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Time Series Observations of Species Composition and Behavioral Interactions of Fish at an Ocean Observatory off the Coast of Georgia

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Abstract

The use of ocean observatories is expanding with the potential for collecting serial data with high temporal resolution at multiple sites within an ecosystem. Integration of underwater video cameras in observatory systems allow observation of vagile species and are useful tools for observing variations in behavior over time. In order to assess the utility of using video records for time series behavioral data I analyzed video records from an observatory site in the South Atlantic Bight (SAB) off the Coast of Georgia collected during the month of November in 2000, 2002 and 2004. Data were used to quantify annual variation in facilitative behaviors of multi-species groups of fishes (i.e., mixed species groups and group foraging behaviors), as well as patterns in species composition and trophic guild membership. Significant changes in the community or in the trophic guild composition over several years. Statistical tests showed that the community and functional roles remained the same over the course of the study based on presence/absence data. However, trophic guild composition showed varied results. Such information will provide insight into complex marine systems, which will help determine management strategies for the resources.

Keywords: Species Interactions, Behavior, Foraging

Introduction

Species interact within communities in multiple ways with positive, neutral or negative outcomes for individuals involved in such interactions as a consequence (i.e., predation, competition, parasitism, mutualism, and commensalism). Much of the focus in the ecological literature has been on predation, competition and parasitic relationships with one or more species experiencing a negative outcome. However, there has been relatively limited attention given to facilitative interactions between species (mutualisms or commensalisms with one or both species experiencing a positive or neutral outcome) and the associated affects on populations and in communities (Bruno et al. 2003). Some interactions are long-term on the order of months to

years. For example, clownfish (subfamily Amphiprioninae) generally live in a host anemone throughout their lifetime (Buston 2004). Other relationships are shorter-term and may change at time scales as small as seconds to minutes while still resulting in facilitated changes in predator avoidance and prey acquisition (e.g., Barber and Auster 2005, Auster et al. 2009). These relationships are common among predators on reefs and in other coastal habitats (ref. Parrish 1993, Sazima et al. 2003, Auster 2005, 2008, Auster et al. 2009).

Many fish species that are small in size and serve as prey for multiple piscivorous fishes occur in large schools to increase their individual chances of survival. However, when groups of predators locate aggregations of prey, their abundance can be greatly reduced. In response to predation pressure, prey aggregations may change location or behavior in an attempt to reduce risk (Auster et al. 2009), although outcomes from such responses are not consistent and multiple studies demonstrate both decreases as well as increases in rates of predation (Sih et al. 1998). Multiple predator species with variable search and attack strategies can facilitate capture of prey and have an additive affect on mortality rates of prey. For example, wading birds (multiple heron species) appear to facilitate predation on prey by smallmouth bass *Micropterus dolomieu* by driving prey to deeper water (Steinmetz et al 2006). Alternatively, multiple predators may interfere or cause shifts in prey distributions that reduce predation rates (Crowder et al. 1997, Safina 1990). If the predator-prey interactions of fishes are commonly mediated by the behavior of co-occurring species, such behavior webs may be important in terms of population processes (*e.g.*, prey consumption and growth rates) of multiple species (Lukoscheck and McCormick 2002, Bruno et al. 2003).

Our understanding of the ecology of reef fish communities has benefited greatly from the ability of scientists to make direct observations underwater. While direct data collection by divers is common, time underwater is limited by depth and the physiological constraints of breathing gases on human observers. Most studies of reef fishes in deep water are generally on the scale of days to weeks. Even decadal scale time series studies in shallow water (< 20 m depth) are based on data sets produced from collections of short forays onto the reef. Video recording is a powerful tool for collection of data on the distribution and abundance of fishes as well as their associated behaviors. Video records can be reviewed by multiple observers (i.e., to validate species identifications and counts) and repeated at multiple speeds to dissect elements of behavior. Imagery can be collected throughout the daylight period and with specialized lighting it is possible to obtain video records throughout the diel cycle. Video has been used extensively by divers and on mobile underwater vehicles (i.e., occupied submersibles, remotely operated vehicles) for what are essentially snapshots of species composition, abundance, patterns of habitat use and other ecological metrics. However, long time series imagery from single sites (i.e., from underwater observatories) is relatively rare despite the lack of understanding of variation in species composition, patterns of habitat use, and species interactions that occur at particular sites on the scale of days to weeks. For example, Smith and Tyler (1973) conducted one such study using a closed-circuit television at 17 m depth off Bimini in the Bahamas. The authors studied patterns of diversity and the functional role of species within a community of reef fishes and used long time period observations to define an assemblage of fishes that were transient through the study site but were functionally important higher trophic level predators. Few studies have examined such variation at short but ecologically relevant time scales over long temporal periods.

SCUBA divers, ROVs and underwater video systems help observe species interactions and behavior in marine ecosystems. Studies conducted using SCUBA diving techniques are generally short-term observations of a community. The studies have the potential to be spatially variable; however, environmental and monetary restrictions may prevent adequate sampling, which may prove temporally restrictive. In addition, there are problems associated with diving activities, which includes the affect of human interference on observations and time constraints. ROVs have similar problem, since humans control the equipment. These machines are expensive and require regular maintenance. Thus, underwater video systems are a useful observational tool. These systems provide a temporally sufficient sampling method that, combined with the other methods, presents a more comprehensive view of ecosystems.

Here I conducted an analysis of video records collected over multiple years at a seafloor observatory in the South Atlantic Bight off the coast of Georgia. My objective was to determine variation in patterns of species composition and group foraging of a subtropical reef fish assemblage. A related objective was to develop a set of approaches for quantifying behavioral attributes of foraging from time series video at fixed emplacements.

Methods

Video imagery was collected in a systematic manner at a site 72 km off the coast of Georgia in 25 m depth as a component of the South Atlantic Bight Synoptic Offshore Observational Network (SABSOON). Barans et al (2005) provides a full description of the camera system, installation on the seafloor, and data handling. Briefly, six wide angle video cameras were mounted in a circular arrangement and emplaced at the center of a 15 m diameter circle of artificial reef structures in a no-fishing area. The reef structures served as a proxy for natural reef structures found throughout the region but could be manipulated for testing the

efficacy of video as a tool for observatory systems. Each camera had two reef structures in the view field. Samples were recorded sequentially for 10 s once an hour between the hours of 12:00 and 22:00 GMT. The cameras had 460 line resolution which is relatively low but allowed for rapid digitization of files at the site and transmission of files to an onshore station via microwave link. Each file contained the camera number, date, time and a ten second monochrome video clip.

In order to assess the utility of time series video for studies of behavioral facilitation in fish communities, we made the *a priori* choice to analyze video records from November 2000, 2002 and 2004. The month of November for each year contained the most continuous sequential files (i.e., versus breaks in the record due to file corruption) as well as had the greatest continuous period of good horizontal visibility underwater. Topaz Movement software (Version 3.5; Topaz Labs LLC, Dallas, Texas) was used to view video clips, sharpen images for identification purposes, count individuals and classify behavior. For each file we recorded species composition (SC) based on taxon and abundance as well as those species exhibiting two classes of behavior: multi-species associations (MSA) defined as species exhibiting coordinated and directed movements in multi-species groups as well as group foraging (GF) defined as those multi-species groups actually exhibiting foraging behavior based on stalking or biting prey. Species exhibiting GF were subsets of species observed in MSA groups.

