The role of flow in determining zooplankton populations inside and outside kelp beds near the San Juan Islands.

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Abstract

This study explored the relationship that flow in *Nereocystis luetkeana* beds has to zooplankton communities in the San Juan Islands. The hypothesis was that current flow rates would decrease further inside a kelp bed and that this would affect the types and densities of zooplankton. More Calanoid copepods were expected outside of the beds and more larval organisms inside the beds. Flow rates were measured by attaching blocks that dissolve over time to kelp at the center, edge and outside the kelp bed and comparing the changes in weight. Zooplankton sampling was done with a water pump and net. Results were statistically inconclusive due to small sample size and difficulty in retrieving blocks. There were possible connections between the rate of flow and the differences in zooplankton communities in and out of kelp beds at different sites. Lower velocity sites appear to have more different communities in and out.

Introduction

Kelp beds play an important role in temperate marine ecosystems through production of biomass. Secondary production via kelp detritus increases the growth rates of benthic suspension feeders through production of particulate organic matter (POM) as the alga grows or degrades (Duggins et al. 1989). Kelp beds also have a large effect on the physical habitat and they provide physical structure that can be used by many organisms. Less study has been done on the effect flow regime has on kelp bed habitats.

The understory canopy (kelps 1-3 meters off of the bottom) was discovered to be in many kelp beds and strongly influenced the habitat's flow regime. Understories in the San Juan Archipelago reduced flow and led to higher particulate deposition than adjacent areas with no macrophytes due to higher particulate residence time (Eckman et al. 1989).

The effect of this understory on various benthic invertebrates was significant, but different for each species tested. Manipulation of the understory revealed that reduced flow, increased sedimentation, reduced light intensity, and reduced algal cover were mechanisms important to the growth and survival of four tested benthic invertebrates (Duggins et al. 1990).

Another important ecosystem directly related to kelp beds are drift habitats, where fixed seaweed becomes dislodged and entangled, floating to the surface. The flow regime of kelp beds may affect the transport of attached kelp to these habitats. In Washington these habitats are composed mostly of *Nereocystis luetkeana, Fucus* spp., and *Zostera marina* (Buckley et al. 1995). Juvenile rockfish of the San Juan Archipelago were found to have complex feeding behaviors and appeared to rely on these drift habitats as transition feeding areas (Gomez-Buckley 2001). These drift habitats also are a safe ground for plankton because they inhibit predation efficiency of juvenile flatfish in the Baltic Sea (Nordström & Booth 2007).

Kelp beds have also shown to affect adjacent ecosystems. Intertidal habitats of central California were strongly affected by offshore kelp beds in several ways: (1) creating a drag force to reduce flow velocities, (2) taking up nutrients needed for larval growth and survival, (3) proving a suitable habitat for larvae, and (4) harboring predators (Gaines & Roughgarden 1987).

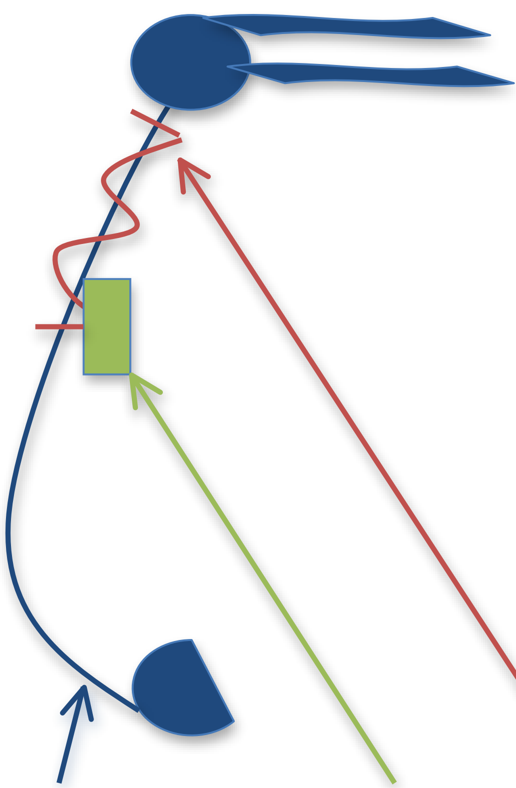
Kelp beds are complex, dynamic ecosystems that have major effects on marine ecosystems as a whole. The effects kelp beds have on adjacent communities is largely due to the transport of particles. The effect that flow has on these community differences will be explored. In this study I will look specifically at the differences in zooplankton communities in and out of surface canopy kelp beds consisting of *N. luetkeana* in the San Juan Archipelago. Flow rate in the middle of the kelp bed, the edge, and directly outside were measured. The hypothesis was that there would be more pelagic copepods outside of the kelp bed, and more larval organisms inside the kelp beds due to reduced flow and more complex habitat to avoid predation.

