

**MICROHABITAT SELECTION BY CARIBBEAN DAMSELFISH IN A MARINE  
PROTECTED AREA, BLUEFIELD'S BAY, JAMAICA**

A Masters Thesis

Presented to

The Graduate College of  
Missouri State University

In Partial Fulfillment

Of the Requirements for the Degree  
Master of Science, Biology

By

Nathanael R. Light

August 2013

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**ABSTRACT**

The main objective of this project was to determine if Caribbean damselfish select microhabitat based on coral morphology. Sampling sites were located within the Bluefield's Bay Marine Sanctuary in Bluefield's Bay, Jamaica. Four species of damselfish were selected, based on their abundance and ecological significance, and were sampled at 17 sites using a passive drift sampling technique in June, 2011. An underwater camera was utilized to capture associations between damselfish and the coral reef. Habitat composition was estimated by dividing the substrate into 14 categories based on morphology. Percent composition was estimated for each substrate group at 30 randomly selected positions within each transect and then averaged to provide an estimate across all 17 transects. Three chi-square goodness of fit tests were then utilized to examine the relationship between damselfish and microhabitat selection. The first included all observed substrate groups. The second excluded sand, and the third excluded all non-coral substrate groups. For all but one species (*C. parasema*), there was a significant difference between habitat selection and availability when analyzing all substrate types with and without sand. However, none of the four target species showed a habitat selection preference towards one group of live coral over another.

**KEYWORDS:** damselfish, microhabitat, Caribbean, Bluefield's Bay, Jamaica

This abstract is approved as to form and content

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Dr. Daniel Beckman  
Chairperson, Advisory Committee  
Missouri State University

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## **ACKNOWLEDGEMENTS**

I would like to thank the following people for their support during the course of my graduate studies: Dr. Daniel Beckman, Dr. John Havel, Dr. Brian Greene, Dr. Chris Barnhart, Dr. Robert Pavlowsky, Dr. Lynn Robbins, Larisa Bishop-Boros, Joshua Rudolph, Carly Johnson, Jennifer Carroll, and my father, to whom I owe my love of science and nature.

## TABLE OF CONTENTS

Introduction.....	1
Diversity of Coral Reef Ecosystem.....	1
Goods and Services.....	2
Impacts to Coral Reefs.....	3
Habitat Selection.....	4
Methods.....	7
Bluefield’s Bay Marine Protected Area, Jamaica.....	7
Passive Drift Sampling.....	7
Video Analysis.....	9
Statistical Analysis.....	10
Results.....	12
Sampling Transects.....	12
Statistical Analysis.....	12
Discussion.....	15
Data Limitations.....	18
Applications and Recommendations.....	19
References.....	21

## LIST OF TABLES

Table 1. Number of individuals observed for each transect by species.....	24
Table 2. Observed associations between species and substrate groups .....	25
Table 3. Percent habitat composition per transect and mean habitat composition across transects.....	26
Table 4. Frequencies of individuals expected to associate with substrate groups .....	27
Table 5. Frequencies of individuals expected to associate with substrate, excluding sand .....	28
Table 6. Frequencies of individuals expected to associate with substrate, excluding non-coral substrates.....	29
Table 7. The chi-square analysis of the associations of <i>Stegastes fuscus</i> with substrate...30	
Table 8. The chi-square analysis of the associations of <i>Stegastes partitus</i> with substrate 30	
Table 9. The chi-square analysis of the associations of <i>Chrysiptera parasema</i> with substrate .....	30
Table 10. The chi-square analysis of the associations of <i>Stegastes leucostictus</i> with substrate .....	31
Table 11. The chi-square analysis of the associations of <i>Stegastes fuscus</i> with substrate, excluding sand .....	31
Table 12. The chi-square analysis of the associations of <i>Stegastes partitus</i> with substrate, excluding sand .....	31
Table 13. The chi-square analysis of the associations of <i>Chrysiptera parasema</i> with substrate, excluding sand .....	32
Table 14. The chi-square analysis of the associations of <i>Stegastes leucostictus</i> with substrate, excluding sand .....	32
Table 15. The chi-square analysis of the associations of <i>Stegastes fuscus</i> with substrate, excluding non-coral substrates.....	32
Table 16. The chi-square analysis of the associations of <i>Stegastes partitus</i> with substrate, excluding non-coral substrates.....	33

Table 17. The chi-square analysis of the associations of *Chrysiptera parasema* with substrate, excluding non-coral substrates .....33

Table 18. The chi-square analysis of the associations of *Stegastes leucostictus* with substrate, excluding non-coral substrates .....33

## LIST OF FIGURES

Figure 1. Microhabitat selection by <i>Stegastes fuscus</i> .....	34
Figure 2. Microhabitat selection by <i>Stegastes partitus</i> .....	34
Figure 3. Microhabitat selection by <i>Chrysiptera parasema</i> .....	35
Figure 4. Microhabitat selection by <i>Stegastes leucostictus</i> .....	35
Figure 5. Microhabitat selection by <i>Stegastes fuscus</i> , excluding sand .....	36
Figure 6. Microhabitat selection by <i>Stegastes partitus</i> , excluding sand.....	36
Figure 7. Microhabitat selection by <i>Chrysiptera parasema</i> , excluding sand .....	37
Figure 8. Microhabitat selection by <i>Stegastes leucostictus</i> , excluding sand .....	37
Figure 9. Microhabitat selection by <i>Stegastes fuscus</i> , excluding non-corals.....	38
Figure 10. Microhabitat selection by <i>Stegastes partitus</i> , excluding non-corals .....	38
Figure 11. Microhabitat selection by <i>Chrysiptera parasema</i> , excluding non-corals.....	39
Figure 12. Microhabitat selection by <i>Stegastes leucostictus</i> , excluding non-corals.....	39



## INTRODUCTION

Coral reef ecosystems are some of the most diverse and productive habitats on planet Earth. Although they cover merely 0.05% (255,000km<sup>2</sup>) of the Earth's surface, they are home to over one third of the ocean's fish species (McAllister, 1991; Spalding and Grenfell, 1997). Located geographically between the Tropic of Cancer and the Tropic of Capricorn (30°N and 30°S respectively) with the highest density occurring near the equator, coral reefs often occur in shallow, nutrient poor water and are limited in distribution by a narrow range of environmental factors such as depth (1-100m), salinity, turbidity, water temperature (18-29°C), ocean currents, and water clarity (Goreau et. al., 1979; Hawaii University, 2001).

The lack of suspended particles and dissolved nutrients allows for clear water conditions which increases the photosynthetic capacity of the symbiotic zooxanthellae that are associated with corals. Although these geographically limiting conditions are typical for most of the Earth's coral reefs, there are also deep water reefs in which corals are not associated with zooxanthellae but instead rely on chemosynthesis from deep ocean vents and suspension feeding on drifting detritus as their primary food sources (NOAA, 2013).

### **Diversity of Coral Reef Ecosystems**

Often described as the “rainforests of the sea”, coral reef ecosystems maintain a high level of diversity. Although there may exist variation between geographically distinct reef ecosystems, on average, coral reefs have been observed to support more than

140 different species of fish from more than 30 families making them one of the most concentrated areas of fish diversity on the planet (Sale et al., 1994).

This diversity may, at least in part, be attributed to the intermediate rate of disturbance in coral reef habitats. The equilibrium hypothesis states that environments in an equilibrium state maintain a low level of diversity through infrequent disturbance, which allows for a balanced allocation of resources and niche diversification. However, coral reefs are often subject to intermediate rates of disturbance, thus diversity could result from this series of disturbances as the ecosystem rarely reaches an equilibrium state (Connell, 1978). This explanation for reef diversity is also supported by the non-equilibrium intermediate disturbance hypothesis which states that high and low frequencies of disturbance support lower diversity whereas environments that experience intermediate frequencies and intensities of disturbance supports the highest level of diversity (Aronson and Precht, 1995).

It has also been proposed that habitat disturbance may immediately result in a decrease in fish abundance and the reef may ultimately support fewer species (Syms and Jones, 2000). Diversity may also be explained by examining the rate of speciation in coral reefs. Although fish species may move freely within a patch reef ecosystem, spatial heterogeneity may ultimately contribute to an increase in species diversity (Connor and Simberloff, 1979; Sale et al., 1994).

### **Goods and Services**

Apart from their apparent environmental and ecological benefits, coral reefs also provide an array of economic and societal benefits. Coral reefs provide approximately

10% of all commercially harvested marine fish annually and it has been estimated that over 50 million people in developing countries depend directly on the reefs for their sustenance and livelihood (Moberg and Folke, 1999). In many areas where coral reef fisheries have been degraded, the primary means of generating income has begun to shift from sustenance fishing toward more environmentally friendly sources of income such as ecotourism. It is perhaps this shift towards sustainable management of reef resources that has led to the greatest localized push towards reef conservation and protection. Such is the case with the Fishermen's Friendly Society in Bluefield's Bay, Jamaica.

