SPONGE DISTRIBUTION AND CORAL REEF COMMUNITY STRUCTURE OFF MACTAN ISLAND, CEBU, PHILIPPINES

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Coral reef community structure was studied during 1994-95 at Mactan Island, off Cebu City, Cebu, Philippines. Three transect lines perpendicular to the shore were surveyed from depths of 7-32m. Transect slack line distances were 55-68m long. Live hard coral represented 29-42% (mean=36%) of categories intercepted and sponges 1-5% (mean=3%), representing the two most abundant groups of benthic organisms. All remaining benthic taxa together comprised only an average of 1% of the intercept distance. The number of sponges intercepted along each line ranged from 4-19 (mean=12). Approximate sponge densities from line intercept data ranged from 1/20m^2 to 1/250m^2 (mean=1/40m^2) and were typically large specimens. Sponge densities off Mactan Island were considerably lower and species richness much higher than that of the Caribbean. A transition frequency matrix was calculated for all line intercepts and a test for a Markov chain was conducted. The most frequently encountered sequence was coral rubble followed by live hard coral (11% sequence frequency). Live hard coral followed by sponges was 5% and sponges followed by live hard coral was 5%. In a similar study of the benthos with five line intercepts parallel to the shore at depths of 7-12 m, the most frequently encountered sequence was live hard coral to sponge and sponge to live hard coral (36%). Sponge to sponge transitions represented 4%. None of the sequences were significant at P=0.05; i.e. the succession of substratum types were independent of each other, supporting the null hypothesis. ❐ *Porifera, Philippines, coral reef, community ecology, benthic, densities, Markov Chains, transects.*

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Field studies on sponges in the Philippines by our group have been ongoing since 1994. Several species of sponges were found to be toxic to fishes and hard corals and research on the effects of three species of allomone-secreting subtidal sponges on adjacent corals are continuuing (Nishiyama, 1999, this volume). Sponges and other marine taxa of the Philippines are poorly known. Gomez (1980) lists 16 publications on marine sponges for the Philippines and few have appeared since that time (e.g., Raymundo & Harper, 1995). No quantitative studies on sponges have been carried out in the Philippines, so far as is known. Therefore, the major objectives of this study were: 1) to determine sponge distribution and abundance and compare it with similar data from other tropical regions, and 2) to characterise coral reef community structure as a basic framework for our continuing research on toxic sponges.

MATERIALS AND METHODS

Coral reef community structure and sponge distributions were studied between 1994-1996 off the Tambuli Resort, at Mactan Island (an 18km × 6km, 7750ha, flat, low limestone reef), off Cebu City, Cebu, Philippines (Fig. 1) (10°17'N, 124°0'E). This site is located approximately 400m N of the University of San Carlos Maribago Marine Station. The Hilutangan Channel between Mactan and Olango Islands is a 300m deep trench (von Bodungen et al., 1985). A gently sloping reef extends to a depth of 10m on each side of the channel then typically, abruptly plunges steeply downward. The slope off the Tambuli resort is considerably less steep. Oceanographic characteristics of channel waters are found in von Bodungen et al. (1985), Anon. (1991a,b) and Ilano & Dacles (1994).

Three line intercepts perpendicular to the shoreline were surveyed 10m apart from 7-32m depth with slack line distances of 55-68m. Five additional line intercepts were surveyed parallel to the shore at depths of 7, 8, 10, 11 and 12m, with slack line distances of 100m, excepting the 12m line, which was 70m in slack length (slack length partially follows the reef contour and the tape is

