

## Distribution, abundance and composition of coral reef zooplankton, Cahuita National Park, Limon, Costa Rica

Alvaro Morales R. and Manuel M. Murillo

Centro de Investigación en Ciencias del Mar y Limnología (CIMAR), Universidad de Costa Rica, San Pedro de Montes de Oca, Costa Rica.

(Rec. 20-I-1994. Rev. 23-I-1995. Accep. 3-IV-1995)

**Abstract:** The zooplankton distribution, abundance and composition at Cahuita coral reef (Cahuita National Park, 9° 45' N and 82° 49' W, Costa Rica) were studied in four stations from January to November 1984. The samples were collected monthly using a net with 0.47m diameter opening and 280µm mesh. Copepods were predominant throughout the year (32-95%), followed by foraminiferans (1-34%), fish larvae and eggs (<1-28%), crustacean larvae (2-13.8%) and chaetognaths (1- 6.5%). Mollusc and echinoderm larvae were also present. High densities of zooplankton were obtained in January, August and October, with peak abundance in May. Low densities were found in April and November. Some groups like Copepoda, Chaetognatha, crustacean larvae and Polychaeta showed significant differences in their abundances from station to station. Amphipoda, Urochordata, mollusc and echinoderm larvae as well as ichthyoplankton showed no such differences. Comparing the rainy and dry season, a significant difference was detected between holo- and merozooplankton abundances; holozooplankton population dominated both in number and diversity. The lower diversity of larval forms is assumed to be a result of strong sedimentation and sediment resuspension. The variability of zooplankton abundance and its distribution are influenced by the current system that predominates in Cahuita. Qualitative analysis suggests that the zooplankton sampled in the Cahuita coral reef corresponds more to pelagic-oceanic zooplankton than to demersal zooplankton. Differences between the sampling stations may reflect the intensity of exchange between the reef water and surrounding water.

**Key words:** Zooplankton, abundance, Cahuita coral reef, Atlantic.

Coral reefs are diverse ecosystems with high productivity and abundance of organisms in relatively nutrient-poor waters (Goreau *et al.* 1971). Although the role of zooplankton in coral reef communities is not yet clear (Roman *et al.* 1990), the energy contribution of planktonic organisms is important (Alldredge & King 1977). In addition, the zooplankton represents a significant part of the diet for various coral reef organisms (Robichaux *et al.* 1981).

The study of ecological aspects of the zooplankton in coral reefs has been facilitated due to the recognition of an "endemic" zooplankton belonging to the reef (Emery 1968), that remains during the day at the bottom and migrates through the water column at night

(Ohlhorst 1982). Abundance and seasonality of coral reef zooplankton have been associated with physical changes of the environment (Mc Williams *et al.* 1981), morphological characteristics of the coral reef (Lefevre 1984), precipitation (Glynn 1973) and patchiness (Moore & Sanders 1976). Vertical distribution has been correlated with differences in the substrate composition (Alldredge & King 1977, Porter & Porter 1977, Birkeland & Smally 1981), lunar periodicity (Alldredge & King 1980) and predation (Alldredge & King 1985). However, information concerning its horizontal patterns is scarce, probably due to inappropriate collection techniques (Sale *et al.* 1978). In spite of this, some studies have

demonstrated the importance of the net import of zooplankton in relation to the reef (Ferraris 1982), and the difference in abundance, composition and behaviour between near-reef and open-reef communities (Echelman & Fishelson 1990).

The Cahuita coral reef is the most important coral reef situated on the Atlantic coast of Costa Rica (Cortés & Guzmán 1985). Ecological observations are available for algae (Wellington 1974), sea urchins (Valdéz & Villalobos 1978, Murillo & Cortés 1984, octocorals (Guzmán & Cortés, 1984), scleractinia (Cortés & Guzmán 1985) and sedimentation (Cortés & Risk 1984, 1985). However, plankton investigation are scarce. Silva (1986) studying nutrient dynamics, phytoplankton biomass and diversity, found significant differences in nutrient concentrations which were related to current patterns and local water turbidity.

The purpose of this study is to describe the Cahuita coral reef zooplankton community, its composition, distribution and abundance during 1984.

## MATERIAL AND METHODS

**Study area:** the geomorphological features of the Cahuita coral reef, its zonation and species composition are similar to the majority of coastal coral reefs of the Caribbean (Milliman 1973). The reef has two crests: an external (northeast - southeast, beginning north from Punta Cahuita, extending approximately 4 km towards Puerto Vargas) and an internal crest, situated 50-100m from the coast (Fig. 1).

According to Cortés (1981), the principal current flows west to southeast, a situation typical for the current in the south of Central America (Björnberg, 1971).

**Sampling:** zooplankton was sampled in four different areas of the coral reef at Cahuita National Park (Fig. 1). Three stations were located inside the lagoon (Sts. 1,2,3) and one outside (St.4). Some characteristics of the stations are listed on Table 1. Samples were collected monthly between January and November 1984. Horizontal tows were conducted in approximately 1m water depth using a plankton net with an opening diameter 0.47m and 280 $\mu$ m mesh size, following Tranter (1968). Tows were done at 4 km/h for 5 minutes

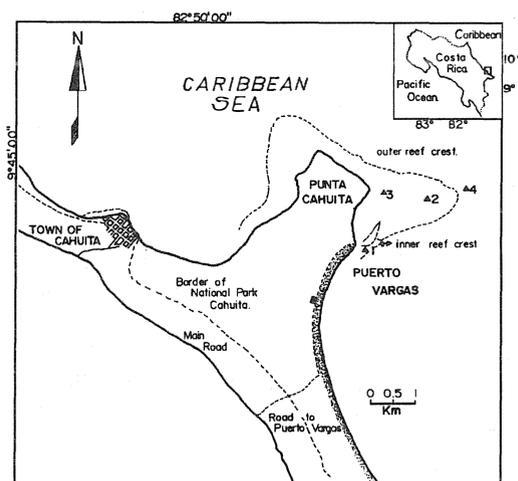


Fig. 1. Location of the sampling stations at Cahuita National Park. (adapted from Cortes 1981 and Silva 1986).

(January-July) and 10 minutes (August-November) and filtered volumen was calculated mathematically.

Zooplankton samples were fixed in 4% formalin - sea water solution. After 48 hours the samples were washed with distilled water and preserved in 70% ethanol. In the laboratory, each sample was subsampled using a Folsom splitter (McEwen *et al.* 1954). One aliquot was obtained for quantitative and qualitative determination. The accuracy of the Folsom splitter was examined using a Chi square test. Concentration of organisms are expressed as  $\text{ind} \cdot \text{m}^{-3}$ . Temperature and salinity were measured at each station. Data on precipitation, wind speed and direction were obtained from the National Meteorological Institute, Costa Rica.