The Fishermen's Friendly Society was organized in the early 2000's by Wolde Cristos in order to promote, and bring awareness to, conservation issues regarding the dwindling fishery in Bluefield's Bay. A formal reorganization of a previously established conservation group in the 1970's, the Bluefield's Bay Fishermen's Friendly Society (BBFFS) helped to establish, and define, the boundary separating the Bluefield's Bay Marine Protected Area (MPA) from surrounding areas that are open to commercial fishing. They also helped to recruit and maintain an agency of conservation agents whose sole duty it is to enforce the no-take regulations throughout the Marine Protected Area. Together, with support from the local community, Cristos and the Fishermen's Friendly Society have made the Marine Protected Area at Bluefield's Bay a model for reef conservation throughout the entirety of Jamaica (BBFFS, 2013).

### **Impacts to Coral Reefs**

Since the average accretion rate of reef building corals is relatively slow (0.6 meters per century), coral reef ecosystems are often slow to recover from anthropogenic

or natural impacts (AIMS, 2011). As the climate continues to change and humans continue to alter the environment in and around coral reefs, corals are faced with a variety of severely degrading issues. The primary issues, both natural and human mediated, affecting Caribbean coral reefs are: sedimentation, pollution, dynamite fishing, ocean acidification, coral bleaching, heavy metal contamination, hurricanes, and El Niño events. The latter two, though naturally occurring during the evolution of reef building corals, only present a lasting negative impact to reef ecosystems when coupled with another anthropogenic impact (Lugo et al., 2000; Fichez et al., 2005; Shah, 2013). As reefs are damaged and degraded, the coral species composition of reefs is beginning to change. Since reef fish are dependent on species-specific interactions with corals, we can expect to observe a shift in microhabitat preference as the availability of coral composition begins to change (Sale et al., 1984; Precht et al., 2010).

### **Habitat Selection**

It is well understood that most reef fish species exist as pelagic juveniles early in their life history and select microhabitat upon settlement before entering a demersal stage as adults (Sale, 1980; Sale et al., 1984; Fowler et al., 1992; Tolimieri, 1995).

Microhabitat preference for specific features of the coral substrate are exhibited upon settlement as pelagic reef fish move down or “settle” onto the reef substrate. Although some reef fish comprise large, schooling populations, there are territorial reef fish, such as damselfish, that have been observed to defend general, all purpose territories and are closely associated with coral microhabitats of the reef ecosystem (Robertson et al., 1981). These territories can be identified and defined by the needs they satisfy in demersal reef

fish assemblages. Territorial reef damselfish secure a discrete portion of the coral substrate that may then be used for food acquisition, nesting sites, and shelter from predators (Thresher, 1983). Many demersal damselfish species use the coral substrate to graze on algae from the reef surface. This symbiotic relationship ensures that the corals remain algae free to perform photosynthesis while also enabling the damselfish to remain well supplied with nutrient rich algae which they may also supplement by feeding on other benthic materials (Robertson, 1996).

Although there are distinct microhabitat characteristics that positively correlate with microhabitat preference among reef fishes, such as the size of the coral, the degree of branching of the coral structure, and its proximity to sand, depth appears to be the most limiting factor influencing reef fish upon settlement (Holbrook et al., 2000; Srinivasan, 2003). Following settlement by pelagic juveniles, interspecific and intraspecific competitive interactions begin to shape the large-scale distribution of territorial damselfish throughout a reef ecosystem by limiting habitat use at small-scale locations (Robertson, 1996).

Due to the variety of natural and anthropogenic impacts to coral reefs, much of the coral substrate is becoming degraded, which often results in a new substrate type composed of rubble from previously live corals. Rubble often occurs as a result of dynamite fishing and natural processes, such as hurricanes, and can be observed in reef ecosystems throughout the Caribbean. When disturbances from dynamite fishing are low, the coral rubble created from this activity may promote an increase in coral polyp recruitment which can replace the damaged reef bed within 5 years; however, if coupled with other degrading impacts, the reef may take decades to recover (Fox and Caldwell,

2006). This coral rubble has become a significant component of the reef substrate in Bluefield's Bay and, based on previous studies, can be expected to support lower densities of damselfish than the live, branching corals that these reef fish prefer (Wilkes et al., 2008). Although Caribbean damselfish have been observed to associate with coral rubble in what appears to be more than a merely random association, the ultimate cause of this association is yet to be described.

Microhabitat preferences may account for the small level of difference among fish assemblages between patch reefs, and, if distances between patch reefs measures in the tens of kilometers, dispersal may limit the spatial synchrony of reef fish from one patch to another (Cheal et al., 2007). Ultimately, these differences in microhabitat preference and selection may influence the large-scale distributions of reef fish within a patch reef ecosystem (Tolimieri, 1995; Tolimieri, 1998). Due to this semi-predictable distribution of reef fishes based on microhabitat preferences, it is becoming increasingly important to understand the characteristics of reef corals that reef fish prefer upon settlement in order to manage a Marine Protected Area (MPA) effectively for both flora and fauna.

For this project I selected four species of damselfish: the dusky damselfish (*Stegastes fuscus*), the yellowtail damselfish (*Chrysiptera parasema*), the beaugregory (*Stegastes leucostictus*), and the bi-colored damselfish (*Stegastes partitus*) based on their relatively high abundance in Bluefield's Bay MPA and their ecological similarities. I hypothesize that Caribbean damselfish will not select coral microhabitats at random or based solely on availability; and, due to the disappearance of large, branching *Acropora* corals in the Caribbean, I also hypothesize that microhabitat selection by damselfish will shift towards larger encrusting, mound and boulder corals.

## **METHODS**

The current research proposal was approved by the Missouri State University Institutional Animal Care and Use Committee (IACUC) in the spring of 2011 and was funded by a Latin American, Caribbean and Hispanic Studies (LACHS) research grant and the Missouri State University Graduate College.

### **Bluefield's Bay Marine Protected Area, Jamaica**

The marine sanctuary in Bluefield's Bay, Jamaica is one of nine marine protected areas established by the Jamaican Ministry of Fisheries and Agriculture in July, 2009 to restore the nation's overharvested marine fisheries. The MPA at Bluefield's Bay is a 3,000 hectare reserve covering an extensive patch reef ecosystem and is located in the Westmoreland Parrish in Southwest Jamaica (latitude: 18 10' 00", longitude: -78 03' 00"). The coral reef at Bluefield's Bay MPA is a vast patch reef ecosystem providing habitat to over 100 species of fish, reptiles, and invertebrates.

### **Passive Drift Sampling**

Since the reef patches are not contiguous, the first field day was spent marking reef patches with a GPS unit in order to delineate sampling transects. Seventeen sampling transects were established across the sanctuary and these data were collected via the implementation of an underwater HD video camera connected to the boat by a 25' telescoping camera mount. These data were collected between May 31, 2011-June 10, 2011 and all reef patches were sampled between 0800-1400hrs on sampling dates.

A passive drift sampling technique was developed to utilize an underwater HD camera based on the standard AGRRA sampling protocol for Caribbean reef ecosystems (Lang et. al., 2010; Carleton and Done, 1995). However, in order to reduce fish avoidance to the presence of a diver and to the boat engine, we did not utilize an underwater diver following a delineated transect as suggested in the AGGRA protocol. Instead the boat was positioned up current from the reef patch to be sampled and the engine was then turned off and, utilizing the current, the vessel was allowed to drift over the sample site with the camera mount attached to the vessel and the camera positioned just above the reef substrate.

On occasion, when the vessel appeared to be drifting off a reef patch and over a large sand/sea grass bed, the vessel was pulled by a snorkeler back towards the reef patch. This was done in order to maximize the amount of information recorded while sampling the transect. All transects were standardized by the amount of time that they were sampled instead of the distance sampled. All transects were sampled for 15 minutes and were selected systematically in order to maximize the number of sites sampled within a given day. Due to the size of the MPA in Bluefield's Bay, all transects were sampled in one distinct area of the MPA before moving on to sample another area of the bay. In total, 17 transects were sampled across the Bluefield's Bay MPA.

While sampling a given transect, we recorded a GPS location every 60 seconds for 15 minutes in order to map the sampling transect on ArcGIS and also to aid in the calculation of an average drift speed and approximate length for each of the 17 transects. GPS coordinates were initially recorded in UTM and later converted to Lat/Long using the RCN Utilities and Tool Conversion Program from Montana State University.



