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Effects Associated with Dredging for Beach Renourishments on Reef Fish Communities Offshore of Miami-Dade County, Florida:

Christian L. Avila
Nova Southeastern University, avilac@miamidade.gov

Effects Associated with Dredging for Beach Renourishments on Reef Fish Communities Offshore of Miami-Dade County, Florida:

By
Christian L. Avila

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Effects Associated with Dredging for Beach Renourishments on Neighboring Reef Fish Communities Offshore of Miami-Dade County, Florida

MASTER OF SCIENCE
THESIS
OF
CHRISTIAN L. AVILA

Approved:

Thesis committee:

Major Professor: ______________________
Richard E. Spieler, Ph.D. Nova Southeastern University

Committee Member: ______________________
David S. Gilliam, Ph.D. Nova Southeastern University

Committee Member: ______________________
Stephen M. Blair, M.S. Miami-Dade County DERM

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ABSTRACT

Beach erosion is an ongoing problem in South Florida. Beach replenishment has been the primary means of maintaining these economically important beaches, and dredging offshore sand deposits, adjacent to reef tracts, has been the pervasive method since the 1970's. Over the past ten years, greater attention has been paid to potential impacts dredging can have on adjacent reef communities, which has led to increased monitoring efforts. With the increase in monitoring efforts, scope has expanded from a strict focus on the benthic community to include the fish communities. This study evaluates the effects of dredging on reef fish communities associated with two separate beach replenishment projects, offshore of Miami-Dade County, Florida, U.S.A. Monitoring programs were developed and conducted by the Miami-Dade, Department of Environmental Resources Management (DERM). Monitoring took place between March 1997 and September 2000, with one project in northern portion of the county, off offshore of Golden Beach, and the other in the southern portion offshore of Key Biscayne. Both monitoring programs employed a Before After Control Impact design, with established test and control reef stations. Eight reef fish visual point count censuses (Bohnsack and Bannerot, 1986) were performed at each station prior to dredging, immediately following dredging, and three periods at bi-quarterly intervals after that.

In general evaluations of both projects showed no indications that dredging activities had major impacts on the fish communities of adjacent reefs. For the Golden Beach project, there was one aspect of the analysis, which may be indicative of dredging related impacts; was species richness at one test station declined significantly following dredging activities (ANOVA p=0.047). However, in terms of abundance, diversity and

Multidimensional scaling (MDS) plots of the Bray-Curtis dissimilarity index did not indicate that dredging activities impacted the test station. During the monitoring period of the Key Biscayne project, the south Florida region was impacted by two tropical storm events, which obscures the isolation of impacts associated with dredging. Changes in the reef fish communities, consistent with the impact and recovery of the tropical storms are evident in species richness, abundance, and MDS plots of the Bray-Curtis dissimilarity index, at both the test and control stations.

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1 INTRODUCTION

1.1 South Florida Reef Tract: Background Information

The northern reef complex off the coast of southeast Florida is a unique component of the Tropical/Subtropical West Atlantic region. An extensive relict reef framework, approximately 85km in length, extends from Miami to West Palm Beach (Lighty, 1977; Lighty et al., 1978). Three major reef tracts run parallel to the coastline in sequentially deeper water, and are locally referred to as the first, second and third reefs. This relict reef system currently supports a diverse benthic (Goldberg, 1973; Maszalek et al., 1977; Jaap, 1984; Blair and Flynn, 1989) and reef fish community (Lindeman, 1997a; Ettinger, 2000; Baron et al. 2004).

Unfortunately, anthropological impacts to the offshore reef communities have been numerous off South Florida due to: dredging activities (Britt Associates, 1979; Courtney et al. 1980; Maszalek, 1980, 1981; Blair and Flynn 1988; Goldberg 1988, 1989; Blair et al. 1990; Lindeman, 1997b), boat groundings (Jaap, 1984), anchor damage (Davis, 1977), sewage (Bright et al., 1981), fishing pressure (Tilmant, 1982; Halas, 1985; Sluka et al. 1998), the presence of potentially harmful pesticides and heavy metals (Glynn et al., 1989), and poor water quality (Richardson et al., 1998). Fortunately, extensive restoration and mitigation efforts have been ongoing in South Florida offshore resources (Miami-Dade DERM unpublished report, 2003).

1.2 Beach Renourishments

Beaches are an important part of the Florida economy generating 17.7 billion dollars annually (Shoreline, Oct. 2003). Beach renourishments, using dredged offshore sources of sand, have been the standard method of beach erosion control in South Florida for the past 25 years (Goldberg, 1989).

Previous studies of impacts associated with beach renourishment activities have primarily focused on benthic organisms (Dodge and Vaisnys 1977; Bak 1978; Britt Associates, 1979; Courtney et al. 1980; Marszalek, 1981; Goldberg 1988, 1989; Blair and Flynn, 1988; Blair et al., 1990, Dodge et al. 1995; Telesnicki and Goldberg 1995). In contrast, little attention has been focused on associated fish communities, and no such studies have been conducted in Miami-Dade County (Courtenay et al. 1980; Lindeman 1997a, b; Baron et al. 2004; Jordan and Spieler in press).

1.3 Statement of Purpose

This study will use data collected by Miami-Dade County Department of Environmental Resources Management (DERM) biologists (including the author) to examine effects that dredging operations may have had on the reef fish community: abundance, species richness and composition. These data were collected as part of monitoring programs designed specifically to assess benthic and fish communities on the reefs adjacent to borrow sources.

1.4 Statement of Significance

The primary outcome from this study is expected to be an improved understanding of how offshore dredging operations, employed in beach renourishment projects, may affect reef fish communities.

2 METHODS

2.1 Sampling Design

Two separate beach renourishment projects were evaluated in this study. The first project had dredging operations taking place in the spring and summer of 1997 and renourished Sunny Isles Beach and portions of Miami Beach. The second project had dredging occur between November 1998 and September 1999 and renourished the beaches of Bal Harbor. Sand deposits located in-between second and third reef tracts, called 'borrow areas' were dredged for beach fill for both projects. Each of the projects had borrow areas located offshore of beaches in different parts of Miami-Dade County; the Sunny Isles/Miami Beach project's borrow area was located offshore of Golden Beach, and the Bal Harbor project utilized a borrow source offshore of Key Biscayne. Because this study focuses on the biological monitoring aspects of these projects, the locations of the borrow areas are more relevant to the study and hence the projects will be referred to by their respective borrow area locations.

A BACI (Before After Control Impact) sampling design (Stweart-Oaten et al. 1986, Underwood 1991, 1992) was used to test for effects to reef fish community, abundance, and composition that dredging operations may have had on reefs adjacent to the borrow area. For the two renourishment projects evaluated in this study, Golden Beach and Key Biscayne (Fig. 1), test stations and control stations were established. Test stations were established on the second and third reefs adjacent to the 'borrow areas'. Equivalent reef areas to the south, which is up current in the study area, were used to establish control stations out of the influence of dredging operations. Preliminary surveys were conducted prior to the initiation of monitoring, to assess the similarity of the test reefs and control reefs in terms of relief and benthic components.

2.2 Golden Beach Borrow Site

Prior to dredging activities in April 1997, four biological monitoring stations were established in north Miami-Dade County offshore the community known as Golden Beach (Fig 1). The two test stations, GB2B and GB3B, were set up adjacent to the borrow area on the second and third reefs respectively (Fig. 2). The two control stations, GB2C and GB3C, were established approximately ten miles to the south, on second and third reef stations respectively, (Fig. 2). The prevailing currents of the region are to the north, thus the control stations, GB2C and GB3C, were considered to be outside the influence of dredging operations. All reef stations had origins (reference points marked with rebar), established on the edge of the adjacent to the borrow area (east of second reef; west edge of third reef). The first sampling period (see section 2.4), designated as the PRE period, was conducted at all stations prior to the initiation of dredging operations in March 1997. All stations were again quantitatively sampled (see section 2.4), after dredging operations in October 1997, referred to as the first quarter sampling; the Q1 period. Six months after the first quarter the third quarter sampling, Q3 period was conducted in June/July 1998. The final sampling was performed one year after the Q3 sampling, in the seventh quarter, Q7, in June/July 1999 (Table 1).

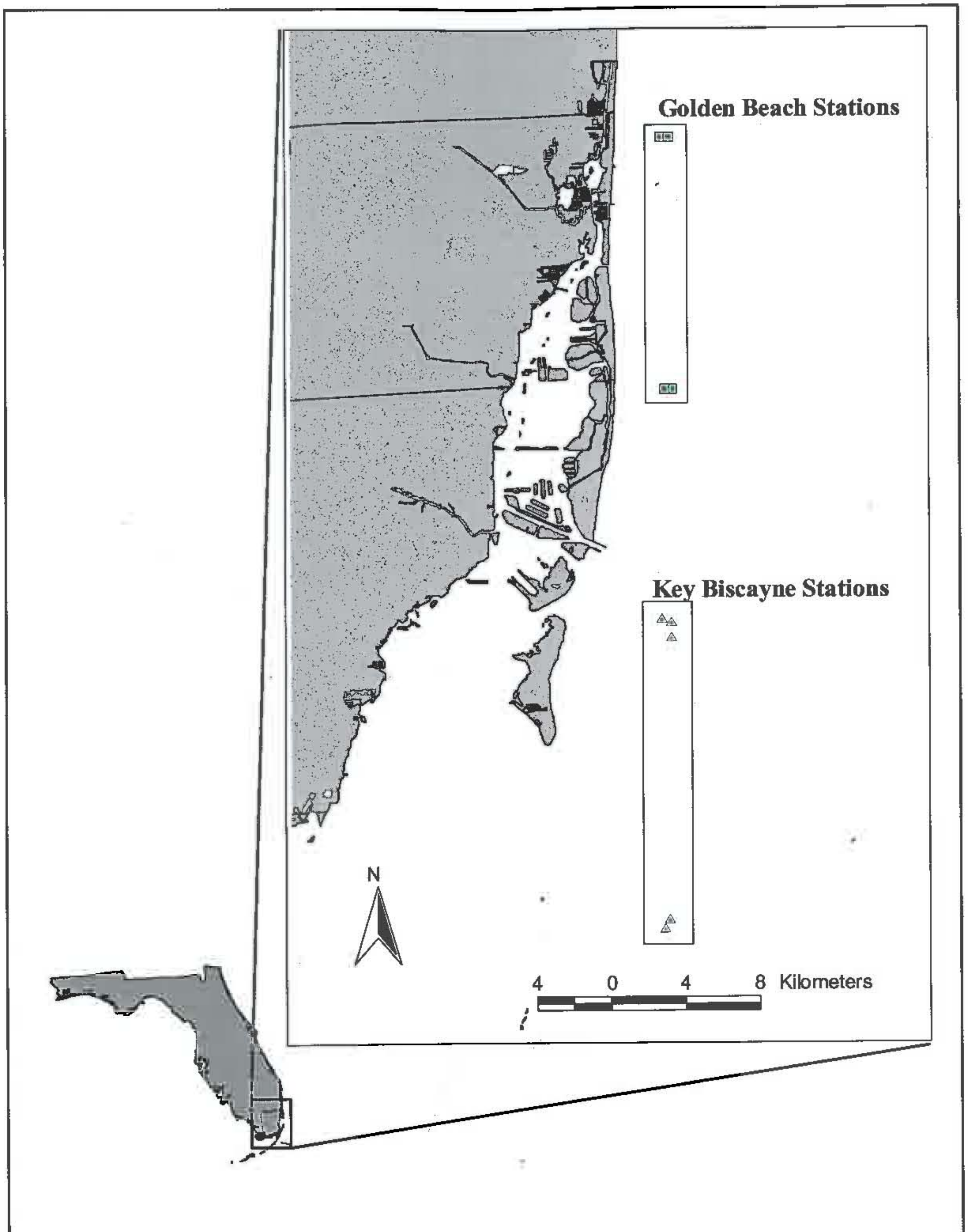

Figure 1. Map of the study region offshore of Miami-Dade County, displaying both the Golden Beach and Key Biscayne Stations.

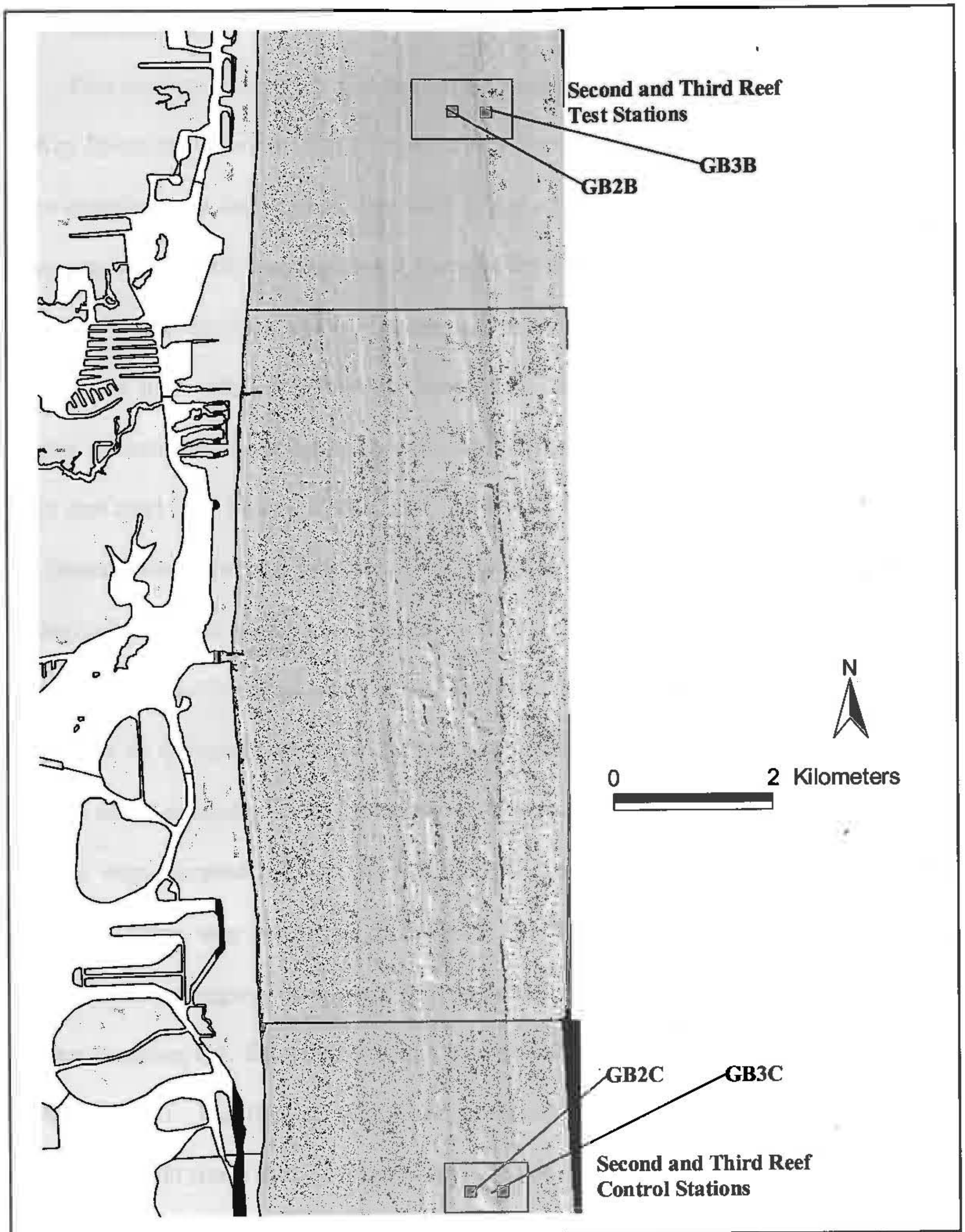

Figure 2. Figure displays the locations of the Golden Beach borrow area test and control stations shown on a LADS (Laser Airborne Depth Sounder) bathymetric survey image.

2.3 Key Biscayne

Five biological monitoring stations were established in South Miami-Dade offshore of Key Biscayne, before dredging began in November of 1998 (Fig 1 & 4). Three stations were established as test stations; two were set up on the third reef adjacent to the borrow area, one to the north and one to the south of the borrow area, and designated KB3NB and KB3SB respectively, and one station was established on a patch reef adjacent to the second reef tract with the second reef tract and designated KB2PB (Fig. 1 and 3). Two control stations were established approximately five miles to the south, on the second and third reef tract near Fowey Rocks, and designated KB2C and KB3C, respectively (Fig. 3). General visual surveys assessed KB2C and KB3C to have similar profiles and to be biologically similar to the second and third reef test stations located adjacent to the borrow area. In addition, as with the Golden Beach project, the prevailing currents of the region are to the north, therefore the location of KB2C and KB3C, to the south of the borrow area, precluded them from being influenced by the dredging operations. All stations were sampled prior to the initiation of dredging operations. Designated as the PRE period this was conducted in September/October 1998. All stations were again sampled after dredging operations were completed, in September 1999, for the first quarter sampling Q1. Sampling was again conducted in the third quarter, Q3, which was in March 2000. The final sampling was performed in the fifth quarter, Q5, in August-September 2000 (see Table 1 for sampling schedule).

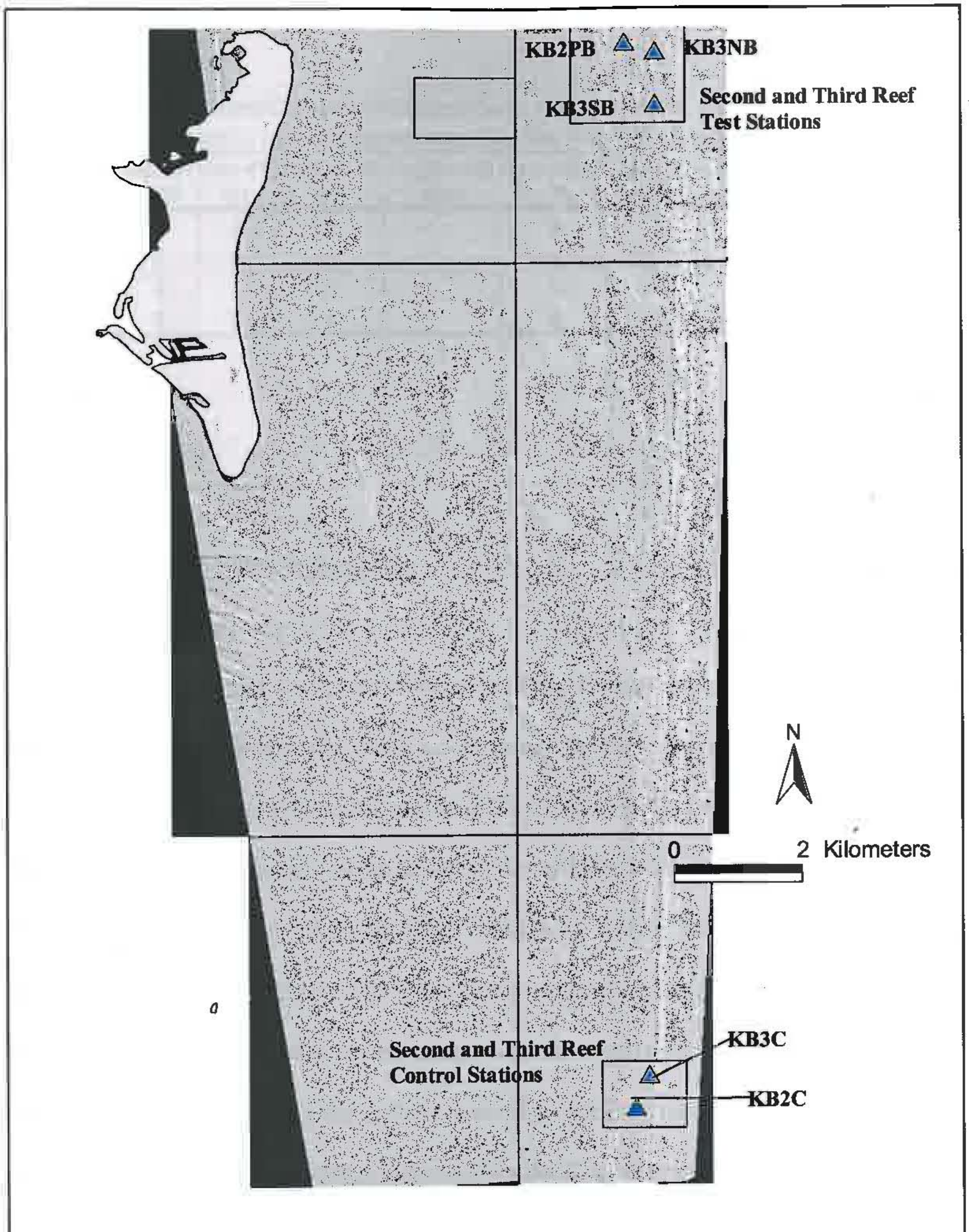

Figure 3. Figure displays the location of the Key Biscayne borrow area test and control stations shown on a LADS (Laser Airborne Depth Sounder) bathymetric survey image.

Table 1. Quarterly sampling periods/Month-Year and number of surveys performed at the both dredging project's monitoring stations: Golden Beach (GB) and Key Biscayne (KB).

STATION	Mar-97 PRE	Oct-97 Q1	Jun/Jul-98 Q3	Sep/Oct-98 PRE	Jun/Jul-99 Q7	Sep-99 Q1	Mar-00 Q3	Aug/Sep-00 Q5
GB2B	8	8	8		8			
GB3B	8	8	8		8			
GB2C	8	8	8		8			
GB3C	8	8	8		8			
KB2PB				8		8	8	8
KB3SB				8		8	8	8
KB3NB				8		8	8	8
KB2C				8		8	8	8
KB3C				8		8	8	8

2.4 Reef Fish Community Sampling

2.4.1 Reef fish censuses

Censuses of reef fish Communitiess were performed using a modified version of the Bohnsack and Bannerot (1986) point count method. An estimated 7.5m radius cylinder, from substrate to surface, was used for all surveys. The original method calls for the diver to remain stationary in the center of the cylinder while performing point counts. This study opted for the diver to swim continuous circles within the cylinder while performing the point counts. The modification improved the ability to collect data in reduced visibility and enhanced capturing data on cryptic species. Utilizing SCUBA, DERM biologists (including the author), trained to perform reef fish surveys, performed all data collections. Fish identifications were assisted by referring to Humman (1994) and Bolke and Chaplin (1968). Data were collected on prefabricated data sheets (Appendix D). Estimates of Fork Length (FL) of fish were assisted using a scaled 30cm PVC pipe fixed to a 1m PVC pipe.