**Statistical procedure:** analysis of variance was applied to determine differences in relative zooplankton abundances during the study period and between the sampling stations. Data were transformed to  $\log(x+1)$  to homogenize the variance (Minello and Mathews 1981). In the case of heterogenous variances, the Kolmogorov-Smirnov test was applied (Siegel 1970). The same test was used to detect differences in the total zooplankton abundance throughout the year. A Chi square test was employed to test for difference in the total abundances between holo- and merozooplankton, according to season (rainy or dry).

Diversity ( $H'$ ) and Simpson's indeces were computed according to Levinton (1982).

TABLE 1

*Morphological characteristics of the stations sampled, National park Cahuita, Limón, Costa Rica*

Station	1	2	3	4
Depth (m)	6	3.5	2	10
Morphological characteristics	Muddy bottom Coral fragments	Kidney stone Massive coral formation at bottom	Kidney stone The sea grass <i>Thalassia testudinum</i> predominates	Kidney stone Bottom cover of benthonic algae and some sponges

## RESULTS

The total zooplankton abundances did not show statistically significant differences throughout the year (Kolmogorov-Smirnov,  $P < 0.05$ ). Peaks of abundance occurred in January and May; minimum numbers were observed in April and November (Fig. 2). Fluctuation in both holo- and merozooplankton are illustrated in Fig. 3. Total abundance and percentage are always higher for the holozooplankton than for those larval forms mentioned above (Table 2). Highly significant differences were obtained in comparing both groups depending on the season (Table 3).

**Holozooplankton:** holozooplankton densities were dominated by copepods and foraminifers (Fig. 4). A peak in copepods abundance occurred in October (812 ind.\*m<sup>-3</sup>, table 2) and minimum densities in February and November. Their percentages ranged from 32% to 92% (Table 2). Foraminiferans were abundant in January (20% of the total abundance),

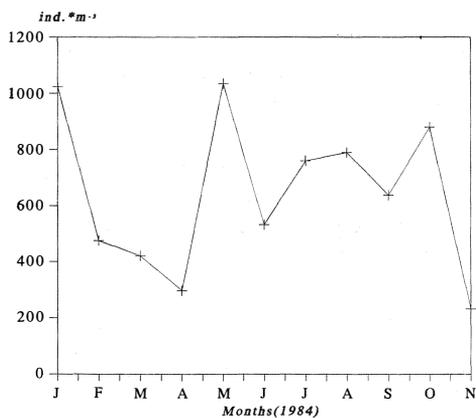


Fig. 2. Total abundance of zooplankton from January to November 1984.

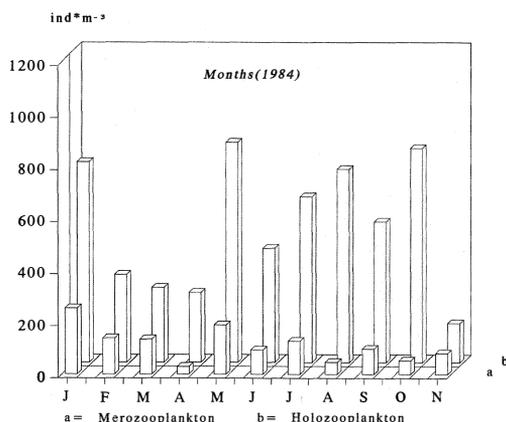


Fig. 3. Total abundance of holo- and merozooplankton in 1984.

February (28%) and May (34.2%); few organisms were collected from August to November. Chaetognata had high densities in February and May, contributing 6.5% and 3.5% respectively to the total abundances.

Salps and appendicularians occurred throughout the year; medusae showed high densities in February and July. The remaining groups were scarce.

**Merozooplankton:** the occurrence of merozooplankton is presented in Fig. 5. Ichthyoplankton was very abundant (especially eggs) during the first five months. Total densities ranged from 2 ind.\*m<sup>-3</sup> in August to 194 ind.\*m<sup>-3</sup> in January (Table 2). In March, ichthyoplankton represented 28% of the total abundance of zooplankton. The families Soleidae, Bothidae, Holocentridae and Carangidae were the most numerous (C. Arias de la Peña, unpublished data). The crustacean larvae were abundant in the second half of year, with abundance ranging from 9 ind.\*m<sup>-3</sup> in March to 115 ind.\*m<sup>-3</sup> in May, representing 2.1% and 11.1% of the total zooplankton abundance per month

TABLE 2

Total abundances (ind. \*m<sup>-3</sup>) and % of zooplankton taxa from January to November 1984, Cahuita Coral Reef

Taxa/month	J	F	m	A	M	J	J	A	S	O	N
Copepoda	527.0 (51.0)	150.0 (32.0)	257.0 (62.0)	234.0 (79.0)	432.0 (42.0)	371.0 (70.0)	601.0 (79.0)	692.0 (88.0)	504.0 (79.0)	812.0 (93.0)	135.0 (68.2)
Foraminifera	204.0 (20.0)	133.0 (28.0)	++ -	++ -	354.0 (34.2)	38.0 (7.1)	8.0 (1.0)	2.0 (*)	2.0 (*)	1.0 (*)	1.0 (*)
Chaetognatha	11.0 (1.0)	31.0 (6.5)	22.0 (5.0)	6.0 (2.0)	36.0 (3.5)	15.0 (2.8)	9.0 (1.0)	30.0 (3.8)	18.0 (2.8)	9.0 (1.0)	13.0 (5.6)
Cnidaria	2.0 (*)	10.0 (2.0)	3.0 (*)	3.0 (1.0)	11.0 (*)	** -	12.0 (1.6)	4.0 (*)	3.0 (*)	++ -	++ -
Amphipoda	2.0 (*)	10.0 (2.0)	3.0 (*)	++ -	2.0 (*)	++ -	2.0 (*)	5.0 (*)	1.0 (*)	2.0 (*)	1.0 (*)
Urochordata	13.0 (1.0)	++ .	2.0 (*)	7.0 (2.4)	1.0 (*)	6.0 (1.1)	1.0 (*)	10.0 (1.2)	10.0 (1.6)	++ -	1.0 (*)
**Other	12.0 (1.0)	3.0 (*)	++ -	18.0 (6.0)	10.0 (*)	9.0 (1.7)	++ -	1.0 (*)	3.0 (*)	4.0 (*)	1.0 (*)
Crustacea larvae	29.0 (2.8)	10.0 (2.0)	9.0 (2.1)	9.0 (3.0)	115.0 (11.1)	33.0 (6.2)	27.0 (3.5)	29.0 (3.7)	36.0 (5.6)	16.0 (1.8)	32.0 (15.5)
Echinod larvae	5.0 (*)	1.0 (*)	++ -	2.0 (*)	6.0 (*)	1.0 (*)	++ -	8.0 (1.0)	1.0 (*)	++ -	36.0 (15.5)
Mollusca larvae	19.0 (1.8)	28.0 (6.0)	5.0 (1.2)	2.0 (*)	3.0 (*)	40.0 (7.5)	++ -	6.0 (*)	20.0 (3.1)	24.0 (2.7)	2.0 (*)
Polychaeta larvae	6.0 (*)	10.0 (2.0)	4.0 (*)	2.0 (*)	17.0 (1.6)	5.0 (*)	3.0 (*)	1.0 (*)	7.0 (1.1)	5.0 (*)	3.0 (1.3)
Ichthyoplankton	194.0 (19.0)	89.0 (19.0)	116.0 (28.0)	14.0 (4.7)	48.0 (4.6)	14.0 (2.6)	97.0 (12.7)	2.0 (*)	33.0 (5.2)	7.0 (*)	7.0 (3.0)
Total	1024.0 (14.4)	475.0 (6.7)	421.0 (5.9)	297.0 (4.2)	1035.0 (14.0)	532.0 (7.5)	760.0 (10.7)	790.0 (44.2)	638.0 (9.0)	880.0 (12.4)	232.0 (3.3)