## **Video Analysis**

Four species of damselfish (*Stegastes fuscus* (dusky damselfish), *Chrysiptera parasema* (yellowtail damselfish), *Stegastes leucostictus* (Beaugregory), and *Stegastes partitus* (bi-colored damselfish)) were selected based on their abundance within the Bluefield's Bay MPA and their degree of ecological similarity.

The marine habitat was divided into 14 substrate groups based on morphology: sand, fire corals, octocorals, pillar and branching corals, rubble, encrusting mound building corals, brain corals, leaf plate and sheet corals, fleshy corals, cup and flower corals, black corals, algae, sea grass, and sponges (Humann & Deloach, 2002). In order to calculate the percent cover for each substrate group, 30 frames were selected from each transect video by using a random number generator. Percent cover was then calculated, for each of the 14 substrate groups, by dividing the screen shot into 4 quadrants and then estimating the percent cover of each substrate group per frame for each of the 30 frames selected in every transect. Dividing the frame into quadrants allowed for a more accurate estimate of the percent cover of each substrate group that was present in each frame. Once all 30 frames had been analyzed, the percent of habitat cover for each of the 14 substrate groups was then averaged to provide an estimate for the entire transect.

The transect videos were then analyzed again to examine the “associations” of the 4 target species with each of the habitat substrate categories. For this analysis, an association was defined as any individual directly adjacent to or utilizing (feeding, hiding, guarding, etc.) a particular coral type for three or more seconds. This definition of association is meant to identify individuals that are actively utilizing the coral habitat as

well as to exclude individuals that are merely passing haphazardly across the reef substrate during the moment the camera captured the images. Associations of each individual of the 4 target species were then recorded for each of the potential 14 substrate groups. Individuals that appeared to be passing haphazardly through the field of view, and were not deemed to be in association with a particular substrate category, were designated No Distinct Association (NDA) and were excluded from the analysis.

### **Statistical Analysis**

Once these data had been quantified, I performed a chi-square goodness of fit test to determine if the target species of damselfish are selecting habitat at random, i.e. based merely on habitat availability. I calculated the mean of the percent habitat cover for each substrate group across all transects. I then calculated the number of each target species that were identified with a particular association across all 17 video transects and entered these data into the table labeled “Observed Data”.

In order to calculate the expected number of individuals for each substrate group, I multiplied the total number of fish per species by the proportion of the total habitat in each habitat category to determine the expected frequency if the fish were choosing habitat at random. Categories with expected values  $<4$  were pooled together into a category designated as “rare classes”. Since the substrate category “sand” proved to be a significant portion of the sampled substrate, yet is not biologically relevant since territorial reef fish do not associate purely with a sand substrate, I conducted three chi-square analyses for each species: the first analysis included all observed substrates as microhabitat categories, the second analysis excluded sand, and the third analysis

excluded all non-coral microhabitat categories (i.e. sand, coral rubble, algae, sea grass and sponges). When calculating the expected number of individuals for the second chi-square analysis, I first had to remove the sand substrate group from the analysis and calculate new proportions of area sampled for each remaining substrate group. To do this, I divided the observed proportion of area sampled for each substrate group ( $A_i$ ) by the sum of the proportions of all substrate groups sampled ( $N$ ) and then calculated the new proportion of area sampled for each substrate group ( $P_i$ ) using the formula  $P_i = A_i / N$ . I then calculated the new expected frequency for each substrate group ( $E_i$ ) using the formula  $E_i = n * P_i$ , where  $n$  equals the number of individuals observed per species. I then used this same procedure to remove all “non-coral” substrate groups for the third chi-square analysis and then calculated a new proportion of area sampled for each substrate group as well as the new expected number of individuals for each of the substrate groups.

## **RESULTS**

### **Sampling Transects**

Seventeen sampling transects were analyzed to estimate the percent habitat composition across all reef patches in the Marine Sanctuary. The number of individuals (N) of each of the four target species, identified in the transect videos, were recorded in T1.

### **Statistical Analysis**

Once individual damselfish had been identified, these data were then analyzed for associations with a particular substrate group (T2). Individuals that were not associated with a particular substrate group (NDA) were excluded from the analysis. Habitat composition was calculated for each transect by randomly selecting 30 frames, using a random number generator, from each video and then the mean was calculated for each substrate group across all 17 transects. The percent composition of each substrate group is represented per transect and then averaged to provide an estimate across all transects (T3). The number of individuals expected to associate with each particular substrate type, assuming that individuals are selecting habitat randomly or based on availability, were calculated by multiplying the total number of individuals of a particular species that were sampled across all transects by the proportion of area sampled for each of the 14 substrate groups and this was done for each of the three chi-square analyses (T4-6).

A chi-square goodness of fit test was then utilized to examine the relationship between the observed associations of each species of damselfish with a particular substrate category and the expected associations. If the expected number of damselfish for each substrate category was  $\geq 4$ , then that substrate type constituted a statistical category. The expected values that were  $< 4$ , were summed to comprise the statistical category “rare classes”. Since sand was a major component of the marine substrate but is not biologically relevant, since reef fish are not known to associate purely with a sand substrate, a separate analysis was conducted which excluded sand as a substrate group.

In total, three chi square analyses were conducted. The first analysis included sand as a substrate category while the second analysis excluded sand as a substrate category and the third analysis excluded all non-coral substrates (sand, algae, sea grass, and sponges). The first analysis indicates that reef fish are selecting against a sand substrate (T7-10, F1-4). The second analysis, which excluded sand as a substrate category, and from the rare class category, indicates that reef fish are selecting for EMB corals and are selecting against rubble substrates and the substrates that comprise the rare class category. However, selection by the yellowtail damselfish (*C. parasema*) did not differ statistically from habitat availability (T11-14, F5-8). The third analysis, which excluded all “non-coral” substrate groups, indicates that reef fish prefer live coral substrates and do not select for non-coral substrate groups. However, in the third analysis, habitat selection did not differ statistically from habitat availability. This indicates that damselfish are selecting microhabitat based on availability and do not exhibit a preference for one coral morphology over another. Only the bicolor damselfish (*S.*

*partitus*) showed a preference for EMB corals and selected against the substrate groups that comprise the rare class category (T15-18, F9-12).

## DISCUSSION

Activities such as dynamite fishing, pollution, terrestrial run-off, over fishing, increased sedimentation, agricultural practices, El Niño events, coral bleaching, and climate change may lead to a dramatic shift in coral species diversity and abundance in Caribbean reefs, ultimately affecting the overall composition and quality of a reef ecosystem. As the diversity and abundance of Caribbean corals change within a reef ecosystem, the association between reef species and the coral habitat is likely to change. This general trend is illustrated by the shift in microhabitat selection by the three spot (*Stegastes planifrons*) damselfish following the loss of the coral genus *Acropora* in the Caribbean. As large, branching corals began to disappear in the Caribbean, microhabitat selection by *S. planifrons* began to shift towards other high structured coral species such as *Montastraea annularis*, a mound building coral (Precht et al., 2010). This shift towards a high structured coral substrate may also enhance survival and growth of juveniles after settlement. Although damselfish have a narrow depth range at settlement independent of microhabitat characteristics, damselfish that settle at more shallow depths are significantly correlated with an increase in growth and survival (Syms and Jones, 2000).

Since many Caribbean damselfish share similar niches within a reef ecosystem, it can be inferred that they also share similar preferences for selecting coral microhabitat; thus a shift in microhabitat selection by the *S. planifrons* due to the loss of *Acropora* corals may reflect a large scale shift in habitat preference for many species of damselfish (Sale et al., 1984). By examining the habitat selection of Caribbean damselfish based on coral morphology, we may develop a better understanding of how microhabitat

preferences of Caribbean reef fish are changing in response to a changing environment and ultimately may be better able to utilize our understanding of these associations when designing and implementing artificial reefs and fisheries management practices. Since there is a positive relationship between live coral cover and the total number of species, artificial reefs that allow for the development of large encrusting, mound and boulder corals, instead of merely attempting to reestablish large branching corals, may ultimately increase the productivity and diversity of reef ecosystems (Bell and Galzin, 1984).

It is also important to note that as microhabitat preferences shift we may also see a change in the rates of colonization during settlement, and thus a change in the levels of interspecific and intraspecific competition. A relatively recent study (Ebersole, 1985), demonstrated that as large, branching *Acropora* corals began to disappear in the Caribbean, the levels of interspecific competition between the beaugregory and the three-spot damselfish was altered. The three-spot damselfish (*Stegastes planifrons*), a more aggressive territorial damselfish was observed to be less competitive regarding settlement on encrusting, mound and boulder corals which allowed for higher rates of colonization by *S. leucostictus*, a less aggressive territorial damselfish. Ultimately, microhabitat preference and aggressive interactions may limit habitat selection (Ebersole, 1985).

