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## A Note on the Distribution of Some Sponges and Corals in a Seagrass Bed, Long Key, Florida

MATTHEW LANDAU, MICHELLE CURTIS, AND SUSANNA REILEY

The ecology of sponges and corals in Florida reefs and on other hard bottoms has received attention in the literature, but in some tropical environments, such as seagrass beds, these organisms are less well known. Surveys reported here provide quantitative baseline estimates of the densities and distributions of some of the common sponges (*Tedania ignis*, *Chondrilla* sp., *Chalinula* sp.) and corals (*Manicina areolata*, *Porites* sp., *Cladocora arbuscula*). A seagrass bed dominated by turtle grass, *Thalassia testudinum*, directly off the eastern coast of Long Key State Park in the Florida Keys was monitored. The numbers of corals and sponges were recorded by snorkelers using 3×3 m random individual quadrats or quadrats in a continuous tract. Seagrass density was recorded on an ordinal scale. Of the organisms examined, only *Manicina* sp. numbers showed a significant, although negative, correlation with seagrass; weak positive relationships between the numbers of *Chondrilla* sp. and *Chalinula* sp. sponges and between the *C. arbuscula* and *Porites* sp. corals were observed. Based on a comparison of the observed numbers with those in Poisson and negative binomial distribution models, all six species that appear have aggregated distributions. The degree of clumping was also quantified using several mathematical indices and was in general agreement with the Poisson probabilities, although when Morista's index is calculated, *M. areolata* clumping resulted in what is probably a high estimate. The data from the continuous grids were used to estimate the size and discreteness of the clumps; the species that had shown positive correlations had radii that were very similar.

### INTRODUCTION

While the ecology of sponges and corals in Florida reefs or on other hard bottoms has received deserved attention (Stevely et al., 1978; Dustan and Halas, 1987; Engel and Pawlik, 2005; Wade-Paige et al., 2005; Dupont et al., 2008; Yee et al., 2011; and others), in some tropical environments, such as seagrass beds, these organisms are less well known (Rutten, 2003).

Spatial patterns of sponges (Bell, 2007; Coggan et al., 2012) and some corals (Karisa et al., 2007) in studies outside the Florida/Caribbean zone seem to be correlated with particular environmental features. This often results in clumped distributions (Krebs, 1999). Deep water corals in the Red Sea show a highly clumped distribution (Fricke and Knauer, 1986), as do sponges in Torres Strait, northern Australia (Duckworth et al., 2009). Bell et al. (2010) found that sponges in Indonesia were predominately randomly distributed at the high coral cover site, but most sponges were negatively associated with other sponges at low coral cover sites prone to sedimentation.

Studies (Voss and Voss, 1955; Zieman, 1982) in the south Florida region have revealed the importance of complex seagrass coastal habitats. Waycott et al. (2009) warned that accelerating losses of seagrasses across the globe threaten the

immediate health and long-term sustainability of coastal ecosystems. They estimated that 58% of the world's seagrass meadows are currently declining, based on 1,800 observations dating back to 1879, and cited two primary causes for the decline: direct impacts from coastal development and dredging activities and the indirect impact of declining water quality. Populations of shallow water invertebrates are subject not only to normal long- and short-term fluctuations in seagrass environments but also to large-scale changes as a result of catastrophic events (Stevely et al., 2011). Although it is generally agreed that these seagrass habitats are important, there have been few quantitative studies on their invertebrate inhabitants. Most work has focused on the seagrasses themselves (Armitage and Fourqurean, 2006; Madden et al., 2009), or the invertebrate fauna studies have been either only qualitative or minimally quantitative (Zischke, 1973; Zieman, 1982). The purpose of the surveys reported here is to provide quantitative baseline estimates of the densities and distributions of some of the common sessile invertebrates in a semitropical seagrass bed.