Eight surveys were performed at each station for each sampling period. Bohnsack and Bannerot (1986) demonstrated in the FL Keys six surveys would include 90% of all species present at a given location. At the onset of the project species area curves were generated to determine the number of surveys needed. Eight surveys were shown to be sufficient to capture >90% of the species present (DERM unpublished data).

During each sampling period, random distances and random headings relative to the origin of each station selected survey locations. Computer programs were used to produce the random distances and headings. Typically, two to four surveys were performed simultaneously during a given dive. Random heading and distance provided the location of the first survey, and center of the successive survey was located at a distance of 15m on a random heading from the center point of the previous survey (Fig. 4).

2.4.2 Reef fish data entry

Fish data were entered into "Reef fish Visual Census" data entry version 1.1 (RVC) (Weinberg, 1998). Proof sheets were generated for each survey, and crosschecked with the field data sheet. Any necessary corrections to the entered data were entered into the database.

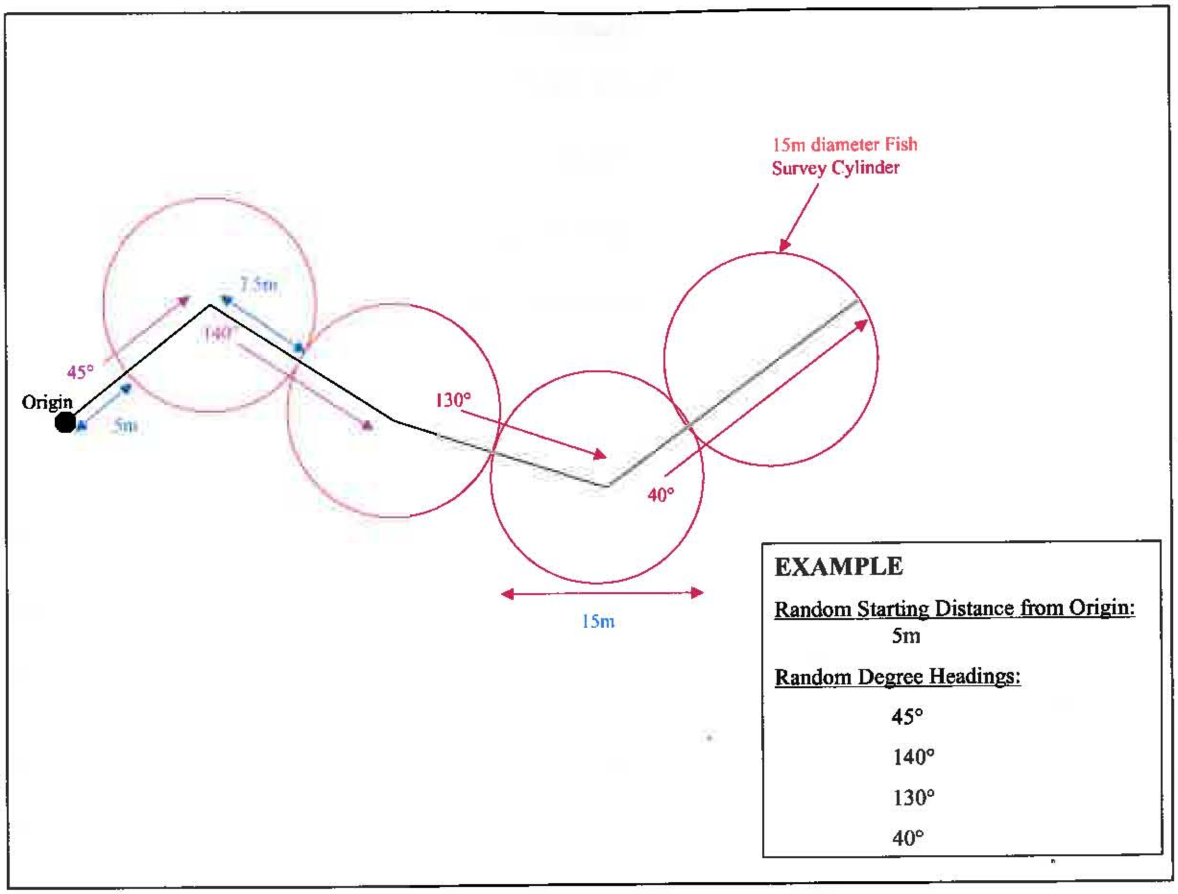

Figure 4. An example diagram of a series of visual fish survey cylinders sampled during a given dive.

2.5 Data Analysis

For all reef fish community parameters, one-way Analysis of Variance (ANOVA) was the primary test utilized for parametric statistical analysis of this study. Following the completion of this study, reviews of the data analysis techniques employed for repeated reef fish community censuses, have found that the assumptions of independent samples required by ANOVA are violated. However, as the appropriate analysis, Mixed Model Repeated Measures Analysis, is more conservative, and most tests with the ANOVA were not significant, the data were not reanalyzed.

2.5.1 Reef fish species richness and abundance

Species richness and abundance have long been recognized as important attributes of a given community, especially as they relate to physical disturbances (Connell, 1978). This analysis was based on the expectation, that if dredging activities represented a major physical disturbance to the reef fish community, then significant decreases would be noted in species richness and abundance.

To establish the degree of similarity among the control and test stations for a given metric, an initial ANOVA test was performed among all the stations PRE period sampling (Table 1). With the extent of similarity established, inferences on trends could be made based on ANOVA tests of for each stations' time series sampling PRE, Q1, Q3, and Q5/Q7. The Student-Newman-Keuls (SNK), Post-hoc test, was employed to test pair-wise comparisons within each stations sampling series.

Additionally, supporting the inferential analysis made on the trends of each station, Two-Way ANOVA tests were performed on the interaction of sampling periods for each test station and its corresponding control station. Abundance data was heterosecdastic, therefore it was transformed using a $\log_{10}$ prior to analysis. Box plots and the ANOVA SNK tests were generated utilizing SPSS 10.0 statistical software, and Two-Way ANOVA tests were performed using Sigma Stat 2.0.

2.5.2 Reef fish mobility guilds

Mobility guilds were employed to gain better resolution of changes to the fish communities. The primary assumption was, that if dredging activities represented a major physical disturbance to the reef fish community, then significant decreases would be measured in the highly mobile guilds due to emigration from the area of disturbance. The concept of reef fish mobility guilds has been utilized by a number of researchers studying the relation of reef fish communitiess to reef structure (Russell et al. 1974; Talbot et al. 1978; Bohnsack and Talbot 1980; Bohnsack et al. 1994; Freidlander and Parrish 1998) and again was primarily used in this study to allow for detection of emigration of highly mobile species and/or the immigration of opportunistic species.

Freidlander and Parrish (1998) defined the mobility guilds proposed for this study. The four guilds used are: Residents (those species with limited movements and well defined home ranges) Semi-vagile type I (S1) (those species with daily movement patterns on the order of tens of meters), Semi-vagile type II (S2) (those species with daily movement patterns on the order of hundreds of meters), and Transients (those species which move rapidly over relatively large distances). The Freidlander and Parrish (1998) study was based in Hawaii, therefore species in this study were assigned to a guild based on similarity to those encountered in the Freidlander and Parrish (1998) study, personal observation, and referring to Caribbean based studies utilizing the concept of mobility guilds (Bohnsack et al. 1994). Appendix A contains the list of all encountered species and their respective designation within these groups.

To establish similarity of abundance within each guild among the control and test stations, an initial ANOVA test was performed among all the stations PRE period. Then an ANOVA was used to test the null hypotheses of no difference for abundance within each guild for each stations' sampling series PRE, Q1, Q3 and Q5/Q7. Post-hoc SNK, tests were employed to test pair-wise comparisons within each stations' sampling series. Additionally, Two-Way ANOVA tests were performed on the interaction of sampling periods for each test station and its corresponding control station. If a series did not pass normality tests, then a $\log_{10}$ transformation was preformed prior to analysis. The Key

Biscayne Transient abundance data could not be normalized using a $\log_{10}$ transformation, therefore, a non-parametric Kruskal-Wallis ANOVA was used.

2.5.3 Diversity index

The Shannon-Weaver diversity index (H') was calculated, utilizing PRIMER 5 statistical software, for all sampling periods (PRE, Q1, Q3, andQ5/7) for each station.

2.5.4 Bray-Curtis dissimilarity index

Consideration was given to the possibility that impacts associated with the dredging projects may cause alterations in the composition of the adjacent reef fish communities. The series of surveys of each station were examined and graphically displayed using multidimensional scaling (MDS) ordination (Field et al., 1982) of Bray-Curtis dissimilarity indices (Bray and Curtis, 1957). This analysis was performed using PRIMER 5 statistical software.

3 RESULTS

3.1 Overview

For the 288 fish surveys conducted a, total of 31,053 fish were counted, 133 species in 35 families (Appendix A). The 128 surveys at the four Golden Beach stations had an observed 11,779 individual fish, and 107 species of fish in 33 families. The 160 surveys performed at the five Key Biscayne stations had an observed 19,274 individual fish, and 118 species of fish in 32 families. Among all surveys conducted for this study, two species of fish were found to be particularly dominate, *Stegastes partitus*, 6,867 individuals, and *Thalasoma bifasciatum*, 5,777 individuals. The combined abundances of these two species account for 40.7% of all fish observed, with *S. partitus* accounting for 22.1%, and *T. bifasciatum* accounting for 18.6%.

3.2 Golden Beach Borrow Site

Dredging activities took place between April-September 1997. Sampling of the Golden Beach stations occurred between March 1997 and July of 1999. During that period of time no named tropical storm events impacted the south Florida region.

3.2.1 Reef fish species richness

Mean reef fish species richness on second reef stations, GB2B and GB2C, ranged from 14.6 to 18.5 species per survey and from 13.5 to 18.4 species per survey on third reef station (Fig. 4). The ANOVA test performed on the PRE sample period did not show a significant difference among all of the stations (p=0.693).

Species richness for the second reef stations did not vary greatly across sampling periods. ANOVA tests did not show any significant differences among the sampling periods for the second reef borrow-area station, GB2B (p=0.236), and the second reef control station, GB2C (p=0.110). Additionally, the results of the Two-Way ANOVA, for the second reef test and control stations, showed no significant difference for the sampling periods (p=0.174).

The third reef borrow area station, GB3B, had a high mean value of 18.4 species per sample for the PRE sampling and the subsequent periods were all less than this value at 13.5, 15.5 and 13.6 for Q1, Q3, and Q7 respectively. ANOVA test for this station was significant among the sampling periods (p=0.047). However, Post-hoc SNK, did not find any pair-wise significant differences between any of the sampling periods. In contrast the third reef control station, GB3C, varied little over the sampling periods, with the mean number of species per sample ranging from 15.4 to 17.0. An ANOVA test did not indicate a difference among the sampling periods (p=0.546) for this station. The two-way ANOVA showed no significant difference for (p=0.427).

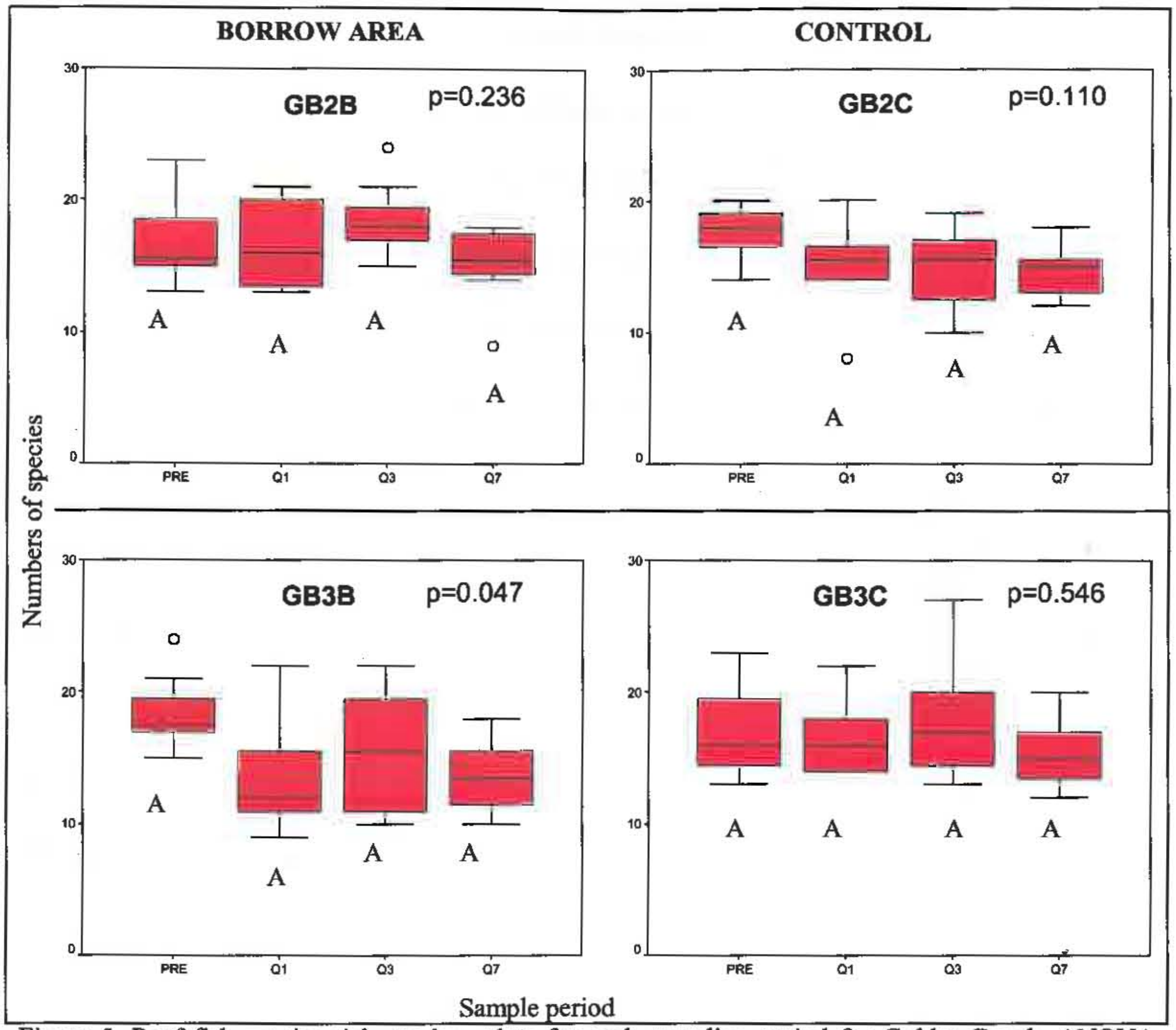

Figure 5. Reef fish species richness box plots for each sampling period for Golden Beach. ANOVA p values are presented and SNK ($p<0.05$) significant results are indicated by non-sharing letter designations. Boxes extend from the 25th to the 75th percentile and the black line indicates median values. Whiskers extend to the upper and lower values within 1.5 box lengths. 'Outliers' values ('O'), are values between 1.5 and 3 box lengths.

3.2.2 Reef fish abundance

The ANOVA test on the PRE period showed no significant difference among all of the stations (p=0.124).

Mean fish abundance on second reef stations ranged from 65.4 to 78.5 per sample, (Fig. 5). Mean fish abundance per sample on GB2B displayed an increasing trend from PRE to Q7 sampling period. However, ANOVA test did not find a significant difference among the sampling periods (p=0.063). The corresponding control station, GB2C, was notably consistent, across all sampling periods, in terms of the mean reef fish abundance per survey, as well as the variation around these mean values. Mean values ranged from 68.5 to 63.5, and ANOVA did not indicate a significant difference (p=0.916) among sampling periods for this station. The Two-Way ANOVA test between the second reef test and control stations sampling periods did not find a significant difference (p=0.427).

Third reef stations' mean fish abundances ranged from 87.1 to 131.0 per sample (Fig. 5). Mean abundance recorded on the third reef borrow area station was essentially consistent across the sampling periods, and there was no significant difference among these periods (ANOVA p=0.387) Similarly, on the corresponding third reef control station, GB3C, the sampling periods were consistent in terms of abundance, and ANOVA did not indicate a significant difference among the sampling periods (p=0.467). Additionally, the Two-Way ANOVA between GB3B and GB3C sampling periods found no significant difference (p=0.654).

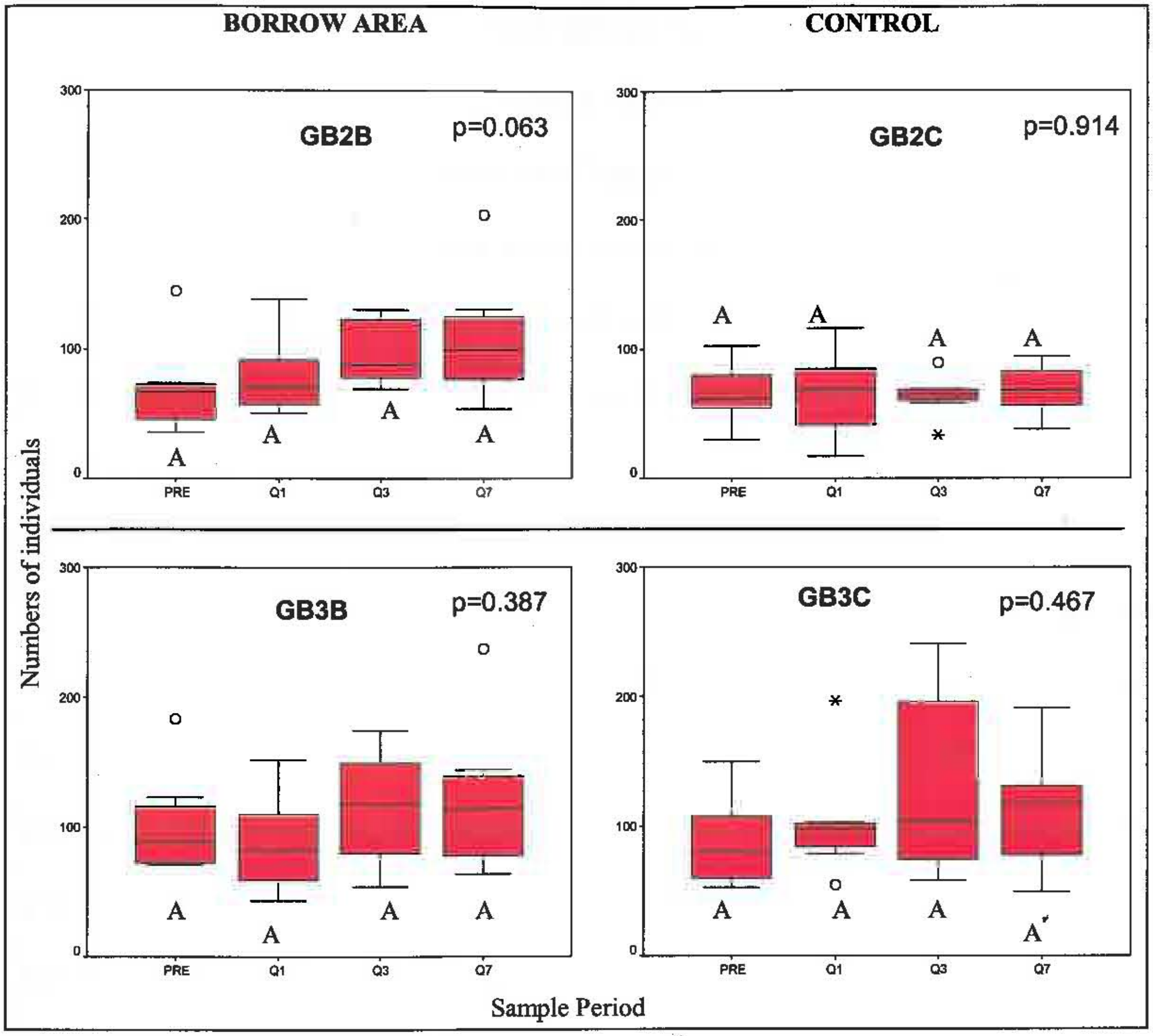

Figure 6. Reef fish abundance box plots of each sampling period for Golden Beach. ANOVA p values are presented and SNK ($p<0.05$) significant results are indicated by non-sharing letter designations. Boxes extend from the 25th to the 75th percentile and the black line indicates median values. Whiskers extend to the upper and lower values within 1.5 box lengths. 'Outliers' values ('O'), are values between 1.5 and 3 box lengths, and 'extreme' (✱) are values greater than 3 box lengths.

3.2.3 Reef fish diversity

Among all stations, mean Shannon–Weaver diversity (SWD) indices ranged from 2.6 – 3.5 (Fig. 6). The ANOVA test results on the PRE period of all stations were significant ($p=0.003$). Post-hoc SNK results indicated that the PRE period of GB2B, GB3C, and GB3B, differed significantly ($p<0.05$) from the high mean value of GB2C.

Mean SWD indices on second reef stations ranged from 3.0 – 3.5 (Fig. 6). The ANOVA test on SWD indices for GB2B did not find a significant difference (p=0.280) among the sampling periods mean values. However, for the corresponding control station, GB2C the sampling periods were significantly different (ANOVA p=0.008). Again, this difference appears driven by the high mean value of 3.5 recorded for the PRE sampling period. SNK (p<0.05) post-hoc tests indicated a significant difference between the PRE sampling period and the Q1, Q3, and Q7 sampling periods. Two-Way ANOVA test results between the control and test stations sampling periods were not significant (p=0.150).

Mean SWD indices on the third reef stations ranged from 2.6-3.1 (Fig. 6). For the test station GB3B ANOVA test did not indicate a significant difference (p=0.175) among the sampling periods. For the third reef control station, GB3C mean SWD index values and variance appear similar throughout the study period. ANOVA indicated the sampling periods were not significantly different for this station (p=0.577). Additionally, Two-Way ANOVA results between the sampling periods of GB3B and GB3C were not significantly different (p=0.761).

