ecosystems in 2100 because humans live disproportionately near waterways and rely on them heavily for waste disposal, transportation, and water supply.

The specific aspect of urbanization that I researched is the direct and indirect effects of pier structures to the environment. Piers, human made structures that are impaled into the sediments along shorelines to house boats for recreational use, are intrinsically linked to the suburban development of coastal watersheds (Sanger & Holland 2002). Pier installment comes with a number of temporary and long term side effects that has been shown to negatively impact the immediate area and its inhabitants. This can be best described in three stages: first is a direct physical and chemical effect on the biotic community surrounding the structure. Pier structures reduce light penetration into the water underneath and in close proximity to the pier which has been shown to result in Eel grass population declines (Burdick and Short 1999).

I also am proposing in this paper the idea that the pillars making up the pier can disrupt the current flow. This disruption would allow for gravitational forces to over come tract forces acting on finer, organic rich clays and slits leading to increased sedimentation. The increased slit and clay deposition in a local area can increase nutrient availability or metallic concentrations in the sediments. Silt and clays, less than 63um, are important in heavy-metal and dissolved organic matter adsorption, transport, and storage within sediments due to the large surface area to mass ratio and geochemical composition of those silts and clays (Thorns 1987, Stone and Droppo 1994, Weis and Weis 1994).

In 1933 pier structures started to be pressure treated with Chrominated Copper Aresnic (CCA) compounds to prevent burrowing and build up fowling communities that deteriorate the pillars. The CCA treated piers have been shown to leach high amounts of Copper (Cu) and small amounts of Chromium (Cr) into the water column resulting in the poisoning of a host of organisms from phytoplankton to a wide variety of benthic residents (Stuaber & Florence 1987, MacDonald et al. 1988, Weis & Weis 1992a, 1995, Brooks 1996). The leaching process is experiences a maximum rate of flux, impacting the local area around the pier, for only the first ninety days after installment after which, the leaching drops to very low concentrations (Weis & Weis 1996, Breslin and Adler-Ivanbrook 1998, Sanger and Holland 2002). Today, piers are now treated with chemical compounds that reduce the concentration of toxins that leach into the water.

Second stage affects come from the function of the pier, boat storage. Some boats are painted with antifowling materials made from Cu and Cr which leach over time leading to affects to the biotic community already addressed above. An alternative chemical consequence is that boats require a zinc disk to help the motor function; however the disk is designed to dissolve over time, leaching zinc ions into the water column and sediment. Zinc (Zn) has been shown to decrease benthic invertebrate survival (Bryant et al. 1985).

Third stage affects appear from the use of the boat leaving or returning to the pier with the motor propeller in gear. The motor can kick-up surficial sediment that is deposited down stream or increases the turbidity of the water column. Once surficial sediment is disturbed, it may take several hours for it to return to its original chemical state. This in turn can deter benthic infauna from settling in that area (Marinelli and Woodin 2002). Additionally, resuspension of material can increase the turbidity in the water column and lead to declines in phytoplankton populations and build up of benthic algae (Van Nieuwenhuvse & La Perriere 1986).

The purpose of this experiment is to conduct a field survey in an area that experiences intense urbanization and boating traffic to observe if the cumulative affects from pier structures can be exaggerated in densely piered shorelines. I will be conducting an investigation into the current sediment grain size composition and metallic concentrations coupled with the rates and composition of sedimentation across a pier density gradient in order to determine if pelagic algae and sediment microbes are being negatively impacted by the pier structures and associated affects.

I would suspect that areas with high pier densities could experience sediment characteristics that favor coarse sandy conditions due to the disruption caused by the boat motor. Poppe et al. 2000 found that gravels and gravelly sands are dominate surficial sediments where the bottom flow is dominated by strong tidal currents, in this case the strong current is coming from the boat. Due to the higher density of piers housing boats, the sediment in that area should contain higher concentrations of metals than areas without piers. I would expect to see the sedimentation of rich organic material due to a reduction in current flow due to the series of pier pillars, however only some of the material would remain due to the boat disruptions. I feel that all of these consequences could lead to lower amounts of growth in pelagic algae from the increased turbidity and metallic concentrations which could lead to lower amounts of microbial activity due to the removal of detritus and the poor source of food (Pusch et al. 1998, Fischer et al. 2002).

Materials and Methods:

The sites were selected from Child's River, a freshwater input into Waquoit Bay, MA. The Child's River shoreline is dotted with year round and seasonal homes in close proximity to the shore and each other. I would estimate at least 90% of the shoreline houses contain either a pier or some form of shoreline modification, a bouldered or wooded wall structure lining the shore (called armoring), or a combination of the two (Figure 1).

I selected my sites based on specific criteria that would allow for controlling factors like the geomorphic structure, the depth gradient, current flow, and amount of anthropogenic influence to remain constant across the sites. Choosing sites that had similar geomorphic conditions and depth profiles proved to be a more arduous task than I expected. I ended up settling on sites that were either across from each other or in close proximity to one another. I controlled the amount of anthropogenic modification to the shoreline by selecting sites that only contained pier structures and no armoring. Child's River is relatively consistent in its bathymetry, with some of the western shoreline having a slightly steeper gradient (Figure 2) than its eastern counter parts. I choose sites on both sides of the river due to the lack of selection that met my criteria.

The *control site*, referred to as site one, is located on the southwestern shore at 41° 34'21.74''N and 70°32'01.51''W, has no pier structure, only one house within fifty meters on either side, and a natural shoreline with emergent plants out of the water. One thing to note about this site is that it appeared to still have boating activity with a shoreline access point in the center of the sampling area. This was chosen specifically to account for forms of anthropogenic disturbances that would be expected to be experienced at the other piered sites, specifically human activities in and along the shoreline. The sampling area for this site was 25 meters along the shoreline with the middle of the 25 meters lining up with the boat entry point.

The *Single pier site*, referred to as site two, has one pier in the center of a twenty five meter stretch and one house with a manicured lawn on the east side of the river. The pier is located at 41°34'37.34''N and 70°31'51.48''W and does not appear to be CCA treated. This site had a pier density of one pier every 25 meters and appeared partially developed.

The *double pier site*, designated site three, contained two piers starting and ending the thirty meter increment, starting at 41°34'28.40'' N and 70°32'00.92''W and ending at 41°34'27.36''N and 70°32'01.72W. The more northern pier was not CCA treated, while the southern pier was, but both piers resided in front of slightly developed houses with natural shorelines. The specific area in question is located in between the two piers and has a density of about one pier every 20 meters and was mildly developed along the shoreline.

The *quad pier site*, apply named site four, had four piers spanning a length of 80 meters is found to start at 41°34'41.23''N and 70°31'54.43W and ending at 41°34'38.62''N and 70°31'55.42" W. Each site appeared to have extensively manicured lawns and with a house to every pier. The northern most pier had an interesting shape, think of the letter 'U' and now put a tail attaching to the shore near the lower left corner and you have the idea. The next northern most pier did not appear to be CCA treated but the rest seemed to be. The southern most pier had an 'L' shape at the end that was made up of a floating structure supported by some kind of hardened, foamy material. This site had a pier density of one pier every 17 meters and the shoreline appeared to be the most developed of the selected sites.

Sediment was sampled using an Eckman benthic grab in order to gain a sense of the living conditions around the various sites. Ten samples were taken at each site; five near shore, about half a meter deep, and five far shore, about a meter and a half deep, along 5 to 12 meter intervals spanning each site. After the sediment was collected in the Eckman grab, sawed off syringes acted as small cores to collect the top two to three centimeters of the benthic grab for analysis, of which I am only interested in. Water retention, sediment grain size was determined through separating particle using various sized sifters (>2mm, >1mm, >500um, >60um, <60um), a CHN analysis was done on a portion of the sample, and a total Cu, Cr, and Zn analysis was also completed, following simplified procedures of Forstner and Salomons (1980) by acidifying 0.1 homogenized grams in 10% metal grade HCL.

