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Human Disturbance of Seagrass Beds in Hoga Island, Indonesia : Impacts on Edge Effects

Anthony John Suleski

Abstract:

Ecosystems are broad classifications of areas where overlapping communities exist which can contain relatively high faunal and floral diversity. These communities characteristically are often influenced by external forces. Disturbances can create incongruencies in these communities and have been demonstrated to change community dynamics in varying ways. Humans are responsible for many disturbances which alter habitat and community structure and many habitat edges or ecotones are artificially created by these human disturbances. In Wakatobi National Park, Hoga Island, Indonesia, three bays exist and are in close proximity to one another with varying levels of human influence. This study investigated how anthropogenic disturbances affect seagrass communities. Boat Bay showed substantial human activity, while the other two bays (Hoga and Mushroom bays), showed limited regular human activity respectively (e.g. boat launching and snorkeling). It was hypothesized that human influences could impact seagrass communities by reducing diversity and abundance of community members and altering the overall structure of the habitat. Seagrass beds within these sites were investigated to assess how human influence may impact faunal community structure, floral characteristics, and changes in water flow. Each of these seagrass communities was divided into shallow edge, core, and deep edge sub-habitats to determine if differences existed with respect to animal density, plant density, and relative water flow, as it has been demonstrated that within habitat variability exists in Seagrass communities. In Boat Bay, the most human influenced system, animal density was lowest and no within habitat differences between edge and core regions was observed. However, in the other two bays substantial differences among the three sub-habitats were observed, suggesting strong edge effects for minimally disturbed systems. Results showed that faunal densities in Mushroom and Hoga Bays averaged 250-400 organisms m^{-2} on the edges, but only 100-150 organisms m^{-2} were identified in the core regions. Differences were also observed in the relative flow rates, where Mushroom and Hoga Bay edge dissolution rates were greater (nearly 2% greater rates of dissolution) than interior rates. Conclusions from this study indicate that human activities reduce faunal density and dampen or eliminate any edge effects existing within seagrass communities. As such, human disturbances negatively impact the within habitat structuring forces of edge effects.

MONTCLAIR STATE UNIVERSITY

HUMAN DISTURBANCE OF SEAGRASS BEDS IN HOGA ISLAND, INDONESIA: IMPACTS ON EDGE EFFECTS

by

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A THESIS

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Introduction:

Ecosystems are broad classifications integrating communities that share similarities with regards to faunal, floral, hydrological, soil and chemical characteristics. Ecosystems are arbitrarily created designations which allow scientists to study areas sharing similar attributes and compare them. Ecosystems are not homogenous and consist of a mosaic pattern of smaller interrelated systems rather than a large continuous system (Saunders 1991). Therefore, there are regions within ecosystems where community types intersect or converge. These transition regions are referred to as edge habitats and the physical factors and ecological processes influencing edge regions can be strikingly different, despite their proximity (Murcia 1995).

Two generalized types of edges include abrupt and diffuse edges. An abrupt edge is a stark demarcation between two community types, while a diffuse edge is a more gradual transition from one to another. Abrupt edges are commonly observed at the edge of a forest which transitions rapidly to a field or meadow, while diffuse edges may be present where habitats intergrade in a patchwork of overlapping species. In seagrass systems, abrupt edges can be seen where the seagrass beds are bounded by sedimentary communities (Bologna and Heck 2002), but they also exhibit diffuse boundaries where shoot density and spatial coverage slowly are reduced to regions where small patches of seagrass exist within the sedimentary communities. In some tropical seagrass systems, shallow grass beds are bounded landward by the emerging intertidal shelf, while deeper edges exist where they again retrograde into sedimentary habitats or are bounded by coral reefs. These transition regions, or edges, are subjected to different physical forces, which subsequently impact sedimentary characteristics (Orth 1977) and larval delivery. As a consequence, certain organisms are more or less successful in these edge regions, in comparison to the core of the habitat due to the changed environment conditions.

Tropical seagrass beds differ from higher-latitudinal seagrass beds in many ways. Greater species richness is common in the tropics with as many as ten different species coexisting in a region, while temperate and sub-arctic regions are generally dominated by one to three species (Hemminga and Duarte 2001). Additionally associated algal species frequently differ with respect to species richness, palatability, and constitutive defensive structures (Morgan and Kitting 1984). Regardless of species composition and richness;

seagrasses are a major food source in these communities through direct consumption (Penhale 1977) and sometimes detrital pathways (Thresher et al. 1992). In addition to these two factors, the grasses provide many of the ecosystem services (Orth et al. 2006; Heck et al. 2008). The seagrasses provide a habitat matrix of intricate niches for smaller invertebrates and vertebrates to live; and supply a well protected nursery habitat for their young to grow up in as well (Beck et al. 2001; Heck et al. 2003). Seagrasses create a diversely stratified system with very large surface areas and many different species of grasses can coexist with one another in the tropics. When this occurs more intricate and unique matrices are created, in and on which organisms can survive and thrive (Cardoso et al. 2007).