++ = < 1 ind.\*m<sup>-3</sup>

(\*) = < 1%

\*\* = Cladocera, Ostracoda, Pycnogonida, Cumacea and Isopoda

TABLE 3

Variation of zooplankton total abundances and % in relation to the season, 1984, Cahuita Coral Reef

	Dry season	Rainy season	Total (ind.*m <sup>-3</sup> )
Holozooplankton	1,815 (31.0%)	4,031 (69.0%)	5,846
Merozooplankton	634 (51.0%)	604 (49.0%)	1,238
Total (ind.*m <sup>-3</sup> )	2,449 (35.0%)	4,635 (65.0%)	7,084

x<sup>2</sup>=170.7 P= 0.95

respectively. The most common families were Pinnotheridae and Xanthidae.

Echinoderm larvae were mainly represented by echinopluteus of *Diadema antillarum* and *Letichinus variegatus*. In general the echinoderm larvae were scarce but a conspicuous peak was obtained in November, in contrast to

mollusc larvae, which had higher densities in the first months of the year (Fig. 5). Polychaeta larvae, represented mainly by families Spionidae, Syllidae and Phyllodocidae, were abundant in February and April. Fig. 6 shows the general distribution of zooplankton during the sampling months for each station. Stations 2 and 4 had more zooplankton than Stations 1 and 3 (Table 4). Holozooplankton was always more abundant than merozooplankton. More than 50% of all groups found at Cahuita showed significant difference, when their abundances were associated with the sampling station. Copepods, chaetognaths, crustacean larvae (reptant) and polychaet larvae showed differences between almost all stations (Fig. 6, ANOVA, P ≤ 0.05). The first rank of St. 2 is related to the tows from January to July, while the second is related to the tows from August to November. Others groups like medusae, crustacean larvae (natantids) larvae and minor

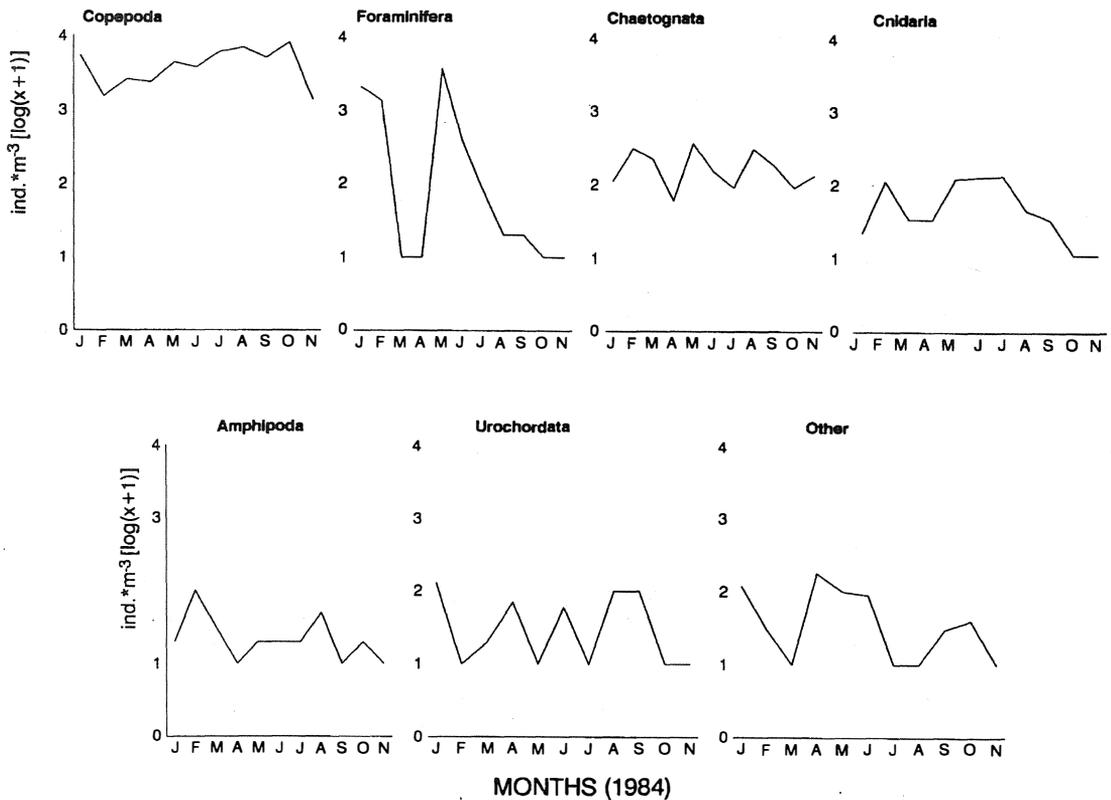


Fig. 4. Total densities of holozooplankton from January to November 1984.

groups showed differences as well, when the Kolmogorov-Smirnov test was applied. The remaining groups indicated no differences in their distribution.

The group diversity at Cahuita was low (Table 5), principally dominated by holozooplankton. Physical factors were constant during the study. Only precipitation in May was higher than during the other months (Table 6). Salinity varied lightly too.