Methods

This study compared flow in and around kelp beds to the corresponding pelagic zooplankton community at three sites in the San Juan Channel: the east and west kelp beds of Turn Rock and the kelp bed of One Mile Reef. The kelp beds on each side of Turn Rock are separated and therefore constitute two independent sites. The first part of my survey consisted of gathering flow velocity measurement inside, on the edge, and outside *N. luetkeana* beds. The hypothesis was that flow velocity would decrease further into the bed due to the physical drag of the kelp. The second part involved sampling zooplankton populations inside and outside of the kelp beds.

Average flow was measured by attaching alabaster blocks to individual *N. luetkeana* and comparing the weight before and after 12 hours and calculating the dissolution rate per hour. He blocks dissolved as a function of water flow with time being constant. Alabaster blocks were approximately 6cm by 7cm by 0.75cmand dried overnight before weighing to ensure no moisture contributed to the data. The blocks were then attached to the kelp via a 0.5m string looped to a zip tie just under where the pneumatocyst tapers. Another zip tie secured the block to the lower part of the stipe Diagram 1). Blocks were attached at low slack tide in the center of the bed, near the edge of the bed, and outside of the bed, and retrieved at the next low slack tide (approximately 12 hours later). The blocks outside of the bed served as the control and were attached to a cement brick anchor secured to a length of rope ending with floats of approximately the same buoyancy as *N. luetkeana* pneumatocysts. After deployment the blocks were re-dried, weighed, and the dissolution per hour was calculated.

Diagram 1: *N. luetkeana* Block Attachment Setup



Zooplankton sampling was done with a sump pump that pumped water through a plankton net. A large plastic bin was placed under the net and served to control the amount of water sampled through the net. 145L of seawater was sampled from inside and outside the kelp beds at each site at 0.5m depth. Samples were then concentrated and preserved in1.6% paraformaldehyde. Organisms were identified into different groups and counted. Populations within sites were then compared by averaging total counts and performing t-test on inside vs. outside as well as across sites.

Results

Flow Results

Data shows that there was a trend towards slightly higher dissolution rates outside of kelp beds than inside. This result was not significant, however ($p > 0.2$, ANOVA: figure 1). Recovery of alabaster blocks after 12 hours was not always successful, creating gaps in the data.

