Flow in the Subtidal Zone:

How fluid flow might determine organism distribution in microhabitats of the San Juan Channel.

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The Salish Sea of Washington State, USA and British Columbia, Canada is characterized by deep narrow channels with saltwater input from the Pacific Ocean and freshwater input from the Frasier River. The San Juan archipelago sits right at the intersection of these two inputs. This region experiences mixed semidiurnal tides and has many narrow passes and abrupt sills that characterize local flow dynamics. A steep drop off close to shore typifies the bathymetry of the sub-tidal habitat.

Some of the more obvious parameters that control where benthic sub-tidal organisms live are light and availability of food, but a few studies have sought to shed some light on how microhabitats created by flow regimes also are an important consideration. Small scale studies on how flow affects benthic communities have shown pieces of how communities and individual species of benthic filter feeders have the highest performance when they are within their target flow range. This range is determined mainly by the physiology of how organisms feed.

The range of flow speeds where an organism can optimally perform is determined by its ability to capture particles as well as their ability to process particles that have been captured by its feeding apparatus. If they cannot get the food to the point of ingestion, performance will be compromised (Eckman and Duggins, 1993). In a study that looked at an assemblage of organisms—bryozoan, polychaete, and barnacles—Eckman and Duggins (1993) found that the flow speeds of an organism's natural habitat were the best predictors of their success. Organisms who lived in high energy environments were the most insensitive to flow speed when tested under controlled laboratory conditions. They suggest that feeding apparatus deformation at high flow speeds could account for the lack of growth in organism who naturally live at lower flow speeds but were subjected to artificially high flow speeds.

Some organisms have two different morphologies depending on the flow speed of their habitats. One study that seeks to explain how filter feeding invertebrates deal with differing flow rates was conducted at Friday Harbor Laboratories looking at bryozoans (Pratt, 2008). Bryozoans can have two different morphologies, species that live in fast moving water form encrusting sheet-shaped colonies and the species in slower, calmer water erect tree-shaped colonies. The shape of the colonies and how well they capture food at high velocities could potentially be used to predict which species of bryozoans have a greater potential to become invasive species (Pratt, 2008).

Unlike bryozoans where species determined colony shape, colonial cnidarians can change their shape if fluid speeds around them change. Attempting to decouple the effects of food resources and the effects of flow speed (Griffith and Newberry, 2008) provided the animals all the food they could want and still found that the morphology of the colonies was correlated to the flow conditions they were experiencing.

Morphology is not the only consideration to take into account when thinking about fluid flow affecting an organism. Benthic autotrophs that have all the light they might need; all the nutrients they might need and are contained in tanks with no flow show low photosynthetic rates. (Mass et. al., 2010). These researchers explained these data by looking at the efflux of oxygen from the organism. If there is nowhere for the oxygen molecules to go, the autotrophs cannot accept any new carbon dioxide molecules into their respiratory pathway, thus slowing down growth.

My research will seek to look at how fluid flow might determine the distribution of *Strongylocentrotus franciscanus* to determine where it can be found in microhabitats of the San Juan Channel based on fluid velocity measurements at several sites. To evaluate relative flow speeds around the San Juan Channel we deployed uniform blocks of alabaster (Muus, 1968; Dot,y 1971; Eckman et. al., 1989), a soft stone, and measured dissolution rates over the course of a month long tidal cycle.

Materials and Methods:

Alabaster preparation

Alabaster blocks were cut into square blocks of 5.5±0.5cm with a height of 2cm. Then they were dried in an oven for 24 hours at 50 degrees C. All blocks had their initial weights taken and were then attached to a hard plastic plate with caulking covering the bottom half of the vertical sides. This left about 1±.3cm of exposed alabaster on all sides. Initial exposed alabaster surface area was calculated using Image J (NIH, Bethesda, MD,USA) to account for irregularities in block size. The caulked alabaster blocks were then strapped to a brick for deployment, to lift the alabaster out of the benthic organisms and standardize their position in the flow. (See Figure 1)

Figure 1: Pre-deployment Alabaster blocks with only the top half of the stone exposed to flow

