Tracking Climate Change, Human Impact, and the overall Oceanic and Terrestrial Health of Estuaries along the Hudson River and Long Island Sound to Influence Policy

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The world is in a state of environmental disarray and one way this can be fixed is through looking at past thriving ecosystems and using this information in order to inform future policies. I remember a time before hurricane Sandy, and everything, at least within my community had appeared environmentally sound. I remember the night when Sandy hit, wind incessantly pounded on my window, beckoning to come in, and the sound of torrential down-pour and emergency vehicles filled the night. The next morning, I looked out of my window, and all I could see was a world covered in branches and of fragments of homes. Everyone in our community had always believed ourselves immune to the wrath of the environment. However, being hit with one of the effects of global climate change had made up realize that we are not immune to climactic catastrophes. The New York Tri- State area was hit hard, with millions of dollars in damage. However, one thing saved us from further catastrophe: the marshes. The marshes had protected us from a further 625 million dollars in damage. It was when I discovered this, that I realized that I wanted to study the marshes to maximize their benefit. A few years later, I had begun doing some research at Alley Pond Environmental Center, where they had recently completed a remediation project, and I learned that, although not perfect, remediating the area had been extremely successful in raising the quality of the water and the land. From that point on, I realized that I wanted to be on the forefront of marsh remediation policies, which led me to seek out this research position at NASA. My mentor for this project was Dorothy M. Peteet and the laboratory work was all preformed at the Lamont-Doherty Earth Observatory affiliated with Columbia University. There were many additional skills required for this project (trying to shake my fear of bugs was most definitely one of them) however learning extra mathematics was not required.

After doing only laboratory work and being left unfulfilled, partaking in field research had made science come alive for me in a way I never thought I'd have the privilege to experience. I have always been drawn to nature, and after this research I have discovered my passion for exploring the outside world even further. In the past I have worked on projects involving alternative forms of energy, microorganisms, neuroscience, and biology. All drawing back to my need to help humanity in someway shape or form. However, after exploring the intricately beautiful marshes of the New York area, I realized that I want to spend my time in scientific discovery doing field work. Exploring the world around me is one of the most fulfilling things I have ever done, and understanding the role of the small bugs, to the graceful egrets soaring the sky above me helps me to gain both a scientific and secular appreciation for the world. This experience was also enriching, because it was the first time where I was surrounded by people whom were also extremely talented and educated on their research area. And their passion for what they were doing fueled my desire to continue research in this field. Research in this field, is also going to be essential as humanity grows, and the number of hurricanes and extreme climactic events increase. Storms like Hurricane Sandy are not once-a-century occurrences anymore; extreme climactic events such as Harvey, Sandy and Maria are happening annually, a product of anthropogenic global climate change that has accelerated greatly in the past years, with the accumulated cyclone energy of this year already reaching double the average. Science, for me, is a way of helping humanity prosper, and it is through research in environmental engineering, and the environmental sciences that I feel that I will be able to bring the greatest good to humanity.

In regard to anyone who wants to pursue a math or science project, my initial piece of advice is “go for it.” Do not be afraid, do not think that you do not know enough or that you don’t have the skillset needed because the beauty of science is that, you’re never going to know enough. Which is why you need to keep reading, collaborating, and doing experiments that you’re passionate about so that you and humanity in general can grow to a knowledge base never thought possible. So whatever you are passionate about, truly, go for it.

The New York metropolitan area is home to 20.2 million people, housing one out of every 16 Americans (US Census Bureau, 2010). In the wake of Hurricane Sandy, attention has been drawn to the region's vulnerability to major storms and has prompted more attention to surge protection afforded by natural barriers, such as marshes. Hurricanes Harvey has recently devastated Houston, Texas, causing billions of dollars in damage. However, much of the damage could have been prevented if the coastal wetlands (marshes) in the area were preserved. In the years before Harvey, policymakers in Houston had allowed for urban development to wipe out the marshes. When Hurricane Harvey hit, there were no natural barriers protecting the city. Thus, the health and human impact on the marshes must be monitored to ensure the future survival of coastal settlements.

Figure 1: This map outlines each of the sites tested (Google Earth).

