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Quantitative Evaluation of Marine Growth on Geosynthetic Reef Trials in Beaufort, North Carolina

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ABSTRACT

In recent years, geotubes, geocontainers, and other geosynthetic products and materials have been applied in coastal settings for the purpose of coastal protection, coastal restoration, and as part of coastal structures such as windfarms and bridge foundations. Geosynthetics are applied in submerged environments and environments that become partially inundated by tide or storms. This includes artificial reefs or artificially stabilized natural reefs, training walls, geosynthetic groynes, offshore breakwaters, and scour mattresses. Previous studies have indentified benefits associated with marine growth on geosynthetic products/materials and have evaluated types of marine growth present and subsequent ecological benefits, however quantification of the amount of marine growth has been limited. Marine growth on geosynthetics in submerged coastal conditions has the ability to remove excess nutrient pollution from water, sequester carbon, and the ability to make these excess nutrients available to predators in the local ecosystem in marine plant and coral form. In order to better understand the growth on these geosynthetic products, Little Environments PLLC conducted a comparative study on a selection of geosynthetic materials, which sought to determine the mass of established marine growth on the various materials. Samples of each geosynthetic were deployed in Taylors Creek, Beaufort, NC for a period of 10 months. After 10 months the samples were exhumed from the trial reef in Taylors Creek, dehydrated, and the mass of the sample evaluated in dry form. Measurement of the dry mass of marine growth, subject to sustained predation, resulted in a range of 1 to 4 kg of marine growth per sq.m. Considering that the plant growth is predominantly nitrogen and carbon based and that there is a current need to sustainably sequester carbon and remove nitrogen from the water column in developing areas, geosynthetic materials can serve as an effective substrate for the purpose of improving water quality and offsetting carbon. Where geosynthetic comprising structures exist or are planned, additional environmental and sustainable benefits may be considered when comparing and considering traditional coastal project approaches, such as rock jetty’s, concrete breakwaters, and seawalls.

Figure 1. Massing of Dehydrated Sample

Figure 2. Sample Reef Growth Rig

INTRODUCTION

In the past, marine growth on manmade structures has been primarily considered as a nuisance. Concrete structures and drive trains for boats, not anticipating the structural effects of marine growth or moving part maintenance, have been hindered by marine growth. As a result, studies have been carried out that identify and design with the intention of anticipating marine growth. For example, the Norwegian University of Science and Technology has developed models for offshore wind farms that anticipate additional loading due to increased friction between ocean current and wind tower foundations covered in marine growth (Muskulus 2012). Further, in regards to geosynthetics in coastal environments, abrasion and UV degradation have been identified as the most common physical variables that limit the life of geosynthetics in coastal environments (Hornsey et.al 2011), as overall chemical stability between seawater and polymers has been achieved.

Marine growth on geosynthetics has significant potential to help address failure due to excessive UV or abrasion exposure in marine environments. While studies have been carried out in the south Pacific Ocean in regards to marine growth on geosynthetics (Edwards and Smith 2005), little detailed analysis has been carried out on marine growth on geosynthetics in the northern Atlantic, specifically the lower east coast of the United States. Previous studies on marine growth have been primarily qualitative in identifying species and have focused on pelagic ecosystems.

The purpose of this study was to identify both the wet and dehydrated mass of marine growth on various geosynthetics submerged in a salt water environment though destructive testing. The following types of geosynthetics were analysed: Slit-film woven geotextile, a staple fiber geotextile, a dual-layer staple fiber geotextile, a HDPE uniaxial geogrid, and a concrete impregnated cloth. While all geosynthetics supported marine growth in a positive manner, the results of this study indicate that some perform better than others from a mass perspective. Additionally, overall hardness of the substrate material appeared to contribute to the type of established marine growth. Ultimately, after simple deductive reasoning and estimative calculations from previous studies, it was determined from this study that the rate of establishment of marine growth on the geosynthetics indicate that geosynthetics a great substrate for supporting marine growth to sequester carbon and nitrogen. Below are two examples of marine growth on an existing geosynthetic substrate of a geotextile container and a geosynthetic-similar substrate of an HDPE oyster cage. Methods, data, observations, discussion, analysis and detailed conclusions are provided below.

