Documenting the relationship between substrate angle and invertebrate assembly patterns:

An approach for assemblage identification

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Abstract:

I looked at the effects of substrate angle on species assemblages across a gradient from horizontal to vertical. In doing so I categorized the sloping gradient of six bins of 15°, and analyzed photographic quadrats placing them into one of these six categories. Additionally I analyzed these quadrats for percent cover down to the lowest taxonomic level. I took this a step farther and grouped these into phyla and “space available”, I did this to further tease apart possible relationships between substrate angle and percent cover across species. Looking at past literature I discussed how substrate angle has only looked at horizontal versus vertical substrate angles, while neglecting the gradient between these two extremes. Using statistical analyses I was able to determine possible extensions to this study, as well as limitations in drawing conclusions from the collected data.

Introduction:

In the subtidal zone substrate angle has a clear effect on species assemblage and an increase in diversity and species richness on vertical walls compared to horizontal substrates has been well documented (Knott et al, 2004; Thomason et al, 2002). Yet there is an evident lack of information describing the correlation between diversity and more specific measures of substrate angle leaving room to quantify this relationship.

There has been extensive research into many of the factors affecting subtidal communities. For example, the effects of storm disturbance and the effects of grazers have been shown to have significant effects on diversity and community assemblages in the subtidal environment (Witman and Dayton, 2001; Coyer et al, 1992; Witman, 1987). Spatial competition is another factor that can determine species assemblage in the subtidal zone. Competition can lead to overgrowth and sometimes also to spatial clearing opening space for new recruits (Bruno and Witman, 1996).

Substrate orientation has been shown to affect species recruitment down to the individual level across most sessile epifauna (Vandermeulen & De Wreede, 1982; Holliday, 1996; Hatcher, 1998; Connell, 1999; Glasby, 2000). It has also been well documented that a combination of texture and orientation (i.e. angle) can have a significant effect on species accumulation and assemblage (Thomason et al, 2002, Glasby & Connell 2006). There have also been links to angle/orientation of substrate and species richness (Thomason et al, 2002; Glasby & Connell, 2006; Witman & Daton 2001). For example, Thomason found that the underside of all the tiles in their experiment had the highest species richness accounting for ~46% of community composition.

With the difference in diversity and species assemblage being well documented on both horizontal and vertical substrates there is a clear gap in research describing species richness, diversity, and assemblage types over varying substrate angles.

With this change in diversity, species assemblage, and species richness being well documented from horizontal to vertical substrates, I wanted to better understand this change by examining the slope as a gradient to see if there is a statistically significant change in diversity or assemblage type across substrate. If so I then want to determine if there is a specific angle at which a significant delineation in species assemblage occurs. Assigning a gradient to a previously bimodal description of substrate, horizontal or vertical, I will be able to more accurately describe species assemblage.

Methods:

Dr. Ken Sebens has set up five permanent study sites in a Marine Protected Area (MPA) near Friday Harbor Washington on San Juan Island, one of the islands in the San Juan Archipelago. At each site, transects are run annually at 3 m depth increments from 3 m down to 27 m feet. During SCUBA dives, each transect of 10 meters in length and is placed in such a way as to cover as much of a hard substrate as possible (Sebens lab), avoiding sand and gravel. Every 10 centimeters along each transect a point of contact count is taken, and at each point the epifauna is recorded to the species when possible. Additionally there are 10 quadrat photographs taken, with the location of the quadrat photos randomized before each year's fall survey. In addition to the point count and quadrat photo data gathering, Sebens lab surveys perform mobile fauna counts during their yearly survey. Due to time constraints I only be looked at the sessile fauna distribution and percent cover at the 15 m transect depth. I used the quadrat photographing methods set out by the Sebens lab to determine percent cover (Figure 1), and chose three of the Sebens lab's permanent transects as well as two additional transects.