Alabaster deployment

The alabaster bricks were placed at 95 sites throughout the San Juan Channel (See Figure 2). The bricks were placed at 3 meter depth increments within a range of 3-27 meters. Divers descended to the preselected locations and cleared all kelp within a 1 meter radius to reduce flow differences and kelp whiplash. If the blocks were on a vertical surface they were secured to the pins marking the site by zip ties. All blocks were in the field for 12±2 days and 3 full rounds were deployed in series leading to about a full lunar cycle of data. In addition to the blocks in the field we placed three identical bricks in a circulating sea water tank with near still flow as a control and three others next to an S4 current velocity meter to enable calibration with flow speed. These calibrations were done following the methods described by Porter et.al. (2000)

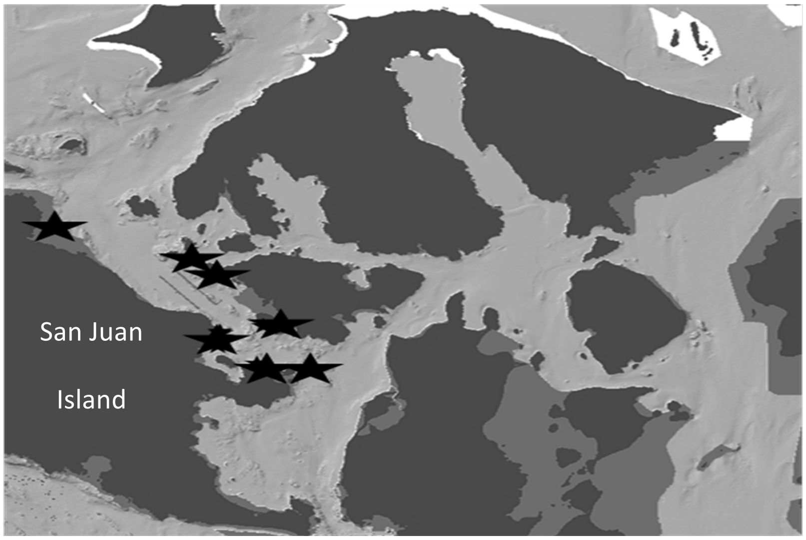

Figure 2: Deployment sites in San Juan Channel, Washington, USA

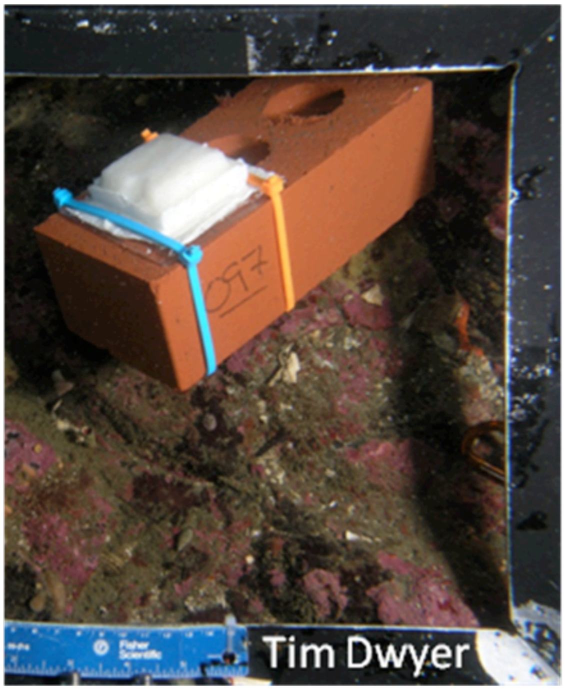

Figure 3: Alabaster attached to brick deployed in the field

Flow analysis

Each block was dried in an oven for 24 hours at 50 degrees C after retrieval and then weighed using the same balance with which initial weights were taken. The difference between final mass and initial mass were used to calculate flows. We took each block and calculated the dissolution rate in grams lost / cm^2 / day to determine which sites would be designated high flow and low flow for the purposes of our analyses. We created five final categories for analyses: low, medium low, medium high, high and very high. Medium high was the median flow range and then the other categories were one standard deviation from the middle for the medium low and high sites and two standard deviations from the middle to be designated low or very high. We also used the data from the S4 meter to calibrate the flow speeds experienced by the alabaster blocks (see Figure 3).