To determine the amount of sedimentation occurring at each site, five sediment traps were constructed out of PVC pipes with a 7.25 height to diameter ratio was used to maximize collection efficiency and maximum weight collection (Hargrave and Burns 1979). They were then suspended a few centimeters above the sediment using a weight attached to the bottom to hold it in place and help up by a floatation device (8 oz. bottle) that did not interfere with the sediment collection (Figure 3). Specifications as to where the traps were placed again were on a site by site basis with the consistency being that they are all placed around one and half meters deep of water based on the low tide. The convenience of testing rates of sedimentation in the fall is that boating activities have ceased, thus any variation in sedimentation between the sites could be attributed to the pier structures. They collected for two weeks and then retrieved for analysis. Once the sediment traps were collected, each site's five collectors sediment was filtered out onto 25mm GFS filters and dry mass was found and a CHN analysis was conducted.

Firm agar was poured into specialized vial containers fitted with fritted glass filters, as done by Hauer and Lamberti (1996) to collect phytoplankton and pelagic algae. Potassium phosphate, ammonium chloride, and granulated agar were mixed together to form the nutrient diffusion substrata that reflected Redfield's ratios of phytoplankton to negate nutrient availability differences between sites to reveal other affects like metal contamination or turbidity. Four nutrient diffusion disks were place out at each site about 10 cm below the surface of the water. After two weeks, the accumulated phytoplankton was collected, removed with acetone and run through a floumeter to determine the concentration of chlorophyll collected.

The final procedure of this experiment was to collect two sediment cores from each site. The sediment cores were sampled around the same area the sediment traps were placed, ranging from one and half to two meters deep at low tide. The location was in close proximity to one of the piers at each site, if a pier was present (the control site cores were taken in the center of the site). Nutrient fluxes were sampled five times over a nine hour period to determine the rates of respiration and nutrient flux, which was then scaled up over a twenty four hour period. The cores were kept in a dark incubator at room temperature (23 degrees Celsius). Oxygen was measured using an oxygen probe. Nitrate, ammonium, and phosphate were sampled using syringes, treated nutrient specific reagents, and run through a spectrophotometers to determine the concentrations.

Results:

Current Sediment Conditions:

Sediment grain size appears to play a major role in determining the sediment characteristics I examined in this survey. Smaller grain sizes (60um) present a smaller surface area to mass ratio that can retain larger amounts of water, metallic particles, or nutrients like nitrogen. The percent grain size composition across the sites do not show any distinct shift in grain size with site one having the highest percentage of 60um (Figure 4), however there no significant difference between the sites. The 2mm grain size increases in the far areas for each site as pier density increases, but again the trend is not significant. Site four, the highest pier density, has the largest percent of grain equal to and greater than 2mm in the far area, which is the only site to show that characteristic. Every site did demonstrate similar characteristics in that the far shore areas have greater percentages of smaller grain sizes (60um and less) and the near shore areas favored larger grain sizes (500um and greater).

The *porosity* of the sediment appears to be greater in the far shore areas for every site (Figure 5). Site one had the highest porosity in both near and far shore areas, however there is little significance due to the standard error bars. *Organic material* loss from ignition is greater in the far shore areas when compared to the near shore areas for every site (Figure 5). The quantity of organic material in the sediment declines as the number of piers increases, however this is a weak trend seeing that site three has the lowest amount of carbon in the far shore area than site four and most of the sites have overlapping error bars. There does appear to be similarities in the insignificant trends seen in the far shore areas between porosity and organic material, but the relationship is not reflected in percentages of *grain less than 60 um* (Figure 5).

The overall *metallic concentration* in the sediment was lower than normal metallic concentrations found in uncontaminated coastal areas (the ranges is about 200 to 400 ug/g) amongst all the sites with the highest concentrations of all tested metals in the control site (Figure 6). The near shore areas shows little variability, except for the control site, while the far shore area showed much variance in Cu and Zn, but no patterns could be established (Figure 6). The far shore sites appear to have significantly higher concentrations of Cu and Zn than the near shore areas, except at the two pier site. This uniform difference between the near shore and far shore in multiple tested components of sediment characteristics lead me to see if the was a relationship between Cu concentrations and percent carbon in the sediment (Figure 7). There appears to be a relatively significant trend, as the percent carbon increases so does the Cu concentrations.

The *CHN analysis* revealed that site one had the highest percent carbon and nitrogen, with the nitrogen concentration declining as pier density increases (Figure 8). The percent carbon shows a similar trend, except that site four's percent carbon is greater than site three's. The percent carbon concentration seems to show corresponding pattern to the carbon loss due to ignition (Figure 5 & 8). The C/N ratios are consistent between the sites which would suggest similarities in the composition, not quantity, of the material found at each site. These results maybe misleading due to errors uncured during the packing procedure prior to the CHN analysis.

Sedimentation Analysis:

The amount deposited in the traps over a period of fourteen days is about 0.005 grams of sediment per day for each site. The differences in the amount of the *material deposited* and the *rates of deposition* across the pier density gradient are not significant; therefore, there is no real difference in the amount of sedimentation each pier experiences (Figure 9). When examining the carbon and nitrogen composition of the deposited materials, it becomes clear that both nutrients increase in presences and deposition as pier density increases (Figure 9). This would suggest that the material being deposited in higher pier density sites is composed of silts and clays, which have absorption capabilities. Unfortunately, the amount deposited into the trap over the two week period was not enough to conduct a grain size, carbon loss from ignition, or metallic analysis.

Biological Assessment:

After setting out four nutrient diffusion disks at every site for fourteen days, site one had the lowest measured *chlorophyll a* concentration (about 1 ug/L) and the rest of the sites had about twice that, with very little difference between them (Figure 10).

Figure 11 shows the active lives of the bacterial community over a nine hour period with oxygen consumption, phosphate adsorption and mobilization, ammonium flux, and the nitrate flux. All of the cores were similar in their trends within each site. Site two had the only cores to contain a near anoxic water column after the nine hour period. Site four and one had the least amount of overall activity for all measured nutrients.

Assuming one mol of oxygen consumed equals one mol of carbon dioxide consumed, the action packed lives within the sediment cores from each site can be revealed. Site one has the lowest daily oxygen consumption of all the cores, and the rest show an decline in respiration as pier density increases (Figure 12). The overall nutrient flux is very low and shows no trends with respect to pier density (Figure 12). The nitrate rate of flux is negative for all of the sites with site one having the largest negative rate and the rest declining as pier density increases. Site one and four are the only site that experienced PO_4 sorption from the water column into the sediment, with site one having the largest rate of flux of the sites, while site three experienced no rate of flux of PO_4 into the water column (Figure 12). The site one cores experienced the largest negative rate of NH_4 flux from the water column and the rest of the sites all experience a positive flux into the water column, with site three having the highest rate (Figure 12). Majority of the PO_4 and NH_4 fluxes were not significantly different between the sites.

The overall impression these results leave is there are no significant trends in sediment composition and metallic concentrations within the surficial sediment associated with pier density. The percent grain size analysis did reveal that high density piers are composed of larger, sandy material. The metallic concentrations are below normal uncontaminated areas, with an anomaly of the control site containing the highest concentration of all tested metals. The rates of sedimentation did not vary between the sites; however, the composition of the material favored a trend of increased nutrient rich materials as pier density increased, supporting my hypothesis. The biotic communities, both pelagic and microbial, did not reveal any significant trends coupled to pier density or the stages of potential affects.

