INFLUENCES OF THE LOGGERHEAD SPONGE (*SPHECIOSPONGIA VESPARIUM*) AND THE VASE SPONGE (*IRCINIA CAMPANA*) ON NEARSHORE HARD-BOTTOM COMMUNITY DEVELOPMENT IN THE FLORIDA KEYS

by

Scott Donahue
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Approved by:

Mark J. Butler IV (Director)

Daniel M. Dauer (Member)

John R. Holsinger (Member)

ABSTRACT

INFLUENCES OF THE LOGGERHEAD SPONGE (*SPHECIOSPONGIA VESPARIUM*) AND THE VASE SPONGE (*IRCINIA CAMPANA*) ON NEARSHORE HARD-BOTTOM COMMUNITY DEVELOPMENT IN THE FLORIDA KEYS

Scott Donahue
Old Dominion University, 2008
Director: Dr. Mark J. Butler IV

Sponges, octocorals, and stony corals are the dominant sessile fauna within shallow, hard-bottom communities in the Florida Keys, FL (USA). The sponge component of these communities is not well studied and has been cyclically decimated from as early as 1844, most recently in south-central Florida Bay in 1991 and 1992, in apparent association with phytoplankton blooms. The purpose of this research was to examine ways in which sponges may contribute to the maintenance of hard-bottom communities. Specifically, I investigated: 1) the effect of sponges and physical structures on local sea floor scouring and thus the potential for maintenance of hard-bottom; 2) the growth and survival of sponge transplants inside and outside of areas historically susceptible to sponge die offs; and 3) the influence of sponges and physical structures on the recruitment of hard-bottom fauna onto artificial substrates. Sponges induce turbulent flow and increase scouring of the benthos immediately adjacent to them under both high and low-flow conditions. In general, the effect of large sponges on scouring was slightly greater than that of similar sized boulders. Loggerhead sponge and Vase sponge transplants grew better in the region subjected to recent sponge die offs than they did elsewhere, including the sites from which they originated. Settlement patterns of invertebrates around sponges could not be quantified as designed due to experimental failure. However, periodic observations of settlement plates revealed a gradual succession from a monotypic stand of red macroalgae (*Laurencia* sp.) after one year, to a mix of red and green macroalgae, one sponge species (*Chondrilla* sp.), and small corals (probably *Siderastrea radians*) by the third year. Furthermore, known spongivorous macroinvertebrates sheltered under the settlement plates and their presence may have altered hard-bottom community development. The results of this study show that sponges can thrive in areas previously impacted by sponge mass mortalities if they can successfully recolonize those areas. Once an area is colonized, sponges may contribute to the persistence of hard-bottom habitat by enhancing local benthic scouring and thus precluding sedimentation and succession to seagrass.

This thesis is dedicated to my father, Paul Joseph Donahue, Sr., without whom I would never have had the opportunity to realize my full potential. His unwavering support and personal sacrifice for me is inspirational and has never gone unnoticed.

ACKNOWLEDGMENTS

First and foremost, I thank my family for supporting me during my challenges over the last seven years, especially my brother Paul and his family for allowing me to stay in their home while writing portions of this thesis. I am also truly fortunate to have friends that have supported me during my entire graduate student tenure as well; the family of Keith O'Brien has helped me too often to count, and I can not say "thank you" enough to them, and to his father Jack and Palladium Graphics for always having a job to come back to. I would like to thank my fellow graduate students Donald C. Behringer Jr., Tom Dolan, Claire Foust, Jason Goldstein, Kathryn Kauffman, and Jennifer Lear for their assistance in the field. Rod Bertelsen and Bob Glazer (FWRI) provided digital photography equipment, and I am indebted to them for this. To John Hunt, Tom Matthews, Bill Sharp, and the rest of the staff of FWRI for their endearing support throughout my "too many" years of graduate research. I thank the staff of the Keys Marine Lab (KML), Long Key, FL, including former manager Kevin McCarthy, for their suggestions and laboratory support. John Stevely, of Florida Sea Grant, provided useful guidance and sponge species identification for portions of this research. I thank Jeanette Worth who provided affordable housing to graduate students in the Keys! To the many faculty members and graduate students met at KML over the years who entertained my "ramblings," including those from Florida State University, State University of New York at Buffalo, University of South Florida, and University of Texas at Austin. Support for this project was provided by a NOAA Coastal Ocean Program grant to Mark Butler.

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INTRODUCTION

The benthic substrate in the shallow (< 5 m) coastal waters of the Florida Keys, Florida (USA) is best described as a mosaic of hard-bottom, seagrass, and soft sediment (Chiappone and Sullivan 1994). Hard-bottom habitat covers about 30% of this coastal zone (Zieman et al. 1989; Field and Butler 1994; Herrnkind et al. 1997), and hard-bottom communities are typified by the dominance of red algae of the genus *Laurencia*, sponges, octocorals, and stony corals on a low-relief limestone platform (Chiappone and Sullivan 1994; Field and Butler 1994; Butler et al. 1995; Butler et al. 1997; Herrnkind et al. 1997; Behringer and Butler 2006). These areas are host to a myriad of obligate and opportunistic invertebrates of both ecological and economic significance including the stone crab (*Menippe mercenaria*), Caribbean spiny lobster (*Panulirus argus*), and some commercially harvested sponge species (namely: Sheepswool sponge, *Hippospongia lachne*; Yellow sponge *Spongia barbara*; Glove sponge *Spongia cheiris*; Grass sponge *Spongia graminea*).

The sponge taxocene in these hard-bottom communities has been cyclically decimated from as early as 1844, the causes of which are largely unknown (Rathbun 1887; Galtsoff 1940; Storr 1964; Butler et al. 1995; but see Feinstein et al. 1955). The mass sponge die-offs in 1991 and 1992 were preceded by large, persistent blooms of cyanobacteria (Butler et al. 1995) and some scientists suggest it may take longer than a decade for the sponge community to return to pre-bloom conditions (Butler et al. 1995; Stevely et al. 1997). Some factors that are likely to affect the reestablishment of these sponge communities include the return of water quality to a condition suitable to support

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The model journal for this thesis is *Bulletin of Marine Science*.

the sustained growth and survival of post-settlement sponges, the availability of suitable substrate for larval sponge settlement, and the availability of larvae from either local or distant parental stocks. Following local extirpation of a species, or numerous species as in the case of sponges in portions of Florida Bay, habitat quality may also be altered in ways unfavorable for growth or survival of the preexisting flora or fauna. For example, Thrush et al. (1996) demonstrated that the rate of faunal recovery is unusually slow in small disturbed patches of soft sediment sandflats following defaunation and that faunal emigration contributes to this slow rate of recovery. However, the most recent sponge die-off in Florida Bay coincided with large and persistent cyanobacteria blooms, which have not returned. The previously affected hard-bottom areas could presumably now support sponges if new recruits are available. If so, then the growth and survival of sponges in regions of Florida Bay formerly subject to sponge die-offs should be similar to those in unimpacted areas. Surprisingly, there is little information on the growth rates of most of the sponge species found in Florida's hard-bottom areas (but see Moore 1908; Crawshay 1939), including large and ubiquitous species such as the Loggerhead sponge (*Spheciospongia vesparium*) and the Vase sponge (*Ircinia campana*).

The factors that influence the recruitment of sponges in shallow hard-bottom areas are also unknown. Allelopathic chemicals produced by sponges and other marine organisms (e.g., alcyonacean, hermatipic, and ahermatipic corals) can limit recruitment on coral reefs (Jackson and Buss 1975; Green et al. 1990; Huysecom et al. 1990; Maida et al. 1995a, b, and others), where competition for space is high and where allelopathic chemicals offer important competitive advantages. However, in shallow hard-bottom communities “open space” is seemingly abundant, suggesting that competition for space may not be as strong as it is on coral reefs.

Importantly, shallow hard-bottom areas usually have a dynamic veneer of sediment overlying limestone bedrock that can be influenced by hydraulic forces, and these factors (i.e., sediment depth and turbulent fluid flow) can also influence the successful recruitment and survival of invertebrate larvae (Gotelli 1988; Rogers 1990; Chiappone and Sullivan 1994; Crimaldi et al. 2002). In marine systems, turbulent fluid flow affects sediment characteristics by sediment lifting, transport, and deposition. For this paper, I define “scour” to be the removal of sediment from around structures (e.g., large sponges) by turbulent flow. Scour may occur via “sand blasting” caused by suspended sediments within flowing water, or by the “lifting” of sediment caused by sheer stresses generated by the fluid as it flows over the surrounding sediment bed. These same forces act on settling larvae or recently settled recruits, thus the true availability of open space for new sponge recruits may depend not only on open hard-bottom but also on the local scouring regime. Along with habitat suitability, the availability of larvae of course plays a prominent role in determining the local potential for recruitment. Again, little is known about dispersal and population connectivity in sponges, although the short duration of the larvae of shallow water tropical sponges suggests that dispersal should be limited and populations virtually closed.

Sponge propagules can be asexual or sexual in origin. Two modes of sexual reproduction are used as taxonomic indicators for porifera: oviparity defines the subclass Tetractinomorpha, and vivipary defines the subclass Ceractinomorpha, with some exceptions (Fromont 1994). As suggested by Reiswig (1973) and Hoppe (1988), the sexual mode of reproduction in sponges may be indicative of a particular life history strategy: oviparity may be associated with selection for a narrow range of habitats, whereas vivipary may constitute a more generalist approach to habitat selection (e.g., “weedy” sponges). Kaye and Reiswig (1991) also suggested that oviparous demosponges are long lived and gonochoric, whereas viviparous demosponges are shorter lived and hermaphroditic. Irrespective of its mode, sexual reproduction results in the creation of a lecithotrophic, negatively phototaxic larval stage that can either swim for up to 48 hours (Kaye 1990; Witte 1994; Leys and Degnan 2001), or settle close to the parent within minutes (Lindquist & Hay 1996). Fecundity of sponges may also be positively correlated with volume and some tropical marine demosponges may be iteroparous (Kaye 1990; Kaye and Rieswig 1991). With these factors in mind, I hypothesize that sponge recruitment is largely local and thus the abundance and diversity of sponge recruits at a site should be a reflection of the diversity and biomass of adult sponges present on that same site.

The purpose of this study was to: 1) determine if large sponges contribute to hydrodynamic maintenance of sediment depth around them via the localized scouring of adjacent sediments; 2) determine the growth and survival of sponge transplants inside and outside of areas historically susceptible to sponge die-off events to assess the suitability of these sites for sponge regrowth; and 3) determine if there is a relationship between the local diversity and biomass of sponges and their recruits in shallow hard-bottom areas.

MATERIALS AND METHODS

Sponge Effects on Scour: I examined the effect of structure on scour at two high-flow (near tidal channels) and two low-flow sites (embayments) on the bayside of the middle Florida Keys (Fig. 1; Appendix A) in July 1999. At each site, I affixed pre- weighed plaster of paris “clod cards” at standardized distances around each structure. I used the change in mass of the clod card as a surrogate for scour (Dotty 1971; Watson 1976; Thompson and Glenn 1994). I tested four types of structure: two sponge species (the Loggerhead sponge *Spheciospongia vesparium* and the Vase sponge *Ircinia campana*), a limestone boulder of similar size as the sponges, and a “no structure” treatment; two replicates per structure treatment per site. Because of their size, the two species of sponges used in the study are those with the highest likelihood of affecting scour and are the two most abundant large sponges in hard-bottom habitat (Herrnkind et al. 1997). Clod cards were placed at 5 cm, 20 cm, and 40 cm away from each treatment structure, in each of the four cardinal directions (i.e., N, S, E, W) so that 12 clod cards were arranged around each structure (Fig. 2). I also quantified two covariates for each replicate structure: structure size (height, base circumference, and maximum circumference; cm) and initial sediment depth (cm) at each clod card location. Clod cards in the no structure treatment were arranged around a barren area with a 30 cm diameter, which was the mean base circumference of the other structure types. No structure was closer than 2 meters to its nearest neighbor. Clod cards were left in the field for approximately 48 hours, collected, dried, and reweighed to determine percent weight loss, thus yielding a relative estimate of scouring regime. These data were analyzed using a split-plot model I

ANOVA to test for differences in clod card weight loss (i.e., scour) among high and low flow sites (whole plot factor) and structures (subplot factor).