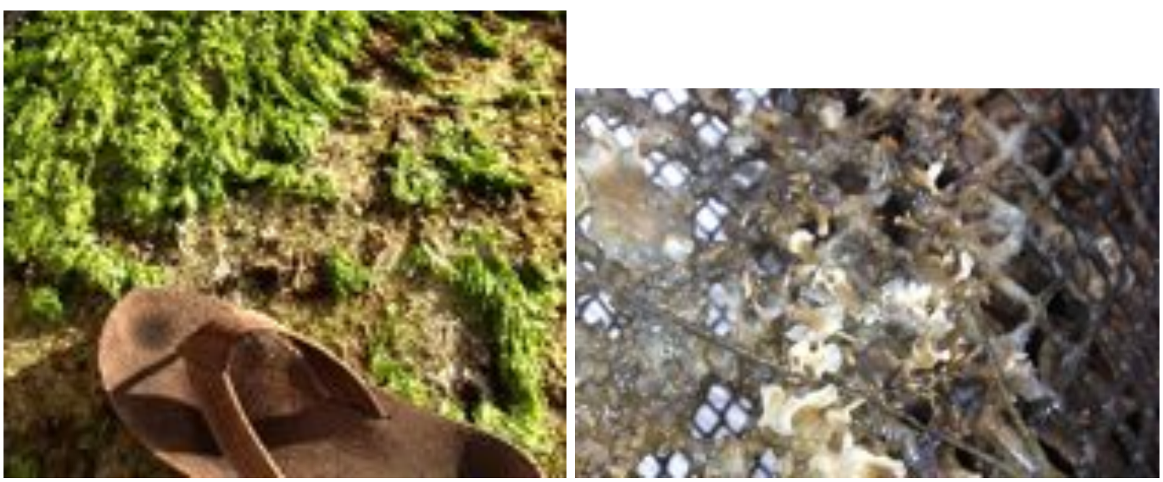

Figure 3. Marine Growth Royal Hawaiian Groin and Marine Growth on Oyster Cages in Beaufort NC

METHODS

This investigation was carried out using five different materials as reef substrate materials. These materials are commonly classified as geosynthetics or geotextiles or coastal geotextiles. The first sample was a composite staple fiber geotextile. The inner layer of the staple fiber geotextile composite was composed of polyester fiber while the outer layer was composed of polypropylene fibers of tan or sand color. The second material was a homogenous staple fiber geotextile, black in color, composed of a blend of polypropylene and polyester staple fibers. The third material was a woven slit-film geotextile of sand color. The fourth material was an HDPE geogrid, frequently used in coastal construction and design. The fifth material was a concrete impregnated cloth product, which due to the weight of the concrete cloth substrate, quantitative results had to be omitted due to the substrate weight being much larger then the mass growth, however qualitative growth results were reported.

A rig, holding the five samples was constructed for deployment into the tidal water column of Taylor's creek, Beaufort, NC, just behind the Rachel Carson reserve. The rig was suspended just above the benthic sediment to simulate the elevated benefit that a geosynthetic structure may provide to ecosystem establishment. The rig was deployed first in June of 2013, monitored on two occasions in December of 2013, and removed in July of 2014. Figure 4 shows the location of the rig relative to the NC shoreline and Figure 8 depicts the construction process of the sample rig. For locations in which the geotextiles were deployed, mock containers or sand bags were fabricated using approximately 20 pounds of sand. Sand was pre-consolidated inside the bags to prevent flapping or waving of the fabric in the current.

Figure 4. Deployment Location

During the removal of materials in July of 2014, marine growth samples were taken from the rig. Sample areas were determined using a 1" by 1" grid and photo documented. Samples were placed into a dehydrator oven to determine the dry mass of the sample and substrate. The geosynthetic material substrate mass was then subtracted from the wet substrate and marine growth mass and the dry substrate and marine growth mass to provide the dry and wet marine growth on each of the samples. Percent water mass composition of the marine growth was also calculated and compared with a previously accepted range for marine plant % water by mass for results verification. Percent water mass composition is the mass of water that is in the tissue and other components of the plant growth on the geosynthetic substrate. Figure 5, Figure 6, and Figure 7 demonstrate the sampling method. A triple beam bar scale was used for massing.