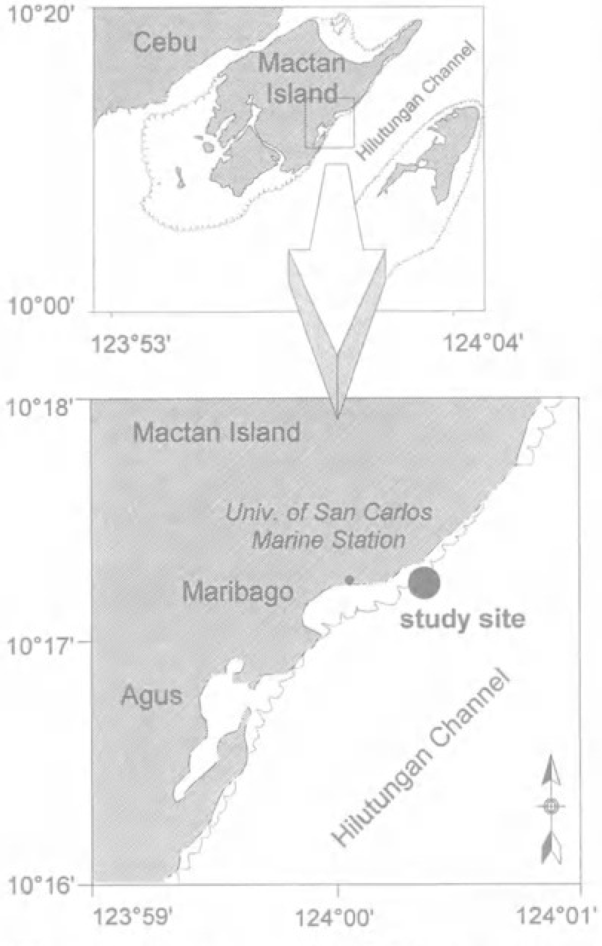

FIG. 1. Mactan Island, Cebu, Philippines, showing study site.

easy to deploy for measurements; see Reichelt et al., 1986, for methodology on reef transects).

Organisms and substrata encountered along transects were recorded as line intercept distances. Most organisms were individuals or single colonies rather than conspecific patches. Toxic sponges reported by Nishyamand Bakus (1999, this volume) were most abundant at depths of 7-12m. The number of transitions between sequences of organisms and substrata was tallied. The null hypothesis was that the sequence of occurrences of benthic organisms and substratum types along transect lines (depth gradients) are random. The results were tested for a Markov chain (i.e. tendency of one thing to be followed by another, as in repeated textile patterns) by the non-parametric chi-square statistic. Markov chain analyses of sequences are commonly used in stratigraphy (Davis, 1986) and in the prediction of plant succession after fires (Isagi & Nakagoshi, 1990). The present study is the second use of Markov chain analysis in coral reef community structure (after Licuanan & Bakus, 1992), so far as is known. There do not appear to be null models developed for Markov-type chain analyses dealing with sequences of substratum types where the species are unidentified (Gotelli & Graves, 1996).

Approximate sponge densities were calculated using a modified Strong's equation (Cox, 1996), as follows:

$$D = (\Sigma\ 1/M)(A/T)$$

where D=density of sponges (no./m^2); M= maximum animal or plant orthogonal width (m) of an organism intercepting the transect line; A= unit area (1m^2); T= total transect length (m).

RESULTS

Line intercept or line transect surveys are recognised as one of the best methods of studying coral reef organisms (e.g. Loya, 1978; Marsh et al., 1984; Reichelt et al., 1986). We compared different sampling methods in the field in Kenya and found that line intercepts gave us density estimates closest to those of actual counts. For example, the densities (no./m^2) of *Padina* (P) on a reef near Mombasa in 1997 and *Ipomoea* (I) leaves on a flat berm at Malindi in 1998 were as follows: actual count (P-10, I-14), point-center quarter (P-2, I-32), stratified random sampling (P-20, I-19) and line intercept (P-16, I-14). The major advantage of using intercept width measurements for density estimates is that the technique is about an order of magnitude more rapid than are direct counts or quadrat studies of organisms underwater. One advantage of using transects both perpendicular and parallel to the shore is that allelochemical effects can be directional (i.e. directional currents) and using only one transect orientation might overlook transitions resulting from such chemicals.