Seagrass beds are extremely important communities in the coral reef, seagrass, mangrove continuum in which they exist because the biological and ecosystem services they provide are essential in tropical ecosystems (Dorenbosch 2004; Unsworth et al. 2008). All three of these communities, which combine together to form a larger ecosystem, are nurseries and breeding grounds for organisms, and perform a massively important buffer to storm surge protection. Some organisms' larval stages will reside in these areas due to their abundance of food and shelter, and lack of larger predatory organisms, until they reach their adult nektonic lives at which time they are larger and more self sufficient (Shibuno et al. 2008). Many sessile organisms' planktonic phases also settle out in these regions due to the slowing of current caused by friction with seagrasses. This begins the settlement phase for many sessile organisms which as larvae have a planktonic life to facilitate dispersal (Eckman 1990). This is not the only hydrological effect however of the stabilizing nature of the seagrass beds.

Seagrasses also serve a function in coastal protection and shoreline erosion by lessening the wave energy during and after wave and storm surges. They trap and stabilize sediment in these areas using their dense rhizome system making them robust to physical forces and coastal erosion (Fonseca et al. 1982; Gambi et al. 1990; Koch 2001). They not only trap and stabilize sediment by their rhizomes, they also slow water by the matrix like system they create with the actual blades of grass. This in turn causes water flow to slow down because of frictional forces and at the same time, deposition and settlement occur. They are one of the many lines of defense to storm surges which are quickly disappearing due to human impact.

Seagrasses are one of the vast myriad of communities under attack on many fronts brought about by human encroachment. These offenses, which include destruction, pollution, and eutrophication, threaten these fragile communities (Orth et al. 2006; Waycott et al. 2009). Humans are producing increasingly more amounts of fertilizer which leach into bays and oceans and extremely harmful to sea grasses, through the process of eutrophication. This is because seagrasses normally compete for resources with phytoplankton and other algae. When there is an abundance of nutrients, simpler organisms such as algae flourish due to their residence in the water column and being able to absorb nutrients readily through their tissues. This creates an algal bloom that can easily outcompete for light killing off much of the seagrass in an area (Biber et al. 2007). For this reason, research must continue in order to preserve and conserve these extremely crucial and unique species of plants from being destroyed.

Natural and human produced events can alter floral and faunal composition in a system. Disturbances are destructive events that alter organismal, chemical, or physical characteristics of a system. Normally, large scale disturbances occur infrequently but have a very large impact on the communities they affect. Small scale disturbances happen more frequently yet are of less overall scale of impact and normally occur in a small area. Small scale examples include tidal flux, rainstorms, and even an event as simple as a human walking over a seagrass bed (Herrera-Silveira et al. 2010; Eckrich and Holmquist 2010), which do not permanently alter a community but will impact it for a few hours to a few days. Disturbances for the most part are very normal events in a community and allow for maximal niche utilization between different species in a community (Menge and Sutherland 1987).

Human disturbances are very different in that high impact events can be created in a relatively quick period of time and sustained indefinitely because humans alter their surrounding environment more than any other organism. Human disturbances last much longer than large natural disturbances, occur more frequently, and have the potential to be of larger magnitude (e.g. Global Climate Change). Humans are the major contributor for many recent population decreases in organisms worldwide (Wake and Vredenburg 2008) and evidence is mounting that we are actually fueling a mass extinction (Ceballos et al. 2010). One of the many disturbances happening to seagrass beds is fragmentation and generation of patchy environments (Short and Wyllie-Echeverria 1995). This activity can however bring about the creation of more edge habitat.

The research presented addressed how different levels of human disturbance on a small island in this region affect the seagrass community. I assessed the following situation: Hoga Island has three bays in close proximity. Within each bay, the seagrass communities are similar in generalized structure, bounded by shallow edges interfacing with the landward edge of the marine system and deeper edge transitions where the seagrass communities intergrade into coral reefs. Each bay has different levels of human impact and around them, ranging from multiple daily boat launchings and beginner SCUBA training to being relatively undisturbed. This creates a situation where two edge regions and one 'core' region exist for each seagrass bed and allow for the development of questions regarding the relative strength of edge effects and the potential that human activities negatively impact the strength of these effects.

The questions I posed is whether there is a difference in the edge habitats in each bay due to the relative human disturbance and will edge effects be more pronounced in areas with fewer disturbances. The specific edge effect I will be looking at will be the abrupt edge of a tropical seagrass bed, what organisms reside there, how the water moves over said areas, and how seagrass growth occurs. What was expected to be found was that with a higher level of human disturbance, the "edge effect" in the micro-region would be weaker and where there was less human interaction, the edge effect would be more pronounced.

Objectives

There were two main objectives to this research:

- Assess if there is a within habitat difference between the interior and edges of seagrass beds and
- Determine whether these within habitat differences are affected by human disturbance.

Materials and Methods:

Study Site

Wakatobi National Park is a small island chain off the south eastern edge of Sulawasi Island, Indonesia (Figure 1). The National Park is about 13,000 square kilometers It is situated to the east of Wallace's ecoregion line and to the west of Weber's ecoregion line. There is significant overlap between each of the two surrounding ecoregions, the Austrliopacific and the Asiatic; creating unique communities with fragile endemic species found in combinations presently nowhere else in the world. Hoga is a small island of the archipelago chain of Wakatobi, and is about 4 square kilometers (Dykes and Gunn 2006). Operation Wallacea, a biological and conservation minded organization, has a base camp on the south-west side of this island. They primarily perform biodiversity, animal behavior, and ecological research on the marine life in and around the surrounding bays. On this island, three bays were chosen for study and represent different levels of human disturbance (Figure 1).

