The Composition of Benthic, Epibiont, and Fish Communities within the Mangroves on Isla San Jose

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Abstract

Mangroves are a unique environment that sit on the edge on the land to ocean boundary in subtropical and tropical environments. This study focuses on the community composition of the mangroves on Isla San Jose in Baja California Sur, Mexico. We evaluated the bottom up controls and the impact of the intermediate disturbance hypothesis within this environment. We looked at the different areas of this habitat including, the main channel, two side channels and the lagoon. In each site we looked at the composition of the benthos, epibionts on the mangrove roots, and the fish community. We predicted that the benthic cover in each location would differ from each other. We predicted that the percent cover of algae, invertebrates, and bare root will differ between sites. In addition to this we expected to see a difference in the types of invertebrates as well. Finally, we predicted that an intermediate level of flow rate would support the highest abundance of invertebrates and fish populations and nutrient availability would have a bottom up control within the system. We found a significant difference in the percent cover of substrate and organic matter for the primary layer of the benthos and of deadwood, coral, leaf, algae, and none for the secondary layer of the benthos between locations. We also found a significant difference in the types of invertebrates between locations as well as the abundance of fish. Though there was a significant difference between the lagoon and channels, the main and side channel were found to not differ significantly from each other. It was found that the intermediate disturbance hypothesis did not have as great of an influence as the bottom up control via nutrient availability. This study provides support for protecting and managing mangroves based on more trophic levels, instead of focusing on the higher trophic levels, like fish. More research needs to be done to accurately capture a complete picture of this vast and complex system.

Introduction

One of the main concepts of ecology tries to explain how the biotic and abiotic factors in a community affects a system. There are two main ideas that try to explain how these factors control the system, top-down and bottom-up. Top-down controls focus on the predators and how their influence affects the prey and bottom-up looks at how the lower trophic levels affect the predators within the community (Menge, B.A. 2000). It has been argued on which control has the higher effect on a community, while others have argued for a combination of them. This paper focuses on the bottom up controls

the nutrients and the benthic environment in mangroves exert on the higher trophic levels.

Nutrients have been studied as exerting bottom-up controls on various systems. In the coral reef systems in Jamaica and southeastern Florida, nutrients have a large bottom-up control on the community (LaPointe, B.E. 1997). It determines the growth and healthiness of coral reefs, which have low nutrient content surrounding waters. These nutrients exert a control over the system that determines how the higher trophic levels, the corals, thrive in this ecosystem. Nutrients availability is essential to not only coral reef habitats but to other marine habitats as well.

The intermediate disturbance hypothesis suggests that local species diversity is maximized when ecological disturbance is neither too rare nor too frequent. At high levels of disturbance, late successional species are in danger of going extinct; and with no disturbance, early successional species can't establish themselves for an extended period of time. However, at intermediate levels of disturbance, diversity is maximized because species that thrive at both early and late successional stages can coexist. In the Mangrove forest on Isla San Jose, we found three distinct habitat types with differing flow rates at mid flood tide. We wanted to investigate how flow rate in the various habitats affected community composition.

Mangroves are a unique community that grow where the land and ocean meet. They are a diverse group of shrubs and trees that can withstand daily flooding and salinity levels that would kill most plants (Scholander, P. F. et al. 1962).There are two main root systems, prop roots that grow from the trunks and hang into the water and an underground root system. The prop root system provides a home for numerous marine animals, including fish, sea turtles, crustaceans, and encrusting and mobile invertebrates (Nagelkerken, I. et al. 2000). They also play a crucial role as nursery communities for many juvenile organisms, mainly fish. This nursery habitat allows populations of commercial fish species to thrive and continually be replenished. However more and more mangrove communities are being converted to commercial shrimp farms and being destroyed for their wood, depleting these vital habitats.

The purpose of this study was to investigate the complex relationship between communities in mangrove ecosystems. Tidal changes create water flow throughout the various mangroves channels, with the greatest flow occurring near the mouth and main channel and the least amount of water flow occurring deeper in the forest. This water flow was used as a proxy for nutrient cycling. Using nutrients as the main bottom up control in the system, we looked at the composition of the benthic community as a determinant for nutrient availability in the system.

We used the mangroves on Isla San Jose in Baja California Sur in Mexico to test the bottom up controls and the intermediate disturbance hypothesis influences within a particular environment. These mangroves are home to one of the most endangered marine animals, the hawksbill turtle, *Eretmochelys imbricata.* The mangroves are

growing in a arid, tropical environment creating a stark contrast between the desert to mangrove transition. This makes these mangroves particularly interesting because of the immediate change in habitat that occurs. The main channel, two side channels, and a part of the east side of the lagoon were measured in this study over a two week period in May of 2017. The flow rate in the mangroves was measured as the variable which influences these communities through the intermediate disturbance hypothesis and the bottom up controls via nutrient cycling.