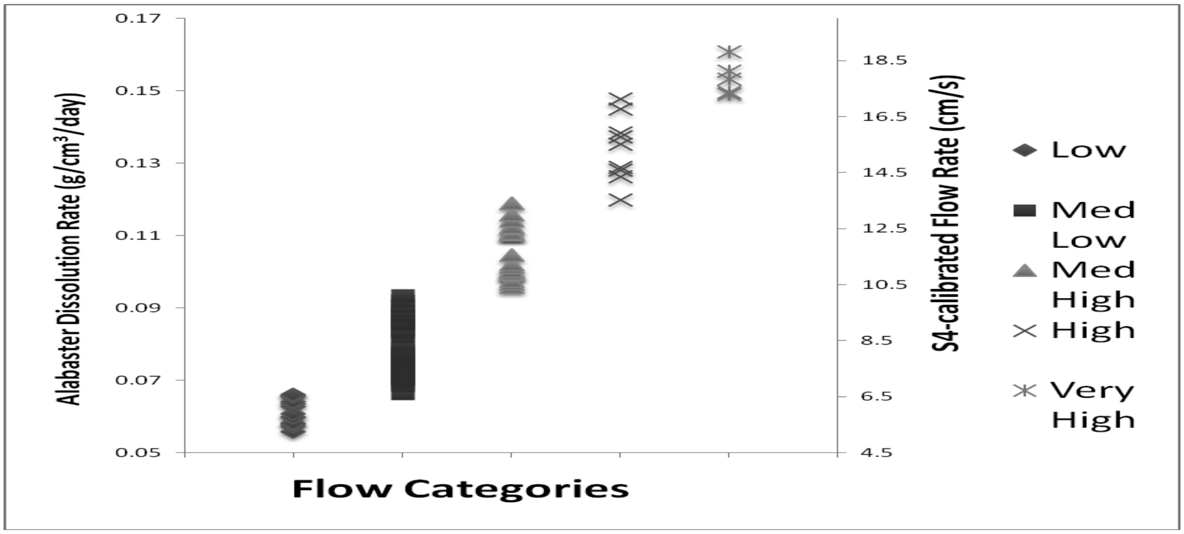

Figure 4: Prepared by Cori Kane and Derek Smith. A S4 current meter was placed at one site with alabaster blocks and then alabaster dissolution rate was plotted by flow category to create an estimate of flow velocity.

Biological Data

Urchin data was collected along 10 meter transects. All mobile fauna were counted and measured within one meter of the transect on either side for non-shady cove sites and one half meter on either side of the transects for all shady cove sites.

Results:

Flow increased with depth and then tapered off after 60 feet/18 meters (See Figure 4).

