The Percent Coverage of Biodiversity on ECOncrete at the Manhattan Side of the Harlem Sea Wall (Hudson-Raritan Estuary, 2018)

Photo credit: Nicholas Ring

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2018

Introduction:

Before European colonization, the New York harbor was lush with life, serving as an outlet to the Atlantic Ocean for many rivers and marshes (MNLA, 2014). However, after hundreds of years of industrialization and environmental degradation (*i.e.* oil spills and combined sewage overflow among others) the harbor is in a relative state of recovery (NY-NJ HEP, 1996) and beginning to look like a shadow of what it once was. According to MNLA (2014) the Harlem River sea wall and bulk heads are falling apart and will collapse in the next decade. The locality's biodiversity is under great strain (Smith, 2015). These developments have generated the opportunity for CIVITAS Citizens, a non-profit community organization (civitasnyc.org/live/), The Billion Oyster Project, and the Harbor SEALs Citizen Science organization to develop a plan to study and propose restoration strategies for the Manhattan sea wall along the East River Esplanade.

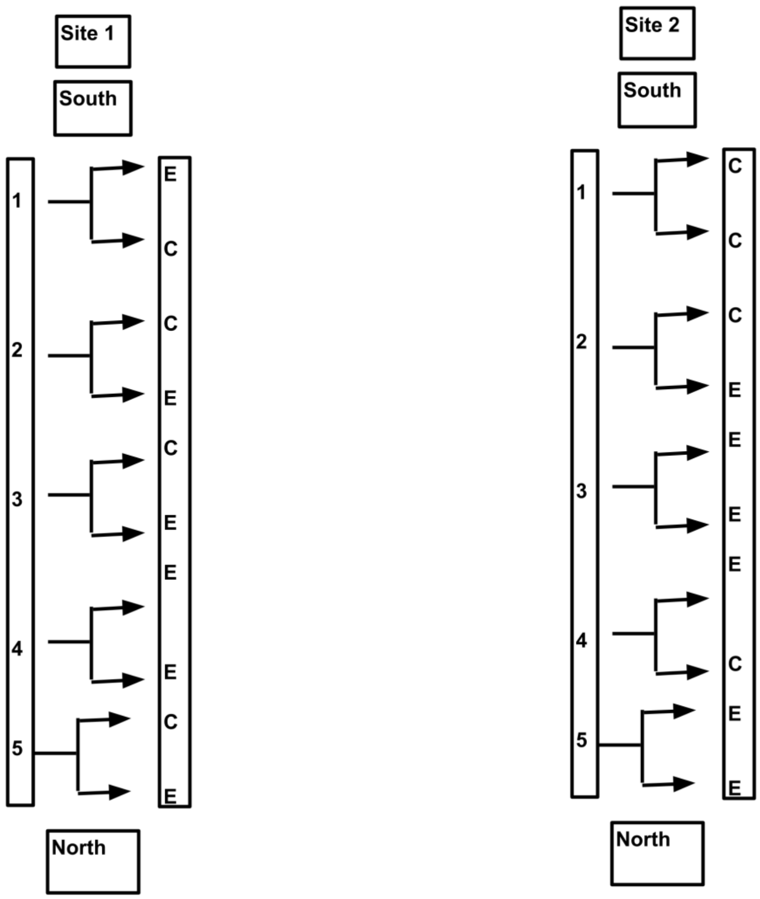
Biodiversity is an important indicator of the health of an ecosystem (Khan, 2002). Biodiversity indexes are the measure of the combination of how many different species and how many individuals within those species there are (Stiling, 1996). Biodiversity is also a good indicator and how those species interact with the ecosystem (Walker, 1992). Driver Organisms present within the community can be more important than other species. They can attract desirable organisms or control the spread of less desirable ones. Oysters can be thought of as a Driver Organism as well as a key stone species. Percent Coverage is calculated for sessile organisms to show how many organisms are in each area.

To enhance the Manhattan Sea Wall and attract biodiversity, ECOncrete ™ was used. ECOncrete is a novel concrete mixture that changes the concrete composition and surface texture of normal Portland cement (Perkol-Finkel & Sella 2014). Portland cement-based Concrete Marine Infrastructure (CMI), has a poor pH for biological recruitment (*i.e.* pH of 13). Most sea organisms live in a pH of 8 (Lukens & Selberg, 2004; EBM, 2004). The physical and chemical structure of Portland cement supports only species highly tolerant to harsh conditions (Chapman & Underwood, 2011). When compared to the standard Portland cement, ECOncrete has a lower surface pH (Perkol-Finkel & Sella, 2014). The lower pH and surface texture allow for a diversity of organisms to colonize ECOncrete such as oysters, corals, barnacles, polychaetes, tunicates, sponges, and mussels (Perkol-Finkel & Sella, 2014). When ECOncrete was tested in the Mediterranean Sea and the Red Sea the textured side of the disk had a higher Percent Coverage of biological material (Perkol-Finkel & Sella 2014). When the same tiles were used in the Hudson River off of Governors Island, the textured side had a much higher recruitment then the non-textured side (Abdo, 2015).

Shelled organisms that colonize ECOncrete such as oysters, barnacles, and others can form a calcitic layer on the ECOncrete that absorbs hydrodynamic impacts, further increasing its durability (Chapman & Underwood, 2011). This calcitic layer may also reduce the costs of maintenance in the long term. The changes to concrete such as its composition, texture, and macro-design would give it the potential to become a beneficial part of the environment, increasing biologic buildup (Risinger 2012). However, there may be effects of concrete on aquatic ecosystems that remain unknown (Connell & Glasby, 1999, Dugan, *et al*., 2011).