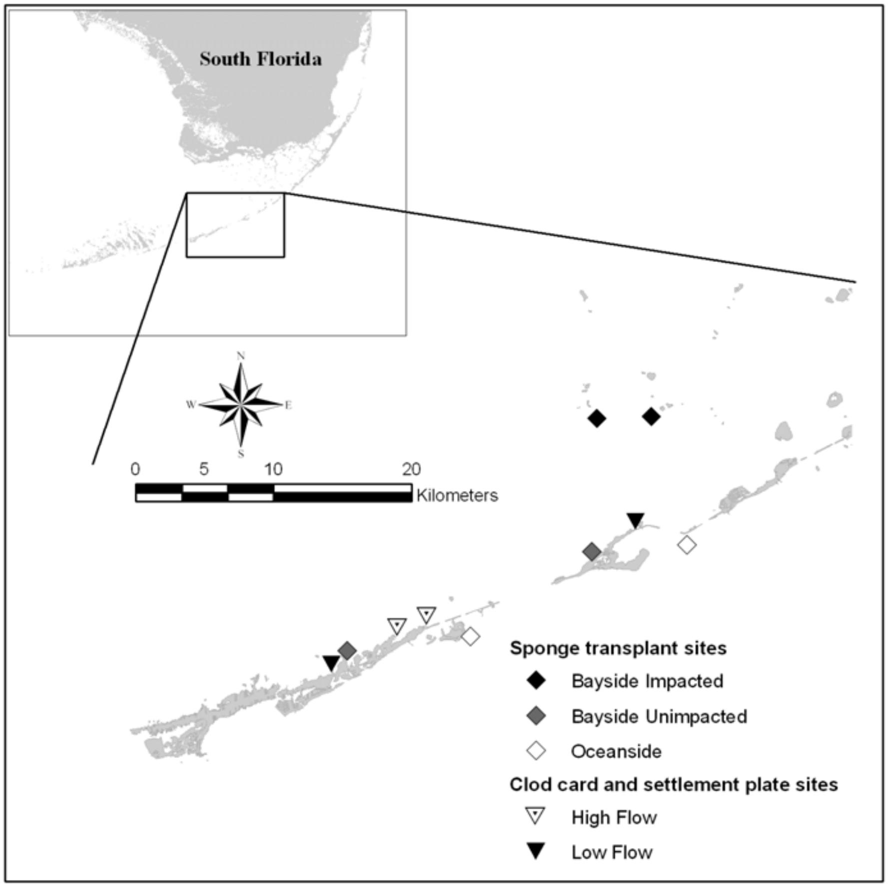


Figure 1. Location of study sites in the Florida Keys, Florida (USA) for different experimental studies.

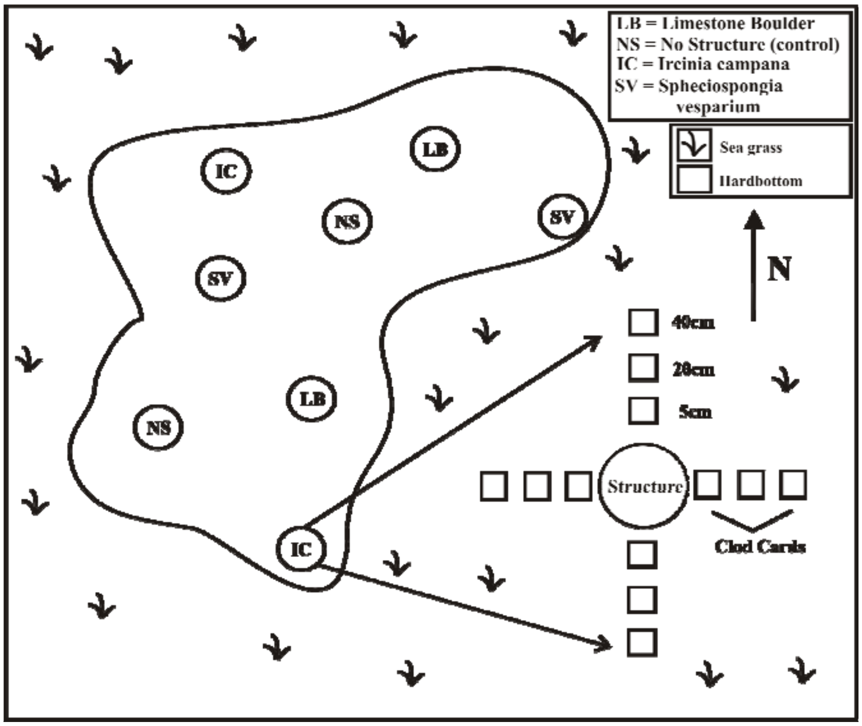


Figure 2. Graphical representation of clod card experimental site, showing the number and types of structure at each site. An array of clod cards was deployed around each structure as is shown in the expanded view. LB, Limestone boulder; NS, No structure; SV, *Spheciospongia vesparium*; IC, *Ircinia campana*

Sponge Growth and Survival: I examined the growth and survival of transplants of three species of sponge (*Spheciospongia vesparium*, *Ircinia campana*, and *Hippospongia lachne*) inside and outside of areas historically susceptible to sponge die off events. The Loggerhead sponge and Vase sponge were chosen because they are the two most numerous and widely distributed large sponges in the near shore hard-bottom areas of the Florida Keys. The third species was chosen because it is a common commercially harvested species for which little growth data existed. To reduce the potential bias in the growth of these sponges due to genotypic differences associated with location, two “donor sites” were chosen to supply the needed sponges for this experiment. The donor sites were similar in sessile community structure and depth (≤ 2 m), but were separated by approximately 19 km.

To begin the experiment, five individual sponges of each species, and from each donor site, were collected and transported to the Keys Marine Laboratory on Long Key, Florida (USA) for processing. Ten equal sized sponge transplants were then made from each donor sponge, yielding genetically identical replicates of each donor individual. Each sponge type was cut into pieces radially, while submerged on flow-through wet tables, then tightly affixed to a cement brick with a cable tie, uniquely tagged, and allowed to heal in a 2000 l flow through mesocosm before transplantation. Cement bricks were used, instead of the common clay brick, because I thought this material best mimicked the native limestone bedrock to which sponges attach. To account for mortality, ten transplants of each individual were made although only six were needed for the experiment (one transplant of each individual per site). For the ball-like sponges (*Spheciospongia vesparium* and *Hippospongia lachne*) I chose donor individuals that were approximately 25cm in diameter to obtain enough tissue for ten equal sized, wedge shaped transplants each greater than 50g wet weight. For the Vase-like sponge, *Ircinia campana*, I chose individuals that would yield ten or more 60 mm x 80 mm transplants; the inside (i.e., “bowl” side) surface of the sponge was oriented face up. On approximately every fifth day during post processing acclimation, sponges were examined for healing, and dead or diseased transplants were removed. Before the sponges were placed into the field on 20 September 2000, I measured the volume (± 5 ml) of each sponge that survived and successfully attached to the bricks by determining its displacement of seawater from a specially designed 10 l bucket (Appendix B).

At least one transplant of each individual, from each species, from each donor site, was transplanted to six experimental treatment sites in the middle Florida Keys (Fig. 1; Appendix A). Two treatment sites were established in the region of Florida Bay that experienced nearly 100% sponge mortality during the 1990-1991 sponge die-off (Bay Impacted), another two sites were established on the bay side of the Florida Keys in a region that had not experienced the recent sponge die-off (Bay Unimpacted), and the final two sites were located on the oceanside of the Florida Keys (Ocean). The Bay Unimpacted sites were the original sponge donor sites. After 10, 18, and 24 months, I returned to the six field sites and quantified the volume of each transplant to ascertain its growth. A Model I repeated-measures ANOVA was used to examine: 1) the effects of transplant site (within subject factor), donor site (among subject factor), and their interaction on mean change in growth of sponges; 2) the effects of region (within subject factor), donor site (among subject factor), and their interaction on mean change in growth of sponges.

Sponge and Sessile Invertebrate Recruitment: To examine the patterns of recruitment of hard-bottom dwelling sponges and other sessile invertebrates in relation to local community structures, I combined hard-bottom community surveys with observations of invertebrate recruitment onto settlement plates. Settlement plates (cement cap blocks, 40 cm L x 20 cm W x 5 cm H) were deployed in July 1999 at each site used in the scour experiment. At each experimental site, I: 1) determined sponge and coral abundances within random quadrats, 2) counted the number of potential predators of new recruits found under each settlement plate, and 3) photographed the number of new recruits on the settlement plates. Two settlement plates were placed adjacent to each of the structures used in the clod card experiment, with the addition of a third replicate of each structure type at all sites. Settlement plates were paired next to each structure, with their long axes centered along the North and East cardinal directions, and abutting the treatment structure (Fig. 3). In June 2003, I photographed each settlement plate. Prior to photography, I fanned each settlement plate

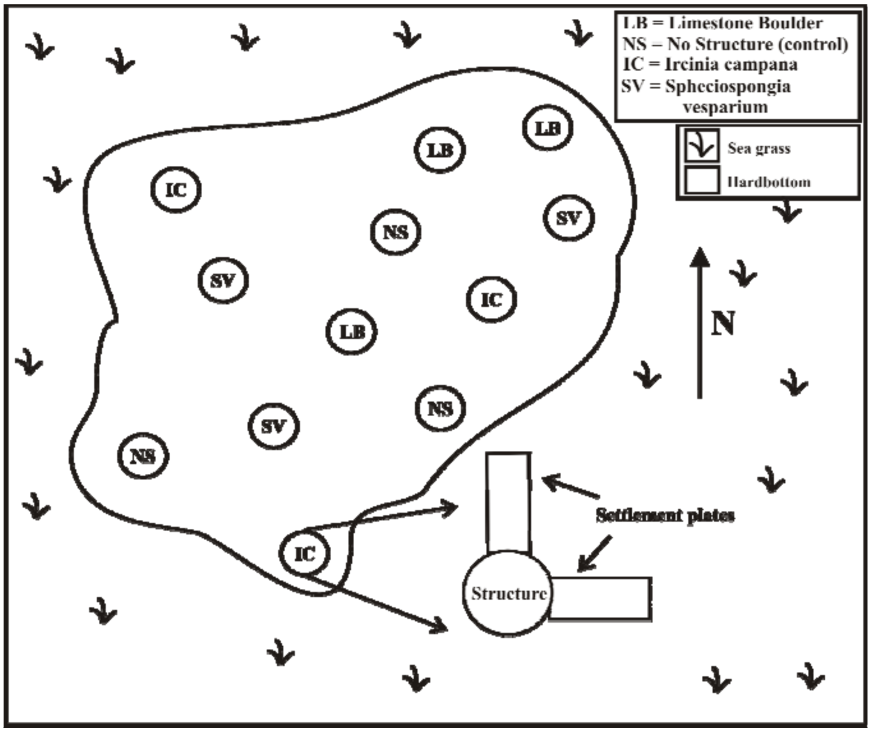


Figure 3. Graphical representation of settlement plate experiment at one site, showing the number and types of structure at each site. Settlement plates were deployed around each structure as is shown in the expanded view. LB, Limestone boulder; NS, No structure; SV, *Spheciospongia vesparium*; IC, *Ircinia campana*

by hand to remove accumulated sediment, and removed all macroalgae. Each settlement plate was then tagged with a unique identifier, outlined with a contrasting wooden frame and scale bar, and the upper surface of the block photographed. I also quantified coral spat and sponge recruits *in situ*. On these same sites, I also quantified the density of 13 sessile invertebrate species (sponges, corals, and octocorals) within 16 non-overlapping, 1m^2 quadrats placed haphazardly at each site. Species occurrences within quadrats at each site were pooled for determination of Shannon-Weiner diversity index (H') and Pielou's evenness indices ($J' = H'/H'_{\text{max}}$) for each site.