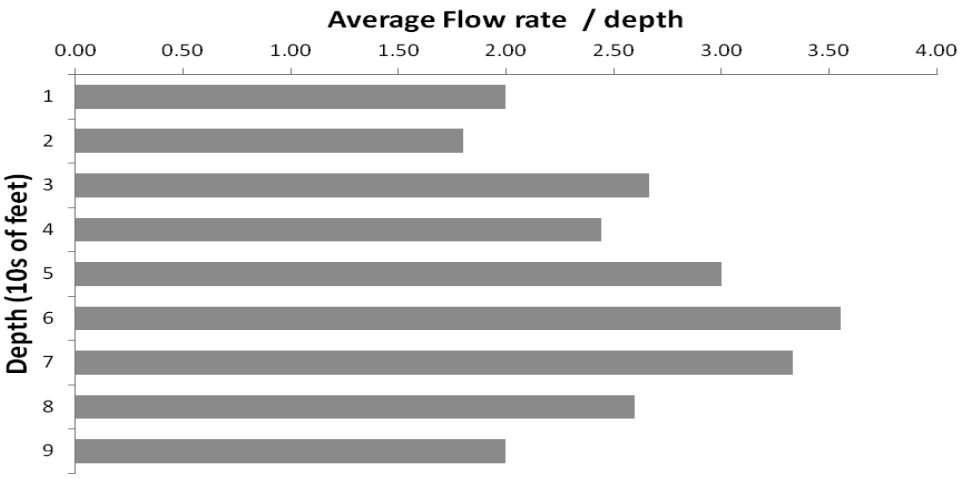

Figure 5: Each flow category (Low, Medium Low, Medium High, High, and Very High) was assigned a number in ascending order, 1 for Low-5 for Very High, and then the mean flow rate for each depth were calculated.

If we make the assumption that alabster dissolution has a liner relationship with flow we can take the one measured flow rate we have and extrapolate the curve in Figure 3 until a current meter can be deployed at more sites.

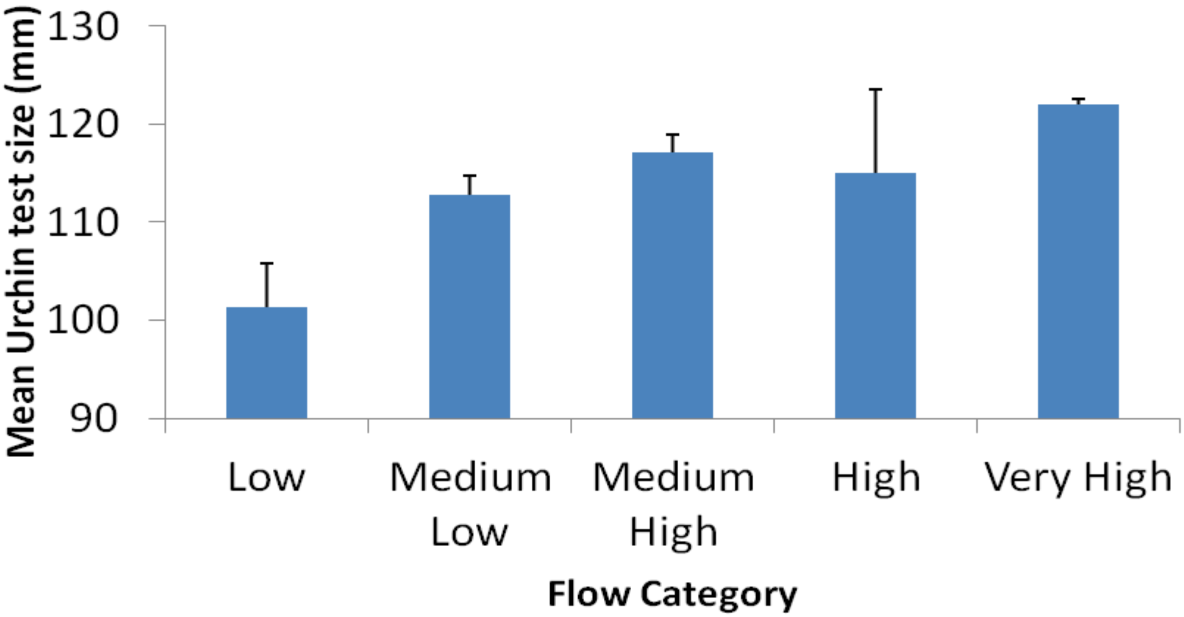

Figure 6: No statistically significant differences between mean test size and flow category (ANOVA α=0.10, p=.144)

The means of the different flow categories do not show a difference but the histograms of the data (see Figure 7) have differing shapes that might lead to a difference in distribution of sizes seen at different flow levels.