It was hypothesized that the addition of ECOncrete would attract a high biodiversity, percent cover, and biotic buildup (Perkol-Finkel & Sella 2014) because of its chemical composition, texture, and spatial-complexity-enhancing properties. This in turn would support the concept of ecological uplift in the locality in the event that new structures are built to replace the crumbling infrastructure.

Project Design:



KEY

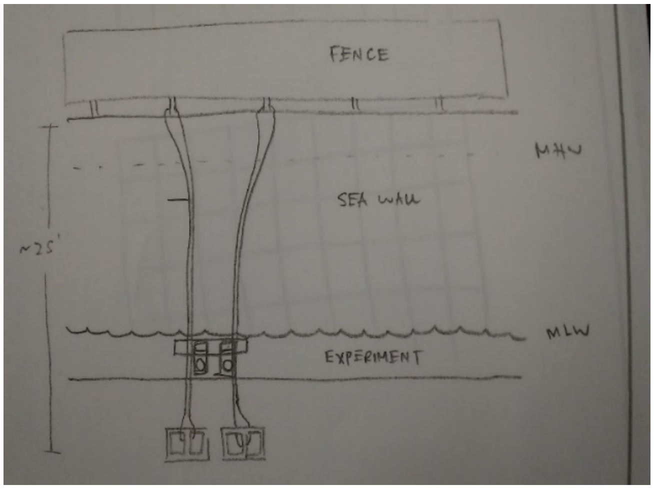
C: Control

E: Experimental

Numbers: names of Platform(s)

North/South: Orientation of disks on the sea wall

Figure 1. Support structures are oriented in the water from north to south. Controlled grids (empty) are labeled with “C”. Experimental grids (ECOncrete disks) are labeled with an “E”. Arrows indicate what grids belong to each structure.



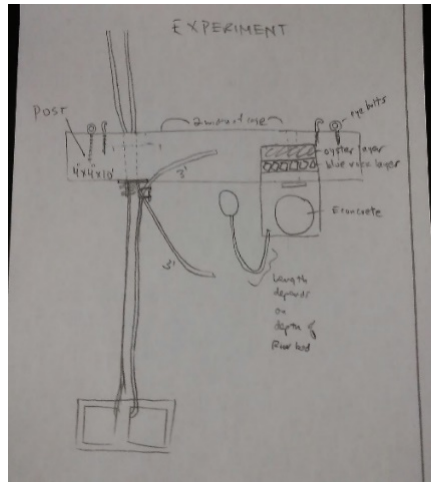


Figure 2. Cage platform that holds two cages at time. To ensure that during the winter they are not damaged by ice the cages age held by cable clamps and washers below mean low tide.

Figure 3. Closeup of the support structure shows how the ECOncrete disk is situated on the wooden post. This figure also shows oysters, blue stone and a mycelium fungus buoy, these are not a part of this experiment and are a part of different experiments that are sharing a working space.

Table 01. Project design chart identifying the objectives and problem associated finding the Biodiversity and Percent coverage of ECOncrete and the Harlem sea wall.

Category	
Scientific Problem	Which substrate, ECOncrete or Portland Cement (sea wall), supports a higher level of biodiversity.
Hypothesis 01	ECOncrete will have higher biodiversity than the sea wall.
Null Hypothesis	There will no measurable difference in biodiversity between ECOncrete disks and the Harlem sea wall.
Objectives	**1.** Compare the measurements of biodiversity of ECOncrete and Portland Cement (sea wall) in the Harlem river **2.** Present conclusions to various stakeholders.

Table 02. Experimental design: Variables associated with the percent coverage of biodiversity on ECOncrete disks.

Independent Variables	**Dependent Variables**	**Controls**	**Constant Variables**
• Concrete type (Sea Wall/Portland or ECOncrete) • Different Sites	• Percent coverage of on ECOncrete disks and on the Harlem sea wall • Biodiversity Indexes	• Grid without ECOncrete	• Design of Support structures • Composition of substrates • Number of disks per site at start

Table 03. A summary of Assumptions, Limitations, Risks and Safety in this experiment

Assumptions	**Limitations and Risks**	**Safety**
1. ECOncrete and the sea wall don't affect each other **2.** ECOncrete and mycelium fungus buoys don't affect each other * **3.** ECOncrete and Eastern Oyster (*Crassostrea Virginica*) shells don't affect each other. * **4.** ECOncrete and blue stone rock don't affect each other. *	**1.** The number of times that can be sampled within a year due to vessel and crew limitations. **2.** The duration of the experiment. **3.** The number of Trials- one. **4.** Vandalism is a risk, the wire rope is exposed on the sidewalk because it's wrapped around the fences, due to this they might be cut, however the buoys will allow us to find them if they are cut or fall.	**1.** Type 3 personal flotation device (PFD) are mandatory when on boats or floating docks. **2**. Gloves **4.** First Aid kit are on vessels when working. **5.** Permission slips required for participation in field work for all workers under the age of 18.

* These three assumptions are based on two other experiments adjacent to this one.

<u>Safety</u>

To ensure the safety of the people while working with water, metal cages, and ECOncrete, a wide variety of safety supplies were used: rubber gloves, safety goggles, face masks, and bodysuits.

Locality:

The cages were deployed as seen in *Figure 1*, the positions of where the six disks were located were determined randomly. Five platforms were dropped at two of the three sites as previously sampled which were site one proximal to Ward's Island Bridge, and site two proximal to 114th street (Smith, 2015).