### MATERIALS AND METHODS

*Study area.*—During the summers of 2011 and 2012, a seagrass bed dominated by turtle grass (*Thalassia testudinum*) directly off the eastern

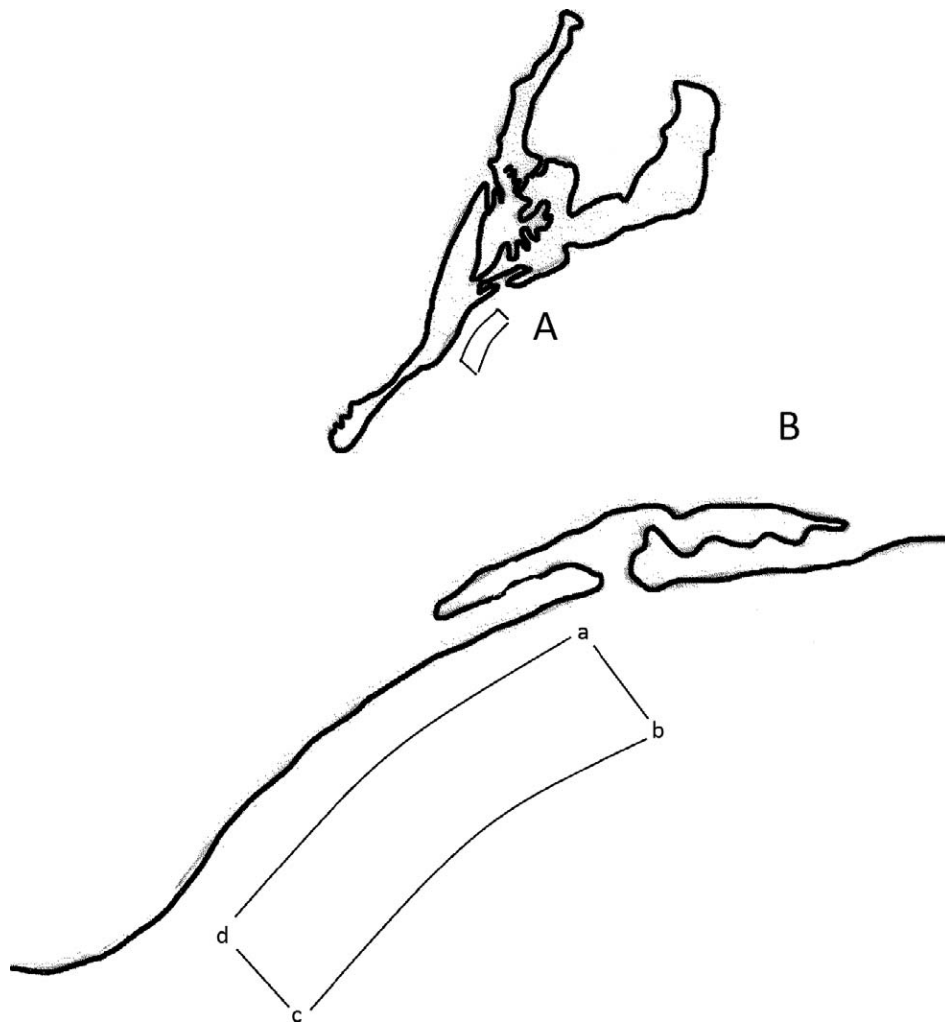


Fig. 1. Sampling area. (A) Sampling area in relation to Long Key, FL. (B) Detail of the sampling area where (a) 24°48.670'N 80°49.301'W, (b) 24°48.542'N 80°49.215'W, (c) 24°48.253'N 80°49.774'W, (d) 24°48.405'N 80°49.993'W. Sampling was done during low tide periods ( $\pm 2$  hr), when water depths were 0.5 to 1.5 m.

coast of Long Key State Park in the Florida Keys was monitored (Fig. 1). Data were collected during low tide periods ( $\pm 2$  hr), when water depths were 0.5 to 1.5 m; surveying at low tide ensured easier observations at the sample area's deeper limits. Quadrats of 9 m<sup>2</sup> were surveyed by two to four snorkelers; quadrats were marked by a chain square (3 × 3 m) held in place with plastic tent pegs. Observations were done using either random quadrats or quadrats in a continuous tract. In the random quadrats, the number and species of corals and sponges were recorded, and seagrass density was estimated on a scale of 1 (sparse) to 5 (dense), in a fashion similar to that of the Braun–Blonquet scale used by Fourqurean et al. (2001); 65 quadrats were surveyed for sponges in 2011, and 54 quadrats were used for

