DISTRIBUTION PATTERNS OF THE MEIOFAUNA IN CORAL REEFS FROM THE NW SHELF OF CUBA.

M. Armenteros [1] *, B. Creagh [1] and G. González-Sansón [1]

(1) Centro de Investigaciones Marinas, Universidad de La Habana. Calle 16 No. 114, Playa, CP 11300, Ciudad Habana,
(*) Corresponding author: Email: maickel@cim.uh.cu

ABSTRACT

The meiofauna from 39 stations were surveyed in coral reefs from the NW shelf of Cuba to describe distribution patterns across five habitats. Temperature and salinity were homogeneous among habitats due to an extensive water exchange between the shelf and adjacent oceanic waters. The sedimentary environment in seagrass meadows was different compared to the other adjacent reef habitats (i.e. higher organic content and smaller grain size). Composition of the meiofauna changed across habitats; harpacticoid copepods tended to be more abundant in well sorted substrates; and nematodes predominated in finer sediments possibly due to their tolerance to hypoxic conditions. The high similarities in the meiofauna composition among reef habitats (patch reef, spur and groove, sandy and rocky flat), despite of different topography and dominant megafaunal groups, suggested the importance of sediment particle size as a factor influencing community structure. Meiofauna were more abundant in reef flats characterized by low topographical complexity, paucity of fishes and large macrofauna, and high exposure to water flow. Relative low densities of meiofauna in reef and muddy habitats from the NW region may be caused, at least partially, by oligotrophic conditions of the sediments.

Key words: meiofauna; coral reefs; seagrass meadows; distribution patterns; ASW, Cuba.

RESUMEN

Se estudió la meiofauna en 39 estaciones en arrecifes coralinos de la plataforma NW de Cuba para describir los patrones de distribución en cinco hábitats. La temperatura y la salinidad fueron homogéneas a través de los hábitats debido al intercambio amplio entre las aguas de la plataforma y las oceánicas. El ambiente sedimentario en los pastos marinos fue diferente al de los otros hábitats arrecifales adyacentes (i.e. más alto contenido orgánico y tamaño de partícula más pequeño). La composición de la meiofauna cambió a través de los hábitats; los copépodos harpacticoides fueron más abundantes en sustratos arenosos, y los nemátodos predominaron en sedimentos más finos posiblemente debido a su tolerancia a condiciones hipóxicas. Existió similitud alta en la composición de la meiofauna entre hábitats arrecifales (cabezos, camellones, plano arenosos y planos rocosos) a pesar de su diferente topografía y grupos dominantes de megafauna; esto sugiere la importancia del tamaño de partícula como factor que influencia la estructura de la comunidad. La meiofauna fue más abundante en planos arrecifales caracterizados por baja complejidad topográfica, escasez de peces y macrofauna grande y alta exposición al flujo de agua. La relativa densidad baja de meiofauna en hábitats arrecifales y fangosos de la región NW pueden ser causados, al menos en parte, por las condiciones oligotróficas de los sedimentos.

Palabras clave: meiofauna; arrecifes coralinos; pastos marinos; patrones de distribución; ASW, Cuba.

The NW shelf of Cuba includes an extensive bank reef system more than 200 km long (Alcolado *et al.*, 2003) called Los Colorados; this is probably the least studied of the large reef systems from Cuba (González-Sansón and Aguilar-Betancourt, 2004). Los Colorados reef system contains a mosaic of tropical habitats associated with reef structures including: seagrass meadows, rocky flats, sand flats, spur and grooves and patch reefs. In the eastern portion of the NW shelf, the topography of coral reefs is different from western part, with a relatively narrow fringe of corals along the coast (i.e. coastal fringe reef).

Communities of conspicuous taxonomic groups (e.g. fishes, stony corals, seaweeds) associated to coral reefs have been extensively studied in widespread regions from tropical shallow waters. Regarding to meiofauna (here defined as metazoans passing through a 500 μm mesh sieve and retained on 45 μm mesh), relatively few studies on their ecology have been carried out (e.g. Boucher and Gourbault, 1990; Gamenick and Giere, 1994) in Atlantic habitats associated to reef systems.