TRANSECTS PERPENDICULAR TO SHORELINE. Live hard coral represented 29-42% (mean=36%) of categories intercepted and sponges 1-5% (mean=3%), representing the two most abundant groups of benthic organisms (Table 1). The standard errors (SE) of the percentage intercept of common categories were relatively small whereas those of the least abundant categories were considerable, due mostly to small numbers. Obviously, increased sample size would improve the results. All remaining large benthic taxa together comprised only an average of 1% of the intercept distance. The number of sponges along each intercept ranged from 4-19 (mean=12). Sponge

TABLE 1. Mactan Island transects, perpendicular to shoreline (7-32m depth regime), showing percentage of total intercept distance ([1]=seagrass was avoided after the first transect).

Category	Line 1	Line 2	Line 3	Mean % ± SE
Live Coral	35	42	29	36 ± 4
Sand	19	24	32	25 ± 4
Coral Rubble	25	22	22	23 ± 1
Dead Coral	7	6	15	9 ± 3
Seagrass[1]	9	-	-	3 ± 3
Sponges	3	5	1	3 ± 1
Other Organisms	2	1	1	1 ± 0.03
Total %	100	100	100	100
Slack Line Distance (m)	55	62	68	62
No. Sponges Measured	14	19	4	12
Total Sponge Width (cm)	111	323	33	156
Sponge Density (No./m^2)	0.02	0.05	0.004	0.025
Sponge Density Converted (No./m^2)	1/50	1/20	1/250	1/40

approximate density from line intercept data ranged from $1/20m^2$ to $1/250m^2$ (mean=$1/40m^2$) and were typically large specimens (Table 1). The most frequently encountered sequence was coral rubble followed by live hard coral (11% sequence frequency) (Table 2A). Live hard coral followed by sponges was 5% and sponges followed by live hard coral was 5%. None of the sequences were significant at P=0.05 (calculated χ^2=0.19; DF=24); i.e. the succession of organisms and substrata were independent of each other. This supports the null hypothesis.

TRANSECTS PARALLEL TO SHORELINE. The sponge percentage of the total transitions increases rapidly from 7-10m depth, then changes rapidly again between 11-12m depth (Table 2B). The most frequently encountered sequence was live hard coral to sponge and sponge to live hard coral (total combined=36%) (Table 2C). Sponge to sponge transitions represented 4%. Sponges were most frequently associated with live coral, dead coral and coral rubble. Again, the sequence of organisms and substrata were independent of each other at P=0.05 (calculated χ^2=12.9; DF=25). This supports the null hypothesis.

DISCUSSION

Beyond the shallow water seagrass community (0-8m depth; principally *Thalassia hemprichii*), sponges represented the second most dominant invertebrate taxon (after hard corals), comprising 1-5% (mean=3%) of intercept distances (depth 7-32m) and 5-28% of transitions. The transition percentage between sponges and live hard corals was 10% for depths of 7-32m and 36% for depths of 7-12m. The dominance of sponges (after hard corals) is typical of the Caribbean but sponge abundance can be considerably greater in the Caribbean than in the Philippines (Table 3). For example, Zea (1994) found that sponges of Santa Marta, Colombia, were an average of about four times as abundant as the sponges of Mactan Island. The species richness and irregular distribution of individual sponges at Mactan Island, however, were considerably greater than at Santa Marta. Species richness can be high in the Caribbean. Alcolado (1979) reported 47 species of sponges at depths of 11-16m in Havana, Cuba. This rough inverse relationship between species richness and abundance was expected (Krebs, 1994).

As in the Caribbean, the sponges of Mactan Island represent the second most important taxon of benthic invertebrates after hard corals. Although there is no universally recognised system of classifying coral reefs based on percentage cover, one frequently used rule of thumb would consider that a 36% coverage (the Mactan Island study site) represents a moderately rich coral reef.

The reefs at Mactan Island are probably not as rich as they were 20 years ago because of dense development of coastal resorts and concomitant anthropogenic effects (principally sewage effluents). The 1997-98 El Niño may have caused the death of many hard corals and the disappearance of numerous toxic sponges in our study area (Nishiyama, unpublished data).