Species accumulation curves were plotted to ascertain the adequacy of sample size for each sample year based on species composition and the two behavior categories. To determine the relative strength of species co-occurrences in samples, Bray-Curtis similarity coefficients were computed for all species pairs observed per sample based on a presence-absence matrix. (Presence-absence versus species-abundance data were used due to the extreme dominance of

several species of small sized schooling species.) Results of a hierarchical clustering procedure based on the Bray-Curtis matrix were used to illustrate the variation in strength of these relationships (Clarke & Gorley, 2001). That is, analyses calculated the probability of the species occurring together in the samples (i.e. SC), and based on the probability of the species engaging in the same behavior together (i.e. MSA and GF). I used species linkages at 40-100% levels to indicate strong relationships and 39-0% to indicate a moderate level of species interactions (note that multi-species associations were required to be in these behavior categories). Community changes for SC, MSA and GF were determined using the ANOSIM test for similarity between years. Tests of guild proportionality using Chi-square tests of homogeneity of distribution on both presence-absence and species abundance data were used to compare trophic composition in overall community structure with MSA and GF species over time. Each species was classified as one of six trophic groups; browsers, herbivores, microinvertivores, macroinvertivores, piscivores, and planktivores based on assignments in Bohnsack et al. (2002) and Auster et al. (2005). Abundance data were transformed using the square root standardization procedure to reduce the influence of the dominant species.

Results

The scientific and common names of the 49 species observed in our samples, as well as abbreviation codes used in our analyses, are listed in Table 1. Note that it was not possible to positively identify some individuals to the level of species, thus genus or other descriptor was used to insure all individuals observed were accounted for in the data set.

Sampling effort varied across years and behavior categories with associated variation in observed species richness (Table 2). All samples collected during the month of November each year are listed but the total number of viewable files is indicated under the SC category. A

variable but low percentage of files were corrupted during the digitization and transmission phases of data acquisition. The year 2000 had the lowest effort.

Table 1: List of all taxa observed in all video samples by scientific name, common name and an abbreviation as used in analyses.

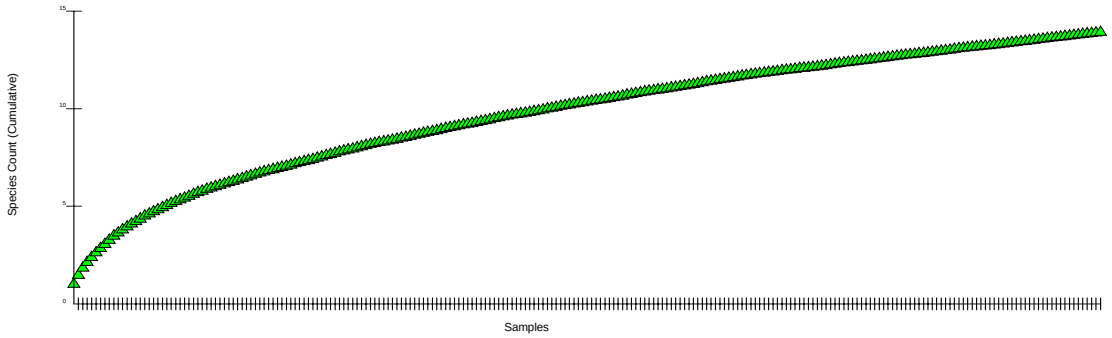
Scientific Name	Common Name	Abbr.	Scientific Name	Common Name	Abbr.
Alueterus schoepfi	Orange filefish	Alsch	*Holocanthus bremudenis*	Blue angelfish	Holbr
Anchoa sp.	Anchovy	Anchoa	*Lutjanus griseus*	Grey snapper	Lutgr
Apogon pseudomaculatus	Two-spot candinalfish	Apopse	*Lutjanus sp.*	Unidentified snapper	Lut
Archosargus probactocephalus	Sheepsheead	Arpro	*Mola mola*	Ocean sunfish	Mola mola
Balistes capriscus	Grey triggerfish	Balcap	*Mugilidae sp.*	Mullet	Mugil
Caranx crysos	Blue runner	Carcry	*Mycteropercta microlepus*	Gag grouper	Mycmic
Caranx ruber	Bar jack	Carru	*Mycteroperca phenax*	Scamp	Mycph
Caranx sp.	Unidentified jack	Cara	*Pagrus sp.*	Porgy	Pargus
Carcharinus limbatus	Blacktip shark	Carli	*Paralichthys sp.*	Flounder	Paral
Canthidermis sufflamen	Ocean triggerfish	Cansu	*Pareques umbrosus*	Cubbyu	Parum
Carcharinus taurus	Sandbar shark	Cart	*Pomacentrus sp.*	Damselfish	Pom
Caretta caretta	Loggerhead sea turtle	Carcar	*Rachycentron canadum*	Cobia	Racan
Centropristis striata	Black seabass	Censt	*Remora remora*	Remora	Remrem
Chaetodipterus faber	Atlantic spadefish	Chafa	*Scombridae ap.*	Mackeral	Scomb
Chaetodon ocellatus	Spotfin butterflyfish	Chaoc	*Selar crumenopthalmus*	Bigeye scad	Secru
Chloroscombrus chrysurus	Atlantic bumper	Chlchr	*Seriola dumerili*	Greater amberjack	Serdu
Cnidaria	Jelly	Cnid	*Seriola rivoliana*	Almaco jack	Seriv
Dasyatis sp.	Stingray	Dasy	*Sphyraena barracuda*	Great barracuda	Sphbar
Decapterus sp.	Scad	Deca	*Stegastes leucostictus*	Beaugregory	Stleu
Echeneis sp.	Shark sucker	Ech	*Stronglyura marina*	Atlantic needlefish	Stmar
Epinephelus sp.	Rock hind	Epine		Larvae	Larvae
Euthynnus alletteratus	Little tunny	Eual		Misc small finfish	Schooling
Giglymystoma cirratum	Nurse shark	Gigcir		Unidentified finfish	Unid fin
Haemulon aurolineatum	Tomtate	Haeauro		Unidentified shark	Unid shark
Halichoeres bivittatus	Slippery dick	Halbi			

Table 2: Summary of sample effort and files attributed to behavior categories for each year. The category of "All samples" indicates total effort but includes files that were corrupted during the acquisition process.

Year	Data Type	No. Video Samples	Total Species
2000	All samples	205	
	SC	196	15
	MSA	12	7
	GF	5	5
2002	All samples	1767	
	SC	1730	49
	MSA	484	29
	GF	191	22
2004	All samples	1087	
	SC	1059	39
	MSA	307	26
	GF	128	18

Species richness and the shape of species accumulation curves varied as a function of sample size between years and behavior category (Figs. 1-3). A clear asymptote for species richness was reached for all samples (those used for assessing species composition) in each of the years 2002 and 2004 while the curve retained a relatively steep slope in 2000 (n = 196, 1730 and 1059 in each successive year respectively). The same pattern emerged for taxa in multi-species associations (Fig. 2). These patterns are likely due to inadequate sample size in 2000. However, steep sloped curves resulted across all years when only those species observed exhibiting group foraging behaviors were included (Fig. 3).

a.



b.