## DISCUSSION

**Temporal variations:** the zooplankton at Cahuita coral reef did not show a clear seasonal pattern (Fig. 2). The no seasonality is a characteristic feature of Caribbean coral reef zooplankton (Moore & Sander 1976), although other tropical regions do show such pattern (McWilliams *et al.* 1981, Sammarco & Crenshaw 1984, McKinnon & Thorold). The

difference found may be associated with physical phenomena. For example, mixing processes produced across turbulence induces local water remotion, which help to bring nutrients into the water column (Waffer *et al.* 1983). A direct consequence is a permanent supply of nutrients, which may be reflected as an increase of the primary production and phytoplankton biomass during a part of the year (Reeve 1970). This condition was found by Silva (1986) during the rainy season at Cahuita coral reef. Zooplankton densities increased significantly in the start of the rainy season. Glynn (1973) found more zooplankton after a hurricane hit the coast of Puerto Rico, increasing nutrient concentrations.

In concordance with other studies (Johannes and Gerber 1974, Moore and Sanders 1976, Ferraris 1982, Vaissiere and Seguin 1984) copepods were the dominant organisms. Their high density during the rainy season coincides with high phytoplankton concentration, typical for these months at Cahuita (Silva 1986).

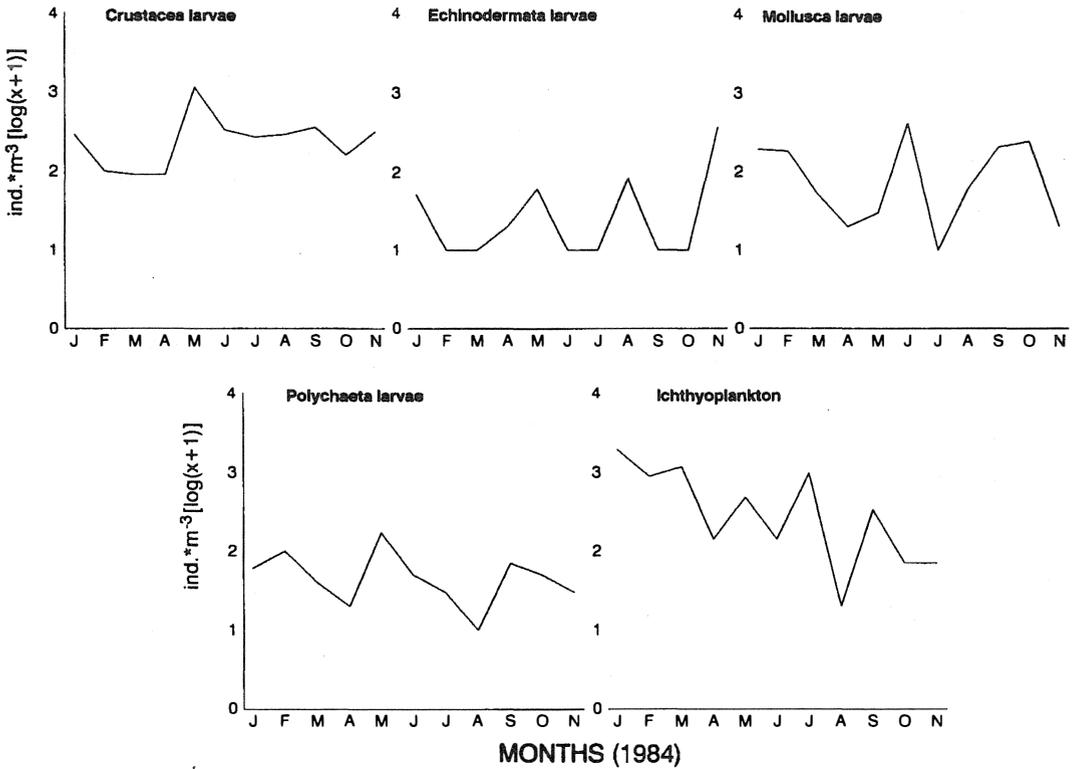


Fig. 5. Total densities of merozooplankton from January to November 1984.

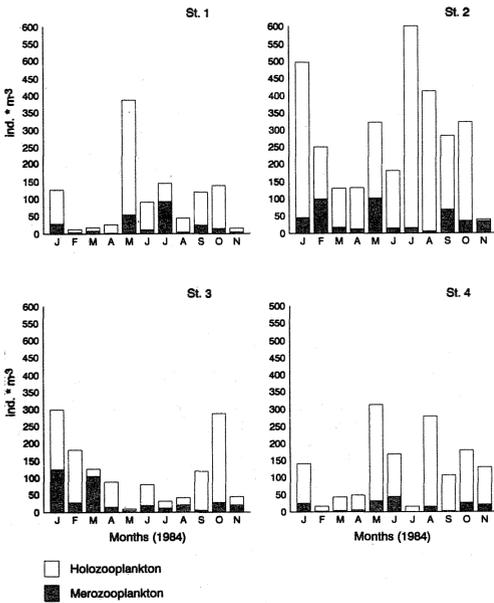


Fig. 6. Total abundances of mero - (first row) and holozooplankton (second row) in each sampling station during 1984.

Abundance of medusae were low, as reported from other reefs (Sammarco and Crenshaw 1984). Changes in the reproductive patterns or differences in the availability of prey, e.g. copepods (Hammer 1977), may have influenced such patterns. Appendicularians and salps, important oceanic groups (Davall & Youngluth 1990), were never numerous. The fluctuation may be associated, as in copepods, with changes in the phytoplankton concentration (Raymont 1983).

The fluctuations of foraminiferans are difficult to explain. They may be representing a successional state. Spinose planktonic species tend toward greater dependence on zooplankton protein than on phytoplankton protein (Anderson 1983, in Hemleben *et al.* 1989). They feed principally on copepods (Spindler *et al.* 1984), in contrast to non-spinose species, which tend to herbivory. During the later maturational stages in spinose species, growth rate decreases and the diet changes from a predominantly herbivorous to a more carnivorous diet starting at the neanic stages. The maturation of

TABLE 4

Total abundances, average and s.d. of zooplankton (ind.\*m<sup>3</sup>) at sampling stations during the study period  
Cahuita Coral Reef

	St.1	St.2	St.3	St.4
Copepoda	475(39.6±37.8)	2426(202±161.1)	724(60.3±68.7)	1138(94.8±77.9)
Foraminifera	358(29.8±84.9)	182(15.2±35)	115(9.58±27.1)	97(8.1±14.7)
Chaetognatha	19(1.58±1.80)	78(8.16±8.02)	52(4.3±6.96)	38(3.17±4.32)
Cnidaria	2(0.16±0.37)	32(2.67±3.10)	7(0.58±0.86)	++
Amphipoda	2(0.15±0.53)	7(0.58±0.76)	18(1.5±2.39)	++
Urochordata	5(0.42±0.89)	32(2.87±4.71)	7(0.58±1.66)	16(1.33<2411.60)
Others*	4(0.33±0.47)	26(2.17±3.10)	21(1.75±3.77)	6(0.5±6.45)
Echinodermata larvae	9(0.75±1.16)	34(2.83±7.65)	3(0.25±0.83)	14(1.17±1.77)
Mollusca larvae	11(0.92±1.11)	82(6.83±8)	9(0.75±1.05)	40(3.3±8.69)
Crustacea larvae	21(1.75±2.28)	185(15.41±21.7)	118(9.8±8.1)	83(6.92±8.05)
Polychaeta larvae	9(0.75±0.92)	35(2.92±2.63)	14(1.17±1.28)	6(0.5±0.65)
Ichthyoplankton	215(17.91±26.2)	146(12.2±21.9)	248(20.7±40.7)	29(2.42±4.39)
Total	1139(94.2±156.7)	3265(272±652.2)	1336(111.3±197)	1467(122.3±307)
	**60.11	41.71	56.6	39.8

++=< ind.\*m<sup>-3</sup>

\*=Ostracoda, Cladocera, Pynogonida, Isopoda, Cumacea

\*\*=Variation Coeff.