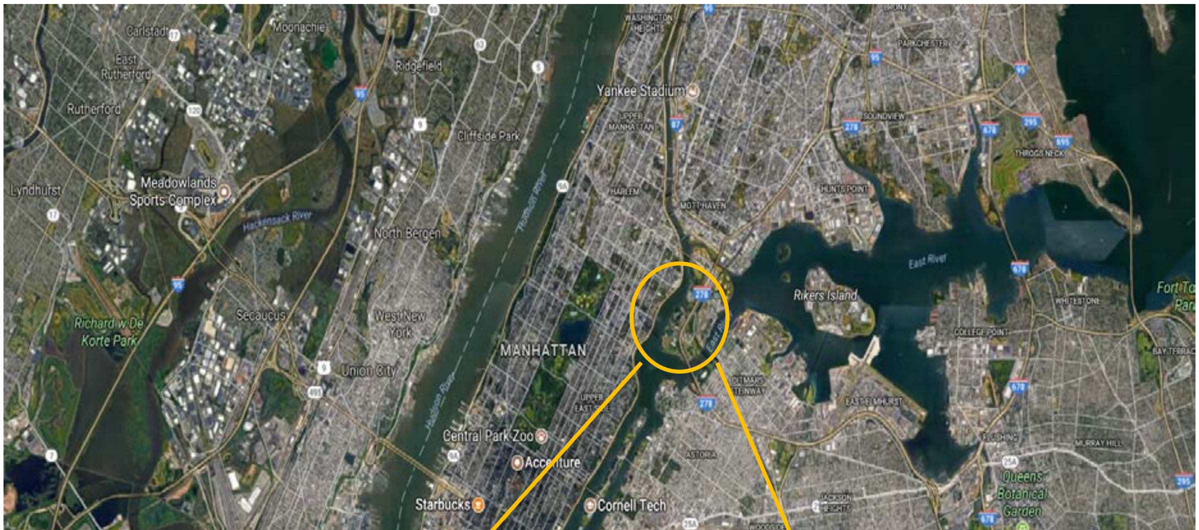


Figure 4.

Upper New York City

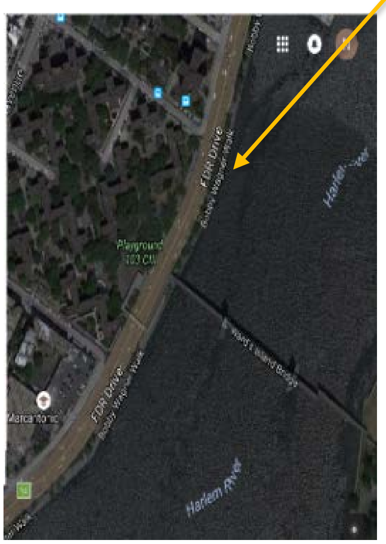


Figure 5.

Site 1: Under the Ward's Island bridge

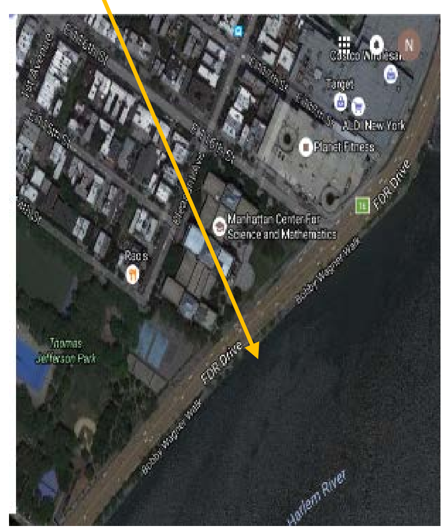


Figure 6.

Site 2: E114st On FDR drive

Procedures

Support Structures

1. Label north “N” and south “S” on the wooden platform.

2. Measure 7 in from the edge of the platform (on both sides) and mark the distance.

3. Drill a whole ½ an inch wide.

4. Drill a hole next to the whole already made smaller than ¼ inch width through the platform though the 7-foot marks (on both sides) and insert a ¼ inch eyehook.

5. Drill two holes in the platform on an adjacent side of the wooden plank. (Drill though the Grid so that the ½ inch wholes are in the middle of the grid) do this on each side.

6. Place ¼ inch washers over the holes and screw in the flat head screws on top of the grid so that the middle of the grid is under the ½ inch drill hole.

7. Measure the distance from the edge of the seawall to the bottom of the river; double that distance and cut that amount in feet of wire rope do this twice, one for each side of the platform.

8. To cut the wire use the equation 2X+6 where “X” is the length of depth of the harbor below the support posts on the fence. And the “Six” in the equation represents extra inches cabling.

9. Loop the wire rope through the drilled hole and one cinder block; place a washer through the wire and place it under the drilled hole to hold the wire in place, do this to both sides.

10. Using heavy-duty steel clamps attach the bottom of both wires together and loop the wires on the bottom of the fence to hold the platform up. (Do this while hanging the platform using two I whole knot lines on each side of the platform.).

11. Use a heavy-duty zip tie to tie the wire rope around the grid.

12. Repeat steps above for every platform.

Deploying Support Structures

1. Bring all pre- built support structures to the disagreed Sea Wall with a bared fence around it.

2. Bring over the number of ECOncrete disks that are supposed to go on the platform.

3. Place the Disk on top of the grid and attach it with 6 heavy duty zip ties, between each prong and through the hole in the center, do this twice to ensure that the disk stays on.

4. Lace the wire rope through the hole in the wooden plank and the Cinder blocks on both sides.

5. Have two people walk onto the wall with two large ropes with eyes.

6. Have them throw over the eyes and place the ends of the plank into the eyes.

7. Pull the two lines until the disks are hanging from them and against the sea wall.

8. Take the free end of the wire rope and loop it around an anchor of the fence. Do this for both sides of the plank.

9. Take the two free ends on each side of the plank hold them together, then with a wire clamp, tie them together.

10. Slowly lower the platform into the water.

11. While holding onto the wire ropes, take the eyes off of the plank.

12. Continue to lower the plank into the water until the wire rope is taught.

Concrete Disks

1. Put all dry compounds in the mixer pail (Aggregate, Sand, ECO P1, Fibers, Slag cement).

2. Weigh 3.1 Kg (6.83 lbs.) of tap water and pour into a small bowl. Then weigh 224 gr. (0.49 lbs.) of Water Reducer and add it to the bowl. Mix it well.