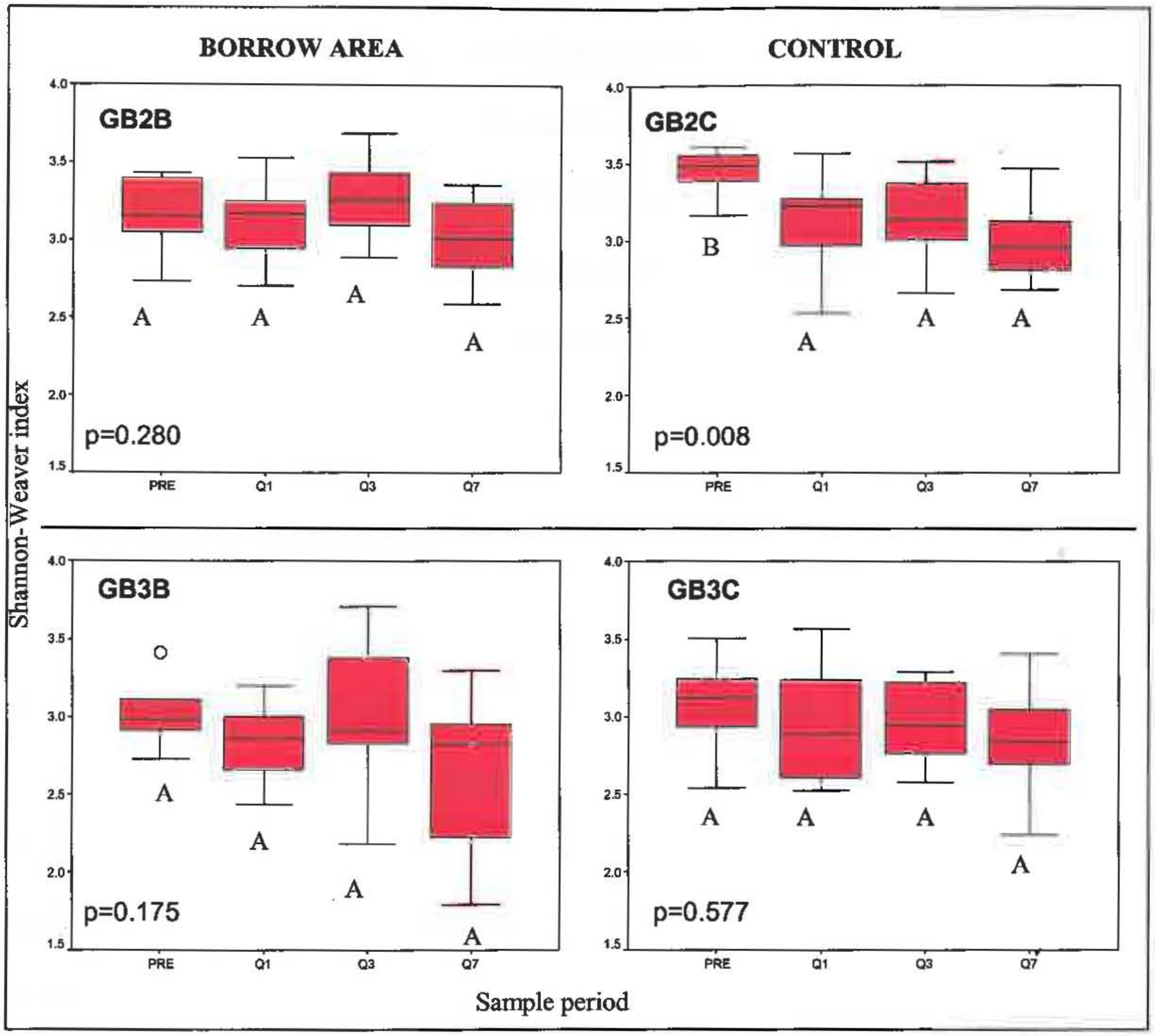

Figure 7. Shannon-Weaver diversity indices box plots of each sampling period for Golden Beach. ANOVA p values are presented and SNK ($p<0.05$) significant results are indicated by non-sharing letter designations. Boxes extend from the 25th to the 75th percentile and the black line indicates median values. Whiskers extend to the upper and lower values within 1.5 box lengths. 'Outliers' ('O'), are values between 1.5 and 3 box lengths.

3.2.4 Reef fish mobility guild abundance

3.2.4.1 Resident Mobility Guild

The ANOVA test on the Second and Third reef stations PRE period Resident fish abundance indicated no significant difference among the stations (p=0.315).

The second reef stations mean Resident fish abundance ranged 25.4 to 60.1 per survey (Fig. 7). A trend of increasing Resident fish abundance was recorded for the second reef test station, GB2B, with higher mean values for each subsequent sampling period. There was a significant difference among the sampling periods for this station (ANOVA p=0.003). Results for SNK post-hoc test showed the PRE and Q1 sampling differed significantly with the Q3 and Q7 sampling periods ($p<0.05$). For the second reef control station, GB2C, mean Resident fish abundance values were within a narrow range across the first three sampling periods, PRE-Q3, with values 25.4 and 28.5 and increased in the Q7 to 38.6. However, the ANOVA test did not indicate a significant difference (p=0.201) existed the sampling periods of this station. Two-Way ANOVA between the sampling periods of GB2B and GB2C did not show a significant difference (p=0.152).

The third reef stations mean Resident fish abundance ranged from 28.6 to 53.4. The third reef test station, GB3B, followed a similar increasing trend as GB2B, although ANOVA showed no significant differences among the sampling periods (p=0.273). The third reef control station, GB3C, mean values ranged from 28.6 to 50.3, and the sampling periods were not significantly different (ANOVA p=0.255). The Two-Way ANOVA tests of the third reef control and test stations sampling periods were not significant (p=0.153).

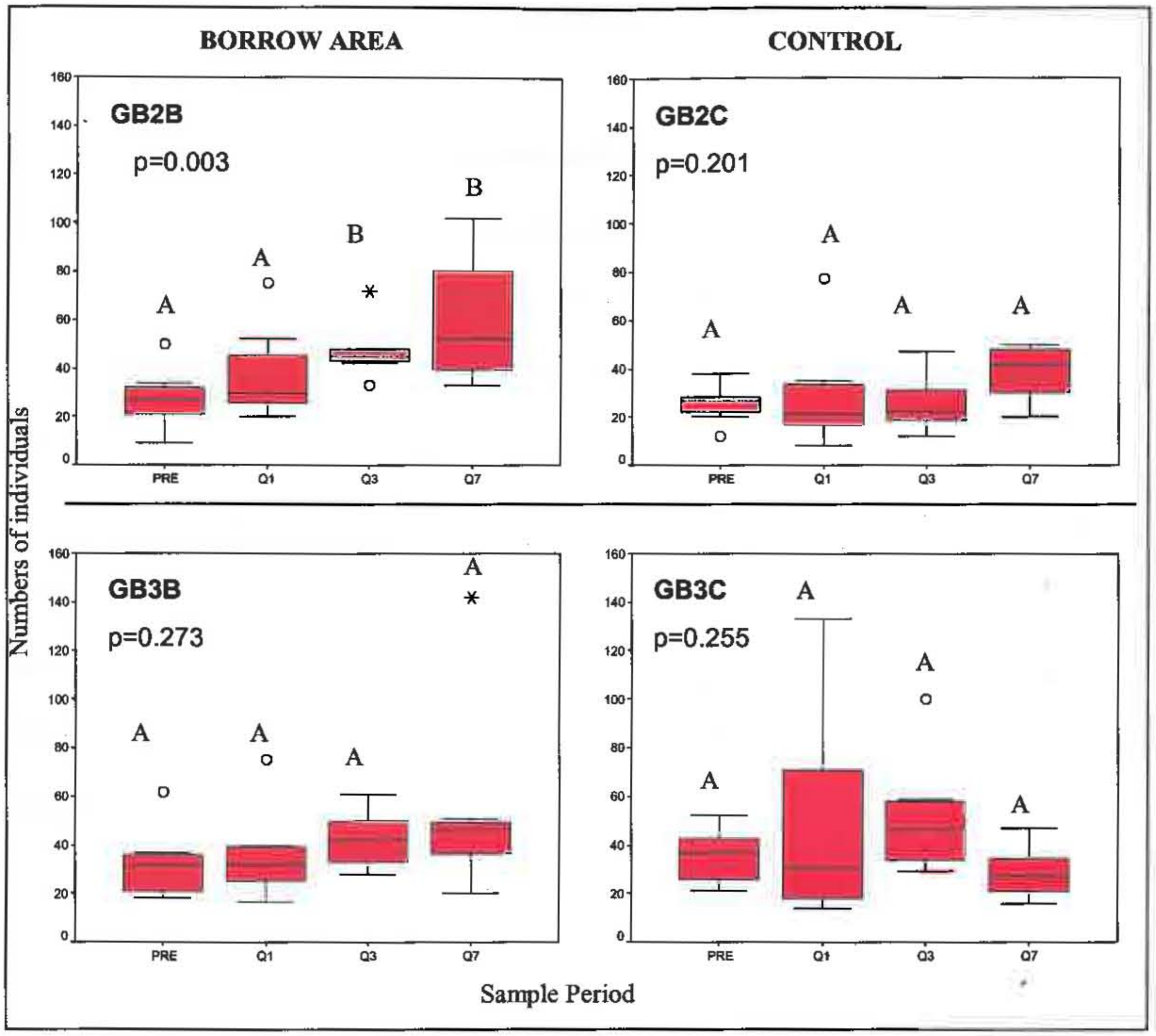

Figure 8. Resident mobility guild abundance box plots of each sampling period for Golden Beach. ANOVA p values are presented and SNK ($p<0.05$) significant results are indicated by non-sharing letter designations. Boxes extend from the 25[th] to the 75[th] percentile and the black line indicates median values. Whiskers extend to the upper and lower values within 1.5 box lengths. 'Outliers' ('O'), are values between 1.5 and 3 box lengths, and 'extreme' (✱) are values greater than 3 box lengths.

3.2.4.2 S1 Mobility Guild: fish with daily movements 10m-100m

The initial ANOVA test of the Second and Third reef PRE period indicated a significant difference among the stations (p=0.023). However, this difference is driven by the higher mean S1 abundance values of the third reef stations ranging from 30.0-31.0 versus the second reef stations ranging 20.0 to 21.0. Post-hoc test confirm this, indicating significant differences between the two second reef stations and the third reef test station (SNK $p<0.05$).

Mean S1 fish abundance on second reef stations ranged from 26.9 to 45.4 (Fig. 8). Each of the second reef stations did not vary greatly over the study period. ANOVA tests did not show a significant difference for GB2B ($p=0.761$) or GB2C ($p=0.806$). Additionally, Two-Way ANOVA did not find a significant difference between the sampling periods of GB2B and GB2C ($p=0.795$)

Mean S1 fish abundance for the third reef stations ranged from 44.1 to 65.9. For each of the third reef stations, and ANOVA tests for each of the stations did not indicate a significant difference for GB2B ($p=0.528$) or GB2C ($p=0.605$). Also, Two-Way ANOVA test did not show a significant difference between the third reef test and control stations sampling periods ($p=0.893$).

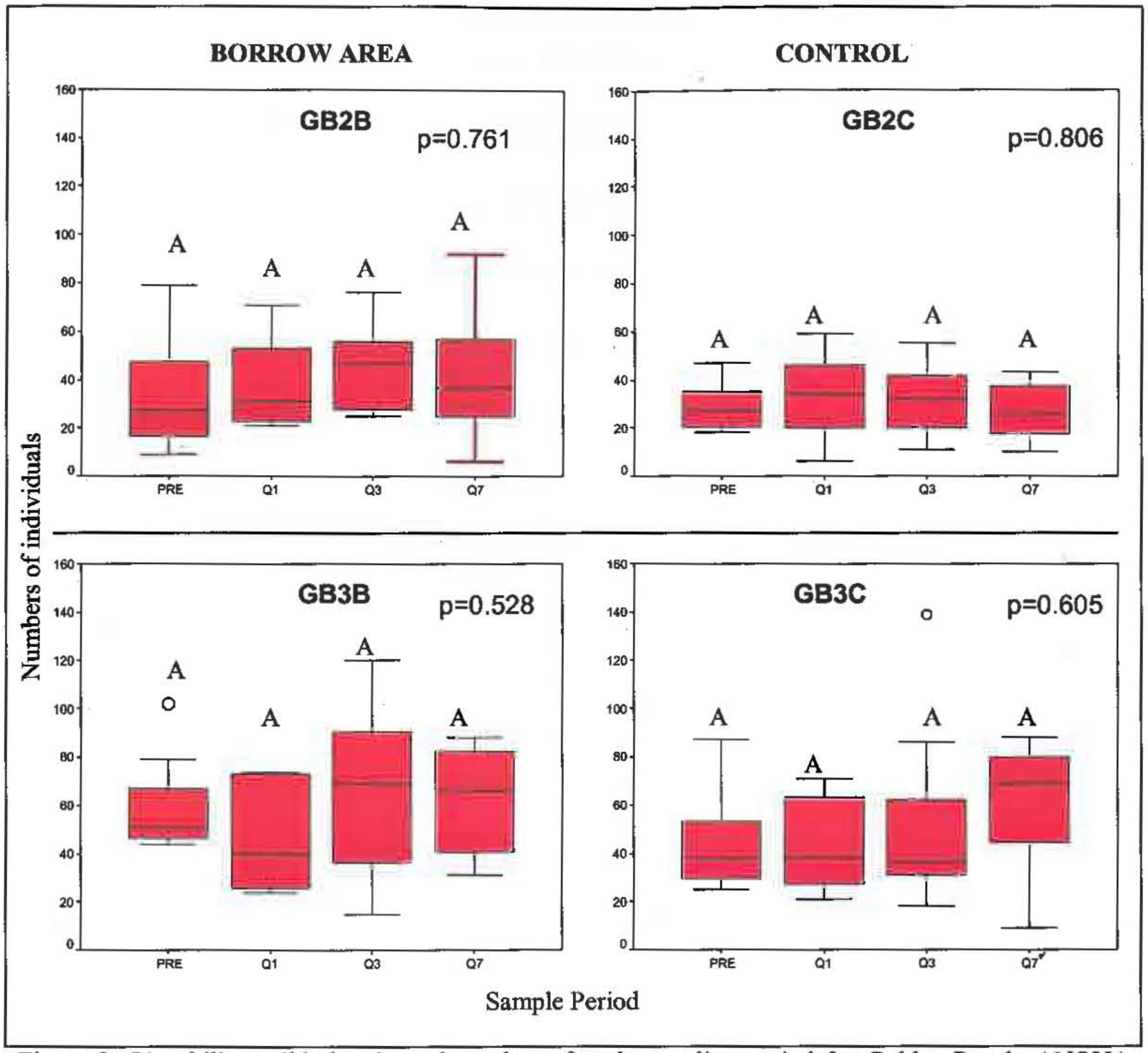

Figure 9. S1mobility guild abundance box plots of each sampling period for Golden Beach. ANOVA p values are presented and SNK ($p<0.05$) significant results are indicated by non-sharing letter designations. Boxes extend from the 25th to the 75th percentile and the black line indicates median values. Whiskers extend to the upper and lower values within 1.5 box lengths. 'Outliers' ('O') are values between 1.5 and 3 box lengths.

3.2.4.3 S2 Mobility Guild: fish with daily movements 100m+

ANOVA test preformed on the PRE period of all stations was indicated no significant difference among the stations (p=0.412).

Mean S2 fish abundance on second reef stations ranged from 2.9 to10.9 (Fig. 9). Mean S2 abundance recorded on GB2B ranged from 3.1 to 7.4, across the sampling periods, and was not significantly different (ANOVA $p=0.179$). For the second reef control station, GB2C, mean S2 fish abundance ranged from 2.9 to 10.9, and the ANOVA test indicated a significant difference ($p=0.037$) among the sampling periods for this station. Post-hoc, SNK, tests showed a significant ($p<0.05$) difference between the higher mean value of PRE versus the lower values of the Q1 and Q7 sampling periods. Although, the sampling periods between the test and control stations were not found to differ significantly (Two-Way ANOVA $p=0.313$).

The third reef stations mean values ranged from 4.0 to 27.5 (Fig. 9). Mean S2 abundance recorded on GB3B ranged from 4.0 to 9.4. ANOVA did not indicate a significant difference ($p=0.071$) existed between the sampling periods of this station. The third reef control station, GB3C, mean S2 fish abundance ranged from 6.0 to 27.5, and the ANOVA test did not show a significant difference among the mean S2 abundance values for this station ($p=0.113$). Two-Way ANOVA did not show a significant difference between the sampling periods of the third reef test and control stations ($p=0.066$).

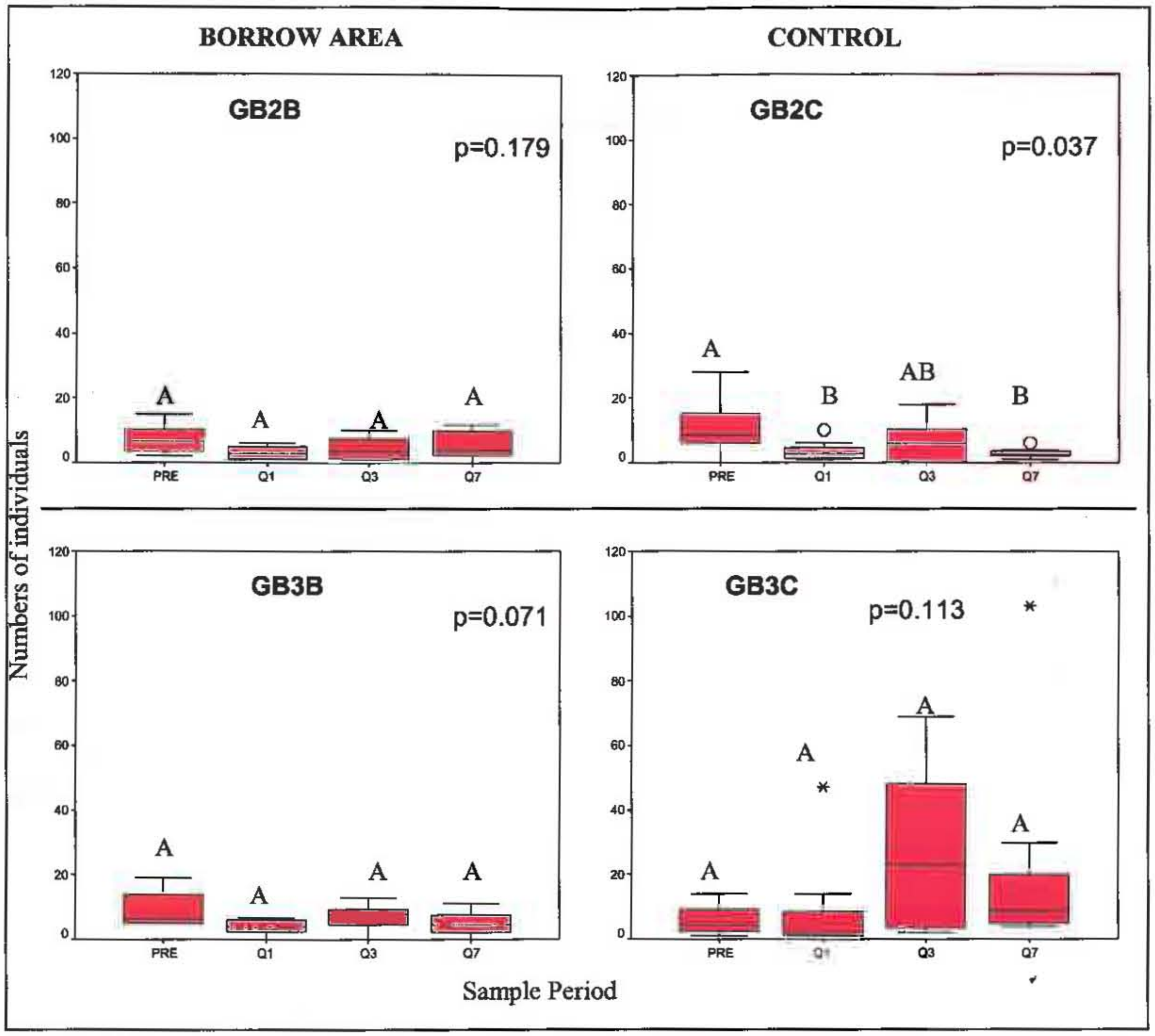

Figure 10. S2 mobility guild abundance box plots of each sampling period for Golden Beach. ANOVA p values are presented and SNK ($p<0.05$) significant results are indicated by non-sharing letter designations. Boxes extend from the 25th to the 75th percentile and the black line indicates median values. Whiskers extend to the upper and lower values within 1.5 box lengths. 'Outliers' ('O'), are values between 1.5 and 3 box lengths, and 'extreme' values (✱) are greater than 3 box lengths.

3.2.4.4 Transients Mobility Guild

Mean transient abundance per sample, was less than 2, for both second and third reef stations for each sampling period throughout the study. Given the nominal abundance of the Transient mobility guild, ANOVA tests were not conducted.

Table 2. Mean Transient guild fish abundance values for all Golden Beach stations.

	2nd REEF		3rd REEF	
Period	GB2B	GB2C	GB3B	GB3C
PRE	0.1	0.3	0.3	1.9
Q1	0.0	0.1	0.1	1.8
Q3	0.3	0.0	0.0	0.6
Q7	0.0	0.1	0.0	0.8

3.2.5 Bray-Curtis dissimilarity

MDS plots of Bray-Curtis dissimilarity indices for each Golden Beach stations' set of samples are presented as figures 10-13. For all second and third reef stations, the samples were inter-dispersed and no clustering was apparent.

