# The Effect of the Composition of Concrete on Biodiversity and Ecology on Benthic Organisms

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# Abstract

While coastal zones occupy less than 15% of Earth's land surface, they are inhabited by nearly two thirds of the human population, making coastal development and urbanized seascapes inevitable (Perkol-Finkel *et al*, 2011). This project will study the effects of customized concrete mixtures of CMI on the compositions of benthic organisms and their ability to provide ecosystem services. Four sampling units with various cement mixtures were placed hanging off of Pier on Governors Island and sampled three times throughout the course of a year. Cement mixtures five and one had the best results for biodiversity index.


# Introduction

Concrete is a poor substrate for marine life in terms of biological recruitment, making the biodiversity, habitat size, and ecology along the coast decrease. Presumably, this is due to a high surface alkalinity (pH~13 compared to ~8 of seawater) and a presence of compounds that are toxic to marine life (Lukens and Selberg, 2004, EBM, 2004). Because of this coastal and marine infrastructures (CMI), such as coastal defense structures, marinas, and ports, create severe stress on natural ecosystems through habitat degradation, pollution and coastal erosion near urbanized shorelines (Sigalon, 2012). CMI often include highly inclined and homogeneous surfaces with minimal surface complexity, compressing the intertidal zone to a narrow belt which supports only high tolerant species (Chapman and Underwood, 2011). Prevalent surface designs and concrete compositions typically lead to reduced biodiversity and to the dominance of invasive and nuisance species (Sigalon, 2012). There are few studies that have examined growth on CMI assemblages that found a noticeable difference in the infrastructures from adjacent natural habitats (Connell, 2000, Lam et al., 2009). Communities developing on CMI are typically less diverse than natural assemblages, and are commonly dominated by nuisance and invasive species

(Glasby et al., 2007). This project will address this problem by changing the composition of concrete in three levels (concrete composition, surface texture and macro-design) and elevating their ability to provide ecosystem services. Changing the composition not only contributes to the structures' durability, stability, and longevity but we hypothesize that it will lead to an increase in species diversity, biomass, and oyster recruitment without compromising its original function.

# Background Information

Muscles, barnacles, and many other organisms in the Harbor Estuary population are decreasing which will in turn affect the water quality, habitat size, the amount of pollution and coastal erosion near urbanized shorelines (Sigalon, 2012). They affect water quality because some species filter the water and help balance parameters as well as heavy metals. When native populations decrease, the nutrients they provide for the ocean and the filtering the do will also decrease leaving the ocean at a lesser state. Changing the composition will make CMI an artificial substratum that acts as a habitat for the invertebrates to grow. Invertebrate species that are expected to found based on other studies are Turf Algae, Solitary Tunicates, Colonial Tunicates, *Sabellidae* (*Serpulid* Worms), Barnacles, Bivalves, and Oysters. In manipulating the concrete infrastructures, they should have the ability to provide valuable ecosystem services including nursing grounds, hubs that filter feeding organisms and shallow water habitats. It will also contribute to the structures durability, stability, and longevity (Sigalon, 2012). This approach allows us to target both composition and design. In doing so, we have developed and tested a series of five innovative concrete matrices aimed at enhancing natural biological assemblages, while still complying with formal requirements of marine construction. The new matrices have reduced alkalinity in comparison to Portland cement, and include various additives that decrease the dominance of Portland cement in the mix, potentially making them more hospitable to marine life (Perkol-Finkel and Sella).

**Preparation of Concrete Matrices**

The matrices tested in this study varied in the amount of Portland cement in the mix, use of other cements, air content, and add-mixer. Crack prevention 25 mm microfibers were included in all matrices. Matrices were mixed by an 80 litre horizontal mixer and were cast into 10x60x160 cm forms with plastic form liners. After 28 days, the concrete sheets were cut by a water jet marble sow into 15x15 cm experimental tiles. As form liner was applied only to one at the bottom face of the form, each tile had one textured and one smooth face. All matrices were tested according to ASTM or EN standards, including: Compression Strength - ASTM C 39 (AASHTO T 22), Water Pressure Penetration Resistance - EN 12390- 8, Chloride Ion penetration Resistance - ASTM C1202–12. Concrete pH values were checked by collecting 5 gr of drilled residue from 0.5cm deep drilled holes on the concrete surface and mixing them in 50 ml of distilled water (pH 7). All tested concrete matrices (MI-M5) showed lower pH values than the Portland cement based mix (9-10.5 compared to 12.5-13.5 respectively, Table 1). In terms of compressive strength, M1-M5 had similar or greater strength as that of Portland cement based mix, with values reaching as much as 39.3 MPa (M2). All matrices except for M4 and M5, which had high air content, presented higher chloride ion penetration resistance (<1500 coulombs) than the Portland cement based mix with similar density (2300-2500 kg/m3), and water pressure penetration resistance (<20 mm).