3. Add the liquid mixture (from section .2) into the mixer pail. All materials listed in the table below should be now in the mixer pail.

4. Let the mixer work for several minutes (5-7 min.)

5. Prepare 10 disk molds, and a spray bottle with mold release oil for concrete (we use Biodiesel for this purpose).

6. Spray the mold with the mold oil and add the concrete mixture into it on a vibrating table, make sure you scatter the concrete mix evenly. Vibrate the table for 1-2 minutes.

7. After casting all 10 disks, let them dry for at least 24 hours before releasing them from the mold. Flip each mold over and gently tap the edge of the mold against a table. Using your hands, catch the concrete units as they detach from the molds after taking out all concrete disks, put them in water to cure for 24 hours.

Support Grid

1. Use the wire cutters to cut the grids into 16x18 squares.

2. Repeat until you have 12

3. Place ECOncrete disk on lower part of grid.

4. On each disk rap 3 heavy duty zip dies around the ECOncrete disk while weaving through the hole in the disk and the support grid.

Wall Grid

1. Cut PVC piping into 4 10.5-inch sections and put them in a square with the elbow connecters, with the un-used holes facing in one direction. This square is the base.

2. Take 3 weights and place them in one of the piping, this will be the bottom.

3. Cut PVC piping into 2 7.00-inch sections and place them in two of the un-used holes that are diagonal from each other.

4. Place the 45° angle on the 7.00-inch PVC piping, point them towards each other.

5. Cut PVC piping into 2 7.65-inch sections and place them into the 45° concoctors.

6. Place 45° concoctors on the 7.65-inch sections facing each other.

7. Cut PVC piping into 1 2.85-inch section and connect them to the 2 45° connectors.

8. Place the Camera mount on the 2.85-inch section.

9. Cut out two more 4.30-inch tubing and place them on the two remaining holes on the base, they should be diagonal from each other.

10. Place two more elbow connectors on top of the new 4.30-inch tubing.

11. Cut out 4 7.65-inch tubing and place those on the available elbow connecters, on each end place a 45-degree connector.

12. Cut out 2 2.8-inch tubing and put them in-between the 45 degree connectors.

Sampling the wall

1. Program the camera to a timer so that it starts taking pictures after 15 seconds, then takes 5 pictures with 1 second intervals.

2. Secure camera to the camera mount

3. Tie two 20 feet of line to the mount to the other side of the weights on the two supports with each should have a Clove hitch.

4. Push the camera button and lower the frame into the water,

5. After at minimum of 20 seconds raise the camera out of the water.

6. Repeat for every structure pulled up.

Sampling the disks

1. Place the disk on a level surface.

2. Write name, date and Disk number on the disk.

3. Place a pH test strip on the Disk and write the results on the Data sheet.

4. Observe the disk and right down any and all organisms found on the Disk

5. Record the Present/Absent data on the data sheet.

6. Start taking pictures of the disk

7. Take a picture of each half of the 3 prongs, between each prong, in the center of the disk, and on the other sides of the disks.

   I. In a note book wright write down what pictures go to each disk.

   II. When you take a picture make sure to use the water proof paper as a divider to cover up all disk area that is not being measured in that picture (i.e. the other half of the prong when looking at the other side of the prong)

   III. When taking a picture of a disk make sure to have a ruler in the shot to show scale.

Materials

Table 04. Cage structures: Will secure ECOncrete disks and any other materials to a sea wall.

Item	Quantity Amount needed (amount advised)	Purpose
Plank (10x4x4)	10	To support the cage structure
Cinder Block	20	To prevent the structure form swaying
ECOncrete disks	12 (20)	To find present coverage of sessile organism
Grid	20 (25)	To mount ECOncrete
Heavy duty zip ties	36 (60)	To mount ECOncrete
Wire rope 250-foot spool-quarter inch	5	To hang the structure
Heavy duty wire cutters	1 (2)	To cut wire rope
Wire clips-half inch	60 (80)	To support the structure
Ratchet	1 (2)	To tighten the wire clips
Ratchet head- Half inch	2 (3)	To tighten the wire clips
Drill	1 (3)	To make holes in the plank
Drill bit- half inch	1 (3)	To secure grid to plank
Drill bit- less than quarter inch	1 (3)	To drill hole though the plank
Drill battery	2 (4)	To power drill
WD40	2	To clean tools
Gloves	As many as are working	To Protect hands from harm
Washers-quarter inch	80 (120)	To secure grid to plank
Flat had screws-quarter inch	80 (120)	To secure grid to plank
Workers	2 (6)	To build the platform

Table 05. ECOncrete disks: This is how you make ECOncrete.

Item	**Quantity** **Amount needed (amount advised)**	**Purpose**
Aggregate (3-6mm)	61.611lbs	To make ECOncrete
Sand	81.58lbs	To make ECOncrete
ECO P1	3.96lbs	To make ECOncrete
Fibers-Alkali fibers (12 mm)	0.14lbs	To make ECOncrete
Slag cement	33.96lbs	To make ECOncrete
Water	13.66lbs	To make ECOncrete
Water reducer	0.98lbs	To make ECOncrete
Container	May very	To store items being weighed
Hanging scale	1 (2)	To weigh items
Concrete mixer	1	To mix the concrete
Bodysuit	4 (6)	To protect skin and clothes from harmful chemicals
Mask	As many as are mixing the ECOncrete	To protect face and lungs from harmful chemicals
Gloves	As many as are mixing the ECOncrete	To protect hands from harmful chemicals
Hose	1	To wash materials
Water	Open tap	To wash materials
Workers	4 (8)	To mix the concrete
ECOncrete disk molds	20	To mold ECOncrete

Table 06. Grids: Will secure ECOncrete disks to the Support structure.

