

PROGRESS REPORT

Hovel and Regan: Eelgrass in San Diego Bay: Assessing Eelgrass Habitat Function for Recreationally Important Species

Funding dates: February 1, 2008 – September 30, 2010

Progress report date: May 1, 2010, covering February 2009, August 2009, and February 2010

Summary of project:

The goal of this proposed project is to enhance our knowledge of the function of seagrass as a habitat for recreationally important species in San Diego Bay (SDB). In SDB, eelgrass serves as a habitat for a variety of species such as juvenile giant kelp fish, barred and spotted sand bass, calico bass, and spiny lobster. Eelgrass may serve as an important refuge for these species, particularly in their juvenile stages, and eelgrass houses many small invertebrates that provide food. Despite the widely cited function of eelgrass as a nursery habitat for species such as these, critical information regarding the function of this habitat is missing. In this project we conduct experiments in SDB and in the new Coastal and Marine Institute Laboratory (site of the new Center for Bay and Coastal Dynamics) that are focused on the effects of eelgrass habitat structure on ecological relationships. These are intended to provide a more complete understanding of how eelgrass functions as a foraging and refuge habitat for organisms in SDB. We have integrated these experiments with a mathematical model that allows us to greatly increase the scope of the results. We also have to use our experiments and model to educate San Diego's youth about marine ecology and the importance of habitat in SDB. In addition to educational benefits for K-12 students, undergraduate, and graduate students, our results can benefit SDB by informing predictions of the consequences of eelgrass loss for SDB organisms, and will provide improved ability to restore seagrass in the event of habitat loss.

Expected results and progress:

The expected results listed in our proposal were:

1. Complete a field experiment in San Diego Bay that examines how seagrass habitat characteristics interact with predation to dictate the abundance and distribution of several seagrass-dependent species.
2. Complete laboratory experiments focused on the effects of organismal behavior on prey survival.
3. Complete a revised version of our predator-prey model using information gleaned from field experiments that predict the consequences of eelgrass loss for SDB, meet with Port personnel to describe the scope of our findings, and submit recommendations for conservation and restoration of eelgrass in SDB based on our findings.

4. Complete a program in which SDSU graduate students and faculty teach K-12 students in two local afterschool programs about the value of SDB habitats for marine species and the value of using mathematical tools to study marine animals.

Our progress to date on these expected results is:

1. *Complete a field experiment in San Diego Bay that examines how seagrass habitat characteristics interact with predation to dictate the abundance and distribution of several seagrass-dependent species*

The field experiment in SDB has been completed; see attached figures 1 – 4. This study was the major portion of a master's thesis for a San Diego State University graduate student, Eliza Moore. In this study, sampling and experimentation were used to determine the preferred habitat of fishes (predators) and invertebrates (prey). We sampled within the edge and interior of eelgrass beds in three locations in SDB for fish abundance and diversity, abundance and diversity of invertebrates, and eelgrass habitat structure. Briefly, we found that eelgrass habitat structure increases from the edge to the interior of beds, that fish preference for edges or interiors varies by species, and that many epifaunal invertebrates prefer dense eelgrass, regardless of location within the bed. In an accompanying field experiment in which we controlled fish (predator) access to discrete areas of eelgrass beds, we found that eelgrass complexity (e.g. the density of eelgrass shoots, or relative biomass of shoots) was the overriding factor in dictating where most small invertebrates (that serve as food for fishes) would be found. However, variation in this trend was prominent, with different species having different preferences.

This portion of the project was published in *Oikos*, a widely-read and high-impact peer-reviewed ecology journal, in early 2010.

2. *Complete laboratory experiments focused on the effects of organismal behavior on prey survival*

One set of laboratory experiments have been completed; the other set of experiments now are being conducted.

The completed experiments (see figures 5 – 6) were performed by an undergraduate honors thesis student at San Diego State (Rachel Lannin). They took place in laboratory aquaria and sought to determine how the structural complexity of seagrass influences the behavior of fish predators and their invertebrate prey during predator-prey interactions. In this experiment, we exposed grass shrimp (prey) to fish predators (juvenile giant kelp fish) in laboratory aquaria, and monitored the foraging behavior of fishes and the escape behaviors of shrimp as the amount of habitat structure in aquaria changed. By transplanting eelgrass into aquaria, shrimp and fish were provided with 6 different levels of eelgrass structure, ranging from very low (20 shoots per m²) to high (320 shoots per m²). We determined whether the survival rate of shrimp varied with the amount of eelgrass structure (this is known as the “habitat-survival function”) but also how fish altered their foraging strategies, and shrimp their escape strategies, with increasing habitat structure. Additionally, we added a treatment in which the abundance of shrimp prey increased with seagrass structural complexity, as this more closely resembles reality. Briefly, we found that shrimp survival increased with seagrass structure to a point, but that the chief cause of the increase in survival appeared to be safety in numbers, rather than an effect of seagrass structure on foraging efficiency of predators (or escape behaviors of prey). In other words, if more shrimp