TABLE 5

Zooplankton groups diversity from January to February 1984, Cahuita Coral Reef

Station	Shannon-Weaver	Simpson	H' max	H' rel	N
1	2.0 (1.29)	0.8 (0.61)	3.1 (3.0)	0.7 (0.43)	22.0 (20.0)
2	1.6 (1.08)	0.6 (0.38)	2.8 (3.0)	0.6 (0.35)	17.0 (21.0)
3	1.8 (1.15)	0.8 (0.45)	3.0 (2.9)	0.6 (0.36)	21.0 (19.0)
4	1.2 (1.12)	0.4 (0.42)	3.0 (3.0)	0.4 (0.36)	21.0 (22.0)

() = Rainy season

TABLE 6

Environmental data measured (average) at stations 1, 2, 3 and 4 in 1984. Cahuita Coral Reef

Month	Water Temp.(°C)	Salinity (ppt)	Precipit. (mm)	Wind Direction	Wind speed (Km/h)
January	23.5	36	9.3	SE*	8.2
February	+	+	0.25	SE	7.9
March	24.5	34	2.61	E**	8.2
April	27.7	35	3.61	SE	8.9
May	+	33	18	SE	7.8
June	+	32	8.8	SE	7.5
July	29	34.5	4	SE	7.5
Agust	26.1	30	10.5	SE	7.8
September	28.7	+	3.85	SE	7.7
October	28	34.5	4.68	SE	8
November	26.5	34	7.58	SE	9

\* South eastern

\*\* Eastern

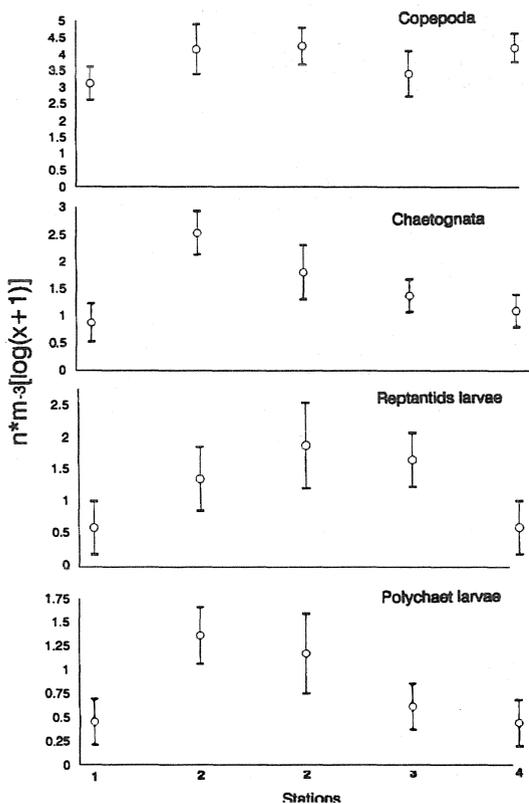


Fig. 7. Average and confidence limits (95%) of the abundances for some zooplankton groups in 1984.

spinose species is faster when prey is abundant (Hemleben *et al.* 1989). Copepods were relatively common in January and May, but very low numbers were obtained in February. Although we are not able to distinguish between spinose and non spinose forms, there is the possibility that the fluctuation of foraminiferans reflects a successional pattern depending on the prey abundance. More investigations on these topic are required.

Other groups like Cladocera are typically rare in coral reef zooplankton samples (Ferraris 1982). At Cahuita the cladocerans contributed significantly in May (Table 2). The high precipitation in May (Table 6) and the subsequent decline in salinity may have caused an increase of cladoceran populations, which is common in neritic regions (Calef & Grice 1967). Amphipods were more abundant in dry months, but generally represent not more than 1% of the zooplankton coral reef samples (Ferraris 1982). This suggests that the majority

of amphipods found in coral reef samples are demersal. In agreement with reports from other regions (Sammarco & Crenshaw 1984), chaetognaths tended to occur in higher densities during the warmer period of the year. The presence of abundant prey (Pearre 1973) together with changes in the reproductive patterns of the population, might cause the observed observed.

With the exception of ichthyoplankton, all larval forms were more numerous during the rainy season (Fig. 5). The fluctuations of crustacean larvae were similar to those reported from other coral reefs (Sale *et al.* 1976, Lefevre 1984), where high densities were obtained in rainy months and lower abundance during dry months (Glynn 1973). Echinoderm larvae were not numerous during the study period, except for a strong rise in November. *Diadema antillarum* Phillips is the most common sea urchin at Cahuita (Valdéz & Villalobos 1978; personal observations). It possesses a spawning peak in October (Lessios 1981). The peak in November (Fig. 5) can be associated with a similar pattern. Furthermore, *D. antillarum* spawns during the new moon (Lessios 1983). In November the tows were done two days after new moon. The low number of *D. antillarum* larvae throughout the year may be related to the high mortality that this specie underwent in 1983 (Murillo and Cortés 1984). Mollusc and polychaet larvae were generally abundant in September and October, supporting other observations for both groups (Glynn 1973, Ferraris 1982).

**Spatial variations:** many groups presented strong differences in their distribution. The patchiness of zooplankton greatly influences the variability in the estimates of distribution and abundances of zooplankton communities (Cassie 1968). Patchiness at large (Yoshioka *et al.* 1985) and at small (Greenblatt 1982) scales are related to spatial and temporal variation in chemical, physical and biological parameters (Levinton 1982). The formation of micro-patchiness across the Lagmuir circulation is expected if the wind speed exceeds  $3\text{m}\cdot\text{s}^{-1}$  (Polland 1977, in Hammer & Schneider 1986). In the Atlantic littoral, the wind speed averages about  $7\text{km}\cdot\text{h}^{-1}$ . Its direction, with only one exception, is always SE throughout the year (Table 6), this is an important condition for the patchiness formation (Parson *et al.* 1984). However a possible cause for the variability in

the distribution of Cahuita zooplankton may be the high proportion of copepods. In many cases copepods comprise between 45% and 95% of the total abundance in zooplankton samples (Longhurst 1985). Its distribution usually is influenced by localized formation of swarms, which may indicate a complex social behaviour (Omori & Hammer 1982). The formation of swarms was common during the study period (Table 2, 1 swarm = 100 - 1,000 ind\*m<sup>-3</sup>, Tranter & George 1972, in Hammer & Carleton 1979).

