Gastropod Larvae and Zooplankton in Reef-Related Areas of the Western Caribbean Sea

Alberto de Jesus-Navarrete
El Colegio de la Frontera Sur, Mexico

Jose Juan Oliva-Rivera
El Colegio de la Frontera Sur

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GASTROPOD LARVAE AND ZOOPLANKTON IN REEF-RELATED AREAS OF THE WESTERN CARIBBEAN SEA.

Alberto de Jesús-Navarrete and José Juan Oliva-Rivera
Departamento de Pesquerías Artesanales, El Colegio de la Frontera Sur Unidad Chetumal, A.P. 424, Chetumal Q. Roo México, C. P. 77000, E-mail: Alberto@nicte-ha.ecosur-qroo.mx

ABSTRACT In order to estimate the composition, distribution and abundance of zooplankton in 3 areas off the western Caribbean, samples were collected in 15 stations at South Coast and Chinchorro Bank, Mexico, and Hol-Chan Belize, from April to December 1996. Duplicate samples (2.5 m^3) were collected bimonthly using a submersible pump. The pumped water was filtered through a 202 µm mesh net yielding a total of 20 zooplankton groups. Chinchorro Bank had 19 groups, South Coast had 15 groups, and Hol-Chan had 14 groups. The most abundant groups were copepods (43.1%), fish eggs (29.0%), foraminifera (12.0%), decapod larvae (5.7%) and gastropod larvae (4.3%). Twenty-seven species of gastropod larvae were identified with *Natica* sp. 1, *Rissoina* sp. 1, *Cerithiopsis hero, Cerithium atratum,* and *Epitonium* sp.1 being dominant. Newly hatched veligers of *Strombus gigas* were collected only at Chinchorro Bank (5.7/10m^{-3}). Zooplankton was diverse and showed marked changes during the sampling months. Chinchorro Bank had a higher number of marine zooplankters than South Coast and Hol-Chan, and this may be related to a greater oceanic influence. In spite of the environmental homogeneity, there were differences in the distribution and abundance of *Strombus* veligers, and this might be related to some water characteristics locally, affecting gastropod reproduction mainly in South Coast and Hol-Chan.

Introduction

Zooplankton communities are dynamic in marine ecosystems. The composition and abundance of reef-related zooplankton differs from those of neritic and oceanic environments, with the difference often being attributed to the shallowness, relatively high temperature, and oligotrophic conditions typical of reef areas (Emery 1968, Sale et al. 1976, Alldredge and King 1977, Alvarez-Cadena et al. 1998). Reef zooplankton are characterized by high diversity and a number of meroplanktonic forms, principally mollusk, decapod, cnidaria and echinodermata larvae (Emery 1968). Some of these are members of the benthos as adults and constitute important fishery resources (Appeldoorn 1994, Stoner and Davis 1997).

In the Mexican Caribbean Sea, zooplankton composition along the northern coast has been investigated. In the bays of this region, copepods, decapod larvae, and fish larvae predominate, with composition varying according to season and habitat heterogeneity (Suárez-Morales et al. 1991, Gasca et al. 1994, Suárez-Morales and Gasca 1996, Alvarez-Cadena et al. 1998, Vásquez-Yeomans 2000). Earlier studies of reef zooplankton in northern Quintana Roo, have indicated a dominance of gammarid amphipods, isopods, mysids, decapod larvae, and fish larvae at night, whereas copepods, siphonophores, chaetognaths, medusae, and salps were dominant during the day (Suárez-Morales and Gasca 1990). In Mahahual, located south of Quintana Roo, copepods and decapod larvae were the most abundant taxa near to the fore reef, but in the reef lagoon, fish larvae, demersal zooplankton, and other meroplanktonic forms were dominant (Castellanos-Osorio and Suárez-Morales 1997, Vásquez-Yeomans et al. 1998). In spite of this information, the reef area and adjacent zones of the southernmost portion of Quintana Roo such as Chinchorro Bank and South Coast have not been surveyed previously.

The objective of this paper is to describe the reef zooplankton community of the Quintana Roo southern coast, the northern coast of Belize, and to analyze the relationships between these areas. Gastropod larval distribution and abundance in these areas are presented for the first time here.

Materials and Methods

Study area. The South Coast (SC) is located along the southern portion of the Yucatan Peninsula, Mexico, and has a mean distance between the shoreline and the barrier reef of about 1 km. The reef lagoon has a mean depth of 3 m and is covered with submerged vegetation. Samples were collected at 4 stations: Hob-Na (18°22′N, 87°47′W), Francesa (18°21′N, 87°47′W), Santa Julia (18°20′N, 87°48′W) and Bacalar Chico (18°11′N, 87°50′W) in May, July, September, and November 1996 (Figire 1).

