# Invertebrate colonization of pier pilings in the Hudson River

Final report submitted to Hudson River Park Trust

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***Executive Summary:***

Hudson River Park spans over 550 acres on the west side of Manhattan, with upwards of 30 piers and pile fields. While the biota of the Hudson River has been well studied, the biota beneath the Park's piers and attached to the piles has not. Previous studies have looked at mobile fish using the piers, as well as organisms inhabiting the benthos; however, the colonizing sessile invertebrates have been largely ignored. To address this gap in understanding, and to further inform habitat enhancement, Hudson River Park Trust commissioned this study to define the sessile invertebrates of pier areas within the Park's estuarine sanctuary. This study makes use of a new camera attachment to increase video quality in high sediment waters, a Clearwater Box® (Sexton Corporation, USA). Divers were given the Clearwater Box® and took video surveys of piles underneath five key piers within Hudson River Park: active Piers 25, 45, 66, and 84, as well as Pier 32 (an abandoned pile field). These piers span the length of the park, and are made from different materials (wood, concrete, steel). The resulting videos (from 111 piles) show that there is no significant difference with respect to the sessile invertebrate community among the piers. The same group of organisms were found on each pier, including encrusting sponges, algae, barnacles and small bivalves (mussels and oysters). Species of interest included ribbed mussels *Geukensia demissa*, oysters *Crassostrea virginica* and blue mussels *Mytilus edulis*. Samples of oysters brought back to the lab were analyzed for condition index; there was no different in tissue mass and condition index between the piers. However, Pier 84 did have significantly more oysters found attached to piles than any other pier. This could be due to water flow at Pier 84 which has one side blocked by the Intrepid. Overall, results show that the unlit zone underneath capped piers is not a dead zone; there are many colonizing species on the piles throughout, from the edges to the center, which provide an important link in the food chain for mobile fish and crustacean species. The use of the Clearwater Box® as a tool to capture underwater videography was also shown to be effective, providing good detail and footage for identifying key invertebrates.

***Introduction:***

Hudson River Park is a waterfront park in New York City, running four miles along the west side of Manhattan and covering 550 acres of land and water. Within the Park there are more than 30 piers and abandoned pile fields, some with municipal and commercial uses. Hudson River Park prioritizes hands on environmental education and science, and engages the public in research with the purpose of

communicating the ecological importance of the Hudson River Estuary. In recent years, Park staff and marine engineer divers working in the Park's estuarine sanctuary waters have reported underwater pilings are colonized by organisms such as barnacles, tube-building polychaetes, mussels and oysters. Additionally, these colonizers provide habitat and food for mobile organisms in the Hudson River, such as crabs, grass shrimp, and fish.

There has been very little research regarding colonizing organisms on these important underwater structural elements along much of New York City's shoreline. A thorough literature search yielded very few articles discussing the marine life underneath piers in the Hudson River Estuary. A survey of the impacts of piers on fish and larger mobile macroinvertebrates underneath Hudson River Park was performed between 1993-1999 (Able & Duffy-Anderson 2005, Able et al., 1999, Able et al., 1998); this long-term study compared different areas under 14-acres of piers and abundances of observed migratory and resident fishes and macrofauna. Variations in the under-pier habitat location and species were found, which more fish were found along edges, in pile fields, and in waters adjacent to piers than actually underneath the pier itself (Able & Duffy-Anderson, 2005; Able et al., 1999, Able et al., 1998). While these results are informative about the types of mobile organisms underneath piers, they do not discuss the sessile, encrusting invertebrates that live on the pilings, providing food and habitat for these mobile scavengers. In addition to peer-reviewed literature, citizen scientist reports are also informative as to the abundance and diversity of invertebrates and vertebrate fauna in the Park's sanctuary waters. However, most projects are focused on mobile organisms, either due to the methods used (fish traps, gill nets, etc. only capture larger mobile individuals) or by choice (perhaps fish make a more attractive species for community projects?). The latest projects in the Park focus on oyster growth and mortality, through the use of "Oyster Restoration Stations" placed along the piers as well as cages placed around pilings at Pier 32 (Hudson River Park, Community Oyster Project 2018 final report).

Quantifying and qualifying the organisms living under multiple piers in the Park will allow for the dissemination of important information for the health, restoration, and management of the Hudson River Estuary ecosystem. Knowing about the abundance and diversity of filter-feeding organisms, such as eastern oysters *Crassostrea virginica* and ribbed mussels *Geukensia demissa* can speak to the volume of water filtered per day in the estuary. Various efforts around the city are focused on restoring bivalves for ecological purposes (as part of the Comprehensive Restoration Plan of the Hudson Estuary

Program); however, a larger population may exist in the River than previously known. Park scientists have been finding large, older oysters on floating docks as well as settlement plates that are removed from the water; additionally, divers have reported larger oysters on pilings as they repair the piers. Additional anecdotal evidence of the success of oysters in Park oyster gardens and projects within Pier 32 lends evidence to the hypothesis that pilings underwater may house a significant population of filter feeding organisms, which may benefit the filtration of estuarine waters, removing harmful particulates and increasing food web biodiversity. Documenting this information may have influence on ecosystem engineering, design of living shorelines and future work done on piers in the greater Hudson River Estuary. The data collected will also inform future management and habitat enhancement projects within the Park. Previous studies have also shown that the amount and type of encrusting organisms on piers does change the flow of water around the pile, potentially making the pier undergo more stress than originally intended. The habitat complexity of the encrusting community creates different microhabitats underneath the pier which has implications for biodiversity as well as water flow (Atilla et al. 2005).