Meiofaunal communities play an important ecological role (Coull, 1999; Danovaro *et al.*, 2004) in the mineralization of organic matter and they act as a link between detritus and higher trophic levels in tropical habitats. Several advantages of meiofauna as environmental indicator of habitat health (see Heip *et al.*, 1988; Kennedy and Jacoby,

1999) suggest the use of this group as a tool in the detection and monitoring of anthropogenic impact. Nevertheless, few studies (e.g. López-Cánovas and Lalana, 2001; Armenteros *et al.*, 2003) have been published on the meiofauna living in sediments associated with coral reefs in Cuba.

The importance of meiofauna on ecosystem dynamics, the increase of human activities in the region (e.g. exploitation of gas and oil) and the lack of background information on this faunal group, suggest the creation of a baseline research on the aforementioned communities. Therefore, this study attempts to compare the structure of meiofaunal communities along several tropical habitats associated to coral reefs (or coral structures) at the extensive region of NW shelf of Cuba.

MATERIALS AND METHODS

The meiofauna from 39 stations were sampled on June 2004 in the NW shelf of Cuba (Fig. 1). Each sampling station was classified after a type of habitat associated to coral reef. Only habitats that contained areas with soft sediment (e.g. sand) were selected; i.e. no reef crest or reef slope habitats were sampled.

i) Patch reef. Isolated rocky structures (4-5 m height with high topographical complexity and high abundance of reef fauna (e.g. fishes, crustaceans, stony corals); the structures were surrounded with sand and the samples were taken in this soft-bottom sediment.

ii) Seagrass meadow. Soft bottoms covered by a variable extension of the seagrass *Thalassia testudinum.* The seagrasses *Syringodium filiforme* and *Halodule wrightii* may also be present. The presence of epiphytes on seagrass blades was very common, and the percentage cover was very variable. This habitat was fundamentally located in the lagoon of reef systems.

iii) Spur and Groove. Long and narrow rocky structures with grooves of sand between them; the samples were taken into the sand deposited in the grooves. The habitat was located between the reef slope and sand flat.

iv) Rocky flat. Extensive flats of rocky bottom with relative small patches of sand (in depressions or holes) or partially covered by carbonate sand (generally as a thin layer less than 10 cm thickness). The presence of conspicuous gorgonians (e.g. *Gorgonia, Pterogorgia, Pseudopterogorgia, Eunicea*) in the habitat was common.

v) Sand flat. Extensive flats of sandy sediment. The presence of vegetation was scarce or absent and the topographical complexity was very low. It is located generally prior the spur and groove structures (in seaward direction).

In each station two cores of 6.16 cm^2 of area were taken for the meiofauna to a depth of 10 cm, and an additional core was taken for determining the percentage of silt/clay. Depth, salinity and bottom-water temperature were measured in situ with an oceanographic probe 4a from Hydrolab Inc.

Samples of meiofauna were preserved in buffered 4 % formalin and processed in the laboratory. Sediment was sieved through 500 and 45 µm meshes, and the material retained on the last sieve was used for extraction of meiofauna. The sorting of animals from the sediment was carried out with a flotation technique in high density solution (commercial sugar crystals plus tap filtered water, 1.18 g cm^{-3}). Decantation was repeated three times in order to increase the efficiency of extraction. The sorted animals were stained out with alcoholic 1% eosin and preserved in buffered 4% formalin. The identification of animals to the major taxa (e.g. nematodes, harpacticoid copepods) was performed under Zeiss stereomicroscope (56X maximum).

Sediment samples for grain size determination were dried out at 70°C for 72 h, weighted and then wet sieved through a 63 µm mesh; the fraction retained in the sieve was dried and weighted again. The percent of silt/clay (S/C) was calculated by difference [i.e. % S/C = (total weight – retained material weight) * 100/ total weight].

The PRIMER 5.2.9 Software (Clarke and Warwick, 2001) was used for data analysis. Similarity matrices were built on meiofauna density data using the Bray-Curtis coefficient. Data were transformed (square root) in order to decrease the contribution of the most abundant taxa (i.e. nematodes and copepods) on the community structure. One-way ANOSIM test was performed on similarity matrix to test differences between habitats. In order to detect differences between each pair of habitats, pairwise tests were performed. Non-metric Multidimensional Scaling (MDS) ordination was carried out for ordination of samples arranged by habitats. Some missing data in abiotic factor matrix prevent to apply BIOENV procedure looking for matching between all abiotic