TABLE 2. Mactan Island transects. A, transects perpendicular to shoreline, running from onshore to offshore, showing transition frequencies ([1]=unbroken dead coral substratum). B, transects parallel to shoreline, showing sponge transitions by depth ([2] =100m slack length except for 12m depth transect which was 70m long). C, transects parallel to shoreline, showing sponge transition frequencies.

A. Category	% Total transition frequencies
Coral Rubble to Live Coral	11
Live Coral to Coral Rubble	9
Live Coral to Sand	8
Sand to Live Coral	8
Live Coral to Live Coral	8
Dead Coral[1] to Live Coral	6
Live Coral to Sponges	5
Sponges to Live Coral	5
Live Coral to Dead Coral	5
Others (numerous transition categories)	35
Total	100

B. Depth (m)	Total no. of transitions[2]	Sponge % of total transitions	No. sponges	Mean (± SE)
7	256	5	6	
8	371	11	16	
10	426	15	32	27±7
11	396	16	31	
12	365	28	48	

C. Category	Percentage of total transitions
Live Coral to Sponge	18
Sponge to Live Coral	18
Sponge to Dead Coral	12
Coral Rubble to Sponge	10
Sand to Sponge	8
Sponge to Sand	8
Dead Coral to Sponge	6
Sponge to Coral Rubble	6
Sponge to Algae	5
Sponge to Sponge	4
Algae to Sponge	3
Others	2
Total	100

The somewhat abrupt change in sponge percentage of total transitions (Table 2B) between depths of 7-10m was the result of the disappearance of seagrass (i.e. it is the edge of the shallow water seagrass community) with a concomitant increase in sponges. The marked increase in sponge transitions at a depth of 10-12m was similar to that recorded by Alcolado (1979) for sponges at depths of 11-16m off Havana, Cuba (Table 3). Presumably this depth is optimal because it provides sufficient light for photosynthesising symbionts and is below the depth of major destruction by hurricanes and typhoons.

None of the transitional sequence patterns of organisms or substrata at Mactan Island were statistically significant, thus the null hypothesis is supported. This was because species richness was very high and individual distributions highly irregular. Tropical island forests show the same patterns (e.g. Fiji Islands, Bakus, pers. obs.). Significant sequential patterns of the benthos would be expected to occur only at larger scales (e.g. community scale changes such as transitions from coral to seagrass) (Isagi & Nakagoshi, 1990).

Bradbury & Young (1983) concluded that hard coral distributions on the Great Barrier Reef were random. This was based on the fact that only 5 species pairs out of 545 species pairs were not random. They concluded that coral interactions on a small scale do not produce random neighbours. They also concluded that random neighbours express the combined workings of many effects but did not specify what those factors were. Licuanan & Bakus (1992) found random distributions of Philippine reef organisms at a depth of 12m at Puerto Galera but a significant non-random unidirectional pattern at 6m depth, possibly the result of strong longshore currents. The possible reasons for the random distributions of benthic organisms are complex and include high species richness (Bakus & Ormsby, 1994), fish predation and grazing on benthic organisms (Bakus, 1964, 1967, 1969), predation on planktonic stages of benthic species (Gili & Coma, 1998), perhaps allelochemical defenses (Bakus et al., 1986, 1989/90) and other factors such as currents (Licuanan & Bakus, 1992). A discussion of these topics is beyond the scope of the present paper.

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TABLE 3. Comparisons of sponge densities (as percentage of intercept distance, ID) between Indo-Pacific and Caribbean localities (?=densities could not be determined from the published data).

Location	Depth (m)	Method	Density (range)	Density (mean)	Source of data
Indo-Pacific					
Cebu, Philippines	7-32	Line intercept	1-5% ID 1/50-1/250 m^2	3% ID 1/40 m^2	this study
Flinders Reef flats, Coral Sea, Australia	1-4	Quadrats	7.3% ID	?	Daniel et al. in Wilkinson (1987)
Caribbean					
Santa Marta, Colomia	17-22	Chain transects	5-24% ID	13% ID	Zea (1994)
Roques National Park, Venezuela	1-35	Quadrats	?	1/2 m^2	Alvarez et al. (1990)
Biscayne National Park, Florida Keys, USA	1-18	Quadrats	3-18/m^2	8/m^2	Schmahl (1990)
Havana, Cuba	1-17 11-16	Quadrats Quadrats	0-15/m^2 15/m^2	6/m^2 ?	Alcolado (1979)

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LITERATURE CITED

ALCOLADO, P.M. 1979. Ecological Structure of the sponge fauna in a reef profile of Cuba. Pp. 297-302. In Lévi, C. & Boury-Esnault, N. (eds) Sponge Biology. Éditions du Centre National de la Recherche Scientifique (291) (CNRS: Paris).