Discussion:

The objective of this project is to determine if pier density increases the negative side effects in an area that is highly urbanized and experiences heavy boat traffic. To do this I examined the current sediment composition, rates and composition of sedimentation, and capabilities for pelagic growth and microbial respiration in the sediment across a gradient of pier densities in Child’s River, MA.

Sediment Status:

A relationship between the distance from the shore and the grain size characteristics was seen in each site which then influenced other aspects of the sediment make up. The near shore areas tend to contain higher percentages of larger grain sizes and lower percentages of silt and clays when compared to the far shore areas within those sites (Figure 4). This discrepancy could be attributed to the tidal fluxes which would remove any fine particle build up in the near shore areas to deeper areas of the river. Alternatively, larger grain found in the soil or sand bordering the water could be eroded into the river, deposited in those shallow areas while the smaller grains move either down stream or to deeper areas in the river.

I found that higher percentages of finer material, <60um, correlates closely to higher percentages of porosity and organic material and copper concentrations in the sediment (Figure 5 and 7) when comparing the near shore areas to the far shore areas, which has also been found by Thorns (1987), Stone and Droppo 1994, Weis and Weis (1994), and Poppe et al. (2000). The control site contained the overall highest percents of porosity and carbon along with the highest metallic contaminants but showed insignificant difference in the percent of silty sediment (<60um) when compared to the rest of the sites in the far shore areas. I was able to demonstrate that the copper concentrations correspond better to percent organic material (Figure 7) than percent silt within the sediments, which I will discuss later. I would attribute the current similarities of fine sediment to the ceasing of boating activities for a couple of weeks prior to sampling. I have shown that sedimentation of finer material correlate to higher pier densities (Figure 9). Therefore the amount of fine material deposited in that short period of time was able to negate the last boating resuspension, making the sites have similar amounts of fine material accumulation. I would expect to see a decline in the percentage of fine material present at a high density site during months when boating activity is present.

The interesting aspect in the sediment is that all of the sites had insignificantly different percents of fine sediment, but significantly different percents of carbon (Figure 5). The percent carbon appear to decline as pier density increases, however, the specific reason as to why these changes are being observed could have multiple facets. First, at sites with numerous piers, it would be expected that the amount of boating activity would correlate to the number of piers. When a boat leaves or docks at a pier the propeller is in gear and can stir up surficial sediments back into the water column, exposing the underlying materials and removing detrital buildup. Second, because of the boat presences increasing the water turbidity and changing the chemical composition of the sediments (Van Nieuwenhuvse and La Perriere 1986, Marinelli and Woodin 2002), there could be less phytoplankton or benthic invertebrates in habiting that area that would contribute to the carbon in the sediment (Pusch et al. 1998, Palmer et al. 2000). Third, the bulk of the microbial community could be much lower than the surficial sediments from the regular boat disruption (Fischer et al. 2002), so the benthic grab was not able to capture their carbon.

Attempting to tie anthropogenic influences like pier structures or boating activities in Child’s River to metallic contamination of surficial sediment in a site proved irrelevant due to the very low concentrations present (Figure 6). This may be due to the fact that not every pier in each site was CCA treated or may have housed a boat during the summer time. Even if an area did contain CCA treated piers, the age of those piers would need to be assessed to establish the amounts of leaching occurring (Weis and Weis 1992a, Breslin and Adler-Ivanbrook 1998, Sanger and Holland 2000). After ninety days, leaching of CCA treated piers drops significantly and residual effects of metallic poisoning follow suit. Sanger and Holland (2000), upon completion of a literature review and investigation into CCA treated pier structures, determined that the metallic contamination is not a concern to the aquatic environment. They suggest that the shore duration of leaching makes the effects temporary, installment of a pier completely devastates the primary producers, detritivores, and other benthic organisms so the leaching has minimal impacts to the biotic community, and finally, any metallic toxins in the water column would be removed by tidal fluxes. Other research has shown that organic ligands can control copper speciation in most natural waters, ameliorating copper toxicity in the sediment and water column (Sunda and Guillard 1976, Dryden et al. 2004). The adsorption of the metals could be an alternative as to why there was not a high metallic presence in the sediments.

The interesting aspect is that the control site, without a pier, had the highest concentrations for all tested metals in both near and far shore areas than most of the sites, even though all measured metal were below normal, uncontaminated coastal water levels. Site one was the furthest down stream so there is a potential that all leached metallic compounds could have been deposited down stream, however site three, the next furthest down stream does not show any build up of metallic concentrations. The geographical locations of the sites do not support any trend that materials are being transported and deposited down stream. Another hypothesis is that site one was closes to the entry point into the estuary of all of the sites, so it could be experiencing the most boating activity, however both conclusions are indefensible.

Sedimentation due to Pier Density

The collected material revealed that the lower pier density sites contained higher rates of deposition; however the trend is not significant. I would expect the deposition rates to increase in the presence of boats in higher pier density locations due to the resuspension of surficial sediment. When examining up the rates of nutrient deposition, there appears to be a trend favoring higher amounts of nutrient build up at the higher pier density sites (Figure 9). This then suggest that the material deposited at the higher pier sites has higher concentrations of silt than at the lower sites due to the correlation shown in the previous figure and previous research (Stone and Droppo 1994, Poppe et al 2000). This is what I expected to see. Poppe et al. (2000) have shown the build up of silty sand and clay marks transitional zones from relatively high to relatively low energy currents in rivers. I assumed that higher density sites would disrupt and slow the flow of the current due to the structural presence to the point where finer material would be able to settle to the bottom, with gravity overcoming the tract forces according to Stokes's Law (Richards 1982).

Wood and Armitage (1997) investigated the effects of fine sediment in loctic environments and found that fine sediment suspension and deposition can negatively affects producers and benthic invertebrates in a number of ways. They suggest that the fine sediment can prevent attachment of algae to benthic substrates or can affect feeding activities by filter feeders due to an increase in clogging of the food pathway from fine sediments. This coupled with boating activities could also prevent build up of food sources for both the microbes and invertebrates. The deposition of these nutrient rich materials is slighted by the resuspension by boat motors. Alternatively, boat motors area also able to mix down some of the deposited materials into the sediment, so at sites with higher pier densities you could expect to find more active microbial communities (Fischer et al. 2002).

Something that may be of concern could be the potential build up of finer material over the non-summer months when boating activities cease. This could allow for less oxygenation of the sediments, coupled with the higher deposition of organic rich materials could raise the anoxic layer closer to the interstitial layer in the spring months only to be removed when boat activities resume, potentially devastating the microbial community. This could then stunt nutrient cycling in that area for crucial periods of time. Alternatively, the deposition of more nutrient rich material into an area could prompt an algae bloom in the spring due to increased microbial activity and nutrient availability that could have negative repercussions to the rest of the local ecosystem.

Biotic Community Conditions

With the clear trend of finer material being deposited in higher pier density sites I then look to the biotic communities to see if there are any distinct patterns associated with pier density or metallic contamination that was not observed in the sediment grabs. The chlorophyll a does not show any decline due to pier presence, in fact, the control site had the lowest amount of growth (Figure 10). The lack of a trend suggests that the water is not toxic from metal contamination and/or the current sedimentation is not a major factor in regulating algal growth. I would expect to see a decrease in algal growth in the water column during boating months due to the potential increase in turbidity from resuspension.