corals in 2012. The numbers of corals and sponges were also recorded in the adjacent quadrats along the continuous tracts; for the sponges, 50 quadrats along a 150-m continuous grid were used, while for the corals, a transect 270 m long was divided into 90 quadrats. Because of the nature of this study, only species that are easily and quickly identified in the field were counted, although other species were certainly present. These included (a) three sponges (*Tedania ignis*, Fire Sponge; *Chondrilla* sp., Chicken Liver Sponge; and *Chalinula* sp., Purple Finger Sponge) and (b) three hard corals (*Manicina areolata*, Rose Coral; *Porites* sp., Finger Coral; and *Cladocora arbuscula*, Tube Coral). Visual identifications were made on the basis of descriptions from many sources, but primarily from Voss

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TABLE 1. Densities and correlations.

Mean density $\pm$ standard deviation (individuals/m <sup>2</sup> )	Correlation probability estimates	First-order partial correlation coefficients and associated probability estimates	
Sponges			
<i>Tedania</i> 0.06 $\pm$ 0.12	<i>Tedania</i> and seagrass, 0.247	$r_{TedChon.Chal} = -0.13$	> 0.20
<i>Chondrilla</i> 0.04 $\pm$ 0.09	<i>Chondrilla</i> and seagrass, 0.261	$r_{TedChal.Chon} = -0.11$	> 0.20
<i>Chalinula</i> 0.19 $\pm$ 0.56	<i>Chalinula</i> and seagrass, 0.164	$r_{ChalChon.Ted} = 0.22$	< 0.10
Corals			
<i>Cladocora</i> 0.66 $\pm$ 1.35	<i>Cladocora</i> and seagrass, 0.82	$r_{CladPort.Man} = 0.248$	< 0.10
<i>Porites</i> 0.29 $\pm$ 0.33	<i>Porites</i> and seagrass, 0.22	$r_{CladMan.Port} = -0.008$	> 0.50
<i>Manicina</i> 0.02 $\pm$ 0.07	<i>Manicina</i> and seagrass, 0.02	$r_{PortMan.Clad} = -0.030$	> 0.50

(1976); Humann and DeLoach (2002); Landau and Gates (2005); Stevely et al. (2011); and South Florida Sponges ([http://www.nova.edu/ncri/sofla\\_sponge\\_guide/index.html](http://www.nova.edu/ncri/sofla_sponge_guide/index.html)).

**Statistics.**—Statistical analysis was done using Ecological Methodology Programs 7.2 (Exeter Software) and WinSTAT 2012.1 (R. Fitch Software). Densities, as mean numbers of individuals/m<sup>2</sup> ( $\pm$  standard deviation), were calculated for the sponges and the corals using the “only random quadrat” data. To determine if invertebrate densities were related to the *T. testudinum* density, the ordinal seagrass scores were compared to the sponge and coral counts using the Spearman’s nonparametric correlation test. To ascertain if there were sponge–sponge or coral–coral relationships, Pearson first-order partial correlation coefficients were calculated to quantify the relationship between two species while the effect of the third species was negated. For variance/mean ratios greater than 1.0, suggesting clumped distributions, the observed counts in the random quadrats were compared with the expected counts using a Poisson distribution as a model for randomness, and then the results were tested using a chi-square goodness-of-fit (Ludwig and Reynolds, 1988); this procedure was repeated using a negative binomial distribution as a model for clumped distributions. To compare the degree of clumping for the six species, using the counts from the random quadrats the Green’s Index of Dispersion (Green, 1966) was calculated, as was the Morisita’s Index of Dispersion (Morisita, 1962); the Morisita’s Standardized Coefficient (Smith-Gill, 1975) was also determined, which allowed us to statistically test ( $\alpha = 0.05$ ) clumping using one-tailed chi-square tests.