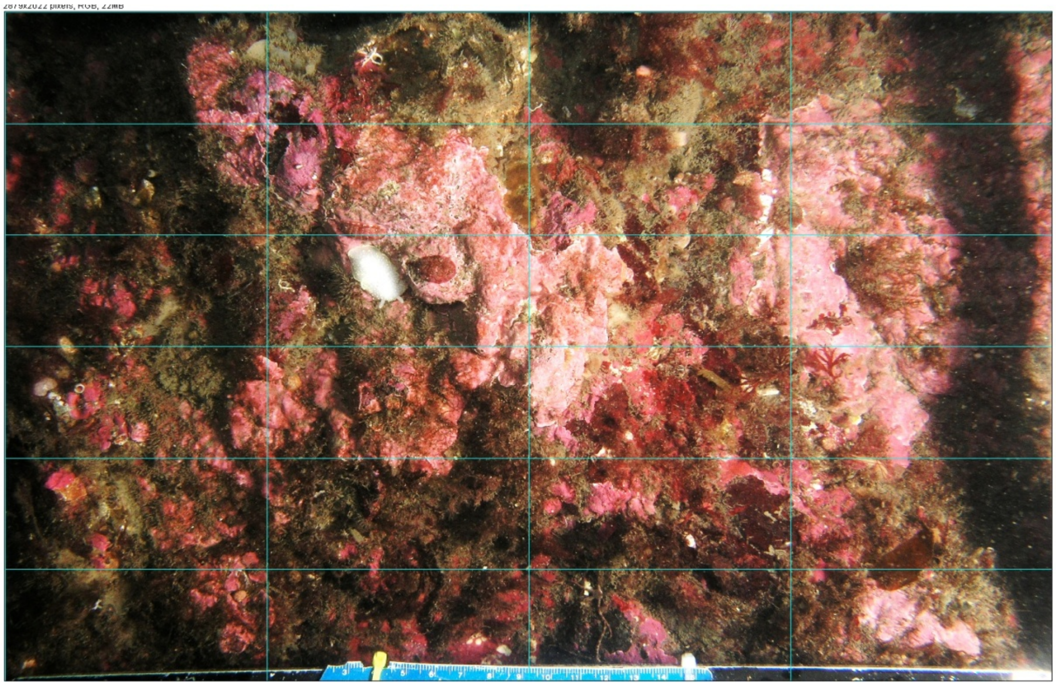

Figure 1. An example of a quadrat photograph ready for analysis for percent cover. This photograph has been gridded into 24 squares, color corrected, and cropped leaving in a ruler to help set scale.

The permanent site locations I used are designated as Madrona, 3 Toes, and Pump House. Additionally, I identified two new transect locations using Multibeam data provided by Dr. Gary Greene and the Canadian Geological Society. I assigned these new transect sites names; Yonder – located north of Madrona, and Slump – located between Pump House and 3 Toes. These sites were picked due to the similarity in substrate, determined using backscatter imagery, and substrate angle as interpreted with ArcGIS. Each site profile exhibited similar slope profiles and substrate make up at the 15m depth. The slope profile was determined by displaying slope in the six 15° slope categories within ArcGIS(Figure 2).