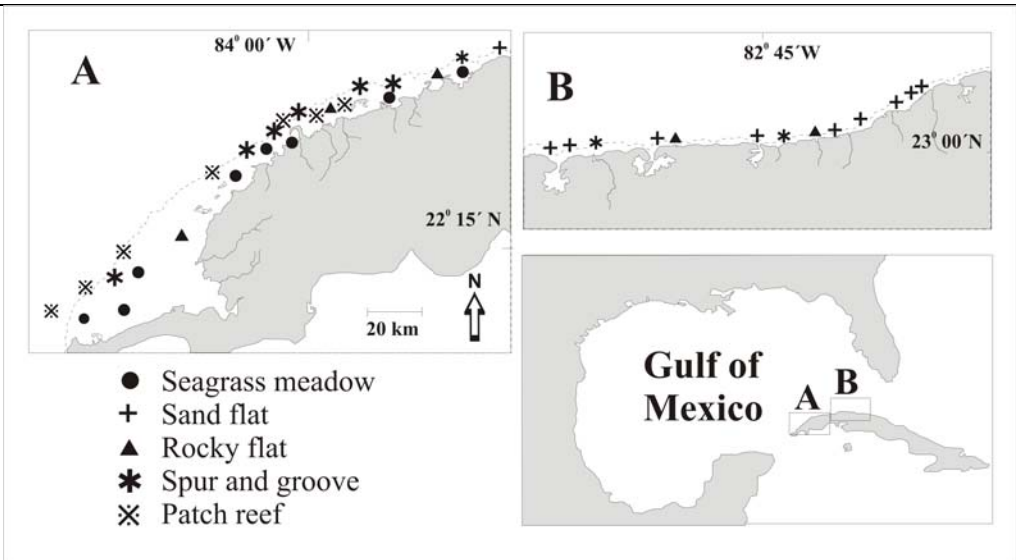

Fig. 1. Study zone. Sampling stations arranged by habitats are showed. The contour of shelf break (approximately 200 m depth) is marked.

variables and faunal multivariate pattern. Therefore, we explored the correlation only between similarity matrices based on % S/C (Euclidian distance) and meiofauna (coefficient of Bray-Curtis). Spearman's rank correlation coefficient was computed between % S/C and density of nematodes, density of copepods and density of all taxa to explore the relationship between size grain and univariate measures of community.

RESULTS

The mean values of salinity (range: 36.6 – 37.0 ‰) and temperature (range: 27.0 – 30.1°C) were notably homogeneous across sampled habitats (Table 1). Remarkable spatial variations were present in the percentage of silt/clay (S/C) (range: 1.1 – 83.3%) and depth (range: 2.5 – 28.0 m). The highest mean value of percent of silt/clay (50 %) and the lowest mean depth (6.7 m) occurred in seagrass meadows; the other habitats showed mean values of % S/C lower than 20% and mean depth higher than 11 m (Table 1).

Ten major meiofaunal taxa were recorded in sampled habitats (Table 2). The average number of major taxa (in brackets) present in each habitat did not show any trend: seagrass meadows (4); spur and groove (5); patch reef (5); rocky flat (6) and sand flat (5). The values of density of total meiofauna showed high variation in the studied area across all habitats (general mean: 249.3; range: 3.2 – 1020.6 animals 10 cm^{-2}). The most abundant taxa were Nematoda and Harpacticoida; and taxon dominance depended on the type of habitat. Copepoda was more abundant in spur and groove, rocky flat and patch reef habitats. In the other two habitats the dominant taxon was Nematoda (Table 2).

There were significant differences among habitats after the one-way global test ANOSIM (R = 0.16; p = 0.001; 999 permutations). The pairwise tests showed significant differences between seagrass meadows and the other habitats. Also, significant differences were observed in the pairs: rocky flat/patch reef and rocky flat/sand flat.

The multivariate community structure of meiofauna was similar across the habitats: patch reef, spur and groove, rocky and sand flats; i.e. samples are clustered together irrespective of type of habitat. Samples belong to seagrass beds were located separate from others in the plot suggesting differences in community structure and higher variability (Fig. 2).

Spearman's correlation coefficient between multivariate pattern of meiofauna and % S/C (as similarity matrix) was 0.53; this would be considered as a relatively high matching. There were no significant correlations between % S/C with neither density of nematodes nor total density. The density of copepods showed signifycant negative correlation (R = - 0.47; p = 0.01; n = 27) with % S/C.

Table 1. Mean values and standard error of abiotic variables in five coral reef habitats from the NW shelf of Cuba. n = number of samples.