The primary layer and secondary layer of the benthic environment was measured and is predicted to differ in percent cover of what materials are there between the three sites. We measured the epibiont communities on the mangrove roots and looked at which type of invertebrates lived in this habitat. It is predicted that the percent cover of algae, invertebrates, and bare root will differ between the three sites and that the types of invertebrates will differ as well. We predict the abundance of fish in each location to vary between sites. We hypothesized that an intermediate level of flow rate supports the most abundance of invertebrate and fish populations. Insight into these relations could better help protect these vital habitats from further destruction. AS well as give us a better idea on other mangrove habitats and how they impact the community around them

Methods and Materials

Study Site

This study took place in the mangroves of Isla San Jose in the Sea of Cortez over two weeks in May 2017. The mangroves are located on the south side of the island and are 2.98km wide and 3.75km across. Of this area, we sampled within a 776m location. Two main species of mangroves grow in this area, the red mangrove, *Rhizophora mangle*, and the white mangrove, *Laguncularia racemosa*. The three main study sites were the main channel, side channel and lagoon. The three sites were broken down into the east and west sides of the main channel, two side channels, and the lagoon, the west side was sampled for approximately 260m. In each site, the community composition of the benthos, mangrove roots, and fish were measured and compared to each other.

General Methods

At each location, we started 20 kicks away from the intersections of the sites to keep the site samples independent of each other. At each sample point, we placed a quadrat on the bottom and recorded benthic data. After the data was collected, the root quadrat was placed directly above the benthic quadrat. Each sample was done 10 kicks away from each other. To keep the distance similar, the same person performed the kicks each time in each location. The fish videos were done at the starting point of the

samples. We would then swim 60 kicks away from the video rig and work backwards, marking with flag tape the end of the 60 kicks. Samples were taken at different tide levels to account for tidal bias. To test flow rate we set a neutrally buoyant floatation device in the water in each of the locations. Once the device was in the water the time was recorded. It was allowed to float for 45 seconds. After that time period distance in meters was recorded. We ran this test three times and took an average to obtain the flow rate of each location.

Benthic Methods

To measure percent cover of the benthos, a 0.5m x 0.5m, four-sided quadrat was used. String was used to create 16 squares with 9 cross-over points. At each point, the substrate, primary layer, and secondary layer was measured. Silt and sand were the two substrates of the sampled sites; sand in the main and side channels and silt in the lagoon. Silt was defined as having a more fine,clay-like texture with a mix broken shells, corals, and other carbonate material; sand had a more grainy texture with a mix of larger broken shell and coral as well as organic substances like splintered wood. If a point landed on the fragments defined in the substrate, it was marked as the substrate type.

The primary layer was categorized as substrate, algae, organic material, coral, rock, invertebrate, and root. Primary organic matter was defined as the thick, detritus material that was immediately on top of the substrate. If this material was not directly on the substrate, it was categorized as a secondary layer. Primary coral is coral that has a layer of sediment on top, if it didn't have this layer it was marked as a secondary layer. Primary invertebrates were organisms that were physically attached to the ground, like the mucus sacs of tube worms. Substrate was categorized as that if there was nothing on top of the substrate.

The superlayer was recorded as anything that was on top of the primary layer. The layer was categorized into dead wood, coral, leaf, shell, algae, invertebrate, none, and organic matter. Secondary algae was any algae that was not growing directly on the substrate. Secondary invertebrates were organisms that were not attached to the substrate, like a nudibranch or a tunicate. The secondary dead wood was any wood that wasn't splintered or mixed in with the substrate, like a dead branch.

Root Methods

In order to sample root composition, a Point-Contact survey was conducted at each site. A 0.5x0.5 meter quadrat was laid in exactly the same spot that the benthic data was collected. The quadrat was used at each sampling site to choose three roots to be sampled. If less than three roots fell within the quadrat then the next closest root was used. On each of the three roots, a rope with 5 knots measuring 7cm apart was used. The first knot was placed at the water line and was not sampled, the four knots

afterwards were laid vertically down the root and at each knot the type of invert, algae, or bare root was recorded. Initially we only recorded if the knot landed on an invert algae or bare root. Once a difference between the sites was established the type of invertebrates were broken down into tunicate, sponge, bryozoan, hydroid, tube worm, and barnacle; and the type of algae was broken down into red/green algae and diatomaceous brown algae (DBA). From the points recorded, the total percent cover of each sample of three roots was obtained. This was repeated at each of the three locations.

Fish Survey Methods

To measure fish abundance in the three different locations we used two GoPro cameras. The cameras were set in a location and allowed to run for twenty minutes. Of that twenty minute video only the middle five minutes were sampled. This allowed the bottom substrate to settle and the fish to come back to the area. By doing this it controlled for the fish being frightened by divers or the camera. After cameras were collected they were moved to a different location in each site and run again. There was a total sample size of twenty one. When looking at the recordings the observed fish were divided into three different categories based on what was seen the most frequent. Yellow Snapper (*Lutganis argentiventris*), Sergeant Major (*Abudefduf troschelii*), and other which contained a wide variety of other species. We looked at the total abundance of fish across each location.

Results

Flow Rate Results

Flow rate was measured in m/s. On the west side of the main channel the average flow rate was 0.2108m/s and on the east side it was 0.0893m/s with an average flow in the main channel 0.15005m/s. In the lagoon, the flow rate was 0.06245m/s and in the side channel it was 0.1118m/s.