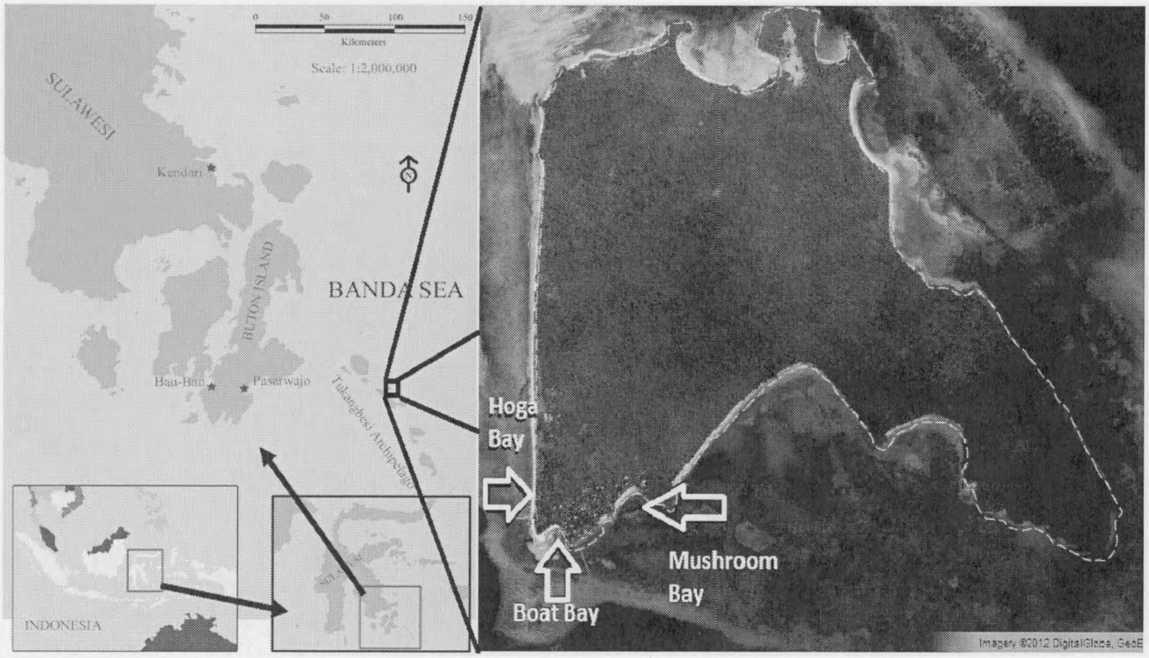

Figure 1.Location of Hoga Island

Boat Bay on the south-west side of the island (Figure 1) where most of the boats launch from daily for SCUBA research to support Operation Wallacea biodiversity studies. This is the most impacted bay receiving daily disturbance from local inhabitants, scientists, and tourists. As many as 30 boats launch daily from this area, some contain more than 10 people. Additionally, most of the indigenous citizens launch their boats from this bay and live in this area temporarily as this island is uninhabited outside of tourism season. Hoga Bay is on the west side of the island and moderately disturbed. Snorkeling here was done daily, however boat traffic did not occur because it was not feasible due to the fact that this region had a high reef crest that prevented even shallow hulled boats from passing. Also, from time to time beginner SCUBA classes would start off here especially in times of spring high tides due to the clarity of the water and the relative safety of keeping inexperienced divers away from the fragile reefs that encircled the island. The final bay investigated was Mushroom Bay, named because of the big mushroom shaped rock in the middle of the bay. This bay, located on the south side of the island, was relatively undisturbed with boats being launched infrequently and limited human activity occurring there.

Research was conducted in seagrass habitats at each of the three sites. The seagrass species encountered were *Syringodium spp.*, *Enhalus acroides*, and *Cymodocea serrulata*. Work was conducted between the months of July and August 2009.

Edge Definition

Seagrass habitats were defined using Bologna and Heck's (2002) definition of an edge as vegetated substrate being within 1m of the sand-grass interface and with the core of the bed being at least 10m away from any sand-grass interface. Additionally the geomorphology of the island created relatively distinct subtidal regions from the shoreline in a regular pattern. Unsworth et. al. (2007) pre-defined distances of 25m, 100m and 175m from the mean high tide mark on Hoga Island. These distances matched the approximate emergence of seagrass on the landward side (25m) and the change into the coral reef (175m) with the center point designating the core region of the seagrass bed. Strong congruencies were found with these two definitions and the 25m, 100m, and 175m marks were found to be within the 1m sand-grass interface. 25m from the mean high tide mark was taken to be the shallow edge. This region was where seagrass started growing and the sandy flat region close to the shore transitioned into a seagrass meadow.

The predominant seagrass species found in this region was *C. serrulata*. The core region of the seagrass bed occurred approximately 100m from the high tide mark. This region was rich with all three species of seagrass. The final zone at 175m from the high tide mark was where the seagrass meadow transitioned into the coral reef. This region contained isolated coral communities but only contained *E. acroides.*

There were three distinct habitat types based on depth, distance from shore, and seagrass species contained within; two edge regions and one core seagrass region. These two edge regions were considered different and unique from one another for the purposes of this research.