A formal study of the biological life encrusting pilings will provide baseline data for a variety of future studies, including piers (and enhancements to pilings) as alternative habitats, and how these colonizers can deteriorate pilings and change water flow around the structures. At the time of this report, New York Governor Cuomo had announced "Revive Mother Nature" a multi-million dollar commitment to restore oysters in Hudson River Park (as well as in the Bronx River and other New York coastal waters); knowing a quantity of oysters underneath existing piers as well as biodiversity estimates of the area are extremely important in planning the new oyster deployment. Building off previous Park studies, including water quality analysis and oyster grow-out cages, a small study was designed to analyze the species richness and abundance of colonizing organisms on underwater piling structures. A study area within the Park was chosen, consisting of five piers that varied in age, material composition, and type of pier (covered vs. pile field). The project spanned from Pier 25 (N. Moore St./ West St., Manhattan) to Pier 84 (W. 44$^{th}$ St./ West St., Manhattan), a distance of 3.5 miles (Figure 1). The piles consisted of wooden, concrete, and steel piles; all were covered piers except Pier 32 (Table 1).

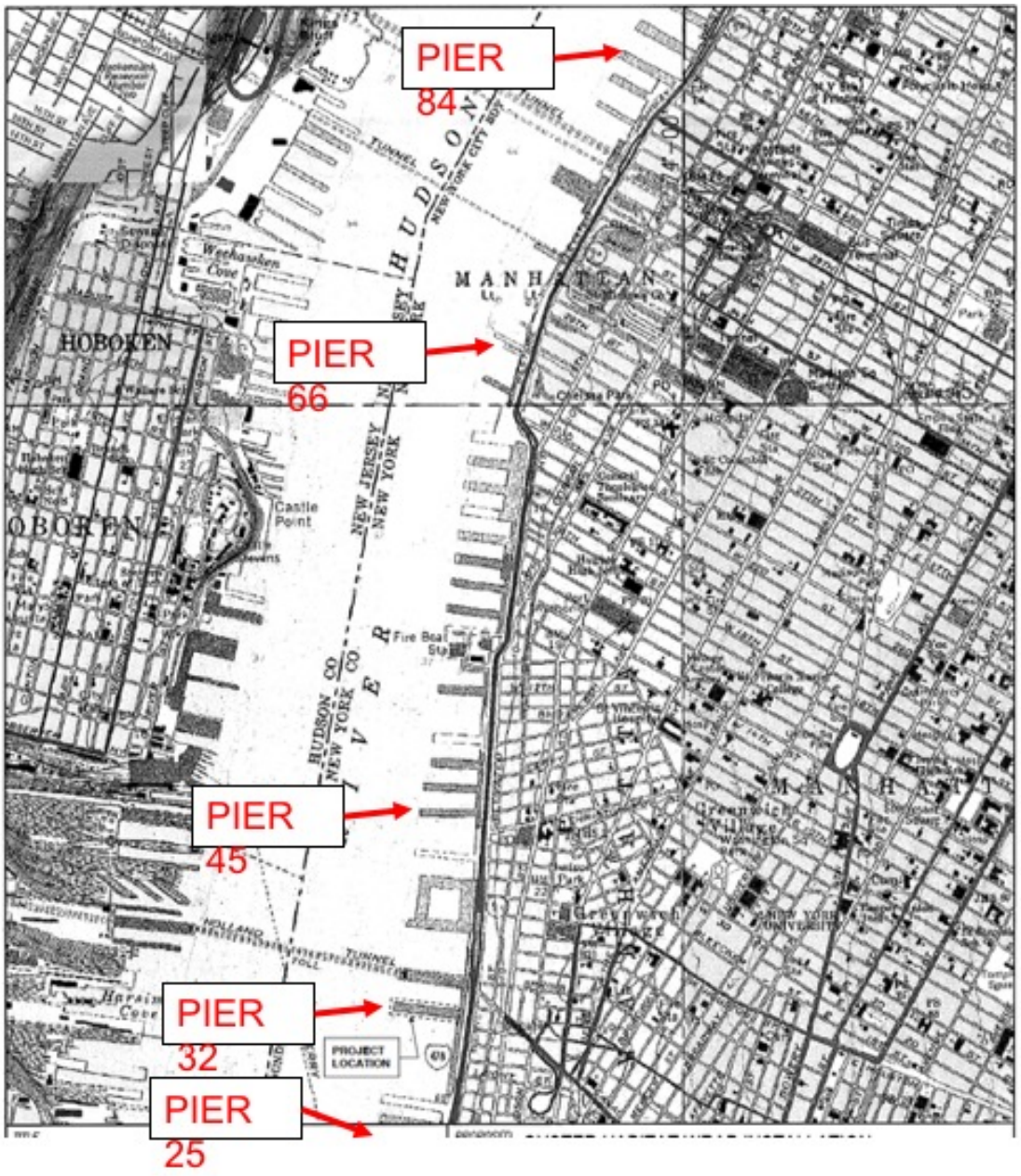


*Figure 1: Map of the chosen pier sites.*

During this investigation, three specific questions were targeted:

1. Does the age of the pile influence in the abundance/diversity of invertebrates colonizing? It was hypothesized that yes, older piles/piers would have fewer species as succession has gone on for longer (climax community reached). Here, the species present will be hardened, encrusting species (e.g., barnacles) which have outcompeted smaller, soft bodied species for space (e.g., tunicates).
2. Does the material of the pile influence abundance/diversity of the invertebrates colonizing? It was hypothesized that yes, wooden piles would have more encrusting (and burrowing) organisms than the steel or concrete piles. The newer steel piles are now coated with antifouling epoxy, thus severely limiting colonizing organisms.
3. Does the location within the pile field (inner or outer edge, closer to shore or furthest away from shore) influence abundance/diversity of invertebrates colonizing? It was hypothesized that yes, piles closest to the shore would have fewer encrusting organisms colonizing on them due to ice scouring/harsh wave action off the bulkhead. Also, piles towards the outer edges would have more diversity as this area may get more light (allowing for some algal colonization)

***Methods:***

*Location:* Five representative piers within Hudson River Park were chosen for this study. The piers were chosen based on their age, construction materials, and proximity/involvement with several other Park projects. Plans for each pier were obtained from Park scientists to show the location of piles within each area of the pier (or an open pile field). Piers were split into three roughly equal sections longitudinally (heading away from the shoreline). Based on information from Park scientists, sampling did not take place within the nearshore zone (~75 m). These were then split into three zones horizontally, with a left/middle/right zone of piles. Using a random number generator, three piles within each zone were selected for sampling. This gives a total of approximately 27 piles per pier; 135 total piles (see below for details)**.**

*Video Surveys:* The Park secured a team of divers from Moffat & Nichol to record all underwater video. All videos were recorded during a 2-week period in May 2019. Water quality data was obtained from the HRECOS station within the Park (at Pier 84). Other than one date of rain, which produced a

noticeably more turbid dive the following day (D. Melnyczuk, lead diver, pers. comm.), there were no extreme weather events that could skew data. The average temperature for the time period was 15.37 ± 1.51ºC; average salinity was 7.63 ± 2.3 psu (HRECOS).

Divers were given a Clearwater Box® (Sexton Corporation, USA). This unique frame allows for "unobstructed imaging of underwater objects" by placing a layer of distilled water in front of a waterproof camera. The camera then shoots photo/video through the clear water, which will greatly improve visibility in turbid waters. The divers then affixed a Go-Pro® Hero 7 camera to the Clearwater Box® (equipped with Lume Cube LED lights), and were able to record short survey videos of each pile. This is a newer piece of equipment, and this project served as a test of the efficacy of this method of underwater videography in the Hudson River. Divers descended down the pile and back up, methodically covering all four faces of the pile. The Clearwater Box® was held right up to the pile, and the diver moved slowly, to maximize the clarity of the video footage.

Divers also removed specimens of special-interest species for in-depth analysis. These specimens included: oysters *Crassostrea virginica* (larger than 3", 10 per pier max), ribbed mussel *Geukensia demissa* (10 per pier max), and blue mussel *Mytilus* spp. (10 per pier max). Mobile species of interest include varying migratory and resident fishes (gobies, flounder, striped bass), grass shrimp *Paleomontes*, sand shrimp *Crangon*, and several decapod crabs (mud crab *Panopeidae,* blue crab *Callinectes sapidus*, invasive Asian shore crab *Hemigrapsus sangineus* and green crab *Carcinus maenus*) (based off Able & Duffy-Anderson 2005). These species were noted in the video analysis (and by divers) but were not brought back to the lab. The bivalves brought back to the lab were shucked, weighed and dried for condition index (Crosby & Gale 1990).

For each pier, standard marine engineering plans were obtained which showed the location of each pile within the pier. The entire length of the pier (beginning at the shoreline) was divided into nine equal sections: near shore, middle, and deep water; outer edge left, middle, outer edge right. Within each section, piles were numbered and a random-number generator was used to choose three piles within that section. This method gives a total of twenty-seven randomly assigned piles to be studied for each pier. After discussing with marine engineers and the dive team, some randomly chosen piles were replaced to create a more efficient sampling scheme for the divers. This still allows for the piles to be randomly

chosen for the most part. Divers did change piles, but they were unseen prior to the change so there was no bias other than location. Methodology also had to be adapted for some of the piers due to changes in shape and condition of parts of the pier; see below for specifics.