Location	Flow Rate of Water (m/s)
Main channel	0.15005 ± 0.0339
Side channel	0.1118 ± 0.0265
Lagoon	0.06245 ± 0.0103

Table 1: Average flow rate of each location ± standard error.

Benthic Results

An ANOVA test was run for all comparisons. Of the measured primary categories, percent cover of substrate and organic matter has significant values across the three

locations ($F_{0.05,29}$=13.1591, p<0.05; $F_{0.05,29}$=18.6419, p<0.05, respectively). The other categories were not significant (Algae, $F_{0.05,29}$=1.7422; coral, $F_{0.05,29}$=1.7438; rock, $F_{0.05,29}$=0.7364; invert, $F_{0.05,29}$=0.1824; root, $F_{0.05,29}$=0.7291; p>0.05).

A Tukey test was run for further analysis. Substrate and organic matter were analyzed as they were significant through the ANOVA analysis (p<0.05). For substrate, the comparisons lagoon vs. main channel and lagoon vs. side channel were significant (p=0.0001, p=0.0018, respectively). The comparison between main channel and side channel was not significant (p=0.3547). For organic matter, lagoon vs. main channel and lagoon vs. side channel was significant (p<0.0001, p=0.0003, respectively) but main channel vs. side channel did not differ significantly (p=0.1988)

Of the measured secondary layer categories five had significant p-values, deadwood ($F_{0.05,29}$=5.7927,p<0.05), coral ($F_{0.05,29}$=5.2412, p<0.05), leaf ($F_{0.05,29}$=4.7439, p<0.05), algae ($F_{0.05,29}$=3.9789, P<0.05), and none ($F_{0.05,29}$=3.8793, p<0.05). The other categories did not have significant values, shell ($F_{0.05,29}$=1.2744, p>0.05; $F_{0.05,29}$=0.1227, p>0.05; $F_{0.05,29}$=1.7602, p>0.05)

A Tukey test was run on the variables used as proxies for nutrient availability (p<0.05). For deadwood, lagoon vs. side channel was significant (p=0.0062) but lagoon vs. main channel and main channel vs. side channel were not significant (p=0.3544, p=0.1660, respectively). For leaf, main channel vs. side channel and main channel vs. lagoon were significant (p=0.0231, p=0.0432, respectively) but side channel vs. lagoon did not differentiate significantly (p=0.9943). For algae, side channel vs. lagoon differed significantly (p=0.0430) but main channel vs. lagoon and main channel vs. side channel did not differ significantly (p=0.0612, p=1.0000, respectively).

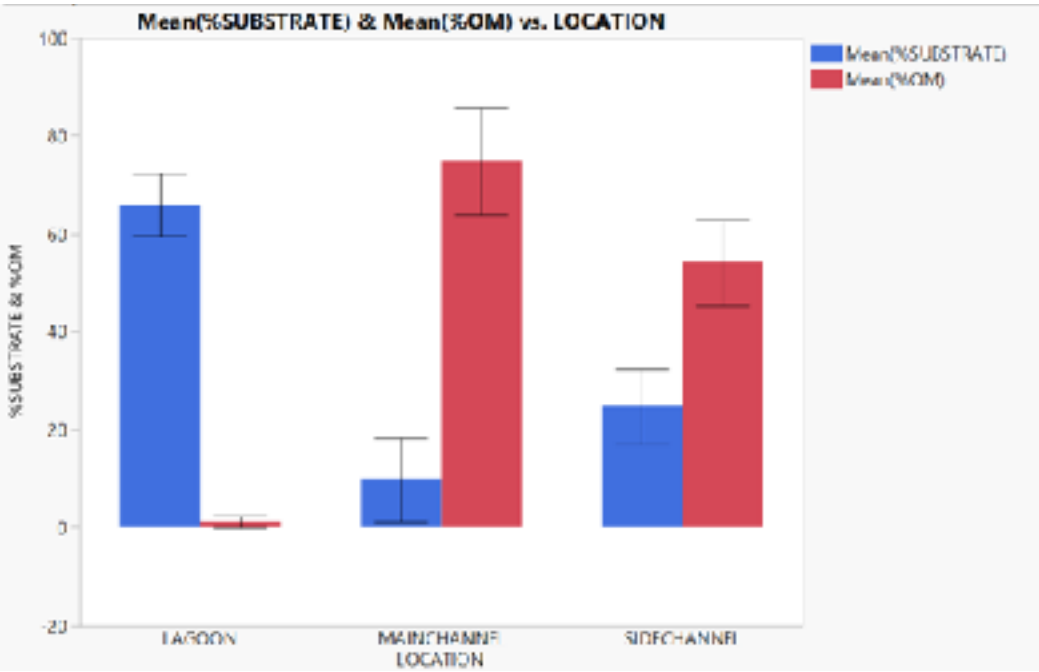

Figure 1: The mean percent cover of substrate and organic matter across all three locations. The bars represent one standard error away from the mean.