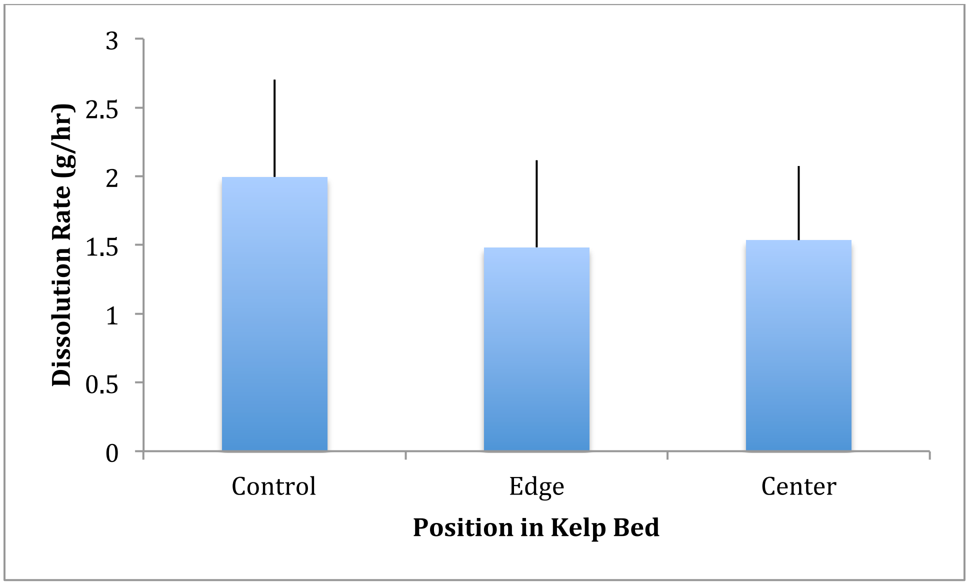


Figure 1: Average Dissolution Rates of alabaster blocks at All Three Sites. 19 blocks = 6 Control, 6 Edge, 7 Center. Error bars are one standard deviation

Average flows at Turn Rock sites appear to be higher than average flows at One Mile Reef ($p > 0.2$, ANOVA: Figures 2 and 3).

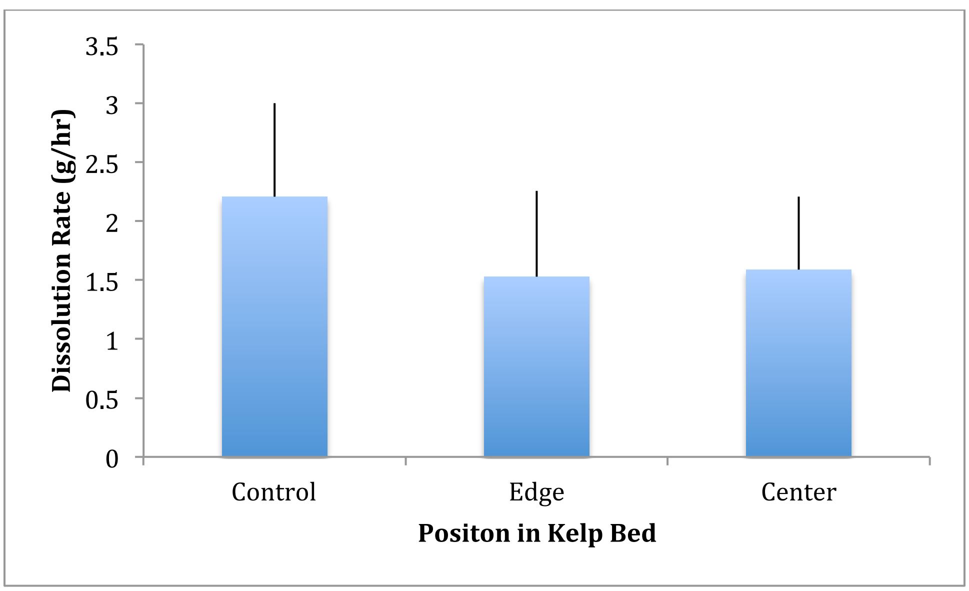


Figure 2: Average Dissolution Rates At Turn Rock Sites. 13 blocks- 4 Control, 3 Edge, 5 Center. Error bars are one standard deviation