Chinchorro Bank (CHB) is a false atoll situated in the Mexican exclusive economic zone (18°23′–18°47′N, 87°14′–87°27′W), and is 46 km long, 19 km wide at its widest part, and has an area of 800 km^2. Its almost elliptic shape shows a strong development of hermatypic coral growth at the windward zone, whereas at leeward the reef is diffuse and semicontinual. Samples were collected in April, July, September, and November 1996, at 6 stations situated within the reef lagoon: Cayo Lobos (18°23′N, 87°21′W), Isla Che (18°30′N, 87°26′W), Cayo Centro (18°33′N, 87°18′W), Cayo Centro Oeste (18°33′N, 87°24′W), Penelope (18°42′N, 87°14′W), and Cayo Norte (18°45′N, 87°47′W) (Figure 1).

Hol-Chan (HCH) is a marine reserve (11.16 km^2) located southwest of Ambergris Key. It is divided into 3shallow zones (1–3 m): Zone A is used for tourism , Zone B is a research area, and Zone C is a species protection area mainly for the queen conch, *Strombus gigas*. Plankton samples were collected in August, October, and December 1996 at 5 stations: Zone A (17°51′N, 87°58′W), Zone B (17°51′N, 87°59′W), Zone C (17°52′N, 87°60′W), North Limit (17°52′N, 87°58′W), and Rocky Point (18°07′N, 87°49′W) (Gibson 1987, Figure1). The reef lagoons at the 3 sites (CHB, SC, HCH)

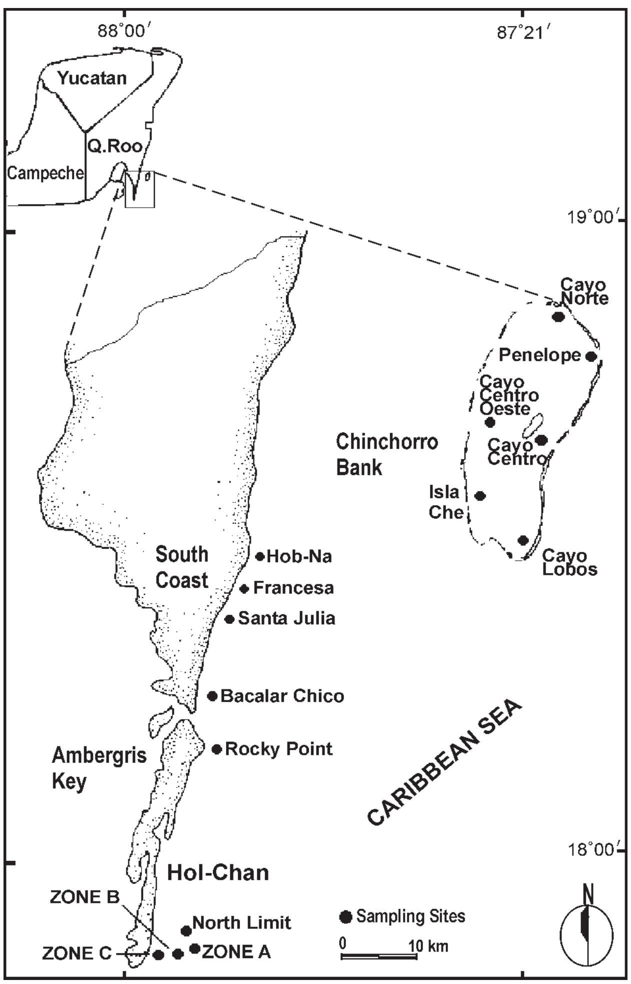

Figure1. Location of sampling stations at Chinchorro Bank, South Coast and Hol-Chan, Southern Caribbean sea.

have sandy bottoms covered with seagrasses (*Thalassia testudinum, Halodule wrigthii,* and *Syringodium filiforme)* and macro algae (*Laurencia poitei, Dyctiota dichotoma, Penicilus capitatus,* and *Avrainvillea* sp.*)*.

Duplicate plankton samples of about 2.5 m³ of seawater were collected using a submersible pump; each sample was filtered through a 202 µm mesh. Samples were fixed in a buffered 5% formalin/sea water solution. Water temperature (°C), salinity (‰) and dissolved oxygen (mg/L) were recorded at each station using either a YSI dissolved oxygen meter or an Ohaus conductivity meter. Samples were taken from the upper 2 m of surface water during the daytime.

Zooplankton were sorted into taxonomic groups using a Zeiss SV-6 stereomicroscope at 50X. Groups were identified with the keys of Boltovskoy (1981) and Raymont (1983). Gastropod larvae were identified following Thiriot-Quievreux (1983), Thiriot-Quievreux and Scheltema (1992), and Davis et al. (1993). All specimens were counted and densities were standardized to number per 10 m^3.