Faunal Assessment

Benthic cores (10.16cm diameter) were taken (N=145) during July to August 2009. Cores were collected from Hoga Bay (n=45), Mushroom Bay (n=45), and Boat Bay(n=30) sites and in equal proportions in the three separate zones detailed above to assess the faunal density in each sub-habitat. Benthic cores were collected to a depth of 15-20cm at haphazardly selected sampling locations meeting the criteria of the above defined habitats within sites. All samples were sieved and processed in the field using a 1 mm mesh sieve. Organisms were identified to lowest possible taxonomic level and enumerated. Pictures were taken of unknown organisms for later identification. All organisms were released alive immediately after sampling in a relatively similar location as to minimally disturb the community.

Seagrass Growth

Relative seagrass growth rates were assessed by clipping the grass at the base of the plant and at a slightly shallower depth in a one meter square plot with scissors. There were three major seagrass types in the area were *Enhalus acoroides, Cymodocea serrulata,* and *Syringodium spp*. One clipping was done at the substrate level, another was done at the top of the *C. serrulata* at about 10-15cm from the substrate interface, and a final control where no clipping was performed. These two disturbance levels would illustrate a high disturbance that would clear cut the area removing above ground biomass (e.g., major grazing event), and a moderate disturbance what would remove most of the *E.*

acorodies but not impact the *C. serrulata* (e.g. moderate storm damage tearing blades). Canopy height was measured as a proxy for the plant growth within the clipped plots. These plots were established in all three habitat zones outlined above (n=9). Measurements of the canopy height were taken and recorded daily for two weeks.

Relative Flow Rates

Relative water flow was estimated by using the dissolution rate of Plaster of Paris cylinders in August 2009. This was performed by using the modification of Komatsu and Kawai's (1992) technique used by Bologna and Heck (2002). This technique assumes that the dissolution is directly related to the flow of the water around Plaster of Paris spheres (Komatsu and Kawai 1992). This was modified in that small tubes were used to minimize the surface abrasion due to grass blades (Bologna and Heck 2002). Cylinders were made by mixing 100g of Plaster of Paris mixture with 100 mL of water. The resulting mixture was poured into 2.5 cm X 5.3 cm cylindrical containers. The containers were allowed to set and dry, and then their tops were sanded flush with the surface of the container. They were then allowed to dry again for approximately one month to achieve a constant dry weight. These containers were then transported to the field, put at heights of 10, 20, 40 and 60 cm above the sediment interface using 2.54cm diameter PVC tubes with straight connectors on top. The reason these heights were chosen was that it would give an appropriate modeling of the water flow in the defined regions of the seagrass beds. *Cymodocea serrulata* rose to about 20cm and *E. acoroides* rose to about 50 cm off the sea floor so these heights would give below, in the middle, and at the top of the canopy level. These sampling apparati were then placed in duplicate in each of the three sub-habitat zones (n=24) outlined above and left for two complete tidal periods (approximately 24 hours). They were then dried for approximately one month and re-weighed to determine the dissolution of plaster lost, which provides a relative comparative assessment of flow in a 24 hours period. Unfortunately, many of the experimental PVC set ups failed due to spring tides which exposed some of the 40 and 60 cm cylinder heights above the substrate on the landward edge. Theft of these and several 20 cm cylinders which were visible resulted in the only complete data set being the 10 cm high cylinders.

Statistical Analyses:

Faunal density was analyzed using a 2-Way ANOVA with site and sub-habitat as independent variables in the model (PROC GLM, SAS ®). Community faunal comparisons were completed using a similarity of percentages (SIMPER) looking at the relative abundance of each faunal group identified in samples and a non-metric Multi-Dimensional Scaling (MDS) analysis which plots together samples which share similarities in the distribution and abundance of taxa within the community data set. Flow rate differences among habitats were analyzed by determining the relative loss of Plaster of Paris. Plant growth was analyzed by using a general linear model (Proc GLM, SAS®) to determine if growth rate differed among habitats.

Results:

Faunal Assessment

Significant differences were observed within and among the grass beds investigated (Figure 2). Specifically, densities were significantly higher in Mushroom and Hoga Bays when compared to Boat Bay ($F_{2,119}=2.86$, $p=0.06$). Edges had significantly greater densities when compared to core regions ($F_{2,119}=12.16$, $p<0.0001$). However, a significant interaction between site and habitat was also observed ($F_{4,119}= 0.91$, $p=0.09$) (Figure 2). When the analysis was conducted with the removal of Boat Bay, no significant differences were observed for site, and no significant difference existed among the sub-habitats.