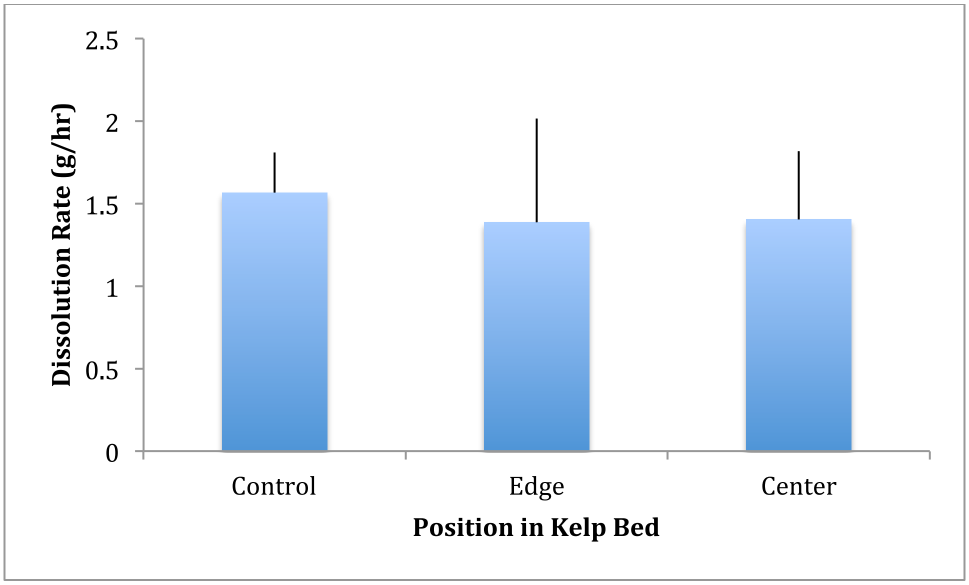


Figure 3: Average Dissolution Rates At One Mile Reef. 6 blocks-2 Control, 2 Edge, 2 Center. Error bars are one standard deviation

Flow rates on either side of Turn Rock are known to be comparable, however due to small sample size, collected data did not support this (p value > 0.2, ANOVA: Figure 4).

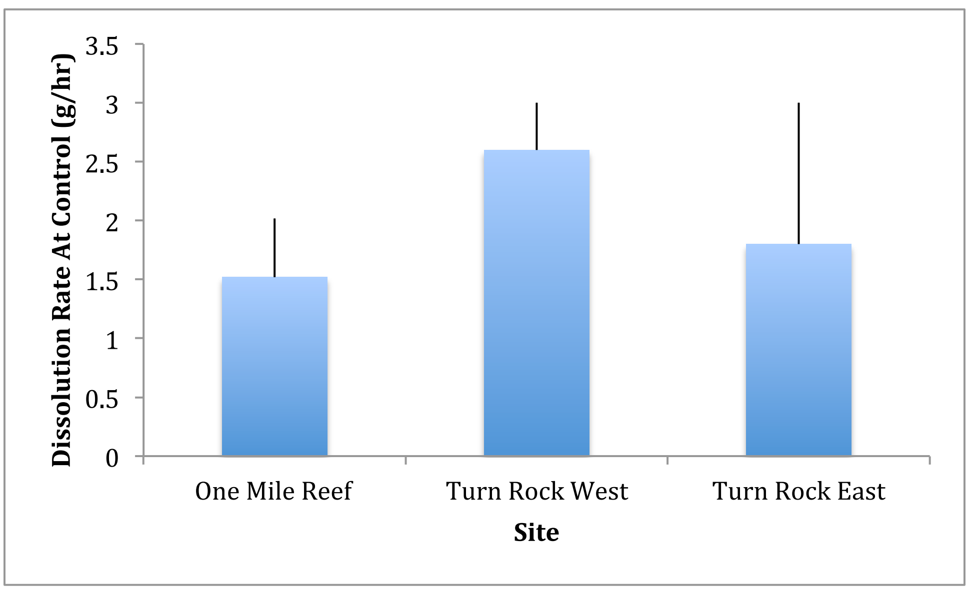


Figure 4: Average Dissolution Rates of Control At All Three Sites. 6 blocks- 2 controls per site. Error bars are one standard deviation

Zooplankton Results

Results showed zooplankton samples inside and outside of kelp beds at all sites to be the same (p value > 0.2, ANOVA: Figures 5,6, and 7). Calculating the average zooplankton density based on the mean total counts at all sites (individual/L) yielded a 0.25 ind/L difference, with the inside kelp beds having slightly more zooplankton.