The overall activity and respiration of the microbial community does not appear to show any clear pattern with pier density, with the lowest amount of respiration occurring at the control site (Figure 12). This low activity can be attributed to the seasonal shifts stunting mineralization, nitrification, and growth processes of the microbes. The only trend favors increased respiration at sites that contained pier structures, which could be attributed to more nutrient rich organic material being deposited in the high pier density areas. Additionally, Fischer et al. (2002) found from field experiments exploring bacterial production in river sediments, that shifting sediments indicated the highest activity, when compared to stratified sediments, due to the mixing of nutrients and oxygen deeper into the sediment. My data partially supports this conclusion due to the fact that all sites with piers have higher respiration than the control site which could be attributed to boating activities. In the summer I would expect to see one of two scenarios; first is an increase in sediment activities in higher density sites due to the mixing of oxygen and nutrients into the sediment (Fischer et al. 2002). Alternatively, I would expect to see lower activity due to the reduction in biotic nutrient sources from boating activities increasing water column turbidity and altering chemical composition of surficial sediments leading to declines in benthic organism inhabitance. The combination of these two affects would lead to decreases in nutrient availability, I suspect more than the amounts being deposited from sedimentation, which would lead to declines in microbial activity.

Conclusion

Higher pier densities in Child's River do not appear to exaggerate the three stage effects of an individual pier during non-summer months. This may be due to the high urbanization and boat traffic influencing the biotic communities, or it could be due to the time of year. It appears investigation into this form of anthropogenic influence requires insight into more than just the pier presence. Because of this, isolating effects from pier structures from the rest of an urbanized environment is very difficult.

Differences in sediment characteristics were only slightly apparent with areas of higher pier density containing sandier sediments due to resuspension from boat motors. All metallic concentrations were very low suggesting that either the sampled piers exceeded the ninety day high leaching period, were not CCA pressure treated, or that all metallic contaminants were being redistributed else where. Sanger and Holland (2002) advocate, based on literature review and experimental analysis, that metallic leaching is not detrimental to living resources due to the area and number of organisms affected is minimal.

I was able to show that higher pier densities correlate to deposition of finer, and nutrient rich materials, but the resuspension of the settled debris from boat motors reduces any affects that type of sedimentation would have on the pelagic and benthic community. The timely aspect of this project was that boating activities ceased. This allowed for the true insight into the material being deposited from pier structure, however geomorphic conditions were not ideal. I would suspect that during the boating season the rate of deposition could not be established due to all of the disruption to the sediments. Additionally, the material collected in the trap would most likely increase in nutrient composition due to the increase in biotic activities and presence in the water column being deposited into the trap.

Even though there appears to be no significantly negative affect on the pelagic primary producers or the sediment decomposers from metallic poisoning or pier density, it is not a fully accurate representation due to the slowing of over all growth in both areas may mask any negative affects that would be seen during the spring or summer months when optimal conditions are achieved.

Areas that I would improve or continue of this project would be to focus on a single pier in a high density area as appose to the whole area. This would present a more sound design to which more accurate depictions of the area can be compared and also give insight into the distance from the pier boating effects are experienced. I would have loved time to investigate the zooplankton and benthic invertebrate populations and to test metallic concentrations within the populations. I would have also liked to examine the characteristics of resuspended sediment due to boating activities to gain insight as to what is being removed from those areas and where it is being deposited.

I would urge that further investigation into pier density and associated affects should be conducted seasonally and across an urbane gradient to truly show the effects of pier structures and boating activities. It maybe that Child's River is too heavily nutrient loaded, urbanized, and trafficked to show any negative side effects that high pier densities could have in coastal environments. I would also advise investigation into the conversion of mooring structures as a form of boat housing to better accommodate the environment. Hopefully in the future we can develop practical hovercrafts to replace motor boats and environmentally logical methods for docking in order to reduce our impacts to our original life source, the water.

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Figures

Figure 1: This is the examined segment of Child's River, note the intensive development on the West shoreline as compared to the East shoreline of the river.

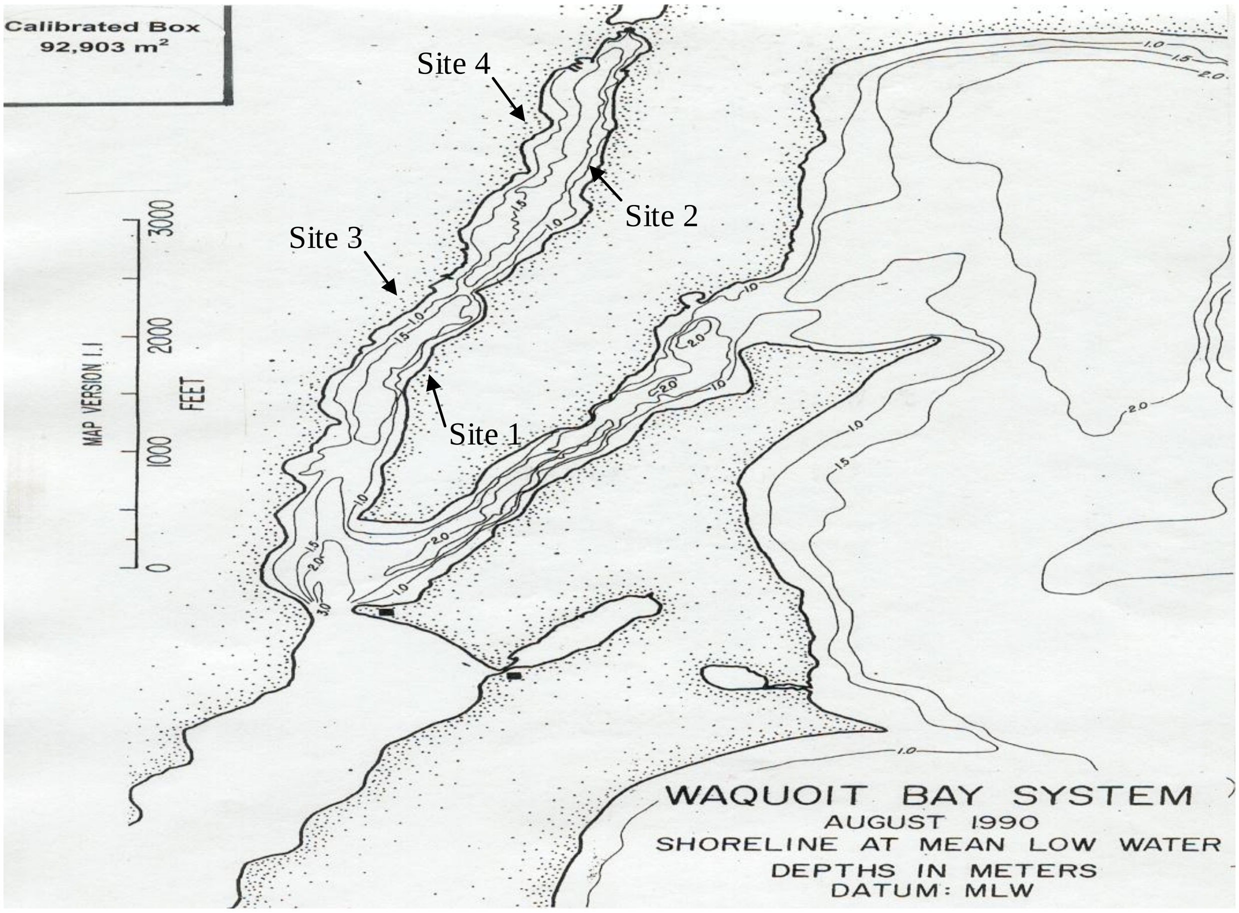
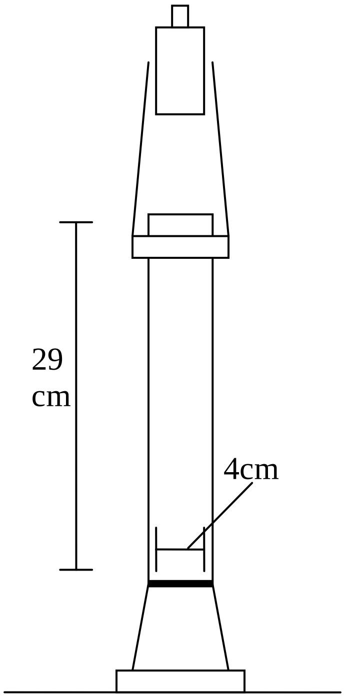


Figure 2: The geomorphic and bathymetry of Child's River in to the Waquoit Bay system with each of the sites locations indicated.