GB2B

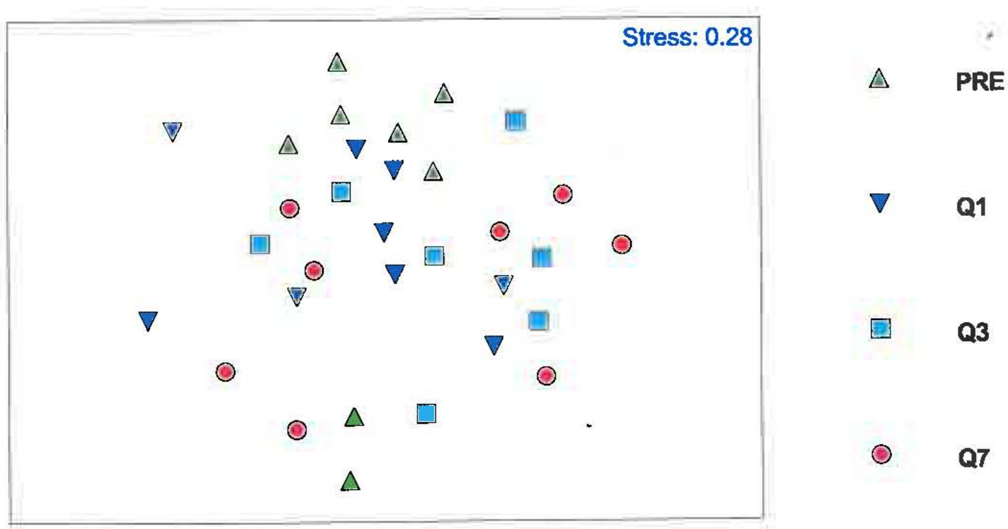

Figure 11. Golden Beach second reef test station MDS plot of Bray-Curtis dissimilarity index for all samples.

GB2C

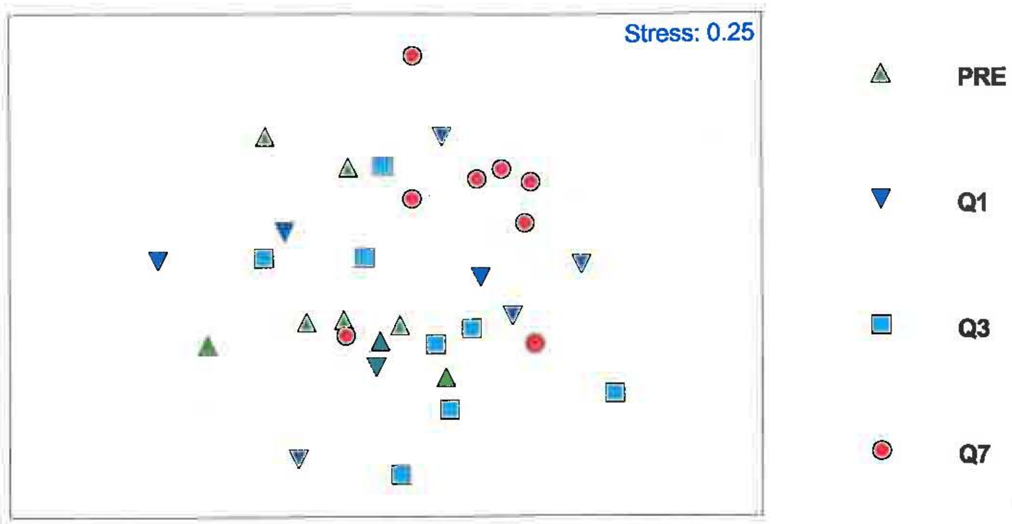

Figure 12. Golden Beach second reef control station MDS plot of Bray-Curtis dissimilarity index for all samples.

GB3B

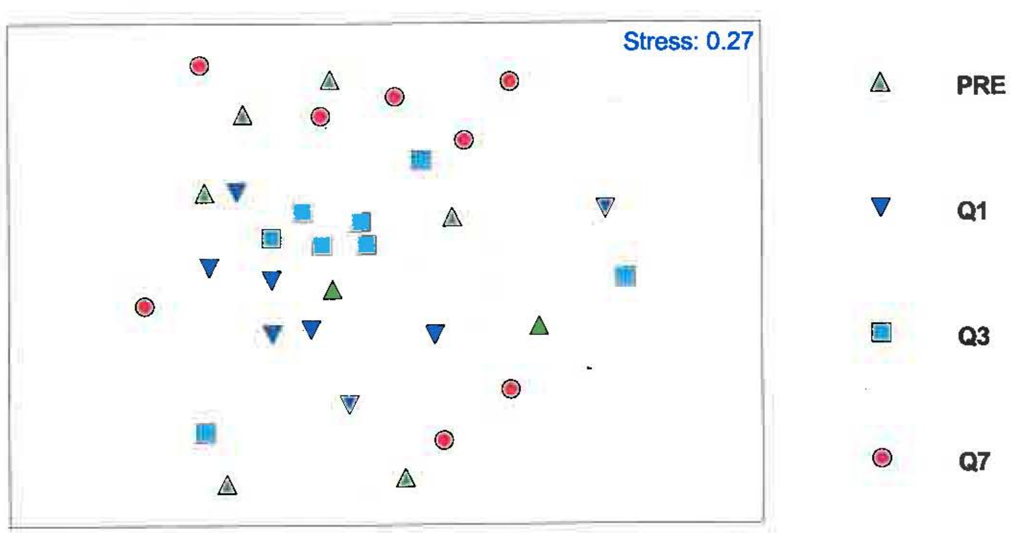

Figure 13. Golden Beach third reef test station MDS plot of Bray-Curtis dissimilarity index for all samples.

GB3C

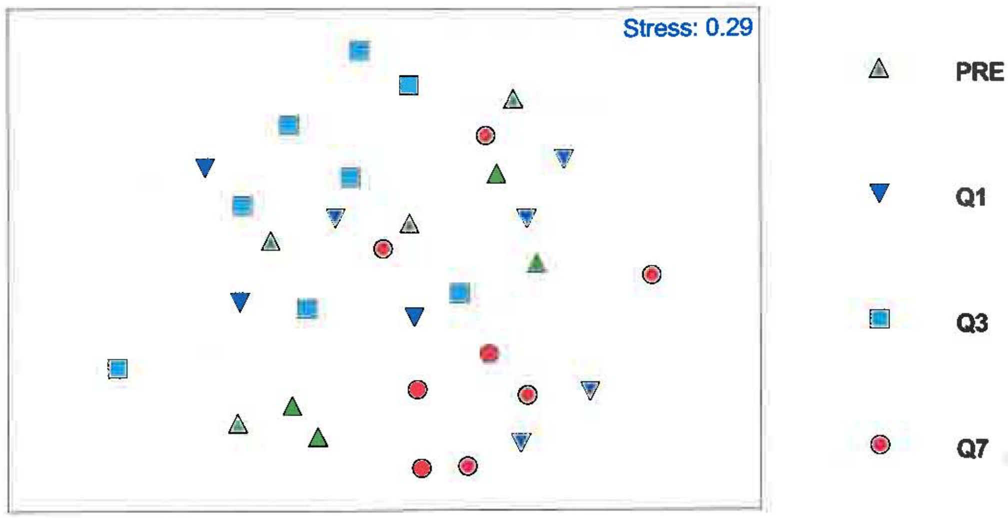

Figure 14. Golden Beach third reef control station MDS plot of Bray-Curtis dissimilarity index for all samples.

3.3 Key Biscayne Borrow Site

Sampling of the Key Biscayne stations took place between September 1998 and September 2000. Active dredging for this project took place between December 1998 and August 1999. During the time period of this project, two major storm events affected the region. Tropical storm Harvey hit South Florida on September 21, 1999, with sustained winds of 45 knots and gusts to 51 knots recorded at Fowey Rocks (National Hurricane Center Archives), this event occurred immediately prior to the Q1 sampling period. Following the Q1 sampling period on October 15, 1999, Hurricane Irene hit South Florida, with sustained wind speeds of 57 knots and gusts to 73 knots recorded at Fowey Rocks (National Hurricane Center Archives).

3.3.1 Reef fish species richness

Reef fish species richness on the Key Biscayne stations ranged from 14.4-22.1. The initial ANOVA test, performed on the PRE period indicated no significant differences among the stations (p=0.066), establishing a baseline in terms of species richness values.

Mean reef fish species richness on second reef stations ranged from 14.4 to 21.0 per sample (Fig. 14). The second-patch reef station, KB2PB, sampling period mean values ranged from 18.4 to 21.0, and there was no significant difference (ANOVA p=0.549) among the sampling periods. For the control station, KB2C, sampling period mean richness values ranged from 17.5 to 19.6, and were significantly different (ANOVA p=0.017). Post-hoc, SNK ($p < 0.05$), tests for this station found a significant difference between the Q1 and Q7 sampling periods. The Two-Way ANOVA test indicated no significant difference between the sampling periods of the second reef control and test stations (p=0.246).

Mean reef fish species richness on the third reef stations ranged from 14.8 to 22.1 (Fig. 14). KB3NB was significantly different between the sampling periods (ANOVA p=0.005). At this station a high mean value recorded in the PRE sampling period was significantly different than the lower mean values recorded during the Q1 and Q3 periods (SNK $p<0.05$). However, the Two-Way ANOVA between the sampling periods of KB3NB and the third reef control station was not significant (p=0.334). The control station, KB3C, and the southern test station KB3SB, did not differ significantly among their respective sampling periods. Additionally, no significant difference was indicated between the sampling periods of KB3SB and KB3C (Two-Way ANOVA, p=0.804).

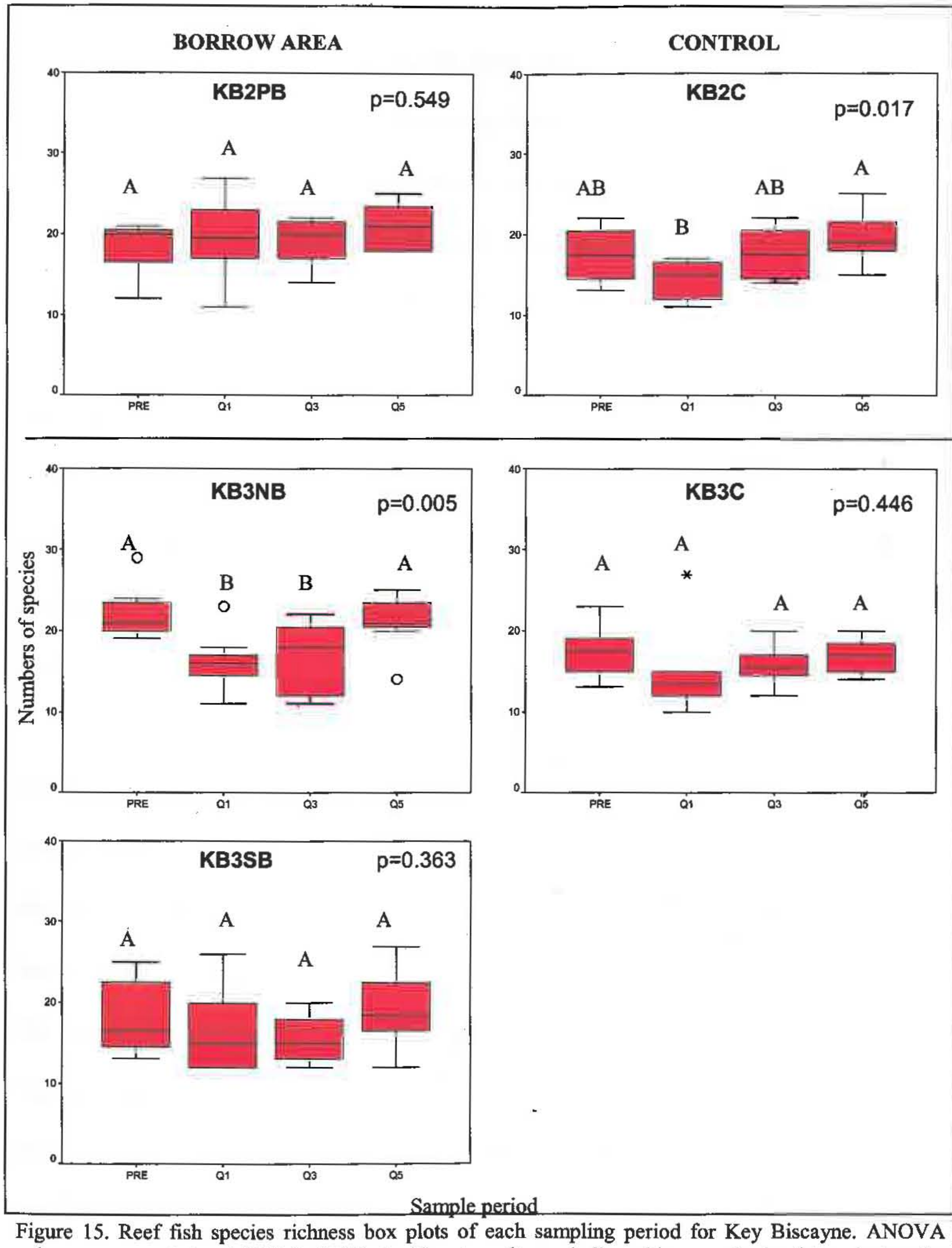

Figure 15. Reef fish species richness box plots of each sampling period for Key Biscayne. ANOVA p values are presented and SNK ($p<0.05$) significant results are indicated by non-sharing letter designations. Boxes extend from the 25th to the 75th percentile and the black line indicates median values. Whiskers extend to the upper and lower values within 1.5 box lengths. 'Outliers' ('O'), are values between 1.5 and 3 box lengths.

3.3.2 Reef fish abundance

Preliminary ANOVA test on the mean abundance of all stations PRE sampling period, indicated no significant difference ($p=0.267$).

Mean reef fish abundance for second reef stations ranged from 98.4 to 184.6 fish per survey (Fig. 15). On KB2PB mean reef fish abundance ranged from 107.4 to 184.6, ANOVA approached a significant difference ($p=0.057$) among the sampling periods for this station. While the second reef control station, KB2C, mean abundance values ranged from 98.4 to 152.9. The sampling periods for this station were significantly different (ANOVA $p=0.030$), and Post-hoc tests (SNK $p<0.05$) indicated the Q2 and Q5 sampling periods were significantly different. The Two-Way ANOVA test between the sampling periods of the second reef test and control stations did not indicate a significant difference ($p=0.256$)

Mean reef fish abundance on third reef stations ranged from 70.9 to 176.5 fish per survey (Fig. 15). The northern third reef test station, KB3NB, mean abundance values ranged from 78.5 to 176.5. A significant difference exists among the sampling periods of this test station (ANOVA $p<0.001$). Post-hoc tests (SNK $p<0.05$) results showed that lower abundance values of Q1 and Q3 sampling periods were different from the PRE and Q5 sampling periods. The southern third reef test station, KB3SB, mean abundance values ranged from 133.5 to 70.5, significant difference existed among the sampling periods (ANOVA $p=0.019$). The first quarter sampling, Q1, had the highest mean abundance and was found to differ significantly from the Q3 sampling with the lowest abundance (SNK, $p<0.005$). The third reef control station, KB3C, mean abundance ranged from 78.6 to 134.3, and these sampling periods were significantly different

(ANOVA, p=0.009). The low mean value recorded during the Q1 period differed significantly from the higher abundances recorded during the PRE and Q5 sampling periods. Two-Way ANOVA test between the third reef control and the northern third reef test sampling periods did not show a significant difference (p=0.135). However, the Two-Way ANOVA test between the third reef control and the southern third reef test station sampling periods was significant (p=0.007). Post-hoc tests indicate this difference is driven by a significant difference in the Q1 period, with a higher mean value recorded at the test station KB3SB (SNK p=0.004).

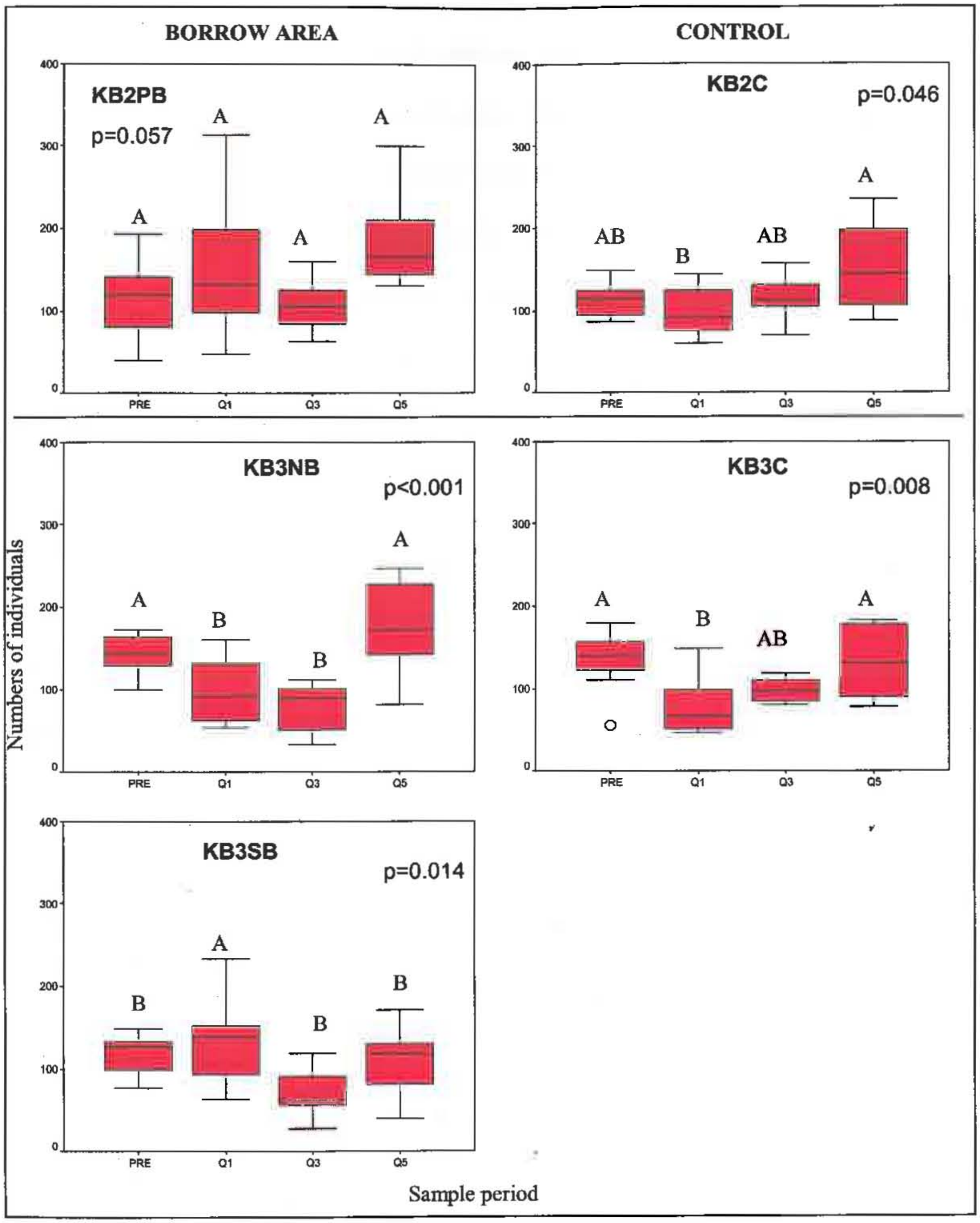

Figure 16. Reef fish abundance box plots of each sampling period for Key Biscayne. ANOVA p values are presented and SNK ($p<0.05$) significant results are indicated by non-sharing letter designations. Boxes extend from the 25[th] to the 75[th] percentile and the black line indicates median values. Whiskers extend to the upper and lower values within 1.5 box lengths. 'Outliers' (O'), are values between 1.5 and 3 box lengths.

3.3.3 Reef fish diversity

Mean reef fish diversity, for all stations, was within a narrow range between, 2.9 to 3.5 (Fig. 16), and did not differ significantly among the sampling periods of any of the stations (ANOVA $p>0.05$). The northern third reef test station, KB3NB, displayed the greatest degree of variation, from a high mean value of 3.5 in the PRE sampling period to a low of 3.1 in the Q1 sampling period. The high mean SWD index value recorded at the KB3NB during the PRE period, resulted in significant differences in the cross-station comparisons. The ANOVA performed on all of the stations PRE period SWD indices, was significant ($p=0.012$) and the Post-hoc SNK test found significant differences ($p<0.05$) between KB3NB and the other two third reef stations. Additionally, the Two-Way ANOVA between the sampling periods of KB3NB and the third reef control, KB3C, was significantly different ($p=0.033$), with the Post-hoc SNK test indicating a significant difference in the PRE period ($p=0.004$).