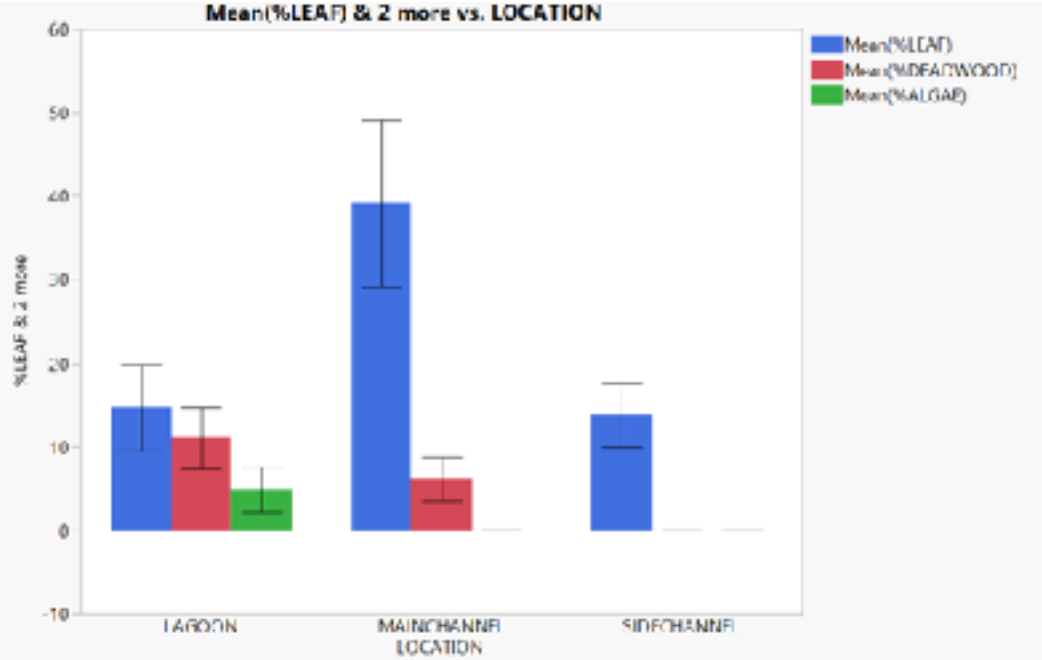

Figure 2: The mean percent cover of leaf, deadwood, and algae as the secondary layer across all three locations. The bars represent one standard error from the mean.

Invertebrates/Roots Results

For our hypothesis that there is a difference between percent cover of epibionts in the three locations, We ran an ANOVA test and found there was a significant difference in percent cover of invertebrates ($T_{(0.05,2)}$= 12.57, $p<0.05$) and bare root ($T_{(0.05,2)}$=13.19, $p<0.0005$) across the three locations. However Percent cover of algae was not significant ($T_{(0.05,2)}$=1.08, $p<0.3634$) (Fig 3).

When invertebrates and algae were split into more specific categories, an ANOVA was run to compare the percent cover of each location. Percent cover of DBA ($T_{(0.05,2)}$=24.71, $p<.0001$), hydroid ($T_{(0.05,2)}$=12.83, $p<0.0001$), bare root ($T_{(0.05,2)}$=12.79, $p<0.0001$), barnacle ($T_{(0.05,2)}$=9.06, $p<0.0001$), sponge ($T_{(0.05,2)}$=4.93, $p=0.0149$), tubeworm ($T_{(0.05,2)}$=16.75, $p<0.0001$), and red/green algae ($T_{(0.05,2)}$=12.56, $p<0.0001$). Percent cover of tunicate ($T_{(0.05,2)}$=3.30, $p=0.052$) was not significant (Fig 4).

In order to compare each site individually, a Tukey test was run. The resulting P-values can be seen on Table 6. For DBA comparing percent cover of lagoon vs side channel and lagoon vs main channel was significant ($p=0.0001$, $p=0.0001$ respectively) but main channel vs side channel was not significant ($p=0.2643$). Percent cover of hydroid was significant across all three comparisons: lagoon vs side, lagoon vs main, and main vs side ($p<0.0001$, $p=0.03$, $p=0.024$ respectively). Percent cover of bare root was significant in comparing lagoon vs side ($p<0.0001$), and lagoon vs main ($p=0.0025$), but was not significant when comparing side vs main ($p=0.36$). Percent cover of barnacles was significant when comparing lagoon vs side ($p=0.001$),and lagoon vs main ($p=0.002$), but was not significant when comparing main vs side ($p=0.97$). Percent cover of sponges was only significant when comparing lagoon vs main ($p=0.01$) and was not significant when comparing lagoon vs side ($p=0.13$) and main vs side ($p=0.37$). Percent cover of tubeworms was significant when comparing lagoon vs side ($p=0.0002$), and main vs side ($p<0.0001$), but was not significant when comparing lagoon vs main ($p=0.96$). Percent cover of red/green algae was significant when comparing lagoon vs side ($p=0.0005$) and main vs side ($p=0.001$), but not significant when comparing lagoon vs main ($p=0.728$).