Floatation Device connected by two fishing lines attached to a collar around the collection tube.

Screw collar attached to the collection tube for floatation adjustment.

Collection tube is made of PVC pipe with a height of BLANK and a diameter of BLANK with an completely open top and sealed bottom.

Weight used to hold the collection tube in place, attached to the bottom using fishing line.

Figure 3: The construction and dimensions of the sediment traps used in this experiment but not scaled to size.

Benthic Grab Analysis:

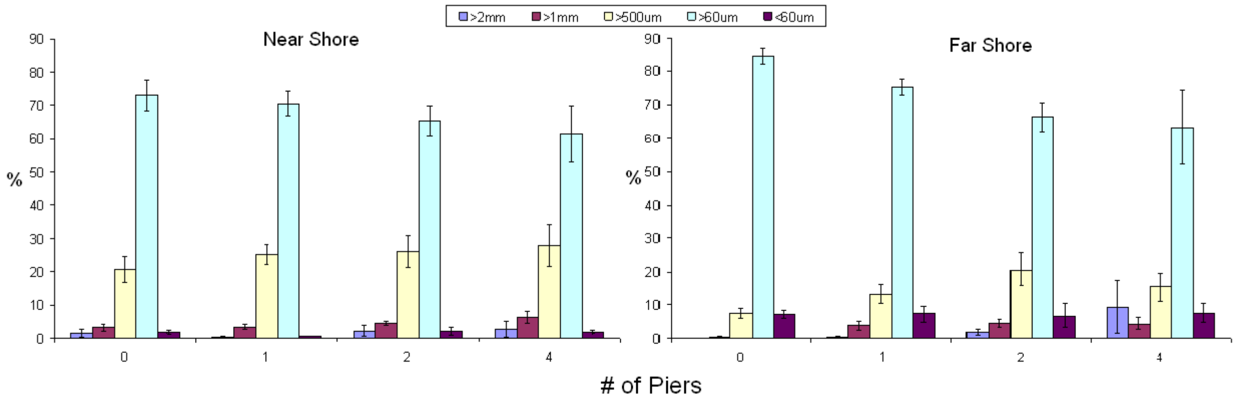


Figure 4: shows the percent of grain sizes sifted in the above sizes for each site and area in each site; near shore (left) and far shore (right).

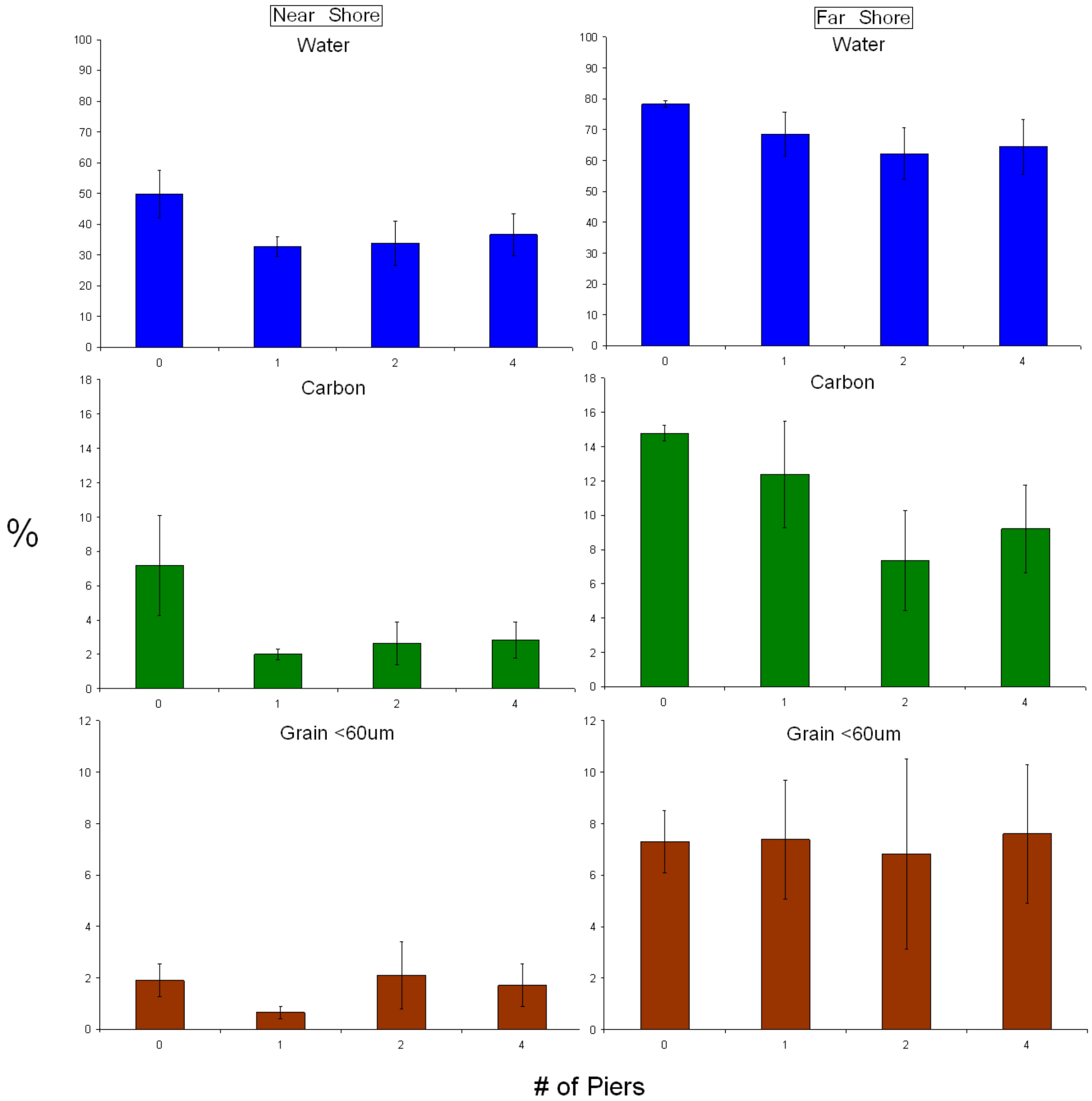


Figure 5: This shows the percent water (top graph), percent carbon in the sediment (middle graph), and the percent grain size less than 60um (bottom graph) for each site and location.