are found in an area of high density seagrass (which we observed was true from objective 1), each shrimp has a reduced chance of being consumed because predators have more shrimp to choose from. This conclusion was supported by the fact that (1) shrimp did not change their escape behaviors with seagrass structure, and (2) fish efficiency at finding shrimp increased with seagrass structure, rather than decreased with structure. Our results are similar to those from some recent studies in Gulf Coast seagrass beds and are interesting because they suggest that increasing seagrass habitat structure does not necessarily result in increased safety for prey (due to habitat structure per se) and decreased efficiency for predators.

The experiments that are underway are being conducted by Kelly Tait, and MS student in the Hovel lab, and are being conducted in outdoor mesocosms provided with flow-through seawater from San Diego Bay. These experiments are designed to determine how seagrass structure influences habitat selection behaviors by epifaunal organisms (grass shrimp). Shrimp are provided with choices of simulated eelgrass habitat within mesocosms (dense eelgrass or sparse eelgrass). Shrimp are released into the mesocosms and allowed to select habitat over a 24 h period, at which point they are collected and their selection is determined. After an initial set of selection experiments with only shrimp and simulated eelgrass within mesocosms, we place fish predators in mesocosms to see how threat of predation influences shrimp decision making. Preliminary results suggest that shrimp prefer dense to sparse eelgrass (which coincides with results from the field experiments in objective 1), but that an increased threat of predation from fishes can reverse this preference (figure 7). This lab experiment is being accompanied by field experiments within seagrass habitat at Shelter Island that are designed to determine if habitat selection by prey organisms under natural conditions mirrors that seen in the laboratory under more controlled conditions (see figure 8 for preliminary results that suggest that shrimp remain in dense seagrass regardless of a predatory threat from fishes, but leave sparse seagrass at higher rates under predatory threats from fishes).

3. *Complete a revised version of our predator-prey mathematical model using information gleaned from field experiments that predict the consequences of eelgrass loss for SDB*

In June 2008 and 2009, PIs Hovel and Regan revised the existing initial mathematical model of how predator and prey organisms interact in eelgrass habitat and how this is influenced by habitat structure. The overall goal is to determine what factors lead to the highest success of juvenile fishes, which constitute mesopredators in seagrass beds (i.e., those animals that hunt for prey, but also are hunted as prey). In 2008, the primary upgrade to the model was the inclusion of habitat complexity (e.g. shoot density and relative biomass) into the digital “landscapes” within which our digital “organisms” interact. Previously, we used the model to evaluate how seagrass habitat fragmentation influenced predator-prey interactions among fishes (predators) and prey (invertebrates like grass shrimp). Now, we have incorporated variability in eelgrass habitat complexity into the landscapes, and based the patterns of habitat complexity on real maps of SDB eelgrass beds obtained from scans made by a scientific echosounder (data obtained by Hovel and Dr. Kwang-Young Kim of Chonham University in Korea; see figure 9). The scans, made in different seasons, have allowed us to structure the modeled landscapes to simulate those in SDB. We are now awaiting the final data analysis of the lab experiment and field experiment so that we can include those results in the model, specifically, aspects of predator and prey behavior and habitat preferences for each trophic level.

In 2009 the PIs incorporated a much more extensive behavioral repertoire for predator and prey organisms into the model. Prey have preferences for particular habitat types (e.g. dense seagrass, or patch edges) based on results from the field experiments from objective 1. Predator and prey behaviors change with eelgrass structure, based on the laboratory experiments conducted already, and those presently being conducted. Preliminary results are presented in figure 10. Briefly, these results suggest that mesopredator success (a combination of how much prey they can consume and how well they survive) change dramatically with different conditions and behaviors, such that increasing levels of dense eelgrass may increase or decrease success.