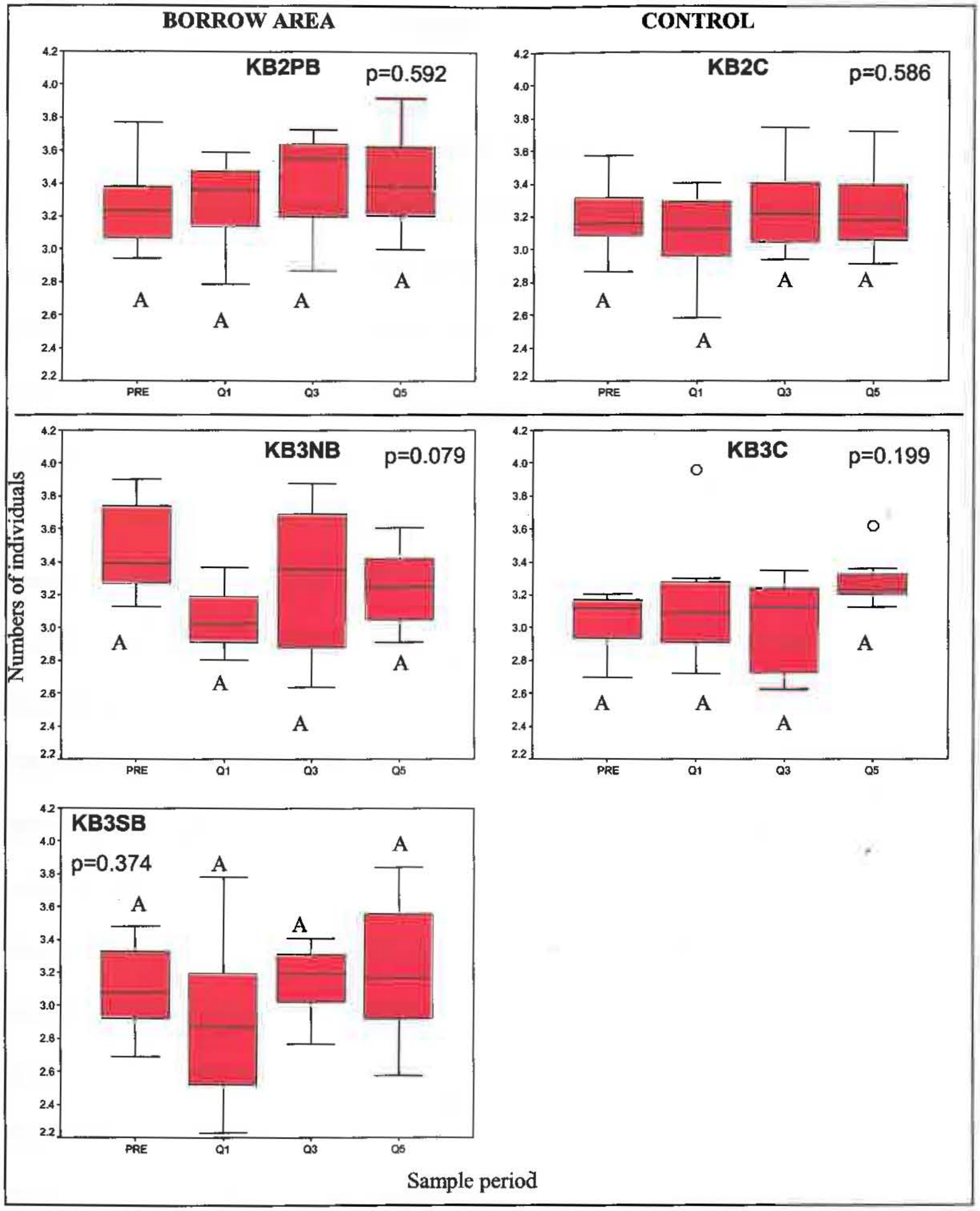

Figure 17. Shannon-Weaver diversity indices box plots of each sampling period for Key Biscayne. ANOVA p values are presented and SNK ($p<0.05$) significant results are indicated by non-sharing letter designations. Boxes extend from the 25th to the 75th percentile and the black line indicates median values. Whiskers extend to the upper and lower values within 1.5 box lengths. 'Outliers' ('O'), are values between 1.5 and 3 box lengths.

3.3.4 Reef fish mobility guild abundance

3.3.4.1 Residents Mobility Guild

For the Key Biscayne stations, mean Resident fish abundance ranged from 35.6-87.3. ANOVA tests found significant differences for the sampling periods of each of the stations, driven in large part by high mean values recorded in the Q5 sampling period. Preliminary ANOVA test of the PRE period of all of the stations indicated significant differences among the stations ($p=0.029$). Post-hoc, SNK test found the southern third reef test station differed significantly from the third reef control station ($p<0.05$).

On the second reef patch station, KB2PB, mean Resident fish abundance per sample ranged from 42.8 to 87.3 (Fig. 17), ANOVA test indicated a significant difference ($p=0.003$) among the sampling periods. A significant difference was found between the high mean resident fish abundance of the Q5 and the lower Resident abundances of the PRE and Q3 sampling periods (SNK $p<0.05$). The second reef control station, KB2C, mean resident fish abundance per sample station ranged from 39.3 to 69.0. The mean value for the PRE through Q3 sampling periods for this station varied little (4 fish per sample), however, due to the high mean value recorded during the Q5 sampling, the sampling periods were found to differ significantly (ANOVA $p=0.004$). Supporting this point of the contrast between the PRE-Q3 versus the Q5 sampling period, post-hoc tests found the Q5 period to differ significantly from the PRE-Q3 sampling periods (SNK $p<0.05$). Two-Way ANOVA did not indicate a significant difference among the sampling periods of the second reef control and test stations ($p=0.188$).

On the northern third reef test station, KB3NB, mean Resident fish abundance per sample ranged from 26.0 to 75.1 (Fig. 17), and these sampling periods were significantly different (ANOVA p<0.001). A trend similar, to the second reef control station, the significant difference is driven by a high mean value recorded in the Q5 sampling period. Post-hoc, tests indicated a significant difference between the Q5 sampling period and the PRE, Q3, and Q5 sampling periods (SNK p<0.05). On the southern third reef test station, KB3SB, mean resident fish abundance ranged from 29.3 to 53.8, there was a significant difference among the sampling periods (ANOVA p=0.008). This difference appears driven, in large part by a high mean value recorded during Q1, post-hoc tests indicate a significant difference between the mean values of Q1 and the PRE and Q3 sampling periods (SNK, p<0.05). The third reef control station, KB3C, mean resident fish abundance ranged from 35.6 to 60.6. ANOVA showed a significant difference (p=0.045) among the sampling periods. However, the post-hoc, SNK, tests did not indicate a significant difference between any of the sampling periods for this station. The Two-Way ANOVA between the sampling periods of KB3C and KB3NB did not indicate a significant difference among the sampling periods (p=0.057). Conversely, the Two-Way ANOVA test between the sampling periods of KB3C and KB3SB did indicate a significant difference (p=0.012). Again, the high value of the control versus the low value of the southern test in the PRE period was the source of the significant difference (SNK p=0.004).

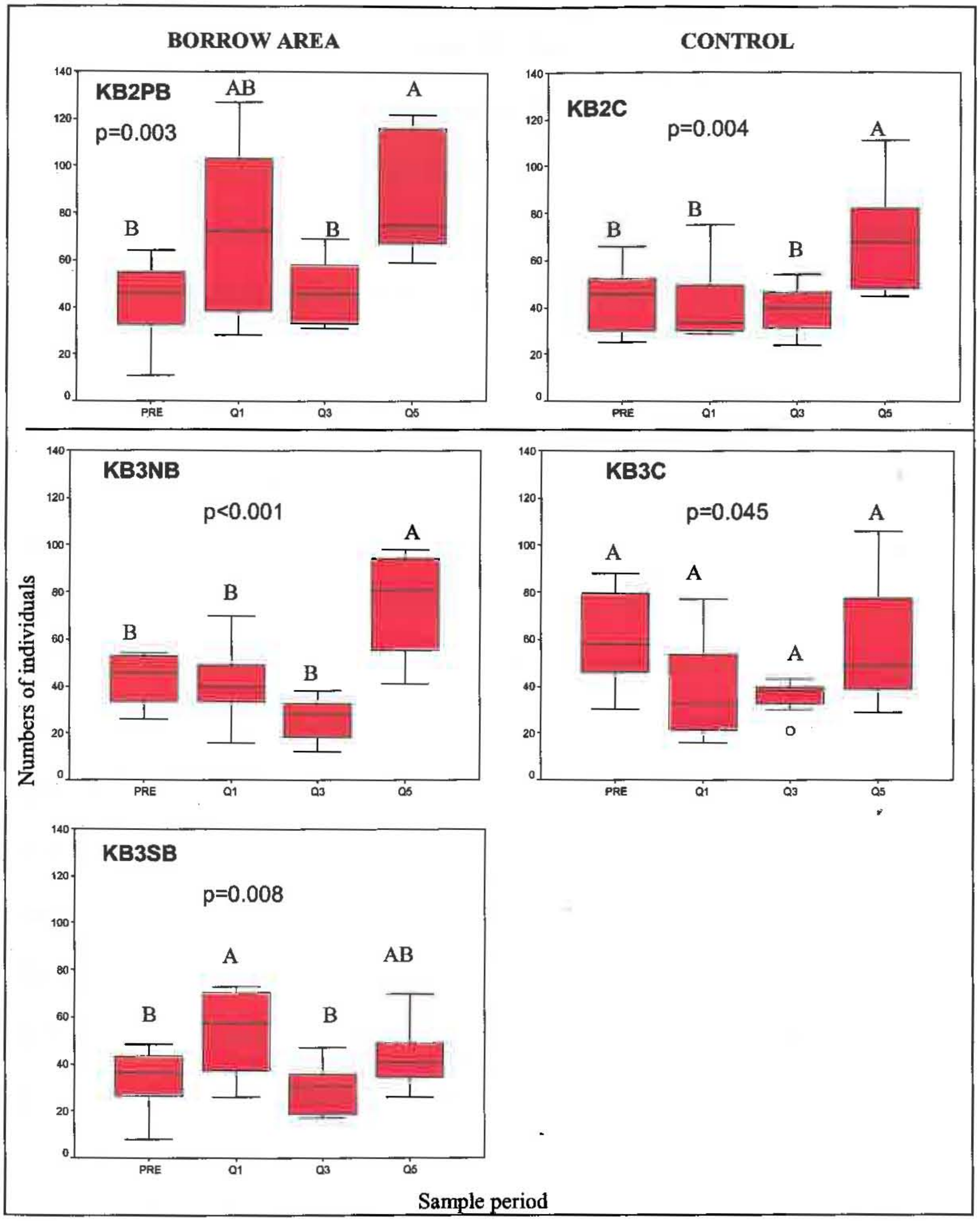

Figure 18. Resident mobility guild abundance box plots of each sampling period for Key Biscayne. ANOVA p values are presented and SNK ($p<0.05$) significant results are indicated by non-sharing letter designations. Boxes extend from the 25th to the 75th percentile and the black line indicates median values. Whiskers extend to the upper and lower values within 1.5 box lengths. 'Outliers' values, ('O'), are values between 1.5 and 3 box lengths.

3.3.4.2 S1 Mobility Guild: fish with daily movements 10m-100m

Initial ANOVA tests on mean S1 fish abundance indicated no significant differences among all of the stations during the PRE period (p=0.166). Mean S1 fish abundance on the second reef patch station, KB2PB, ranged from 46.1 to 68. (Fig. 18), and the sampling periods did not differ (ANOVA p=0.301). Mean S1 fish abundance on the second reef control station, KB2C, ranged from 48.9 to 76.1, this stations sampling periods did not differ either (ANOVA p=0.120). Two-Way ANOVA between the periods of the second reef test and control stations indicated no significant differences (p=0.911).

Mean S1 fish abundance, on the third reef stations, ranged from 33.3 to 85.9 per sample (Fig. 18). Mean S1 fish abundance on the third reef stations followed a similar pattern across sampling periods; high mean values in the PRE and Q5, and lower mean values in the Q1 and Q3 sampling periods. ANOVA suggested a significant difference among the sampling periods of each third reef station, KB3NB (p=0.006), KB3SB (p=0.013) and KB3C (p=0.021). Post-hoc, tests for the test station, KB3NB, suggested a significant difference (SNK p<0.05) between the PRE and Q3 periods and the highest mean value of the Q5 period was significantly different than the Q1 and Q3 periods. For the other test station, KB3SB, the high mean value of the PRE period was significantly different than the lower value of the Q3 period (SNK p<0.05). The third reef control station, KB3C, had significant differences between the high mean value of the PRE and Q5 periods, versus the lower mean value of the Q1 period (SNK p<0.05) The mean S1 abundance Two-Way ANOVA test indicated no significant differences between the periods of the third reef control, KB3C, and the two test stations; KB3NB (p=0.372) and KB3SB (p=0.078).

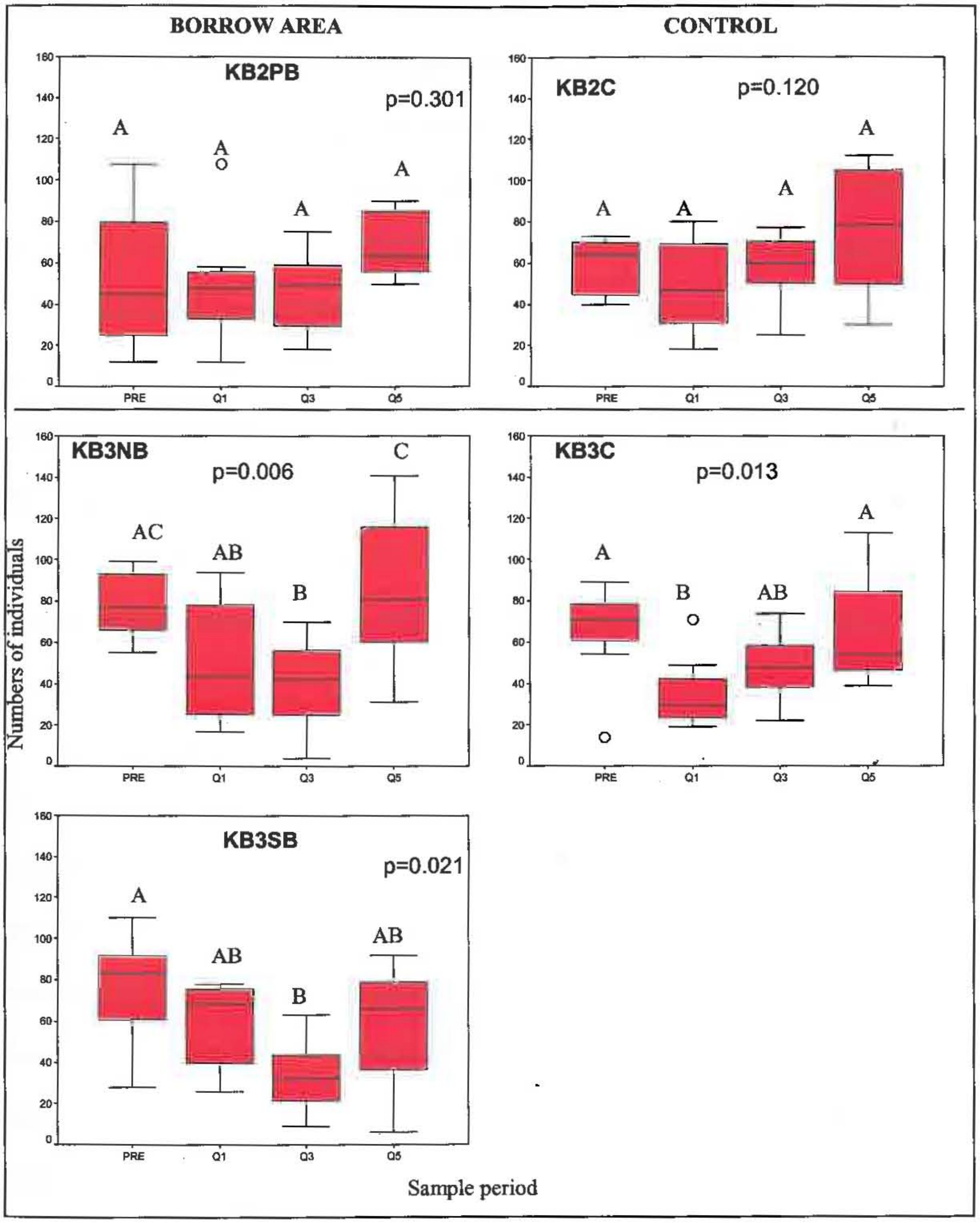

Figure 19. S1 mobility guild abundance box plots of each sampling period for Key Biscayne. ANOVA p values are presented and SNK ($p<0.05$) significant results are indicated by non-sharing letter designations. Boxes extend from the 25[th] to the 75[th] percentile and the black line indicates median values. Whiskers extend to the upper and lower values within 1.5 box lengths. 'Outliers' ('O'), are values between 1.5 and 3 box lengths.

3.3.4.3 S2 Mobility Guild: fish with daily movements 100m+

ANOVA test performed on mean S2 abundance for the PRE sampling period of all of the stations indicated no significant difference between the stations (p=0.570).

Mean S2 fish abundance on second reef stations ranged from 6.5 to 28.5 per sample. The second reef patch station, KB2PB, mean sampling period S2 fish abundance ranged from 14.6 to 28.5 (Fig. 19), and the sampling periods did differ significantly (ANOVA p=0.934). Mean S2 fish abundance on control station, KB2C, ranged from 6.5 to 17.6, and these sampling periods were significantly different (ANOVA p=0.006). This difference is driven by the high mean value recorded during the Q3 sampling period, and this period was different than the lower values of the PRE, Q1, and Q5 periods (SNK $p<0.05$). Two-Way ANOVA between the sampling periods of the second reef test and control stations indicated no significant differences between the sampling periods (p=0.322).

Mean S2 fish abundance on third reef stations ranged from 4.3 to 13.0 per sample (Fig. 19). Significant differences were not present among the sampling periods of southern test station, KB3SB (ANOVA p=0.985) and the control station KB3C (p=0.365). However, significant differences were present among the sampling periods of the northern test station, KB3NB (ANOVA p=0.008). This difference was driven by the low mean value recorded during the Q1 sampling period. Post-hoc, SNK ($p<0.05$), tests indicated a significant difference between the PRE, Q3, and Q5 sampling periods in relation to the Q1 sampling period for this station. However this trend was not significantly different than the control stations, as neither of the Two-Way ANOVA tests between the periods of the third reef control and the two test stations were significant; KB3NB ($p=0.935$) and KB3SB ($p=0.358$).

3.3.4.4 Transients

Mean transient abundance ranged from 0.0 to 12.8 (Fig. 21). Initial tests of the PRE period mean Transient fish abundance for all of the stations indicated no significant difference (non-parametric ANOVA $p= 0.089$). Mean transient abundance for each of the stations sampling periods was relatively low and with the exception of KB3NB no differences were found among the stations sampling periods (non-parametric ANOVA $p>0.05$). For KB3NB significant differences were shown between the sampling periods (non-parametric ANOVA $p=0.020$). Although, post-hoc SNK tests did not indicate any significant differences between any of the sampling periods ($p>0.05$).

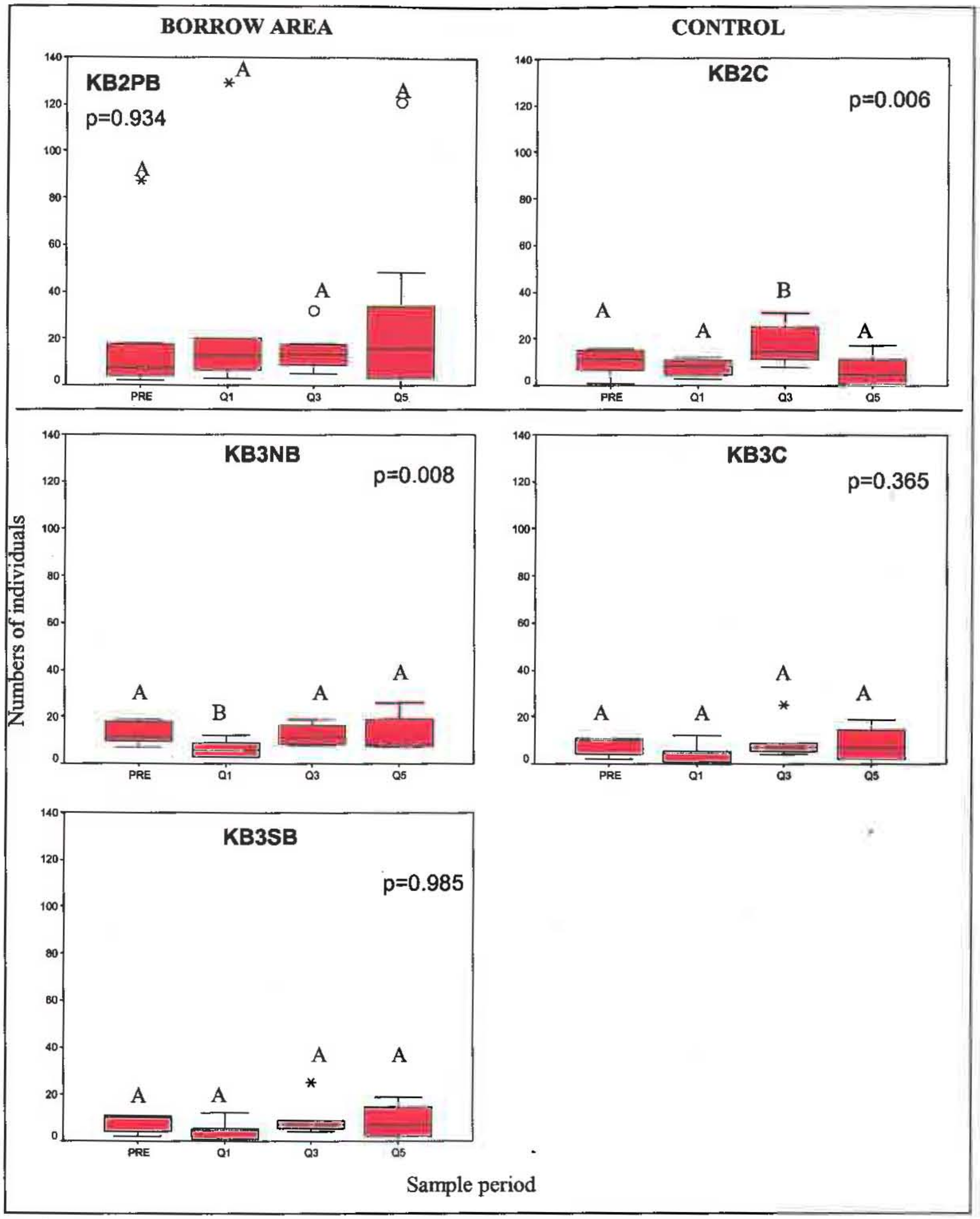

Figure 20. S2 mobility guild abundance box plots of each sampling period for Key Biscayne. ANOVA p values are presented and SNK ($p<0.05$) significant results are indicated by non-sharing letter designations. Boxes extend from the 25th to the 75th percentile and the black line indicates median values. Whiskers extend to the upper and lower values within 1.5 box lengths. 'Outliers' ('O'), are values between 1.5 and 3 box lengths, and 'extreme' values (✱) are greater than 3 box lengths.