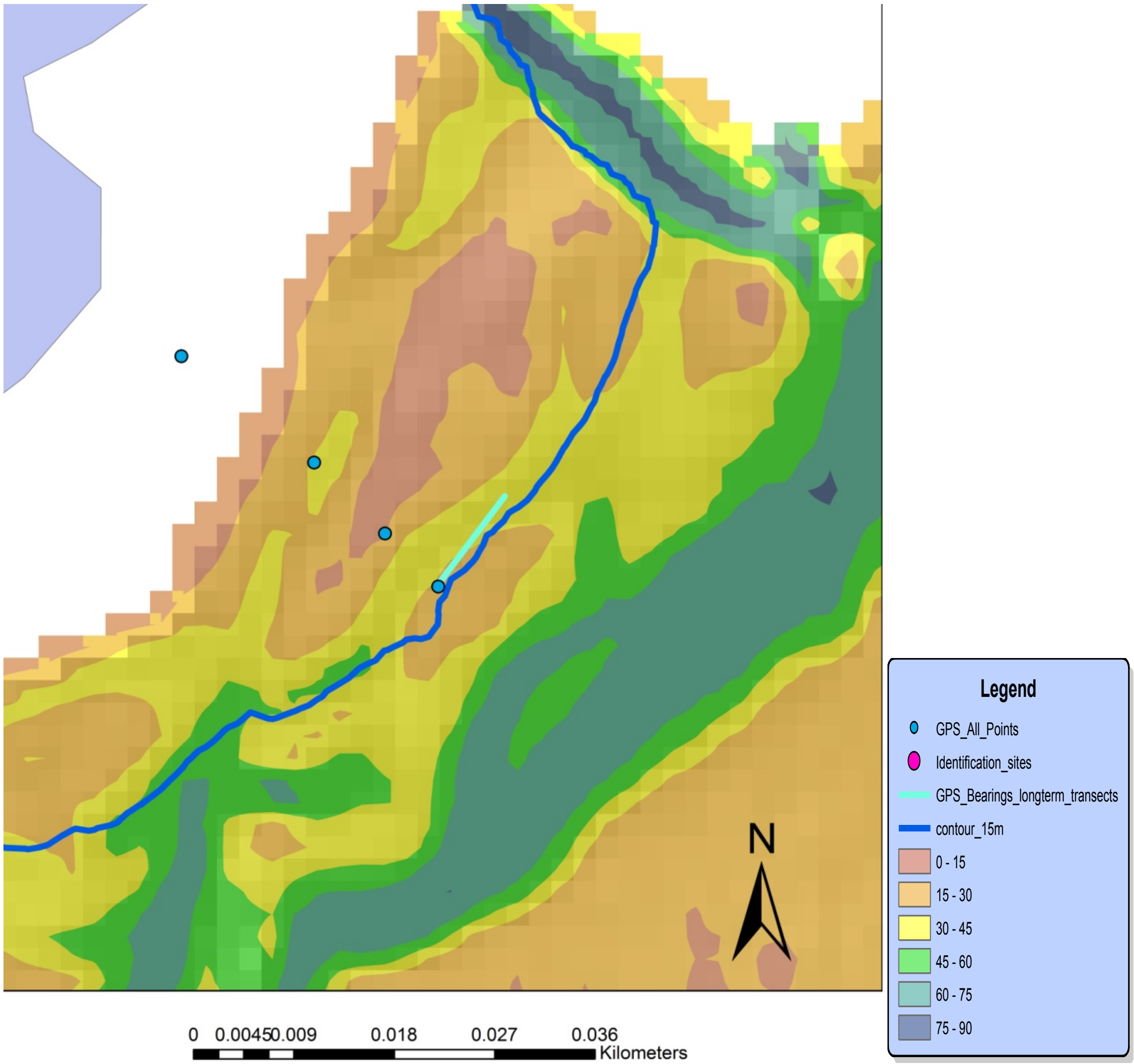

Figure 2. An example of slope in 15° categories as seen in ArcGIS.

The quadrat photographs were gathered using SCUBA and using the same Methods developed by the Sebens lab. In addition to the Sebens procedures substrate angle was estimated in situ by the divers and recorded for each photograph. From the data collected photographic analysis is done using ImageJ and a metric developed with Megan Dethier to give an estimate of percent cover. Angles were determined by measuring substrate angle from horizontal to vertical and divide this change into 6 categories, or 15° bins.

1: 0°- 15°

2: 16°- 30°

3: 31°- 45°

4: 46°-60°

5: 61°-75°

6: 76°- 90°

Results:

Using JMP, PRIMER as well as R statistical packages, I was able to take my data to determine some possible patterns between substrate angle and percent cover. I ran multiple statistic analyses to determine these patterns. First I ran principle components analysis to try to determine any potential patterns between substrate angle and species assemblage (Figure 3).