**Biological considerations about the spatial variability of zooplankton:** biological factors, such as competition and predation, may be playing an important role in the control of zooplankton distribution and abundance (Lasker 1981). Some groups - like fish - maintain different strategies to minimize the predation impact (Johannes 1978). Coral reef fish frequently spawn their eggs where they are easily transported by the current into open ocean (Lasker 1981). The eggs and fish larvae were very scarce at St. 2 and 4 (Table 4). At these stations a high number of copepods and crustacean larvae was found. Neritic copepods usually have been considered herbivorous, but some belong to omnivorous groups (Longhurst 1985); it has been showed that some species damage eggs and fish larvae (Turner *et al.* 1985). Zoea for their part may be active predators on ichthyoplankton (Brewer *et al.* 1984). It is also apparent that biological interactions may control the distribution and abundance of eggs and fish larvae (Sameoto 1984).

The degree of biological interactions between zooplankton groups at Cahuita may be a response to the oceanic water exchange intensity, which probably reflects the high difference between the inside stations and the outside station. The flow direction of the current (northwest - southeast) at Cahuita supports the idea that more zooplankton should be sampled at Sts. 2 and 4. It is generally accepted that most zooplankton drift across the reef comes from surrounding oceanic waters (Alldredge and King 1977). The Cahuita zooplankton corresponds more to pelagic - oceanic than to a demersal zooplankton. Crustacean larvae, polychaet and mollusc larvae, ichthyoplankton as well as copepods, appendicularians and chatognats are more abundant in non-demersal samples

(Ferraris 1982). However, the high variability in its distribution is a direct consequence of the relatively rapid changes in time and space of plankton communities (Greenblatt 1982). Such variability is reflected in the high variation coefficients found at each station (Table 4).

In general, in coral reef a great abundance of meroplanktonic forms exists as a consequence of the presence of many benthic phyla in the coral reef (Porter *et al.* 1978). The low density and abundance of larval forms can be associated with the impact produced by a high sedimentation rate and a high resuspension rate of sediments, which are common feature at Cahuita coral reef (Cortés 1981, Cortés and Risk 1984).

Zooplankton densities reported here are very low in comparison to other Caribbean coral reefs (Glynn 1973, Ferraris 1982). The Cahuita coral reef ecosystem suffers great stress due to high sedimentation and high resuspension of sediments (Risk *et al.* 1980, Cortés 1981, Cortés & Risk 1985). Investigations have suggested that suspended sediment may reduce herbivory, reproductive success and development of copepods (Paffenhöfer 1972, Arrunda *et al.* 1983). The effects of sediments on copepod reproductive biology have been demonstrated. The copepods production could decline at high suspended sediment concentrations (up to 400 mg/l, Sellner & Bundy 1987). White & Dagg (1989) obtained reduced egg production rates by *Acartia tonsa* when the suspended sediment concentration was higher than 1,000 mg/l. Although the concentration of suspended sediments in Cahuita appears not to be significant for copepod reproduction (7.4 mg/l, Cortés & Risk 1984, Table 2), the high sediment resuspension rates (Cortés & Risk, 1984) may play a major role for the copepod.

#### ACKNOWLEDGEMENTS

The research was supported by Vicerrectoría de Investigación, Universidad de Costa Rica (grants 02070816 to M.M. Murillo). The comments of J. Cortés and two anonymous referees are gratefully acknowledged as they contributed to a substantial improvement of the manuscript.

## RESUMEN

La distribución, abundancia y composición del zooplancton en el arrecife coralino de Cahuita ( Parque Nacional de Cahuita, 9° 45' N y 82° 49' W, Limón, Costa Rica) fueron estudiadas en cuatro estaciones de enero a noviembre de 1984. Las muestras fueron colectadas mensualmente con una red de plancton de 0.47m de apertura y 280 µm de poro. Copepodos fueron el grupo dominante a lo largo del año (32- 95%), seguidos por foraminíferos (1-34%), huevos y larvas de peces (<1-28%), larvas de crustáceos (2-13.8%) y quetognatos (1-6.5%). Larvas de moluscos y de equinodermos estuvieron también presentes. Altas densidades de zooplankton fueron obtenidas en enero, agosto y octubre, con un pico de abundancia en mayo. Bajas densidades fueron encontradas en abril y noviembre. Grupos como los copépodos, quetognatos, larvas de crustáceos (reptántidos) y las larvas de poliquetos mostraron diferencias significativas en su distribución entre casi todas las estaciones de muestreo. Anfipodos, urocordados, larvas de moluscos y equinodermos así como el ictioplancton no mostraron diferencias en su distribución. Diferencias significativas fueron detectadas en las abundancias del holo - y merozooplankton al compararse las estaciones del año; las poblaciones de holozooplankton dominaron tanto en número como en diversidad. La baja diversidad de las formas larvas puede ser un resultado de la fuerte sedimentación y resuspensión de sedimentos. La variabilidad en la abundancia y distribución del zooplankton están influenciadas por el patrón de corrientes que predominan en Cahuita. Análisis cualitativo sugiere que el zooplankton muestreado en el arrecife coralino de Cahuita corresponde más a un zooplankton pelágico-oceánico que a un zooplankton demersal. Diferencias entre las estaciones de muestreo podrían reflejar la intensidad de intercambio entre las aguas del arrecife y las aguas oceánicas circunvecinas.