| | *PIER 25* | *PIER 32* | *PIER 45* | *PIER 66** | *PIER 84* |
|---|---|---|---|---|---|
| *AGE OF PIER/PILES* | 2008 | 1931 (TOP REMOVED 2002) | 2002 | 2005 | 2005 |
| *MATERIAL OF PILES* | CONCRETE | WOOD | CONCRETE | STEEL | CONCRETE |
| *LOCATION OF PILE WITHIN PIER* | ZONES 1-9 | ZONES 1-20** | ZONES 1-9 | ZONES 1-9 | ZONES 1-9 |
| *TYPE OF PIER* | COVERED | UNCOVERED PILE FIELD | COVERED | COVERED | COVERED |

Table 1: Chosen piers for project. **Note: Pier 66 is constructed of steel piles which are coated with an epoxy to prevent fouling. Anecdotal reports have shown that the epoxy has begun to wear off the in the intertidal zone due to mechanical degradation. Upon first diving, it was noted by divers that there was less colonization on these pilings; therefore, only 5 piles were surveyed from this pier, and extra piles added to pier 45. ** Note: Each pier was divided into 9 zones, 3 along the width and 3 along the length. However, for Pier 32, since many of the piles are deteriorated, the entire pile field was divided in half widthwise, and then into 10 equal sections along the length, for a total of 20 zones of piles. See methods for a more in-depth description of sampling methodology.*

| PIER 25 | | | | | |
|---|---|---|---|---|---|
| NEAR SHORE | BENT 3-13 | *PILE LINE ABC* | B6 | B9 | C10 |
| | | *PILE LINE DE* | E3 | D7 | D9 |
| | | *PILE LINE FGH* | F10 | H3 | H11 |
| MIDDLE | BENT 14-24 | *PILE LINE ABC* | B20 | C19 | C24 |
| | | *PILE LINE DE* | D16 | D21 | E20 |
| | | *PILE LINE FGH* | F18 | G17 | H20 |
| DEEP WATER | BENT 25-35 | *PILE LINE ABC* | B32 | C27 | C30 |
| | | *PILE LINE DE* | D33 | E27 | E35 |
| | | *PILE LINE FGH* | F29 | F35 | H28 |

Table 2: Pilings surveyed at Pier 25. These piles are made of concrete, were installed in 2008, and are covered by a pier above. Located at West St/ N. Moore St., Manhattan. This is the southern end of Hudson River Park.

| PIER 32 (PILE FIELD) | | | | |
|---|---|---|---|---|
| *ZONES 1-20* | 1 | 6 | 8 | 13 |
| | 14 | 19 | Oyster Wraps | |

Table 3: Pilings surveyed at Pier 32. For this pile field, different methods had to be used due to the number of piles, the uncertainty of their condition, and the lack of details on the drawings provided. The pile field was divided into 20 equal sections (lengthwise: 10 sections, across: 2 sections, for a total of 20). Using a random number generator, five of these sections were chosen to be surveyed (50% of the pier). Divers were instructed to randomly choose 3 full-length piles within the given section to video (for a total of 15 piles from the pile field). With the removal of extra piles from Pier 66, additional piles were added in that had existing "oyster wraps" on them. The oyster wraps are used by the Park to study a new technique for oyster restoration on pilings. The piles in this field are wooden, originally installed in 1931, and uncovered (the top of the pier was removed in 2002). Located at West St./ Canal St., Manhattan.

| PIER 45 | | | | | |
|---|---|---|---|---|---|
| *NEAR SHORE* | BENT 1-11 | *PILES* | B1 | B6 | B9 |
| | | | C4 | E2 | E7 |
| | | | F5 | F10 | G7 |
| *MIDDLE* | BENT 12-23 | *PILES* | A21 | B17 | B21 |
| | | | C20 | D18 | E16 |
| | | | F13 | F15 | G14 |
| *DEEP WATER* | BENT 24-35 | *PILES* | A31 | A35 | B31 |
| | | | C27 | C33 | E30 |
| | | | F25 | G28 | G32 |
| | | | A24 | G26 | F34 |
| | | | A34 | B29 | G27 |

Table 4: Pilings surveyed at Pier 45. These pilings were installed in 2002 and are made of concrete. This pier is located close to Park offices, near W 10th St/ West St. in Manhattan. Additional piles were added on here (after the truncated schedule for Pier 66) since upon first video inspection, this pier seemed to have the most colonization.

| PIER 66 | | | | | |
|---|---|---|---|---|---|
| *NEAR SHORE* | BENT 29-19 | *PILES* | A23 | B24 | A19 |
| *MIDDLE* | BENT 18-8 | *PILES* | A11 | B18 | B12 |
| *DEEP WATER* | BENT 7-1 | *PILES* | C2 | B6 | C5 |

Table 5: Pilings surveyed at Pier 66. This pier was constructed in 2005. The pilings in bents 1-29 are constructed out of steel, which is the focus material for this pier. The near-shore pilings are made of concrete and not being surveyed during this exercise. The steel piles were coated with anti-fouling epoxy. This pier is located at W 26th St/ West St. in Manhattan. During initial videos, it was noted that these piles had less fouling than others; thus, 4 of the originally selected piles were not recorded, instead focusing effort more on other piers.