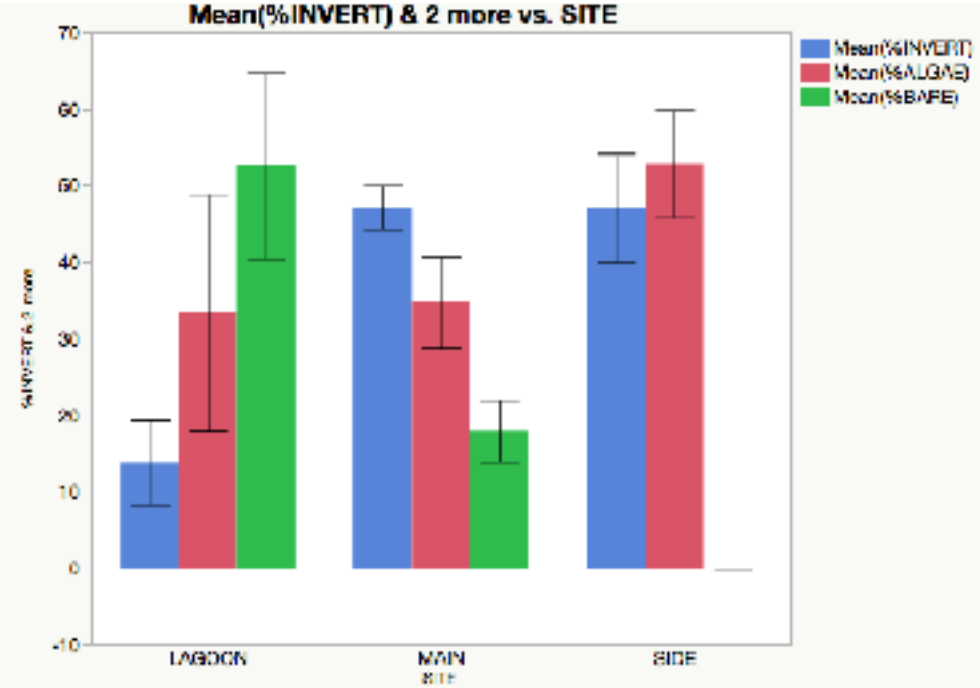

Figure 3. Mean percent cover of of algae, and invertebrates, and bare roots across all three locations. Each bar represents one standard error from the mean.

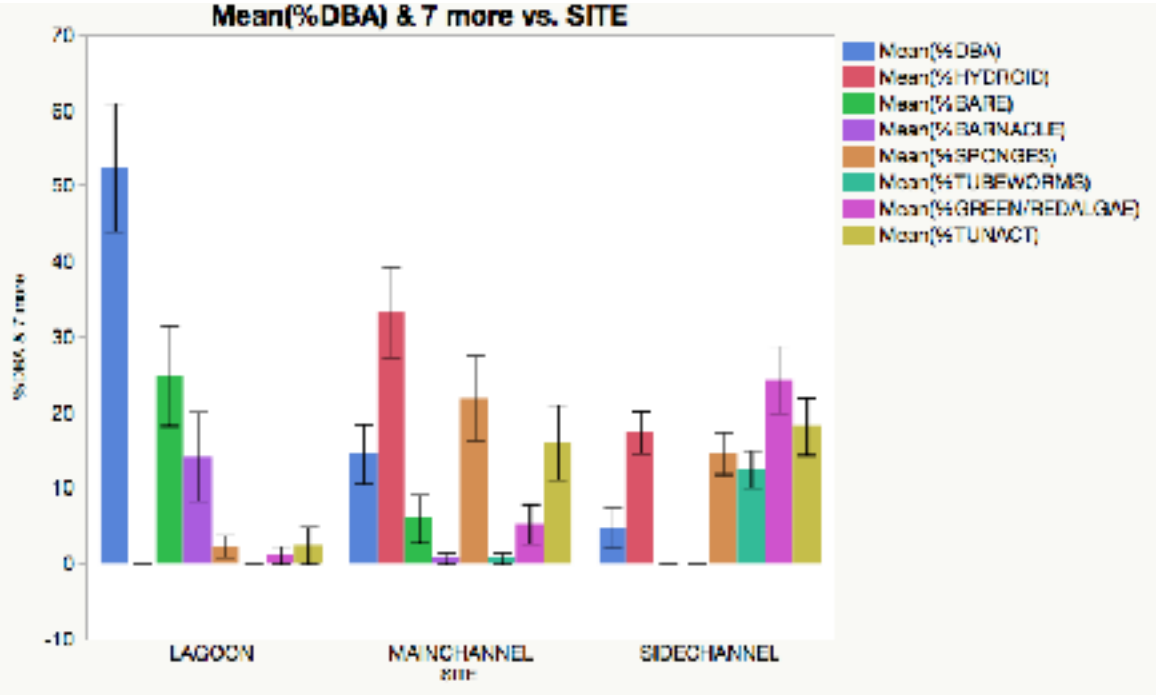

Figure 4. Mean percent cover of invert species on roots across all three locations. Bars represent one standard error from the mean.

Fish Results

We compared the mean total fish across the three different location using an ANOVA test. There was a significant difference in the abundance of fish. ($F_{0.05,20}$=5.0817, p<0.0178) (Fig.5) To compare the sites individually a Tukey test was ran. This data follows the same pattern with a significant difference between the lagoon and side channel (p=0.0180) and a non significant difference between the main and side channel (p=.7538).