4. *Complete a program in which SDSU graduate students and faculty teach K-12 students in two local afterschool programs about the value of SDB habitats for marine species and the value of using mathematical tools to study marine animals.*

We have conducted a variety of exercises with the Ocean Discovery Institute (formerly Aquatic Adventures) to educate underrepresented youth about marine ecology, the value of marine habitats, and mathematical modeling. The group has visited the Coastal and Marine Institute Laboratory to conduct an experiment examining how habitat influences predator-prey interactions. This simple experiment quantified how the efficiency of hunting for small fishes changes with the addition of habitat structure into experimental arenas. Second, we have conducted two instructional sessions in the SDSU Biology Department's computer laboratory, in which students used our mathematical model to perform an experiment on predator-prey interactions in simulated seagrass habitat. The students were given a short lecture to introduce the concept of modeling, and they then followed instructions to build their own mathematical model in NetLogo. This simple model allowed the students to create a world in which predator and prey organisms interact, and in which habitat can be added or removed to act as a protective area for prey. Finally, the students used our full model for seagrass habitat to test how changing the behaviors of the organisms influenced the effectiveness of seagrass nursery habitat.

The following is an email received from the Ocean Discovery Institute after our February 2010 computer lab exercise.

Kevin –

We loved the opportunity to work with you last week. Exposing our students to as many hands on opportunities with scientists as possible is definitely a cornerstone to our program. We appreciate the time and effort you dedicate to this program with innovative ideas that push our students to think in different ways about science and see the opportunities that their education can afford them.

I'll include this link in our weekly newsletter to our students – I'm sure they will be very excited!

Thanks so much Kevin!

Take care ☺

Melissa

Melissa Katigbak

After-School Programs Coordinator

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Figure 1. Sites for surveys and experiments for Objective 1. SI = Shelter Island, NCB = north Coronado Bridge, SCB = South Coronado Bridge.

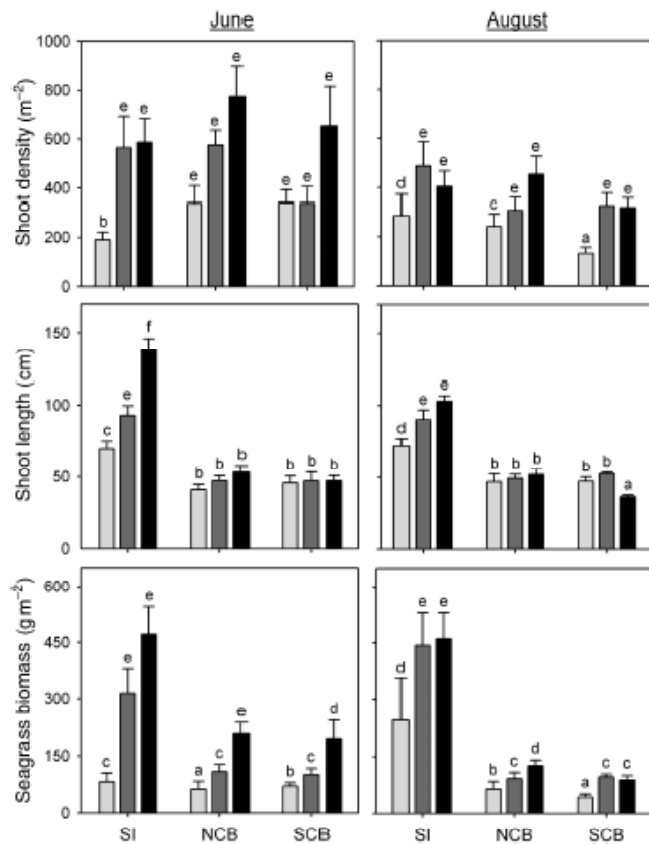


Figure 2. Results of eelgrass sampling surveys in 2008 showing that eelgrass habitat structure (measured as biomass, shoot length, or shoot density) generally increases from eelgrass patch edges (light gray bars) to inner edges (dark gray bars) and interiors (black bars), but that trends are site-specific. Sites are Shelter Island, North Coronado Bridge, South Coronado Bridge.