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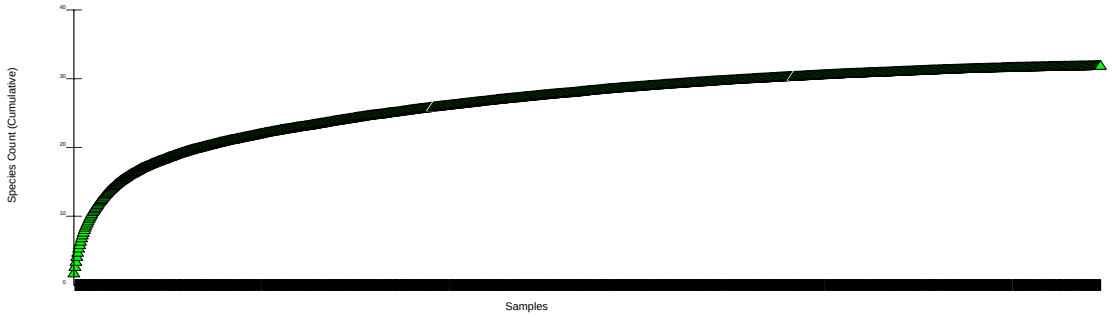
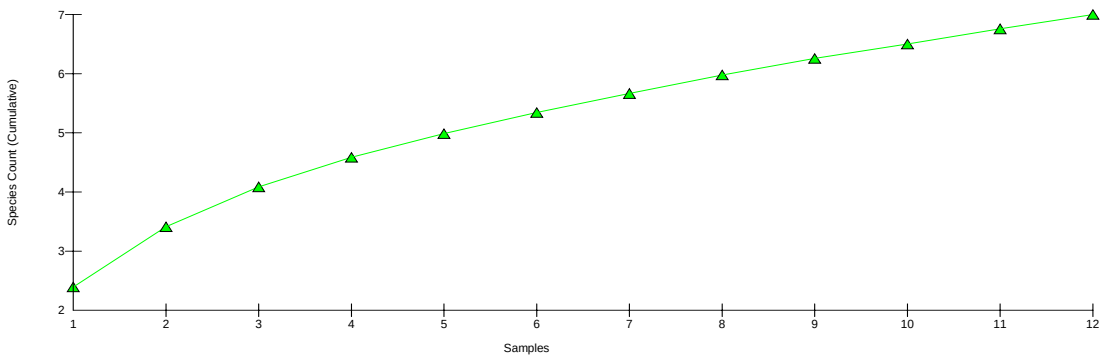
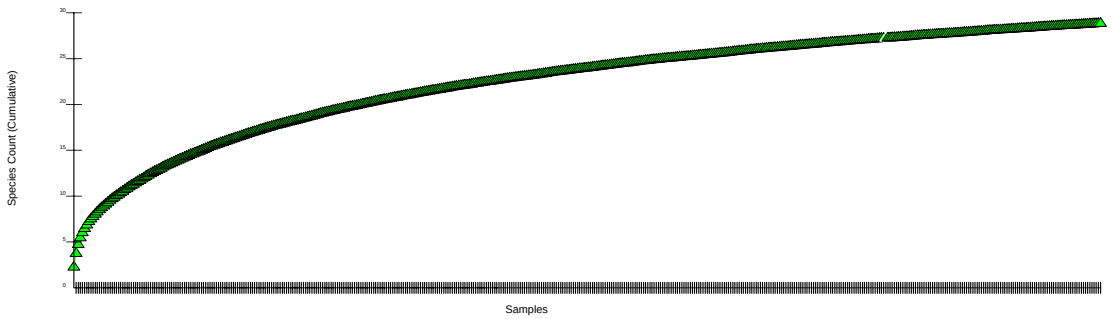


Figure 1: Species accumulation curves based on species presence-absence data for 2000 (a), 2002 (b) and 2004 (c). The datasets contained 196, 1730 and 1059 samples respectively. The number of samples is on the x-axis, and the number of species is on the y-axis.

a.



b.



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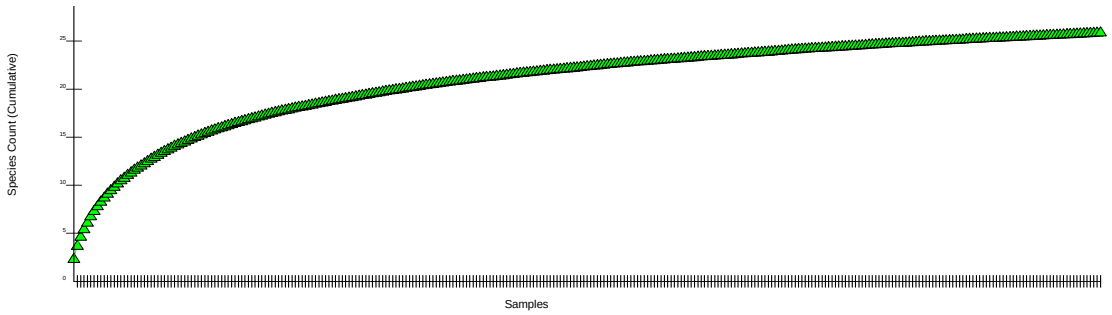
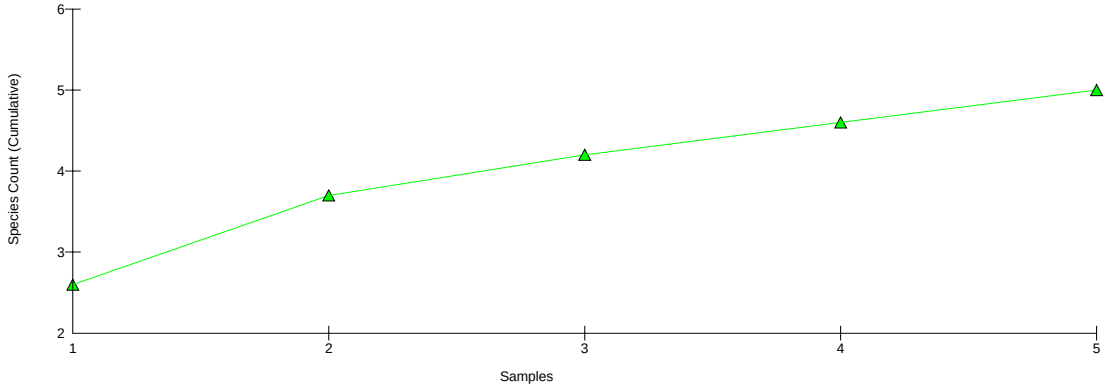
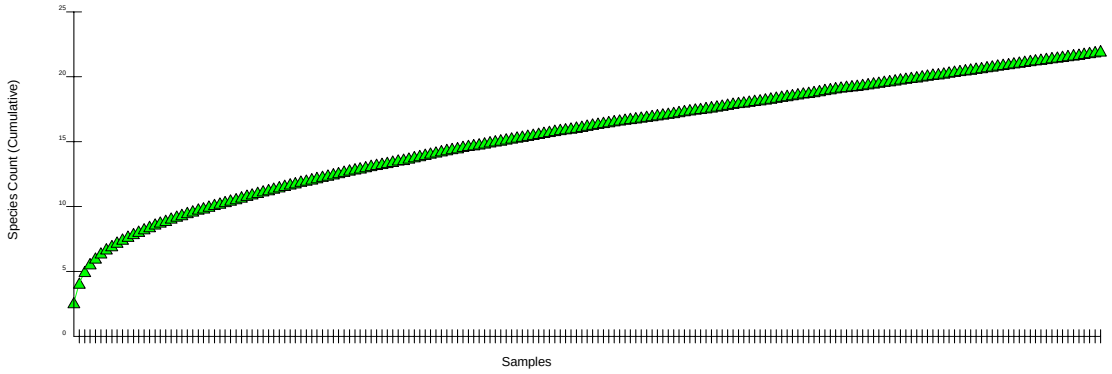


Figure 2: Species accumulation curves for multi-species associations based on species presence-absence in 2000 (a), 2002 (b) and 2004 (c). The datasets contained 12, 484 and 307 samples respectively. The number of samples is on the x-axis, and the number of species is on the y-axis.

a.



b.