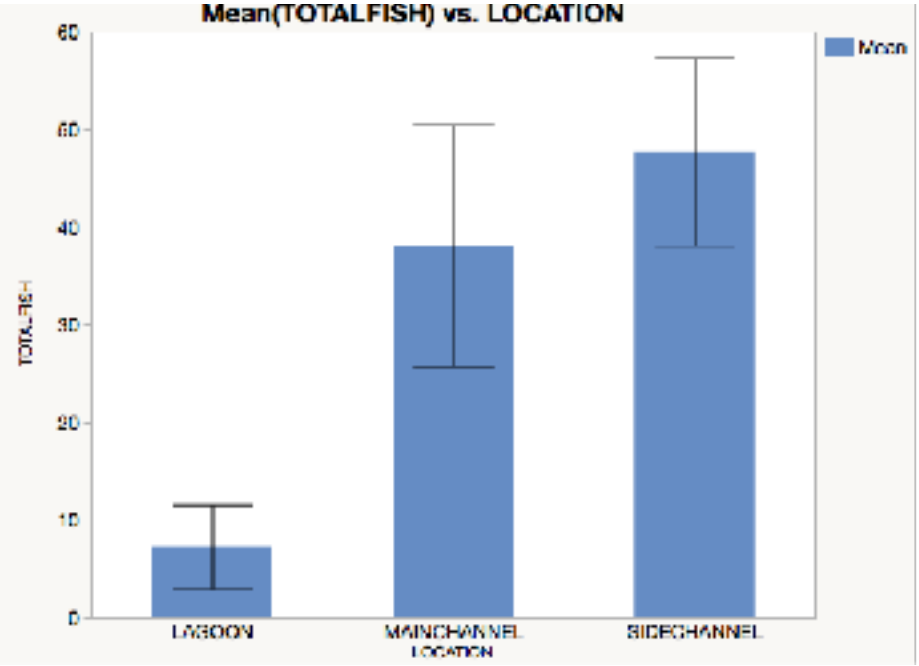

Figure 5. Mean total fish across the three different locations. The bars represent standard error.

Discussion

Our data does not fully support our original hypotheses that all three channels will differ from each other in benthic cover, invertebrate root cover, and fish abundance. It was found that the main and side channel do not differentiate from each other however, the lagoon significantly differentiated from the two other sites. The results from the benthic, invertebrate, and fish community compositions support this analysis. Similarly, the data correlates with the measured flow rates at each location; the flow rates of the main and side channel were very similar to each other but each differed from the Lagoon. The results indicate that the intermediate disturbance hypothesis has a relatively low influence on the mangrove community compared to bottom up controls driven by the nutrients in this system. Further studies within other mangroves should be conducted to see if these results can be applied elsewhere.

Water Flow

The flow rate was determined to be an important variable in this study because it could be used to determine the amount of nutrient cycling and potentially the disturbance that occurs within a system. The flow rate was lowest in the lagoon and

highest in the main channel with the side channel only slightly lower than the main. This indicates that the nutrient cycling within the two channels is higher which would support more organisms and provide a larger amount of nutrients into the system. Since there was no intermediate flow rate, the intermediate disturbance hypothesis was considered to have a low influence over the communities via the water flow. This relationship is reflected in the benthic, root cover and fish abundance data as well.

Benthic

The main difference between the sites in the primary layer was with the organic matter and substrate cover. The organic matter was the thick, detritus material that overlaid the substrate. Because mangroves are anoxic, detritus driven systems (Scholander, P.F. et al. 1962) the organic matter can be considered as a proxy for the nutrients within the system. The areas with the most organic matter were the main and side channels. The organic matter substance is thought to control the higher trophic levels via nutrient availability. Because organic matter may be acting as a bottom-up control in the mangrove system, more nutrients would be found in area of high organic matter cover which would provide a more favorable home for invertebrates and fish. Where there was no organic matter, the primary layer was more likely to be substrate (Fig 1). The lagoon had the least amount of organic matter and the most amount of bare substrate acting as the primary layer; this area was where the least amount of organisms were found which supports organic matter as a bottom-up control on the system.

The highest amount of organic matter was found in the areas with the greatest flow rate. It was thought that with higher water flow the organic matter would be cycled and moved more frequently; however our results do not support this theory. An explanation could lie within the methods used to sample water flow rates. The water flow was sampled directly next to the prop roots in order to get an estimation of the water flow that occurred where we took samples. However, the root system may slow the water flow even further than the water adjacent to the system, providing calmer waters for more organic matter to settle on the bottom. Because we only measured water flow at the surface, it is also possible that water flow differs with depth throughout the water column, preventing organic matter and other substances on the bottom from being moved.

The secondary layer had a greater number of significant categories than the primary layer (Fig 2). Three categories, deadwood, leaf and algae, were used as proxies for nutrient availability as they are all organic substances. The main channel had the highest percent cover of leaves, where the lagoon had the highest percent cover of algae. Many algae species need a hard surface to attach themselves to and the lagoon had greater amounts of dead branches or corals where the algae could attach itself (Jackson, J.B.C. 1977). Whereas the algae in the main and side channels

grew straight from the substrate. This could be due to algae growing from the root system beneath the substrate in the main and side channels or because the substrate in this location was more conducive to algae growth.