ALVAREZ, B., DIAZ, M.C. & LAUGHLIN, R.A. 1990. The sponge fauna on a fringing coral reef in Venezuela, I: composition, distribution, and abundance. Pp. 358-366. In Rutzler, K. (ed.) New Perspectives in Sponge Biology. (Smithsonian Institution Press: Washington DC).

ANONYMOUS 1991a. Pacific Cebu Report. Baseline Marine Resource Assessment. Final Report, July. Pp. 1-56. (University of San Carlos, Marine Biology Section: Cebu, Philippines).

1991b. Environmental Impact Study of proposed reclamations in the Municipalities of Lapulapa City, Cordova and Consolacion. Part 2. Cordova. Area Research and Training Center. Department of Marine Biology, Water Resources Center. (University of San Carlos, Marine Biology Section: Cebu, Philippines).

BAKUS, G.J. 1964. The effects of fish grazing on invertebrate evolution in shallow tropical waters. Allan Hancock Foundation Occasional Papers (27): 1-29.

1967. The feeding habits of fishes and primary production at Eniwetok, Marshall Islands. Micronesica 3: 135-149.

1969. Energetics and feeding in shallow marine waters. International Revue of General and Experimental Zoology 4: 275-369.

BAKUS, G.J. & ORMSBY, B. 1994. Comparison of species richness and dominance in northern Papua New Guinea and Northern Gulf of Alaska. Pp. 169-174. In Soest, R.W.M. Van, Kempen, T.M.G. van & Braekman, J.C. (eds) Sponges in Time and Space. (Balkema: Rotterdam).

BAKUS, G.J., TARGETT, N.M. & SCHULTE, B. 1986. Chemical ecology of marine organisms: an overview. Journal of Chemical Ecology 12(5): 951-987.

BAKUS, G.J., STEBBINS, T.D., LLOYD, K., CHANEY, H., WRIGHT, M.T., BAKUS, G.J., PONZINI, C., EID, C., HUNTER, L., ADAMCZESKI, M. & CREWS, P. 1989/90. Unpalatability and dominance on coral reefs in the Fiji and Maldive Islands. Indian Journal of Zoology and Aquatic Biology 1&2(1): 34-53.

BODUNGEN, R. VON, BALZER, W., BÖLTER, M., GRAF, G., LIEBEZEIT, G. & POLLEHNE, F. 1985. Chemical and biological investigations of the pelagic system of the Hilutangan Channel (Cebu, Philippines). The Philippine Scientist 22: 4-24.

BRADBURY, R.H. & YOUNG, P.C. 1983. Coral interactions and community structure: an analysis of spatial pattern. Marine Ecology Progress Series 11: 265-271.

COX, G. W. 1996. Laboratory Manual of General Ecology. 7th Edition. (William C. Brown: Dubuque).

DAVIS, J.C. 1986. Statistics and Data Analysis in Geology. (John Wiley & Sons: New York).

GILI, J-M. & COMA, R. 1998. Benthic suspension feeders: their paramount role in littoral marine food webs. TREE 13(8): 316-321.

GOMEZ, E.D. 1980. Section K, Porifera. Pp. 35-36. In Bibliography of Philippine marine science - 1978. (Filipinas Foundation, Inc. and Marine Sciences Center, University of the Philippines: Manila).

GOTELLI, N.J. & GRAVES, G.R. 1996. Null Models in Ecology. (Smithsonian Institution Press: Washington, DC).