Table 1: Physical parameters of the various innovative concrete matrices in comparison to Portland cement.

| Matrix | Water/ Cement Ratio | pH | Average Compression Strength (Mpa) | Weight (Kg/m$^3$) | Water Pressure Penetration Resistance (mm) | Chloride Penetration Resistance (Coulombs) |
|---|---|---|---|---|---|---|
| **M1** | 0.3 | 9-10 | 32.5 | 2300-2500 | <20 | <1500 |
| **M2** | 0.3 | 9.5-10.5 | 48.5 | 2300-2500 | <20 | <1000 |
| **M3** | 0.3 | 9.5-10.5 | 39.3 | 2300-2500 | <20 | <1000 |
| **M4** | 0.3 | 9-10 | 31.1 | 1400-1800 | NR | NR |
| **M5** | 0.3 | 9-10 | 31.9 | 1400-1800 | NR | NR |
| **Portland** | 0.30 -0.25 | 12.5-13.5 | 32 | 2300-2500 | <20 | >2000 |

NR- Not relevant for high air content concrete

# Project Design Chart

| SCIENTIFIC PROBLEM |
|---|
| Coastal and marine infrastructures around the world are causing a decrease in coastal marine biodiversity and ecology in those areas because they are made of a poor substrate that also brings in invasive species to the area. |
| **HYPOTHESIS** |
| If concrete is a poor substrate then adding ECOncrete™ to it will make marine infrastructures biologically and ecologically active because it alters its composition and texture without compromising its original function. |
| **OBJECTIVES** |
| Encouraging benthic build-up |
| **INDEPENDENT VARIABLES (TREATMENTS)** |
| Five different ECOncrete ™ matrices |
| **DEPENDANT VARIABLES** |
| Benthic invertebrates |
| Biodiversity |
| Biomass |
| Oyster recruitment |
| If the species are invasive or not |
| **CONTROL** |
| Portland Cement concrete tiles |
| Rough side and a smooth side to each concrete and ECOncrete ™ tile |
| **CONSTANTS** |
| The size of the concrete tiles |
| A rough and smooth side of the |
| Type of rope used |
| The checking of tiles |
| Concrete |
| **ASSUMPTIONS** |
| Concrete surfaces will be used for future maritime composition. |
| Will make the use of coastal infrastructures longer and decrease the cost in maintenance |
| To increase the biodiversity of the coastal marine habitats and get rid of invasive species |
| To increase the growth of algae along the coast |

# Locality

Figure 1. Pier 101 on Governor's Island. This experiment was conducted at Pier 101. The boxes represent the location of each unit. One to four (left to right)


Figure 2. Pier 101 Governor's Island, New York, NY with Pier 101 marked as "A".

# Materials

| Item | Quantity | Function |
|---|---|---|
| Magnifying glass | 5 | Viewing organisms |
| Rubbermaid tubs | 4 | Storing units after retrieval |
| Digital dissection scope (AmScope) | 1 | Viewing and photographing invertebrates |
| Tweezers and needles | 4 | Examine invertebrates |
| Info sheets | | Notes and data |
| Electrical ties | 1 | Tying units that break off |
| Carabineers | 4 | To secure onto anchor knot |
| Field guides | 3 | Identification |
| 50ml test tubes | | To hold samples taken back to the lab for sampling |
| 1x1cm Grids | 2 | Surveying invertebrates |
| Surgical gloves | A box | In case of stingers on tiles |
| Spectrometer | 1 | Chlorophyll |
| Buckets with line | 2 | Supplying water for the units |
| Line roll (8mm) | 1 | Tie to the anchors in order to pull up the units |
| Aprons | 8 | To protect you |
| Alcohol | | Storing samples of organisms |
| Camera | 2 | To fit into the stereoscope and take photos of the units before they are extracted from the Harbor |
| Anchors | 3 | To secure the units to the seabed |
| 6x6 inch tiles | 16 | Used to test the experiment on |
| scraper | 2 | Used to take benthic organisms and algae off tiles to collect data |
| Buckets | 6 | Contain units and collect water to place them into |
| Petri Dishes | 6 | Contain organisms for later observation |