The main and side channel having more leaf cover on the benthos could be due to the fact that the channels have two sides to them, thus more leaves available to the system. The lagoon in the mangrove have mangrove trees on one side and a wide space that lead to a sandbar on the other. The fact that there are more leaves in the channels further supports that the main and side channel are more nutrient rich and because of this have more invertebrates and fish within the area.

It is interesting to note that there was no deadwood found in the side channels. A few dead branches were observed to be in the side channel but none fell into the measured quadrats. The lack of deadwood could be because the side channel decomposes wood and other organic material quicker than the main channel and lagoon, or because higher surface flow rate would carry newly-dropped wood out of the side channel.

Invertebrates/Roots

Overall there was a significant difference in percent cover of invertebrates and bare root in the three sites (Fig 3). The main and side channel had significantly more invertebrate percent cover than the lagoon but the two channels did not significantly differ from each other. Similarly, There was significantly more bare root in the lagoon than the main and side channel, however the main and side channel did not significantly differ. However, there was no significant difference between percent cover of algae in the three locations. For this reason our hypotheses that there would be a difference in percent cover of algae, invertebrate and bare root was only partially supported.

When species of invertebrates were looked at individually we found there was an overall significant difference in percent cover of the various species in the three locations. In the lagoon there was significantly more DBA, barnacle, and bare root than in both the main and side channel. In the main channel there was significantly more percent cover of hydroids than in the side channel or lagoon. In the side channel there was significantly more tubeworms and red/green algae than in the main channel or lagoon. Sponges had a significantly higher percent cover in the main and side channel when compared to the lagoon, however, the main and side channel did not significantly differ from each other. Similarly the lagoon had significantly more percent cover of bare root, than the main and side channel; however the two channels did not significantly differ from each other. Tunicates were not significant across the three sites however it was observed that the main and side channel had relatively more percent cover of tunicates than the lagoon.

This distribution of species mirrors our water flow measurements. The lagoon, with the lowest rate of water flow, was mostly composed of bare root, DBA, and

barnacles. Barnacles are able to extend projections to feed and would be better adapted for areas with low water flow, or less organic matter, where there might not be a constant influx of fresh nutrients. Similarly, less water flow would allow more DBA to settle on substrate and coat the roots. The side channel had an intermediate amount of water flow and organic material, so while more mobile species like tube-worms were found there significantly more often, a more steady supply of nutrients also allowed encrusting species such as sponges and tunicates to thrive. Similarly, faster water flow would prevent DBA from settling on the Roots and allow red/green algae to grow. The main channel had the greatest relative water flow, allowing filter feeding invertebrates such as hydroids and sponges to dominate (Leonard, Levine et. al 1998). However, while the side channel did have an intermediate rate of water flow, the rate did not significantly differ from the main channel, so many of the same species are found in both channels; for example while tunicates and sponges were found in both side and main channel, the percent cover of each did not significantly differ in the two locations. Both channels would have relatively similar water and nutrient cycling.

Fish

There was a significant difference in the total abundance of fish across the three locations. The side channel had the highest mean abundance of fish. The main channel had less than that and the lagoon had the lowest mean. It is possible that in the lagoon, the mangrove roots were mostly bare or had little to no invertebrates on them, creating an unsuitable environment for fish to eat and grow. This would explain the lower abundance of fish found in the lagoon. The main channel had a relatively higher flow of water. This could exclude younger fish due to harsh conditions. Though it was not tested directly, we noticed a trend of larger or possibly more adult fish in the main channel. More work needs to be done to determine if there is a significant difference in the age or size of fish at each location. The side channel had the highest abundance of fish. This could be for a number of reasons. The intermediate flow of water could create a preferred habitat for fish to feed and survive. In addition to food resources it could serve as protection from stronger currents and predators.

Conclusion

Originally it was thought that the distribution of species within the mangrove community would be influenced more by the intermediate disturbance hypothesis. However, the results did not fully support this hypothesis. Although there was a significant difference across the three locations for all benthic, invertebrate, and fish data, when the sites were compared individually to each other, there was not a significant difference between main and side channel. However this pattern mirrors the flow rates of each location, so more research should be done over a greater period of time to determine how much the flow rate impacts the system. Similarly, this pattern

could show that bottom-up controls such as amount of organic matter could be affected by abiotic factors and prove to be a more significant factor for higher trophic levels.

A higher nutrient availability makes a system be able to thrive and thus allow more species to live within the environment (Rosemond et al. 1993). This is one reason why mangroves have a high species composition (Nagelkerken, I et al. 2008). This study reveals how important it is to not only protect and manage parts of mangroves, but the entire mangrove system. With each channel that grows, more nutrients are put into the system and more organisms can thrive; however this is only possible with the continued protection and subsequent growth of this habitat. This paper emphasizes the importance of studying not only the profitable species, but the organisms that provide the support for these species. Mangroves all over the world are nurseries to many species of fish and are vital to establishing sustainable fishing practices (Nagelkerken, I. et al. 2008). Unfortunately many mangrove forests are currently being overfished or converted to aquaculture farms (Nagelkerken, I. et al. 2008). As the oceans become depleted due to commercial fishing and little regulation, it is more important than ever to identify and protect key habitats. Further research into the complexities of mangrove systems and the aspects that most influence community health would allow for more effective regulations.