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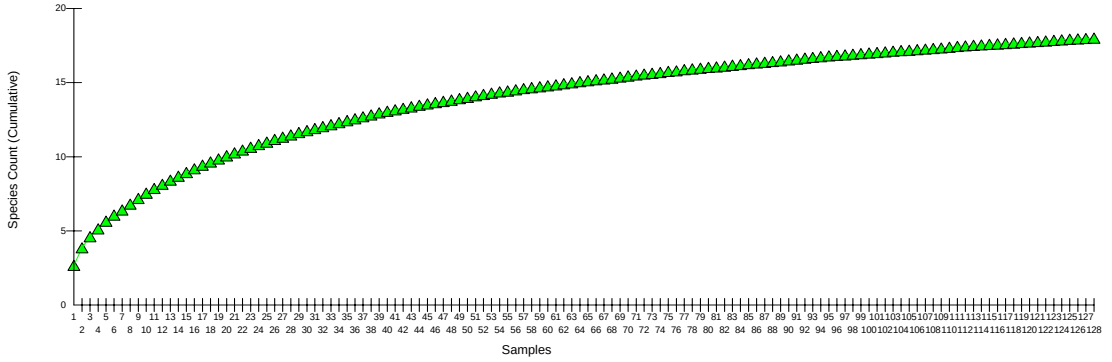


Figure 3: Species accumulation curves for group foragers based on species presence-absence in 2000 (a), 2002 (b) and 2004 (c). The datasets contained 5, 191 and 128 samples respectively. The number of samples is on the x-axis, and the number of species is on the y-axis.

We classified species in samples into six trophic groups (i.e., browsers, herbivores, microinvertivores, macroinvertivores, piscivores, and planktivores) in order to compare and contrast trophic composition between years and behavior categories. Based on abundance data, planktivores dominated all years and behaviors, which comprised over 95% of the total individuals observed (Fig. 4). Further, even using species richness data only, planktivores dominated overall SC for all three years (Fig. 5a). However, the year 2000 had a noticeably different guild structure than found in years 2002 and 2004. MSA (Fig. 5b) and GF (Fig. 5c) bouts were dominated by planktivores in 2000 but piscivores in 2002 and 2004.

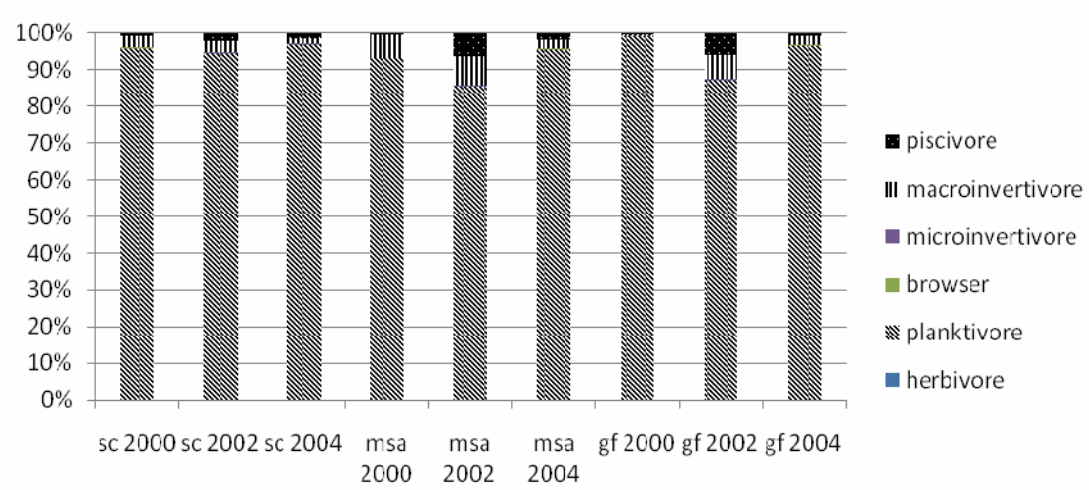
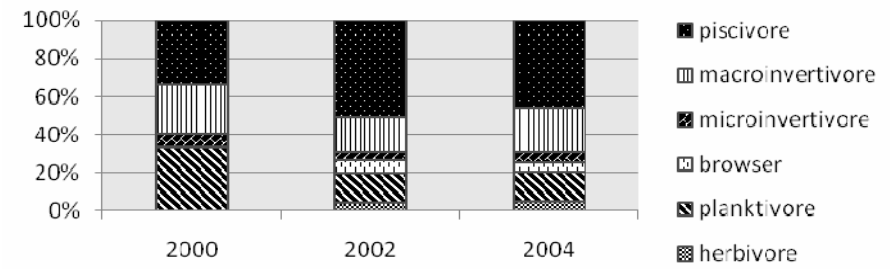
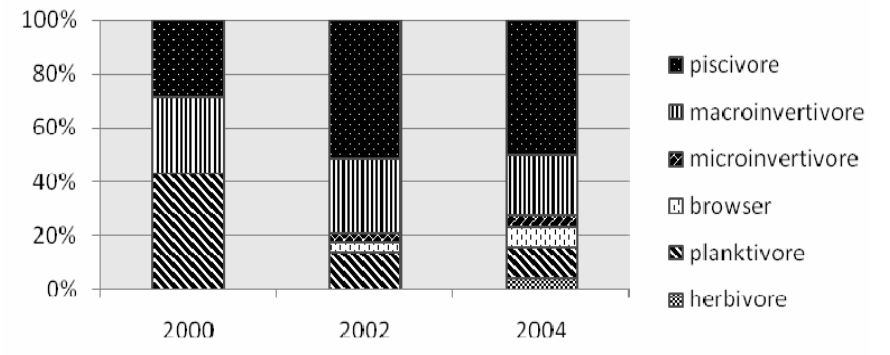


Figure 4: Trophic guild composition across years for community composition and each behavior category based on species abundance data. Values are a percentage of the total number of individuals in each category of each year.

a



b



C

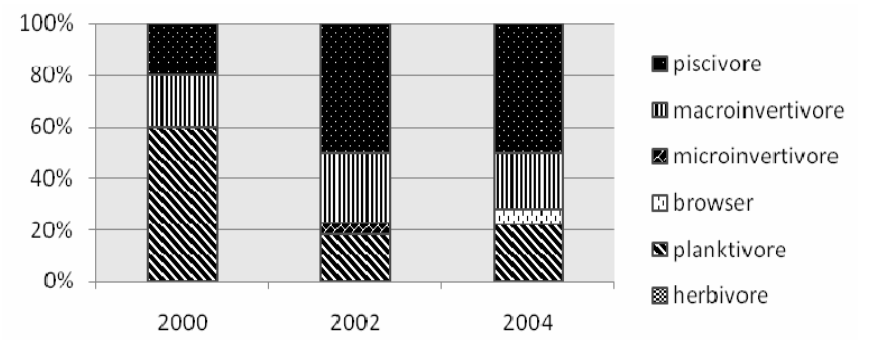


Figure 5: Trophic guild composition across years as a percentage of species in each year (from presence-absencedata) for (a) community composition, (b) multi-species associations and (c) group foragers.

The relationships between species varied between years and behaviors; however, many of the same species engaged in consistent strong relationships. In the time frame of the study, several strong relationships between species were apparent. For example, tomtate were generally strongly associated with other schooling fishes (i.e., those classified as unidentified finfish and

schooling fish) each year (Fig.6). Gag grouper and scamp were strongly associated in 2002 (Fig. 6b) and 2004 (Fig. 6c), but were observed with different associated species each year. While it is clear that the strengths and some relationships vary, there are consistent patterns of associations between species.