The anoxic environment of the marshes holds an entire array of human history. By considering the organic, and inorganic content of the marshes, as well as the macrofossils within them, one can gain an understanding of the anthropogenic effect on the marshes, and its influence on the health of the surrounding environment (Kirwan et al, 2013). Marshes provide a variety of services to humans including sequestering carbon and protection from storm surges created by severe hurricanes, thus in studying the past climatic and anthropogenic influences on the marshes, the optimal environment for the marshes can be replicated to extend the beneficial influence of marshes (Wei-Jun, et al, 2003) (Kirwan, etl al, 2013) (Alley Pond Remediation Plan 2014).

The Hudson River and Gateway Estuaries are vital and complex ecosystems that provide numerous benefits to New York City, its residents, and its wildlife. By coring various sites including: Piermont Marsh, Alley Creek Marsh, Iona Marsh and Pelham Bay Marsh, the paleoclimatic data from the New York region can be analyzed to understand the human impact. These sediment cores from these regions were subject to LOI (loss-on-ignition) analysis. Loss-on-ignition measures the percent of carbon "lost-on-ignition." Thus, making the term loss-on-ignition synonymous to the percent of organic matter present within a core during a particular time period. All the sediment cores show evidence of human influence based on the fluctuations in carbon content percentages (LOI percentages). In noting when the changes in carbon occurred and pairing this with human developments in the respective areas, this research can be used to inform marsh conservation policy by pinpointing which kinds of human activity decrease the carbon content and thus decrease organic matter within the marsh. With the trends of the global climate, it is more than necessary to have ecosystems such as marshes to prevent flooding, save money in infrastructure damage and save lives.

Site	Type	Vegetation	Human Impacts
Pelham (40.8506° N, 73.8210° W)	**Salt Marsh**	● Saltmarsh cordgrass *(Spartina alterniflora)* ● Saltmeadow cordgrass *(Spartina patens)* ● Saltgrass *(Distichlis spicata)* ● Common Reed *(Phragmites australis)* (Gedn, et al, 2009)	• Significant coastal development occurred nearby in the 1930's including the construction of nearby Orchard Beach • Golf course in close proximity (NYC Parks, 2017)
Iona (41° 18′ 14″ N, 73° 58′ 38″ W)	**Brackish Marsh**	● Cattails (*Typha Angustifolia*) ● Switchgrass (*Panicum Virgatum*) ● Common Reed (*Phragmites Australis*) (Pederson, et al, 2005)	• Nearby railroad that is still in operation as of 2017 (Department of Environmental Conservation, 2017)
Piermont (41◦00'N, 73◦55'W)	**Brackish Marsh**	● **Common Reed (*Phragmites australis*) (most dominant)** ● Saltmarsh cordgrass *(Spartina alterniflora)* ● Salt marsh bulrush (*Scirpus robustus)* ● Three square bulrush *(Scirpus americanus)* ● Narrow-leaved cattails *(Typha angustifolia)* ● Dwarf spike rush *(Eleocharis pavula)* (New York Invasive Species)	• Discharge point near where the Sparkill Creek meets the Hudson River • High concentrations of fecal indicator bacteria, Enterococcus: 97% of samples failed EPA standards at the Piermont- Draw Bridge (immediately adjacent to marsh) (Riverkeeper, 2017)
Alley Creek (40.76° N, 73.75° W)	**Salt Marsh**	● Saltmarsh cordgrass *(Spartina alterniflora)* ● Common Reed (*Phragmites australis)* ● Saltmeadow cordgrass *(Spartina patens)* ● Saltgrass *(Distichlis spicata)* (Alley Creek Watershed Management and Habitat Restoration Plan, 2014)	• A major road has been adjacent to the marsh since 1779. • In 2011, A sewer overflow facility was constructed, which resulted in a 51% decrease in combined sewer overflow being released into the Alley Creek and Little Neck Bay • Much of the *Phragmites* was removed during the remediation and replaced with Cordgrass. (Alley Creek Watershed Management and Habitat Restoration Plan, 2014)

All of these locations were chosen due to their proximity to human settlement. Therefore, each of the cores will show fluctuations in carbon content based on the different human effects in each location.