RESULTS

Sponge Effects on Scour: Scour, as indicated by the loss of mass of plaster-of-paris clod cards, was significantly affected by the combined effects of flow regime, physical structure, and distance from the structure (Appendix C). At high flow sites, Vase sponges (*Ircinia campana*) enhanced scour close to the sponge, but generally, the presence of physical structures decreased scour at distances of 20 – 40 cm. At low-flow sites, only Loggerhead sponges (*Spheciospongia vesparium)* appeared to alter scour by increasing dissolution of the clod card at all distances tested, especially close to the sponge. Scour was nearly twice as high at high-flow sites than low flow sites (Fig. 4).

Sponge Growth and Survival: Mortality of sponges during the study and misidentification of some Sheepswool sponges (*Hippospongia lachne*) during the initial collection resulted in lower sample sizes for each species and transplant site than intended. After correcting all mislabeled commercial sponges (some were Yellow sponges, *Spongia barbara*), I determined that replication existed for only one donor site for each of those two commercial species. Therefore, I examined only Sheepswool sponges from the Burnt Point donor site and Yellow sponges from the donor site at Long Key. Mortality of the Sheepswool sponges transplanted to one Oceanside site (Duck Key) was 100% within 18 months, and 65% transplanted back to the Burnt Point donor site died within 24 months. Mortality of Loggerhead sponges (*Spheciospongia*

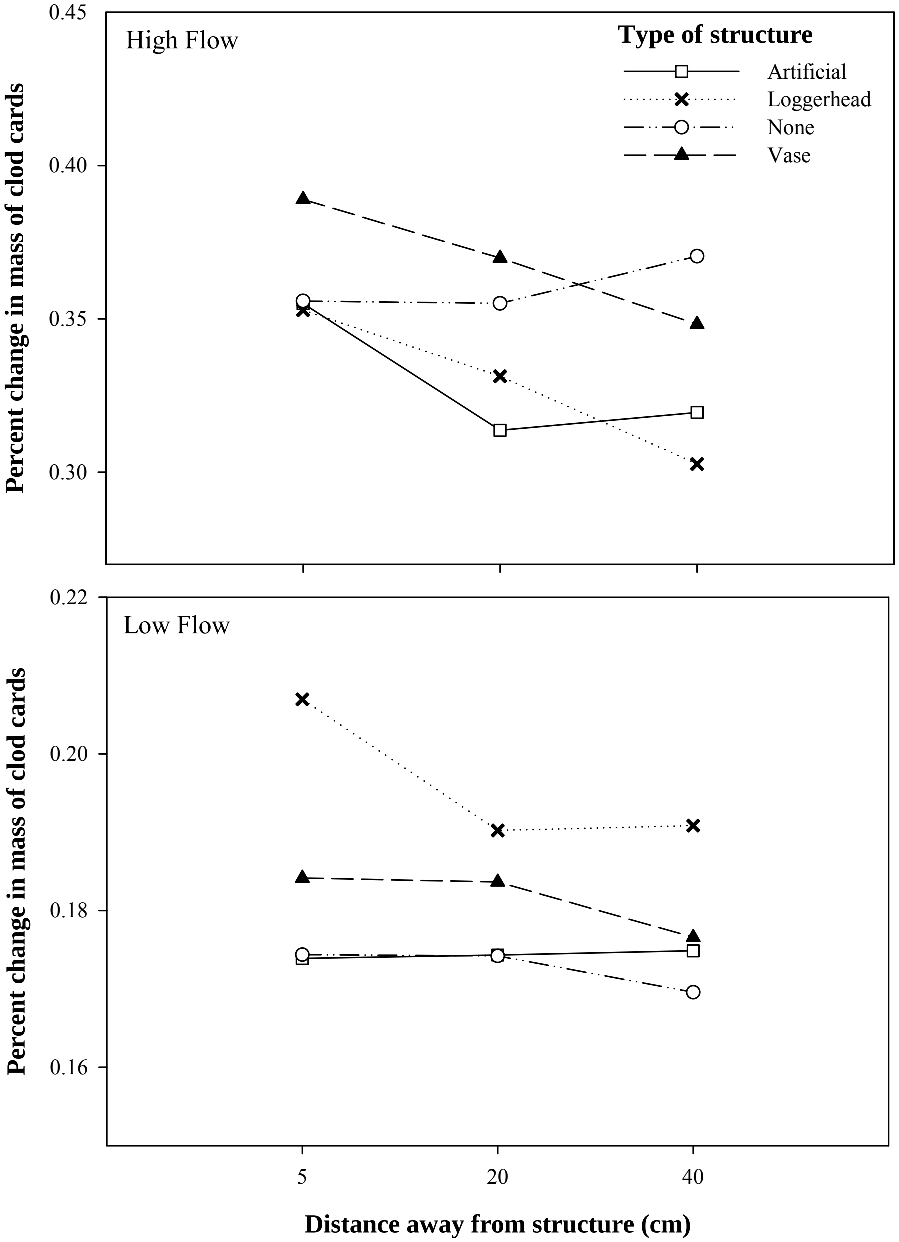


Figure 4. Mean percent change in mass of clod cards at three distances, in High flow (top) and Low flow (bottom) regimes, during a 2 day trial

vesparium) and Vase sponges (*Ircinia campana*) was 14% and 17%, respectively, during the two-year study. In contrast, mortality of Yellow sponges was low (4.3%) over the same time period. Growth of Yellow sponges was highest at the Long Key (Bayside –

Impacted) site but growth did not differ significantly among sites (*F* = 1.66, df = 5, p = 0.23; Appendix E) or regions (*F* = 4.07, df = 2, p = 0.08; Fig. 5). The growth rate for Yellow sponges was 150.8 ± 40.3 ml (mean ± SE) every 24 months, but notably two individuals tripled in volume, and seven doubled in volume during the experiment. Similarly, the growth of Vase sponges did not differ significantly among sites (*F* = 1.855; df = 5; p =0.190; Appendix E) or regions (*F* = 3.109; df = 2; p = 0.082; Fig. 5) to which they were transplanted. Additionally, growth of Vase sponges was not affected by the donor site population from which they came (*F* = 0.027; df = 5; p = 0.885; Appendix D) (*F* = 1.401; df = 2; p = 0.281; Fig. 6). The growth rate of Vase sponges was 247.2 ± 30.6 ml (mean ± SE) every 24 months. Vase sponge transplants were morphing into their characteristic vase-like phenotype at approximately 10 months, and were completely vase shaped by the end of the 24 month experiment. The growth of Loggerhead sponges differed significantly among sites (*F* = 6.771; df = 5; p = 0.005; Appendix E) and regions (*F* = 4.251; df = 2; p = 0.033; Fig. 5), with the fastest growth occurring in the Impacted region. However, like the Vase sponge, the growth of Loggerhead sponges was not affected by the donor site population from which they came (F = 0.355; df = 5; p = 0.612; Appendix D) (*F* = 0.493; df = 2; p = 0.502; Fig. 6). The growth rate of Loggerhead sponges in the Impacted region was 160.5 ± 31.5 ml (mean ± SE), and 11.5 ± 11.4 ml (mean ± SE) in the other regions every 24 months. Loggerhead sponge transplants from the Burnt Point donor site showed the strongest response to transplantation at all sites (Appendix D). There was no effect of transplant size on growth for any species in the study.

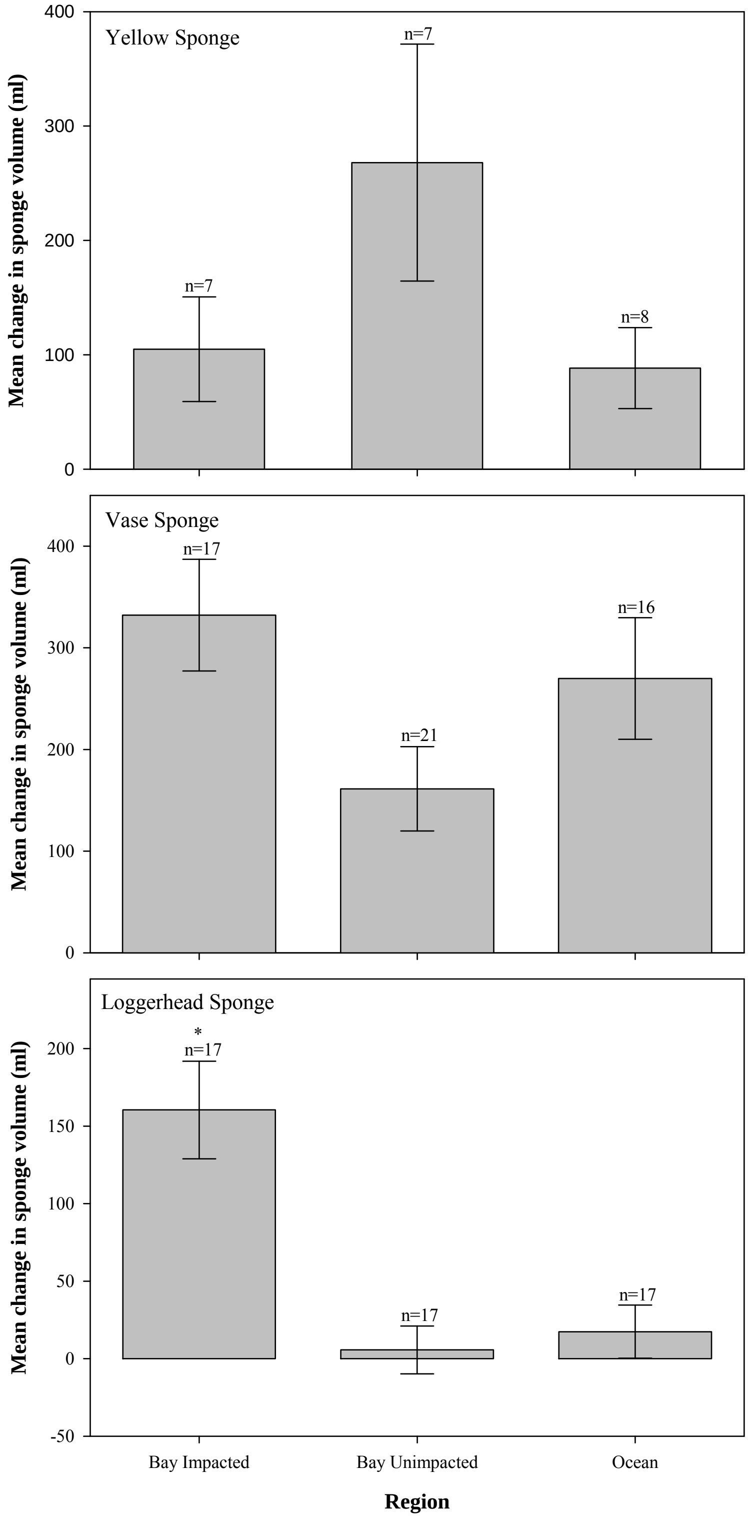


Figure 5. Change in volume of Yellow sponge (top), Vase sponge (middle), and Loggerhead sponge (bottom) in each region (mean ± SE)