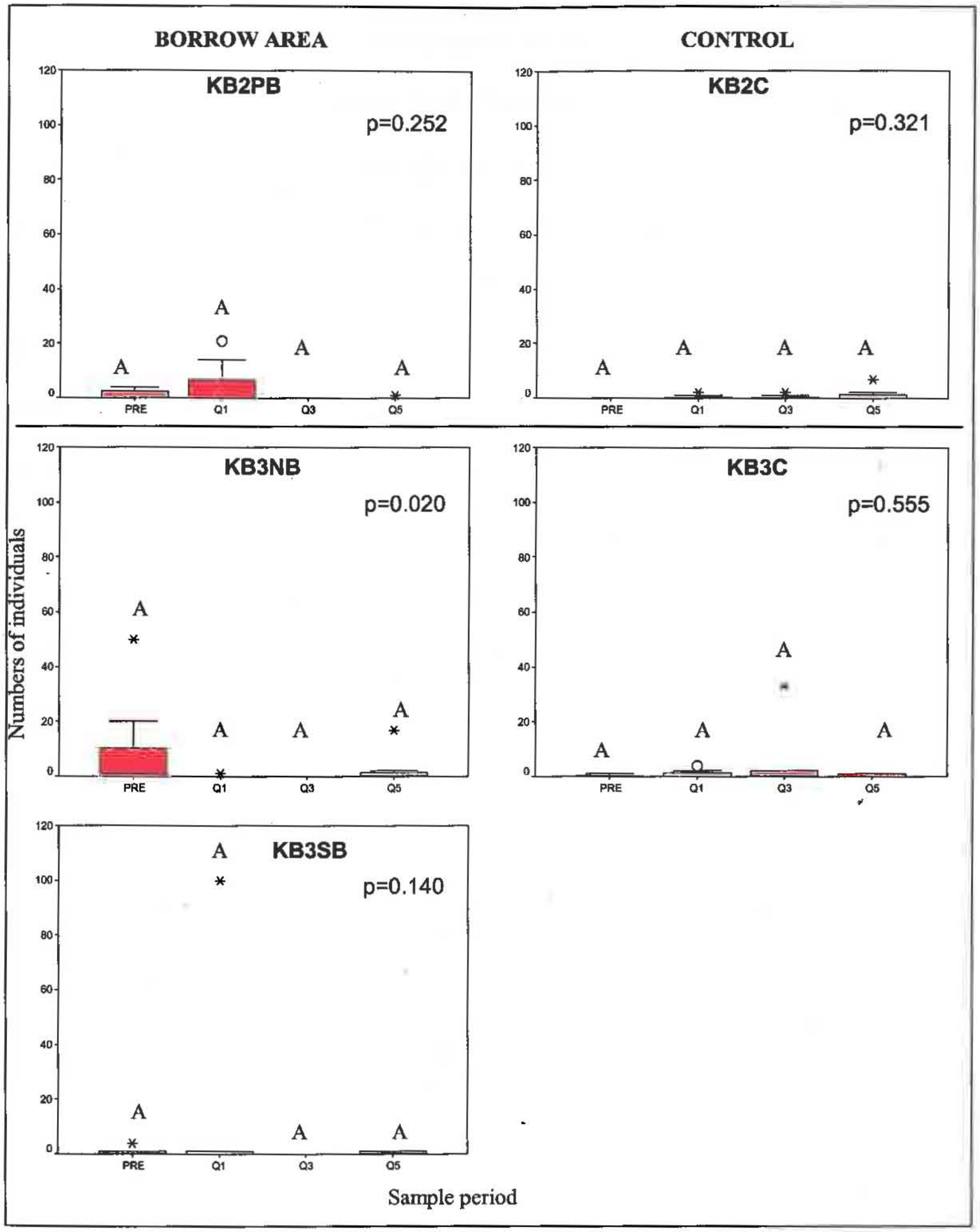

Figure 21. Transient mobility guild abundance box plots of each sampling period for Key Biscayne. ANOVA p values are presented and SNK ($p<0.05$) significant results are indicated by non-sharing letter designations. Boxes extend from the 25th to the 75th percentile and the black line indicates median values. Whiskers extend to the upper and lower values within 1.5 box lengths. 'Outliers' ('O'), are values between 1.5 and 3 box lengths, and 'extreme' values (✱) are greater than 3 box lengths.

3.3.5 Bray-Curtis dissimilarity

MDS plots of Bray-Curtis dissimilarity indices for each of the Key Biscayne stations' set of samples are presented as Figures 22-26. The second reef test station, KB2PB, displays some central clustering of the PRE, Q3, and Q5 sampling periods with the Q1 sampling period dispersed and away from the central clustering (Fig. 22). This pattern is similar to that of the second reef control station, KB2C (Fig. 23). The northern third reef test station, KB3NB (Fig. 24), displayed some clustering of the PRE and Q5 sampling periods, while the Q1 and Q3 periods were dispersed away from this clustering. The southern third reef test station, KB3SB (Fig. 25), displayed some clustering of the PRE, Q1, and Q5 sampling periods, however the Q3 was dispersed thought the plot. The third reef control station (Fig. 26), KB3C, displayed a tight cluster of the PRE period followed by dispersion away from this cluster in the Q1 period, and successive tighter clustering of the Q3 and Q5 periods moving successively in the direction of the PRE cluster.

KB2PB

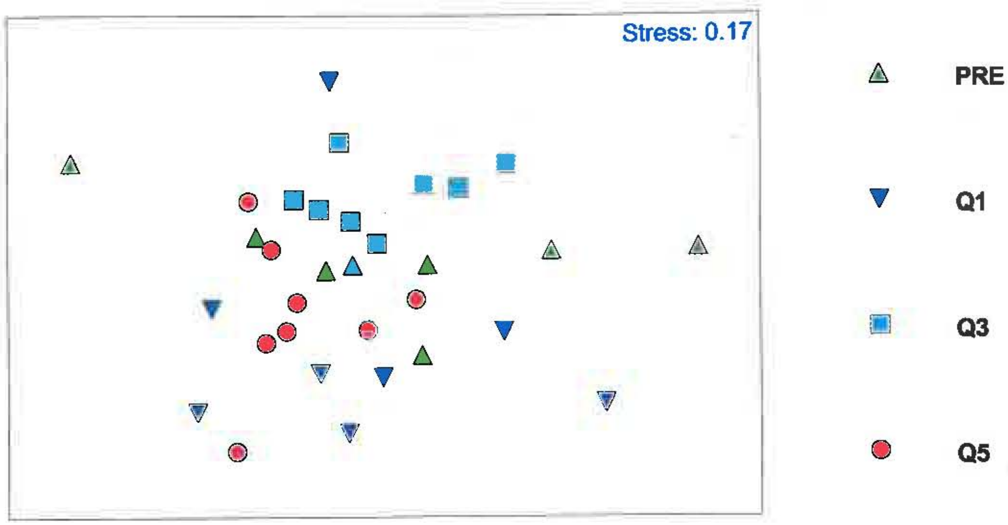

Figure 22. Key Biscayne second reef test station MDS plot of Bray-Curtis dissimilarity index for all samples.

KB2C

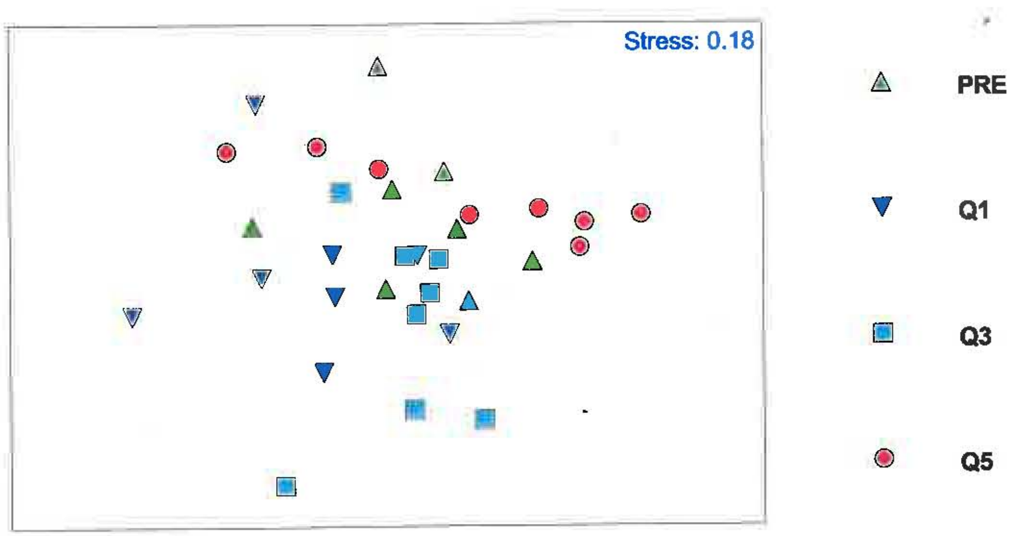

Figure 23. Key Biscayne second reef control station MDS plot of Bray-Curtis dissimilarity index for all samples.

KB3NB

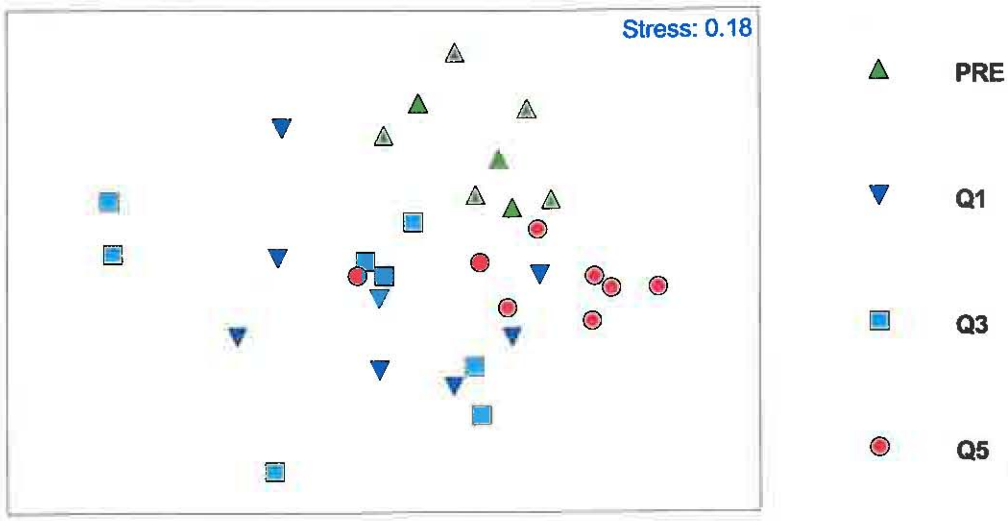

Figure 24. Key Biscayne northern third reef test station MDS plot of Bray-Curtis dissimilarity index for all samples.

KB3SB

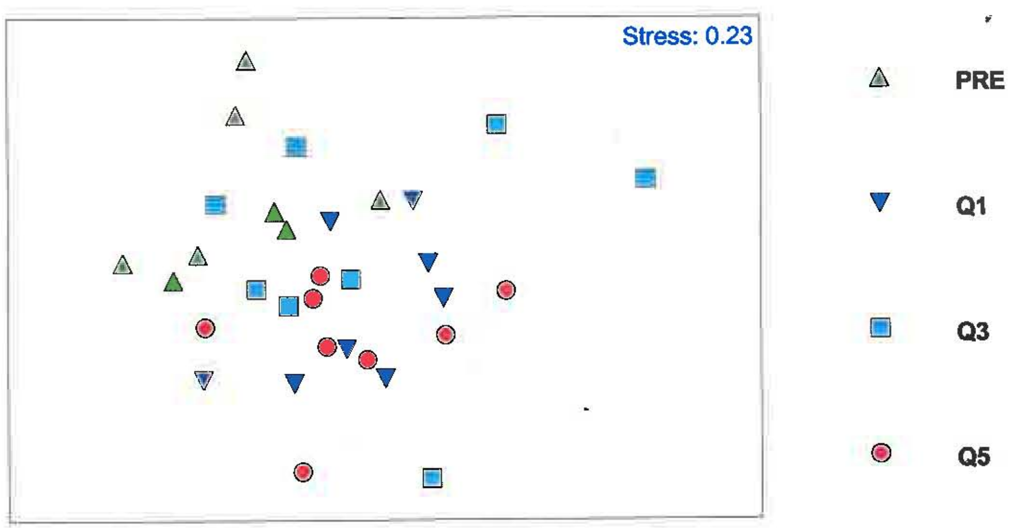

Figure 25. Key Biscayne southern third reef test station MDS plot of Bray-Curtis dissimilarity index for all samples.

KB3C

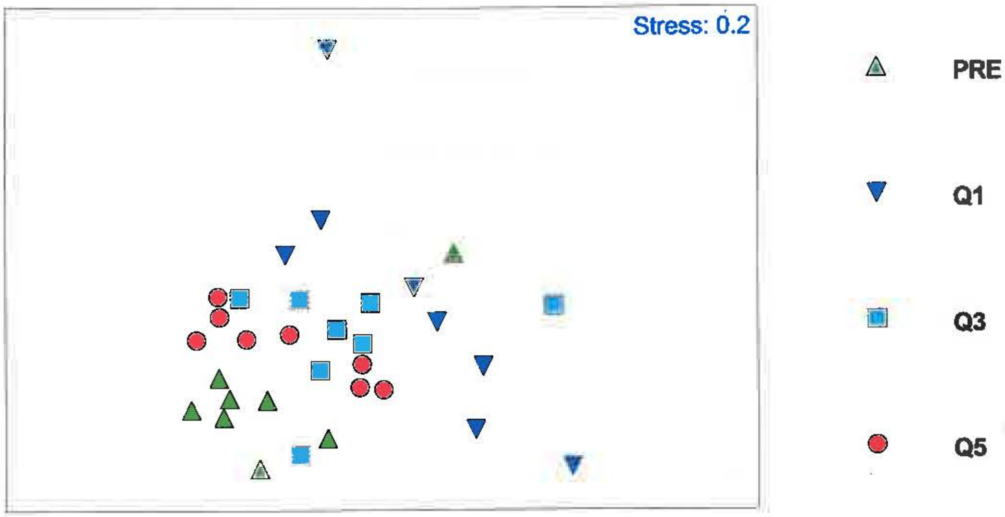

Figure 26. Key Biscayne third reef control station MDS plot of Bray-Curtis dissimilarity index for all samples.

4 DISSCUSSION

4.1 Golden Beach Borrow Site

Reviews of tropical storm activity indicated that no major storm events took place between the PRE and Q7 sampling period. In terms of the evaluations conducted, no indications of significant dredging impacts were apparent on the fish communities. Although two notable points, may suggest some minor impact to the test stations. The third reef test station experienced a decrease in mean species richness from the PRE period to the three consecutive sampling periods. The mean range of 13.5-15.5 species per sample for the three periods following dredging is slightly lower when compared to the 15.5-18 recorded at the third reef control station of this project and those sampled in other studies to the north in Broward County (Ettinger, 2000; Gilliam et. al, 2002). However, in terms of Shannon-Weaver diversity indices, abundance, abundance of mobility guilds, and Bray-Curtis MDS plots, no significant changes were documented at this station, and it was essentially consistent with the control stations. On the second reef test station, a trend of increasing fish abundance occurred through the PRE-Q7 sampling periods. This increase in overall abundance was driven by increases in abundance within the resident guild. In this case, consideration is given to the possibility that changes in the fish community resulting from dredging activities may be manifested as increases in the abundance of certain species, which are attracted to the turbid and light sedimentation conditions created by dredging activities (Wilber et al., 2003). Reviews of the raw data showed *Stegastes partitius*, *Coryphoterus glaucofraenum*, and *Canthigaster rostrata* contributed the greatest to this increase. Given the general sand dwelling nature of *C. glaucofraenum*, an increase in sediment deposits on a reef may increase desirable habitat, which in turn may give rise to an increase in abundance of this species. However, to establish a direct link between dredging activities and an increase in abundance of *C. glaucofraenum*, would require additional studies. Further, it is recognized that population fluctuations, such as this one, can be explained by recruitment pulses (Doherty and Williams 1988). However, the increases in *S. partitus* and *C. rostrata* are contradictory to what is expected, if dredging activities resulted in significant alterations and loss of the benthic substrate and the benthic community.

For the second reef control station, it is noted that significantly higher diversity was calculated for the PRE period versus the three successive sampling periods. Indicating that changes can occur to a reef fish community parameter in the apparent absence of any disturbances.

4.2 Key Biscayne Borrow Site

Evaluations of potential impacts, resulting from dredging activities, to the test stations of this project will be difficult in light of the two major storm events which impacted the area during the monitoring period of this project. It has been documented, on local reefs that fall and winter storms can result in decreases in fish abundance (Bohnsack et. al, 1994). Further, it has long been recognized that tropical cyclones can reduce reef fish abundance and species richness (Lassig, 1983; Doherty and Williams, 1988).

The second-patch reef test station was consistent with the control stations, in terms of species richness and diversity. However, in terms of abundance the test station experienced a notable increase in the Q1 sampling period, while both controls experienced decreases, presumably impacted by tropical storm Harvey. As with the Golden Beach project, closer reviews of the raw data were conducted, to examine the possibility of a given species opportunistically taking advantage of the turbid and light sedementation conditions generated by the dredging activities. The higher abundance, at KB2PB, was driven primarily by the Resident guild and in part by the S2 (fish with daily movements on the order of 100s of meters) guild. The Resident guild major contributing species in the Q1 sampling period was *Coryphoterus glaucofraenum* and *Coryphoterus personatus*. The S2 guild contributions consisted of high numbers of *Haemulon aurolineatum*. Although, the second and third reef control stations experienced decreases in overall abundance, both had notable increases in *C. glaucofraenum*. Again, increases in this species may be an indication of increased sediment deposition creating improved conditions for this species, or simply a recruitment pulse. However, the increased presence of *H. aurolineatum* is counter to what would be expected from significant impacts associated with dredging activities, as this is a highly mobile species which is capable of relocating in response to adverse conditions. The Bray-Curtis MDS plots, suggest that the second-patch reef test station, was similarly effected by the tropical storm events as the control stations, all three stations displayed a similar clustering of the PRE, Q3, and Q5 samples, while the Q1 samples were spread out away from the other periods. The third reef control station displays the most pronounced example of this clustering, with the Q1 samples dispersed furthest from the PRE samples, and the Q3 and Q5 samples clustering successively closer to the PRE samples, suggesting a recovery to a community similar to the PRE period.

The northern third reef test station experienced significantly lower species richness in the Q1 and Q3 sampling periods. These records of lower species richness coincided with significantly lower abundance in the same periods. A similar pattern of lower abundance in the Q1 and Q3 sampling periods was recorded at the third reef control station. This suggests the storms events had a similar effect on both stations in terms of abundance and this in turn confounds the isolation of possible effects associated with dredging activities for the northern third reef test station. However, the southern third reef test station, showed an increase in mean abundance from the PRE to Q1 sampling periods. The increase in abundance at this station was driven by increases in the Resident and Transient guilds. The species, which contributed the greatest to the increase to the Resident guild, was *C. glaucofraenum*. Similarly, while the northern third reef station experienced a decrease in abundance, this station also experienced an increase in *C. glaucofraenum*. Again, notable increases in *C. glaucofraenum* were experienced at both control stations. Widespread increases of this species may be a result of increases in suitable habitat resulting from the increased sand deposits generated by the multiple tropical storms. However, the increased abundance may also be the result of a recruitment pulse, which occurred throughout the reef system (Victor, 1986).

In terms of the S1 (10m-100m) mobility guild, all three of the third reef stations, the two test and the one control, had a similar pattern of higher abundance in the PRE and Q5 sampling periods, and lower abundance in the Q1 and Q3 periods (Fig 19). This pattern, which is evident in the overall abundance (except KB3SB; Q1), is also evident in Bray-Curtis MDS plots. Thus, the northern and southern third reef test stations displayed a similar pattern of close clustering of the PRE and Q5 samples, with some dispersion of the Q1 samples and greater dispersion of the Q3 samples. While, as stated previously, the third reef control station Bray-Curtis MDS plot displayed a tight cluster of the PRE samples, and a dispersion of the Q1 samples, and successive tighter clustering in the, Q3 and Q5 samples in the direction of the PRE samples.

Based on the trends of abundance and the Bray-Curtis MDS plots, the primary contrast between the third reef test stations and the control station is the apparent degree of impact of the different storm events. The effect of tropical storm Harvey is more evident in the Q1 period of the control station, and the effect of hurricane Irene, which had a more northerly track than Harvey, is more evident in the Q3 period of the test stations.

5 SUMMARY

In terms of the sampling methodology employed and the parameters evaluated, there is no clear indication that the dredging activities of either project had a significant impact on the fish communities of the surrounding reefs. However, while the modified Bohnsack-Bannerot reef fish visual census methodology is better suited to sampling cryptic fishes, the cryptic component of this study may not have been fully and consistently represented in the data. Previous studies have shown that dredging activities can impact cryptic species such as, *Opisthognathus* sp., which can suffer shelter loss as a result of small-scale burials (Courtney, et al. 1980). Therefore, impacts may have occurred to the surrounding reef fish communities that the method employed is not sensitive to detecting.

With regards to the Golden Beach project, changes were noted in evaluation parameters, to both test and control stations. Although, without clear trends in multiple evaluation parameters of the test station communities, and in contrast to the control stations, no distinction can be made between natural fluctuations and potential impacts resulting from dredging activities. Further expanding on the point of natural fluctuations, temporal differences in abundance and richness have been documented on local reef fish communities (Gilliam et al. 2002; Jordan and Spieler in press).

With regards to the Key Biscayne project, the occurrence of two tropical storm events during the monitoring period confound efforts to distinguish potential impacts resulting from dredging operations, as impacts from those storm events dominate the trends in the population evaluation parameters.

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7 APPENDIX A: SPECIES LIST

Table 3. List of species encountered and assigned mobility guild.