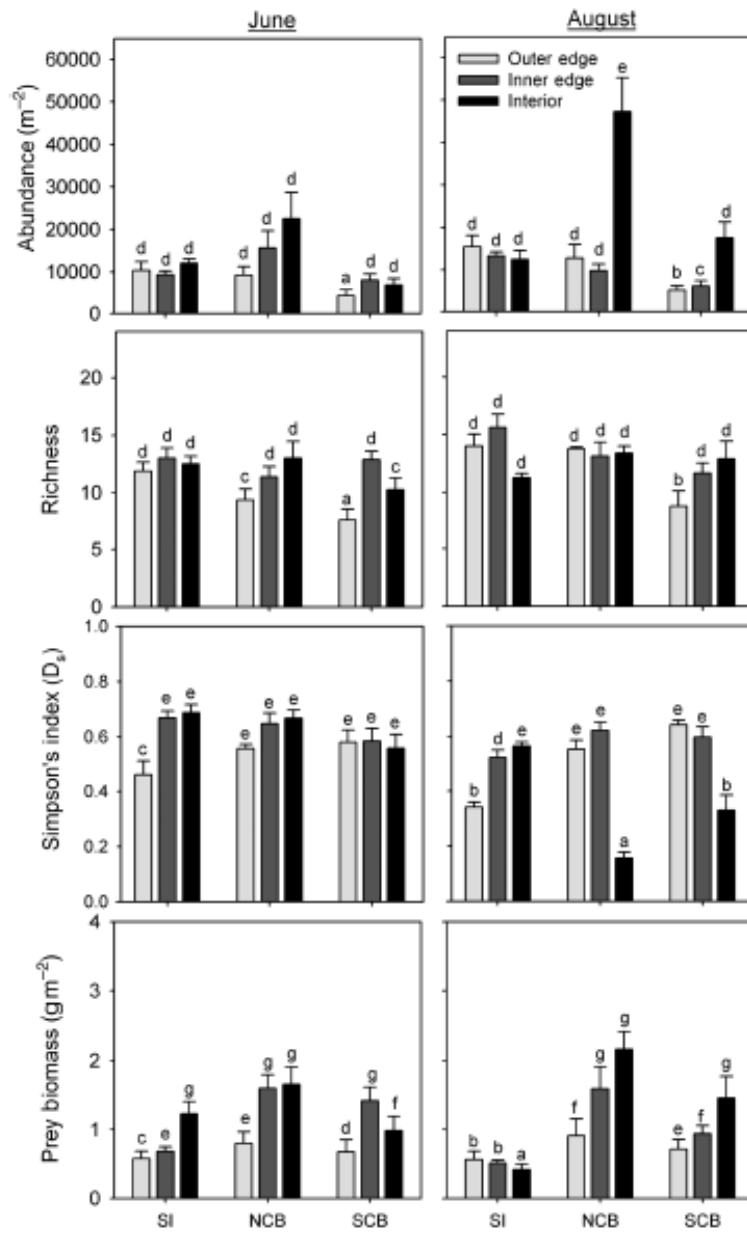


Figure 3. Abundance, species richness, diversity, and biomass of epifauna (generally, small crustaceans and mollusks that serve as prey for fishes) at three sites (Shelter Island, North Coronado Bridge, South Coronado Bridge) in SDB in 2008. Bars, from left to right for each group, represent samples at edges, inner edges, and interiors of eelgrass patches.