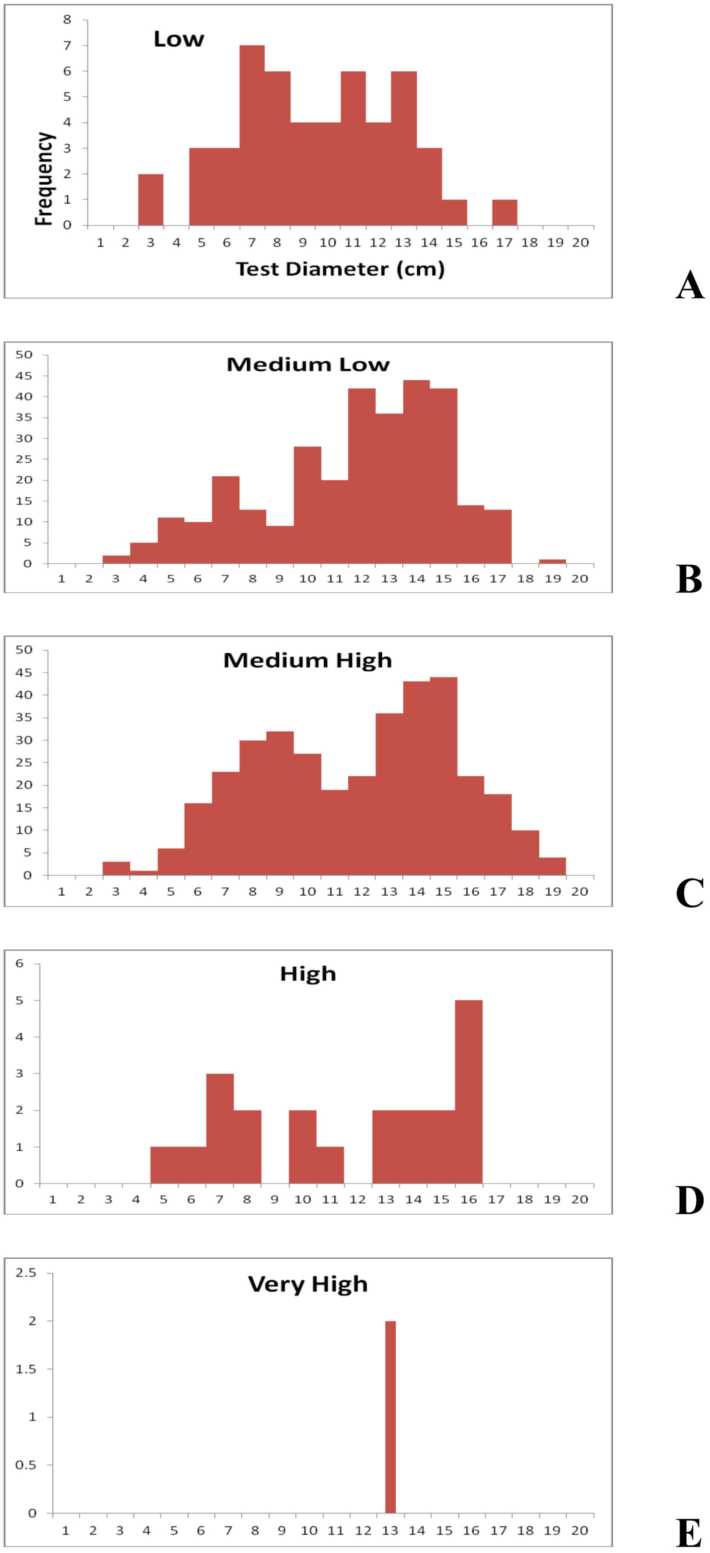

Figure 7: Histograms of mean urchin test diameter (cm) at 5 flow levels. Note Very High flow catogory on ly had two urchins