Item	**Quantity** **Amount needed (amount advised)**	**Purpose**
Gloves	As many as are working	To protect the hands from harm.

Wire cutters	1 (3)	To cut vinyl coated steel mesh
Workers	1 (4)	To build the grids
Vinyl coated steel mesh	2880in^2 (3600in^2)	To construct the grid

Table 07. Camera mount: Will be able to secure a camera and take a picture of the sea wall remotely.

Item	Quantity **Amount needed (amount advised)**	Purpose
¾ inch PVC piping	81.15 inch (100 inch)	To construct the frame
¾ inch 45° angle PVC connector	10 (14)	To construct the frame
¾ inch PVC Elbow Connector	4 (6)	To construct the frame
Saw	1	To cut the PVC
Ruler	1	To measure the PVC and Drill holes
Orange fishing line (spool)	1 (2)	To form the grid
White paint	1 Gallon	To outline disk
ECOncrete disk	1	To outline disk
Power drill	1	To drill
Drill bit (size tbt)	2	To drill
Drill bit (size tbt)	2	To drill
Line	2 20-foot spools	To hang the Grid and anchor
Anchor	3	To weigh down the grid

Camera (Stylus tg-870)	1	To take pictures of the wall
Camera mount (2x Amco Bike mounts)	1	To attach the camera and lights to the Grid
Underwater camera light (2x Sea frog)	2 (3)	To illuminate the wall

(Table 08) Sampling supplies: Supplies needed to sample ECOncrete disks and sea wall.

Item	**Quantity** **Amount needed (amount advised)**	**Purpose**
Hanging frame	1	To take pictures of the wall
Bottles of filtered water	1 (2)	To wash camera and keep metal objects safe from rust
Stereoscope	3	To identify unknown organisms
Marine Animals of southern New England and New York (Weiss, H. M. (1995). Marine animals of Southern New England and New York: identification keys to common nearshore and shallow water macrofauna. Hartford, CT: State Geological and Natural History Survey.)	1 (3)	To identify unknown organisms (use a book that has organisms from your geological location)
Water proof paper	3 (12) sheets	To use as a divider
Ruler	1 (3)	To use as a reference
Test tubes	24	To store unknown organism
Ziplock bags	9	To hold test tubes
Clip boards	3	To hold data sheets
Pencils	12	To write on data sheets

Labeling tape	1 roll	To label test tubes
sharpies	1 (3)	To label test tubes
Dissection kit	2 (6)	To identify unknown organisms
Petri dish	6	To identify unknown organisms
pH test strips	1 (2) bottle	To find the pH of the disk
Rubber maid box	4	To store and transport materials

Results

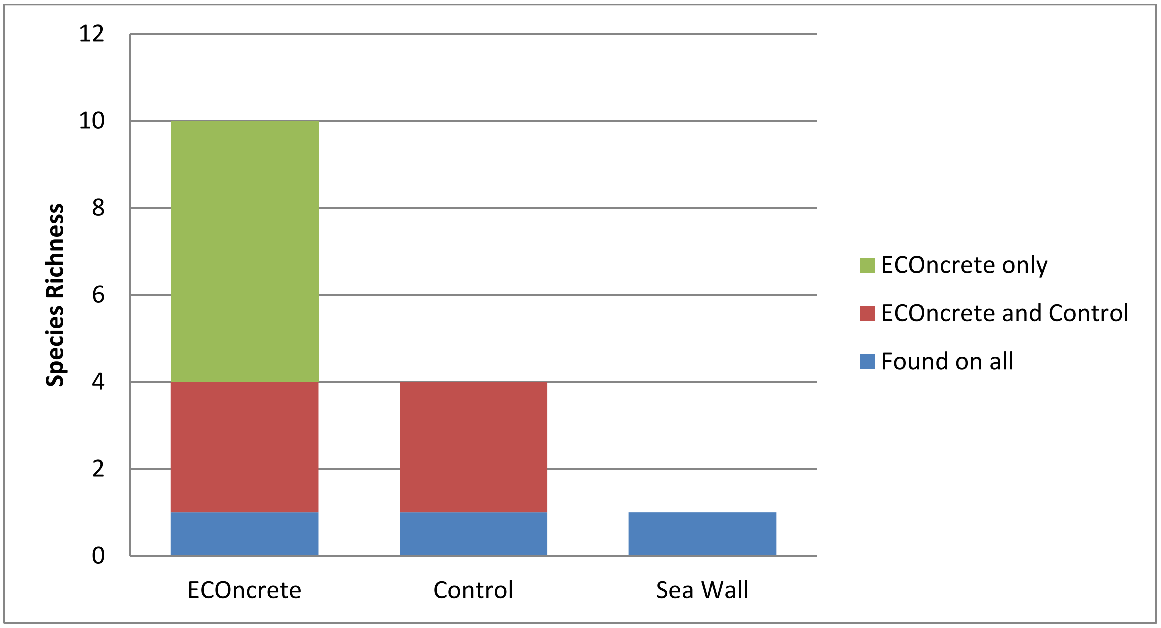


Figure 07. Species Richness Found and Shared Between Tested Surfaces: Count of different species found on experient and control. Key: blue are the species found on all substrates, red are species found in the EConcrete disk and control, and the green are species found only on the EConcrete.