# Procedures

*Steps for deploying units*

1. Lay four units (each with six 6x6 inch settlement tiles) flat on the Pier's dock.
2. Make sure each tiles has a numbered tag attached to its upper portion (tie with extra ties just in case one broke off).
3. Put anchors on one side of each unit and tie them with a bowline knot to the unit roughly 1 foot away from its closet tiles.
4. Attach the other end of each unit to the dock 10-15 feet apart
5. Completely submerge the units into the Harbor
6. Have a diver/snorkeler verify the setup is in place

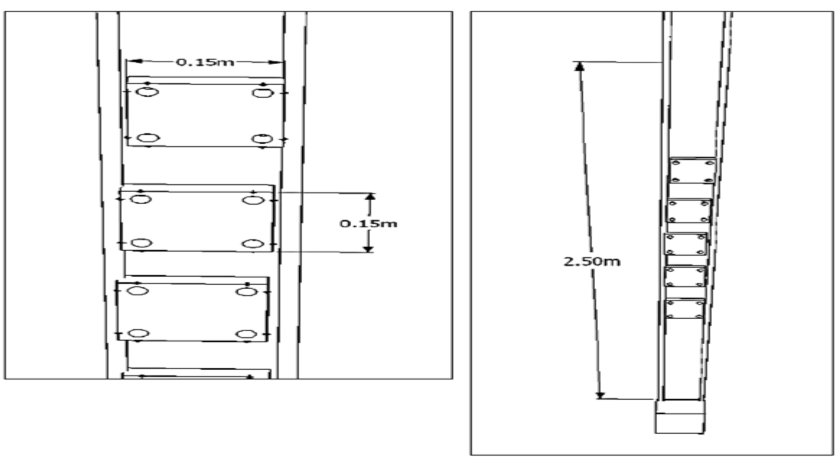


Figure 3. Schematic illustration of the concrete test units composed of 6x6 inch tiles attached to ropes. Each unit is placed randomly on the ropes to see which depth will affect the benthic build up on the matrices.

*Steps for collecting data*

1. Pull units up from out the water
2. Untie the anchor from the units and unhook the units from the dock
3. Place it in a bucket with water
4. Bring it to the Rubbermaid tubs for examination
5. Identify the unit be examined
6. Before getting data from each tile, identify tiles number and take a picture of the rough and smooth sides
7. Write down the amounts of each invertebrate down on the info sheet and if there are any new invertebrates, catalog them
8. (if needed) get samples of any invertebrates that need further examination
9. On the smooth side of each tiles, section it off into quadrants
10. Take samples of two out of the four and put them into labeled tubes


Figure 4. Shimrit and I examining the tiles in a Rubbermaid tub. Using a 1x1cm grid to estimate the amount of each invertebrate that it on a tub at Pier 101 and writing the data on info sheets.

# Results

June 2012 was the third month that the units were monitored and little to no invertebrates was seen on the tiles. August 2012 was the sixth month that the units were monitored with a visible increase in the amount of benthic invertebrates but the data shows otherwise. There are five different matrices with different compositions each has a tough (T) and a smooth (S) side.