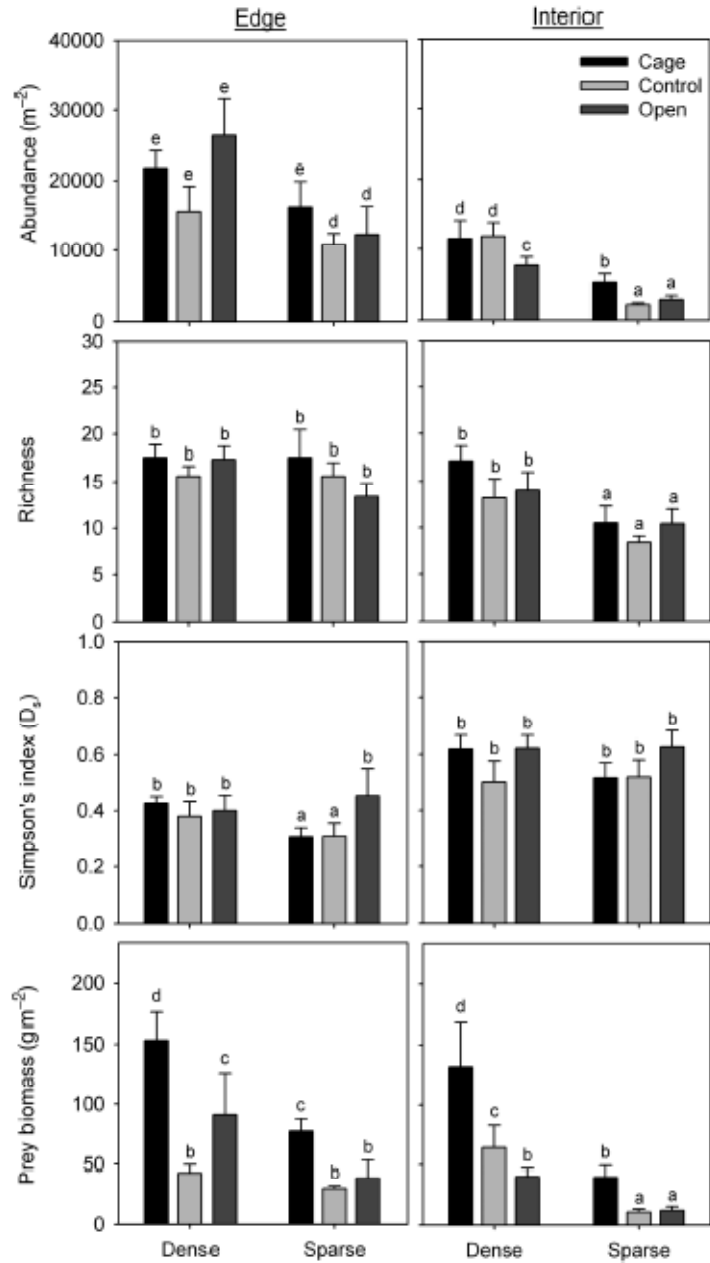


Figure 4. Results from the field experiment in 2008. Artificial seagrass (dense or sparse) was used to control seagrass habitat structure in small plots within the edges or interiors of eelgrass patches. Caged plots were protected from fish predation, and open and control plots allowed fish predators access to the artificial seagrass. The experiment tested whether the epifaunal community differed between patch edges and interiors, between dense and sparse seagrass, and between treatments with and without fish predators. Generally, epifauna (prey for fishes) preferred dense eelgrass, though some common prey items (e.g. amphipods) preferred patch edges. Fish predation overall was not as important as location and structure in dictating epifaunal abundance.

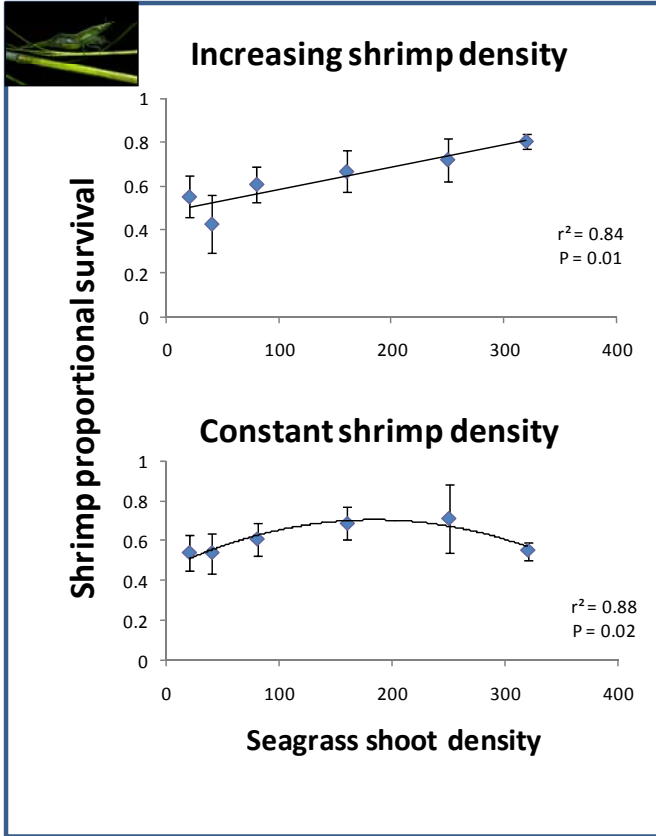
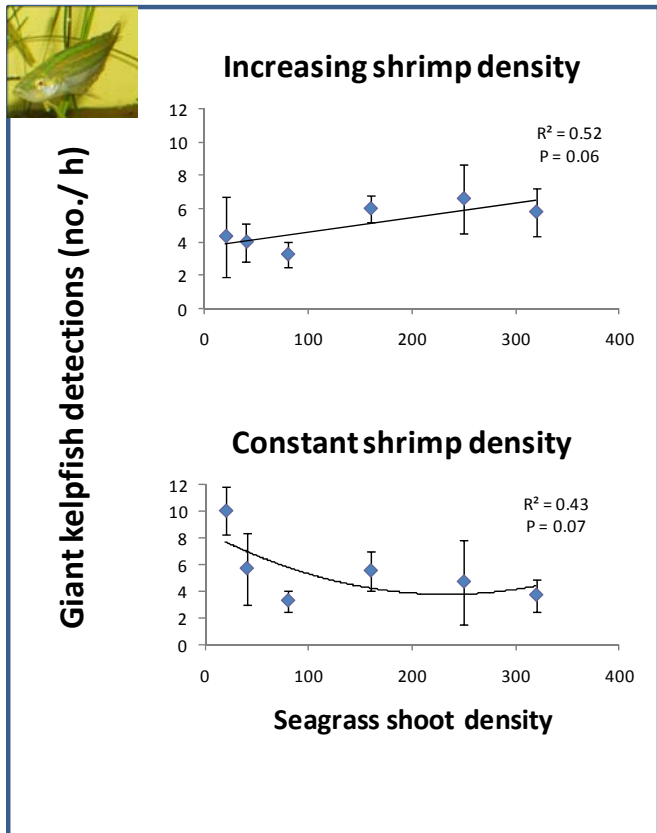