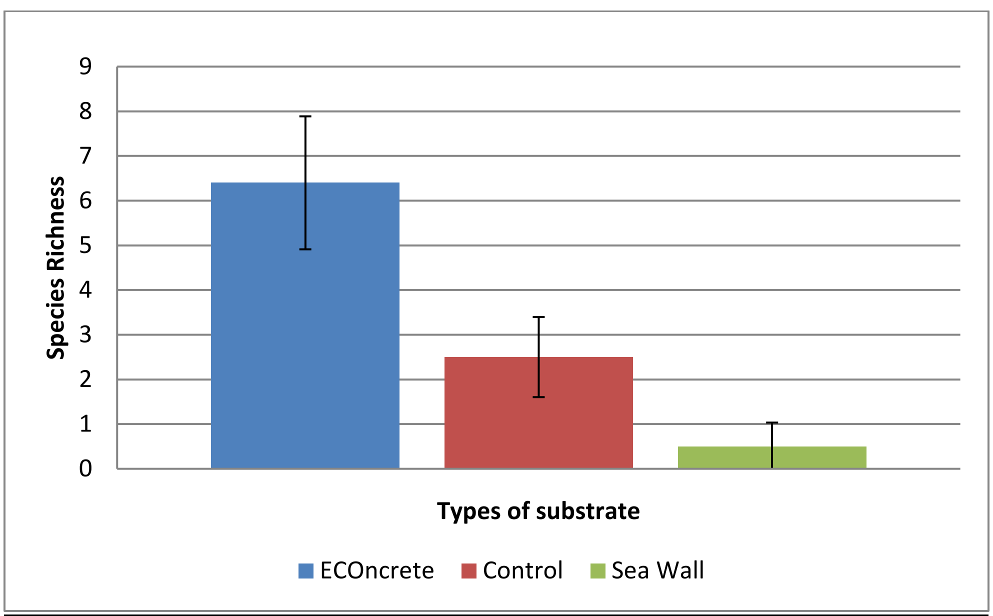


Figure 08. Average Species RichnessFound on Substrates: The average number of species found on the different substrates tested (EConcrete, Control, and Sea Wall) along with the standard deviation: the blue bar is the EConcrete, the red bar is the control (grid), and the green is the sea wall.

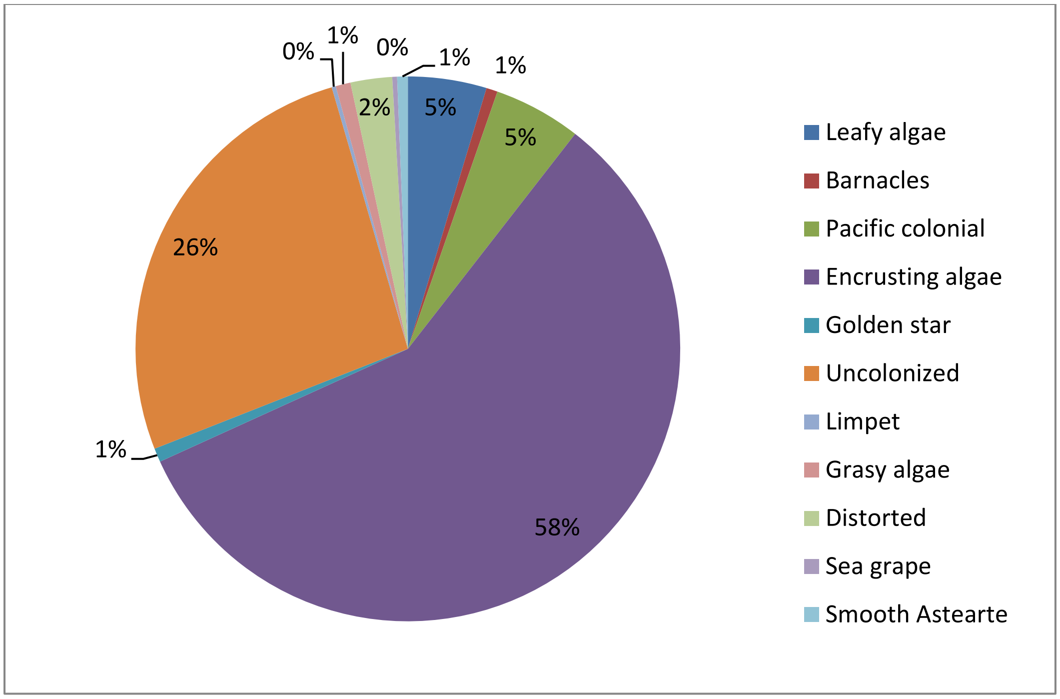


Figure 09. Average Percent Cover on Econcrete Disks on Site 01: The average number percent cover of biodivercity on all ECOncrete disks found on site one. All but 2 disks have all 10 pictures, 2 of the disks have 9/10 pictures.