I hypothesized that damselfish would not select microhabitat based solely on availability and this hypothesis was not supported by the data. In analysis two, when considering all substrate types except sand, three out of four species selected for EMB corals and selected against rubble and the groups comprising the rare class category. The yellowtail damselfish (*C. parasema*) was the only species to select habitat based on availability in analysis two ( $p=0.1275$ ). In analysis three, there was not a statistical



difference between habitat selection and habitat availability when I removed all non-coral substrates. However, the bicolor damselfish (*S. partitus*), did select for EMB corals and against the coral substrates that comprise the rare class category and was the only species to exhibit preference for a particular coral morphology in analysis three. Since the four target species of damselfish analyzed by this study share similar ecological preferences, I expected them to select similar microhabitats. Although there was not a statistical difference between microhabitat selection and coral substrate availability, these data show that the four species of damselfish select against sand and non-coral substrates but do not exhibit a preference for a particular coral morphology over available substrate groups. All four species selected microhabitat based on availability. These results are not congruent with studies by Precht et al., 2010 and Sale et al., 1984 since damselfish are selecting microhabitat based on availability.

Although none of the four target species were found to be in association with a rubble substrate, Tolimieri (1998) found that the species of coral that comprises coral rubble may be a determining factor prompting associations with members of *S. partitus* and *S. leucostictus*. My study was unable to differentiate between the rubble of different coral species and thus all coral rubble was congregated into one distinct substrate group. Although my study was able to identify some substrate groups that damselfish selected against, it was not able to identify the precise feature(s) of the coral substrate that attract damselfish after settlement.

## **Data Limitations**

Due to the variable clarity of the water in Bluefield's Bay and the resolution limits of the HD sampling camera, it is possible that some juvenile damselfish were not detected during the video analysis. During the video analysis, I was also not able to identify any of the small coral morphologies that, although infrequent, are assumed to be present in the Bluefield's Bay MPA. Coral morphology types, such as the cup and flower corals and the fleshy corals, would be difficult to identify using only the HD camera since its distance above the substrate varied slightly across and within each transect during sampling. However, the sampling method worked well for the larger coral morphologies as described by Carelton and Done (1995).

Although I attempted to keep the camera at a relatively uniform distance from the substrate, the depth of the camera from the water's surface had to be adjusted several times within a transect to avoid large mounds of boulder coral, and thus the camera's field of view is not uniform within a transect or across the transects sampled. Since I did not know the exact distance from the camera to the coral substrate, I was unable calculate the size of objects and the area sampled. This standardization would have allowed for me to identify the optimal distance between the camera and the reef substrate and thus would have provided the optimal balance between detail and field of view. In retrospect, it would have been beneficial to have measured and marked several meter intervals on the side of the telescopic camera mount in order to determine the cameras exact distance from the surface when submerged. This, in addition to the depth measurements taken every minute throughout each transect, would have allowed me to calculate the exact distance of the camera above the coral substrate and to keep the field of view consistent

from one transect to another. It would also have allowed for me to calculate the total area sampled by the cameras field of view and would have possibly allowed for me to estimate the distance from the observed association on the reef patch to the sand bed at the edge of the reef patch.

### **Applications and Recommendations**

The complete recovery of the ecosystem at Bluefield's Bay is being hindered by the lack of enforcement regarding fishing practices in and around the MPA. The lack of financial support from the Jamaican Ministry of Agriculture and Fisheries prevents the Fishermen's Friendly Society and other conservation agencies from hiring an adequate amount of personnel and equipment to properly monitor the MPA and enforce its regulations. During our stay in Bluefield's Bay we witnessed several incidents of illegal fishing and netting within the MPA and the game wardens in the MPA were only occasionally able to confiscate illegally placed nets and equipment. Despite the several notices issued to violators of the MPA laws, only one individual was brought through the judicial process and this merely resulted in a minimal fine. It may take more than ten years for a highly regulated marine protected area to show significant recovery from the devastating impacts of overfishing and the employment of fishing methods that damage reef habitat (Aburto-Oropeza et al., 2011), and without continued assistance both from community organizations and the Jamaican government the Bluefield's Bay MPA may be several years from showing levels of significant recovery.

Although we can expect to see an increase in the abundance and diversity of opportunistic carnivorous fish species once a MPA has been closed to fishing, without the

reestablishment of reef habitat we cannot expect to obtain an increase in the diversity and abundance of herbivores (McClanahan et al., 2011). The reestablishment of herbivores, especially exploitative grazers in the family *Scaridae*, may ultimately promote coral cover. However, if the population of exploitative grazers is not kept in check through predation, coral cover is expected to decrease rapidly over a period of a few decades (Mumby, 2006). It is for this reason that MPA's must be managed using an ecosystem approach that promotes the reintroduction and preservation of both carnivorous and herbivorous species in order to provide a balanced, sustainable habitat.

The recent addition of an artificial reef within the MPA in 2010 was a great leap forward towards the reestablishment of lost reef habitat and the desired increase in fish biomass. Although an increase in enforcement and regulation is necessary to promote the long-term success of such a project, an increase in live coral cover up to 2% in the Bluefield's Bay MPA will lead to a significant increase in fish biomass, ultimately aiding in the restoration of the reef ecosystem and the fishery in southwest Jamaica's newest MPA (Bell and Galzin, 1984). Despite its achievements and setbacks, there is a desperate need for more scientific research within the Bluefield's Bay MPA as well as funding for MPA enforcement and conservation.

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Table 1. Number of individual fish observed for each transect by species.

Video #	N	<i>S. fuscus</i> (Dusky)	<i>S. partitus</i> (Bi-colored)	<i>C. parasema</i> (Yellowtail)	<i>S. leucostictus</i> (Beaugregory)
643	1	1	0	0	0
656	5	2	3	0	0
702	9	5	3	0	1
717	4	3	1	0	0
736	7	6	1	0	0
801	24	16	5	1	2
816	15	12	2	0	1
611	25	12	9	4	0
626	31	20	4	1	6
642	37	29	1	5	2
546	27	23	1	3	0
420	7	0	0	6	1
405	7	1	0	0	6
602	23	13	7	2	1
751	15	13	2	0	0
812	22	21	0	1	0
456	5	4	1	0	0
Sum	264	181	40	23	20



Table 2. Observed associations between species and substrate group.

<b>Observed</b>	<i>S. fuscus</i>	<i>S. partitus</i>	<i>C. parasema</i>	<i>S. leucostictus</i>	Total
FC	1	1	0	0	2
OC	4	0	0	2	6
PB	14	0	3	2	19
EMB	93	19	10	11	133
BrC	0	0	0	0	0
LPS	12	1	2	0	15
FIC	0	0	0	0	0
CF	0	0	0	0	0
BIC	0	0	0	0	0
<b>Sand</b>	0	0	0	0	0
<b>R</b>	17	4	3	0	24
<b>AL</b>	1	0	0	0	1
<b>SG</b>	1	0	0	0	1
<b>SP</b>	0	0	0	0	0
NDA	36	10	5	5	56
<b>Total</b>	<b>179</b>	<b>35</b>	<b>22</b>	<b>20</b>	470

\* FC (fire corals), OC (octocorals), PB (pillar and branching corals), EMB (encrusting, mound, and boulder corals), BrC (brain corals), LPS (leaf, plate, and sheet corals), FIC (fleshy corals), CF (cup and flower corals), BIC (black corals), **R** (rubble), **AL** (algae), **SG** (sea grass), **SP** (sponges), NDA (no distinct association).

\*Non-coral substrate groups (**bold**)

Table 3. Percent habitat composition per transect and the mean habitat composition across all transects.