The Iona and Piermont Marsh were chosen specifically because of their location on the Hudson River, this means that the health of these locations will have some influence from the materials (organic or inorganic) that are coming from upstream, thus broadening the anthropogenic effect that the carbon content of these cores reflect. The Piermont Core is particularly interesting since it has the influence of waste water, which may or may not influence the carbon content of the cores.

Alley Creek and Pelham were chosen since they are exposed to the Long Island Sound, a much more stagnant body of water. Alley Creek, like Piermont, has had exposure to waste water, however in recent years has been remediated, so the waste water exposure to the marsh has been almost eliminated besides for events of significant water runoff.

a. Sediment Coring

A Russian corer (a modified Livingston corer with a diameter of 2 inches and a 1m length) was used to collect the sediment cores at each of the locations of interest. Two-meter probes were used to check the depth of areas. Afterwards, the sample was taken from the corer and then wrapped in 2 layers of plastic wrap and 1 layer of aluminum foil. Careful consideration was taken to ensure that the entire core remained intact. Upon return to the laboratory, the sediment core was placed in the core refrigerator to preserve the core. (Pederson, et al, 2005)

b. Loss on Ignition

At every 4 cm, a 1gram sample of the sediment core was taken, and placed into a weighed crucible, and this wet weight was measured. Taking the measurements at 4cm, is a sufficient frequency to ensure that all changes in the trends of carbon content are visible. The crucible was then placed in an oven at 110°C for ~24 hours in order to remove all water, and then this dry weight was measured. (Kemp, et al, 2017) Following this, the crucible was placed in a 550°C oven for ~2 hours in order to remove organic matter, and also subsequently weighed. Percent organic and inorganic matter was calculated (Equation 1).

$$\%Loss\ On\ Ignition\ = \frac{Weight\ after\ incineration\ 550^\circ - crucible\ weight}{weight\ after\ evaporation\ at\ 110^\circ - crucible\ weight} * 100 \qquad \text{(Equation 1)}$$

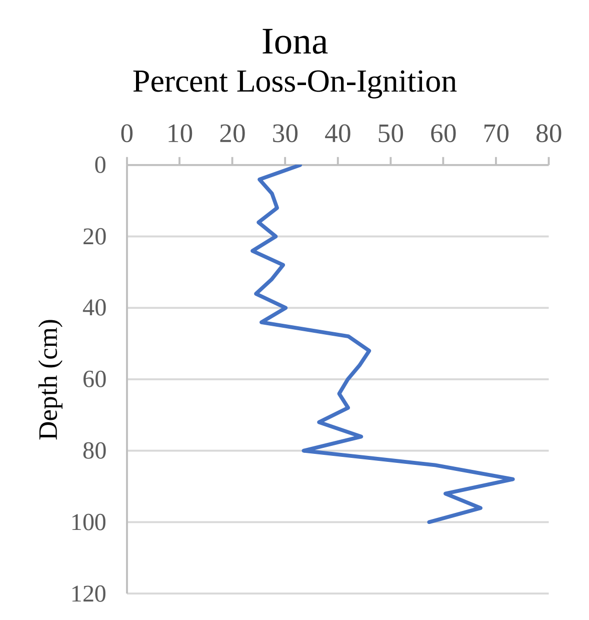

Figure 2: The Iona LOI graph has a large amount of dips, with the largest percent LOI at a lower depth, with this shifting at approximately 100cm.

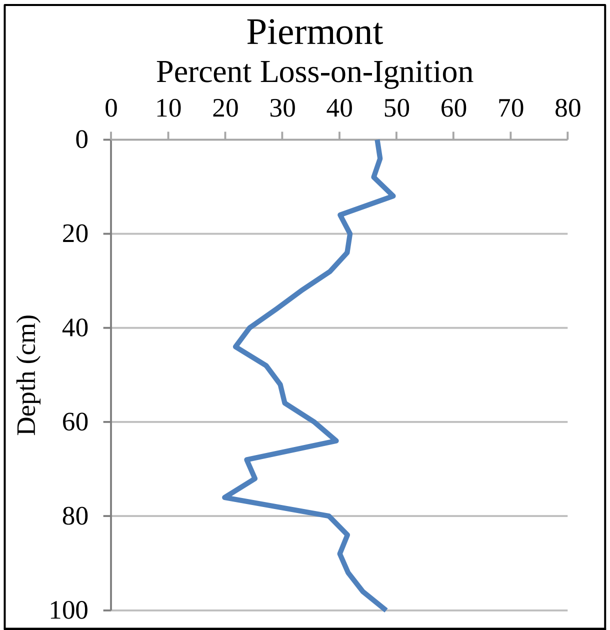

Figure 3: The Piermont LOI graph shows a large shift in organic matter at 80cm. Greatly increasing, into an inconsistent pattern of organic matter.