Habitat	n	Depth (m)	Salinity (‰)	Temperature (°C)	% Silt/Clay
Patch reef	7	16.5 ± 3.9	36.7 ± 0.0	29.0 ± 0.2	9.1 ± 2.6
Seagrass meadow	8	6.7 ± 1.2	36.8 ± 0.1	29.6 ± 0.1	49.6 ± 10.1
Spur and groove	9	16.5 ± 1.0	36.6 ± 0.0	28.4 ± 0.2	17.0 ± 5.5
Rocky flat	5	11.3 ± 0.8	36.7 ± 0.1	28.5 ± 0.4	3.0 ± 1.4
Sand flat	8	13.1 ± 1.2	36.6 ± 0.0	27.6 ± 0.2	12.3 ± 1.4

Table 2. Mean values and standard error of meiofaunal density (animals 10 cm^{-2}) in five coral reef habitats from the NW shelf of Cuba. n = Number of samples, Other includes the taxa: Isopoda, Tanaidacea, Amphipoda, Cumacea and Kynorhyncha.

Habitat	n	Nematoda	Copepoda	Polychaeta	Ostracoda	Acari	Other	Total
Patch reef	13	54.0 ± 10.5	104.3 ± 15.8	19.3 ± 3.6	4.5 ± 1.7	0.4 ± 0.3	8.0 ± 3.3	190.4 ± 24.9
Seagrass meadow	14	92.7 ± 23.2	39.6 ± 26.2	7.6 ± 3.8	1.5 ± 0.6	2.4 ± 1.1	4.2 ± 1.7	148.0 ± 41.1
Spur and Groove	18	67.6 ± 21.4	136.0 ± 30.2	21.6 ± 3.8	10.5 ± 3.1	2.6 ± 0.8	5.0 ± 1.4	243.3 ± 47.4
Rocky flat	9	74.0 ± 38.0	181.6 ± 42.0	27.2 ± 7.9	15.3 ± 9.0	8.1 ± 5.2	10.4 ± 5.4	316.6 ± 70.3
Sand flat	20	171.4 ± 44.3	131.1 ± 19.1	20.7 ± 2.8	5.5 ± 1.8	2.1 ± 0.7	2.8 ± 0.7	333.7 ± 57.0

DISCUSSION

The values of salinity and temperature reported across the studied area were typical of coral reefs in summer (=wet) season. The observed homogeneity along approximately 200 km extension of reef system was due to an extensive exchange of shelf waters with the Gulf of Mexico (González-Sansón and Aguilar-Betancourt, 2004). The recorded silt/clay percentages indicate that sedimentary environment in seagrass meadows was essentially different from other habitats. The retention of fine sediments by the canopy of *Thalassia testudinum* is a characteristic feature of seagrass systems worldwide (Hemminga and Duarte, 2000). Similar protective effect should be offered the rocky structures in spur and groove habitat, which was ranked second in silt/clay content.

Increased diversity and abundance in seagrass meadows in contrast with unvegetated areas has been reported for meiofaunal copepods (Hicks, 1986) and nematodes (Ndaro and Olafsson, 1999). Possible explanations are more food availability, sediment stability, protection from predators, and habitat complexity in seagrass meadows than in adjacent unvegetated habitats (Orth and Heck, 1984). However, there were no differences at the highest taxonomic levels in those studies. Probably, the high taxonomic level used in the present study failed to detecting differences in the number of taxa between seagrass meadows and the other surveyed habitats.

The relative composition of dominant taxa (i.e. nematodes and harpacticoids copepods) changed across the habitats. Copepods tend to be dominant in sandy, well oxygenated sediments (Hicks and Coull, 1983) such as patch reefs, spur and grooves and rocky flats. In muddy bottoms (e.g. seagrass meadows) just a few mm below the upper layer the sediment is anoxic (Dye, 1983). Nematodes are