Video	Sand	FC	OC	PB	R	EMB	BrC	LPS	FIC	CF	BIC	AL	SG	SP
643	28.8	4.6	2.9	3.8	16.3	20.0	0.0	10.0	0.6	0.0	1.3	11.9	0.0	0.0
656	60.0	0.9	4.7	0.3	15.6	9.4	0.0	0.6	0.0	0.0	0.0	7.8	0.0	0.6
702	10.2	4.5	1.0	3.8	21.4	38.3	0.0	5.0	0.2	0.0	0.0	11.4	4.3	0.0
717	16.0	3.0	1.0	7.0	23.0	26.0	1.0	6.0	0.0	0.0	0.0	17.0	0.0	0.0
736	23.8	0.0	4.6	1.3	14.6	30.8	0.0	5.4	0.0	0.0	5.0	12.1	0.4	1.3
801	26.4	2.2	9.3	3.3	15.5	28.3	0.5	4.1	0.0	0.0	0.3	2.1	7.3	0.9
816	9.8	5.5	2.5	3.8	14.2	42.2	0.3	6.5	0.0	0.0	0.2	14.2	0.2	1.0
611	9.0	5.8	2.5	6.3	23.8	28.3	0.2	4.2	0.0	0.0	0.2	0.2	19.3	0.2
626	9.1	2.7	1.1	5.2	45.7	32.9	0.0	2.3	0.0	0.0	0.0	1.1	0.0	0.0
642	15.0	2.4	1.2	3.5	33.6	39.1	0.2	4.7	0.0	0.0	0.0	0.0	0.0	0.3
546	0.9	0.4	4.1	6.0	29.4	47.2	0.4	8.3	0.0	0.0	0.0	0.4	2.2	0.9
420	52.8	0.0	0.5	0.3	0.7	7.7	0.0	0.3	0.0	0.0	0.0	37.7	0.0	0.0
405	57.3	0.0	0.0	0.0	0.3	16.3	0.0	0.0	0.0	0.0	0.0	25.8	0.0	0.2
602	0.0	2.4	1.6	7.3	37.1	35.5	0.3	4.3	0.0	0.0	0.0	0.3	10.3	0.9
751	33.4	0.2	0.5	1.3	50.5	13.9	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
812	8.2	0.2	0.3	2.7	64.0	21.0	1.7	0.3	0.0	0.0	0.0	1.7	0.0	0.0
456	3.5	0.5	0.3	6.7	20.3	15.5	0.2	1.3	0.0	0.0	0.0	0.0	51.5	0.2
Mean	20.57	1.95	2.1	3.59	26.27	26.96	0.28	3.25	0.02	0	0.22	7.84	6.6	0.38

Table 4. Frequencies of individuals expected to associate with substrate groups.

Substrate Group	Proportion of Area Sampled P(x)	<i>S. fuscus</i> E(x)	<i>S. partitus</i> E(x)	<i>C. parasema</i> E(x)	<i>S. leucostictus</i> E(x)
Sand	.2057	<u>29.41</u>	<u>5.14</u>	3.70	3.08
FC	.0195	2.75	0.48	0.35	0.29
OC	.0210	3.00	0.53	0.38	0.32
PB	.0359	<u>5.14</u>	0.90	0.65	0.54
EMB	.2696	<u>38.55</u>	<u>6.74</u>	<u>4.85</u>	<u>4.04</u>
BrC	.0028	0.41	0.07	0.05	0.04
LPS	.0325	<u>4.65</u>	0.82	0.59	0.49
FIC	.0002	0.35	0.06	0.06	0.04
CF	.0000	0.00	0.00	0.00	0.00
BIC	.0022	0.32	0.06	0.04	0.03
R	.2627	<u>37.56</u>	<u>6.57</u>	<u>4.73</u>	<u>3.94</u>
AL	.0784	<u>11.22</u>	1.96	1.96	1.18
SG	.0660	<u>9.45</u>	1.65	1.65	0.99
SP	.0038	0.55	0.10	0.01	0.06
Sum	1.0	N=143	N=25	N=18	N=15

\*Underlined values are distinct substrate groups, non-underlined values comprise “rare class” category.  $E(x) = N \cdot P(x)$

Table 5. Frequencies of individuals expected to associate with substrate, excluding sand.

Substrate Group	Proportion of Area Sampled P(x)	<i>S. fuscus</i> E(x)	<i>S. partitus</i> E(x)	<i>C. parasema</i> E(x)	<i>S. leucostictus</i> E(x)
FC	.0242	3.46	0.60	0.44	0.36
OC	.0264	3.77	0.66	0.47	0.40
PB	.0451	<u>6.45</u>	1.13	0.81	0.68
EMB	.3383	<u>48.38</u>	<u>8.46</u>	<u>6.09</u>	<u>5.07</u>
BrC	.0036	0.51	0.09	0.06	0.05
LPS	.0408	<u>5.83</u>	1.02	0.73	0.61
FIC	.0031	0.44	0.08	0.06	0.05
CF	.0000	0.00	0.00	0.00	0.00
BIC	.0028	0.40	0.07	0.05	0.04
R	.3297	<u>47.14</u>	<u>8.24</u>	<u>5.93</u>	<u>4.95</u>
AL	.0985	<u>14.08</u>	2.46	1.77	1.48
SG	.0829	<u>11.85</u>	2.07	1.49	1.24
SP	.0048	0.69	0.12	0.09	0.07
Sum	1.0	N=143	N=25	N=18	N=15

\*Underlined values are distinct substrate groups, non-underlined values comprise “rare class” category.  $E(x) = N \cdot P(x)$

Table 6. Frequencies of individuals expected to associate with substrate, excluding non-coral substrates.

Substrate Group	Proportion of Area Sampled P(x)	<i>S. fuscus</i> E(x)	<i>S. partitus</i> E(x)	<i>C. parasema</i> E(x)	<i>S. leucostictus</i> E(x)
FC	.0499	<u>6.19</u>	1.05	0.75	0.75
OC	.0545	<u>6.75</u>	1.14	0.82	0.82
PB	.0931	<u>11.55</u>	1.96	1.40	1.40
EMB	.6988	<u>86.65</u>	<u>14.67</u>	<u>10.48</u>	<u>10.48</u>
BrC	.0073	0.91	0.15	0.11	0.11
LPS	.0843	<u>10.45</u>	1.77	1.26	1.26
FIC	.0064	0.79	0.13	0.10	1.10
CF	.0000	0.00	0.00	0.00	0.00
BIC	.0057	0.71	0.12	0.09	0.09
Sum	1.0	N=124	N=21	N=15	N=15

\*Underlined values are distinct substrate groups, non-underlined values comprise “rare class” category.  $E(x) = N \cdot P(x)$

Table 7: The chi-square analysis of the association of *Stegastes fuscus* with substrate groups.

Substrate Group	Observed (O)	Expected (E)	(O-E) <sup>2</sup> /E
PB	14	6.43	8.91
Rubble	17	47.02	19.17
EMB	93	48.26	41.49
LPS	12	5.82	6.56
AL	1	14.04	12.11
SG	1	11.82	9.91
Sand	0	36.81	1.67
Rare Class	5	8.84	36.81
Total	143	143	
X <sup>2</sup>			136.63
p value			p=<0.0001

Table 8. The chi-square analysis of the association of *Stegastes partitus* with substrate groups.

Substrate Group	Observed (O)	Expected (E)	(O-E) <sup>2</sup> /E
Rubble	4	9.19	2.93
EMB	19	9.44	9.7
Sand	0	7.2	7.2
Rare Class	2	9.18	5.62
Total	25	25	
X <sup>2</sup>			25.45
p value			p=0.000022

Table 9. The chi-square analysis of the association of *Chrysiptera parasema* with substrate groups.

Substrate Group	Observed (O)	Expected (E)	(O-E) <sup>2</sup> /E
Rubble	3	5.78	1.34
EMB	10	5.93	2.79
Rare Class	5	10.36	2.77
Total	18	18	
X <sup>2</sup>			6.90
p value			p=0.3171

Table 10. The chi-square analysis of the association of *Stegastes leucostictus* with substrate groups.

Substrate Group	Observed (O)	Expected (E)	(O-E) <sup>2</sup> /E
Rubble	0	5.25	5.25
EMB	11	5.39	5.83
Rare Class	4	9.36	3.07
Total	15	15	
X <sup>2</sup>			14.16
p value			p=0.00085

Table 11: The chi-square analysis of the association of *Stegastes fuscus* with substrate, excluding sand.

Substrate Group	Observed (O)	Expected (E)	(O-E) <sup>2</sup> /E
FC	1	3.46	1.75
OC	4	3.77	0.01
PB	14	6.45	8.85
Rubble	17	47.14	19.27
EMB	93	48.38	41.15
LPS	12	5.83	6.51
AL	1	14.08	12.15
SG	1	11.85	9.94
Rare Class	5	9.26	1.96
Total	143	143	
X <sup>2</sup>			101.59
p value			p=<0.0001

Table 12: The chi-square analysis of the association of *Stegastes partitus* with substrate, excluding sand.

Substrate Group	Observed (O)	Expected (E)	(O-E) <sup>2</sup> /E
Rubble	4	8.24	2.18
EMB	19	8.46	13.14
Rare Class	2	8.30	4.78
Total	25	25	
X <sup>2</sup>			20.10
p value			p=<0.0001

Table 13: The chi-square analysis of the association of *Chrysiptera parasema* with substrate, excluding sand.

Substrate Group	Observed (O)	Expected (E)	(O-E) <sup>2</sup> /E
Rubble	3	5.93	1.45
EMB	10	6.09	2.51
Rare Class	5	5.98	0.16
Total	18	18	
X <sup>2</sup>			4.12
p value			p=0.1275

Table 14: The chi-square analysis of the association of *Stegastes leucostictus* with substrate, excluding sand.