Figure 5. Results from the laboratory experiments for objective 2. As seagrass structural complexity increased, grass shrimp prey had higher survival when grass shrimp density increased with seagrass structure, but not when shrimp density was held constant. Increases in shrimp density with structure are common for small crustacean prey in seagrass habitat, but the protective value of seagrass often is experimentally assessed with constant levels of prey.

Figure 6. Results from the laboratory experiments for objective 2. As seagrass structural complexity increased, juvenile giant kelpfish predators were able to detect more prey when shrimp density increased with seagrass structure, but not when prey density was held constant.



Giant kelpfish detections (no./h)

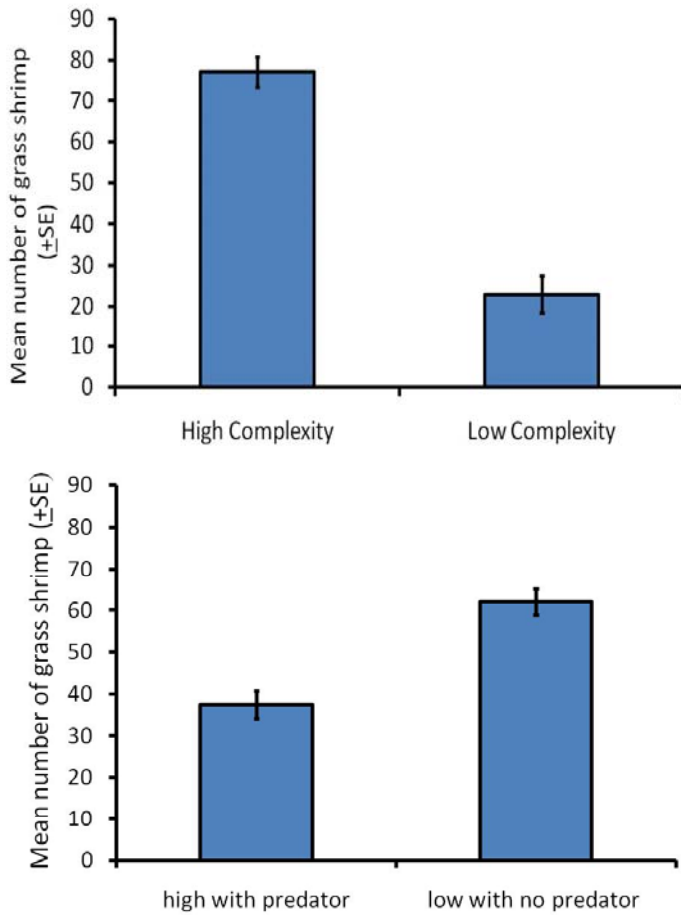


Figure 7. Preliminary results from laboratory mesocosm experiments in which shrimp prey are allowed to choose between high complexity and low complexity seagrass. In trials without predators (upper panel), shrimp strongly prefer high complexity seagrass. When predators are added to the high complexity seagrass (lower panel), shrimp switch their preference to low complexity seagrass.