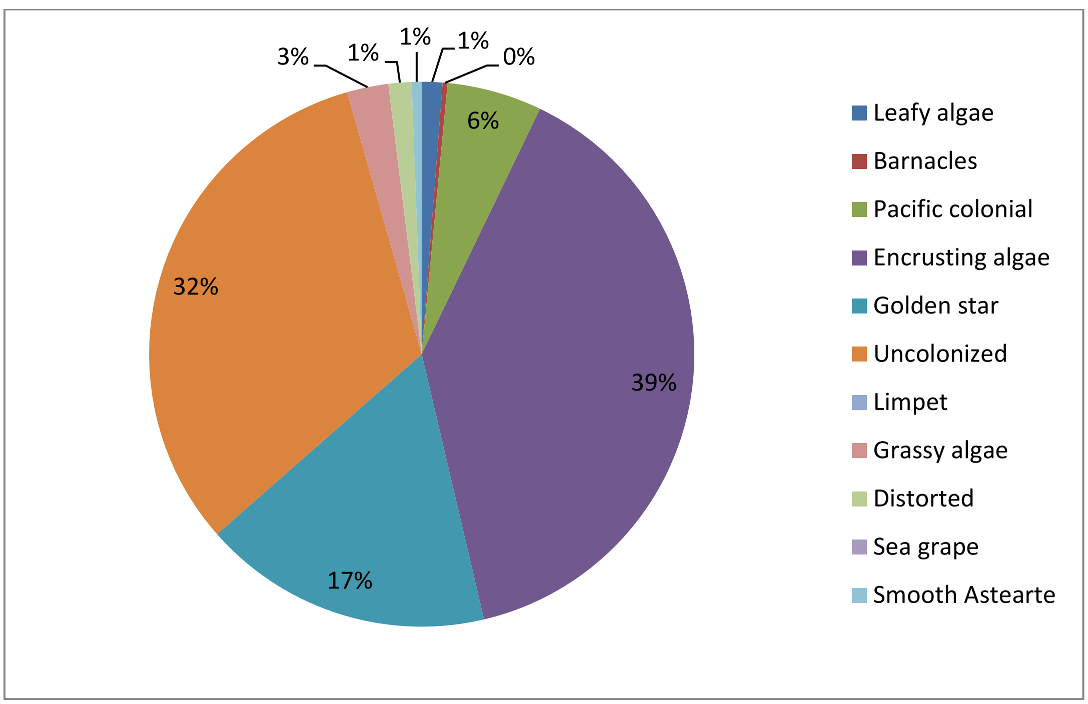


Figure 10. Average Percent Cover on Econcrete Disks on Site 02: The average number percent cover of biodivercity on all ECOncrete disks found on site two. Only 2 out of 6 disks were recovered and able to be observed.

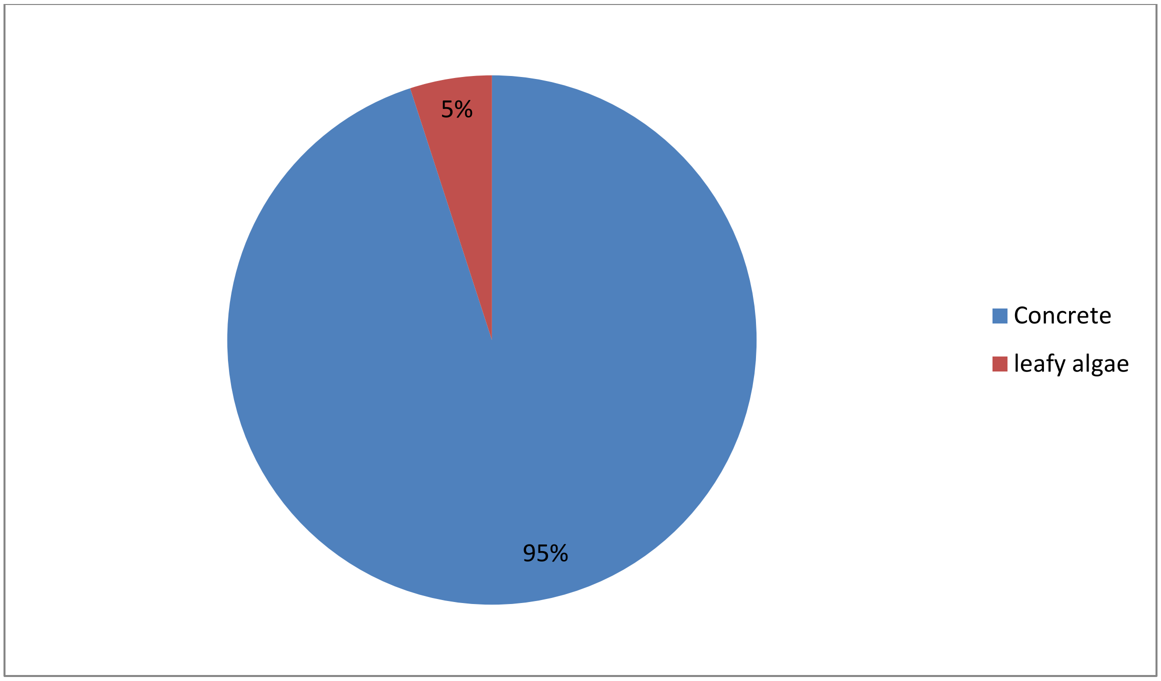


Figure 11. Average Percent Cover on the Sea Wall at Site 01: The average number percent cover of biodivercity on all sea wall pictures taken at site one.