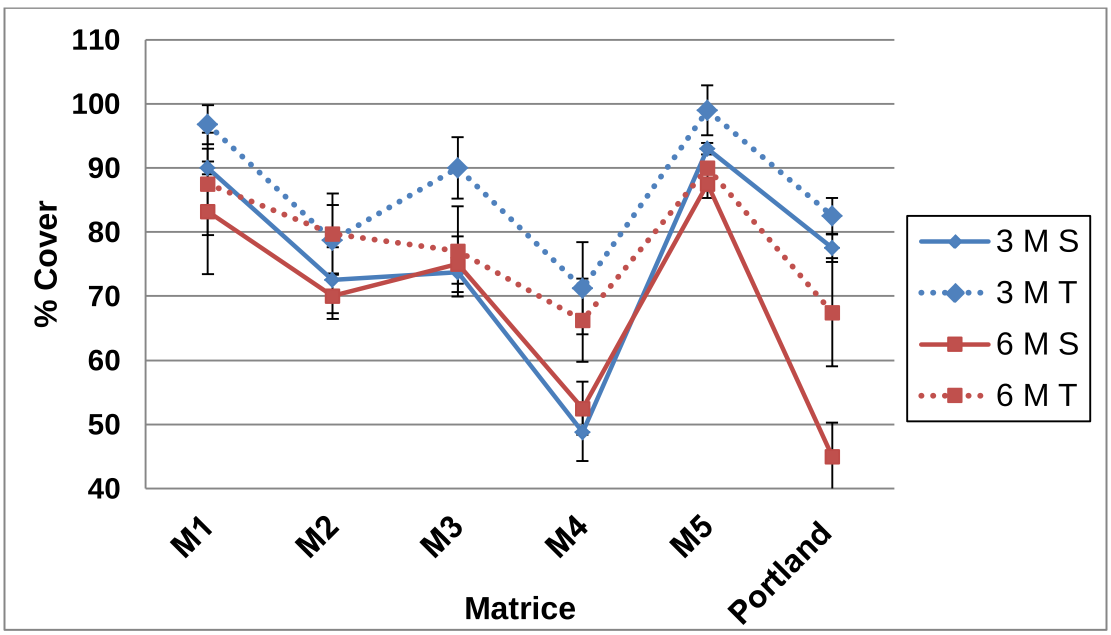


Figure 5. Averaged Percent Live Coverage at Pier 101 (June 2012 and August 2012). The graph above compares the live coverage on the tough and smooth sides of each matrice in both the sampling times. The third month's tough side of the tiles had a larger percent live coverage than the sixth month's tiles.

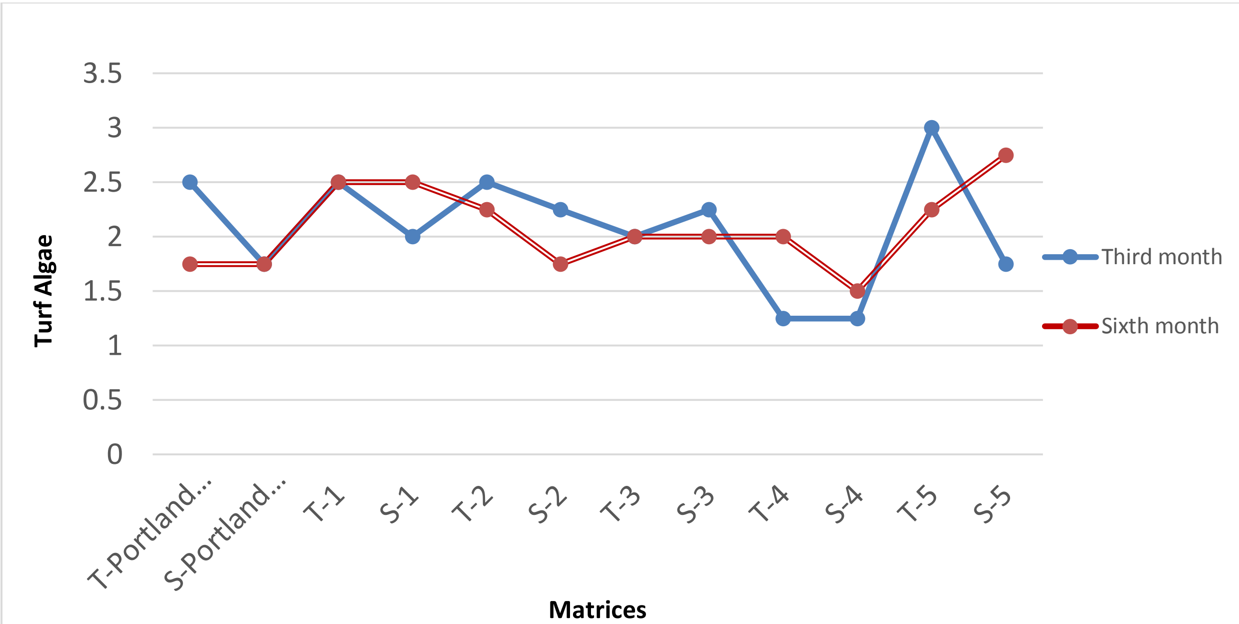


Figure 6. Averaged Turf Algae at Pier 101 (June 2012 and August 2012). The graph above shows the difference in the visible amounts of turf algae each tiles had. The amount of turf algae that was found in both times of monitoring varied.