Because mangroves are such a diverse and complex system, more research must be done to fully understand them. In our study, benthic cover was used as a proxy for nutrient availability, but allochthonous input from the canopy cover was not measured. Branches hang over and grow into the water; leaves constantly fall off as a mechanism for getting rid of the salt the mangroves absorb (Scholander, P.F. et al. 1962). This leaf litter contributes to the nutrient availability in the system and may have a strong influence on community composition. Similarly, currents deeper in the water column may have a greater effect on benthic composition and, in future studies, should be measured in conjunction with surface currents over. In addition, this study should be applied to other mangrove habitats across the world to see if these patterns of community composition in relation to water flow and nutrient cycling are present as well.

Awknowlegdments

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Supplemental Tables

Benthic Community

Primary (ANOVA)

Category	**P-Value**
Algae	0.1943
Coral	0.2287
Rock	0.4882
Invert	0.8343
Root	0.4916
Substrate	0.0001*
Organic Matter	<0.0001*

Table 2: The resulting p-values for each category when the percent cover was compared across the three locations. * designates a significant value.

Primary (Tukey Test)

Category	First Location	Second Location	P-Value
Substrate	LAGOON	MAIN CHANNEL	<0.0001*
Substrate	LAGOON	SIDE CHANNEL	0.0006*
Substrate	SIDE CHANNEL	MAIN CHANNEL	0.1727
Organic Matter	LAGOON	MAINCHANNEL	<0.0001*
Organic Matter	LAGOON	SIDE CHANNEL	0.0003*
Organic Matter	SIDE CHANNEL	MAIN CHANNEL	0.1988

Table 3: The resultant p-values for a tukey test comparing the three locations. *denotes significance.

Secondary (ANOVA)

Category	P-Value
DeadWood	0.0081*
Coral	0.0119*
Leaf	0.0172*
Shell	0.2959
Algae	0.0306*
Invert	0.8850
None	0.0330*
Organic Matter	0.1912

Table 4: The resulting p-value when comparing the percent cover of each category across the three locations. *designates a significant value.

Secondary (Tukey test)

Category	First Location	Second Location	p-value
DeadWood	LAGOON	MAIN CHANNEL	0.3544
DeadWood	LAGOON	SIDE CHANNEL	0.0062*
DeadWood	SIDE CHANNEL	MAIN CHANNEL	0.1660
Leaf	LAGOON	MAIN CHANNEL	0.0432*
Leaf	LAGOON	SIDE CHANNEL	0.9943
Leaf	SIDE CHANNEL	MAIN CHANNEL	0.0231*
Algae	LAGOON	MAIN CHANNEL	0.0612
Algae	LAGOON	SIDE CHANNEL	0.0430*
Algae	SIDE CHANNEL	MAIN CHANNEL	1.0000

Table 5: The resulting p-values for a tukey test comparing all three sites. Only the categories used in the discussion were analyzed. *denotes significance.

Invertebrate (Tukey)

Category	First Location	Second Location	p-value
DBA	LAGOON	SIDE CHANNEL	0.0001*
DBA	LAGOON	MAIN CHANNEL	0.0001*
DBA	SIDE CHANNEL	MAIN CHANNEL	0.26
HYDROID	LAGOON	SIDE CHANNEL	0.0001*
HYDROID	LAGOON	MAIN CHANNEL	0.033*

HYDROID	SIDE CHANNEL	MAIN CHANNEL	0.024*
BARE ROOT	LAGOON	SIDE CHANNEL	0.0001*
BARE ROOT	LAGOON	MAIN CHANNEL	0.0025*
BARE ROOT	SIDE CHANNEL	MAIN CHANNEL	0.36
BARNACLE	LAGOON	SIDE CHANNEL	0.0014*
BARNACLE	LAGOON	MAIN CHANNEL	0.0028*
BARNACLE	SIDE CHANNEL	MAIN CHANNEL	0.97*
SPONGE	LAGOON	SIDE CHANNEL	0.01*
SPONGE	LAGOON	MAIN CHANNEL	0.13
SPONGE	SIDE CHANNEL	MAIN CHANNEL	0.37
TUBEWORM	LAGOON	SIDE CHANNEL	0.0002*
TUBEWORM	LAGOON	MAIN CHANNEL	0.96
TUBEWORM	SIDE CHANNEL	MAIN CHANNEL	0.0001*
RED/GREEN ALGAE	LAGOON	SIDE CHANNEL	0.0005*
RED/GREEN ALGAE	LAGOON	MAIN CHANNEL	0.72
RED/GREEN ALGAE	SIDE CHANNEL	MAIN CHANNEL	0.001*
TUNICATE	LAGOON	SIDE CHANNEL	0.051
TUNICATE	LAGOON	MAIN CHANNEL	0.11
TUNICATE	SIDE CHANNEL	MAIN CHANNEL	0.92

Table 6: The resulting p-values for a tukey test comparing all three sites. *denotes significance