Figure 5. Example Massing of Sample after Dehydration

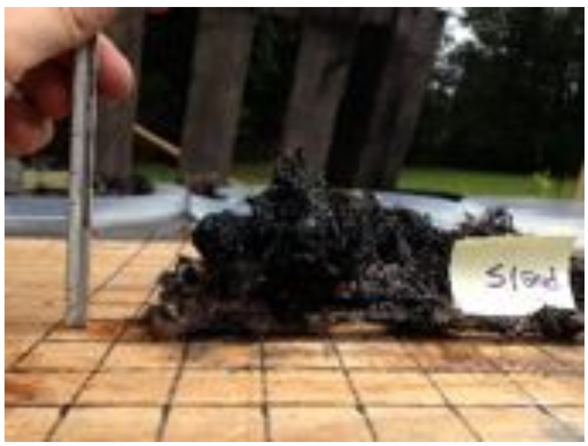

Figure 6.Example Material Growth Observed from the Side

Figure 7. Example Wet Growth on Substrate Sample on 1” by 1” grid for Area

RESULTS, DATA, AND OBSERVATIONS

Table 1 provides the quantitative marine growth on the various geosynthetics. The dual layer staple fiber geotextile provided the largest mass accumulation of marine growth by both wet and dry mass. Visual observations of growth on the dual layer staple fiber geotextile showed softer growth material at the end of the full year of submergence. Additionally, during site visits, numerous fish and crabs were observed vacating the materials upon temporary rig removal and inspection. This occurred on several occasions and inferences are discussed later. Harder and less porous substrates like the concrete cloth and the uniaxial geogrid supported more hardened growth such as scallops, barnacles, and oysters while the staple fiber textiles supported maritime aquatic plants such as *Gracilaria* spp. as well as numerous tunicate species.

Table 1. Sustained Dry and Wet Plant Mass Accumulation on Various Geosynthetics after 1 year of Submergence

Textile Substrate Type	Material Mass Alone [g/sq.cm]	Wet Material and Marine Growth Mass [g/sq.cm]	Marine Growth mass Alone [g/sq.cm]	Dehydrated MarineGrowth Mass [g/sq.cm]	Marine Growth Percent Water (%)
Slit Film Woven	*0.095*	*0.758*	*0.663*	*0.109*	*84%*
Staple Fiber	*0.095*	*1.109*	*1.014*	*0.163*	*84%*
Dual Layer Staple Fiber	*0.145*	*1.397*	*1.252*	*0.389*	*69%*
Uniaxial Geogrid	*0.0526*	*0.953*	*0.900*	*0.188*	*79%*
Average	**0.0969**	**1.054**	**0.957**	**0.212**	**79%**

Figures 8, 9, and 10 show the overall rig at deployment in June of 2013, at observation in December of 2013, and at removal in July of 2014. Prevalence of predominant species in the local environment can influence overall colonization and this can be observed in Figures 9 and 10. Figure 9 depicts marine growth during winter months, during which time *Gracilaria* spp. along with numerous species of tunicates were predominant on the geosynthetic substrates. Growth depth on the substrate at this time was approximately 2 inches. Tube pea crabs (*Pinnixa chaetopterana*) and scallops were living amongst the *Gracilaria* spp. and tunicates during this inspection. Transitioning from the winter of 2013 to summer months of 2014, growth on the material switch to more hardened growth accompanied by the jelly like Bryozoans. During the summer inspection in July of 2014, preliminary oyster growth was present, angle wings had established, additional pea crabs were residing on the sample, and both barnacles and sea slugs were present. *Gracilaria* spp. remained in patchy areas. Of noteworthy importance, during the winter inspection in which soft plant/algae was predominant, a layer of silt, approximately 0.5 inches thick was observed deposited at the base of the marine growth. This layer, however, was not observed at the time of removal in July of 2014.