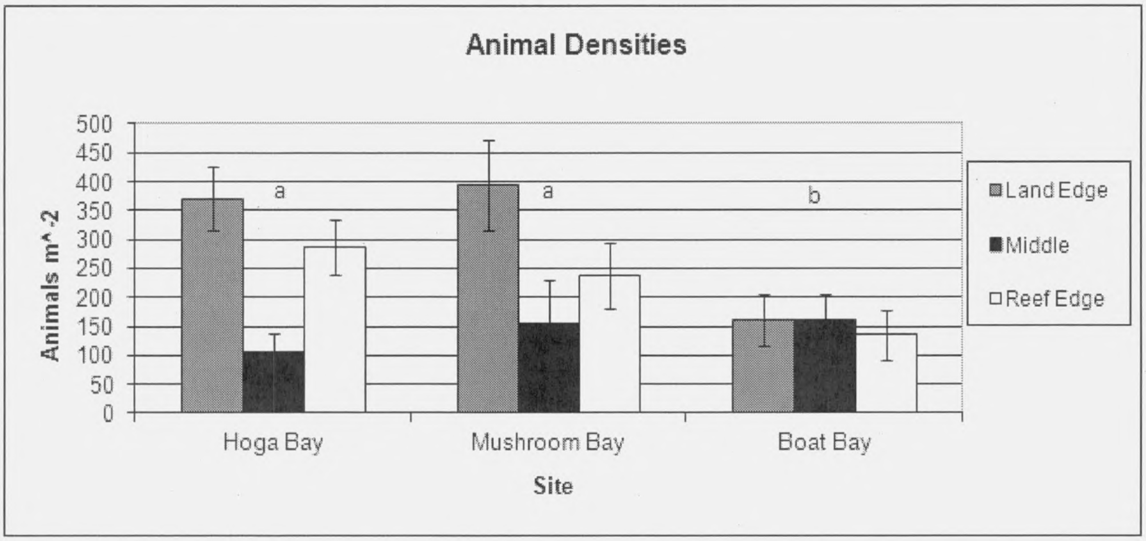

Figure 2. Comparison of faunal density among the sub-habitats for the three bays investigated. Values presented are average ± SD.

Faunal and Community Differences

Only three taxonomic groups were sufficiently abundant to assess their distribution. Polycheates were substantially more abundant along the shallow landward edge, potentially experiencing reduced predation pressure, while crabs and snails were equally abundant along reef and shallow edges, but depressed in core regions of the beds. The rest of the animals found were found in such low quantities (Appendix 1), it was not possible to conduct a statistical analysis.

A SIMPER analysis was performed to determine the similarity among the faunal communities among the bays and differences associated with the three sub-habitats. What is evident from the analyses is the dominance of Polychaeta among all sites and sub-habitats (Tables 1, 2). This may be a result of all polychaetes being grouped due to lack of taxonomic precision. This is most evident for Mushroom Bay (Table 1) and for core regions of the grass beds (Table 2). Other contributing taxonomic groups included Brachyuran crabs, brittle stars, and an unidentified species of gastropod.

	Hoga Bay		Mushroom Bay		Boat Bay	
Hoga Bay	Average Similarity	38.07%				
		Contribution				
	Polychaeta	85.37%				
	Brachyura	9.53%				
Mushroom Bay	Dissimilarity	62.10%	Average Similarity	37.24		
		Contribution		Contribution		
	Polychaeta	20.42%	Polychaeta	90.71%		
	Brachyura	16.27%				
	Bivalvia	6.93%				
	Gastropod A	6.70%				
	Ophiuroidea	6.66%				
	Amphipoda	5.23%				
	Paguroidea	5.00%				
	Nematoda	4.75%				
	Echinoidea A	4.55%				
	Caridae A	4.00%				
	Cypraea	3.83%				
	Caridae B	1.93%				
Boat Bay	Dissimilarity	73.56%	Dissimilarity	73.18%	Average Similarity	19.98%
		Contribution		Contribution		Contribution
	Polychaeta	25.07%	Polychaeta	26.62%	Polychaeta	60.66%
	Brachyura	14.91%	Gastropod A	13.60%	Gastropod A	17.54%
	Gastropod A	11.46%	Brachyura	12.9%	Brachyura	8.9%
	Ophiuroidea	9.50%	Bivalvia	9.30%	Ophiuroidea	6.33%
	Bivalvia	8.45%	Ophiuroidea	8.34%		
	Paguroidea	5.14%	Paguroidea	6.32%		
	Nematoda	3.81%	Amphipoda	5.02%		
	Isopoda	3.62%	Caridae A	3.68%		
	Amphipoda	3.09%	Cypraea	3.58%		
	Caridae A	2.48%	Isopoda	2.44%		

Table 1. Contributing taxa defining and discriminating each bay's faunal composition based upon SIMPER analysis. Values represent the individual percent contribution to defining the fauna responsible for the relationship.

	Land Edge	Core Bed	Reef Edge
Land Edge	Average Similarity 28.33% Contribution Polychaeta 81.19% Brachyura 7.34% Gastropod A 4.02%		
Core Bed	Dissimilarity 64.30% Contribution Polychaeta 24.25% Brachyura 15.99% Bivalvia 9.43% Gastropod A 9.29% Amphipoda 6.53% Paguroidea 5.40% Ophiuroidea 5.32% Nematoda 5.03% Cypraea 3.50% Caridae A 2.70%	Average Similarity 46.84% Contribution Polychaeta 92.93%	
Reef Edge	Dissimilarity 70.41% Contribution Polychaeta 21.22% Brachyura 13.56% Gastropod A 10.20% Ophiuroidea 8.72% Bivalvia 6.61% Paguroidea 6.05% Amphipoda 4.23% Caridae 3.86% Echinoidea A 3.79% Nematoda 3.61% Isopoda 2.99% Cypraea 1.93%	Dissimilarity 63.24% Contribution Polychaeta 24.58% Brachyura 17.17% Ophiuroidea 9.52% Bivalvia 8.83% Gastropod A 8.73% Echinoidea A 6.04% Caridae A 4.14% Paguroidea 3.99% Cypraea 3.62% Isopoda 3.22%	Average Similarity 29.63% Contribution Polychaeta 80.10% Brachyura 8.20% Ophiuroidea 4.54%

Table 2. Contributing taxa defining and discriminating each sub-habitat's faunal composition based upon SIMPER analysis. Values represent the individual percent contribution to defining the fauna responsible for the relationship.