| PIER 84 | | | | | |
|---|---|---|---|---|---|
| *NEAR SHORE* | BENT 27-20 | *PILES* | A24 | B20 | C23 |
| | | | D20 | E26 | F22 |
| | | | G25 | H27 | H22 |
| *MIDDLE* | BENT 19-12 | *PILES* | A19 | B17 | B15 |
| | | | E19 | F17 | F15 |
| | | | G14 | H17 | H16 |
| *DEEP WATER* | BENT 11-5 | *PILES* | A10 | B9 | C7 |
| | | | D11 | E8 | F6 |
| | | | G10 | I9 | I7 |

Table 6: Pilings surveyed at Pier 84. This pier was constructed out of concrete piles in 2005. This pier is located at W. 44th St./ West St. in Manhattan. This is at the northern end of Hudson River Park.

***Results:***

Due to changes with divers during the actual surveys, only 111 piles were surveyed. However, there was still enough replicates across all pile zones and piers to draw statistical conclusions. Video analysis was completed by two researchers, with approximately 30% of each pier being double-viewed to ensure accuracy. Results were then reviewed by the PI and any anomalies thoroughly checked.

Across all piers, the same encrusting species were found. The spiny sour weed *Desmarestia aculeata*, along with orange boring sponge *Cliona* and branching sponge *Haliclona loosanofi* were abundant along all piers. These grew in small clumps at all depths, often coated in sediment. Harder encrusting species such as *Semibalanus balanoides* barnacles were abundant closer to the tops of piles (near the water line). Since the sampling was done in early spring, before barnacles reproduce and colonize anew, most of the barnacles found were dead or sloughed off with winter ice (scars were observed on the videos). Filter feeding bivalves *Mytilus edulis* and *Geukensia demissa* were observed on piles, though ribbed mussels

were only found at the northernmost pier, Pier 84. Colonial tunicates as well as solitary tunicates (*Molgula manhattensis*) were observed on more southern pier, Pier 25.

| *PIER* | *NEAR* | *MID* | *FAR* |
|---|---|---|---|
| *25* | 9 | 8 | 11 |
| *32* | 8 | | |
| *45* | 8 | 11 | 12 |
| *66* | 6 | 5 | 7 |
| *84* | 8 | 8 | 9 |

Table 7: Species richness across the piers. There was no significant difference between the species found on each pier. Additionally, there was no difference between species richness closer to shore, or further out.

| *PIER* | *25* | *32* | *45* | *66* | *84* |
|---|---|---|---|---|---|
| *25* | X | 0.74 | 0.75 | 0.84 | 0.82 |
| *32* | X | X | 0.67 | 0.75 | 0.82 |
| *45* | X | X | X | 0.76 | 0.73 |
| *66* | X | X | X | X | 0.82 |
| *84* | X | X | X | X | X |

Table 8: Sorenson's coefficient examining community similarity across the piers. The closer to 1, the more similar the community.

Oysters *Crassostrea virginica* were found on all piers, in varying amounts. Many scars (single valve still stuck to the pile), or box oysters (dead oyster but with both valves still attached) were found along with the live oysters. Oysters ranged in size, but there was a large percentage of the oysters above 4cm (possibly indicating an older age, but the shells were not dated). Shells were often covered in barnacles and other epibionts (e.g., sponge, encrusting bryozoan, or tunicates), but shells were relatively hard and

thicker in shape. Condition index was calculated on several oysters collected from Pier 45; the condition index was 5.88 ± 2.54 ($n$=8). Compared to sites around the Hudson Raritan Estuary, this is in line with the average condition index for early spring oysters (Fitzgerald, pers. obsv.).

| *PIER* | *NEAR* | *MID* | *FAR* | ***TOTAL LIVE OYSTERS SURVEYED*** |
|---|---|---|---|---|
| *25* | 3 | 1 | 7 | **11** |
| *32* | 1 | | | **1** |
| *45* | 2 | 6 | 7 | **15** |
| *66* | 0 | 1 | 0 | **1** |
| *84* | 27 | 22 | 39 | **88** |

Table 9: Number of live oysters found during video surveys. There were significantly more oysters observed at Pier 84 than all others (Student's $t$-test, $p$<0.01). There were no significant differences between the quantity of oysters found closer to the bulkhead (near) or further out along the pier (far). At Pier 84, where the most oysters were found, there was no difference between the number of oysters found on the outer sections of piles, and the innermost piles.

***Conclusions:***

This project saw the implementation of novel methodology to discover what organisms are living in a region of the Park difficult to assess. The area underneath the piers was thought to be barren and dark, with little living organisms. However, as more information about oysters living under the piers surfaces (e.g., news stories such as "It's the biggest oyster found in NY in 100 years" from the NY Times, September 2018) it is important to catalog and quantify all organisms living in the Park borders-including those not readily seen.

