EXAMINING THE RELATIONSHIP BETWEEN EXPOSURE AND VEGETATION ON THE HUDSON RIVER SHORELINE

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Abstract. Exposure is the combination of physical forces exerted upon the shoreline by the water, which includes waves, currents, and, where applicable, tides. The primary purpose of this study was to look into the relationship between exposure and two vegetation attributes, species richness and biomass. A secondary purpose was to find a quantifiable measure of exposure to explain the collected data. Five sites along the shore of the Hudson River, New York, were selected on a gradient of exposure going from very sheltered to very exposed. Vegetation data were collected via transects running downslope from the high tide mark. Two exposure variables were measured, current and fetch. They were measured with a current meter and calculated from weather data respectively. Exposure metrics based on wind fetch were extremely promising, and the vegetation data strongly suggested a direct relationship between exposure and species richness.

INTRODUCTION

Exposure (the collective effect of wave energy, currents, wind and in some cases tides) should be a very important factor in determining the characteristics of a shoreline. High levels of exposure lead to rougher, larger grade sediment through the erosion of fine grade sediment (Keddy, 1982). The removal of fine grade sediment eliminates most soil that many plants require for rooting and nutrients. In addition, exposure has a direct effect on shoreline life through the simple battering of plants and animals.

However, it turns out in practice that exposure is hard to study and has not been investigated very much (Strayer et al. 2012). What measures exist are either unsuited to fresh water or unreliable. For instance the rate of gypsum dissolution has been commonly used but as Porter et al. (2000) argue it is a very problematic measure to use due to the mixed flow nature of a river. The use of dynamometers in the style of Bell and Denny (1994) while seeming good in theory has issues in its actual implementation. Readings from dynamometers at a single site can vary to an incredible degree, raising serious questions about whether the data are representative of the actual exposure. Measuring exposure due to fetch is dependent only on good weather data as it takes into account the wave generation by wind traveling over exposed water. This means it ignores the potentially important wave generation by boats that are constantly using the Hudson. Similarly measuring current is straightforward and accounts for an important part of exposure, but it doesn't account for many other sources of exposure. Because of this many studies use indirect means of measurement to quantify exposure such as fetch and substrate size (Keddy 1982).

This study had two main foci. First, I investigated the relationship between exposure and vegetative life on the shoreline. The specific hypotheses were that increasing exposure would lead to decreasing plant richness and biomass. This inverse relationship could be brought about either directly through battering of plant life or indirectly through the erosion of sediment needed by many plants. The second focus was to try and find a quantitative factor of exposure that would match with intuition and explain whatever pattern was observed in the vegetation. To this end I investigated current and fetch as measures of exposure. In terms of the vegetative study I focused on a few specific descriptors, those being species richness and biomass. In addition I looked at species distribution to try and assess whether certain species occupy specific areas or niches in the exposure gradient.

METHODS

Five sites were selected on Cruger Island, NY. Cruger Island is located in the Hudson River, a tidal estuary, and as such is subject to tidal forces as well as winds, wakes, and currents. The sites were chosen to represent various points along an exposure gradient from very sheltered to very exposed. The choice of sites and assessment of relative exposure was made by visual inspection of several factors. Firstly sediment grade was taken as an indicator of exposure since higher levels of exposure should lead to larger sediment grade. Location was also key as several sites were located in a cove that was protected from the wind. Finally vegetative protection in the form of water-chestnut (*Trapa natans*) and spatterdock (*Nuphar advena*) was noted since these large stands broke many waves and decreased the actual energy reaching the shore. Figure 1 shows the location of the island in the river as well as the location of the five sites on the island. The sampling sites were marked with an upper elevation of 1.12 m above mean lower low water. This elevation was chosen as it was the lowest high tide predicted for the time period in which we sampled. This ensured that the study area would feel the effects of tide every day during sampling to avoid undesired variance.

Vegetative sampling was conducted along a transect using a 0.5 m quadrat, and was conducted in late July and early August 2012 during low tide. The transect began at the 1.12 m high elevation mark and ran downslope perpendicular to the shoreline. Elevation measurements were taken every meter horizontally and the transect continued until either a depth of 0.5 meters below mean lower low water was reached or the ground flattened out and elevation change effectively stopped. Quadrat sampling occurred every meter and quadrats were taken on either side of the transect (Figure 2). Plants were counted by species and clippings were taken to measure biomass (after drying at 60^{o}C). The number of species at each site was also recorded for the determination of species richness.