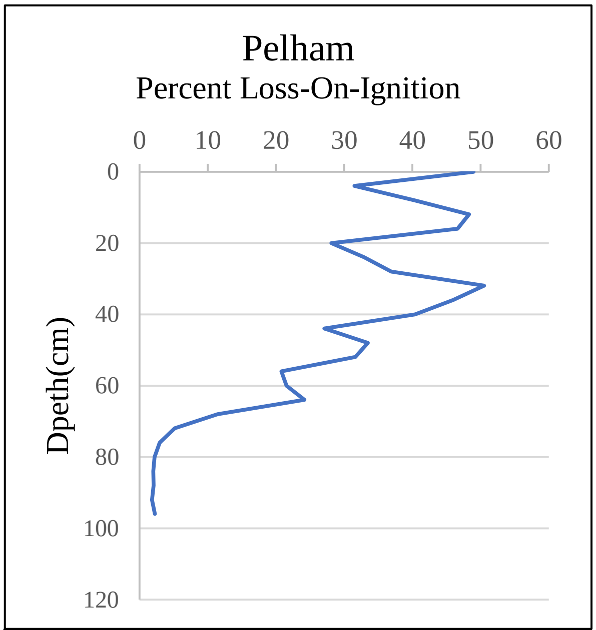

Figure 4: The Pelham LOI graph starts with an extremely low percent LOI and then gradually becomes higher with consistently shifting rates after a depth of 60cm.

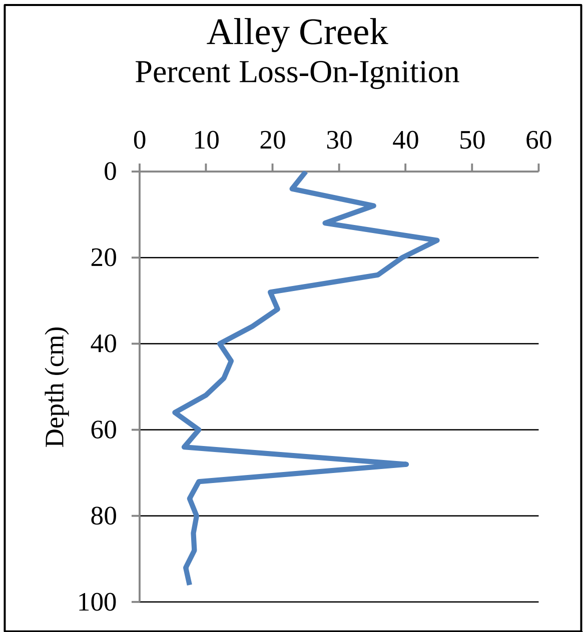

Figure 5: The Alley Creek LOI graph starts with an extremely low percent LOI and has one anomaly at 68cm. Afterwards, the graph trends to a higher percentage of LOI.