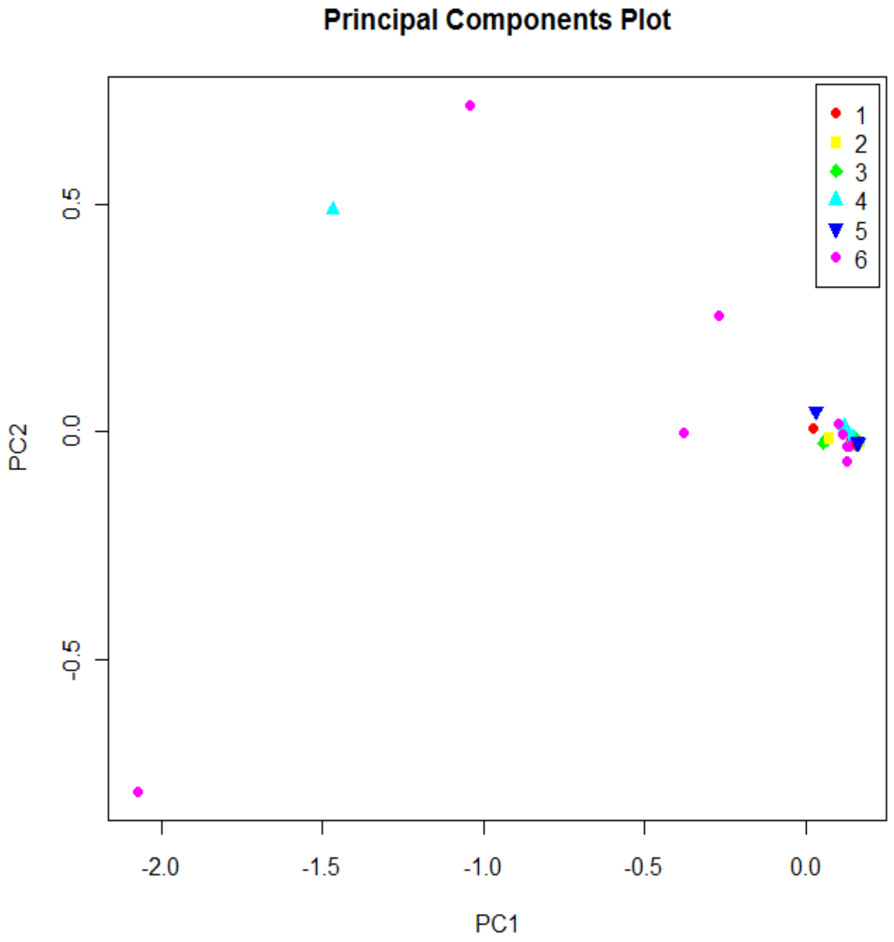

Figure 3. The data clumps together with the exception of four photographs measured with a slope of six, and one with a slope of four. The five outliers are not grouped showing little similarity to one another. This indicates that the diversity of the vertical slopes is no more similar to other vertical surfaces than it is to the main cluster. There is no other clumping, indicating that on a whole most of the photo quadrats are not significantly different.

These two components accounted for 75% of the variability. So the clustering indicates that angle has very little to do with the differences we see in the photographs.

Next I used a nested ANOVA with site as the main independent variable with my angle categories (1-6) nested within site. The dependent variable was percent cover of species, or categorical groups when species identification was impractical to impossible. Additionally I grouped species into phyla as well as creating a category for space available for statistical analysis. Space available is a category defined as a combination of pink crustose coralline algae, maroon encrusting algae, and bare space. These were lumped together since all three can be used as recruitment space by many other organisms. Grouping species to phyla and grouping "space available" ended up showing the highest level of significance (Figure 4), while angle had less of a significant effect on a species level.

PHYLA	**Site Significance**	**15° Angle(Site) Significance**	**30° Angle (Site) Significance**
Space Available (Crustose Algae and Bare Space)	x	x	p=0.012
Chordata	x	x	x
Bryozoa	x	p=0.0247	p=0.0012
Porifera	p=0.0475	x	x
Mollusca	p=0.0012	x	p=0.0009
Annelida	$p<0.0001$	x	x

Figure 4. Showing significant correlations between location, and angle in two bin sizes.