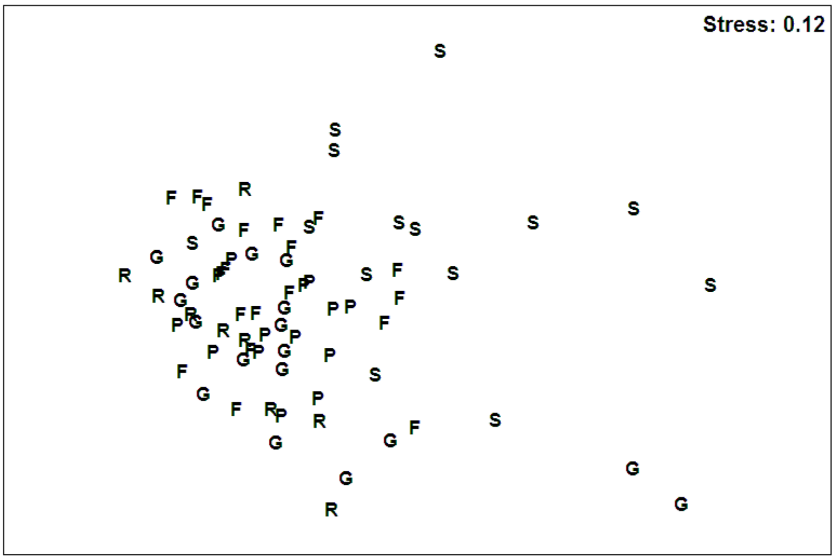

Fig. 2. Multidimensional scaling ordination plot of samples arranged by habitats. Data of meiofauna density was transformed with square root. The sample labels: P = Patch reef; S = Seagrass meadow; G = Spur and groove; R = Rocky flat and F = Sand flat.

more tolerant to this environment and they can be found in the anoxic layers of sediment (Jensen, 1987; Steyaert *et al.*, 1999).

The similarity of meiofauna community structure in sandy reef habitats was high, despite of notable differences in topographical architecture and megafaunal dominant groups. This suggests that the microenvironment (e.g. decomposition of particular mats of organic labile matter, patches of sandy sediment) play an important role in the distribution of meiofauna at centimeter scales (Hodda, 1990). In the present study, the homogeneity (particularly in particle size composition) of sediments among sandy habitats should be the main cause of meiofauna similarity. However, only the multivariate measures of the community contained enough information to detect changes in the meiofauna regarding percentage of silt/clay.

In soft bottom habitats, the particle size composition and the hydrodynamic regime are major ecological factor determining the faunal communities (Hall, 1994). In the present study, is difficult to state which of them is most important for meiofauna. In agreement with the results of López-Cánovas and Lalana (2001), we found that the proportion and density of copepods is higher in physically exposed habitats (i.e. rocky flat and patch reef). This suggests that the negative effects on meiofauna from sediment reworking could be less important than the sediment oxygenation (enhanced by well sorted sediments) caused by high water flow. Also, the increased input of organic matter due to sub-erosive flow of water would be a factor that enhances the presence of meiofauna (Gamenick and Giere, 1994).

The total density of meiofauna in the present survey was in the order of hundreds of individuals in 10 cm^2 of sediment, in closed agreement with total density values in muddy bottoms of the Cuban NW shelf (Armenteros *et al.*, unpublished data) and in coral reefs from Discovery Bay, Jamaica (range: 36 – 168 animals 10 cm^{-2}; Gamenick and Giere, 1994) . Meiofaunal densities, in other coral reef habitats of the Cuban SW shelf (López-Cánovas and Lalana, 2001), show higher values (range 520 – 4 191 animals 10 cm^{-2}) than the present study. Estimates of meiofaunal density in tropical coral reefs from Red Sea and South Pacific (see Boucher and Gourbault, 1990 for compilation) were higher than the present study as well. These differences could be related to oligotrophic conditions prevailing in the NW region of Cuban shelf.

The sampling stations located near the cities and river mouths (Figure 1B) did not show clear differentiation of other stations far from pollution sources. There were two possible explanations: i) there was no persistence (and therefore deleterious effects) of pollutants in the sediments due to elevated hydrodynamic regime of the NW shelf; and/or ii) the used high taxonomic levels were not sensitive enough to detect anthropogenic changes. In temperate habitats, some authors (e.g. Heip *et al.*, 1988; Warwick, 1988) suggest that meiofauna identification (e.g. nematodes and copepods) at family level would be adequate to detect responses of benthic communities to pollution, but in tropical habitats further studies are necessary in order to validate this statement.

In summary, the composition of meiofaunal communities changes across habitats, with harpacticoid copepods dominating in well sorted sediments and nematodes in seagrass meadows. The microenvironment (cm- scale) in coral reefs is more important for meiofauna than differences in topographical complexity and large size fauna among the reef habitats. The hydrodynamic regime appears to be an important process in structuring the meiofauna in coral reefs.

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