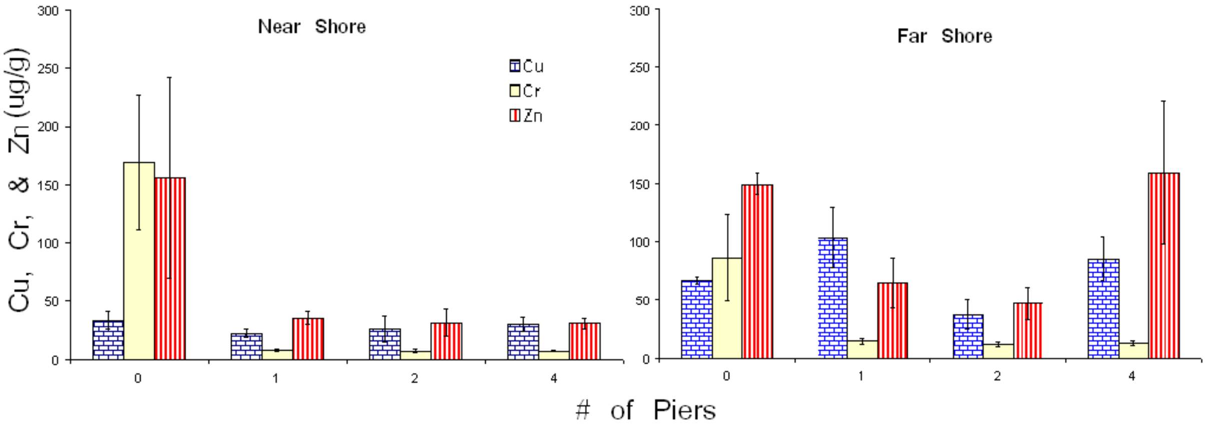


Figure 6: Shows the Cu, Cr, and Zn concentrations for each site/area. Embedded in the graph are the average Cu, Cr, and Zn concentrations for each site.

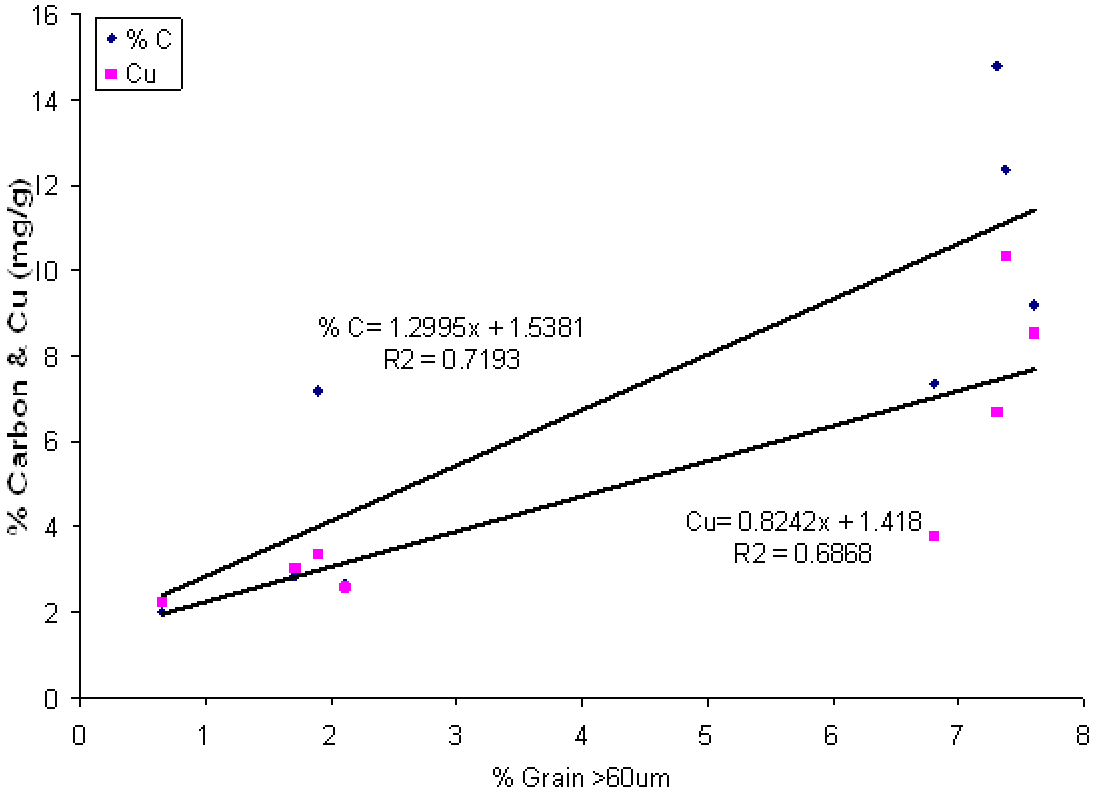


Figure 7: Plots percent carbon in sediment and copper concentration against the percent of grain less than 60um found in all of the sites.