Significance was found at all phyla levels, except Chordata. There were significant effects found on the site level, with the exception of Bryozoa, Chordata, and space available. While using the 15° angle categories only showed significance in the phyla Bryozoa. Yet, when the angle categories were grouped into 30° bins a larger effect of angle on Bryozoa, Mollusca, as well as space available become more significance.

To further explore the slope when it is broken into 30° bins I ran a correlative heat map with site photographs by angle, grouped as horizontal, sloping, and vertical, in an attempt to find a correlation between substrate angle and assembly patterns (Figure 5).

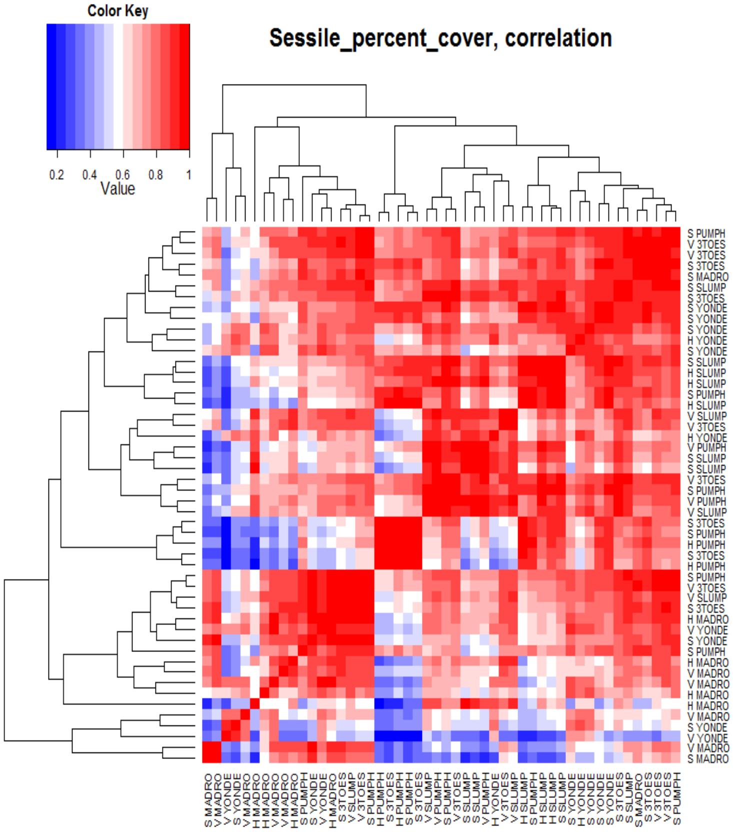

Figure 5. Correlative heatmap that compares vertical, sloping, and horizontal across all substrate angles.

In this image look at either the upper or lower half divided by a diagonal line through the middle. A red square indicates no difference, where a blue square indicates a large difference. What this graph shows is that over all there are relatively few changes in species assemblage that can be indicated purely from substrate angle.

Across all sites, and all substrate angles most of the dissimilarity between sites was driven by a five categories. These five drivers were maroon encrusting algae, pink crustose coralline algae, hydro-bryozoan confusion, tube complex, and bare space. All species and categories were given abbreviations that were used when estimating percent cover as well as during analysis. For these five categories the codes were: EALM – maroon encrusting algae; CCAP – crustose coralline algae; HBCO – hydro-bryozoan confusion; TUBC – tube complex ; BASP – and bare space. Looking across all five sites these five categories were always the top four contributors to dissimilarity between sites. These drivers did not always appear as the top five dissimilarity contributors, but a combination always comprised the top four dissimilarity contributors. As an example:

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Groups 3TOES  &  MADRONA

Average dissimilarity = 36.65


                3TOES        MADRONA

Species     Av.Abund       Av.Abund  Av.Diss  Diss/SD  Contrib%  Cum.%

CCAP            0.60           0.38     4.17     1.43     11.38  11.38

EALM            0.44           0.52     3.03     1.12      8.28  19.66

TUBC            0.15           0.23     2.87     1.41      7.84  27.50

HBCO            0.46           0.45     2.29     1.21      6.24  33.74

ENBR            0.12           0.18     2.19     1.31      5.98  39.72

DICL            0.00           0.12     2.14     1.01      5.84  45.55

PDMC            0.06           0.12     1.94     1.21      5.30  50.85
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TETR	0.13	0.07	1.80	1.77	4.90	55.75
BASP	0.19	0.22	1.72	1.27	4.68	60.43

In this case bare space is the ninth contributor to dissimilarity between 3-Toes and Madrona, yet the other four contributors still comprise the top four spots. Looking across all sites 32.14% to 42.59% of all dissimilarity can be accounted for by the top four dissimilarity contributors, all of which are from the top five dissimilarity contributors..

Discussion:

These findings were interesting in many ways. There were differences across substrate angle, but these were often not significant. The largest amount of variability can be accounted for by looking at five contributing categories. This was particularly interesting when you look at how these categories are used in the benthic environment. Four of the five groups are often grown over and used as substrate by colonizing sessile invertebrates. There may even be a slight pattern when looking at space available across the substrate angles (Figure 6).

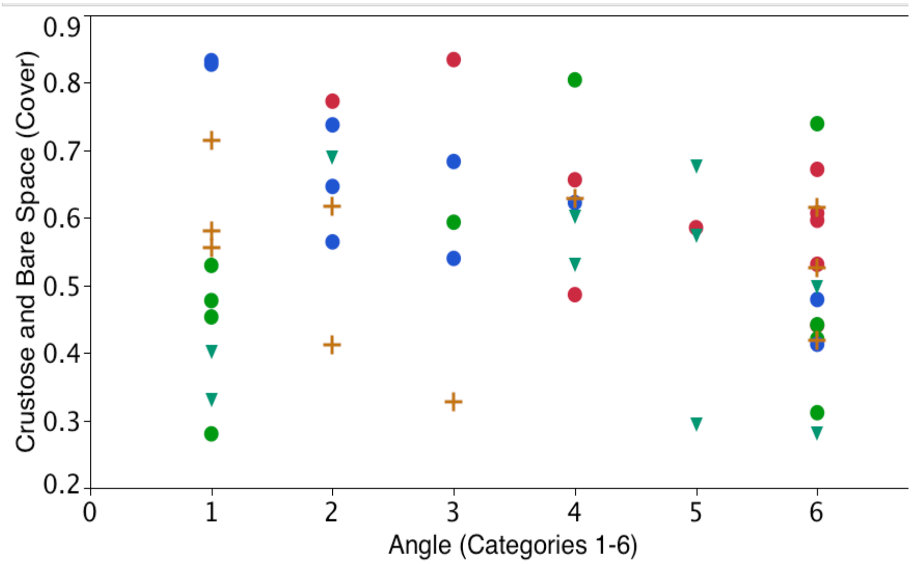

Figure 6. Space available for all photo quadrats, plotted as percent cover to substrate angle.

This pattern is a slight hump showing less space available at horizontal, increasing through the gradient of angles. Then decreasing again as it approaches vertical. When breaking this out site by site, the pattern is not always there or is very sensitive to leave one out analysis (Figures 7, 8, and 9).