To avoid excessive clipping of spatterdock that was prominent throughout several of the sites a calibration was created instead. Ten stalks from areas nearby but outside of study sites were collected, measured, and weighed for biomass. Based on this height was determined to be the best predictor of biomass with an equation of biomass = 0.18212*e^(0.038608*height) and R^2 = 0.959. Spatterdock encountered in quadrat sampling were counted and measured, biomass was calculated using the calibration and measured height.

Current was measured roughly half way between high and low tide with a Marsh-McBirney Flo-mate Model 2000 current meter. The 0.2, 0.4, 0.8 method was used for calculating the average current speed (Marsh-McBirney 1990). Fetch was calculated using the equation Exposure = Σ V*P*F as described by the Robbins et al (2000). V, P, and F being velocity of wind, duration of wind, and measured fetch respectively. Weather data were provided by a weather station operated by the Cary Institute of Ecosystem Studies (Kelly, 2012). Mean wind speed and direction was taken for the 20-day period of fieldwork. Fetch was found for each day along the mean wind direction using the Google Earth ruler tool.

Linear regression was used to evaluate all data. The sites were ordered 1 to 5 from most sheltered to most exposed.

RESULTS

As can be seen in Fig. 3 it is highly suggestive that species richness is affected by exposure. As exposure increases richness shows a general decrease following the predictions of my hypothesis. Conversely biomass does not seem to be related as predicted to exposure. As also seen in Fig. 3 linear regression of biomass clearly shows no linear relationship between biomass and exposure.

Figure 4 shows the results of the current and fetch measurements plotted against the ranking of the sites based on visual inspection. While current does not adequately match my subjective ranking of exposure fetch comes quite close. Current, at the very least, is not one of the primary forces determining exposure. However, given these results fetch could be an important variable in the ultimate level of exposure at Cruger Island.

DISCUSSION

It would appear that exposure has an effect upon plant species richness. Furthermore, as expected increased exposure leads to less richness. This means that as direct battering of plants, erosion, and other effects of exposure increase fewer types of plants are capable of surviving. It seems this logic does not apply to biomass as well. While one might think that with increased physical forces biomass would decrease that does not seem to be the case. While in the high exposure sites biomass was very low it did not generally decrease as exposure rose. There simply is no linear relationship between biomass and exposure as there is between richness and exposure. That said, it does not mean there isn't a relationship, it just means the relationship is different then expected. A potentially important factor is sediment size. Biomass increased between sites 1 and 3 only to drastically decrease at site 4 and 5. Sites 1-3 still possess muddy fine sediment while sites 4 and 5 are composed primarily of fine and rough gravel. So this relationship may be based on both the direct effects of exposure on plants and the erosion caused by exposure.

In terms of measuring exposure it would seem current is poor metric, at least at these sites; it does not correlate to the observed gradient of exposure. While it no doubt contributes to the overall level of exposure it does not seem to be the prime determinant since observed exposure appears to be almost independent of it. Conversely fetch does appear to correlate with exposure at these sites. Due to the level of correlation it seems fair to speculate that fetch may be one the larger factors of exposure on Cruger Island. Levels of exposure in different locales may be determined by different factors. A complete measurement for exposure remains unfound, however, there are still many options left for research. For instance, fetch accounts for wave energy but not waves generated by boat wakes. The Hudson River is a major shipping lane and boat wakes from large tankers may deliver large amounts of energy to the shore. Finding a reliable way to record total wave energy and not just wind-driven waves could prove very helpful. But as mentioned before variables of exposure can be difficult to quantify and until we find ways of measuring most of these variables exposure will remain elusive at best.

The obvious next step in exposure research is to find a reliable and comprehensive way to quantify levels of exposure on various shorelines. This would allow for further rigor in studies as well as data that can be compared with other studies. Beyond this step, identifying the exact relationship between exposure and biomass could prove interesting, as it does not appear to be a simple linear one. In general the relationship between exposure and shore zone vegetation is rich with potential research. Without quantifiable measures of exposure only limited work has been done. While work with exposure can be done the results cannot be compared between shorelines, as without a quantified, replicable, and complete measure empirical comparisons can't be made.