The results of this study show that there is a small group of commonly seen encrusting organisms within the Park. Though the piles are of differing materials and ages, there was no significant difference observed with respect to community structure. This indicates that the piles may have reached the climax community. At that time, the dominant species have established a hold on all available space, and all encrusting organisms must compete for space. Organisms may overgrow already established base organisms (this was seen with the bushy bryozoan, which grew out over barnacle layers). Mobile organisms were the same among all piers, which is to be expected in such a small spatial area. These are commonly seen organisms within the entire saline portion of the Hudson Raritan Estuary (e.g., blue crabs, skilletfish, grass shrimp).

This project focused attention on species of importance to the estuary, including oysters and mussels. These filter feeding bivalves have the ability to remove sediments and pollutants in the water, depositing them on to the benthos (benthic-pelagic coupling). The populations of these bivalves differed between the piers, with more oysters being found on Pier 84 than anywhere else. This may be due in part to the location of Pier 84 (more upriver, closer to a possible source population in the Hudson River), due to water flow around the pilings at that particular location, or due to lack of disturbance near the pier. Pier 84 is a newer pier (2005) with pilings made of concrete. Pier 84 is bordered on the southern side by the Circle Line pier (which has high levels of boat traffic) and to the north by the USS Intrepid (where no motorboats are permitted and the Intrepid sits on the sediment). This may create favorable water flow conditions which keep larvae in the water column near the piles, resulting in high levels of recruitment. Whichever the reason, it is recommended to consider this site (Pier 84) as a potential restoration site due to an existing population of wild oysters under the pier. Oysters are able to settle out of the water column and survive on the piles, the entire length of the pier.

Mussels (both blue and ribbed) were found in moderate abundances around the pilings of all piers. These mussels use their byssal threads to attach to the piling, and to each other, to form dense clusters. Though mostly single (or double) mussels were observed, there were some clumps of 10-20 mussels observed on Pier 84. Mussels can filter nearly as much water as an oyster, and therefore are of importance when any calculations involving water quality are performed (e.g., when determining nitrogen removal rates or pollutant clearance rates for a system). Mussels may enhance biodiversity of

mobile fauna, and along with oysters can provide a high degree of benthic-pelagic coupling and help to clean the water column.

The Park has combined sewer outfalls (CSOs) underneath all piers chosen for this project. During the video survey, there was no observable CSO outfall; diver notes show that it rained once and an increase in turbidity was noted the following day. Constant water quality monitoring within the Park (HRECOS) as well as NYC.gov Waterbody Advisories (https://www1.nyc.gov/site/dep/water/waterbody-advisories.page) ensure safe conditions in the water. No waterbody advisories were issued during the dive period, indicating CSO outfall release was not high. Marine invertebrates, such as those observed on the piers in this study, have varying tolerances to sewage effluent (e.g., Stabili et al., 2013; Cabral-Oliveira et al., 2014). Several species of plant and animal can be used as "indicator" species in polluted environments, including the presence of Ulva sea lettuce.

One species of concern seen in videos was the oyster drill *Urosalpinx cinerea*. This predatory gastropod was observed on several piers, including Pier 45 and 84. In higher saline waters oyster drills occur in large densities and can destroy populations of oyster spat, though not usually a concern in the Hudson River, varying amounts of rainfall seasonally can affect salinity and may lead to a population boom of these predators. Oyster drills should be monitored around any restoration project to determine the percentage of mortality due to predators. It was not surprising to see oyster drills on piles since there was live oysters found there too. Drill "scars" (holes in shells) could not be observed in the video, but that may be due to their small size.

Future recommendations for these piers include continuing to monitor the biodiversity on pilings through any oyster restoration projects. The input of large quantities of oysters into the Hudson River in the next few years may result in an influx of spat into the system. With that, spat will be searching for a hard substrate on which to land during the 2-week planktonic larval period. The pilings below piers provide a perfect habitat for an oyster, where they are protected from wave action and ice scouring, food abundantly flows by in the river, and there are minimal mobile predators. The use of pilings as potential oyster "reef" habitat in New York City is not new (Brooklyn Bridge Park ECOncrete project) and may occur in the Park with the addition of spat and broodstock into the system. The more oysters are in the system, the more mobile fauna will be found underneath the piers. This includes an increase in small

fishes (e.g., skilletfish, oyster toadfish) as well as migratory fishes in the River (e.g., striped bass); crustaceans (e.g., blue crab) will also become more abundant.

The efficacy of the Clearwater Box® waterproof camera housing was tested during this project, and showed that even in extremely cloudy, turbid water good underwater photography could be achieved. The case worked well to vastly improve water clarity and visibility, even in the dark underneath piers. The first videos taken are not as good quality, as the divers went too quickly up and down. However, by reviewing the videos each evening after diving, analysts were able to give tips to the divers to improve video quality (i.e., go slower up and down piles, pause, brush sediment off oysters to tell if live or dead). The case is now being tested at another location in the Hudson Raritan Estuary, and will be used to monitor other projects within the Park (i.e., oyster wraps).