Using the quadrat counts from the continuous grids to look at the distributions of the sponges and corals, we applied the graphical two-term local quadrat variance (TTLQV) method developed by Hill (1973). With this method, “blocks” are groupings of adjacent quadrats; for example, a

block size of 3 refers to variances calculated when three combined adjacent quadrats are compared to other groupings of three adjacent quadrats. Block size is then graphed against the variance. Variance peaks occur at the radius of a species’ clump, so the distance between clumps is twice the block size where the variance is greatest. For example, a peak at a block size of 5 would mean a clump radius of 15 m in our experiment, since each original quadrat was 3 m. The variance values in the y-axis are an indication of the discreteness of the clumps.

## RESULTS

The mean densities of the sponges and corals are shown in Table 1. Of the organisms examined, only *M. areolata* numbers showed a significant correlation with seagrass; this relationship was negative (Spearman’s rank correlation coefficient,  $r_s = -0.316$ ). The Pearson first-order partial correlation coefficients indicate there is a weak positive relationship between the numbers of *Chondrilla* sp. and *Chalinula* sp. sponges and between the *C. arbuscula* and *Porites* sp. corals.

All six species had variance/mean ratios greater than 1.0 (Table 2) and, therefore, possibly had aggregated (clumped) distributions. The results for all species indicate that based on the Poisson distribution, randomness can be rejected. When the observed data were compared to the expected values generated by the negative binomial, four species were found to be in agreement with the negative binomial distribution, but the two species that seemed to display the greatest clumping, *Chalinula* sp. and *C. arbuscula*, were not in agreement. The degree of clumping is also shown in Table 2. Since all species had standardized coefficients greater than 0.5, all appeared to be significantly ( $\alpha = 0.05$ ) clumped. Certain differences can be observed when comparing Green’s and Morisita’s indices; in particular rose coral, *M. areolata*, looks to be less clumped than do the other

TABLE 2. Distribution parameters.

Sponges (S) and corals (C)	Variance/mean ratio	$\chi^2$ and probability estimates using a Poisson distribution as a model for expected randomness		$\chi^2$ and probability estimates using a negative binomial as a model for expected clumping		Green's index (degree of clumping)	Morisita's index (degree of clumping)	Morisita's Standardized Coefficient (degree of clumping)
<i>Tedania</i> (S)	2.268	145.143	< 0.0001	3.172	0.8686	0.037	3.387	0.5133
<i>Chondrilla</i> (S)	1.741	111.417	0.0002	1.165	0.9786	0.032	3.062	0.5081
<i>Chalinula</i> (S)	15.134	968.569	< 0.0001	45.458	0.0265	0.131	9.376	0.5639
<i>Cladocora</i> (C)	24.789	1,313.838	< 0.0001	111.919	< 0.0001	0.449	4.952	0.5367
<i>Porites</i> (C)	3.366	178.396	< 0.0001	10.889	0.6201	0.045	1.909	0.5071
<i>Manicina</i> (C)	2.208	117.000	< 0.0001	6.1933	0.2879	0.023	9.000	0.5522

species when the Green's index is calculated, but greater than four of the five others appear to be less clumped when the Morisita's index is used.

The results of the TTLQV calculations are shown in Figure 2. *M. areolata*, when plotted, gave a weak peak at only 0.05 variance units and is therefore not meaningful, nor is it presented in Figure 2. *T. ignis* aggregates seem somewhat small and diffused, having a peak of 0.32 variance units, lower than expected based on the Table 2 indices, and a mean clump radius of seven blocks. *Chondrilla* sp. and *Chalinula* had similar radii, being 26 m and 27 m, respectively. For the corals *C. arbuscula* and *Porites* sp., they had identical radii of 10 m and similar peaks of 51.3 and 86.6 variance units, respectively.

#### DISCUSSION

*M. areolata* numbers showed a significant negative correlation with seagrass, which is in agreement with the results obtained by Ruiz-Zarate et al. (2000), who found that in high-density seagrass zones the coral was under stress, as indicated by a lowered zooxanthellae density. They demonstrated a significant decrease in the number of zooxanthellae per square centimeter, even though Chlorophyll a (Chl a) per zooxanthella and Chl a per square centimeter were not affected, suggesting that stress resulted in either the expulsion or digestion of the symbionts due to low light conditions.