Utilizing MDS after doing the SIMPER analysis, similarities can be assessed in community structure. When these data are looked at for similarity of community structure in an MDS plot, based upon bay, there is a clumping of Boat Bay (denoted by the red symbols) and a light clumping of Mushroom Bay (denoted by the blue symbols) (Figure 3). This signifies that the more similar samples are, the more together the data points should appear. The green symbols signify Hoga Bay and are about as spread out if not a little more than the blue Mushroom Bay points. In the next MDS plot (Figure. 4), the data are grouped by habitat region, and the clumping occurs for the grass bed interior region (denoted by the red symbols) and the coral reef edge (denoted by the blue symbols), however there is a larger spread for the land edge of the bed (green symbols). Once again, data points are close to one another when community structure is similar and therefore the interior regions are very similar which is shown by the closely clustered red shapes, while the edges, blue and green shapes, are more dissimilar.

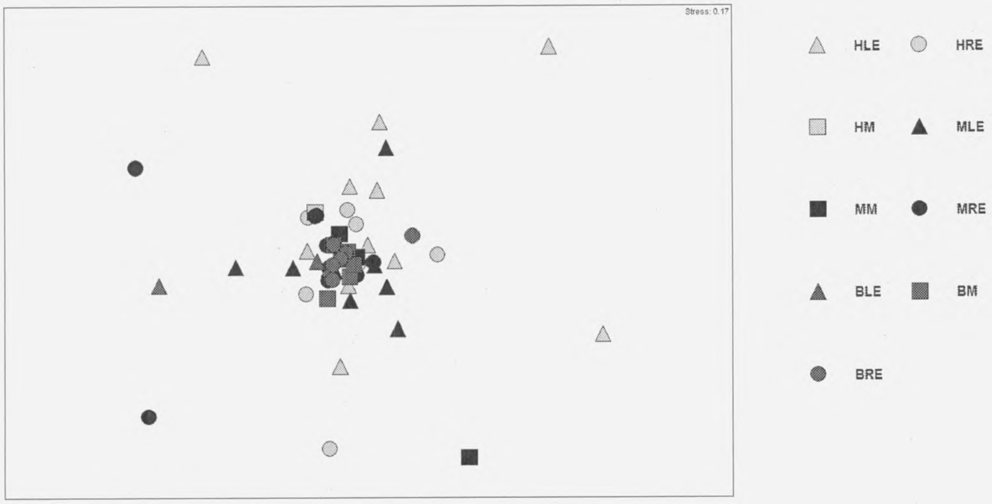

Figure 3. MDS plot of faunal community structure highlighting differences among study sites.

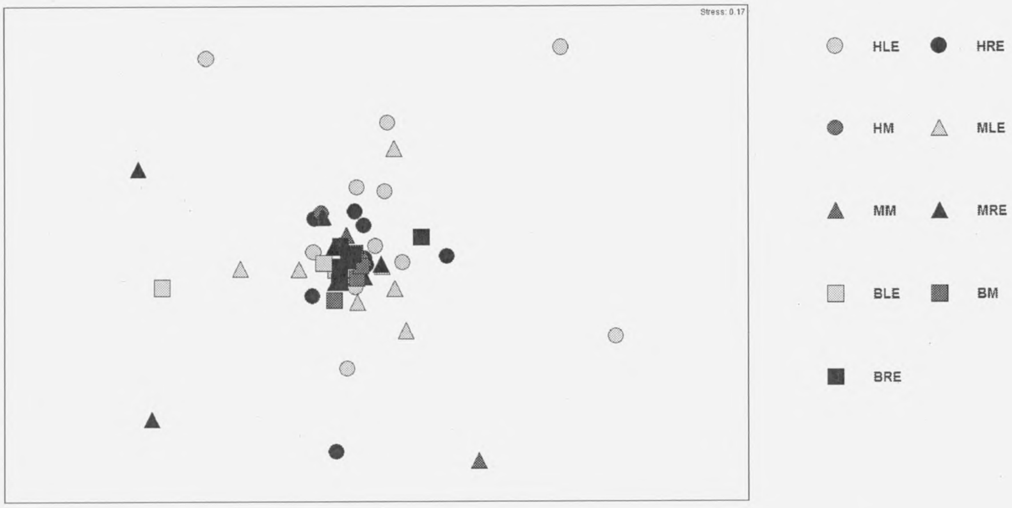

Figure 4. MDS plot of faunal community structure highlighting differences among sub-habitats.

Relative Flow Rates

The flow rate experiment shows that there is a difference in dissolution from interior sections to the edge regions of the bed (Figure 5). Data suggest that at the lowest depth compared flow rate was reduced at interior sections of the grass beds compared to the edge, regardless of site.