LITERATURE CITED

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APPENDIX

FIGURE 1. The study site. Cruger Island is shown on the left in the center of the picture. Due to the railway the island can be reached on foot and has a protected bay on the NE side. On the right the locations of the 5 sites are marked. North is to the top of both photos. (Photos taken in Google Earth)

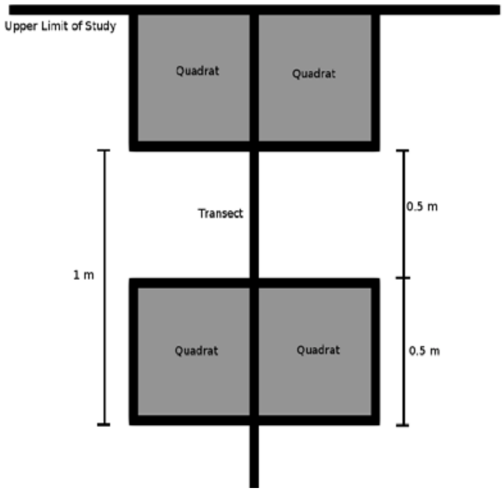

FIGURE 2. The pattern of quadrat sampling. The transect extended from the upper limit of the study with 0.5 m quadrat samples on either side occurring every meter.

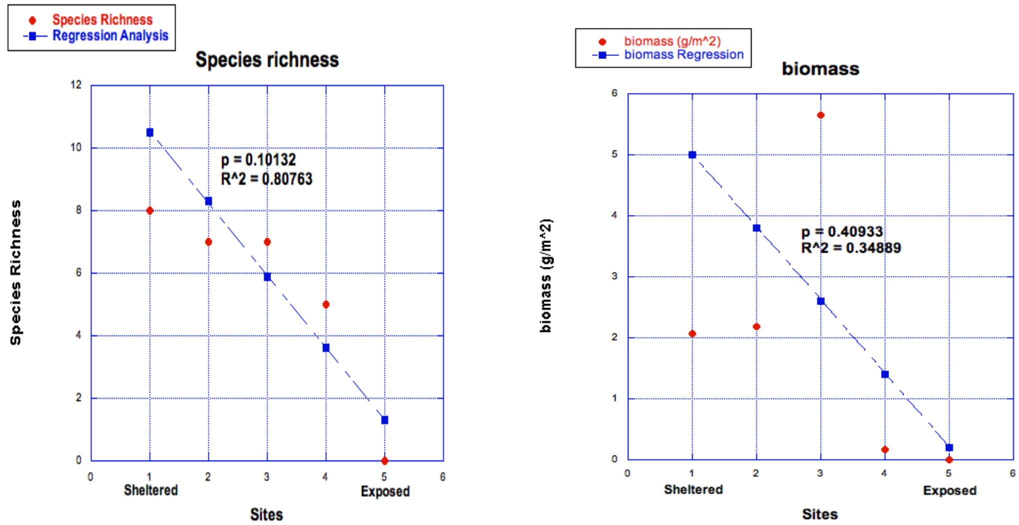

FIGURE 3. Species richness and biomass are plotted against the sites ranked from left to right in order of decreasing exposure.

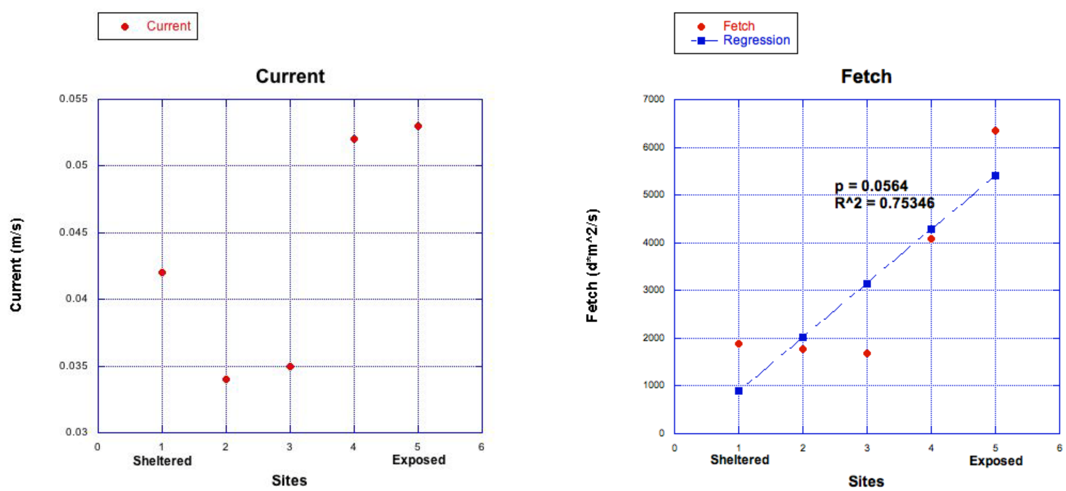

FIGURE 4. Current and fetch are plotted against the sites in order of decrease exposure left to right.