The multi-species associations showed similar patterns of strong associations between the small schooling prey fish like anchovy, scad and small unidentified schooling fish each year (Fig. 7). In 2000, this was the only strong association (Fig. 7a). Yet in 2002 and 2004, these species were commonly observed with a range of other taxa (Fig. 7b and 7c). Blue runner and greater amberjack were strongly associated in 2002 and 2004, but not in 2000 (Fig. 7). There were some relationships that occurred in one year but did not occur in other years. For example, gag grouper and scamp exhibited a strong relationship in 2002, but did not strongly associate with any other species in 2004, and did not occur in 2000 (Fig. 7).

Scad, small unidentified schooling fish and anchovy were strongly associated in foraging bouts in 2000 (Fig. 8a). Anchovy and scad were linked at about the 90% level in 2000, 55% in 2002, and 80% in 2004 (Fig. 8). Small unidentified schooling fish were linked at the 60% level with the other two species in 2000, at the 20% level in 2002, and at 60% in 2004 (Fig. 8). Yet the species foraged with tomtate in 2002 and 2004, and bigeye scad in 2002 (Fig. 8). Few species foraged in the same groups, except for the small schooling prey species.

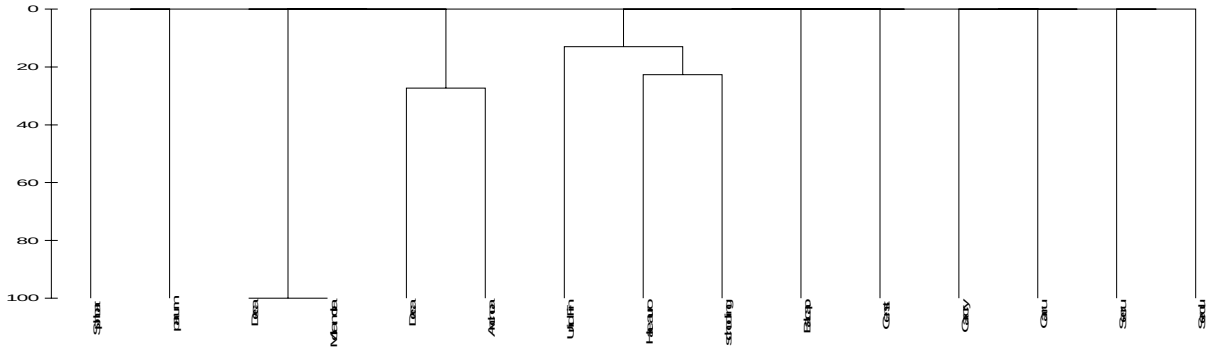
We found five reoccurring associations with over 40% strength: anchovy, scad, and small unidentified schooling fish; blacktip shark and remora; small unidentified schooling fish, tomtate and scad; greater amberjack and blue runner; and unid finfish and damselfish. For relationships less than the 40% level, we observed two reoccurring relationships: gag grouper and scamp; and bigeye scad with anchovy, tomtate, small unidentified schooling fish and scad. Overall, there

were 36 species from a total of 49 species observed in this study that had quantitatively demonstrable strong relationships. Of these, 34 engaged in multi-species associations. Table 3 provides a summary of the species found in strong (>40%) and moderate strength (<40%) relationships with other species.

Table 3: Summary of the variable strengths of species relationships in multi-species relationships. Species were classified based on the range of similarity values in hierarchical clustering. The data were broken down into greater than 40%, greater than 20% and less than 20% strengths. Species highlighted in yellow were observed in strong (>40%) and moderate (>20 and <20%) relationships. Species in orange were found in >40% and >20%. Species in red engaged in >40% relationships and <20% relationships. Species in purple engaged in <40% relationships. Species in white were only found in a strong relationship in one of the levels.

<20%	>20%	>40%
Atlantic spadefish	anchovy	anchovy
bar jack	Atlantic needlefish	blacktip shark
blue anglefish	bigeye scad	blue runner
cubbyu	black seabass	damselfish
gag grouper	blue anglefish	greater amberjack
great barracuda	blue runner	little tunny
greater amberjack	cubbyu	remora
grey triggerfish	gag grouper	scad
little tunny	great barracuda	tomtate
nurse shark	greater amberjack	unidentified finfish
ocean triggerfish	grey triggerfish	unidentified shark
orange filefish	jelly	unidentified small schooling fish
porgy	porgy	
sandbar shark	rock hind	
scamp	sandbar shark	
sheepshead	scad	
tomtate	scamp	
unidentified jack	stingray	
unidentified shark	tomtate	
unidentified snapper	unidentified finfish	
	unidentified small schooling fish	
	unidentified snapper	

a



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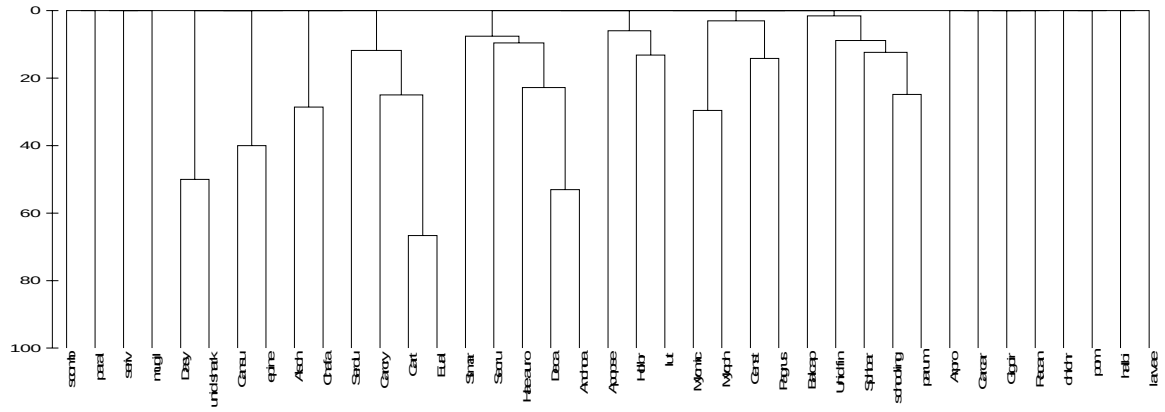