Substrate Group	Observed (O)	Expected (E)	(O-E) <sup>2</sup> /E
Rubble	0	4.95	4.95
EMB	11	5.07	6.92
Rare Class	4	4.98	0.19
Total	15	15	
X <sup>2</sup>			12.06
p value			p=0.0024

Table 15: The chi-square analysis of the association of *Stegastes fuscus* with substrate, excluding non-coral substrates.

Substrate Group	Observed (O)	Expected (E)	(O-E) <sup>2</sup> /E
FC	1	6.19	4.35
OC	4	6.75	1.12
PB	14	11.55	0.52
EMB	93	86.65	0.47
LPS	12	10.45	0.23
CF	0	0	0
Rare Class	0	2.41	2.41
Total	124	124	
X <sup>2</sup>			9.11
p value			p=0.1049



Table 16: The chi-square analysis of the association of *Stegastes partitus* with substrate, excluding non-coral substrates.

Substrate Group	Observed (O)	Expected (E)	(O-E) <sup>2</sup> /E
EMB	19	14.67	0.02
Rare Class	2	6.33	2.96
Total	21	21	
X <sup>2</sup>			4.23
p value			p=0.0397

Table 17: The chi-square analysis of the association of *Chrysiptera parasema* with substrate, excluding non-coral substrates.

Substrate Group	Observed (O)	Expected (E)	(O-E) <sup>2</sup> /E
EMB	10	10.48	4.43
Rare Class	5	4.52	0.02
Total	15	15	
X <sup>2</sup>			0.07
p value			p=0.7865

Table 18: The chi-square analysis of the association of *Stegastes leucostictus* with substrate, excluding non-coral substrates.

Substrate Group	Observed (O)	Expected (E)	(O-E) <sup>2</sup> /E
EMB	11	10.48	0.03
Rare Class	4	4.52	0.06
Total	15	15	
X <sup>2</sup>			0.09
p value			p=0.7704