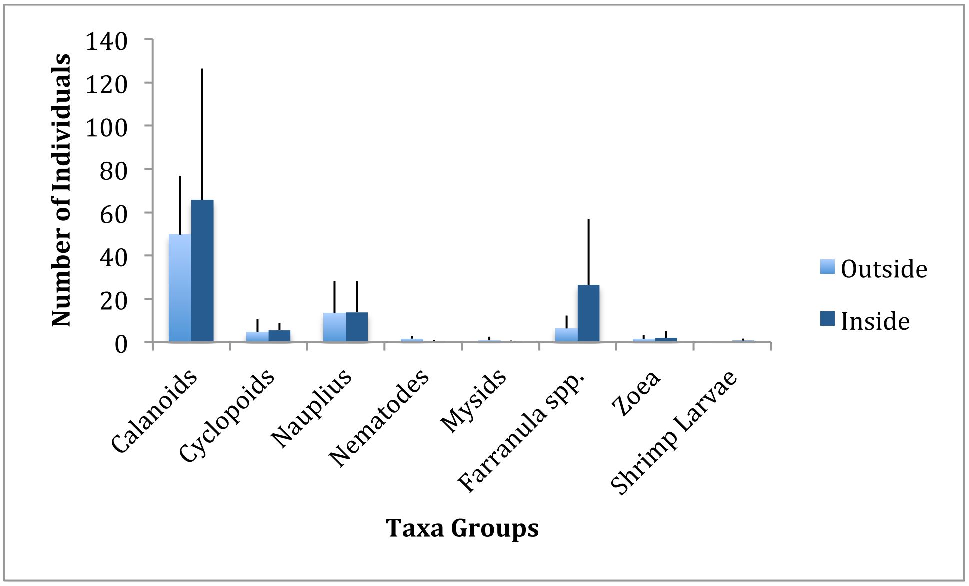


Figure 5: Average Zooplankton Numbers At All Three Sites. 12 samples total- 4 samples taken at each site: 2 inside and 2 outside. Error bars are one standard deviation

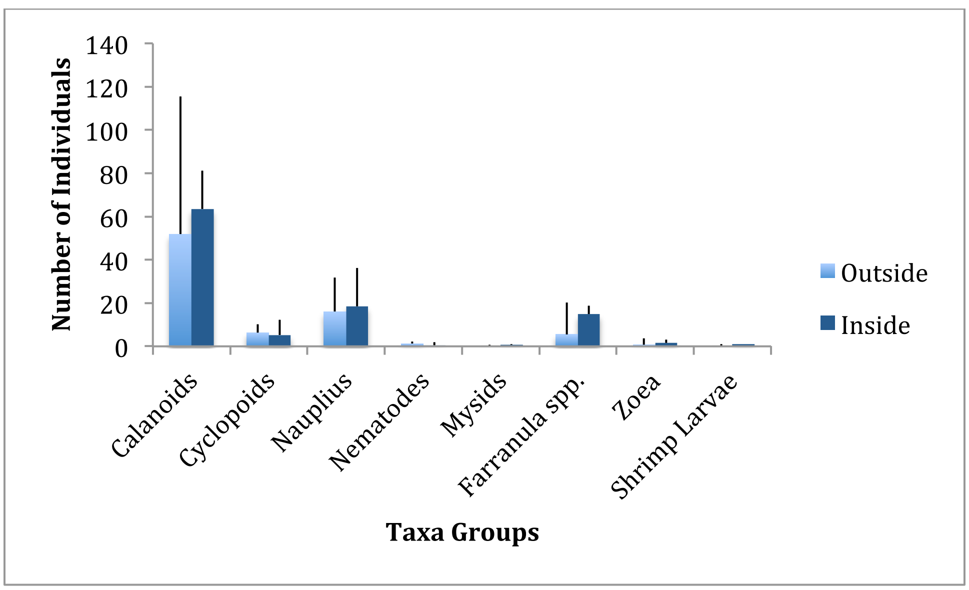


Figure 6 Average Zooplankton Numbers at Turn Rock Sites 8 samples- 4 samples taken at each site: 2 inside and 2 outside. Error bars are one standard deviation.