## REFERENCIAS

- Allredge, A. & J.M. King. 1977 Distribution, abundance and substrate preference of demersal zooplankton at Lizard Island Lagoon, Great Barrier Reef. *Mar. Biol.* 41: 317-333.
- Allredge, A. & J.M. King. 1980 Effects of moon light on the vertical migrati patterns of demersal zooplankton. *J. exp. mar. Biol. Ecol.* 44: 133-156.
- Allredge, A. & J.M. King. 1985 The distance demersal zooplankton migrate above the benthos: implications for predation. *Mar. Biol.* 84: 253-260.
- Angel, M.V. 1985. Vertical migrations in the oceanic realm: possible causes and probable effects. *Contrib. Mar. Sci.* 27: 45-70.
- Arrunda, J.A., G.R. Marzolf & R.T. Faulk. 1983 The role of suspended sediments in the nutrition of zooplankton in turbid reservoirs. *Ecology* 64: 1225-1235.
- Birkelay, C. & T.L. Smalley. 1981 Comparison of demersal plankton from comparable substrates from a high island and an atoll. p. 437-442. *In* E.D. Gomez (ed.). *Proc. 4th Int. Symp. Coral Reef. Marine Sciences Center. University of Phillipines. Quezon City, Filipinas.*
- Björnberg, T.S. 1971. Distribution of plankton relative to the general circulation system in the area of the Caribbean Sea and adjacent regions. p. 343-356. *In* UNESCO (ed.). *Symposium on Investigations and Resources of the Caribbean Sea and Adjacent Regions.* UNESCO, Paris.
- Brewer, G.D., G.S. Kleppel & M. Dempsey. 1984 Apparent predation on ichtyoplankton by zooplankton and fishes in nearshore waters of southern California. *Mar. Biol.* 80: 17-28.
- Calef, G.W. & G.D. Grice. 1967 Influence of the Amazon River outflow on the ecology of the western tropical Atlantic.II. Zooplankton abundance, copepod distribution, with remarks on the fauna of low salinity areas. *J. Mar. Res.* 25: 84-94.
- Cassie, R. M. 1968 Sample designs.p. 105-122. *In* D.J. Tranter (ed.). *Zooplankton Sampling. Monographs on oceanographic methodology.* UNESCO. Paris.
- Cortés, J. 1981 The coral reef at Cahuita, Costa Rica: a reef under stress. M.Sc. Thesis, McMaster University, Hamilton, Ontario, Canada.
- Cortés, J. & M.J. Risk. 1984 El arrecife del Parque Nacional Cahuita, Costa Rica. *Rev. Biol. Trop.* 32: 109-121.
- Cortés, J. & M.J. Risk. 1985 A reef under siltation stress Cahuita, Costa Rica. *Bull. Mar. Sci.* 36: 339-356.
- Cortés, J. & H.Guzmán 1985 Organismos de los arrecifes coralinos de Costa Rica. III. Descripción y distribución geográfica de los corales escleractinios (Anthozoa:Scleractinia) de la costa Caribe. *Brenesia* 24: 63-123.
- Davall, P.J. & M.J. Youngbluth. 1990 Heterotrophic activity on appendicularians (Tunicata: Appendicularia) houses in mesopelagic regions and their potential contribution to particle flux. *Deep Sea Res.* 37: 285-294.
- Echelman, T. & L. Fishelson. 1990. Surface zooplankton dynamics and community structure in the Gulf of Aqaba (Eilat), Red Sea. *Mar. Biol.* 107: 179-190.
- Emery, A.R. 1968. Preliminary observations on coral reef plankton. *Limnol. & Oceanog.* 13: 293-303.
- Ferraris, J.D. 1982 Surface zooplankton at Carrie Bow Cay, Belize. *Smith. Cont. Mar. Sci.* 12: 239-251.
- Forward, R.B. 1988. Diel vertical migration: zooplankton photobiology and behaviour. *Ocean. Mar. Biol. Ann. Rev.* 26: 361-393.
- Gerber, R.P. & N. Marshall. 1982 Characterization of the suspended organic matter and feeding by the lagoon zooplankton at Enewetok Atoll. *Bull. Mar. Sci.* 32: 290-300.

- Glynn, P. 1973 Ecology of a Caribbean Coral Reef. The Porites reef - flat biotope: Part II. Plankton community with evidence for depletion. *Mar. Biol.* 22: 1-21.
- Goreau, T., N.I. Goreau & C.M. Younge. 1971 Reef Corals: Autotrophs or heterotrophs?. *Biol. Bull.* 141: 247-260.
- Greenblatt, P.R. 1982. Small - scale horizontal distribution of zooplankton Taxa. *Mar. Biol.* 67: 97-111.
- Guzmán, H. & J. Cortés. 1984 Organismos de los arrecifes coralinos de Costa Rica. II. Lista de octocorales (Cnidaria) de la costa atlántica de Costa Rica. *Brenesia*: 61-63.
- Hammer, W.H. 1977 Observation at sea of live tropical zooplankton. p. 284-296. *In* Proceedings of the Symposium Warm Water Zooplankton. UNESCO, Paris.
- Hammer, W.H. & J.H. Carleton. 1979 Copepod swarms: attributes and role in coral reef ecosystems. *Limnol. & Oceanogr.* 24: 1-14.
- Hammer, W.H. & D. Schneider. 1986. Regularly spaced rows on medusae in the Bering Sea: role of a Lagmiur circulation. *Limnol. Oceanogr.* 31: 171-180.
- Hargraves, P.E. 1982 Plankton diatoms (Bacillariophyceae) from Carrie Bow Cay, Belize. *Smith. Cont. Mar. Sci.* 12: 153-166.
- Hemleben, Ch., M. Spindler & O.R. Anderson. 1989. Modern planktonic Foraminifera. Springer Verlag, Heidelberg. 363 p.
- Johannes, R.E. 1978. Reproductive strategies of coastal marine fishes in the tropics. *Biol. Fish.* 3: 65-84.
- Johannes, R.E. & R. Gerber. 1974 Import and export of net plankton by an Eniwetok coral reef community. p.97-104. *In* Great Barrier Reef Committee (ed.). Proc. Sec. Int. Cor. Reef Symp., Brisbane, Australia.
- Lasker, L. 1981. Marine Fish Larvae: morphology, ecology and relation to fisheries. Washington University, Seattle, Washington. 132p.
- Lefevre, M. 1984 Repartition de la biomasse zooplancton que autour de l'île de Moorea (Polynesie Francaise). *J. Rech. Oceanogr.* 9: 20-22.
- Lessios, H.A. 1981 Reproductive periodicity of the echinoids *Diadema* and *Echinometra* on the two coasts of Panama. *J. exp. mar. Biol. Ecol.* 50: 47-61.
- Levinton, J.S. 1982. Marine Ecology. Prentice Hall, New Jersey. 524p.
- Lewis, J.B. 1977 Processes of organic production on coral reefs. *Biol. Rev.* 52: 305-347.
- Longhurst, A.R. 1985 Relationship between diversity and the vertical structure of the upper ocean. *Deep Sea Res.* 32: 1535-1570.
- McEwen, M.W. Johnson & T.R. Folsom. 1954 A statistical analysis of the performance of the Folsom Plankton Sample Splitter, based upon test observations. *Arch. Met. Geophys. Klimatol.* 7: 1502-527.
- McKinnon, A.D. & S.E. Thorold. 1993 Zooplankton community structure and copepod eggs production in coastal waters of the central Greaty Barrier Reef lagoon. *J. Plankt. Res.* 15: 1387-1411.
- McWilliams, P.S., P.F. Sale & D.T. Anderson. 1981 Seasonal changes in resident zooplankton sampled by emergence traps in one tree lagoon, Great Barrier Reef. *J. exp. mar. Biol. Ecol.* 52: 185-203.
- Milliman, J.D. 1973 Caribbean coral reef. p.: 1-44. *In* O.A. Jones & R. Edea (eds). Biology and Geology of coral reef. Academic, New York.
- Minello, T.J. & G.A. Mathwes. 1981 Variability of zooplankton tows in a shallow estuary. *Contrib. Mari. Sci.* 24: 81-92.
- Moore, E. & F. Sander. 1976 Quantitative and qualitative aspects of the zooplankton and breeding patterns of copepods at two caribbean coral reef stations. *Est. and Coast. Mar. Sci.* 4:589-607.
- Murillo, M.M. & J. Cortés. 1984 Alta mortalidad en la población del erizo de mar *Diadema antillarum* Phillipi (Echinodermata: Echinoidea) en el Parque Nacional Cahuita, Limón, Costa Rica. *Rev. Biol. Trop.* 32: 167-169.
- Ohlhorst, S.L. 1982 Diel migrations patterns of demersal reef zooplankton. *J. exp. mar. Biol. Ecol.* 60: 1-15.
- Omori, M. and W.M. Hammer. 1982 Patchy distribution of zooplankton: behavior, population assessment, and sampling problems. *Mar. Biol.* 72: 193-200.
- Paffenhöfer, G.A. 1972. The effect of suspended "red mud" on mortality, body weight, and growth of the marine planktonic copepod *Calanus helgolandicus*. *Water, Air Soil Poll.* 1: 314-321.
- Parson, T., M. Takahasi & B. Hargraves. 1984. Biological Oceanographic Process. Pergamon, New York. 323p.
- Pearre, S. 1973 Vertical migration and feeding in *Sagitta elegans* Verril. *Ecology* 54:300-314.
- Porter, J.M. & K.G. Porter. 1977 Quantitative sampling of demersal zooplankton migrating from different coral reef substrates. *Limnol. & Oceanogr.* 22: 553-556.
- Porter, J.M. & K.G. Porter & S.L. Ohlhorst. 1978 Resident reef plankton. p. 499-514. *In* Stoddart, D.R. & R.E. Johannes (ed.). Coral Reef Methodology. Monographs oceanographic Methodology. UNESCO, Paris
- Raymont, J.E.G. 1983. Plankton and Productivity in the Oceans. Vol. II. Zooplankton. Pergamon, New York. 824p.
- Reeve, M.R. 1970. Seasonal changes in the zooplankton of south Biscayne Bay and some problems of assessing the effects on the zooplankton of natural and artificial thermal and other fluctuations. *Bull. Mar. Sci.* 20: 894-921.