The weak positive relationship between *Chondrilla* sp. and *Chalinula* sp. sponges and between *C. arbuscula* and *Porites* sp. corals might be the result of positive interactions between these species pairs, but interactions between sessile invertebrates, including sponges and corals, are more likely to be negative (Wellington, 1980; Bak et al., 1982; Aerts and van Soest, 1997). Some sponges appear to produce chemicals that other sponges avoid (Engel and Pawlik, 2000; Kubanek et al., 2002); therefore, the more likely explanation for the positive partial correlations observed in this study is that the species have

similar microenvironmental preferences. It is interesting that the species pairs that have positive correlations (Table 1) had clump radii that were almost identical (Fig. 2), suggesting an underlying common factor.

Poisson models indicate that the distributions for all of the six species are nonrandom, and this, combined with the fact that all the variance/mean ratios were > 1.0, suggests that the distributions are clumped. Clumped distributions can often be modeled as negative binomials (Anscombe, 1949; Bowden et al., 1969). *Chalinula* sp. and *C. arbuscula*, which seemed to display the greatest degree of clumping, however, did not fit the negative binomial model, but as Taylor et al. (1979) pointed out, there are substantial limitations to using the negative binomial as a model for aggregation. In particular, it seems to be inconsistent in measuring aggregation, as we found here.

With respect to the indices of clumping, the scarcity of *M. areolata* in the study area ( $0.02 \pm 0.07/m^2$ ) makes some statistical conclusions about that species suspect, in particular the contrast between the Green's index and Morisita's index. Green's index is based on Poisson series expectations, while Morisita's, derived from information theory, makes use of counts of individuals in separate quadrats, so it is sensitive to sample size. When *M. areolata* is removed from the data set, it becomes clear, using both indices, that *Chalinula* sp. and *C. arbuscula* are both strongly clumped, while the other three species of sponges and corals show moderate clumping. Using Green's index, *Chalinula* sp. seems to be less clumped than *C. arbuscula*, but this is not true when Morisita's index is used; the agreement with variance peaks in the TTLQV plots suggests that Morisita's index may be more useful in studies of sessile benthic invertebrates in seagrass environments, at least when the sample sizes are not too small. *Chalinula* in the Red Sea were found to have very short planktonic larval periods and usually settled within 4.5 hr, followed by a rapid