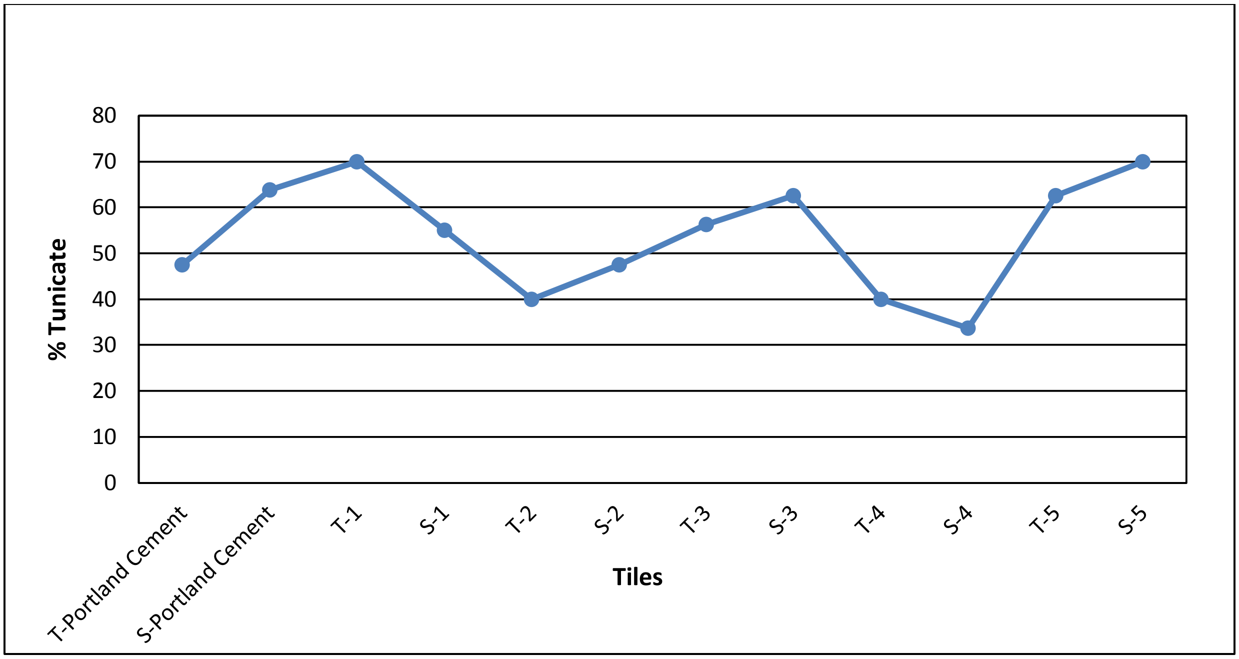


Figure 7. Averaged Percent of Tunicate at Pier 101 (June 2012). This graph shows the difference in each tile's tunicate percentage. The types of tunicates counted here was colonial tunicates. The smooth side of matrice five at 70% and the tough side of matrice one at 70% have the highest reading in colonial tunicate percent coverage while the smooth of side of matrice four has the lowest percent at 36%.