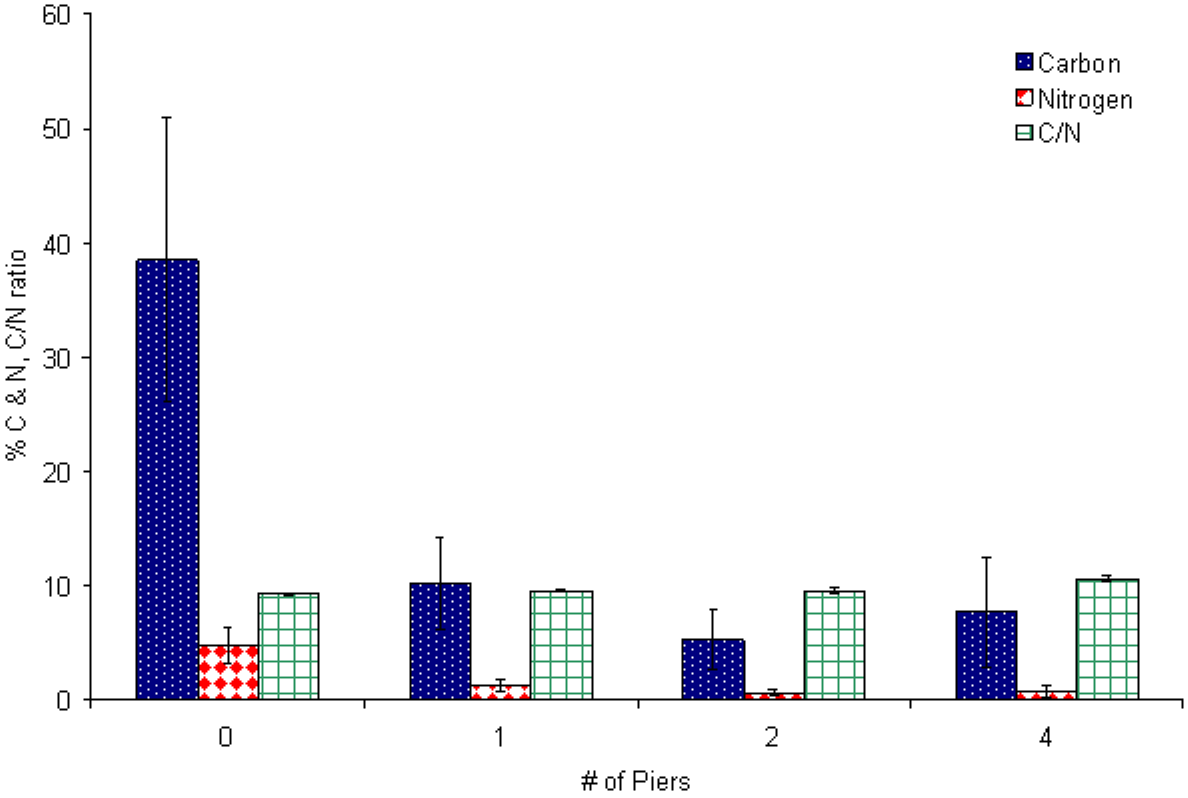
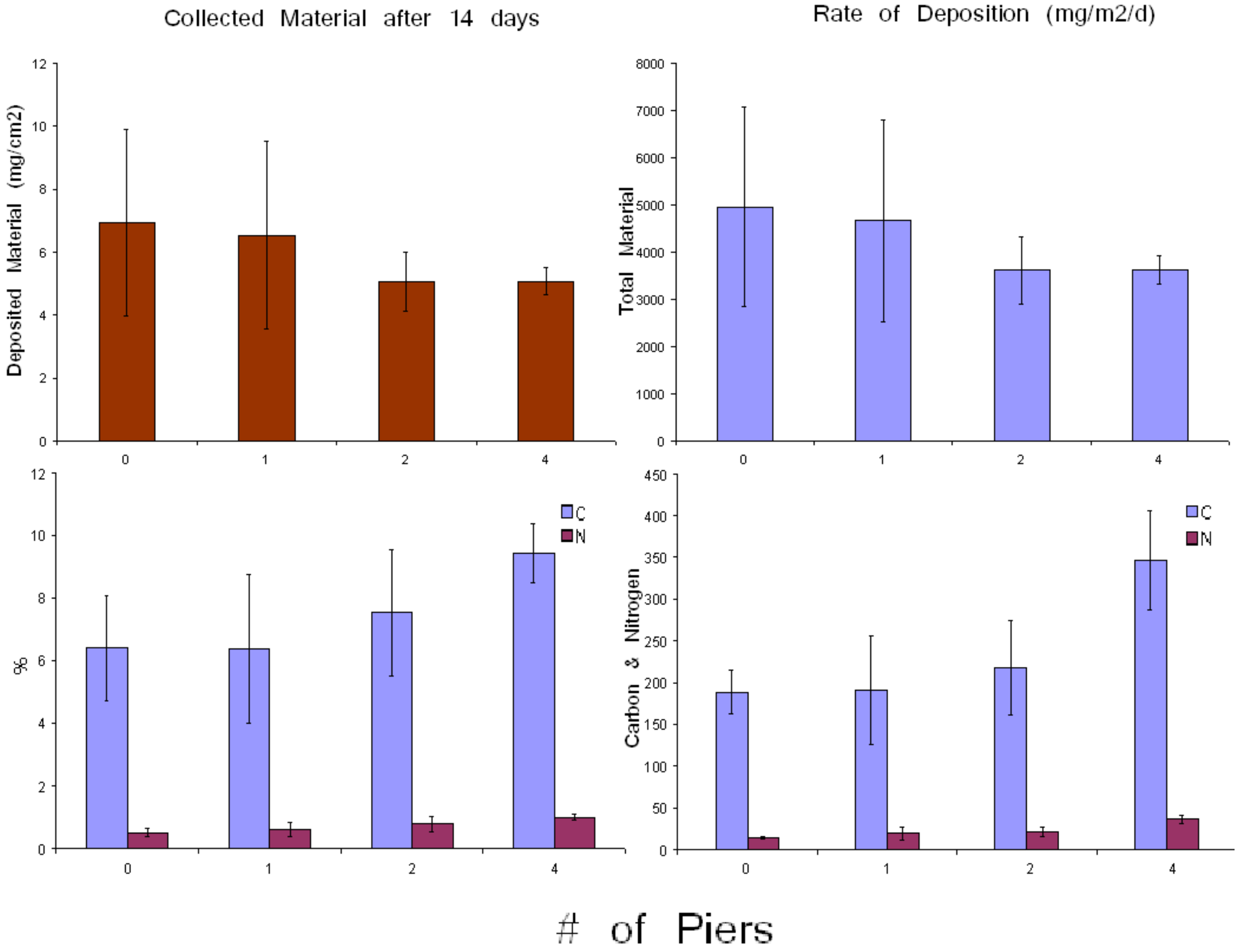


Figure 8: Presents the homogenized benthic grab's % C and N as well as the C/N ratio for each site.

Sediment Trap Analysis:



Collected Material after 14 days

Rate of Deposition (mg/m2/d)

Figure 9: Shows the averaged mass (top left graph) and percent carbon and nitrogen (bottom left graph) of trapped, suspended material collected in the traps after a 14 days week collection period as well as the deposition rate of the total material (top right graph) and carbon and nitrogen (bottom right graph) across a pier density gradient.

Chlorophyll a Analysis:

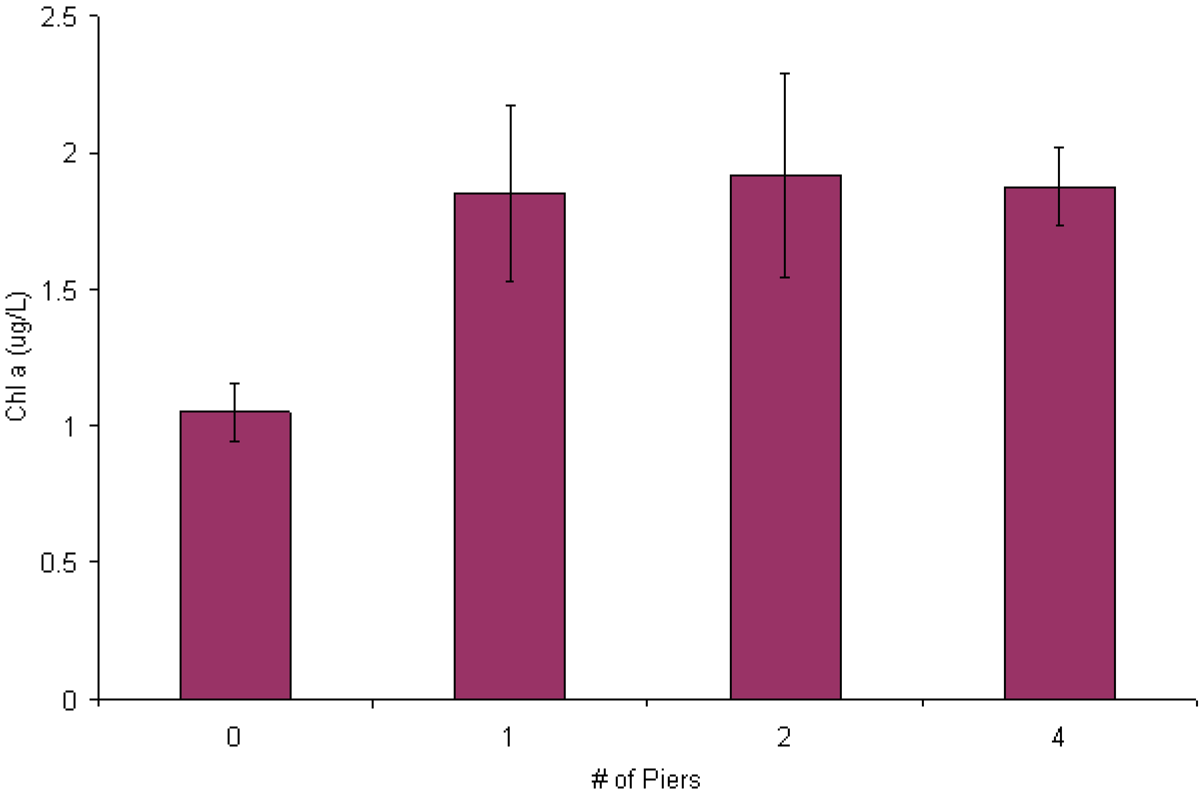


Figure 10: Shows the concentration of chlorophyll a after two weeks of field exposure for each site.