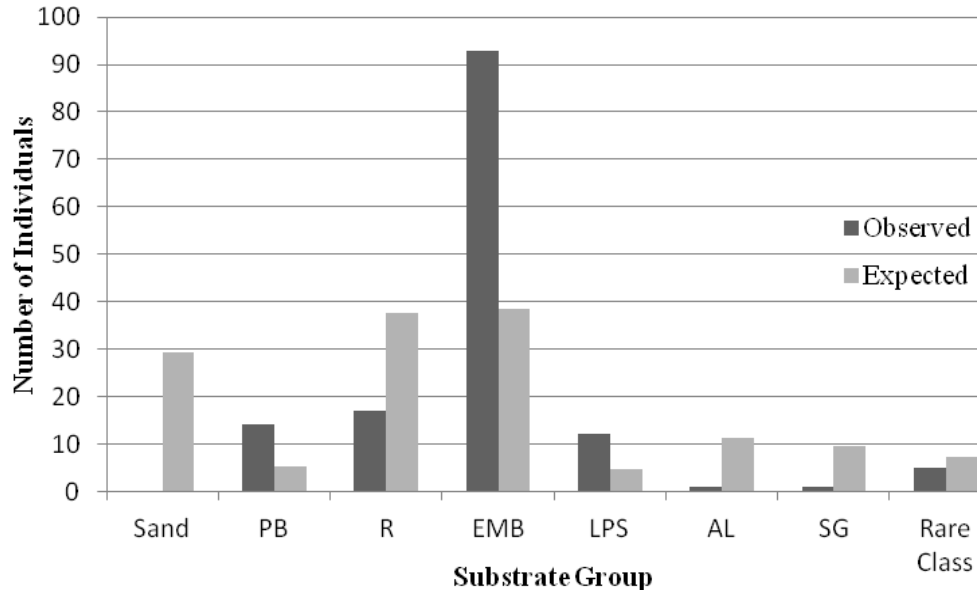


Figure 1. Microhabitat selection by *S. fuscus*;  $p < 0.001$ ,  $N = 143$

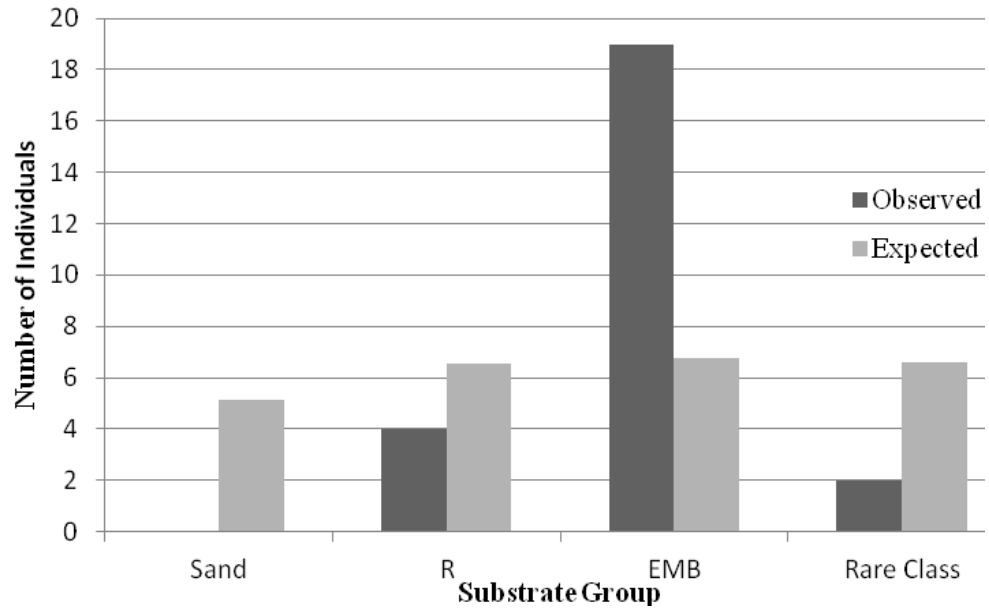


Figure 2. Microhabitat selection by *S. partitus*;  $p < 0.0001$ ,  $N = 25$

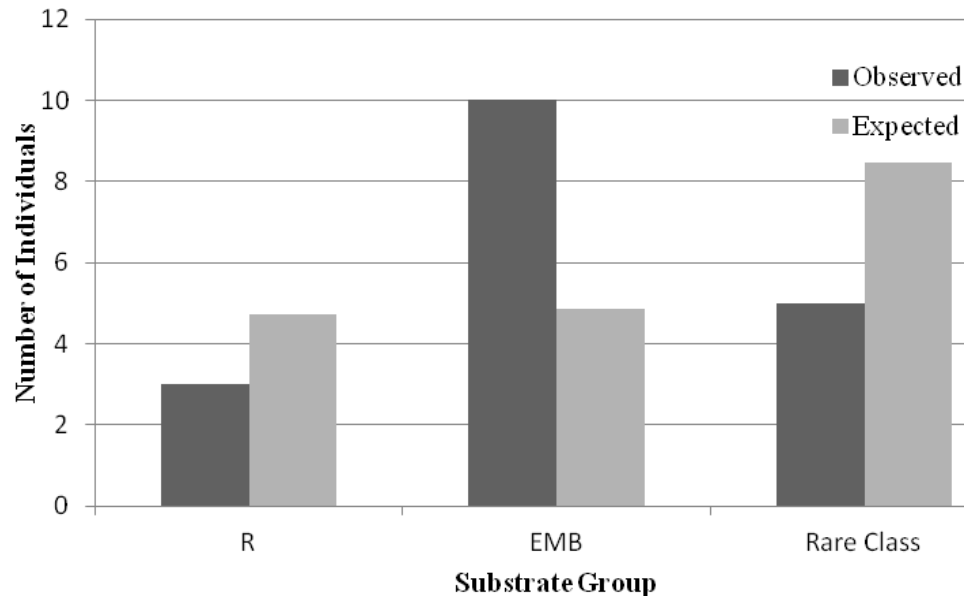


Figure 3. Microhabitat selection by *C. parasema*;  $p=0.0234$ ,  $N=18$

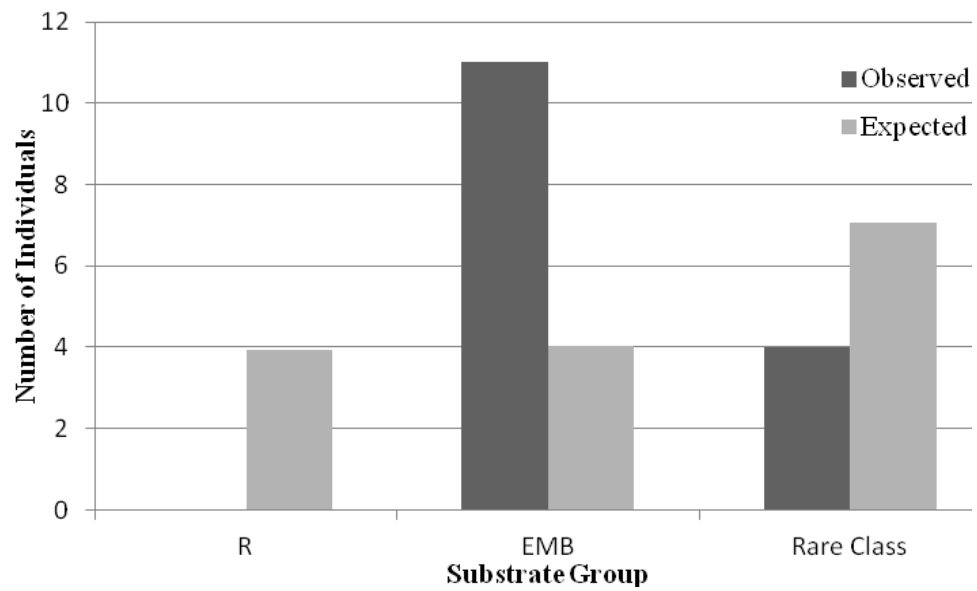


Figure 4. Microhabitat selection by *S. leucostictus*;  $p=0.0002$ ,  $N=15$

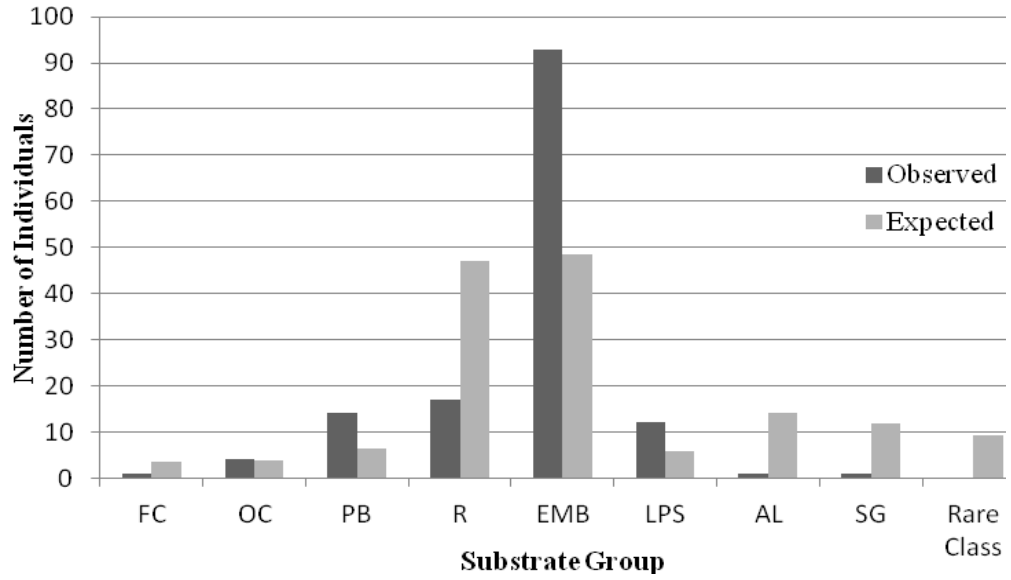


Figure 5. Microhabitat selection by *S. fuscus*, excluding sand;  $p < 0.0001$ ,  $N = 143$

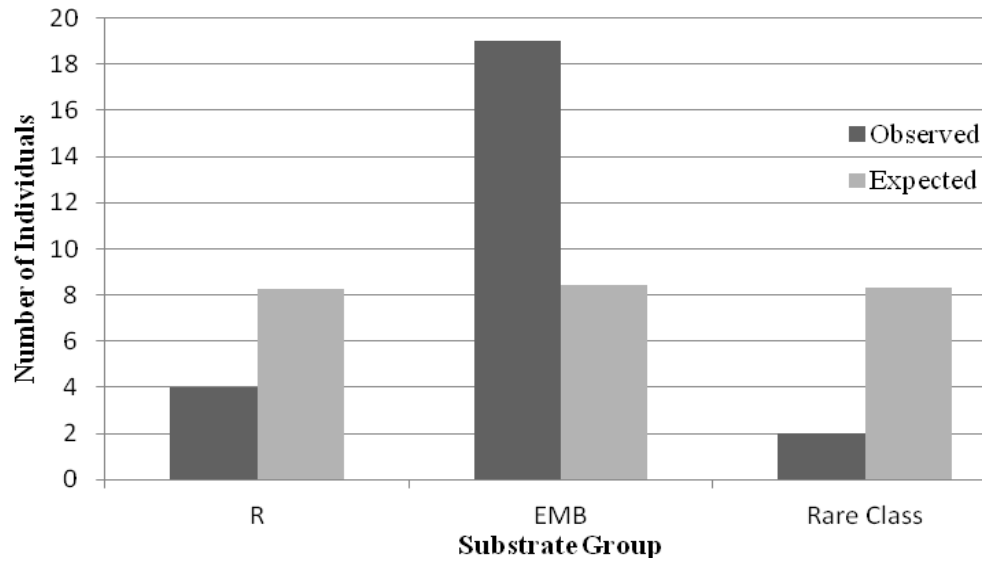


Figure 6. Microhabitat selection by *S. partitus*, excluding sand;  $p < 0.0001$ ,  $N = 25$

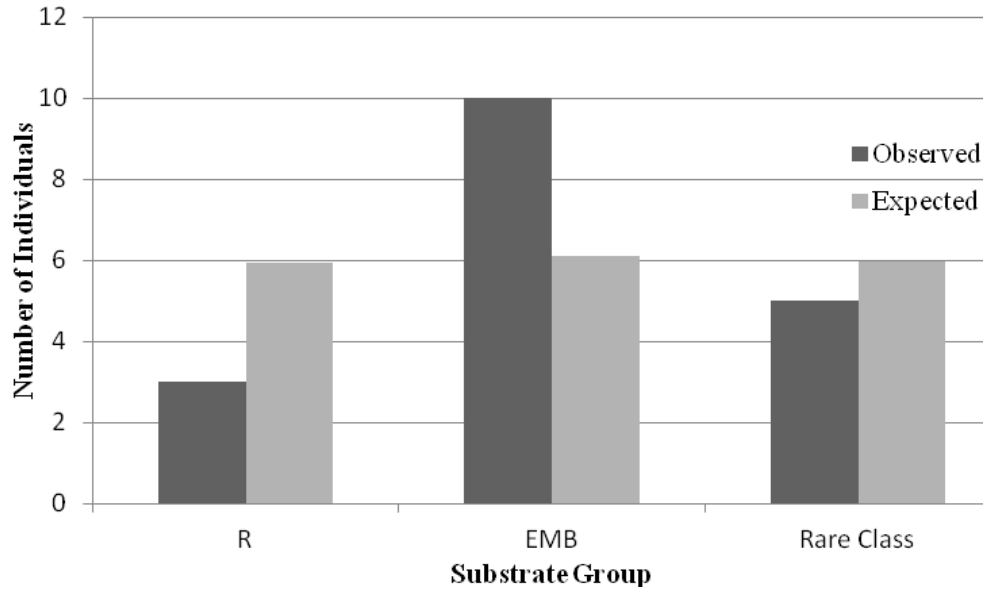


Figure 7: Microhabitat selection by *C. parasema*, excluding sand;  $p=0.1275$ ,  $N=18$

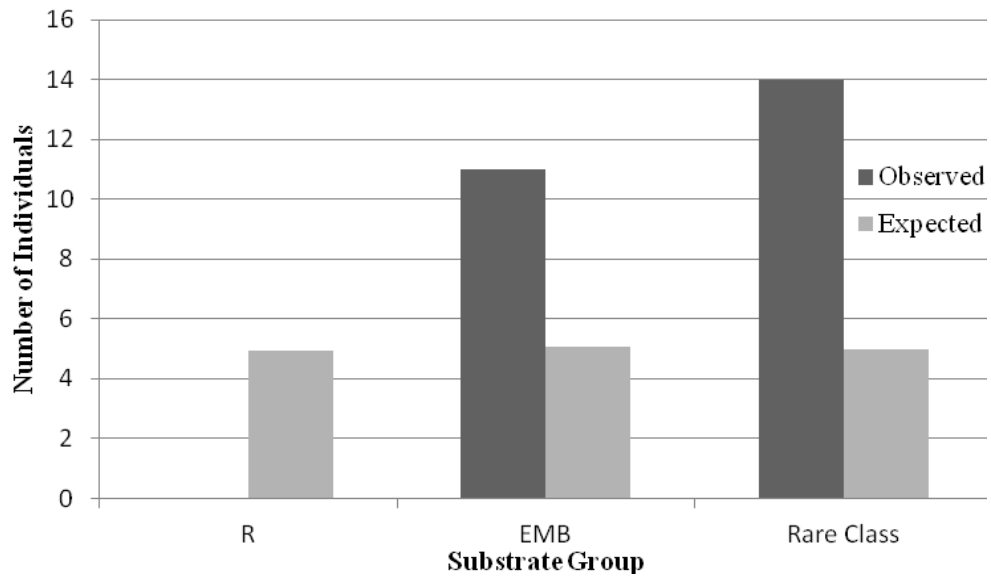


Figure 8: Microhabitat selection by *S. leucostictus*, excluding sand;  $p=0.0024$ ,  $N=15$