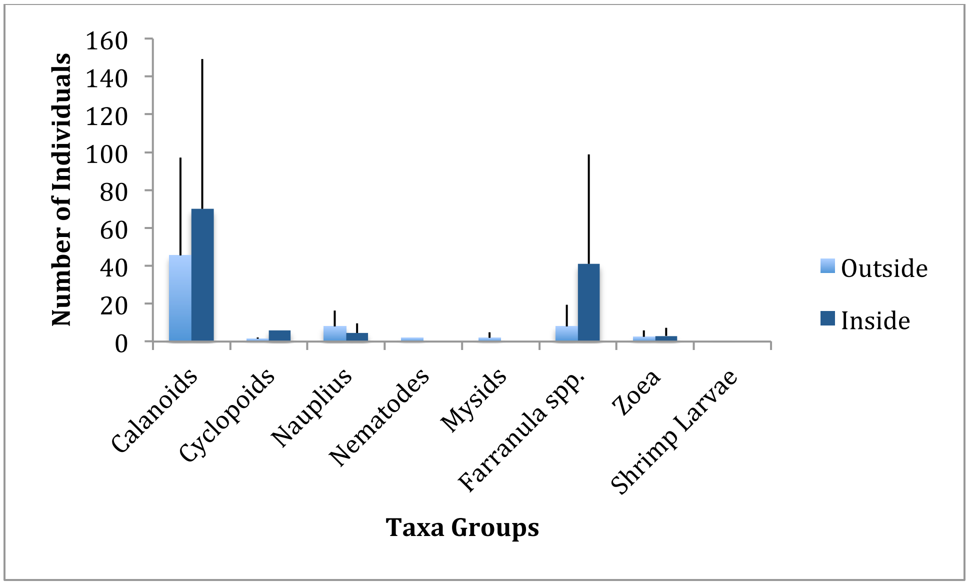


Figure 7 Average Zooplankton Numbers at One Mile Reef. 4 samples- 2 inside and 2 outside. Error bars are one standard deviation.

Calanoid copepods dominated samples both inside and outside the kelp beds. *Farranula* spp. cyclopoid copepods also appear to have a preference for kelp beds ($P > 0.25$, ANOVA: Figures 5 and 7). The number of *Farranula* spp. also increased dramatically between the first and second sampling rounds (5/31 low slack and 6/1 low slack).

Discussion

Flow field data suggests that kelp beds do have reduced flow in comparison to the surrounding pelagic environment. This is likely caused by the collective physical drag that the kelps exert on passing water. This, along with the fact that kelp beds provide complex 3D structures to hide in, may be one of the reasons why many larval and juvenile animals live in them. Data also suggest that flow at Turn Rock sites is higher than that of One Mile Reef (see figure 4) and therefore allowed a comparison between higher flow sites and lower flow sites.

The trends in zooplankton data could suggest that Calanoids are more abundant in a pelagic environment, while cyclopoids (specifically the *Farranula* spp.) prefer a kelp bed environment (Figures 5 and 7), although densities of zooplankton were not significantly different between inside and outside of kelp beds. The samples taken in and out of kelp beds at Turn Rock also appeared to be more uniform than the samples taken in and out of One Mile Reef (Figures 6 and 7). This may be due to there being a higher flow rate at Turn Rock sites, which resulted in zooplankton being physically forced out.

The effect that flow has on specific kelp beds could lead to different results in zooplankton communities in the same local area. Flow could also affect how specific beds interact with surrounding habitats like the intertidal or drift habitats. Certain kelp beds may contribute more material to different areas based on the strength and direction of the water flowing through it. One Mile Reef was a rockier, shallower bed with lower flow that tended to have more floating kelp detritus in it than either of the two Turn Rock beds. Flow is one of the many features that make each kelp bed unique and therefore gives rise to differing ecosystem interactions. Once again the effects that kelp beds have on surrounding habitats is more intricate and complex than originally thought.

The lack of uniformity of the kelp beds may have also contributed to higher velocity inside (i.e. a gap running through the center). More flow trials and zooplankton sampling regularly done over the course of a tidal month would be needed to draw stronger conclusions based on field data.

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