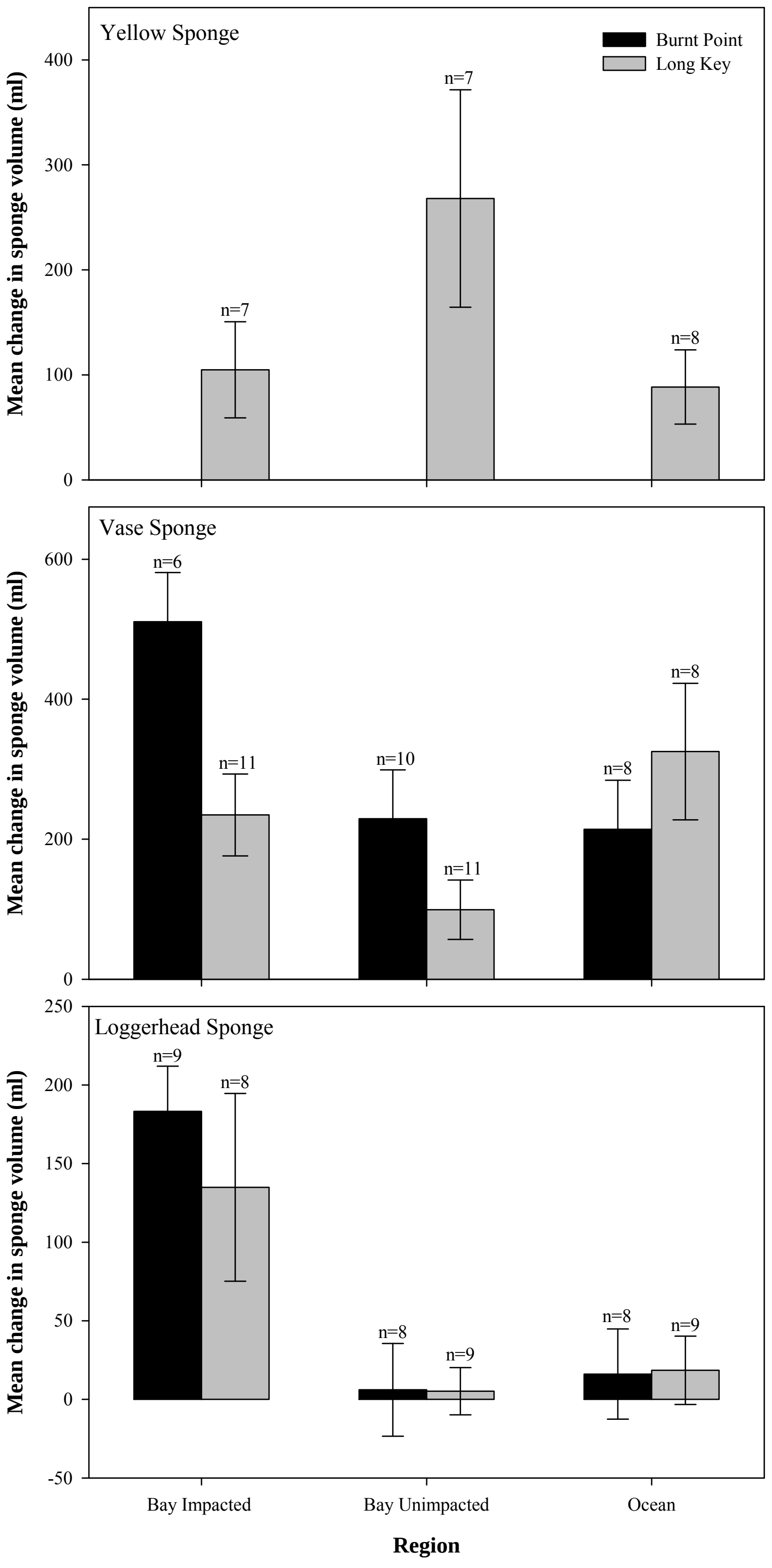


Figure 6. Change in volume of Yellow sponge (top), Vase sponge (middle), and Loggerhead sponge (bottom) in each region (mean ± SE), separated by donor site.

Sponge and Sessile Invertebrate Recruitment:

Hard-bottom Community Structure: Sessile invertebrate densities estimated from quadrat sampling were pooled for each site to obtain Shannon-Weiner diversity (*H')* and Pielou's *evenness* indices (*J')*. All sites were similar in respect to community diversity and evenness (Fig. 7). The most abundant benthic taxa on all four sites were the sponges *Cinachyra* sp. and *Chondrilla* sp., and the Lesser Starlet coral *Siderastrea radians*.

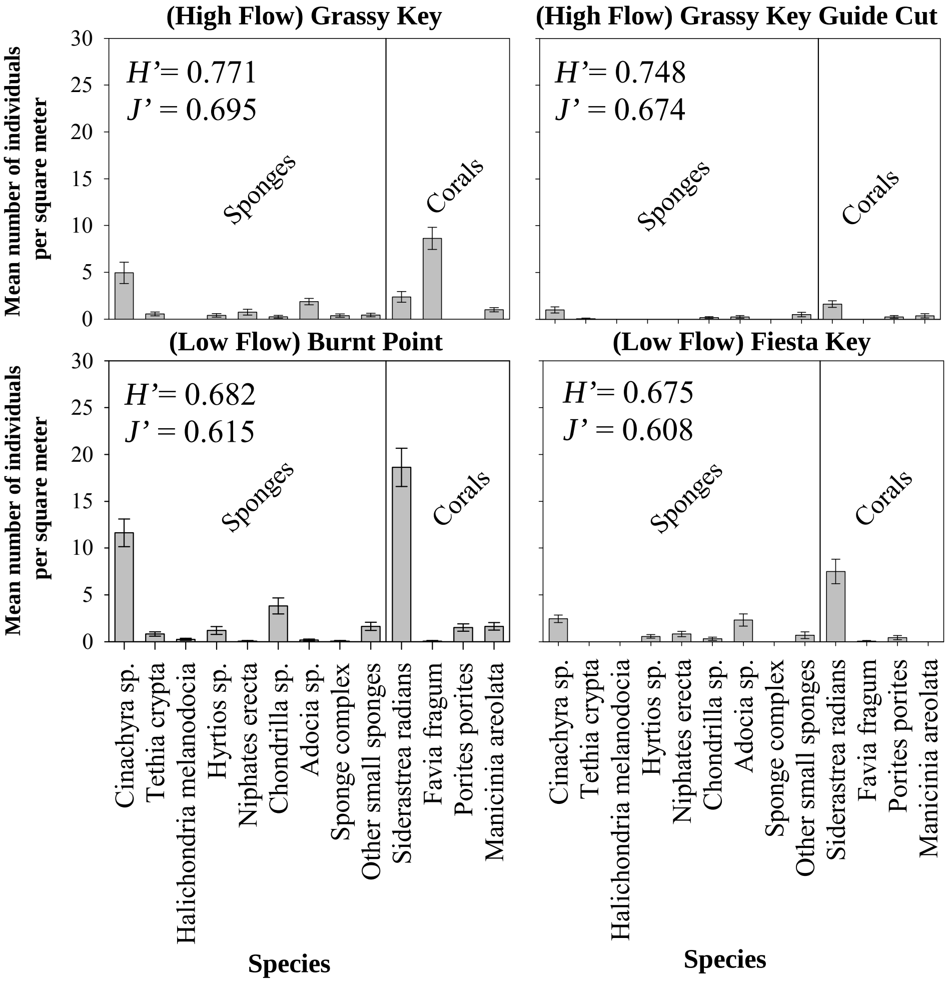


Figure 7. Number of individuals of each species per square meter, per site (mean ± SE). Shannon-Weiner diversity index (*H'*) and the evenness index (*J'*) are shown. Panel titles indicate flow regime, in parentheses, and site name.

Recruitment of Sponges and Sessile Invertebrates: The settlement plates shifted away from the benthic structure treatments during the first year, so the experiment as designed was ruined. Therefore, I only quantified the recruitment of sessile macroinvertebrates on settlement plates in June 2003, forty-five months after deployment. My occasional observations of community development during the time period suggest that development proceeded from a near monospecific stand of red macroalgae (*Laurencia* sp.) in June 2000, to a mixed algal community in July 2001 dominated by red macroalgae (*Laurencia* sp.) and green macroalgae (*Acetabularia* sp.), and finally to one that included coral spat (probably *Siderastrea radians*), and an encrusting sponge (chicken liver sponge: *Chondrilla* sp.). Most notably, no large sponges (e.g., *Spheciospongia vesparium* and *Ircinia campana*) recruited to the settlement plates, which was the primary focus of this experiment.

Four of the nine small sponge species found on the settlement plates were also found on the sites (i.e., quantified in the quadrats) but these four sponges represented 72% of all settlers (Appendix G). In all, forty-three sponges recruited on to the settlement plates; they were *Chondrilla* sp. (49%), *Adocia* sp. (12%), *Halichondria melanodocia* (9%), and an unknown sponge (9%). Burnt Point had both the highest natural density of individuals and settlement of *Chondrilla* sp. (four sponges/ m^2 and 81% of total settlement, respectively), and all *Chondrilla* sp. recruitment occurred on only six of the twenty-two settlement plates. All *Adocia* sp. recruitment occurred at the Grassy Key site, which had 0.3 sponges/ m^2 and the highest diversity of sponge settlers (H'= 0.82). There were no obvious trends in the relationships between the settlement of these four species to their site densities and flow regimes (appendix H).

The Lesser Starlet coral (*Siderastrea radians*) was also a common recruit on these settlement plates at all sites (Fig. 8), but was most abundant at the Grassy Key Guide Cut and Fiesta Key sites where they were also larger and therefore appeared to have settled earlier (Fig. 9). Various macroinvertebrates were also found underneath each settlement plate, which could have contributed to some form of grazing predation on new sponge settlers. These organisms were identified and are presented in Appendix F.

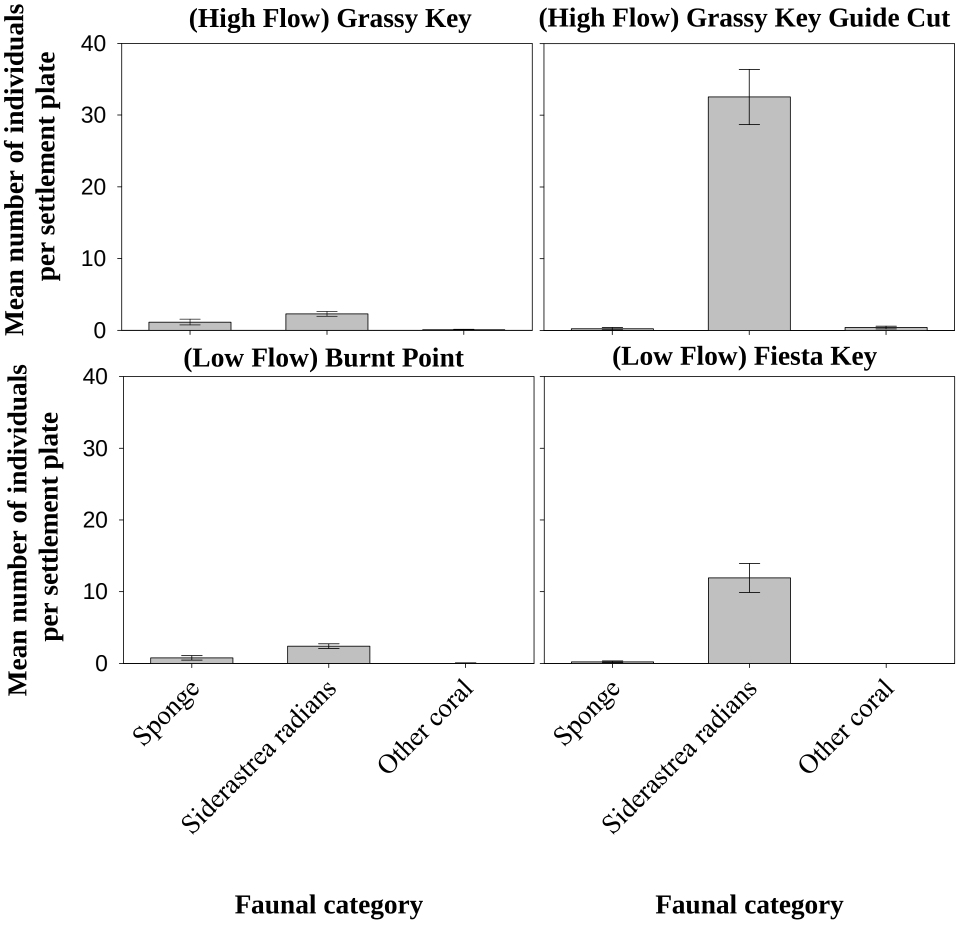


Figure 8. Number of new recruits of each faunal category per block, per site (mean ± SE). Panel titles indicate flow regime, in parentheses, and site name.