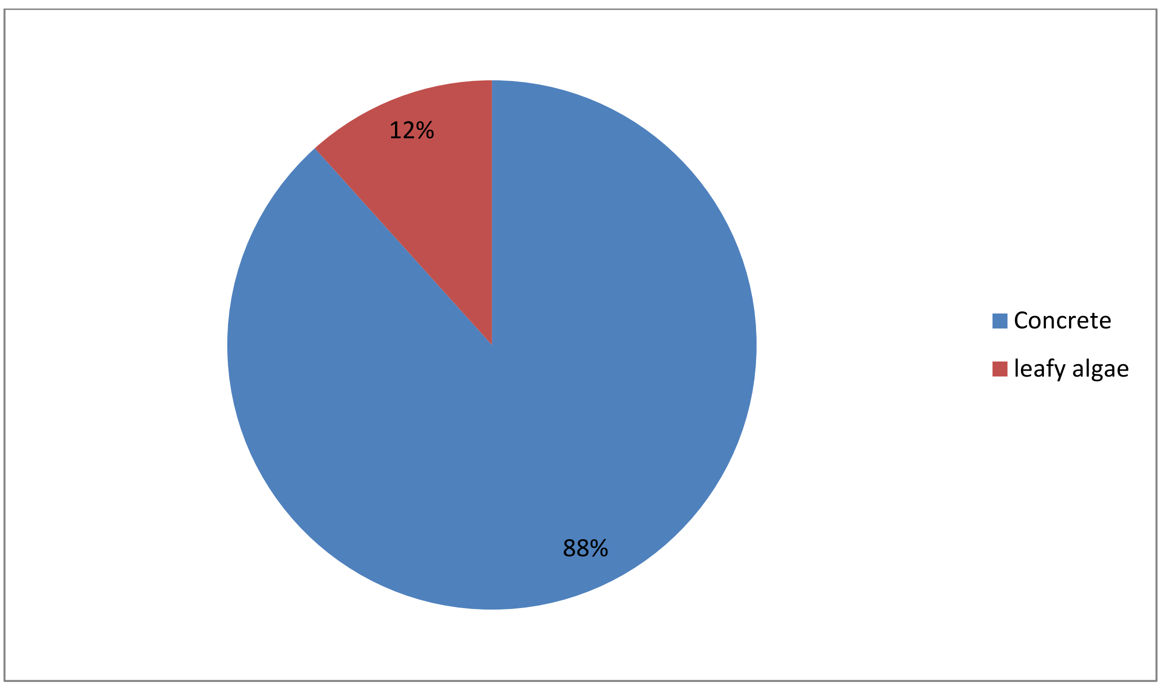


Figure 12. Average Percent Cover on the Sea Wall at Site 02: The average number percent cover of biodivercity on all sea wall pictures taken at site one. Only 3 out of 5 sites were able to be recorded.

The ECOncrete disks attracted a higher number of species (Figure 07). On the north site sea wall only grassy algae was found. The control grids had only specific colonial tunicates, grassy algae, meaty algae, and encrusting algae. Meanwhile the ECOncrete disks had common sea grapes, boring sponges, golden star tunicates, Testudinalis limpets, barnacles, Smooth Astearte, along with all other species found on the Sea Wall and the Controls. The average number of species found on each substrate (*i.e.* ECOncrete, sea wall, control grid) shows that the number of different species found on the sea wall (0.5) was a fraction of that of the ECOncrete disks (6.4) (Figure 08).

On site one (Figure 9), on average 8.29% of the disk was covered in sessile invertebrates. This included a combination of Pacific Colonial tunicate, Golden star tunicate, barnacles, Smooth Astearte, Testudinalis Limpet, and Sea grape. On average the most common sessile invertebrate present on the ECOncrete disks were Pacific colonial tunicates, covering 5.94% of the disks. These percentages do not include algae. When including leafy, grassy, and encrusting algae the percent coverage was 75.15%. Encrusting algae covered 60.99% of the disks. On average, 32.75% of the ECOncrete disk surfaces was exposed.

On site two (Figure 10), on average 24.2% of the disks were covered in sessile invertebrates that included, Pacific Colonial tunicate, Golden star tunicate, barnacles, and Smooth Astearte. Of these species Golden star tunicate are on average the most common covering 17.55% of the disk. When including leafy, grassy, and encrusting algae the percent coverage was 67.95%. Again, the most common specie was encrusting algae covering an average of 40% of the disks. In comparison to site one there were more cases of exposed ECOncrete.

At site one sea wall there was only 5% cover of Leafy algae and 95% of the wall was lifeless. At site two sea wall there was 12% cover of leafy algae, the other 88% was uncovered sea wall (Figures 11 & 12).

Analysis

Together these data suggest that the higher number of species found on the ECOncrete disk demonstrates a higher level of biodiversity. The average number of species on the ECOncrete was nearly 13 times larger than the average number of species on the sea wall. The maximum species richness on the ECOncrete disks was nine (9) as compared to one (1) on the sea wall. This could be a result of the ECOncrete disk's pH of 9 (Perkol-Finkel & Sella 2014), when compared to Portland cement's extremely alkaline pH of 13 (Lukens and Selberg., 2004; EBM, 2004). These results could also be caused by the ECOncrete's shape, texture (Perkol-Finkel & Sella 2014) and the addition of spatial complexity (Mauricio Gonzalez, Pers. Comm.) when compared to the smoother, flatter sea wall.

Golden Star Tunicates, the sessile invertebrate most common at site two, were an invasive species (Curran, L. 2013). The Golden Star Tunicates ability both to reproduce quickly and to filter water gives it a major advantage over other species when it comes competition (Curran, L. 2013). Where the Golden Star Tunicate dominated the percent cover, there was a general lack of richness.

The species that colonized the ECOncrete disks have been found in other similar studies in the Hudson River (Abdo, 2015) with colonial tunicates and Sea Grapes being on each substrate. However, the ECOncrete disks had more recorded sessile invertebrates and algae.

It is important to note that although 30 live oysters were directly above each ECOncrete disk, no oyster spat was discovered on the disks, wall, grids, or live oysters.

Conclusion

This experiment supports the hypothesis that ECOncrete can attract more biodiversity of sessile invertebrates and Ecological Uplift. The addition of ecologically friendly concrete that imparts spatial complexity and a safe colonizing surface can support biodiversity. On the other hand, the data collected demonstrates that the sea wall in place, with its characteristically high pH and barren surface texture is unfriendly towards biodiversity. It is recommended that restoration efforts employ ecologically friendly and spatially complex Concrete Marine Infrastructure. ECOncrete is one of these alternatives. By using the artificial sea wall, it is possible to experiment with new shapes and patterns to see what level of surface complexity would attract the highest biodiversity and Ecological Uplift.

Acknowledgements

I would like to thank Nailea Rodriguez for helping me edit and proofread this article and helping me lead the citizen science team. I would also like to thank Melanie Smith, Mauricio Gonzalez, and Liz Burmester for all of the advice that they have given to me along the way. I would like to thank the New York City Harbor SEALs, a citizen science organization that helped in the creation and deployment of the ECOncrete and support structures.

I would also like to thank CIVITAS a nonprofit organization working to restore the Harlem River and has helped New York City become a sustainable city.

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