Sediment Core Analysis:

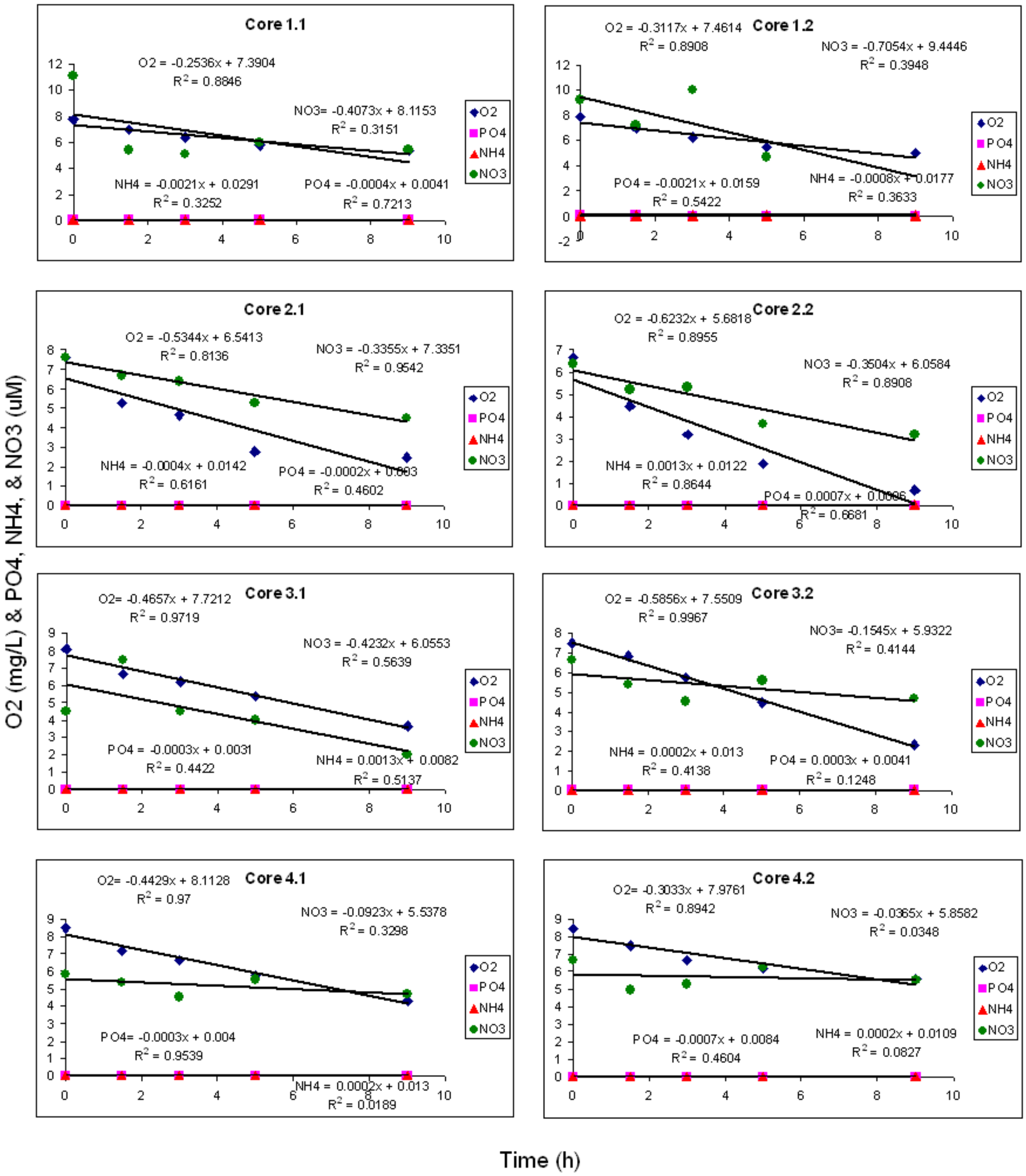


Figure 11: Compares the nutrient flux rates of dissolved O_2, PO_4, NH_4, NO_3 between the sampled sediment cores from each site (two per site) over a nine hour period. Flux rates and regression values are also visible on the figure for each sites nutrient.

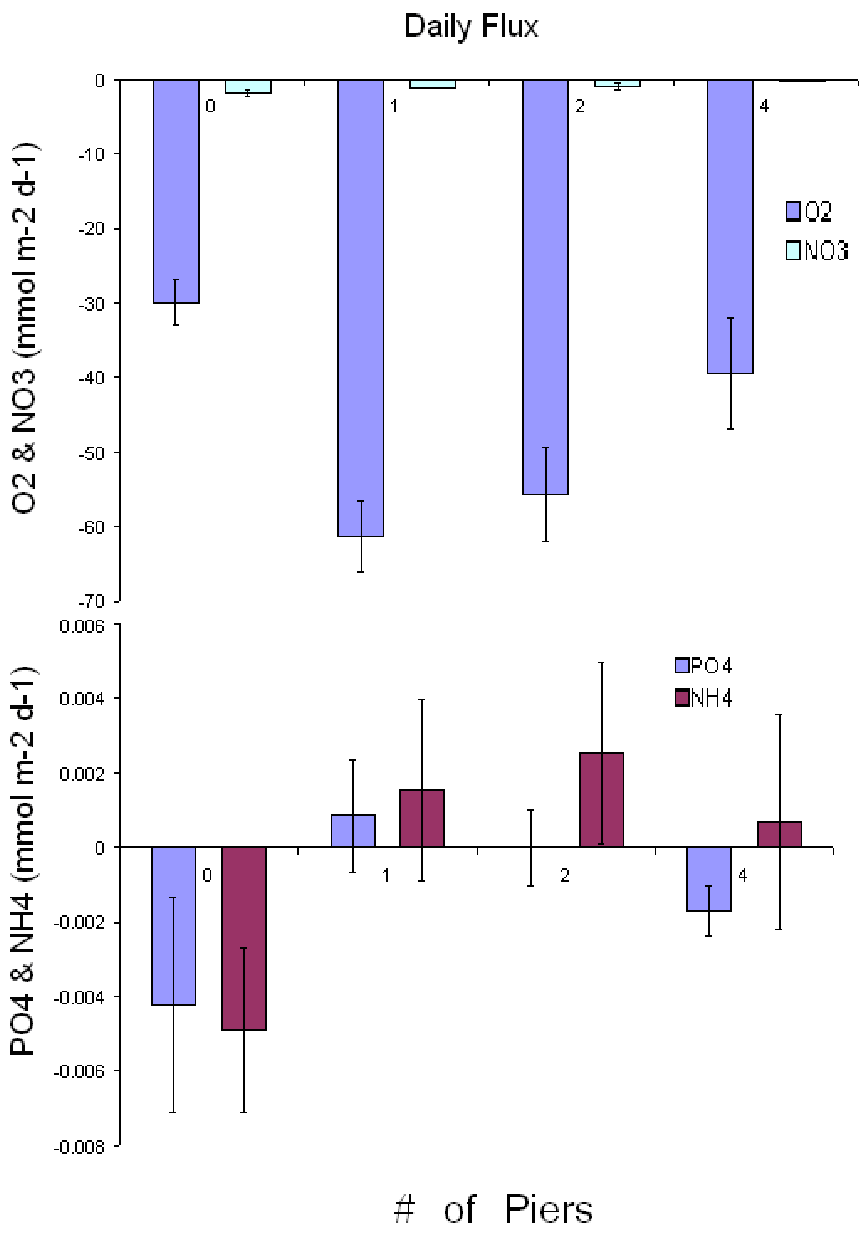


Figure 12: Shows the average flux rate of O$_2$, NO$_3$, PO4, and NH$_4$ per meter squared per day from each of the sites.