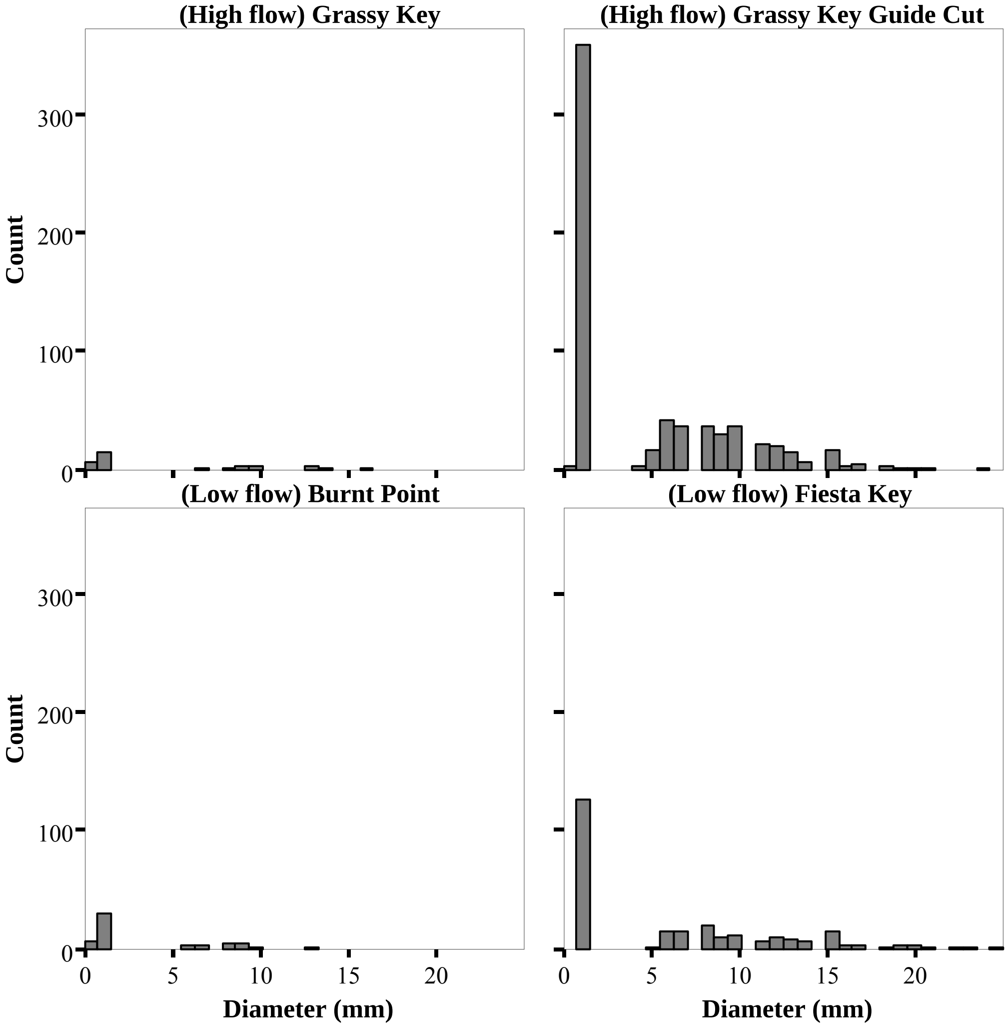


Figure 9. Number of polyps per coral colony diameter by site (mean ± SE). Panel titles indicate flow regime, in parentheses, and site name

DISCUSSION

In near shore hard-bottom habitat, large sponges appear to alter fluid flow enough to enhance small-scale (< 50 cm) scouring near their base, which presumably affects the depth and size-structure of adjacent sediments. Eckman (1983) described the importance of near-bed flow and how structures (e.g., seagrass, worm tubes, simulated marsh grass stalks, etc.) alter fluid circulation, thus effecting deposition rates and scour of sediment. Additionally, Vogel (1994) suggested that flow patterns behind a cylinder (e.g., a sponge) can produce attached or shedding vortices, thus these turbulent vortices could be a mechanism by which scour at sub-meter scale is enhanced, and the likelihood of advective sediment transport increased. My results show that at high-flow sites, tall pliable structures (e.g., *Ircinia campana*) enhanced scouring near the base of the structure and that rigid structures (e.g., *Spheciospongia vesparium* and boulders) reduced scouring at distances up to 40 cm away. At low-flow sites, scouring was minimal, but was elevated very close to large, rigid Loggerhead sponges. Interestingly, scouring was consistently higher near Loggerhead sponges than near rock boulders that were nearly twice the size of the Loggerhead sponges tested (boulder volume = 11.3 ± 5.9 l; mean Loggerhead volume 5.6 ± 6.6 l(mean ± SD)). Weisz (2006) determined that Loggerhead sponges can pump up to 22,000 l of water/day/l of sponge, thus the biogenic amplification of water flow of this magnitude around Loggerhead sponges might cross the threshold sheer stress necessary for erosion of sediments close to the sponge (Pritchard 2005) compared to that observed around boulders. In general, the effect of both sponge species on scouring was slightly greater than that of the boulders. These changes in water flow are likely to influence the settlement of sessile fauna larvae near large sponges, thus altering the patterns of recruitment in near shore hard-bottom areas. Large sponges may also have beneficial consequences for nearby juveniles and adults by increasing near-bottom turbulence, which is known to enhance the delivery of planktonic food necessary for filter feeder growth (Pile and Young 1999).

All of the sponges tested grew and survived at least as well in the region impacted by the sponge die-off as in their site of origin. Furthermore, Loggerhead sponge transplants grew better in the impacted region than anywhere else. The exceptional growth of sponges transplanted into areas previously affected by algal blooms and sponge die-off demonstrates that these areas are now capable of sustaining sponge growth, or at least that the conditions that caused the die-off did not return to the area during the study period. As expected, Loggerhead sponge transplants grew at a slower rate than did the other species in this experiment, regardless of their initial size, confirming that this oviparous species is slower growing than the other large viviparous sponge species (e.g., Vase sponge and Yellow sponge) found in near shore hard-bottom areas. Additionally, Yellow sponge (*Spongia barbara*) transplants from Long Key showed similar growth rates at all locations and regions. Few of the Yellow sponge transplants died after transplantation (4% in 710 days), a finding similar to that found in its Mediterranean congener *S. agaricina*, where only 2% died in 873 days (Verdenal and Vacelet 1990). Nearly half of the Yellow sponge transplants more than doubled in volume during this 710 day experiment, so it may be considered a good candidate for propagation and perhaps for reintroduction to areas of Florida Bay that have not recovered from the early 1990s sponge die-off. Conversely, mortality of Sheepswool sponges (*Hippospongia lachne*), another commercially valuable species, was high and gradually increased during the experiment; however, transplants of this species have been successfully grown in other studies (Moore 1908; Mark Butler, Old Dominion University, unpublished data).

The sessile community in the old die-off area is still relatively depauperate, so it is possible that the elevated growth of sponges there is a result of intra-phyletic competitive release. Food limitation could explain the reduction in sponge growth that occurred at Burnt Point (for both Loggerhead and Vase sponges) and Craig Key (for Vase sponges), both of which have diverse and structurally complex hard-bottom community assemblages compared to the die-off area. Sponges have an extraordinary ability to pump and filter water (Gerrodette & Flechsig 1979; Turon et al. 1998; Ribes et al. 1999; Weisz 2006), so it follows that the elevated sponge growth observed in the die-off area occurred in the absence of other sponge competitors. In contrast, the growth of sponges in areas with intact, abundant, and diverse sponge communities was reduced. *In situ* and laboratory measurements of filtration by several species of sponge found in the Florida Keys indicate that species differ in their rates and specificity of removal of phytoplankton, bacteria, and virus from the water column (Kathryn Kauffman pers comm, Old Dominion University). The potential confounding effects of epibenthic, inter-phyletic competition for food (e.g., between sponges and octocorals or scleractinian corals) was considered but published studies show that, in general, octocorals and scleractinian corals utilize larger prey items from the water column in the form of particulate organic matter (zooplankton >5 µm) (Ribes et al. 1998) compared with sponges that primarily utilize ultraplankton (<5 µm)(Pile et al. 1997) for their carbon source, presumably from sediment organic matter (Behringer and Butler 2006).

Food limitation was not the only factor considered when examining these differences in sponge growth. Due to the experimental design of this portion of my research, the additional and perhaps synergistic effects of light availability, turbidity, current regimes, and sedimentation rates were not quantified but all are known to affect sponge growth (Wilkinson and Vacelet 1979; Gerrodette & Flechsig 1979; Duckworth & Battershill 2003; Roberts et al. 2006). Adult sponges are also prey for a variety of taxa including turtles (Meylan 1988), fishes (Randall and Hartman 1968; Ayling 1981; Wulff 1994; Pawlik et al. 1995), gastropods (Pawlik et al. 1988), starfish (Wulff 1995), and polychaetes (Fauchald and Jumars, 1979; Pawlik, 1983). However, I saw no evidence of whole or partial predation of any transplanted sponge in this experiment, so differences in spongivory are an unlikely explaination for the differences in sponge growth among regions. Although the cause is unknown, the results of this study show that adult sponges grow and thrive in areas previously impacted by sponge mass mortalities, thus the scarcity of sponges in those areas are more likely to be due to factors influencing larval dispersal, settlement, and survival rather than food limitation. For example, the return of large sponges into the die off area could be stymied by the short planktonic duration of the lecithotrophic sponge larvae, which minimizes larval transport (Todd 1998; Miriani et al. 2006). Sponge larval dispersal can also be influenced by temperature (Maldonado and Young 1996), local and landscape hydrographic regimes, larval life span, and species specific larval behavior (sensu Miriani et al. 2006). Although de Voogd et al. (2006) suggest that distance from parental stocks may not be an important factor in structuring either viviparous or oviparous sponge communities, such results may be species-specific and probably highly dependent on local hydrodynamic conditions. The latter factor is especially relevant in the geographically complex network of hard-bottom areas within

Florida Bay, which are often hydrographically isolated from one another by emergent mud banks and islands.

In this study, my examination of the relationship between the presence of large sponges and the recruitment of sessile organisms nearby yielded inconclusive results because the settlement plates I used shifted position during the experiment. However, my periodic observations of the communities that developed on the settlement plates, along with a more thorough quantification of conditions on them after four years provides a “snapshot” of the pattern of hard-bottom community development in areas unaffected by the sponge die off.

Large sponges (e.g., Loggerhead and Vase sponges) did not recruit to the settlement plates as I had originally hypothesized. Other studies have shown that larval recruitment is often greater where adults live in higher densities because of dispersal limitation (Zea 1993; Miriani et al. 2006). As I stated earlier, fish and other grazing invertebrates could have increased post settlement mortality of large sponge larvae in the study areas. According to published literature, 27 - 52% of the macroinvertebrates found under rubble in the Florida Keys are brittle stars (Hendler et al. 1995), including the spongivor *Echinaster sentus* (Hendler et al. 1995; Waddell and Pawlik 2000). I expected to see low numbers of large sponge recruits areas with high densities of brittle stars (i.e., potential predators) under the settlement plates, which was indeed the case. However, the opposite effect was observed for the smaller sponge species. The recruitment of small sponges was higher at sites that had higher densities of brittlestars and Lesser Starlet corals (potential space competitors) (Appendix F) in association with the settlement plates. Even so, these “one time” observations of the relationships between natural sponge densities, possible predation, and sponge settlement offer only weak inference as to the processes that influence the recruitment of sponges in these areas.