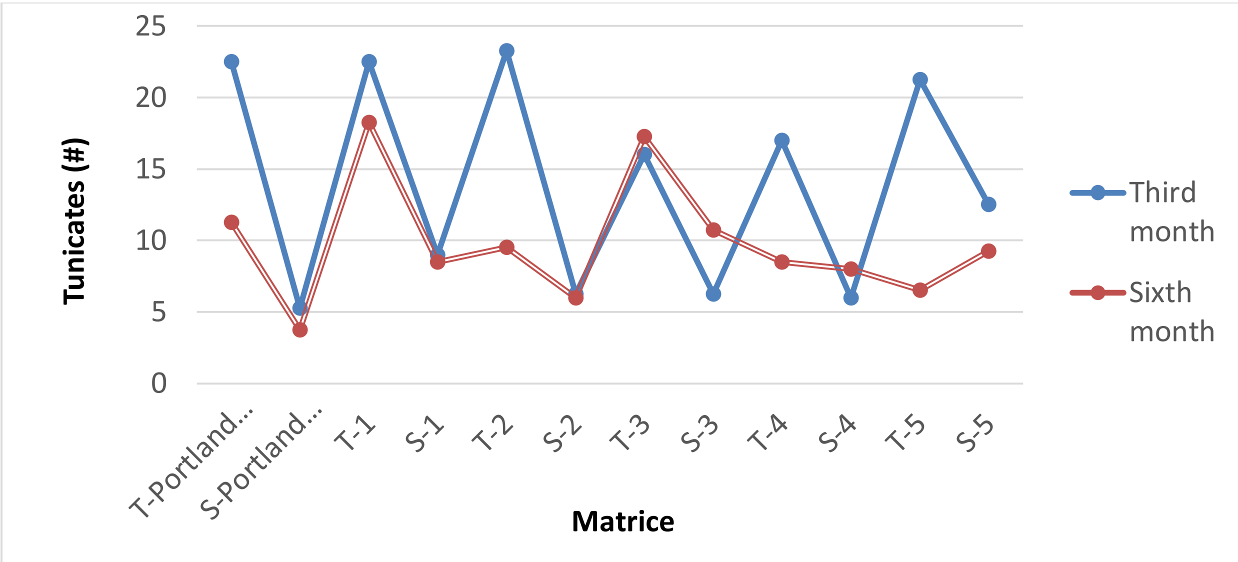


Figure 8. Averaged Number of Tunicates at Pier 101 (June 2012 and August 2012). This graph shows the difference in each tile's number of tunicates. The type of tunicate counted here was solitary tunicates. Based on this graph, the tough sides of each matrice have a larger amount of solitary tunicates growing on its surface than the smooth sides.

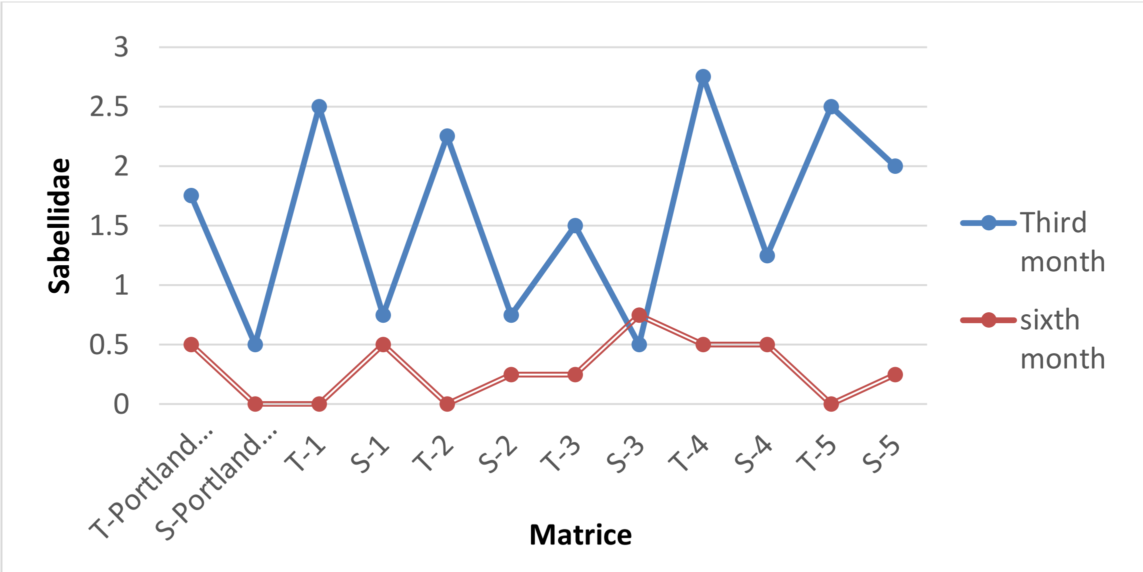


Figure 9. Average Number of Sabellidae at Pier 101 (June 2012 and August 2012). This graph shows the difference in the amount of Sabellidae each tiles and its surface had. Sabellidae is a worm that builds tubes out of parchment, sand, and bits of shell. The scale is 3-high 2-medium 1-low. Based on the graph, each tiles tough side had a larger amount of Sabellidae on its surface than the smooth side.