Scientific Name	FAMILY	Mobility
Abudefduf saxatilis	POMACENTRIDAE	R
Abudefduf taurus	POMACENTRIDAE	R
Acanthurus bahianus	ACANTHURIDAE	S2
Acanthurus chirurgus	ACANTHURIDAE	S2
Acanthurus coeruleus	ACANTHURIDAE	S1
Aluterus scriptus	BALISTIDAE	T
Anisotremus surinamensis	HAEMULIDAE	S1
Anisotremus virginicus	HAEMULIDAE	S1
Apogon binotatus	APOGONIDAE	R
Aulostomus maculatus	AULOSTOMIDAE	S1
Balistes capriscus	BALISTIDAE	S2
Balistes vetula	BALISTIDAE	S2
Bodianus rufus	LABRIDAE	S1
Bothus lunatus	BOTHIDAE	S1
Calamus bajonado	SPARIDAE	S2
Calamus calamus	SPARIDAE	S2
Calamus penna	SPARIDAE	S2
Calamus sp.	SPARIDAE	-
Cantherhines macrocerus	BALISTIDAE	R
Cantherhines pullus	BALISTIDAE	R
Canthidermis sufflamen	BALISTIDAE	T
Canthigaster rostrata	TETRAODONTIDAE	R
Caranx crysos	CARANGIDAE	T
Caranx ruber	CARANGIDAE	T
Chaetodiperus faber	EPHIPPIDAE	S2
Chaetodon capistratus	CHAETODONTIDAE	S1
Chaetodon ocellatus	CHAETODONTIDAE	S1
Chaetodon sedentarius	CHAETODONTIDAE	S1
Chaetodon striatus	CHAETODONTIDAE	S1
Chromis cyaneus	POMACENTRIDAE	R
Chromis insolatus	POMACENTRIDAE	R
Chromis multilineatus	POMACENTRIDAE	R
Chromis scotti	POMACENTRIDAE	R
Clepticus parrai	LABRIDAE	S2
Coryphopterus dicrus	GOBIIDAE	R
Coryphopterus glaucofraenum	GOBIIDAE	R
Coryphopterus personatus	GOBIIDAE	R
Coryphopterus sp.	GOBIIDAE	R
Cryptotomus roseus	SCARIDAE	S1
Dasyatis americana	DASYATIDAE	T
Decapterus punctatus	CARANGIDAE	T
Decapterus species	CARANGIDAE	T
Diodon holocanthus	DIODONTIDAE	S1
Diodon hystrix	DIODONTIDAE	S1
Echeneis naucrates	ECHENEIDAE	T
Epinephelus adscensionis	SERRANIDAE	R
Epinephelus cruentatus	SERRANIDAE	R
Epinephelus fulvus	SERRANIDAE	S1
Epinephelus guttatus	SERRANIDAE	S1

Table 3 (continued). List of species encountered and assigned mobility guild.

Scientific Name	FAMILY	Mobility
Equetus lanceolatus	SCIAENIDAE	R
Ginglymostoma cirratum	ORECTOLOBIDAE	T
Gnatholepis thompsoni	GOBIIDAE	R
Gobiosoma evelynae	GOBIIDAE	R
Gymnothorax funebris	MURAENIDAE	R
Gymnothorax miliaris	MURAENIDAE	R
Gymnothorax moringa	MURAENIDAE	R
Haemulon aurolineatum	HAEMULIDAE	S2
Haemulon carbonarium	HAEMULIDAE	S2
Haemulon flavolineatum	HAEMULIDAE	S2
Haemulon melanurum	HAEMULIDAE	S2
Haemulon plumieri	HAEMULIDAE	S2
Haemulon sciurus	HAEMULIDAE	S2
Haemulon sp.	HAEMULIDAE	S2
Halichoeres bivittatus	LABRIDAE	S1
Halichoeres cyanocephalus	LABRIDAE	S1
Halichoeres garnoti	LABRIDAE	S1
Halichoeres maculipinna	LABRIDAE	S1
Halichoeres radiatus	LABRIDAE	S1
Holacanthus bermudensis	POMACANTHIDAE	S1
Holacanthus ciliaris	POMACANTHIDAE	S1
Holacanthus tricolor	POMACANTHIDAE	R
Holocentrus adscensionis	HOLOCENTRIDAE	S1
Holocentrus marianus	HOLOCENTRIDAE	S1
Holocentrus rufus	HOLOCENTRIDAE	S1
Hyploplectrus nigricans	SERRANIDAE	R
Hypoplectrus gemma	SERRANIDAE	R
Hypoplectrus indigo	SERRANIDAE	R
Hypoplectrus puella	SERRANIDAE	R
Hypoplectrus unicolor	SERRANIDAE	R
Ioglossus calliurus	GOBIIDAE	R
Ioglossus helenae	GOBIIDAE	R
Lachnolaimus maximus	LABRIDAE	S2
Lactophrys polygonia	OSTRACIIDAE	S1
Lactophrys quadricornis	OSTRACIIDAE	S1
Lactophrys triqueter	OSTRACIIDAE	S1
Lutjanus analis	LUTJANIDAE	S2
Lutjanus apodus	LUTJANIDAE	S2
Lutjanus jocu	LUTJANIDAE	S2
Lutjanus synagris	LUTJANIDAE	S2
Malacanthus plumieri	MALACANTHIDAE	R
Monacanthus hispidus	BALISTIDAE	R
Monacanthus tuckeri	BALISTIDAE	R
Mulloidichthys martinicus	MULLIDAE	S2
Mycteroperca bonaci	SERRANIDAE	S2
Mycteroperca interstitialis	SERRANIDAE	S1
Mycteroperca venenosa	SERRANIDAE	S2
Myripristis jacobus	HOLOCENTRIDAE	S1

Table 3 (continued). List of species encountered and assigned mobility guild.

Scientific Name	FAMILY	Mobility
Ocyurus chrysurus	LUTJANIDAE	S2
Opistognathus aurifrons	OPISTOGNATHIDAE	R
Pomacanthus arcuatus	POMACANTHIDAE	S1
Pomacanthus paru	POMACANTHIDAE	S1
Stegastes fuscus	POMACENTRIDAE	R
Stegastes leucostictus	POMACENTRIDAE	R
Stegastes partitus	POMACENTRIDAE	R
Stegastes variabilis	POMACENTRIDAE	R
Priacanthus arenatus	PRIACANTHIDAE	R
Priacanthus cruentatus	PRIACANTHIDAE	R
Pseudupeneus maculatus	MULLIDAE	S1
Rypticus saponaceus	GRAMMISTIDAE	S1
Scarus coelestinus	SCARIDAE	S2
Scarus coeruleus	SCARIDAE	S2
Scarus croicensis	SCARIDAE	S1
Scarus guacamaia	SCARIDAE	S2
Scarus sp.	SCARIDAE	–
Scarus taeniopterus	SCARIDAE	S1
Scomberomorus maculatus	SCOMBRIDAE	T
Scomberomorus regalis	SCOMBRIDAE	T
Scorpaena plumieri	SCORPAENIDAE	R
Serranus baldwini	SERRANIDAE	R
Serranus tabacarius	SERRANIDAE	S1
Serranus tigrinus	SERRANIDAE	S1
Serranus tortugarum	SERRANIDAE	R
Sparisoma atomarium	SCARIDAE	S1
Sparisoma aurofrenatum	SCARIDAE	S1
Sparisoma chrysopterum	SCARIDAE	S2
Sparisoma rubripinne	SCARIDAE	S2
Sparisoma viride	SCARIDAE	S2
Sphoeroides spengleri	TETRAODONTIDAE	S1
Sphyraena barracuda	SPHYRAENIDAE	T
Synodus foetens	SYNODONTIDAE	R
Synodus intermedius	SYNODONTIDAE	R
Urolophus jamaicensis	DASYATIDAE	T

APPENDIX B: Golden Beach raw data.

Table 4. Station GB2B list of species in order of total prevalence.

Scientific Name	PRE	Q1	Q3	Q7	Total
Stegastes partitus	150	109	189	219	667
Thalassoma bifasciatum	60	68	114	138	380
Coryphopterus glaucofraenum	20	68	69	118	275
Halichoeres garnoti	54	46	66	85	251
Sparisoma aurofrenatum	26	28	45	32	131
Canthigaster rostrata	13	22	44	29	108
Serranus tigrinus	24	26	33	24	107
Coryphopterus personatus	5	51	21	22	99
Sparisoma atomarium	19	27	28	5	79
Serranus tabacarius	17	22	14	15	68
Acanthurus bahianus	28	6	13	15	62
Acanthurus chirurgus	20	11	14	15	60
Chaetodon sedentarius	16	12	19	9	56
Scarus taeniopterus	20	18	6	0	44
Cryptotomus roseus	3	36	0	3	42
Opistognathus aurifrons	0	0	1	40	41
Serranus baldwini	3	6	7	19	35
Halichoeres bivittatus	12	2	2	8	24
Serranus tortugarum	0	15	6	0	21
Balistes capriscus	3	4	3	8	18
Holacanthus tricolor	9	1	8	0	18
Coryphopterus dicrus	5	10	0	0	15
Gnatholepis thompsoni	0	0	0	15	15
Stegastes variabilis	0	1	10	3	14
Lachnolaimus maximus	2	2	5	4	13
Hypoplectrus unicolor	1	3	5	3	12
Monacanthus hispidus	4	1	2	5	12
Acanthurus coeruleus	3	3	3	2	11
Diodon holocanthus	2	3	2	3	10
Cantherhines pullus	3	3	1	2	9
Pomacanthus arcuatus	3	3	3	0	9
Pomacanthus paru	3	1	3	2	9
Sphoeroides spengleri	6	2	0	0	8
Chaetodon ocellatus	1	1	2	3	7
Hypoplectrus gemma	2	0	5	0	7
Ioglossus calliurus	0	2	0	5	7
Pseudupeneus maculatus	0	0	7	0	7
Balistes vetula	5	0	0	1	6
Chromis cyaneus	0	2	4	0	6
Holocentrus rufus	0	0	2	4	6
Lactophrys quadricornis	1	3	0	1	5
Bodianus rufus	1	2	1	0	4
Chaetodon capistratus	0	0	4	0	4
Halichoeres maculipinna	0	0	3	0	3
Holacanthus bermudensis	0	2	1	0	3

Table 4(continued). Station GB2B list of species in order of total prevalence.

Scientific Name	PRE	Q1	Q3	Q7	Total
Scarus croicensis	0	0	3	0	3
Apogon binotatus	2	0	0	0	2
Cantherhines macrocerus	1	0	0	1	2
Epinephelus cruentatus	0	0	2	0	2
Epinephelus morio	0	2	0	0	2
Haemulon plumieri	0	0	1	1	2
Holacanthus ciliaris	0	0	2	0	2
Malacanthus plumieri	0	1	1	0	2
Monacanthus tuckeri	2	0	0	0	2
Sphyraena barracuda	0	0	2	0	2
Aulostomus maculatus	0	1	0	0	1
Caranx ruber	1	0	0	0	1
Epinephelus fulvus	1	0	0	0	1
Gobiosoma evelynae	0	1	0	0	1
Gymnothorax miliaris	0	1	0	0	1
Haemulon flavolineatum	0	0	0	1	1
Haemulon sciurus	1	0	0	0	1
Hypoplectrus indigo	0	0	1	0	1
Hypoplectrus puella	0	0	1	0	1
Lactophrys triqueter	0	0	0	1	1
Rypticus saponaceus	0	0	0	1	1
Total	552	628	778	862	2820

Table 5. Station GB2C list of species in order of total prevalence.

Scientific Name	PRE	Q1	Q3	Q7	Total
Stegastes partitus	125	94	117	156	492
Halichoeres garnoti	55	65	50	34	204
Coryphopterus glaucofraenum	21	51	35	93	200
Thalassoma bifasciatum	44	39	87	30	200
Sparisoma aurofrenatum	17	25	28	47	117
Serranus tigrinus	34	10	20	14	78
Acanthurus chirurgus	38	12	18	9	77
Serranus tabacarius	34	16	20	3	73
Acanthurus bahianus	36	11	13	7	67
Cryptotomus roseus	0	56	3	8	67
Stegastes variabilis	10	4	12	27	53
Canthigaster rostrata	9	9	21	12	51
Coryphopterus personatus	4	46	0	0	50
Halichoeres bivittatus	1	4	15	27	47
Sparisoma atomarium	18	7	0	7	32
Chaetodon sedentarius	5	2	9	14	30
Scarus taeniopterus	4	18	0	2	24
Halichoeres maculipinna	2	3	6	7	18
Sphoeroides spengleri	4	1	6	7	18
Balistes capriscus	5	3	5	3	16
Holacanthus tricolor	11	4	1	0	16
Serranus baldwini	4	3	6	2	15
Acanthurus coeruleus	0	10	1	0	11
Monacanthus hispidus	4	1	1	4	10
Scarus croicensis	0	0	0	10	10
Gnatholepis thompsoni	0	5	0	4	9
Cantherhines pullus	5	3	0	0	8
Pomacanthus arcuatus	2	4	0	2	8
Diodon holocanthus	2	2	1	2	7
Haemulon plumieri	2	0	5	0	7
Hypoplectrus unicolor	1	3	2	1	7
Chaetodiperus faber	0	0	6	0	6
Hypoplectrus puella	1	1	0	4	6
Lachnolaimus maximus	3	2	1	0	6
Bodianus rufus	5	0	0	0	5
Chaetodon ocellatus	2	0	3	0	5
Hypoplectrus gemma	4	1	0	0	5
Ioglossus helenae	0	0	0	3	3
Monacanthus tuckeri	0	0	3	0	3
Opistognathus aurifrons	2	0	1	0	3
Stegastes leucostictus	0	0	3	0	3
Serranus tortugarum	3	0	0	0	3
Sparisoma viride	2	0	1	0	3
Apogon binotatus	0	0	0	2	2
Coryphopterus dicrus	0	1	1	0	2
Haemulon sciurus	0	0	2	0	2
Lactophrys quadricornis	1	0	1	0	2
Pomacanthus paru	0	2	0	0	2

Table 5 (continued). Station GB2C list of species in order of total prevalence.

Scientific Name	PRE	Q1	Q3	Q7	Total
Sparisoma rubripinne	1	0	1	0	2
Urolophus jamaicensis	1	0	0	1	2
Aluterus scriptus	1	0	0	0	1
Anisotremus virginicus	0	0	1	0	1
Aulostomus maculatus	0	0	0	1	1
Balistes vetula	0	0	0	1	1
Calamus calamus	0	0	0	1	1
Calamus penna	0	0	0	1	1
Chromis cyaneus	0	1	0	0	1
Epinephelus cruentatus	0	0	0	1	1
Equetus acuminatus	0	1	0	0	1
Gymnothorax funebris	1	0	0	0	1
Holacanthus bermudensis	0	1	0	0	1
Holocentrus rufus	0	0	1	0	1
Lactophrys triqueter	1	0	0	0	1
Lutjanus analis	0	1	0	0	1
Pseudupeneus maculatus	0	0	1	0	1
Scomberomorus maculatus	0	1	0	0	1
Sparisoma chrysopterum	0	0	0	1	1
Total	525	523	508	548	2104

Table 6. Station GB3B list of species in order of total prevalence.

Scientific Name	PRE	Q1	Q3	Q7	Total
Thalassoma bifasciatum	245	153	211	274	883
Stegastes partitus	161	73	169	220	623
Coryphopterus glaucofraenum	19	111	80	58	268
Halichoeres garnoti	62	61	72	57	252
Sparisoma aurofrenatum	47	47	94	55	243
Coryphopterus personatus	0	74	2	106	182
Canthigaster rostrata	25	21	44	32	122
Acanthurus bahianus	43	17	32	23	115
Serranus tabacarius	26	28	36	11	101
Serranus tigrinus	19	16	32	24	91
Chaetodon sedentarius	21	6	36	20	83
Scarus taeniopterus	15	16	11	11	53
Acanthurus chirurgus	18	5	14	3	40
Acanthurus coeruleus	4	5	12	8	29
Cryptotomus roseus	3	22	4	0	29
Holacanthus tricolor	13	1	13	2	29
Sparisoma atomarium	2	14	0	10	26
Haemulon plumieri	2	5	0	11	18
Hypoplectrus unicolor	5	1	7	0	13
Serranus baldwini	3	2	5	3	13
Bodianus rufus	4	2	0	6	12
Chromis cyaneus	11	0	0	0	11
Diodon holocanthus	1	1	1	7	10
Chaetodon ocellatus	5	0	4	0	9
Lachnolaimus maximus	2	2	3	1	8
Pomacanthus arcuatus	6	1	1	0	8
Scarus croicensis	2	0	0	6	8
Epinephelus cruentatus	0	1	6	0	7
Holacanthus bermudensis	3	2	2	0	7
Pseudupeneus maculatus	0	0	5	2	7
Opistognathus aurifrons	2	0	0	3	5
Sparisoma rubripinne	4	0	0	1	5
Sparisoma viride	0	0	5	0	5
Apogon binotatus	1	1	2	0	4
Cantherhines pullus	1	0	2	1	4
Chaetodon capistratus	1	2	1	0	4
Chromis scotti	4	0	0	0	4
Monacanthus hispidus	3	0	1	0	4
Pomacanthus paru	2	1	0	1	4
Stegastes variabilis	1	0	3	0	4
Anisotremus virginicus	1	0	2	0	3
Balistes capriscus	3	0	0	0	3
Calamus penna	0	3	0	0	3
Halichoeres bivittatus	1	0	1	1	3
Hypoplectrus gemma	3	0	0	0	3
Monacanthus tuckeri	3	0	0	0	3
Mulloidichthys martinicus	0	0	3	0	3
Stegastes leucostictus	1	0	1	1	3

Table 6 (continued). Station GB3B list of species in order of total prevalence.

Scientific Name	PRE	Q1	Q3	Q7	Total
Chaetodon striatus	2	0	0	0	2
Holocentrus rufus	1	0	0	1	2
Lactophrys quadricornis	1	0	0	1	2
Malacanthus plumieri	0	0	2	0	2
Serranus tortugarum	0	0	2	0	2
Urolophus jamaicensis	2	0	0	0	2
Coryphopterus dicrus	1	0	0	0	1
Epinephelus adscensionis	0	1	0	0	1
Epinephelus guttatus	1	0	0	0	1
Epinephelus morio	1	0	0	0	1
Epinephelus sp.	0	1	0	0	1
Equetus acuminatus	0	0	0	1	1
Haemulon sciurus	1	0	0	0	1
Holacanthus ciliaris	0	0	1	0	1
Lactophrys polygonia	0	0	0	1	1
Lactophrys triqueter	0	0	0	1	1
Scarus guacamaia	1	0	0	0	1
Scomberomorus regalis	0	1	0	0	1
Sphoeroides spengleri	0	0	1	0	1
Total	809	697	923	963	3392

Table 7. Station GB3C list of species in order of total prevalence.

Scientific Name	PRE	Q1	Q3	Q7	Total
Thalassoma bifasciatum	116	120	197	274	707
Stegastes partitus	216	136	202	86	640
Coryphopterus personatus	5	189	75	24	293
Sparisoma aurofrenatum	77	66	61	43	247
Halichoeres garnoti	45	37	51	85	218
Clepticus parrai	10	6	80	120	216
Coryphopterus glaucofraenum	22	30	42	66	160
Acanthurus bahianus	20	15	18	41	94
Haemulon flavolineatum	0	0	88	0	88
Canthigaster rostrata	14	8	30	20	72
Scarus taeniopterus	15	27	18	11	71
Serranus tigrinus	9	14	14	6	43
Scarus croicensis	2	14	11	15	42
Serranus tabacarius	20	9	5	7	41
Acanthurus coeruleus	14	3	10	9	36
Chaetodon sedentarius	9	15	4	8	36
Chaetodiperus faber	0	35	0	0	35
Caranx ruber	13	11	2	6	32
Cryptotomus roseus	0	17	0	10	27
Opistognathus aurifrons	0	0	9	17	26
Sparisoma atomarium	17	2	3	1	23
Chaetodon ocellatus	7	7	3	3	20
Chaetodon capistratus	7	4	4	2	17
Acanthurus chirurgus	4	3	4	5	16
Coryphopterus dicrus	0	4	10	0	14
Halichoeres bivittatus	0	1	7	5	13
Abudefduf saxatilis	2	0	10	0	12
Haemulon plumieri	7	3	1	1	12
Haemulon sciurus	2	0	10	0	12
Hypoplectrus unicolor	4	3	3	2	12
Anisotremus surinamensis	0	0	11	0	11
Pseudupeneus maculatus	3	1	5	1	10
Serranus baldwini	1	1	0	8	10
Epinephelus cruentatus	3	4	1	1	9
Pomacanthus arcuatus	5	1	0	3	9
Stegastes variabilis	1	4	4	0	9
Sparisoma viride	2	0	5	2	9
Holacanthus tricolor	4	2	2	0	8
Lutjanus synagris	0	0	8	0	8
Gnatholepis thompsoni	0	0	6	0	6
Holacanthus bermudensis	4	0	2	0	6
Sparisoma rubripinne	1	3	2	0	6
Haemulon aurolineatum	0	5	0	0	5
Bodianus rufus	0	3	1	0	4
Cantherhines pullus	1	0	0	3	4
Chromis cyaneus	2	1	1	0	4
Chromis scotti	0	0	4	0	4
Lachnolaimus maximus	0	1	1	2	4

Table 7 (continued). Station GB3C list of species in order of total prevalence

Scientific Name	PRE	Q1	Q3	Q7	Total
Urolophus jamaicensis	2	1	1	0	4
Abudefduf taurus	0	0	3	0	3
Chromis multilineatus	3	0	0	0	3
Hypoplectrus gemma	2	1	0	0	3
Myripristis jacobus	0	0	3	0	3
Pomacanthus paru	0	2	1	0	3
Stegastes leucostictus	0	2	1	0	3
Sparisoma chrysopterum	0	0	2	1	3
Sphoeroides spengleri	1	2	0	0	3
Anisotremus virginicus	0	0	2	0	2
Chaetodon striatus	0	0	2	0	2
Holocentrus rufus	0	2	0	0	2
Lactophrys quadricornis	1	0	1	0	2
Monacanthus hispidus	2	0	0	0	2
Scarus coeruleus	1	0	0	1	2
Apogon binotatus	0	0	1	0	1
Aulostomus maculatus	0	0	1	0	1
Balistes vetula	0	0	0	1	1
Calamus sp.	0	0	0	1	1
Canthidermis sufflamen	0	1	0	0	1
Caranx crysos	0	1	0	0	1
Chromis insolatus	0	1	0	0	1
Diodon holocanthus	1	0	0	0	1
Echeneis naucrates	0	0	1	0	1
Epinephelus guttatus	0	0	0	1	1
Epinephelus morio	0	0	1	0	1
Equetus acuminatus	1	0	0	0	1
Ginglymostoma cirratum	0	0	1	0	1
Gymnothorax miliaris	0	0	0	1	1
Halichoeres cyanocephalus	0	1	0	0	1
Hypoplectrus indigo	0	0	1	0	1
Lactophrys polygonia	0	1	0	0	1
Lactophrys triqueter	0	1	0	0	1
Monacanthus tuckeri	0	0	1	0	1
Scarus guacamaia	1	0	0	0	1
Scorpaena plumieri	0	0	0	1	1
Synodus foetens	1	0	0	0	1
Total	700	821	1048	894	3463

APPENDIX C: Key Biscayne raw data.