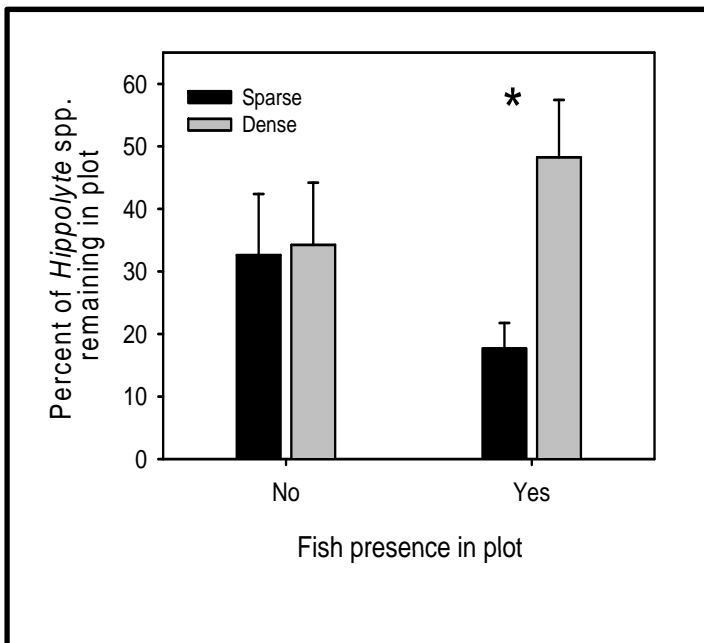


Figure 8. Results of a manipulative field experiment conducted at Shelter Island in San Diego Bay in summer 2008 to examine retention rates of grass shrimp in sparse and dense seagrass patches. Grass shrimp (200 m⁻²) were stained with neutral red and released within cages that excluded mesopredators or included mesopredators (= 2 juvenile giant kelpfish). Data represent the percent of stained shrimp that remained within the starting location after 2 h. Error bars denote 1 SE.