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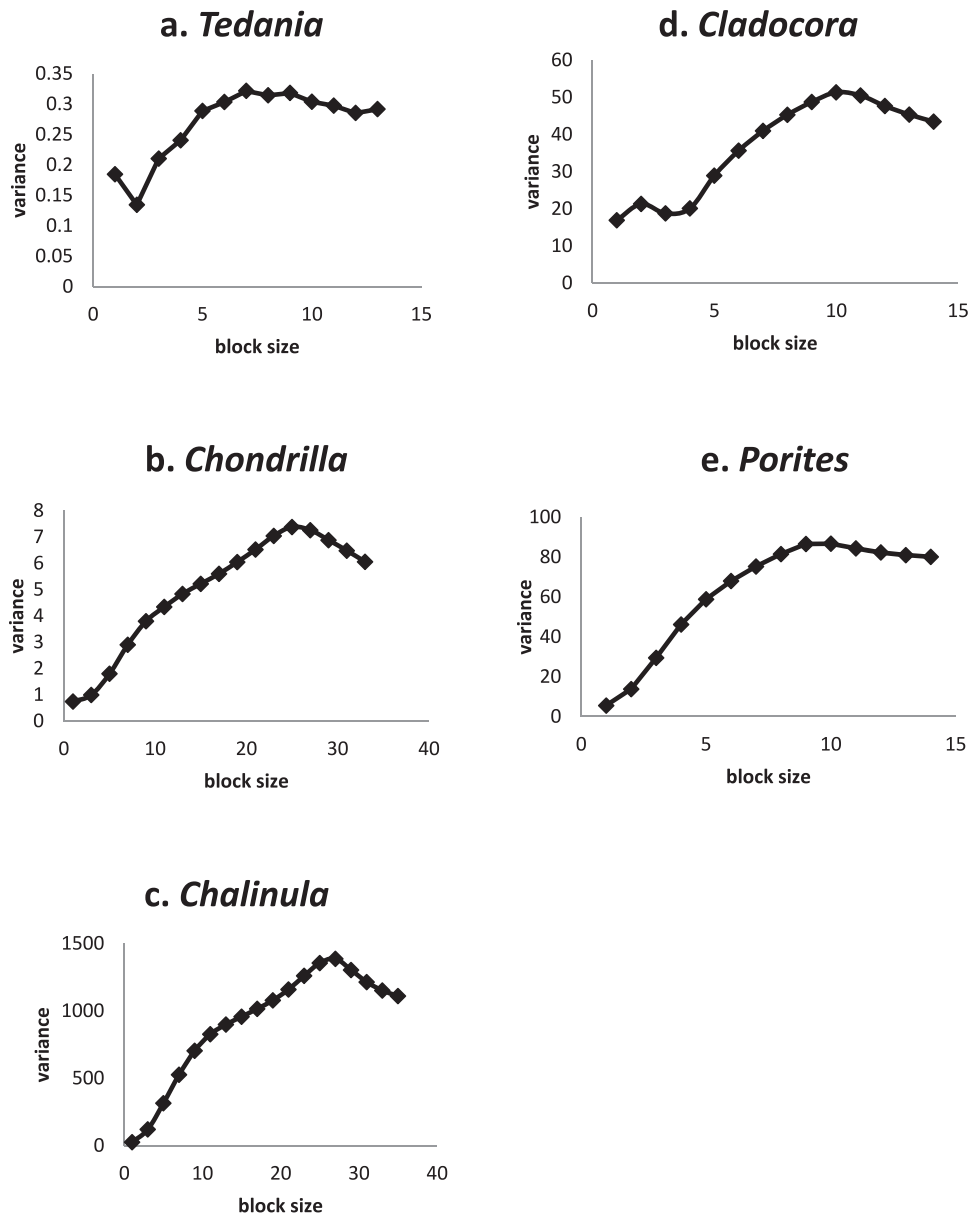


Fig. 2. TTLQV plots.

metamorphosis lasting only 1 to 6 hr (Ilan and Loya, 1990), and this might contribute to its significant clumping (Table 2; Fig. 2).

Concerning the other two species of sponges, *Chondrilla* sp. seems to be less distinctly clumped than *T. ignis*. *T. ignis*, which has been found in a variety of seagrass bed environments (Kuenen and Debrot, 1995), has larvae that seem to prefer settlement in shaded areas (Maldonado and Young, 1996). *Chondrilla* sp. does not seem to be especially affected by light (Wilkinson and

Vacelet, 1979), which might explain the smaller indices we observed. The coral *C. arbuscula* was more common (Table 1) and had greater clumping indices (Table 2) than did *Porites* sp., even though several studies of local seagrass environments document the presence of *Porites* and not of *C. arbuscula* (Zischke, 1973; Zieman, 1982). Fragmentation of corals seems to be a function of shape (Smith and Hughes, 1999); *C. arbuscula* is a branching coral and may be more prone to fragmentation than is *Porites*. Like some

corals, the distribution patterns of many sponges may also be related to their asexual reproduction (fragmentation or budding). In seagrass habitats, the dispersal of fragments could be limited to a few tens of meters, as they can quickly become trapped between the seagrass blades. *C. arbuscula* is also resistant to the effects of suspended sediments and burial (Rice and Hunter, 1999), conditions that might co-occur with fragmentation. It is possible that the *C. arbuscula* density and clumping is the result of this asexual propagation.

This survey provides quantitative baseline estimates of the densities and distributions of some of the common sponges and corals in a semitropical seagrass bed. While *M. areolata* densities were low, compared to those found in more tropical environments (Johnson, 1992; Ruiz-Zarate et al., 2000), for which reason we are loath to draw conclusions about its spatial distribution, the other corals and sponges were clearly in aggregate distributions. Clump radius estimates for seagrass bed sessile invertebrates have not been reported and may give some insight concerning microenvironmental preferences. This clumping is especially intriguing in light of the fact that species that seem to be found in association, as seen using the first-order partial correlation coefficients, also have very similar clump radii.

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