Table 8. Station KB2PB list of species in order of total prevalence.

Scientific Name	PRE	Q1	Q3	Q5	Total
Stegastes partitus	199	164	208	300	871
Thalassoma bifasciatum	187	134	180	238	739
Coryphopterus personatus	11	193	9	170	383
Coryphopterus glaucofraenum	72	132	39	70	313
Sparisoma aurofrenatum	57	89	39	111	296
Halichoeres garnoti	43	51	29	62	185
Canthigaster rostrata	17	44	48	68	177
Haemulon aurolineatum	55	113	1	0	169
Haemulon flavolineatum	11	24	30	90	155
Scarus croicensis	27	34	54	17	132
Haemulon sciurus	21	25	6	75	127
Halichoeres bivittatus	34	17	17	18	86
Pseudupeneus maculatus	26	16	0	32	74
Scarus taeniopterus	13	20	10	24	67
Stegastes leucostictus	12	19	11	11	53
Acanthurus bahianus	18	13	10	11	52
Stegastes variabilis	7	7	10	20	44
Caranx crysos	6	34	0	0	40
Lutjanus griseus	2	8	3	22	35
Epinephelus cruentatus	4	10	6	13	33
Hypoplectrus unicolor	3	7	7	16	33
Ocyurus chrysurus	1	6	14	7	28
Lachnolaimus maximus	12	4	3	6	25
Lutjanus synagris	0	4	21	0	25
Haemulon plumieri	9	1	7	7	24
Serranus tigrinus	5	4	3	12	24
Acanthurus chirurgus	4	0	13	1	18
Acanthurus coeruleus	2	6	3	7	18
Chaetodon ocellatus	5	4	2	2	13
Holacanthus tricolor	3	2	4	4	13
Sparisoma atomarium	5	0	0	8	13
Anisotremus virginicus	0	4	6	0	10
Aulostomus maculatus	2	1	5	2	10
Bodianus rufus	0	4	2	4	10
Chaetodon capistratus	2	2	6	0	10
Equetus acuminatus	2	1	3	4	10
Gnatholepis thompsoni	2	0	0	8	10
Haemulon carbonarium	6	0	4	0	10
Sparisoma viride	4	3	0	3	10
Cryptotomus roseus	0	0	4	5	9
Ioglossus calliurus	1	2	0	6	9
Mycteroperca bonaci	0	6	3	0	9
Pomacanthus arcuatus	3	2	2	2	9
Balistes capriscus	3	3	0	2	8
Chaetodon sedentarius	4	2	0	2	8
Stegastes fuscus	0	0	8	0	8

Table 8 (continued). Station KB2PB list of species in order of total prevalence.

Scientific Name	PRE	Q1	Q3	Q5	Total
Hypoplectrus gemma	0	2	4	1	7
Coryphopterus dicrus	0	0	6	0	6
Monacanthus hispidus	0	0	5	1	6
Serranus tabacarius	0	0	2	3	5
Coryphopterus species	0	0	4	0	4
Opistognathus aurifrons	2	0	0	2	4
Anisotremus surinamensis	0	0	3	0	3
Decapterus punctatus	3	0	0	0	3
Hypoplectrus puella	3	0	0	0	3
Lutjanus analis	1	0	0	2	3
Cantherhines pullus	0	0	0	2	2
Diodon holocanthus	2	0	0	0	2
Epinephelus adscensionis	2	0	0	0	2
Holacanthus ciliaris	0	2	0	0	2
Serranus baldwini	0	0	0	2	2
Calamus calamus	0	0	0	1	1
Caranx ruber	0	1	0	0	1
Diodon hystrix	0	0	1	0	1
Epinephelus guttatus	0	1	0	0	1
Epinephelus morio	0	0	0	1	1
Gymnothorax miliaris	0	0	1	0	1
Gymnothorax moringa	1	0	0	0	1
Halichoeres radiatus	0	0	1	0	1
Holacanthus bermudensis	0	0	0	1	1
Hyploplectrus nigricans	1	0	0	0	1
Mycteroperca venenosa	0	0	1	0	1
Pomacanthus paru	1	0	0	0	1
Scarus coeruleus	0	0	1	0	1
Scomberomorus regalis	0	0	0	1	1
Sparisoma rubripinne	0	1	0	0	1
Sphoeroides spengleri	1	0	0	0	1
Total	917	1222	859	1477	4475

Table 9. Station KB2C list of species in order of total prevalence.

Scientific Name	PRE	Q1	Q3	Q5	Total
Thalassoma bifasciatum	204	182	273	258	917
Stegastes partitus	236	139	175	362	912
Coryphopterus glaucofraenum	66	135	70	57	328
Halichoeres garnoti	33	41	62	129	265
Sparisoma aurofrenatum	82	72	36	69	259
Halichoeres bivittatus	48	22	18	20	108
Acanthurus bahianus	13	22	29	22	86
Canthigaster rostrata	10	16	33	17	76
Acanthurus coeruleus	19	15	13	15	62
Haemulon sciurus	3	0	50	1	54
Scarus taeniopterus	19	4	5	24	52
Gnatholepis thompsoni	6	16	1	27	50
Scarus croicensis	14	19	11	5	49
Serranus tigrinus	10	5	17	14	46
Acanthurus chirurgus	17	19	5	3	44
Coryphopterus personatus	0	3	10	23	36
Chromis multilineatus	12	0	7	15	34
Chaetodon sedentarius	7	8	5	7	27
Chaetodon capistratus	8	6	2	8	24
Lutjanus griseus	7	0	17	0	24
Ocyurus chrysurus	19	5	0	0	24
Sparisoma atomarium	2	2	0	19	23
Sparisoma viride	6	7	5	4	22
Cryptotomus roseus	1	1	0	15	17
Ioglossus calliurus	0	7	2	8	17
Haemulon plumieri	5	0	10	1	16
Hypoplectrus unicolor	4	3	7	2	16
Lutjanus apodus	0	0	5	11	16
Pseudupeneus maculatus	12	0	3	1	16
Sparisoma rubripinne	0	5	9	1	15
Stegastes variabilis	5	2	2	5	14
Chromis cyaneus	0	0	0	13	13
Haemulon flavolineatum	7	0	0	6	13
Halichoeres maculipinna	2	1	0	10	13
Lachnolaimus maximus	1	4	5	3	13
Opistognathus aurifrons	0	0	0	12	12
Epinephelus cruentatus	1	5	1	3	10
Holacanthus tricolor	3	1	1	5	10
Pomacanthus arcuatus	4	2	2	2	10
Pomacanthus paru	1	0	9	0	10
Chaetodon striatus	2	4	0	2	8
Anisotremus virginicus	0	0	5	2	7
Caranx crysos	0	0	0	7	7
Serranus tabacarius	0	5	1	1	7
Caranx ruber	0	3	3	0	6
Bodianus rufus	1	0	0	4	5
Chaetodon ocellatus	0	2	0	2	4
Stegastes leucostictus	1	2	1	0	4

Table 9 (continued). Station KB2C list of species in order of total prevalence.

Scientific Name	PRE	Q1	Q3	Q5	Total
Chromis scotti	0	0	0	3	3
Serranus baldwini	3	0	0	0	3
Anisotremus surinamensis	0	0	2	0	2
Epinephelus morio	1	1	0	0	2
Haemulon sp.	0	0	2	0	2
Ioglossus helenae	0	0	2	0	2
Monacanthus hispidus	0	0	2	0	2
Mycteroperca bonaci	0	0	2	0	2
Sparisoma chrysopterum	2	0	0	0	2
Aluterus scriptus	0	0	0	1	1
Calamus bajonado	1	0	0	0	1
Dasyatis americana	0	0	0	1	1
Diodon holocanthus	1	0	0	0	1
Gymnothorax moringa	0	1	0	0	1
Haemulon aurolineatum	1	0	0	0	1
Haemulon melanurum	0	0	1	0	1
Holacanthus ciliaris	0	0	0	1	1
Holocentrus rufus	0	0	0	1	1
Scarus sp.	0	0	1	0	1
Scomberomorus regalis	0	0	0	1	1
Total	900	787	922	1223	3832

Table 10. Station KB3NB list of species in order of total prevalence.

Scientific Name	PRE	Q1	Q3	Q5	Total
Stegastes partitus	264	191	125	445	1025
Thalassoma bifasciatum	129	192	145	265	731
Halichoeres garnoti	86	64	44	125	319
Halichoeres bivittatus	167	17	37	27	248
Sparisoma aurofrenatum	80	32	17	82	211
Coryphopterus glaucofraenum	5	102	25	78	210
Acanthurus bahianus	41	12	37	42	132
Canthigaster rostrata	19	13	31	39	102
Cryptotomus roseus	0	12	9	77	98
Serranus tigrinus	24	25	11	22	82
Acanthurus chirurgus	19	15	25	13	72
Caranx ruber	50	0	0	17	67
Scarus croicensis	39	15	4	6	64
Stegastes variabilis	23	10	14	7	54
Haemulon plumieri	14	11	13	7	45
Chaetodon sedentarius	10	11	13	9	43
Scarus taeniopterus	28	0	6	7	41
Serranus tabacarius	7	15	0	15	37
Lachnolaimus maximus	6	4	8	11	29
Sparisoma atomarium	2	1	5	19	27
Acanthurus coeruleus	7	2	4	10	23
Caranx crysos	21	0	0	1	22
Chaetodon ocellatus	10	7	2	2	21
Balistes capriscus	2	0	5	12	19
Pseudupeneus maculatus	11	5	2	1	19
Epinephelus cruentatus	8	4	1	5	18
Sparisoma viride	11	0	2	3	16
Holocentrus rufus	4	1	4	5	14
Hypoplectrus unicolor	4	0	3	6	13
Stegastes leucostictus	5	3	4	1	13
Sphoeroides spengleri	2	1	5	4	12
Epinephelus morio	2	0	7	2	11
Sparisoma chrysopterum	4	0	1	5	10
Pomacanthus arcuatus	5	1	2	1	9
Serranus baldwini	4	4	0	0	8
Diodon holocanthus	0	1	5	1	7
Holacanthus tricolor	3	0	1	3	7
Sparisoma rubripinne	0	4	0	3	7
Chaetodon capistratus	4	0	0	2	6
Pomacanthus paru	3	1	0	2	6
Haemulon flavolineatum	1	4	0	0	5
Lutjanus analis	0	1	0	4	5
Opistognathus aurifrons	0	0	0	5	5
Cantherhines pullus	1	2	0	1	4
Ioglossus calliurus	0	0	2	2	4
Lactophrys quadricornis	0	0	0	4	4
Aluterus scriptus	0	0	0	3	3
Calamus calamus	0	0	2	1	3

Table 10 (continued). Station KB3NB list of species in order of total prevalence.

Scientific Name	PRE	Q1	Q3	Q7	Total
Coryphopterus dicrus	3	0	0	0	3
Hypoplectrus gemma	0	0	0	3	3
Hypoplectrus puella	1	2	0	0	3
Lutjanus jocu	3	0	0	0	3
Malacanthus plumieri	0	0	0	3	3
Monacanthus hispidus	0	0	2	1	3
Anisotremus virginicus	0	0	2	0	2
Chaetodon striatus	2	0	0	0	2
Gymnothorax moringa	2	0	0	0	2
Halichoeres maculipinna	0	0	2	0	2
Holacanthus ciliaris	1	0	1	0	2
Holocentrus marianus	1	1	0	0	2
Monacanthus tuckeri	0	0	0	2	2
Myripristis jacobus	2	0	0	0	2
Scorpaena plumieri	2	0	0	0	2
Aulostomus maculatus	0	0	0	1	1
Bothus lunatus	1	0	0	0	1
Haemulon sciurus	1	0	0	0	1
Holacanthus bermudensis	1	0	0	0	1
Holocentrus adscensionis	0	1	0	0	1
Scomberomorus regalis	1	0	0	0	1
Sphyraena barracuda	1	0	0	0	1
Urolophus jamaicensis	0	1	0	0	1
Total	1147	788	628	1412	3975

Table 11. Station KB3SB list of species in order of total prevalence.

Scientific Name	PRE	Q1	Q3	Q5	Total
Stegastes partitus	176	187	145	221	729
Thalassoma bifasciatum	98	205	93	179	575
Halichoeres bivittatus	202	48	52	19	321
Coryphopterus glaucofraenum	23	193	37	64	317
Halichoeres garnoti	113	79	40	73	305
Sparisoma aurofrenatum	58	48	21	54	181
Caranx crysos	2	100	0	0	102
Acanthurus bahianus	20	21	38	21	100
Canthigaster rostrata	15	23	22	33	93
Serranus tigrinus	20	21	11	13	65
Acanthurus chirurgus	17	24	10	12	63
Cryptotomus roseus	0	2	0	49	51
Stegastes variabilis	35	3	7	3	48
Chaetodon sedentarius	8	10	11	9	38
Balistes capriscus	5	3	6	17	31
Pomacanthus paru	26	0	1	4	31
Sparisoma atomarium	18	8	0	4	30
Chaetodon capistratus	6	7	6	7	26
Acanthurus coeruleus	4	11	3	7	25
Serranus tabacarius	6	8	2	8	24
Scarus taeniopterus	12	6	0	4	22
Pseudupeneus maculatus	14	0	2	5	21
Chaetodon ocellatus	4	8	4	4	20
Scarus croicensis	11	2	1	6	20
Lachnolaimus maximus	4	4	5	6	19
Epinephelus cruentatus	2	2	4	5	13
Epinephelus morio	2	1	5	4	12
Gnatholepis thompsoni	0	7	2	3	12
Haemulon plumieri	3	5	0	1	9
Ioglossus calliurus	0	5	2	2	9
Stegastes leucostictus	4	4	0	1	9
Anisotremus virginicus	1	1	4	2	8
Holocentrus rufus	1	0	2	4	7
Coryphopterus dicrus	6	0	0	0	6
Sparisoma chrysopterum	6	0	0	0	6
Chaetodon striatus	1	2	0	2	5
Holacanthus tricolor	2	0	0	3	5
Hypoplectrus unicolor	0	3	2	0	5
Serranus baldwini	3	1	0	1	5
Sparisoma viride	1	3	0	1	5
Sphoeroides spengleri	0	2	1	2	5
Aulostomus maculatus	0	1	1	2	4
Caranx ruber	3	0	0	1	4
Coryphopterus personatus	0	0	4	0	4
Bodianus rufus	0	0	2	1	3
Cantherhines macrocerus	0	0	3	0	3
Epinephelus guttatus	2	1	0	0	3
Lactophrys quadricornis	0	0	2	1	3

Table 11 (continued). Station KB3SB list of species in order of total prevalence.

Scientific Name	PRE	Q1	Q3	Q5	Total
Pomacanthus arcuatus	2	0	1	0	3
Priacanthus cruentatus	0	0	2	1	3
Sparisoma rubripinne	0	0	2	1	3
Urolophus jamaicensis	2	0	0	1	3
Cantherhines pullus	0	0	0	2	2
Diodon holocanthus	1	0	0	1	2
Halichoeres maculipinna	0	0	2	0	2
Holacanthus ciliaris	1	0	0	1	2
Holocentrus adscensionis	0	2	0	0	2
Hypoplectrus puella	1	0	0	1	2
Lutjanus analis	0	2	0	0	2
Monacanthus hispidus	0	0	2	0	2
Opistognathus aurifrons	0	2	0	0	2
Scomberomorus regalis	0	0	0	2	2
Aluterus scriptus	0	1	0	0	1
Diodon hystrix	0	0	1	0	1
Echeneis naucrates	0	1	0	0	1
Equetus lanceolatus	0	0	0	1	1
Haemulon carbonarium	0	0	1	0	1
Haemulon melanurum	1	0	0	0	1
Holacanthus bermudensis	0	0	1	0	1
Holocentrus marianus	0	0	1	0	1
Hypoplectrus gemma	0	0	0	1	1
Lactophrys polygonia	0	0	1	0	1
Malacanthus plumieri	0	0	0	1	1
Monacanthus tuckeri	0	0	1	0	1
Priacanthus arenatus	1	0	0	0	1
Scarus coeruleus	0	1	0	0	1
Serranus tortugarum	0	0	0	1	1
Synodus intermedius	0	0	1	0	1
Halichoeres sp.	1	0	0	0	1
Total	944	1068	567	872	3451

Table 12. Station KB3C list of species in order of total prevalence.

Scientific Name	PRE	Q1	Q3	Q5	Total
Stegastes partitus	353	90	190	275	908
Thalassoma bifasciatum	142	95	211	197	645
Coryphopterus glaucofraenum	73	101	46	86	306
Sparisoma aurofrenatum	71	46	37	87	241
Halichoeres bivittatus	117	41	34	23	215
Halichoeres garnoti	41	40	41	75	197
Coryphopterus personatus	4	66	1	40	111
Acanthurus chirurgus	30	15	16	41	102
Canthigaster rostrata	22	27	24	23	96
Acanthurus bahianus	23	10	35	19	87
Scarus croicensis	43	10	2	24	79
Serranus tigrinus	13	11	12	21	57
Sparisoma atomarium	37	1	7	5	50
Cryptotomus roseus	15	0	0	31	46
Acanthurus coeruleus	7	3	10	13	33
Decapterus species	0	0	30	1	31
Gnatholepis thompsoni	2	1	7	21	31
Chaetodon sedentarius	11	6	6	6	29
Stegastes variabilis	16	3	5	4	28
Chaetodon capistratus	7	4	7	1	19
Chaetodon ocellatus	0	4	8	6	18
Scarus taeniopterus	6	0	2	10	18
Serranus tabacarius	3	10	0	5	18
Sparisoma viride	1	4	12	0	17
Pseudupeneus maculatus	3	2	1	10	16
Chromis cyaneus	5	2	0	2	9
Holacanthus tricolor	3	4	0	2	9
Epinephelus cruentatus	0	2	3	2	7
Hypoplectrus puella	3	0	1	3	7
Halichoeres maculipinna	1	1	2	2	6
Opistognathus aurifrons	0	3	0	3	6
Caranx crysos	0	2	3	0	5
Chaetodon striatus	2	0	1	2	5
Ioglossus calliurus	0	3	0	2	5
Lachnolaimus maximus	0	1	3	1	5
Pomacanthus paru	3	0	2	0	5
Aluterus scriptus	0	0	4	0	4
Balistes capriscus	3	0	0	1	4
Cantherhines pullus	0	1	3	0	4
Haemulon plumieri	2	0	2	0	4
Hypoplectrus unicolor	1	0	2	1	4
Stegastes leucostictus	0	2	2	0	4
Urolophus jamaicensis	2	2	0	0	4
Caranx ruber	0	3	0	0	3
Holacanthus bermudensis	0	2	0	1	3
Sparisoma rubripinne	1	0	0	2	3
Chromis scotti	0	0	0	2	2
Epinephelus morio	0	0	2	0	2

Table 12(continued). Station KB3C list of species in order of total prevalence.

Scientific Name	PRE	Q1	Q3	Q5	Total
Gymnothorax moringa	1	1	0	0	2
Haemulon aurolineatum	2	0	0	0	2
Holacanthus ciliaris	0	1	1	0	2
Hyploplectrus nigricans	2	0	0	0	2
Mycteroperca interstitialis	0	0	2	0	2
Scarus coeruleus	0	0	0	2	2
Sphyraena barracuda	0	0	1	1	2
Anisotremus virginicus	0	1	0	0	1
Apogon binotatus	0	1	0	0	1
Balistes vetula	0	1	0	0	1
Diodon holocanthus	0	0	0	1	1
Epinephelus guttatus	1	0	0	0	1
Haemulon carbonarium	0	0	1	0	1
Haemulon sciurus	1	0	0	0	1
Halichoeres cyanocephalus	0	0	0	1	1
Holocentrus rufus	0	0	0	1	1
Hypoplectrus gemma	0	1	0	0	1
Lactophrys triqueter	0	1	0	0	1
Lutjanus analis	0	0	1	0	1
Monacanthus hispidus	0	0	1	0	1
Myripristis jacobus	1	0	0	0	1
Ocyurus chrysurus	0	1	0	0	1
Pomacanthus arcuatus	0	1	0	0	1
Scarus coelestinus	0	1	0	0	1
Scarus guacamaia	0	1	0	0	1
Scomberomorus regalis	0	0	0	1	1
Total	1074	629	781	1057	3541

8 **APPENDIX D:** Prefabricated reef fish point-count data sheet.

LOCATION:________ **HABITAT:**________ **OSERVER**________

DEPTH:________ **VISIBILTIY:**________ **MODULE #**________

START TIME:________ **STOP TIME:**________ **TOTAL TIME:**________

SPECIES (code)	#	LENGTH (cm) MEAN	MIN	MAX
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				

BOTTOM CONFIGURATION DIAGRAM

N ↑

NATURAL REEF	ART. REEF
_____ % HC	_____ % MODULE
_____ % SC	_____ % BOULDERS
_____ % SP	_____ % SAND/RUBBLE
_____ % AL	100 %
_____ % BARE	
_____ % SAND/RUBBLE	
100 %	

AVG. RELIEF:______**FT**

HABITAT INDEX ______ **(0-4)**

SPECIES (code) AFTER 5 min.

1	12
2	13
3	14
4	15
5	16
6	17
7	18
8	19
9	20
10	21
11	22