The goal of this study was to understand how human influence changed the presence of organic and inorganic matter within the core (indicated by the loss-on-ignition percentage). The Iona and Piermont Marshes are located on the Hudson River (Figure 1) with the Piermont Marsh being slightly downstream from the Iona Marsh. Thus, these two sites are optimal for comparison as they are exposed to the same types of sediment and organic matter from the Hudson River and thus they should show similar trends (Pederson, et al, 2005). Both the Iona (Figure 2) and Piermont (Figure 3) LOI graphs show evidence of a recent increase in the inorganic content of the cores, and this may be attributed to the beginning of significant European Settlement, which occurred around 1625, within the region (Pederson, et al 2005). European contact brought with it various invasive species such as *Phragmites* which may have caused an increase in organic content, however this species is more apparent within the high marsh area while the area cored in this study was the low marsh (Pederson et al, 2005). The other interesting aspect of the Piermont and Iona cores is that they were both exposed to a railroad at some point within their history. It is inferred that each of them was introduced to these railroads at approximately 55cm of their depth, which would put that depth of a time between the 1860s and 1950s due to the fact that both graphs (Figure 2 and Figure 3) show a downward shift in their carbon content (Pederson, et al, 2005). The presence of a railroad would increase the inorganic content of the cores. This is due to the fact that the construction of railroads releases many inorganic particles into the environment including the steel that is used to build the railroads (Barbier, et al, 2011). Also, the continued use of railroads introduces metal, and other materials (such as asphalt) that are required for the maintenance and use of the railroads. While the Iona inorganic content remains high due to continued use of the railroad, the Piermont core shows an increase in percentage of organic matter which may be explained by the discontinued use of the

Piermont railroad near the estuary in 1966 (Wong, et al, 1999). The other reason that Piermont may show an increase in organic matter is its connection with sparkhill, which is a creek that is exposed to a sewage pipe that releases human waste products and was built shortly after 1914 (Documents of the Assembly of the State of New York, 2014). The introduction of human waste products would increase carbon content considering that this product is composed mainly of organic materials (Barbosa, 2012).

The Alley Creek core and the Pelham sites are more directly exposed to the water of the Long Island sound which is more stagnant than the water of a river (Costanza, et al, 2008). Both Alley Creek and Pelham are initially found to have an extremely low LOI; this is thought to possibly indicate a transgressive sequence (Wigand, et al, 2014).

The Alley Creek location generally has a low percent loss-on-ignition, this may be attributed to the large amount of human influence within that area. Northern Boulevard runs approximately 60 feet from the tested location, and that road has been present on maps since 1779 (NYS Department of Transportation). It was in the 1860/1870s that asphalt began being used to pave roads within the United States (National Asphalt Pavement Association, 2017). Therefore, the asphalt and other inorganic materials used to make that road, as well as the Long Island Expressway that is also within a few hundred feet of the tested location, may have contributed to a large influx of inorganic material. The large increase in organic material that begins at a depth of 30cm may be attributed to the use of the Alley Creek as a waste discharge point up until recently. Then, during 2014, Alley Pond Environmental Center began a remediation project focused on decreasing the amount of the sewage that ran into the creek (now sewage only runs into the water during extreme rain events) and increasing the biodiversity of the area (Alley Pond Restoration Plan, 2014). This may have caused the slight increase of organic materials at 4cm. At a depth of 68cm of Alley Creek, there is a spike in organic material. This may have been caused by a piece of decomposing material within the core (such as a plant or animal matter) and it may not be representative of the true carbon content of the sediment. This point will be retested in further examination of the core.

The main differences between Piermont and Iona, and Alley Creek and Pelham is evidence of a transgressive sequence. The transgressive sequence is the formation of a marsh (Hena, et al, 2007). Each of them starts with an extremely low Loss-On-Ignition, which is when they are thought to be a mudflat or a sandy beach, and each of them gradually gain Loss-On-Ignition percentages, which is when they become a marsh (Hena, et al, 2007). While both Alley Creek and Pelham (the sites on the Long Island Sound) show evidence of being fairly young marshes, the Piermont and Iona show evidence of having existed for a much longer time period, or evidence of having been exposed to faster rates of deposition as the cores have not been time stamped with pollen analysis yet.

The dates and changes in loss-on-ignition of these cores can be confirmed with macrofossil analysis; analyzing specific kinds of plant and animal matter within a core at a specific depth. The macrofossil analysis procedure however, is still underway.

Humans have had an ultimately negative effect on the carbon content of the cores, indicative of a decrease in the marshes overall health. Marshes are an essential ecosystem as they had saved 625 million dollars in property damage during Sandy, and they would have mitigated some of the devastating flooding during hurricane Harvey if lawmakers had not permitted coastal developments. (Akpan, 2017) Therefore, it is necessary to use this research to inform marsh conservation policy as marshes will be integral as global climate change increase the frequency of extreme weather events such as Sandy and Harvey.

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