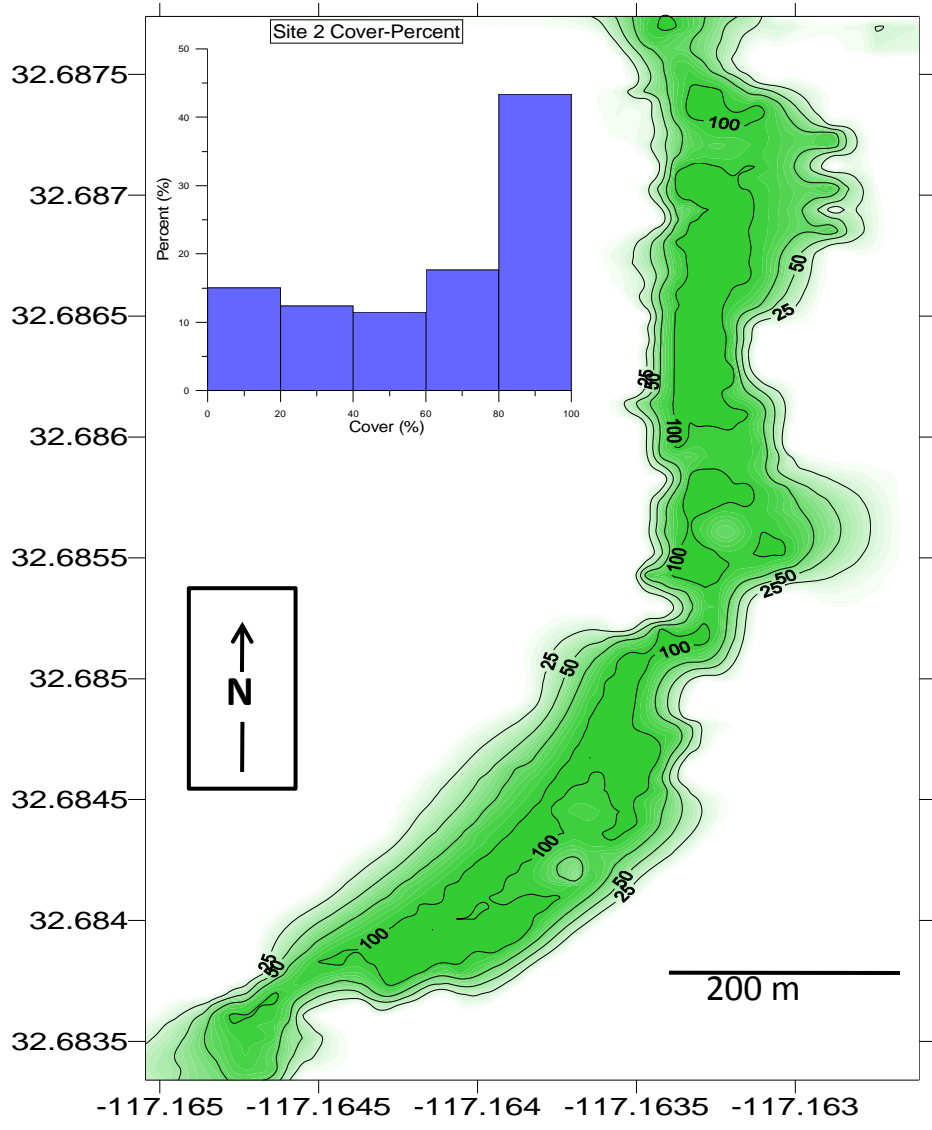


Figure 9. Map of seagrass biomass at Shelter Island in summer 2008. Contour lines denote relative levels of seagrass biomass, with 100% representing full seagrass cover. Note how biomass generally increases from the patch edge to interior. Inset shows the proportion of total seagrass habitat comprised of each biomass category; this site is dominated by high eelgrass biomass.

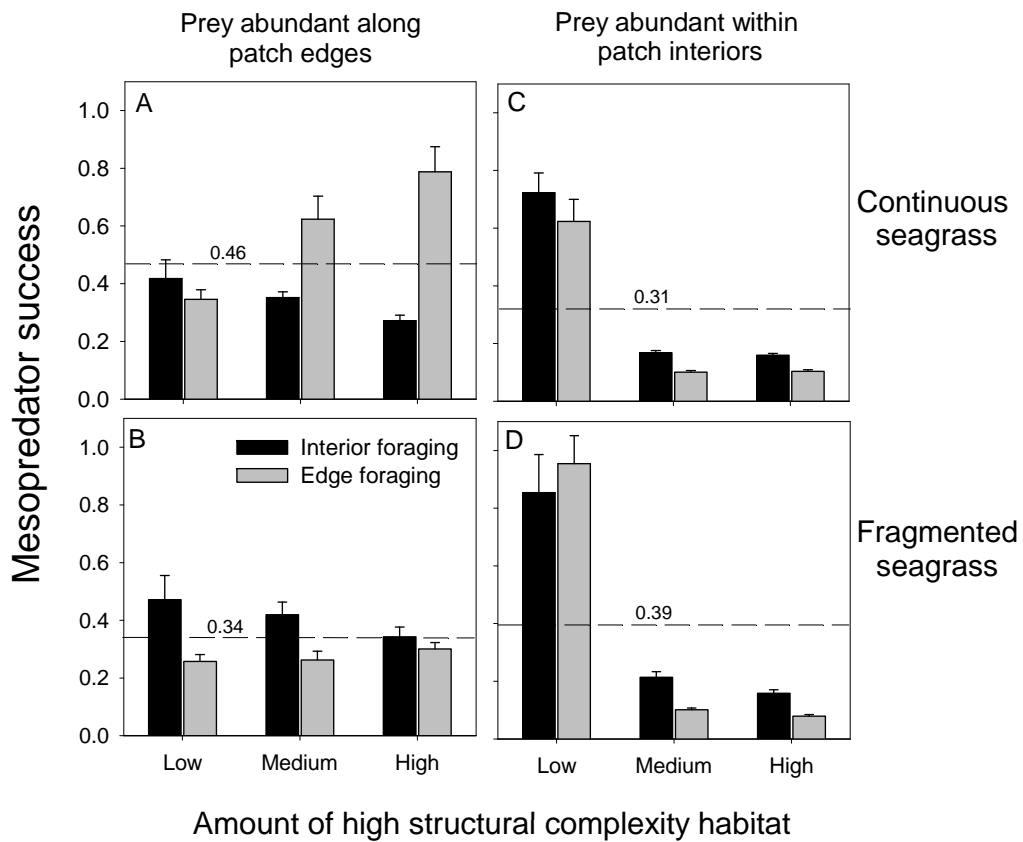


Figure 10. Preliminary results from the mathematical model in which prey and predators are placed into continuous or fragmented seagrass habitat. Within each landscape type, the amount of seagrass that constitutes protective, high complexity seagrass varies from low, to medium, to high. In keeping with results from the field, epifaunal prey are either abundant along patch edges, or within patch interiors. Finally, the predators are provided with preferences for foraging at patch edges, or within patch interiors. The preliminary results indicate that the success of juvenile fish mesopredators (Y axis; this is a ratio of prey consumed to mortality, with higher success representing more prey consumed and higher survival) increases with structural complexity in continuous seagrass when prey are abundant along patch edges and fish mesopredators forage along edges. In all other situations, however, mesopredator success decreases with structural complexity, either due to lower prey biomass consumed (e.g. if prey are abundant in regions not commonly occupied by fish mesopredators) or if fish mesopredators have lower foraging success due to an increase in structural complexity.