CONCLUSIONS

The results of this study offer new insight to the influences of large sponges in the development and maintenance of near shore hard-bottom habitat. The effect of large sponges on scouring was slightly greater than that of similar sized boulders, and large sponges induce turbulent flow and increased scouring of the benthos under both high and low-flow conditions in the area immediately adjacent to them. Additionally, Loggerhead sponge and Vase sponge transplants grew better in the region subjected to recent sponge die offs than they did elsewhere, including the sites from which they originated, thus sponges can thrive in areas previously impacted by sponge mass mortalities if they can overcome barriers to dispersal and successfully recolonize those areas. Once an area is colonized, sponges may contribute to the persistence of hard-bottom habitat by enhancing local benthic scouring and thus precluding sedimentation and succession to seagrass. My study was the first to determine growth rates for the Loggerhead sponge (*Spheciospongia vesparium*) and the Vase sponge (*Ircinia campana*), which are two structurally important demosponges in near shore hard-bottom communities in the Florida Keys, and it is also the first to successfully transplant any *Ircinia* species.

REFERENCES

Ayling, A. L. 1981. The role of biological disturbance in temperate subtidal encrusting communities. Ecology 62:830–847.

Behringer, D. C. and M. J. Butler IV. 2006. Stable isotope analysis of production and trophic relationships in a tropical marine hard-bottom community. Oecologia. 148: 334-341.

Butler, M. J. IV, J. H. Hunt, W. F. Herrnkind, M. J. Childress, R. Bertelsen, W. Sharp, T. Matthews, J. Field, and H. Marshall. 1995. Cascading disturbances in Florida Bay, USA: cyanobacteria bloom, sponge mortality, and implications for juvenile spiny lobsters *Panulirus argus*. Mar. Ecol. Prog. Ser. 129: 119-125.

Butler, M. J. IV, W. F. Herrnkind, J. H. Hunt. 1997. Factors affecting the recruitment of juvenile Caribbean spiny lobsters dwelling in macroalgae. Bull. Mar. Sci. 61: 3-19.

Chiappone, M., and K. M. Sullivan. 1994. Ecological structure and dynamics of nearshore hard-bottom communities in the Florida Keys. Bull. Mar. Sci. 54:747-756.

Crawshay, L. R. 1939. Studies in the market sponges: I. Growth from the planted cutting. J. Mar. Biol. Assoc. UK. 23:553-574.

Crimaldi, J P., J. K. Thompson, J. H. Rosman, R. J. Lowe, and J. R. Koseff. 2002. Hydrodynamics of larval settlement: The influence of turbulent stress events at potential recruitment sites. Limnol. Oceanogr. 47: 1137-1151.

de Voogd, N. J., D. F. R. Cleary, B. W. Hoeksema, A. Noor, and R. W. M. van Soest. 2006. Sponge beta diversity in the Spermonde Archipelago, SW Sulawesi, Indonesia. Mar. Ecol. Prog. Ser. 309: 131-142.

Doty, M. S. 1971. Measurement of Water Movement in reference to Benthic Algal Growth. Botanica Marilla. 14: 32-35.

Duckworth, A. and C. Battershill. 2003. Sponge aquaculture for the production of biologically active metabolites: the influence of farming protocols and environment. Aquaculture. 221:311-329.

Eckman, J. E. 1983. Hydrodynamic Processes Affecting Benthic Recruitment. Limnol. Oceanogr. 28: 241-257.

Fauchald, K. and P. A. Jumars. 1979. The diet of worms: A studyof polychaete feeding guilds. Oceanogr. Mar. Biol. A. Rev. 17: 193–282.

Feinstein, A., A. R. Ceurvels, R. F. Hutton, and E. Snoek. 1955. Red tide outbreaks off the Florida west coast. Florida State Board of Conservation. 55 – 15; 39p.

Field, J. M. and M. J. Butler, IV. 1994. The influence of temperature, salinity, and larval transport on the distribution of juvenile spiny lobsters, *Panulirus argus*, in Florida Bay. Crustaceana 67: 26-45.

Fromont, J. 1994. The reproductive biology of tropical species of *Haplosclerida* and *Petrosida* on the Great Barrier Reef. Pages 307-311 *in* van Soest, R. W. M., Th. M. G. van Kempen, and J. C. Braekman. eds. Sponges in time and space. A. A. Balkema, Rotterdam, Netherlands.

Galtsoff, P. S. 1940. Wasting disease causing mortality of sponges in West Indies and Gulf of Mexico. Proc. 8th Amer. Sci. Cong. 3: 411-421.

Gerrodette, T. and A. O. Flechsig. 1979. Sediment-induced reduction in the pumping rate of the tropical sponge *Verongia lacunosa*. Mar. Biol. 55:103-110.

Gotelli, N. J. 1988. Determinants of recruitment, juvenile growth, and spatial distribution of a shallow-water gorgonian. Ecol. 69: 157-166.

Green, G., P. Gomez and G. J. Bakus. 1990. Antimicrobial and ichthyotoxic properties of marine sponges from Mexican waters. Pages 109-114 *in* Rutzler, K.ed. New perspectives in sponge biology. Smithsonian Institution Press, Washington, D. C., USA.

Hendler, G., J. E. Miller, D. L. Pawson and K. M. Porter, eds. 1995. Echinoderms of Florida and the Caribbean: Sea Stars, Sea Urchins, and Allies. Smithsonian Institution Press, Washington London.

Herrnkind, W. F., M. J. Butler IV, J. H. Hunt, and M. Childress. 1997. Role of physical refugia: implications from a mass sponge die-off in a lobster nursery in Florida. Marine and Freshwater Research. 48:759-769.

Hoppe, W. F. 1988. Reproductive patterns in three species of large coral reef sponges. Coral Reefs. 7: 45-50.

Huysecom, J., G. Van de Vyver, J. Breaekman and D. Daloze. 1990. Chemical defense in sponges from North Brittany. Pages 115-118 *in* Rutzler, K. ed. New perspectives in sponge biology. Smithsonian Institution Press, Washington, D. C.

Jackson, J. B. C. and L. Buss. 1975. Allelopathy and spatial competition among coral reef invertebrates. Proc. Natn. Acad. Sci. U.S.A. 72: 5160-5163.

Kaye, H. 1990. Reproduction in West Indian commercial sponges: oogenesis, larval development, and behavior. Pages 161-169 *in* Rutzler, K. ed. New perspectives in sponge biology. Smithsonian Institution Press, Washington, D. C.

Kaye, H. R., and H. M. Reiswig. 1991. Sexual reproduction in four Caribbean commercial sponges. I: Reproductive cycles and spermatogenesis. Invertebr. Reprod. Dev. 19: 1-11.

Leys, S. P. and B. M. Degnan. 2001. Cytological basis of photoresponsive behavior in a sponge larva. Biol. Bull. 201: 323-338.

Lindquist, N., and M. E. Hay. 1996. Palatability and chemical defense of marine invertebrate larvae. Ecol. Mon. 66:431-450.

Maida, M., P. W. Sammarco and J. C. Coll. 1995a. Effects of soft coral recruitment. I: Directional allelopathy and inhibition of settlement. Mar. Ecol. Prog. Ser. 121: 191-202.

_________, ______________ and ____________. 1995b. Directional allelopathic effects of the soft coral *Sinularia flexibilis* (Alcyonacea: Octocorallia) on scleractinian coral recruitment. Bull. Mar. Sci. 56: 303-311.

Maldonado, M., and C. Young. 1996. Effects of physical factors on larval behavior, settlement and recruitment of four tropical demosponges. Mar. Ecol. Prog. Ser. 138: 169-180.

Meylan, A. 1988. Spongivory in hawksbill turtles: A diet of glass. Science 239: 393–395.

Miriani, S., M. J. Uriz, X. Turon, and T. Alocverro. 2006. Dispersal strategies in sponge larvae: integrating the life history of larvae and the hydrologic component. Oecologia 149: 174–184

Moore, H. F. 1908. A practical method of sponge culture. Bul. Bur. Fish 28:545-585.

Pawlik, J. R. 1983. A sponge-eating worm from Bermuda: *Branchiosyllis oculata* (Polychaeta, Syllidae). PSZNI: Mar. Ecol. 4:65–79.

__________, B. Chanas, R. J. Toonen and W. Fenical. 1995. Defenses of Caribbean sponges against predatory reef fish. I. Chemichal deterrency. Mar. Ecol. Prog. Ser. 127: 183-194.

__________, M. R. Kernan, T. F. Molinski, M. K. Harper, and D. J. Faulkner. 1988. Defensive chemicals of the Spanish Dancer nudibranch, *Hexabranchus sanguineus*, and its egg ribbons: Macrolides derived from a sponge diet. J. Exp. Mar. Biol. Ecol. 119: 99–109.

Pile, A. J., M. R. Patterson, M. Savarese, V. I. Chernykh, and V. A. Failkov. 1997. Trophic effects of sponge feeding within Lake Baikal's littoral zone. 2. Sponge abundance, diet, feeding efficiency, and carbon flux. Limnol. Oceanogr. 42: 178-184.

Pile, A. J. and C. M. Young. 1999. Plankton availability and retention efficiencies of cold-seep symbiotic mussels. Limnol. Oceanogr. 44: 1833-1839.

Pritchard, D. 2005. Suspended sediment transport along an idealized tidal embayment: settling lag, residual transport and the interpretation of tidal signals. Ocean Dynamics 55: 124–136.

Randall, J. E. and W. D. Hartman. 1968. Sponge feeding fishes of the West-Indies. Mar. Biol. 1:216–225.

Rathbun, R.1887. The sponge fishery and trade. Pages 817-841 *in* Goode, G. B. ed. The fisheries and fishery industries of the United States. Section 5, Volume 2.

Reiswig, H. 1973. Population dynamics of three Jamaican Demospongiae. Bull. Mar. Sci. 23: 191-226.

Ribes, M., R. Coma, and J. M. Gili. 1998. Heterotrophic feeding by gorgonian corals with symbiotic zooxanthella. Limnol. Oceanogr. 43: 1170-1179.

Ribes, M., R. Coma, and J. M. Gili. 1999. Natural diet and grazing rate of the temperate sponge *Dysidea avara* (Demospongiae,Dendroceratida) throughout an annual cycle. Mar. Ecol. Prog. Ser. 176:179-190.

Roberts D.E., A. R. Davis, and S.P. Cummins. 2006. Experimental manipulation of shade, silt, nutrients and salinity on the temporate reef sponge *Cymbastela concentrica*. Mar. Ecol. Prog. Ser. 307:143-154.

Rogers, C. S. 1990. Responses of coral reefs and reef organisms to sedimentation. Mar. Ecol. Prog. Ser. 62: 185-202.

Stevely, J. M., D. E. Sweat and K. M. Sokol. 1997. Survey of the recovery of Florida Keys sponge populations following a widespread sponge mortality. Contract Report to Florida Fish and Wildlife Conservation Commission; Agreement number MR252. Marathon, Florida.

Storr, J. F. 1964. Ecology of the Gulf of Mexico commercial sponges and its relation to the fishery. U. S. Fish and Wildlife Service Special Scientific Report 466. Washington, D.C.

Todd, C. D. 1998. Larval supply and recruitment of benthic invertebrates: do larvae always disperse as much as we believe? Hydrobiologia. 376:1-21.

Thompson, T. L. and E. P. Glenn. 1994. Plaster standards to measure water motion. Limnol. Oceanogr. 39: 1768-1779.

Thrush, S.F., R. B. Whitlatch, R. D. Pridmore, J. E. Hewitt, V. J. Cummings, and M. R. Wilkinson. 1996. Scale-dependent recolonization: The role of sediment stability in a dynamic sandflat habitat. Ecology. 77:2472 - 2487.