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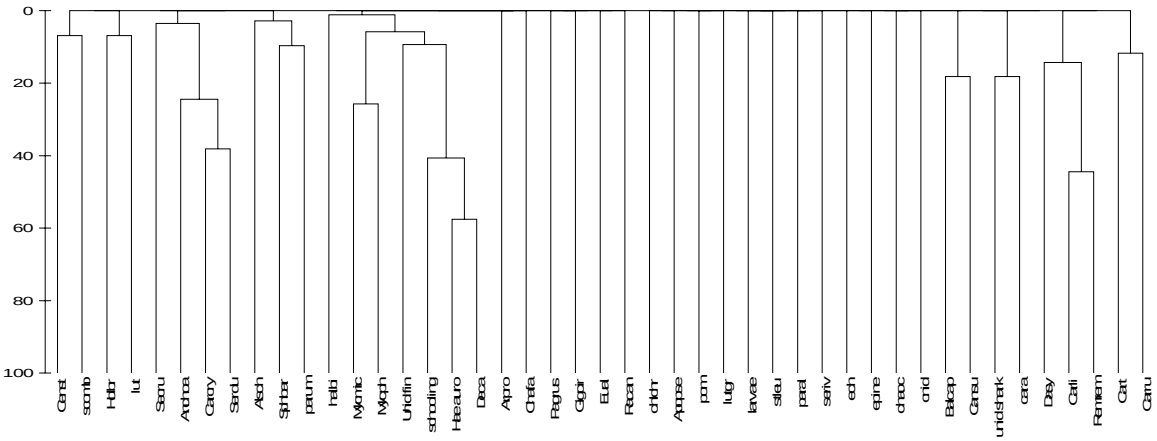
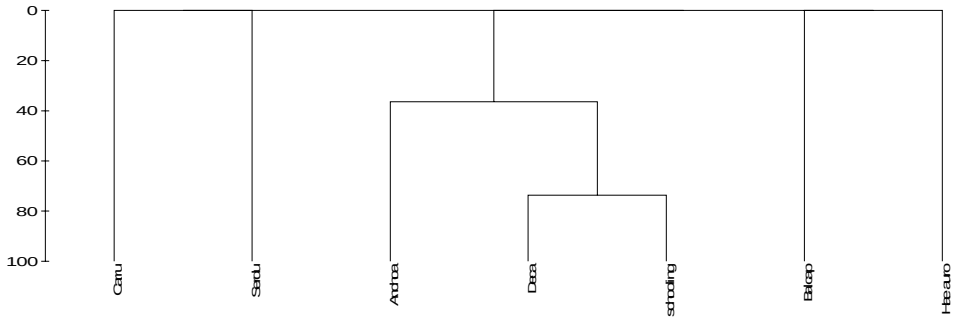


Figure 6: Strong relationships or high probabilities of the species occurring together in the same sample have values closer to 100. Weak relationships are close to zero. These are derived from presence/absence of species in the community from 2000 (a) 2002 (b) and 2004 (c).

a



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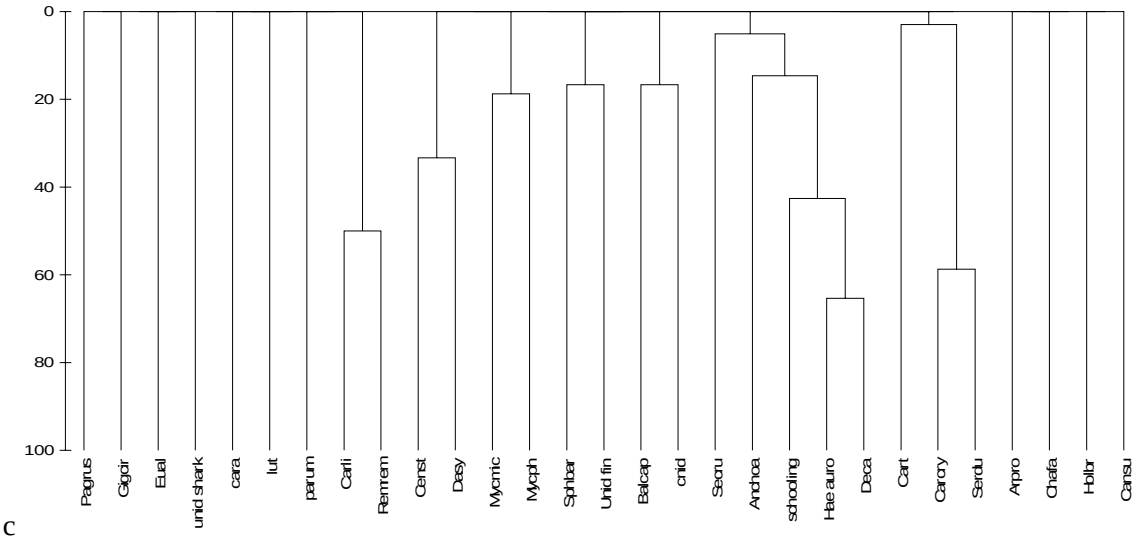


c

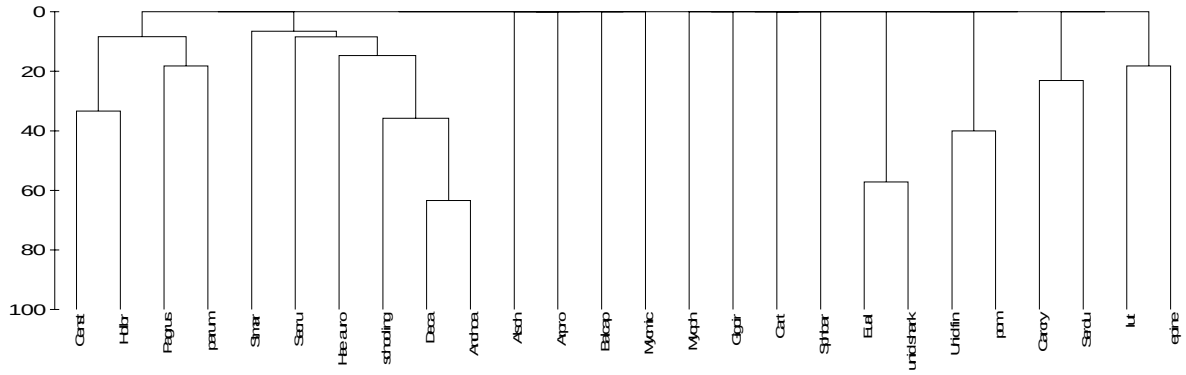
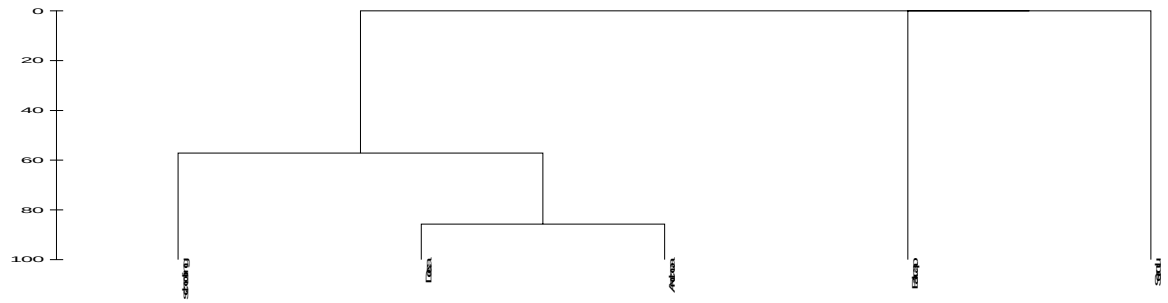
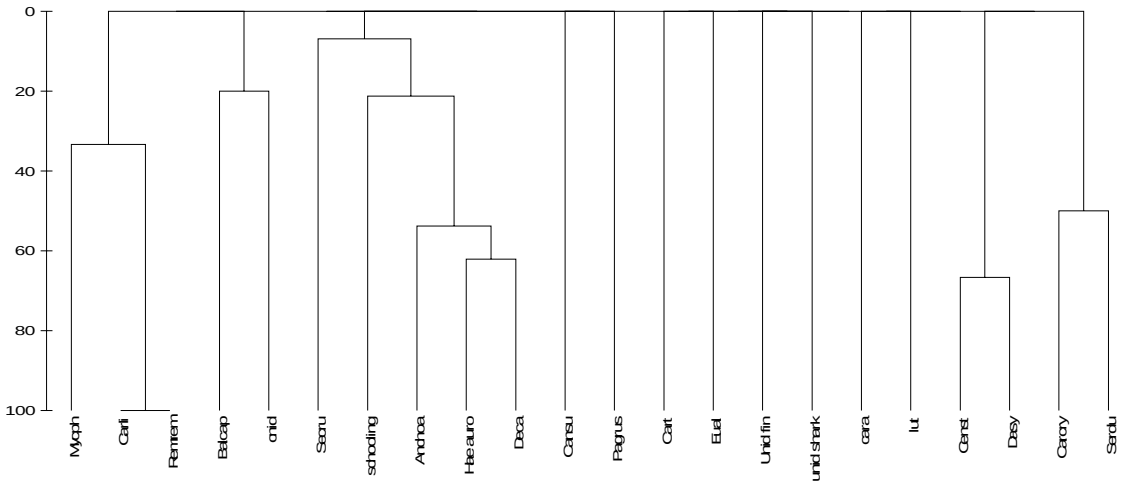