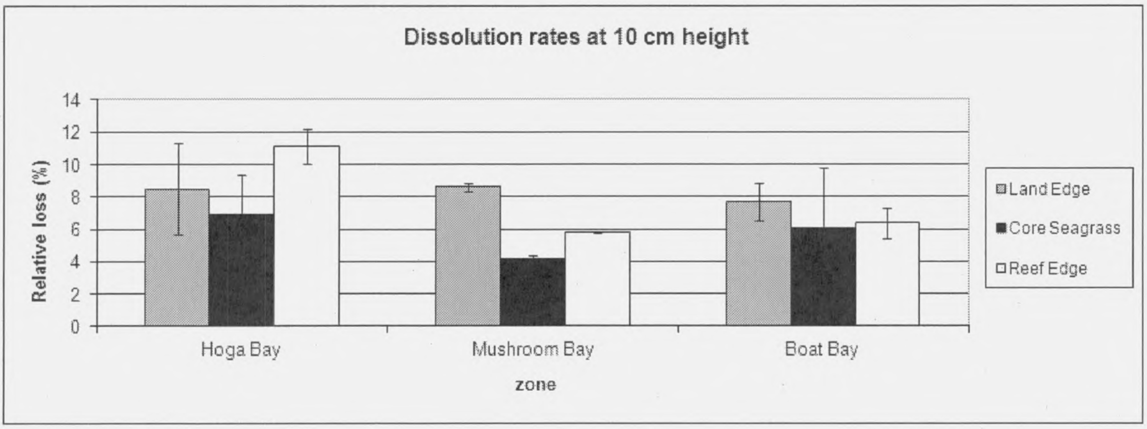

Figure 5. Dissolution rates at 10 cm height off the bottom. Values presented are average ± SD.

At ten cm height, the "U-shaped" trend that is seen is because of the speeding up of flow on the edge regions resulting in more dissolution of the plaster of Paris component. The "U-Shaped" trend is present for all three bays. The two bays with less disturbance, Hoga and Mushroom Bay, showed greater relative differences in dissolution; while Boat Bay shows this same trend, but was muted. Unfortunately, with the loss of the cylinders at the different depths, it was not possible to generate a depth by dissolution rate to assess the within and above canopy flow rates.

Seagrass Growth

The vegetative growth experiment showed that the core seagrass bed area and the landward edge grew faster than the reef seagrass edge area (Figure 6). Slope analysis demonstrated significantly greater growth at the land edge compared to the reef edge ($F_{2,66} = 3.8$, $p<0.003$) but core growth did not differ from either edge habitat. It must be noted here however that there were different seagrass species being cut in these regions, and that *E. acrodies* grew faster in the core bed area than in the reef edge area but land edge was *C. serrulata* while reef edge was primarily *E. acrodies*.

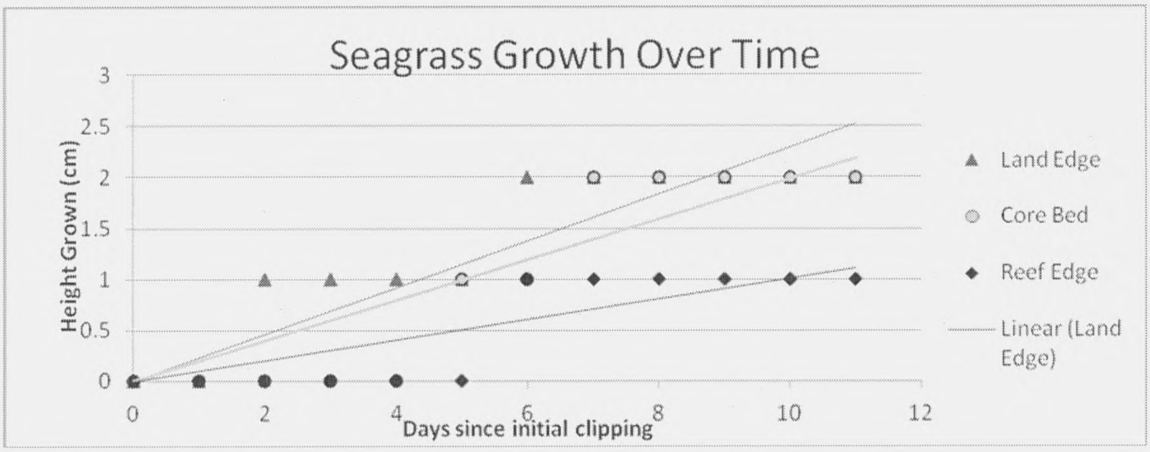

Figure 6. Seagrass growth over time.

Discussion:

Edge effects are present in all bays investigated, but human disturbance seems to dampen the response. Boat Bay, the area with the highest disturbance rates, had extremely subdued edge effects with animal densities being nearly equal among core and edge regions and flow rates being similar as well. Even though edge effects were dampened in Boat Bay, the effects were seen throughout the other two bays studied in the faunal, hydrological, and vegetative growth results. In regards to faunal density, edges had greater densities of organisms than the core seagrass meadows. It is interesting to point out that there were fewer organisms at the deep edge than in the shallow edge, although this is just an observation and not statistically significant. This may be due to predation potential of reef fish adjacent to the deep edge. It has been demonstrated that several groups of predatory fish leave coral communities and forage among grass beds (Ahmadia et. al. 2012). The seagrasses provide them with refuge and trophic resources, therefore the proximity to the reef increases the probability that predators will use this region. However, unless predation is significantly higher in the core region of the bed, this argument does not explain the substantially lower abundance of organisms within the core region (Figure 2). Several arguments were proposed by Bologna and Heck (2002) to explain the discrepancies between edge and interior habitats and a few similarities can be drawn between these two studies.

Polycheates are very important to edge habitats, obviously being one of the most densely habituating organisms living there. Gastropods were also found in abundance in both communities, however there were more species found in Florida (<100) than in Indonesia (>10). It is very interesting however to mention that many of the underlying reasons as to why these organisms inhabited where they were, were for similar reasons. Water flow in both communities underwent similar changes.