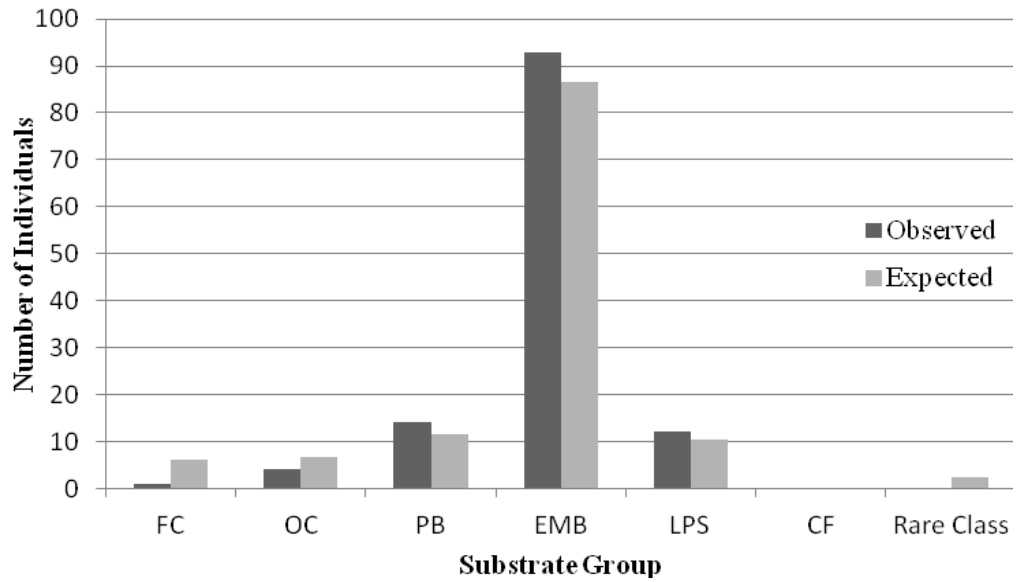


Figure 9. Microhabitat selection by *S. fuscus*, excluding non-coral substrates;  $p=0.1049$ ,  $N=124$

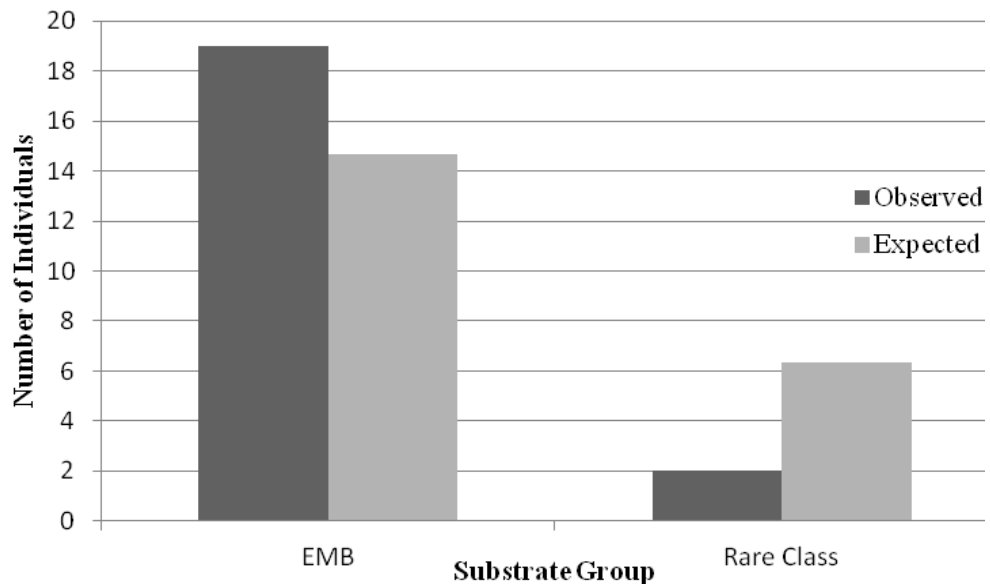


Figure 10. Microhabitat selection by *S. partitus*, excluding non-coral substrates;  $p=0.0397$ ,  $N=21$

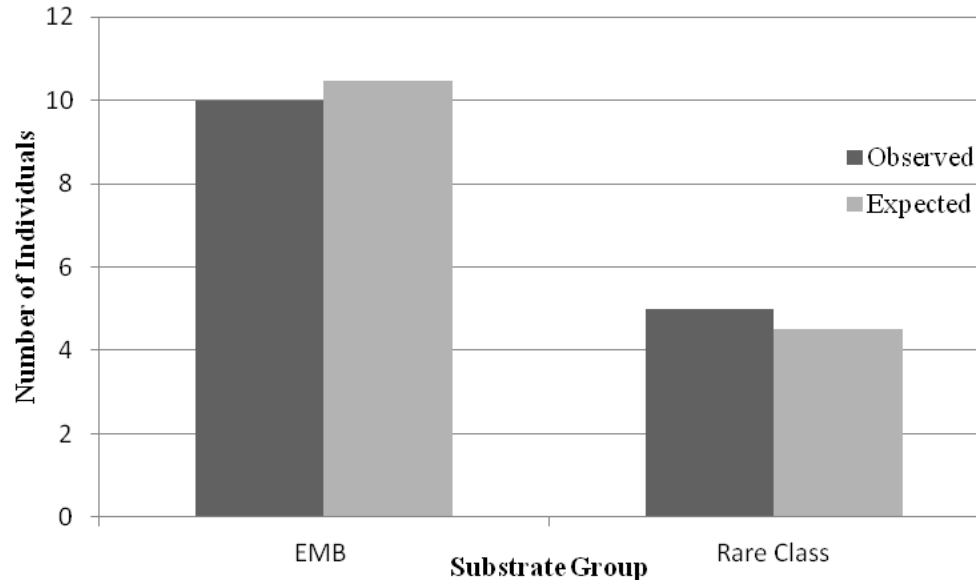


Figure 11. Microhabitat selection by *C. parasema*, excluding non-coral substrates;  $p=0.7865$ ,  $N=15$

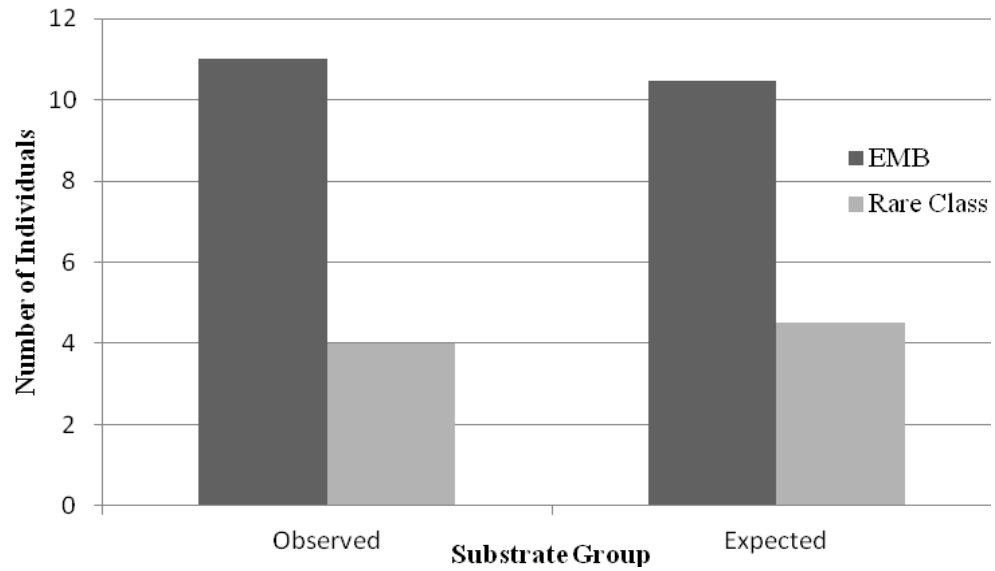


Figure 12. Microhabitat selection by *S. leucostictus*, excluding non-coral substrates;  $p=0.7704$ ,  $N=15$