ILANO, A.S. & DACLES, T.P.U. 1994. Environmental key parameters, light, temperature and salinity. Pp. 15-18. In Schramm, W. & Dy, D.T. (eds) Energy flow and nutrient exchange in a tropical fringing reef. Research Paper, FIMFS Consortium summer course, 4 April to 4 May, 1994 (University of San Carlos, Marine Biology Section: Cebu, Philippines)

ISAGI, Y. & NAKAGOSHI, N. 1990. A Markov approach for describing post-fire succession of vegetation. Ecological Research 5: 163-171.

KREBS, C.J. 1994. Ecology. 4th Edition. (Harper Collins College Publishers: New York).

LICUANAN, W.Y. & BAKUS, G.J. 1992. Coral spatial distributions: the ghost of competition past roused? Pp. 545-549. In Proceedings of the 7th International Coral Reef Symposium. Vol. 1 (University of Guam: Agana, Guam).

LOYA, Y. 1978. Plotless and transect methods. Pp. 197-218. In Stoddart, D.R. & Johannes, R.E. (eds) Coral reefs: research methods. (UNESCO: Paris).

MARSH, M., BRADBURY, R.H. & REICHELT, R.E. 1984. Determination of the physical parameters of coral distributions using line transect data. Coral Reefs 2: 175-180.

RAYMUNDO, L.J.H. & HARPER, M.K. 1995. Notes on the ecology and distribution of sponge genera (Porifera: Demospongiae) of the central Visayas, Philippines. Pp. 39-52. In Proceedings of the 3rd National Symposium on Marine Science. Philippine Scientist, Special Issue (1995).

REICHELT, R.E., LOYA, Y. & BRADBURY, R.H. 1986. Patterns in the use of space by benthic communities on two coral reefs of the Great Barrier Reef. Coral Reefs 5(2): 73-80.

SCHMAHL, G.P. 1990. Community structure and ecology of sponges associated with four southern Florida coral reefs. Pp. 376-383. In Rutzler, K. (ed.) New Perspectives in Sponge Biology. (Smithsonian Institution Press: Washington DC).

WILKINSON, C.R. 1987. Productivity and abundance of large sponge populations on Flinders Reef flats, Coral Sea. Coral Reefs 5: 183-188.

ZEA, S. 1994. Patterns of coral and sponge abundance in stressed coral reefs at Santa Marta, Colombian Caribbean. Pp. 257-264. In Soest, R.W.M., Van Kempen, T.M.G. & Braekman, J.C. (eds) Sponges in Time and Space. (Balkema: Rotterdam).

SPONGES, INDICATORS OF MARINE ENVIRONMENTAL HEALTH. *Memoirs of the Queensland Museum 44: 50. 1999*:- There is an urgent need for marine ecosystem indicators to facilitate management aimed at either ameliorating impacts or guiding sustainable utilisation of marine resources. We propose that qualitative and quantitative examination of marine benthic communities will provide robust indication of responses to short and long term environmental conditions, and further suggest that information exists which permits the creation of a hierarchy of indicators for establishing ecosystem health in a regional context. These are in the form of identifiable marine community assemblages, together with biomass and growth indices determined from morphological parameters associated with the characterising species for each assemblage. Examples are provided to demonstrate the sensitivity of such indicators by focusing on sponge characterised communities. The composition of assemblages and population statistics of key species reflect ecosystem disturbances following catastrophic sediment deposition following cyclones, and in response to more recent and relatively short-term impacts. The latter include responses to sediment disruption from trawling and sand mining, and responses to water quality change during algal bloom events.

Marine environmental indicators are likely to take the form of well-defined ecotypes described by characterising species presence. These species have known ranges of tolerance to environmental variables such as light, current, food supply, turbidity, BOD, and sediment regime. They are by their very nature, relevant at a regional level and will be set in the context of a biogeographic classification for any coast or shelf. They can be further refined by interrogation of models relating population structure of key species to biological and physical attributes of the environment. ❒ *Porifera, growth, morphology, indicators, environmental health, marine resources, benthic communities.*

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