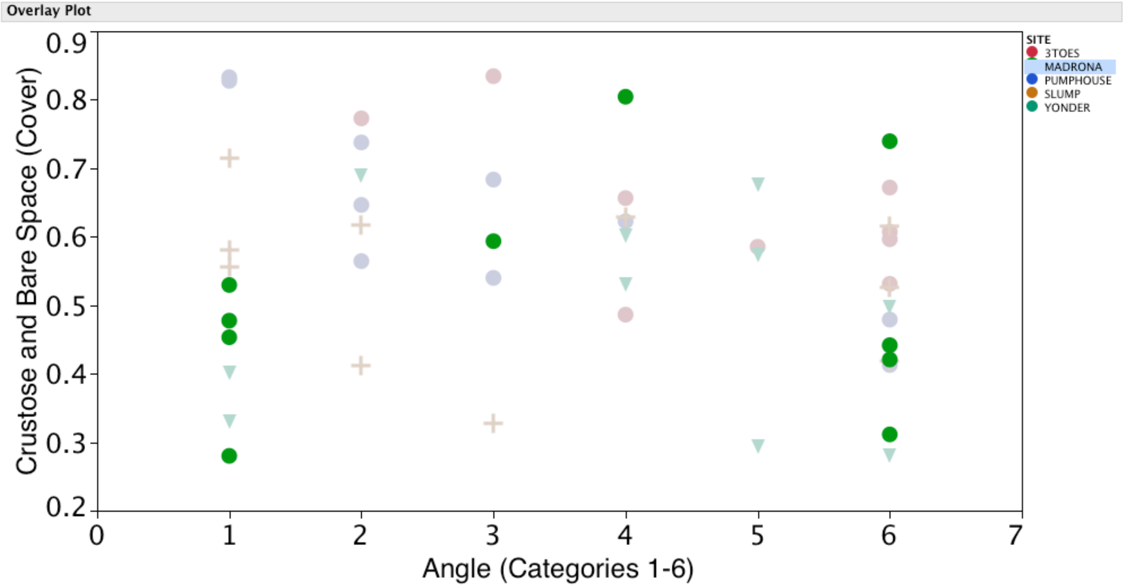

Figure 7. Madrona space available, showing a possible hump pattern.

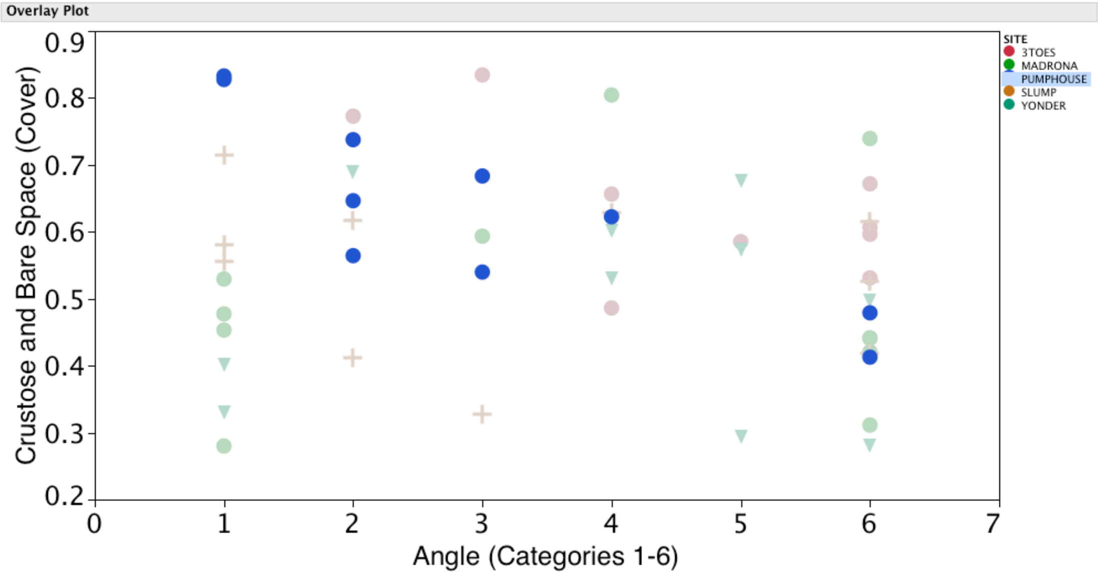

Figure 8. Pumphouse, possibly showing a linear decrease in space available.