Turon, X., I. Tarjuelo, and M. J. Uriz. 1998. Growth dynamics and mortality of the encrusting sponge *Crambe crambe* (Poecilosclerida) in contrasting habitats: correlation with population structure and investment in defense. Functional Ecology. 12:631-639.

Verdenal, B. and J. Vacelet. 1990. Sponge culture on vertical ropes in the Northwestern Mediterranean Sea. Pages 416-424 *in* Rutzler, K. ed. New perspectives in sponge biology. Smithsonian Institution Press, Washington, D. C.

Vogel, S. ed.1994. Life in moving fluids. Prinston University Press, New Jersey, USA.

Waddell, W. and J. R. Pawlik. 2000. Defenses of Caribbean sponges against invertebrate predators. II. Assays with sea stars. Mar. Ecol. Prog. Ser. 195: 133-144.

Watson, A. L. 1976. Preliminary observations on the influence of water movement on population structure in *Ancorina corticata* (Carter)(Choristida:Demospongiae). Proc. New Zeland Ecol. Soc. 23: 45-50.

Weisz, J.B. 2006. Measuring impacts of associated microbial communities on Caribbean reef sponges: searching for symbiosis. Ph.D. Thesis, University of North Carolina at Chapel Hill.

Wilkinson C. R. and J. Vacelet. 1979. Transplantation of marine sponges to different conditions of light and current. J. Exp. Mar. Biol. Ecol. 37:91-104.

Witte, U. and D. Barthel. 1994. Reproductive cycle and oogenesis of *Halichondria panicea* (Pallas) in Kiel Bight. Pages 297-305 *in* van Soest, R. W. M., Th. M. G. van

Kempen, and J. C. Braekman. eds. Sponges in time and space. A. A. Balkema, Rotterdam, Netherlands.

Wulff, J. L. 1994. Sponge-feeding by Caribbean angelfishes, trunkfishes, and filefishes. Pages 265-271 *in* van Soest, R. W. M., Th. M. G. van Kempen, and J. C. Braekman. eds. Sponges in time and space. A. A. Balkema, Rotterdam, Netherlands.

_________. 1995. Sponge feeding by the Caribeean starfish *Oreaster reticulatus*. Mar. Biol. 123: 313-325.

Zea, S. 1993. Recruitment of Demosponges (Porifera, Demospongiae) in rocky and coral reef habitats of Santa Marta, Colombian Carribean. PSZNI: Mar. Ecol. 14:1–21

Zieman, J. C., J. W. Fourqurean, and R. L. Iverson. 1989. Distribution, abundance, and productivity of seagrasses and macroalgae in Florida Bay. Bull. Mar. Sci. 44:292-311.

APPENDIX A

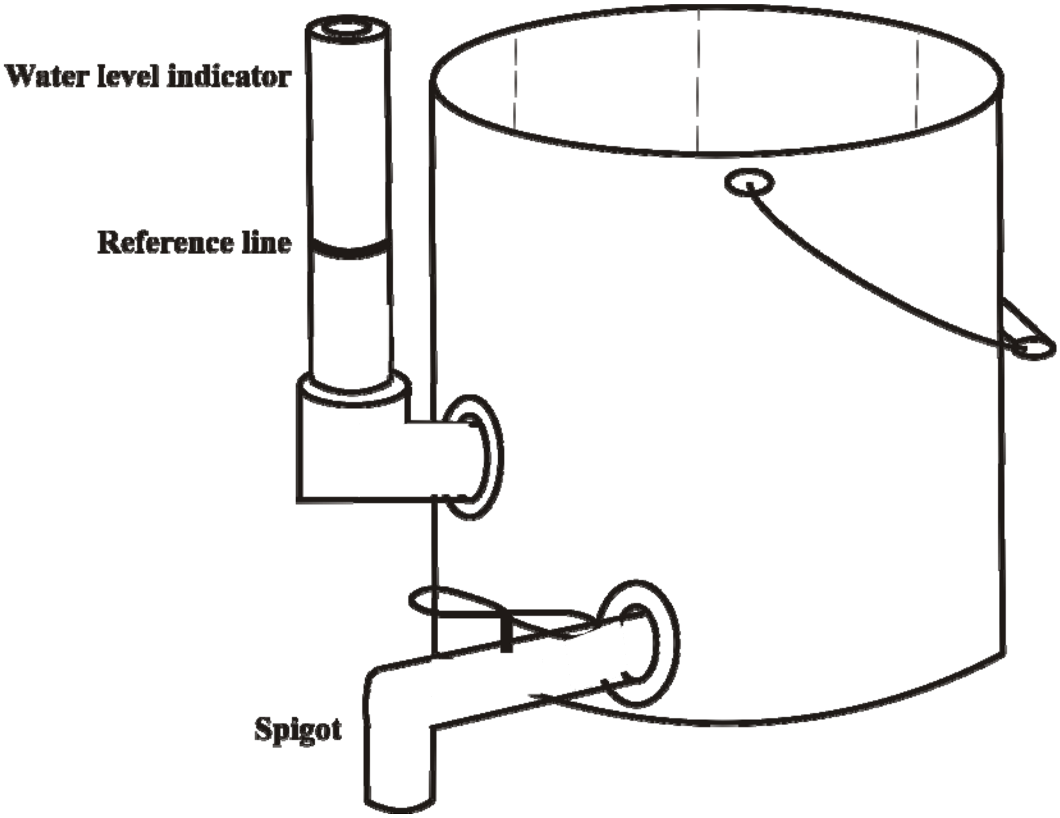
LOCATION OF ALL EXPERIMENTAL SITES.

Site Name	**Experiment**	**Latitude (dd mm.mmm)**	**Longitude (dd mm.mmm)**
Arsnickers	Sponge Growth	N 24º 54.648	W080º 49.261
Buchanan Keys	Sponge Growth	N 24º 54.717	W080º 47.126
Burnt Point	Sponge Growth	N 24º 45.534	W080º 59.018
Long Key	Sponge Growth	N 24º 49.414	W080º 49.445
Duck Key	Sponge Growth	N 24º 46.101	W080º 54.201
Craig Key	Sponge Growth	N 24º 49.678	W080º 45.740
Burnt Point	Scour and Settlement	N 24º 44.980	W080º 59.627
Grassy Key	Scour and Settlement	N 24º 46.423	W080º 57.052
Grassy Key Guide Cut	Scour and Settlement	N 24º 46.867	W080º 55.902
Fiesta Key	Scour and Settlement	N 24º 50.592	W080º 47.728

APPENDIX B

CONSTRUCTION AND USE OF SPONGE VOLUME MEASURING DEVICE.

Two round holes were cut in 10 liter plastic paint bucket. Into one hole I attached a pvc elbow fitting and a 20cm length of clear tubing to serve as a water level indicator. A spigot for draining the seawater was inserted into the other hole. The bucket was filled with seawater to a reference line on the water level indicator, then the sponge transplant was introduced into the bucket. The displaced seawater was then captured into a graduated cylinder by opening the spigot until the water returned to the reference level. The volume of the displaced water is the volume of the sponge plus that of the brick. Since the same bricks were used throughout this experiment, the mean displacement of 10 bricks was determined and used as the volume to subtract from all displacement measurements to extrapolate the volume of the sponge tissue only.



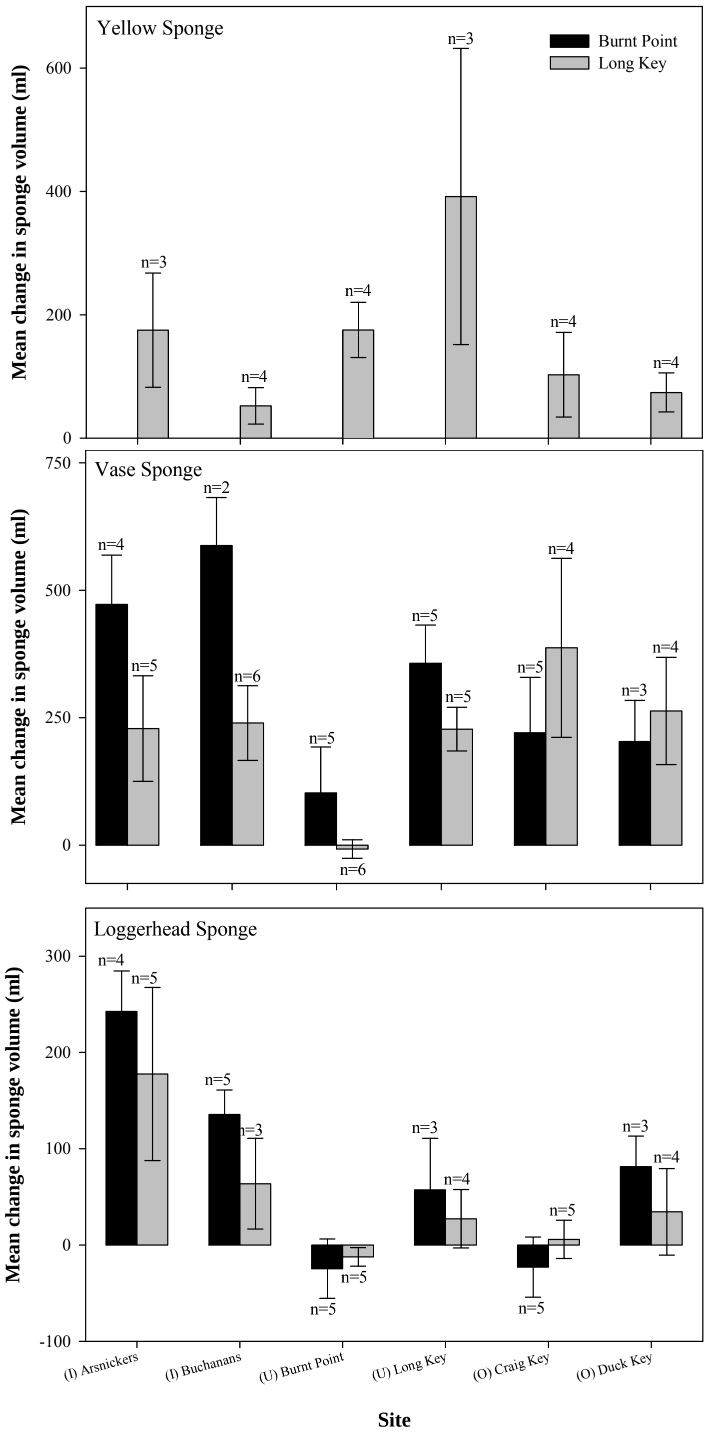
APPENDIX C

RESULTS OF A 2 X 4 X 3 REPEATED MEASURES ANOVA TESTING THE EFFECTS OF FLOW, STRUCTURE, AND DISTANCE ON CLOD CARD CHANGE IN MASS.