In closing, while no significant differences were discerned between the piers (with respect to pile material, position of the pile in the pier, and age of the pile), this study did have two significant results. First, this work showed that there was abundant invertebrate colonization underneath the piers. The videos showed that all piles were almost 100% covered with sessile encrusting invertebrates (save for the very top intertidal area where ice scouring may have occurred in the previous months), and many had important species such as filter feeding mussels and oysters. Secondly, this project confirmed that using the Clearwater Box® waterproof camera housing was a useful methodology to employ when doing work in the Park. Future studies with oysters and fish underneath and around piers should make use of this technology and provide an in-depth look at the underwater habitat available to organisms in the Park. To further examine the role of invertebrates within the pier area, monitoring studies of underwater pile fields where oyster projects will take place should include invertebrate diversity not only in the oyster cages but also attached to the piers; the addition of more filter feeding bivalves to the piers may alter the colonization of piles by early larvae (i.e., barnacles and bivalve larvae that may be filtered out of the water column by filter-feeding individuals).

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***Appendix: Selected photos from video dive recordings. More can be found at https://drive.google.com/open?id=1bLV3jUaNgAQ667phKhfWqae5WwWe5muu***

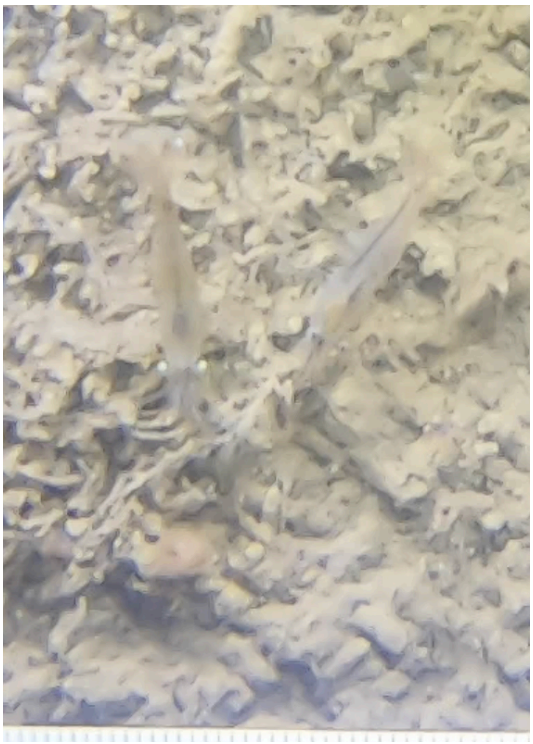

Photo 1: two *Palaemonetes* grass shrimp, Pier 45.

Photo 2: Large (~4cm) live oyster *C. virginica*, Pier 45. The ruler was left in frame to show size.

Photo 3: Skilletfish *Gobiesox strumosus*, Pier 45.

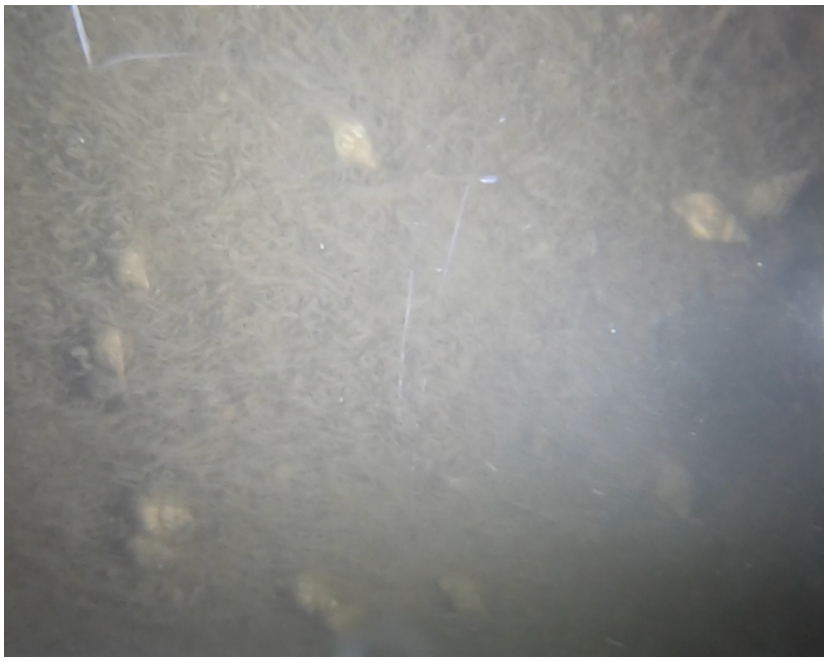

Photo 4: multiple oyster drill *Urosalpinx cinerea* snails, Pier 25.

Photo 5: Clump of blue mussel *Mytilus edulis*, Pier 25

Photo 6: very large oyster (~6cm), Pier 25. Side view to show valves and closed edge.

Photo 7: colonial tunicate (black), small anemones (orange) and bryozoan (white), Pier 25.