Figure 7: Strong relationships or high probabilities of the species associating together in a sample have values closer to 100. Weak relationships are close to zero. These are derived from presence/absence of multi-species associations in the community from 2000 (a) 2002 (b) and 2004 (c).

a



b



c

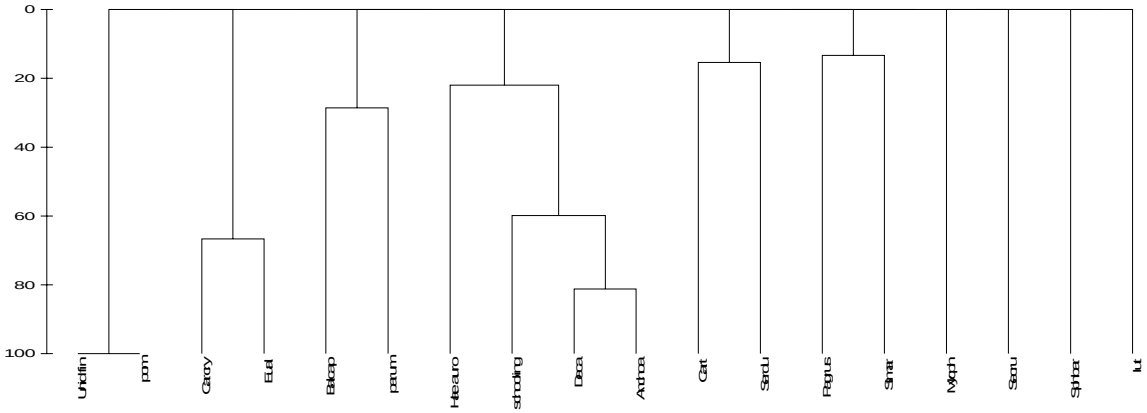


Figure 8: Strong relationships or high probabilities of the species foraging together in the same sample have values closer to 100. Weak relationships are close to zero. These are derived from presence/absence of group foragers in the community from 2000 (a) 2002 (b) and 2004 (c).

Table 4 summarizes the chi square results for guild proportionality, which produced mixed results. We used the 95% confidence interval to determine significance for all analyses. The comparison between years based on species richness data resulted in significant p-values (i.e. values less than 0.05). The same comparison based on abundance data produced significant p-values for MSA and GF only (i.e. the p-value was greater than 0.05). The analysis of species richness data and abundance data produced significant p-values in 2000 and insignificant p-values in 2002 and 2004 for both datasets.

Table 4: The p-values resulting from the chi square test for guild proportionality. P-values less than 0.005 are considered significant based on the 95% confidence level and are denoted by *. The comparisons between years for MSA and GF were significant for both species richness and abundance data. SC was only significant in species richness data. The comparison between SC, MSA and GF in 2000 for both species richness and abundance data were significant. Yet in 2002 and 2004, these comparisons were not significant.

Test of Guild Proportionality			
Species Richness Data		**Abundance Data**	
Category	P-Value	Category	P-Value
SC	0.007*	SC	0.387
MSA	<0.001*	MSA	0.009*
GF	<0.001*	GF	<0.001*
2000	0.005*	2000	0.014*
2002	0.914	2002	0.297
2004	0.165	2004	VA

I used ANOSIM to test for significant changes in community structure and the functional roles of the community between years. R values were not significant for SC, MSA, and GF. Despite the lack of significance in the results of ANOSIM analyses, I calculated the average dissimilarity between classes using SIMPER for illustrative purposes (Table 5).

Table 5. The resulting values from tests for significant changes in the community structure and the functional roles of the community between years. There was no significant change of the species in the community, in MSAs or in GF bouts over the course of the observations.

Years compared for SC	Average Dissimilarity	ANOSIM R-value
2000 and 2002	23.51	NS
2002 and 2004	23.12	NS
2004 and 2000	24.69	NS
Years compared for MSA	Average Dissimilarity	ANOSIM R-value
2000 and 2002	61.95	NS
2002 and 2004	60.41	NS
2004 and 2000	56.70	NS
Years compared for GF	Average Dissimilarity	ANOSIM R-value
2000 and 2002	58.84	NS
2002 and 2004	57.29	NS
2004 and 2000	47.65	NS

Discussion

Overall my results demonstrate that there are consistent patterns in species composition, multi-species associations, and group foraging associations over the time period of observations and suggest such patterns are conservative properties of the local reef fish community. However, differences in trophic composition between years suggest that functional roles within the local community can change over time. Further, I have shown that time series video adequately sampled the local community on the scale of days to weeks, within the constraints of video resolution, and recorded rare events evidenced by the limited number of direct foraging behaviors in comparison to sample size. Video observations revealed a total of 49 taxa in the local community with 43 identifiable to genus or species level. All species were found in previous studies in the region are considered reef dominants, with few small benthic and cryptic species observed (e.g., Sedberry and Van Dolah 1984, Barans et al. 2005). I suspect that the difference in sample size between years could have an effect on the outcome of the analyses, although general patterns will certainly emerge, as differences in sample size are known to confound patterns of species richness and composition. The most extreme example is found in

the two behavior categories in the 2000 data set that contained less than 15 samples each. The linear pattern in the species accumulation curve clearly indicate that these low numbers do not sufficiently represent the diversity of interacting species and the interpretation of statistical comparisons based on those data should be viewed accordingly. The species accumulation curves for each year indicate that that the fish community was sampled sufficiently to represent patterns of species composition and abundance. There were also sufficient samples to describe multi-species associations and group foraging from 2002 and 2004. However, an increased sampling rate (i.e., more samples per hour) or longer sampling period (i.e., > 10 s) would increase the probability of capturing group foraging bouts on video. It is important to note that planktivores accounted for approximately 95% of the total individuals observed. This is due to the large schools and aggregations of juvenile stages of fish species (i.e., tomtate) and mid-water species that attain relatively small size at maturity (i.e., scads and anchovies). The dominance of these few species would have masked the patterns I wanted to discern in the analyses so we made the *a priori* decision to use presence/absence data rather than abundance in our multivariate analyses

As a way to differentiate the strength of behavioral relationships between species (both MSR and GF classes), I identified strong relationships as those with a level of similarity between 100 and 40% and moderate relationships were between 39 and 0%. There was an association between scamp and gag grouper at about the 25% level that was observed from multi-species associations in 2002. Blue runner and greater amberjack had 40% strength in SC from 2002 (Fig. 6b), 10% strength in SC from 2004 (Fig. 6c), 60% strength in MSA from 2002 (Fig. 7b), 20% strength in MSA from 2004 (Fig. 7c), and about 50% strength in GF from 2002 (Fig. 8b). Auster et al (2009) found 5% strength between these two species in the same region. These

examples of strong associations were also found in a study by Auster et al (2009) in the same region, which suggest that the relationships are conservative properties of the local community, and that the relationships are long lasting since they occurred over the course of this study and in the study from 2008.