Hydrologically, a seagrass bed experiences reduction of flow at the bottom substrata due to frictional forces and acceleration over the canopy (Gambi et. al 1990). Unfortunately, the logistical challenges regarding the tidal fluctuation and removal of experimental units only allowed me to assess 10cm above the sediment level. Based on the results, greater dissolution (i.e., flow velocity) rates were observed at the edges of the beds. This overall result was expected and similar to Gambi et. al (1990) who demonstrated that due to frictional forces and by using flow rate apparati, that flow rate in a grass bed will increase as distance from the sea floor increases. Understanding why the site with greater human activity would dampen the physical flow differences is difficult to interpret. Perhaps the seagrass canopy was different among sites and flow was not appreciable changed at Boat Bay.

Data suggest faster flow or increased turbulence at the edges of the bed with a reduction of the flow inside the core. This is mainly because of the displacement of water at the bottom forcing more water to travel over the top canopy. This trend causes anything being carried near the bottom of the water column to settle at a faster rate (Peterson et. al. 2006).

The growth of seagrass in the middle of the bed had on average the greatest growth rate. This was possibly due to the fact that all of the energy of the surrounding plants got shunted to the cut plants due to the constraints of the non-destructive sampling methods that were required in this area. This is because seagrasses normally occur in beds which are comprised of clonal replication. Therefore, when one member of the clonal unit comes under attack, the other members will give that one energy to grow. With rhizomes still intact, this energy transfer happened quite readily. The next fastest area that grew was the landward edge. The deep edge was slowest to grow because of a combination of the afore mentioned issue of energy transfer. It is important to note however that this part of the study was only done in one bay, Hoga Bay. Only one bay was chosen because of time constraints and because of its medium human disturbance level which I believed would be most representative of the region. One other interesting item to mention is that different seagrass species were in different abundances.

Enhalus. acoroides was found at the reef edge and interior beds while *C. serrulata* was mostly found only on the landward edge of the grass bed. When one looks at the data in this way, one can readily see that the core seagrass region would grow faster than the reef edge due to the shunting issues. The whole growth curve is thrown off therefore by the inclusion of the other seagrass species which grew faster due to it being a smaller and possibly faster growing species of grass. The two different species of grass came together, but normally the *C. serrulata* would wane out before the core seagrass bed region.

Marine diversity is at a peak in the Indo-Pacific due to the age of the system leading to high rates of speciation, especially in fish (Allen 2000), and convergence of biogeographic regions. It is well accepted that this region is highly diverse (Bouchet 2002), but results from my research indicate that taxa richness (Appendix I) and relative density (>400 individuals m^{-2}) was low. This is probably due to a number of key differences in this region as compared to the other tropical regions. It has been previously noted that this area is in near pristine condition (Unsworth et al. 2010), therefore many different species of fish and larger invertebrates predate upon the benthic invertebrates. This predation could greatly impact how many of these organisms can survive. It could also however just impact size of individuals. Due to certain constraints, only organisms that could be seen unaided were accounted for. Perhaps many others escaped this naked eye observation.

Humans are one of the most intrusive species, disturbing many areas and disrupting many ecosystem processes. Even when researching a nearly pristine area, the effects of human encroachment can be seen. Paving of small roads on the island, daily boat traffic, and tourist activity and habitation has drastically affected the one heavily impacted bay of the island. The overall lessening of an edge effect in Boat Bay could be seen in every aspect of ecological study. Faunal density decreases were so much that there was no significant difference at all between edge and interior bed. Hydrological flow rates were very similar between core and edge which would cause settlement differences. Edges are crucially important areas that contain increased species richness and density of organisms that vastly contribute to the overall larger ecosystem picture.

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Appendix I: Animal totals for bays and subregions

	Hoga Bay			Mushroom Bay			Boat Bay		
	LE	M	RE	LE	M	RE	LE	M	RE
Aschelminthes									
Nematoda	5	0	0	0	2	0	0	0	0
Mollusca									
Gastropoda									
Cypraea	0	0	0	1	2	4	0	0	0
Gatropod A	0	0	3	2	0	2	3	2	1
Gatropod B	1	0	1	0	0	0	0	0	0
Bivalvia									
Bivalve A	2	0	2	3	1	2	1	2	0
Annelida									
Polychaeta									
Polychete	18	9	15	28	8	9	2	6	5
Arthropoda									
Decapoda									
Peracarida									
Isopod	1	0	1	0	0	0	0	0	1
Amphipod	1	0	1	5	1	0	0	1	0
Malacostraca									
Brachyura	7	3	3	4	1	4	1	1	2
Caridae A	0	0	2	1	3	1	1	0	0
Caridae B	1	0	0	1	0	0	0	0	0
Paguroidea	1	0	1	2	1	1	1	0	1
Hoplocarida									
Stomatopoda	3	0	2	0	0	1	0	0	0
Echinodermata									
Echinoidea									
Echinoidea A	0	1	1	0	0	2	0	0	0
Echinoidea B	0	0	0	0	0	1	0	0	0
Holothuroidea									
Holothuroidea	0	0	0	1	0	0	1	0	0
Asterozoa									
Ophiuroidea	2	0	3	0	0	2	3	1	1
Hemichordata									
Enteropneusta									
Enteropneusta	1	0	0	0	0	0	0	0	0
Chordata									
Sygnathidae	1	0	0	0	0	0	0	0	0