Source	df	MS	*F*	p
Flow	1	18434.851	1319.111	0.018
Error(Flow)	1	13.975		
Structure	7	65.564	59.425	0.000
Structure * Flow	7	69.346	62.853	0.000
Error(Structure)	7	1.103		
Distance	2	91.684	9.422	0.096
Distance * Flow	2	63.023	6.477	0.134
Error(Distance)	2	9.731		
Structure * Distance	14	11.899	9.116	0.000
Structure * Distance * Flow	14	14.175	10.859	0.000
Error(Direction*Distance)	14	1.305		

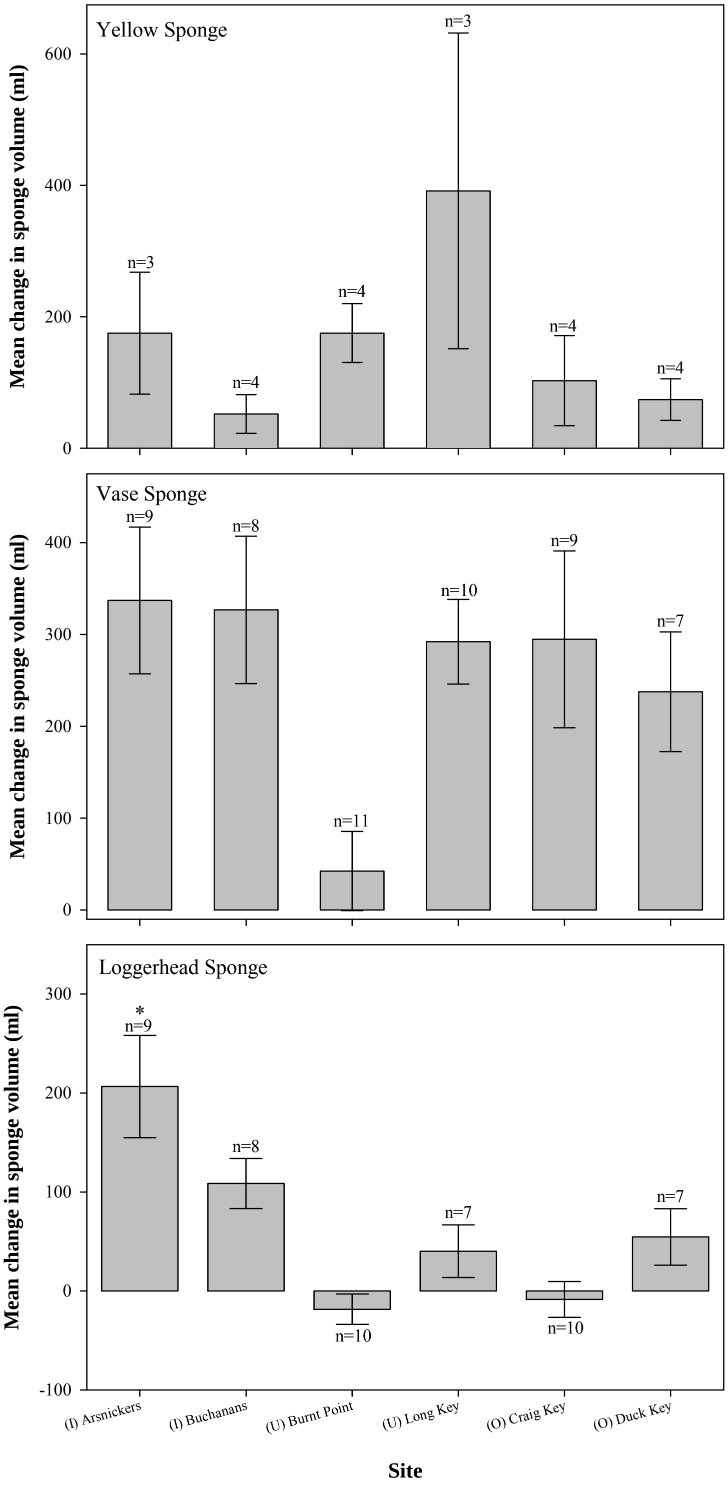
APPENDIX D

CHANGE IN VOLUME OF YELLOW SPONGE (TOP), LOGGERHEAD SPONGE (MIDDLE), AND VASE SPONGE (BOTTOM) AT EACH SITE (MEAN ± SE), SEPARATED BY DONOR SITE. LETTERS SHOWN IN PARENTHESES ARE I = IMPACTED, U = UNIMPACTED, O = OCEAN.



APPENDIX E

CHANGE IN VOLUME OF YELLOW SPONGE (TOP), LOGGERHEAD SPONGE (MIDDLE), AND VASE SPONGE (BOTTOM) AT EACH SITE (MEAN ± SE).



APPENDIX F

TYPE AND NUMBER OF POTENTIAL SPONGE RECRUIT PREDATORS RESIDING UNDER SETTLEMENT PLATES AT EACH SITE. FLOW REGIME, SHOWN IN PARENTHESIS, IS FOLLOWED BY THE SITE NAME.

Site	Predator category	Name	Total number of individuals
(High flow) Grassy Key	Echinoderm	*Ophiocoma echinata*	2
	Echinoderm	Ophiocoma sp.	6
	Echinoderm	Ophioderma sp.	8
	Echinoderm	*Ophiopsila riisei*	24
	Echinoderm	class Holothuroidea	36
	Chiton	Polyplacophora sp.	12
	Keyhole limpet	class Gastropoda	6
	Bearded Fireworm	*Hermodice carunculata*	1
(High flow) Grassy Key Guide Cut	Echinoderm	*Ophiopsila riisei*	2
	Echinoderm	class Holothuroidea	8
	Chiton	Polyplacophora sp.	1
	Key hole limpet	class Gastropoda	8
	Fish	*Opsanus beta*	2
(Low flow) Burnt Point	Echinoderm	*Echinaster sentus*	3
	Echinoderm	class Holothuroidea	26
	Echinoderm	*Ophiopsila riisei*	120
	Chiton	Polyplacophora sp.	20
	Keyhole limpet	class Gastropoda	1
	Bearded Fireworm	*Hermodice carunculata*	1
	Octopus	*Octopus briarius*	2
(Low flow) Fiesta Key	Echinoderm	class Holothuroidea	1
	Keyhole limpet	class Gastropoda	6
	Octopus	*Octopus briarius*	1
	Stomatopod	Stomatopoda	1
	Stone Crab	*Menippe mercinaria*	2
	Fish	*Opsanus beta*	2

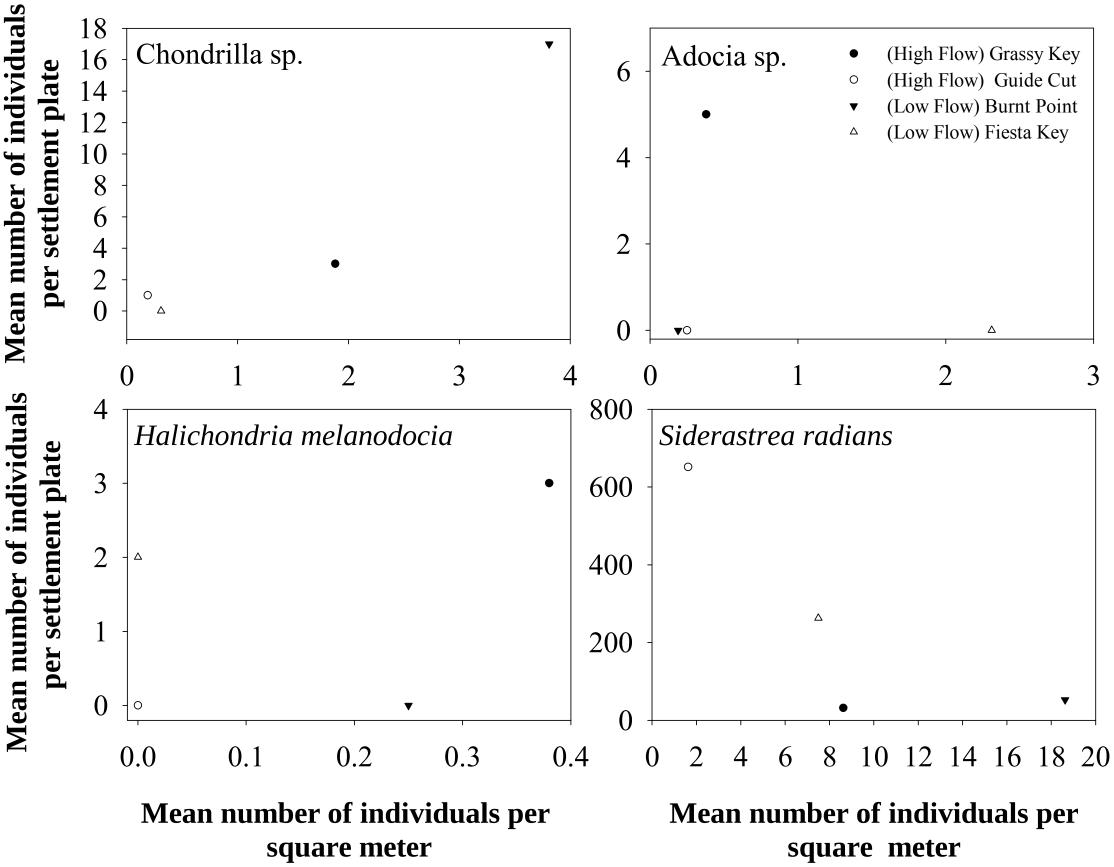
APPENDIX G

TOTAL NUMBER OF SETTLING SPONGES PER SITE. FLOW REGIME, SHOWN IN PARENTHESIS, IS FOLLOWED BY THE SITE NAME.

Site	Type	Name	Total number of individuals
(High flow) Grassy key	Sponge	*Adocia* sp.	5
	Sponge	*Aplysina* sp.	3
	Sponge	*Chondrilla* sp.	3
	Sponge	*Halichondria melanadocia*	3
	Sponge	*Niphates erecta*	1
	Sponge	Unknown sponge	1
	Coral	*Manicina areolata*	1
	Coral	*Siderastrea radians*	32
(High flow) Grassy Key Guide Cut	Sponge	*Anthosigmella varians*	1
	Sponge	*Chondrilla* sp.	1
	Sponge	Unknown sponge	3
	Coral	*Favia fragum*	1
	Coral	*Manicina areolata*	4
	Coral	*Porites* sp.	3
	Coral	*Siderastrea radians*	651
(Low flow) Burnt Point	Sponge	*Chondrilla* sp.	17
	Coral	*Manicina areolata*	1
	Coral	*Siderastrea radians*	53
(Low flow) Fiesta Key	Sponge	*Anthosigmella varians*	1
	Sponge	*Halichondria melanadocia*	2
	Sponge	*Spongia barbara dura*	1
	Sponge	*Tadania* sp.	1
	Coral	*Siderastrea radians*	262

APPENDIX H

MEAN NUMBER OF SETTLING INDIVIDUALS OF FOUR SPECIES VERSUS THE MEAN NUMBER OF THOSE INDIVIDUALS PER SQUARE METER AT EACH SITE. NOTE: ALL AXES USE DIFFERENT SCALES.



VITA

SCOTT DONAHUE

EDUCATION	M.S. Biology, expected 2007, Old Dominion University, Department of Biological Sciences, Norfolk, VA 23529 B.S. Biology, 1994, University of South Florida, Tampa, FL
THESIS	Influences of the Loggerhead sponge (*Spheciospongia vesparium*) and the Vase sponge (*Ircinia campana*) on nearshore hard-bottom community development in the Florida Keys.

PROFESSIONAL EXPERIENCE

4/06 – present	Associate Science Coordinator, Florida Keys National Marine Sanctuary, Key West, FL
8/03 – 4/06	Environmental Specialist III, Florida Keys National Marine Sanctuary, Key West, FL
4/03 – 7/03	Marine Research Associate (OPS), Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, Marathon, Florida.
8/02 - 10/02	Marine Research Associate (OPS), Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, Marathon, Florida.

PRESENTATIONS

Butler, M.J., S. Donahue, and T. Dolan. 2004. Everglades restoration and the consequent effects of altered salinity on nursery habitat structure and spiny lobster recruitment. 7th International Lobster Conference and Workshop, Hobart, Tasmania

Butler, Mark J. IV, Scott Donahue, and Tom Dolan. 2002. Everglades restoration and the effects of changing salinity on hard-bottom communities in Florida Bay. 31st Annual Benthic Ecology Meeting, Orlando, FL.

Butler, Mark J. IV and Scott Donahue. 2001. The potential effects of changing salinity on hard-bottom habitat and spiny lobster recruitment in Florida Bay. Florida Bay Conference, Key Largo, FL.

PUBLICATIONS

Matthews, T. and S. Donahue. 1997. By-Catch Abundance, Mortality, and Escape Rates in Wire and Wooden Spiny Lobster Traps. Proc. Gulf Carib. Fish. Inst. 49:280-298.