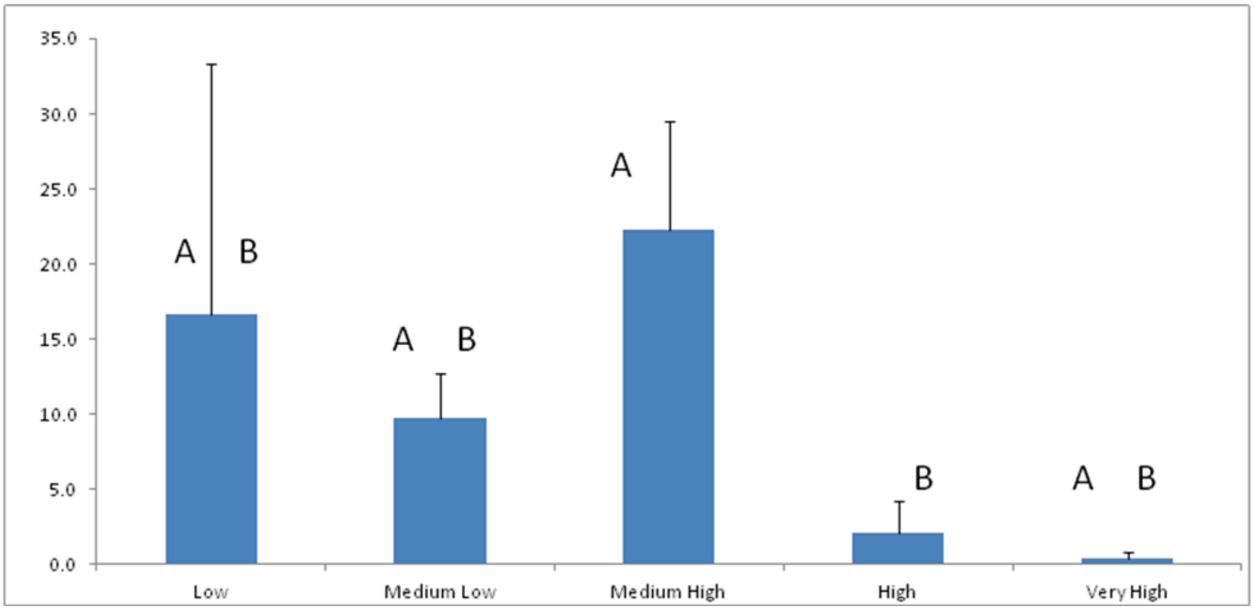

Figure 8: Absolute urchin count at each flow catogory. Disimilar letters represent statistically different counts (ANOVA α=0.10, p=0.072)

Above the median flow urchin counts are significantly diminished. I looked at mean urchin test diameter in relation to depth as well as flow but found nothing of significance to report.

Discussion:

Using alabaster or clod cards to measure flow was established over 40 years ago (Doty, 1971,Muus 1968) to measure mass transfer at many different underwater sites cheaply. If they are calibrated correctly in the field with a flow meter (Porter et. al, 2000) alabaster dissolution rates are a good proxy for flow speed. Similar methods have been used previously (Eckman et. al., 1989) to study kelp but I looked at *S. franciscanus* distributions by flow categories. While mean urchin test diameter was not significant between flow categories a more in depth look at the frequency distributions between sites might show that even though the mean diameter is not significantly different, the distribution of sizes might show us a more nuanced picture.

When taking into account the number of urchins only and not their size there is a significant difference between the Medium High flow sites and the High flow sites. This could be explained by the fact that these urchins are not hydro dynamically shaped their spines are used to trap drift algae (Duggins, 1981; Britton-Simmons et al., 2009) but their shape in increased flow will rip them off the hard substrate leaving them vulnerable to predation. *S. franciscanus* has a unique feature that is not found in all sea urchins; it has the ability to change to orientation of its spines from a 'pin-cushion shape' to a more limpet like shape (Stewart and Britton-Simmons, 2011; Warburton, 1976). This adaptation explains why we found some urchins in these high flow sites but not many.

Because *S. franciscanus* needs flow past its spines to catch kelp drifting by they were not found in high numbers at the very low velocity sites. Likewise they were not found at high flow sites due to the hydrodynamic forces such as lift and drag. The deep sub-tidal red urchin's distribution is determined by finding a flow regime that will give the organism enough food but not increase its chances at becoming food for a predator.

Future research into large mobile fauna distributions based on flow needs to be done with *S. franciscanus* as well as others like *Parastichopus californicus* among others. To improve the data set, deploying multiple bricks at sites now known for a high loss percentage in the field would give us a more complete picture as well as accurate flow measurements with the S4 flow meter. Readings at very high flow sites would be of particular use because we saw evidence of urchins but we are currently working under the assumption that there is a liner relationship between flow velocity and mass transfer rates of alabaster.

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