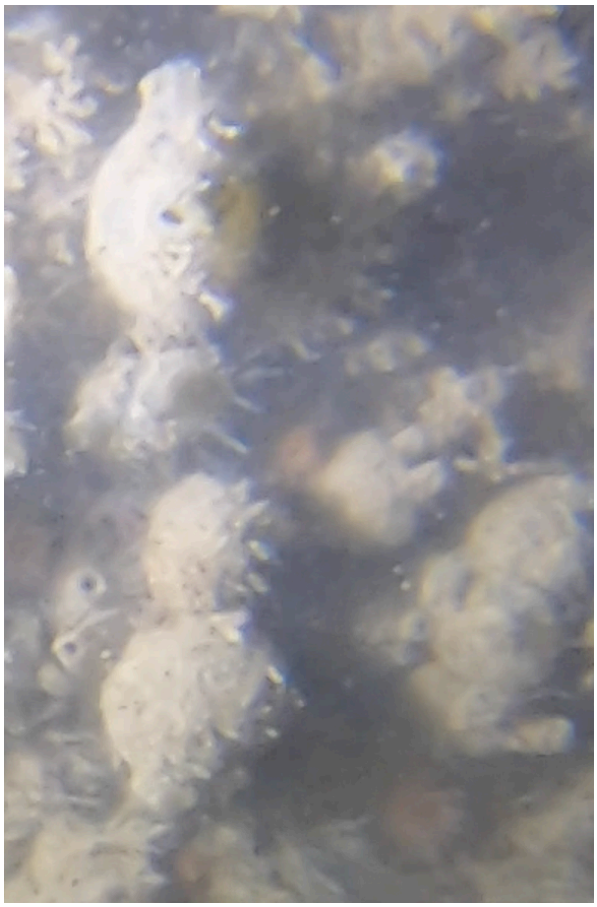

Photo 8: *Molgula manhattenensis*, Pier 25

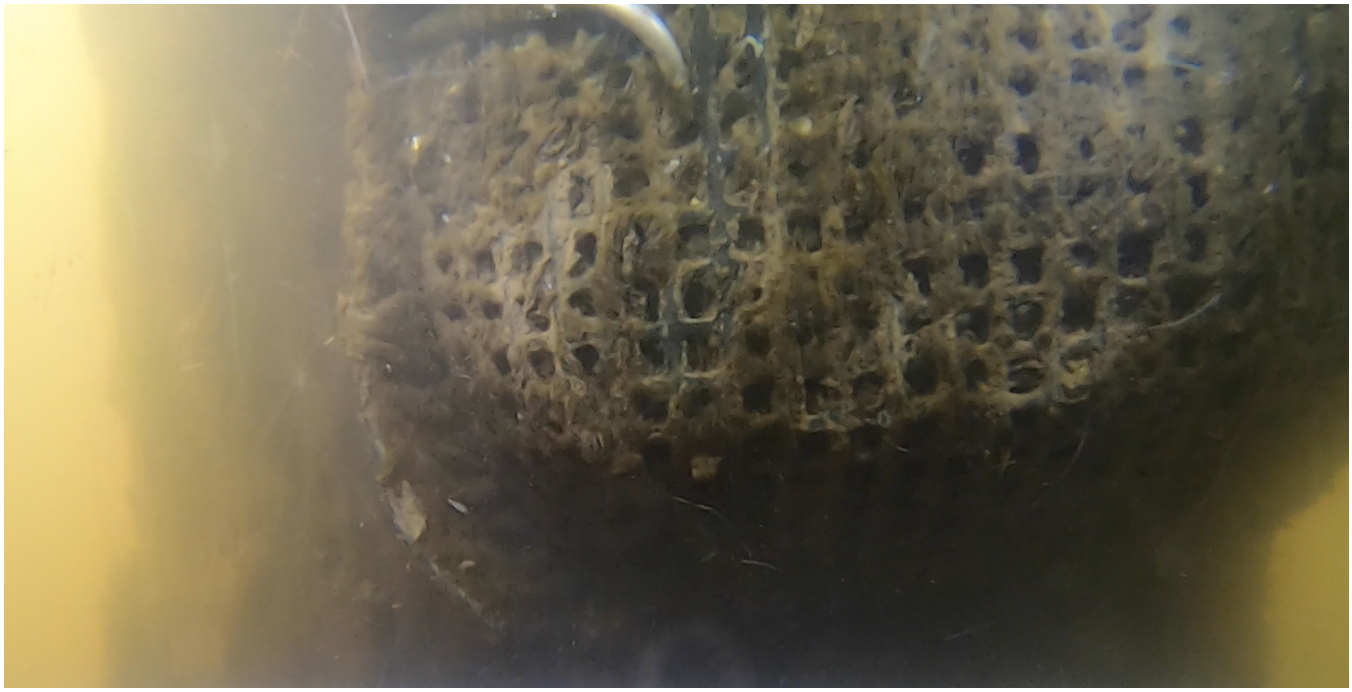

Photo 9: Oyster wrap underwater, Pier 32

Photo 10: Pile erosion, Pier 32. It is possible this is from shipworms Teredinidae; no worms observed but markings consistent with shipworm damage.

Photo 12: Ribbed mussels *Geukensia demissa* growing on an oyster scar, Pier 84.