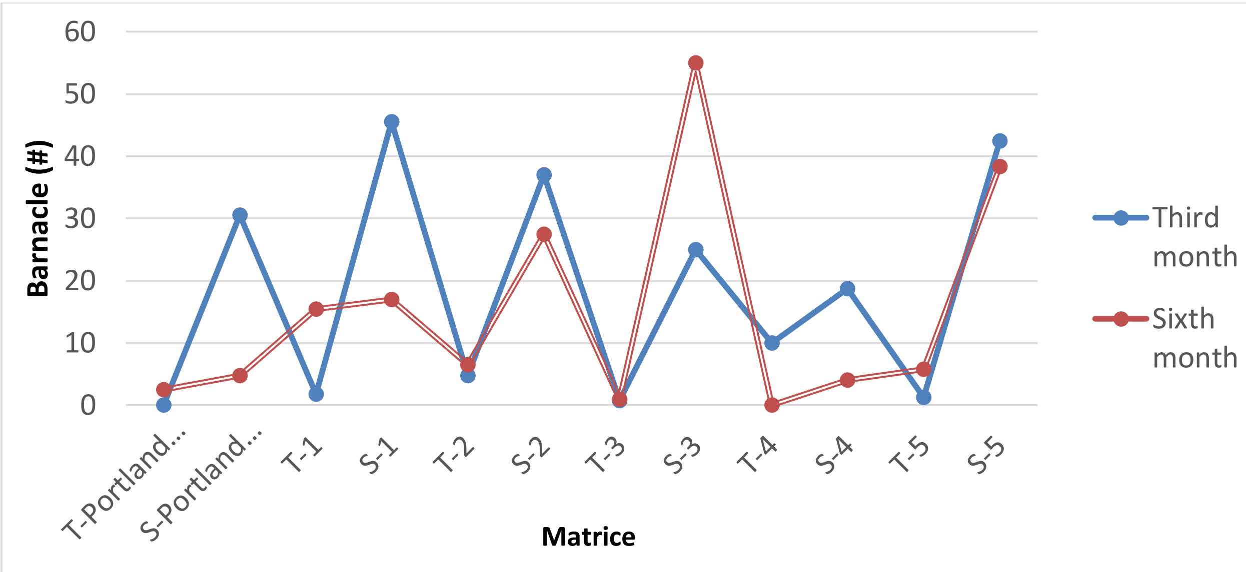


Figure 10. Averaged Number of Barnacles at Pier 101 (June 2012 and August 2012). This graph shows the difference in each tile's amount of Barnacles. Based on this graph, each tiles Tough surface has a smaller amount of barnacles than the tile's smooth surface.

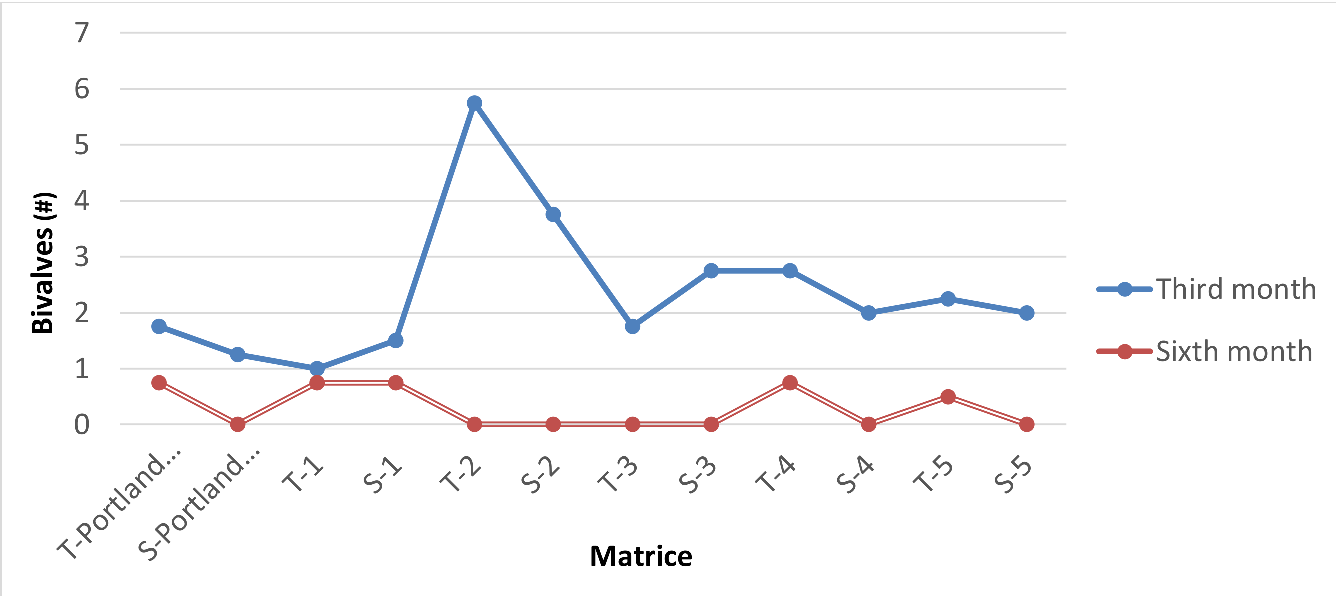


Figure 11. Averaged Number of Bivalves at Pier 101 (June 2012 and August 2012). This graph shows the difference in each tile's amount of bivalves. The trend's consistency was disrupted by matrice two's tough side that spiked up to 5.75 then the trend went back to a steady decrease and increase of ±1-2 in the third month however it decreased in the sixth month to 0.