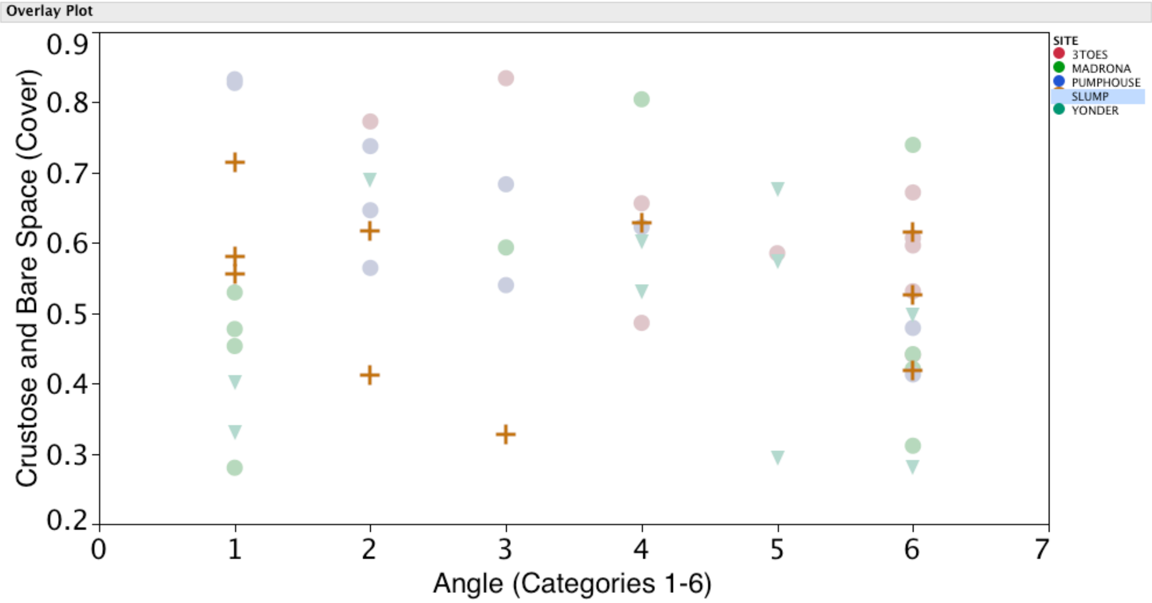

Figure 9. Yonder, possibly showing a linear pattern.

These data are inconclusive when it comes to the effects of substrate angle in determining specific assemblage patterns. Space available had the lowest p value, indicating using this category would provide the strongest correlations between substrate angle and species assemblage.

Conclusions;

The overall similarity across substrate angle from horizontal to vertical indicates that to identify a pattern in assemblage patterns a larger N value is needed. Because of this I believe my current N value of 50 quadrat photographs is insufficient to identifying species assemblage patterns at the 15m transect depth. Three proposed ways to increase the resolution on the effects of substrate angle on species assemblage are: temporal comparisons using multi-year data from the Sebens lab's photo quadrats; the inclusion of multiple transect depths to explore the effects depth may play in species assemblages; and re-gridding Dr. Greene's multibeam data to a higher resolution to improve slope identification with remote sensing.

Using the long term photo quadrat analysis from the Sebens lab would allow for a much larger data set that could be analyzed without the required time and money associated with in situ data collection. The Sebens categorization of horizontal, sloping, and vertical has been shown to be an effective resolution in picking up assembly changes across the substrate angles. Using these data would then give the needed information without requiring the gathering of new data.

Using multiple transect depths would then be a way to determine if and how depth plays a role in specie assembly patterns. A recent analysis of the Sebens lab's point count data identified a transition point in species assemblages near 15m depth (Cori, Derek). This leads me to believe that a portion of the ambiguity to my data was due to my sample depth being in this transition zone. So, the inclusion of a broader depth range could account and correct for this possible depth bias.

With ArcGIS and the multibeam bathymetry data used, there was a definite discrepancy in what the resolution would allow me to determine from the remote sensing. I would propose gridding these data down to a 0.5 m grid size. At this point re-surveying the sites could potentially allow me to us ArcGIS as a tool when identifying new or potential survey sites. Using remote sensing in this fashion would be a powerful tool, allowing for habitat location at a fraction of the time, labor, and cost associated with in situ methods.

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