- Risk, M.J., M.M. Murillo & J. Cortés. 1980 Observaciones biológicas preliminares sobre el arrecife coralino en el Parque Nacional de Cahuita, Costa Rica. *Rev. Biol. Trop.* 28: 361-382.
- Robichaux, D.M., A.C. Cohen, M.J. Reaka & D. Allen. 1981 Experiments with zooplankton on coral reef, or, will the real demersal plankton please come up?. *Mar. Ecol.* 2: 77-94.
- Roman, M.R., M.J. Furnas & M.M. Mullin. 1990 Zooplankton abundance and grazing at Davies Reef, Great Barrier Reef, Australia. *Mar. Biol.* 105: 75-82.
- Sale, P.F., P.S. McWilliams & D.T. Anderson. 1976 Composition of the near-reef zooplankton at Heron Reef, Great Barrier Reef. *Mar. Biol.* 34: 59-66.
- Sale, P.F., P.S. McWilliams & D.T. Anderson. 1978 Faunal relationships among near-reef zooplankton at three locations on Heron Reef, Great Barrier Reef, and seasonal changes. *Mar. Biol.* 49: 133-145.
- Sameoto, D.D. 1984 Environmental factors influencing diurnal distribution of zooplankton and ichthyoplankton. *J. Plank. Res.* 6: 767-792.
- Sammarco, P.W. & H. Crenshaw. 1984 Plankton community dynamics of the central Great Barrier Reef Lagoon: Analysis of data from Ikeda et al. *Mar. Biol.* 82: 167-189.
- Sellner, K.G. & M.H. Bundy. 1987 Preliminary results of experiments to determine the effects of suspended sediments on the estuarine copepod *Eurytemora affinis*. *Contrib. Shelf Res.* 7: 1435-1438.
- Siegel, S. 1970 Estadística no paramétrica aplicada a las ciencias de la conducta. Trillas, México D.F., 342p.
- Silva, M. 1986 Productividad primaria, biomasa del fitoplancton y la relación con parámetros físico-químicos en el arrecife coralino del Parque Nacional Cahuita. Tesis de Licenciatura, Escuela de Biología, Universidad de Costa Rica, San José, Costa Rica.
- Spindler, M., C. Hemleben, J.B. Salomons & L.P. Smith. 1984 Feeding behavior of some planktonic foraminifers in laboratory cultures. *J. Foraminif. Res.* 14: 237-249.
- Tranter, D.J. 1968 Zooplankton Sampling. Monographs on oceanographic methodology. UNESCO, Paris. 174p.
- Turner, J.T., P.A. Tester & W.F. Hettler. 1985 Zooplankton feeding ecology: A laboratory study of predation on fish eggs and larvae by copepod *Anomalocera ornata* and *Centropages typicus*. *Mar. Biol.* 90: 1-8.
- Vaissiere, R. & G. Seguin. 1984 Initial observations on the zooplankton microdistribution of the fringing coral reef at Aqaba (Jordan). *Mar. Biol.* 83: 1-11.
- Valdéz, M.F. & C. Villalobos. 1978 Distribución espacial, correlación con el substrato y grado de agregación en *Diadema antillarum* (Echinodermata: Echinoidea). *Rev. Biol. Trop.* 26: 237-245.
- Waffer, M.V., P. le Corre & J.L. Birrier. 1983 Nutrients and primary production in permanently well mixed temperate coastal waters. *Estuar. Coast. Mar. sci.* 17: 431-446.
- Wellington, G.M. 1974 The benthic flora of Punta Cahuita: An annotated list of species with new addition to the Costa Rica atlantic flora. *Brenesia* 3: 30-321.
- White, J.R. & M.J. Dagg 1989 Effects of suspended sediments on egg production of the calanoid copepod *Acartia tonsa*. *Mar. Biol.* 102: 315-319.
- Yoshiaka, P.M., G.P. Owen & D. Pesante. 1985. Spatial and temporal variation in caribbean zooplankton near Puerto Rico. *J. Plank. Res.* 7: 733-751.