There are two main classifications for multi-species associations (Lukoscheck and McCormick, 2002). Shoaling associations include large schools of small fish, typically herbivores, which contain a nuclear or focal species that other fish join. Many species exhibit this type of behavior for avoiding predation and finding food. Attendant associations typically involve fewer individuals where few individuals of one species use the behavior of another species to facilitate obtaining prey. This classification is subdivided into four groups. Following and scavenging species obtain food from the scraps of the nuclear species. Hunting by riding occurs frequently between remoras and sharks. This is when one species attaches hitches a ride with another species to locate food. A few individuals of a species form a school with a few individuals from another species in inter-specific joint hunting associations. For example, Auster (2008) showed shark mackerel joining a school of bigeye trevally to approach and capture prey. The final association, aggressive mimicry, occurs when the predator blends in to the surrounding environment and appears harmless until the timing is right to attack its prey.

Species aggregate in large groups for feeding and mating purposes, which increase their vulnerability to predators and commercial fishing operations, especially in a habitual location. Some species are part of the same trophic guild, which may benefit one or more species associating together. For example, this may be the underlying reason for the observed strong relationships between scad, anchovy and small unidentified schooling fish. This is an example of a shoaling association. Residing in larger groups tends to reduce the individual probability of

being eaten; however, it does not completely remove the threat associated with predators. Thus, observing greater amberjack and anchovy in mixed species groups indicates that all MSAs are not necessarily facilitative in nature.

Blue runner association with greater amber jack could be an example of either inter-specific joint hunting or following and scavenging associations (Lukoscheck and McCormick 2002). Often, blue runner associated with greater amber jacks and engaged in foraging behaviors together. It was difficult to determine which species was leading and which was following, which suggests that the association may be inter-specific joint hunting. However, the relationship could also be following and scavenging, depending on which species is the nuclear species. Blacktip shark frequently associated with remora, which could be another example of inter-specific joint hunting, depending on the location of the remora relative to the shark. If the remora was attached to the shark, which was not common in this study, the association would have been hunting by riding. However, inter-specific joint hunting is a more likely description of this association.

In the GF dendogram from 2002, the blacktip shark and remora appear to have 100% strength to their relationship. This suggests that every time one species was foraging the other species participated as well. We will not draw any conclusions about this association because the species were observed infrequently. The species were observed and foraged only a couple times, which happened together. Thus, it is difficult to determine if the association is significant or a coincidence. Species at 0% did not necessarily have zero accounts of associating or foraging with the other species. This value merely shows that the species did not associate or forage with any particular species relative to the other species observed.

A change in community structure could have cascading effects on other species, in part mediated by changes in facilitative interactions. Changes could be caused by anthropogenic influences as well as natural processes. For example, heavy fishing pressure on piscivorous fishes has resulted in shifts in abundance of other functional groups with deleterious effects across multiple trophic levels (Jackson et al. 2001, Micheli and Halpern 2005, Newman et al. 2006).

The guild proportionality tests indicate there were significant differences in trophic guild composition between years. Different factors could produce such a pattern. Perhaps there were high rates of predation on the small prey species, which would agree with trends observed in trophic guild composition. In SC, MSA, and GF, there was a decrease in planktivores from 2000 to 2002 and an increase in piscivores. Perhaps piscivores were attracted to the area because of high prey species density or diversity. Then, planktivores declined in abundance either due to emigration or high rates of predation. It would be of interesting to dissect patterns between years as there is a clear decline in planktivore abundance.

The test results also indicate that the trophic guilds observed in multi-species associations and the group foraging behaviors represent the trophic composition of the entire community. In other words, members of the diversity of trophic guilds within SC, MSA and GF within each year are proportional. For each year, the sample size of MSA was less than 1/3 of SC yet the MSA species diversity was about half that of SC. Similarly, species diversity of GF included about 1/2 the species as SC in less than 1/5 the samples as SC. Since the chi square tests show that the trophic guilds of the functional groups represent the entire community, we would assume that there would be a relationship between these community classifications.

ANOSIM results support the null hypothesis, which states there is no change in community structure or the functional groups between years. Since the community structure was not significantly different over time, it suggests that sampling effort was sufficient. A problem with observatory designs in general is that there is little opportunity for collecting data as spatial replicates. That is, we collect high resolution data at one site and assume this is representative for a larger region. If the results showed a change in community structure over time, we would have to consider the possibility that the sampling technique does not sufficiently sample the local community, among other possibilities such as the anthropogenic and natural modifications previously mentioned.

Since there was no change in MSA and GF between years, we conclude that the functional role of the community stays the same over the course of observations. In other words, the facilitative interactions are long lasting and are an important component of the community interactions that increase fitness of individuals.

The video camera system proved useful in the observation of species composition, multi-species associations and group foraging behavior. There are advantages and disadvantages that are important to note for considerations of future use. In general, underwater video camera systems are temporally sufficient. The cameras record video clips over a time period that could not be sampled by divers. When considering diving operations, one must consider weather conditions, depth and other factors that limit human exposure to the ocean environment. Financial constraints for ship time and personnel also limit sampling using diving methods. The presence of diver also may have an effect on species behavior.

On the other hand, large video sample sizes require more time to turn images into data. The cost of the system itself and underwater maintenance (i.e. sending divers to clean the lens) is

also time consuming. In addition, the detail in video files is constrained due to limits on file size, as well as variation in visibility. There were several instances where a leaf or a fish would block the view field of the camera. When diving, we could relocate to obtain a better view. At times, visibility would also obstruct the view. Some files contained zero species because of this. The cameras recorded 460 resolution, which is relatively low compared to other systems. This allowed faster files transfer but restricted the ability to accurately identify the species at times. Identification was limited to the fish in the foreground.

Visibility and resolution factors combined raise the suspicion that smaller fish in the background were not observed or censused. At times, we noticed that some species of piscivores (eg. barracuda and triggerfish) were followed by small schooling fish. This was a common observation when the species were close to the camera, but was not apparent when the piscivores occurred in the distance. In addition, the ability to identify species was inhibited by low visibility and low resolution of video. There were over 10 taxa that resulted in identifications above the species level. Perhaps, this problem can be solved by increasing the resolution of the video while increasing computing power for digitization and transmission. Baring such change some additional effort using direct observations over a wider spatial area would supplement and enhance the results here.

Temporally, the SABSOON underwater video camera provided insight on the characteristic composition of the local community. When everything functioned properly, the system recorded over 60 samples daily. However, this particular configuration prevented sufficient observations to address spatial variability. The use of similar underwater video observatories in adjacent areas would also help determine if the behavioral patterns are site specific or if the observed patterns are widely applicable

The South Atlantic Bight spans the region from Cape Hatteras off North Carolina to the Florida Keys. This sub-tropical region supports a diversity of marine species with some of tropical origin while others have centers of distribution in the warm temperate zone to the north. Frequent upwelling events occur due to the Gulf Stream running north along the continental shelf and slope. This current pulls the surface water away from the coast, which bring the nutrient rich bottom water to the surface. The nutrients encourage phytoplankton blooms, which provide food for the local community. However, spatially complex seafloor habitats are limited in distribution and provide important shelter resources for predators and prey. Use of artificial reefs for habitat proxies can provide a standard approach for assessing spatial variability in fish communities across a wide range of oceanographic conditions.

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