Observations at Deployment, December 30th 2013, and July 18th 2014

Figure 8. Rig with Marine Growth on June 10th 2013 Prior to Deployment

Figure 9. Rig with Marine Growth on December 30th, 2013 (Winter)

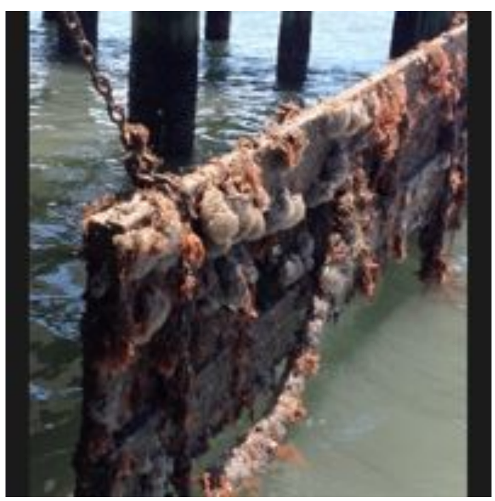

Figure 10. Rig with Marine Growth on July 18th, 2014 (Summer)

December 30th, 2013 Qualitative Observations

Fig. 11a. Layered Staple Fiber

Fig. 11b. Staple Fiber

Fig.11c. HDPE Grid

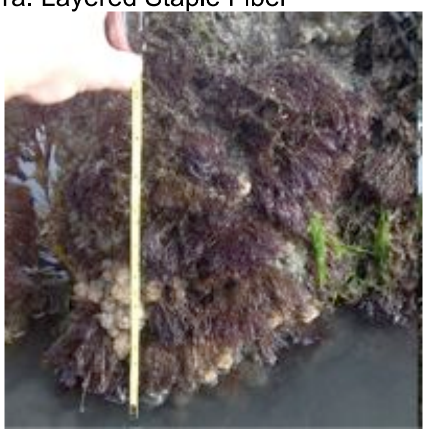

Fig. 11d. Slit Film Woven

Fig. 11e. Concrete Cloth

July 18th 2014 Qualitative Observations

Figure 12.Observed Marine Growth (Cyrtopleura Costata Clam)

Figure 13.Observed Marine Growth (Bryozoa)

Figure 14.Observed Marine Growth

Figure 15.Observed Marine Growth (Establishing Oysters)

ANALYSIS/ DISCUSSION

The results of this study imply that geosynthetics can support a range of marine growth, and this marine growth will vary seasonally. Visual observations showed more marine growth on all geosynthetics during the winter months as compared to summer months. During the winter months where the softer marine growth predominated, all geosynthetic were colonized by the soft marine growth. Predication by pelagic and estuarine species is know to increase during the spring and early summer, suggesting that total marine growth on the geosynthetic substrates could have increased significantly from the net measured or sustained accumulated marine growth from June of 2013 to July of 2014. This means that the use of the data from this study could conservatively be used for estimating plant growth. Additionally, the data from this study indicates that growth supported on geosynthetics could be used for generating nitrogen and carbon sequestering under sea reefs or structures that feed raw nitrogen and carbon back into the food chain.

The percent dry plant tissue or percent plant water aligns with many studies that report plant composition. These compositions have been summarized by Indergaard & Minsaas (1991), which identify aquatic marine plants to typically range between 70 and 90 percent water. With the rest of this evaluation falling into this comprehensive range, one can deduct that the quantitative measurements and methods were appropriate and accurate. With additional information or indications on the rates of predication in a local area, one may use the above data to further identify the amount of nitrogen or carbon sequestered or re-introduced into the food chain.

Observational data by Edwards and Smith (2005) of a geotextile reef off Queensland Australia supports the results of this study as a predominance of algal growth was also observed on their geotextile assemblages. Coincidence between the data in the south pacific and the North Atlantic could lead to application of geosynthetics for offsetting environment impacts in the form of nitrogen or carbon sequestration in the south pacific and also through the comparison of data.

CONCLUSIONS

Data from this study suggests that geosynthetics support marine growth and the following are the specific conclusions of this study:

1. All the evaluated geosynthetics support marine growth that were deployed in an estuarine conditions.
2. Seasonal changes may affect the type of growth on the containers.
3. Significant amounts of growth occurred to support estimation for nitrogen sequestration or carbon sequestration when applied to a large-scale reef or artificially stabilized natural reef.
4. Predication on the reef sample was indicative of ecosystem establishment and conversion of dissolve nutrients into marine growth and subsequent reintroduction into the pelagic food chain can be assumed.
5. Softer substrate geosynthetics support softer growth such as *Gracilaria* spp. while harder substrate geosynthetics support harder growth such as barnacles.
6. Many other environmental factors may effect what establishes on a geosynthetic substrate and consultation with a specialist or implementation of a trial reef is recommended.

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Vacinity map from www.google.co/maps