# Analysis

Coastal and marine infrastructures around the world are causing a decrease in coastal biodiversity and ecology in those areas because they are made of a poor substrate. CMI is composed of a substrate that is toxic to the native species but brings in invasive species to the area that are equipped to withstand its parameters. Changing the composition of the infrastructures not only contributes to the structures' durability, stability, and longevity but we hypothesize that it will lead to an increase in species diversity, biomass, and oyster recruitment.

This work examines an innovative approach of applying slight modifications to the composition and surface texture of concrete, aimed at facilitating marine grow and encouraging enhanced biogenic buildup (Shimrit & Ido, 2013). Out of the five matrices, three have shown more benthic build-up than Portland cement (matrice one, four, and five). This can be seen in the parameters tested in the field during monitoring times. These matrices have produced a larger amount of live coverage, Turf Algae, Tunicate (percentage), Sabellidae, and Barnacles. Other than the invertebrates that are expected to be found, there were several organisms found on the units that we did not expect but they did not affect our findings.

CMI are often used for coastal defense (e.g., breakwaters and seawalls), weight and stability plays a major role in structural performance (Shimrit & Ido, 2013). In this study, ecologically active concrete matrices accumulated significantly more inorganic matter than Portland cement (Shimrit & Ido, 2013). Biogenic buildup of ecosystem engineers like oysters, serpulid worms, barnacles and corals, increases the structures' weight, contributing to its stability and strength (Risinger, 2012).

# Conclusions

- Three of the five matrices tested (MI, M4 and M5) were found to be ecologically active, exhibiting enhanced recruitment capabilities in comparison to standard Portland cement.
- Enhanced recruitment capabilities of natural assemblages of marine flora and fauna onto concrete based CMI yields valuable structural, environmental and socio-economic advantages.

# Suggestions

1. Different seasons affected the types of benthic invertebrates that grew on the tiles.
2. Use a better program to make the graphs in results
3. Keep track of materials
4. Monitor data more frequently

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# Annex


Figure 12. Shimrit and Ido observing the tiles and obtaining data. Thomas looking at a slide of an invertebrate with the stereoscope. (June 2012).

Figure 13. The entire crew of the project after monitoring the units and deploying them back into the water (June 2012).

Figure 14. Shimrit viewing the units and showing how the benthic build-up may not seem visible but that is it. Depending on the season, the growth and types of invertebrates change.

Figure 15. A photo of one of the units taken. This tiles has 100 % live coverage (June 2012).

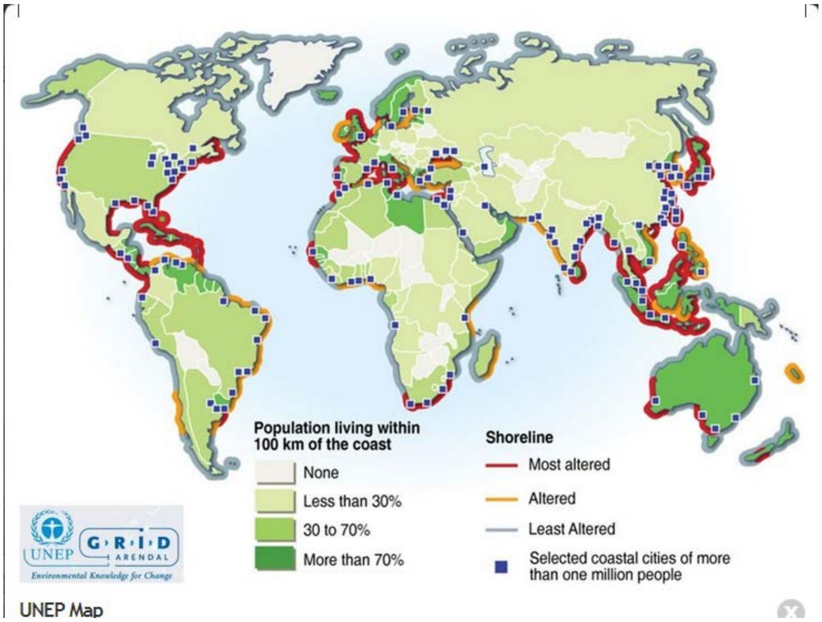


Figure 16. This is a map that shows the shorelines around the world that are effected by human population. The darkest coastal areas is where the building of coastal and marine infrastructures was inevitable because that is where the majority of the population lives.