Density data for the 6 most abundant zooplankton groups were analyzed with ANOVA methods. Sites and groups were considered as factors and density data were transformed to Ln (x + 1) prior to analysis. Tukey's HSD range test ($P < 0.05$) was employed to find differences among factors (Statgraphics 7.0 Manugistics 1993), if a significant ANOVA was detected.

RESULTS

The 3 areas were similar in regard to winter temperature, salinity, and dissolved oxygen (Table 1). The taxonomic analysis revealed 20 zooplankton groups; 19 groups occurred at CHB, 15 occurred at SC, and 14 occurred at HCH. At CHB copepods were the most abundant (44.4%) at the 3 sites, followed by fish eggs (31.9%), foraminiferans (8.4%), decapod larvae (7.7%), and gastropod larvae (2.6%). At SC fish larvae were the most abundant group (31.0%); copepods represented 25.5%, followed by foraminiferans (10.4%), and fish eggs (4.7%). At HCH copepods (46.6%), foraminiferans (21.3%), and fish eggs were the most abundant groups. These 6 groups were widely distributed in the study area and represented over (92%) of the total abundance (Table 2).

The highest zooplankton density was recorded at CHB (3625 ± 3687/10m^{-3}), followed by HCH (2295.4 ± 2441.95/10m^{-3}), and SC (685 ± 975/10m^{-3}). At CHB the highest abundance was recorded in September (7565/10m^{-3}) and the lowest in July (1519/10m^{-3}). At HCH in

TABLE 1

Salinity (‰), water temperature (°C), and dissolved oxygen (DO, mg/l) in Chinchorro Bank (CHB), South coast (SC) and Hol-Chan (HCH) from April to December 1996.

Location / Date	T °C	Salinity ‰	DO (mg/l)
CHB			
24/04/96	27.5	36.2	6.5
10/07/96	28.4	36.0	6.2
04/09/96	28.5	36.0	6.3
4/11/96	27.5	35.8	6.7
Mean	27.9	36.0	6.4
SD	0.55	0.16	0.22
SC			
25/05/96	28.9	36.1	6.5
26/07/96	28.6	36.3	6.8
28/09/96	28.7	36.0	6.4
26/11/96	28.1	35.1	6.8
Mean	28.6	35.8	6.6
SD	0.34	0.53	0.21
HCH			
13/08/96	28.6	36.2	6.7
15/10/96	27.7	35.8	6.8
10/12/96	27.0	35.7	6.8
Mean	27.8	35.9	6.8
SD	0.80	0.26	0.06

October the highest abundance was 4472/10m^{-3} and the lowest occurred in August (292.6/10m^{-3}). At SC the highest density values were registered in November (1407/10m^{-3}) and minimum in May (205/10m^{-3}) (Table 2).

Amphipods, euphausids, ostracods, pteropods, and stomatopods were absent at SC. At HCH apendicularians, amphipods, salps, stomatopods, and echinodermata were not collected, whereas at CHB ostracods were absent (Figure 2). There were no significant differences in densities among species and sites (two-way ANOVA, $F_{2,17} = 1.524$, $P > 0.05$). A total of 27 species of gastropod larvae occurred in the study area. In HCH 21 species were recorded. *Natica* sp. 1, *Rissoina* sp. 1, *Cerithiopsis hero* (Bartsch, 1911), *Cerithium atratum* (Born, 1778), *Epitonium* sp. 1, *Epitonium* sp. 3, and *Atlanta* sp. 1 were the most abundant. Twelve gastropod species were found at CHB. *Natica* sp. 1, *Rissoina* sp. 1, and *Creceis aciculata* were the most abundant. SC had 13 species, with *Natica* sp. 1 and *Mitrella* sp. 1 being the most abundant. Larvae of queen conch (*Strombus gigas* Linnaeus, 1758) occurred only at CHB. One larva of *Strombus raninus* (Gmelin, 1791) was found at SC (Table 3).

Gastropod larvae showed a similar seasonal variation pattern as zooplankton. Pearson correlations showed strong correlation between zooplankton and gastropod larvae densities at CHB ($r^2 = 0.933$) and HCH ($r^2 = 0.950$), whereas in SC an inverse relation was found ($r^2 = 0.265$) (Figure 3).

DISCUSSION

Apparently there is considerable environmental homogeneity in the Caribbean reefs and this is reflected in the associated zooplankton communities (Moore and Sander 1976, Morales and Murillo 1996). However, seasonal variations may be pronounced, as in the case of the central Great Barrier Reef of Australia (McWilliam et al. 1981, Sammarco and Crenshaw 1984).

The number of zooplankton groups in this study agrees with other studies conducted in the Caribbean, despite the different sampling methods. At Cahuita National Park, Morales and Murillo (1996) using plankton tows, found 17 zooplankton groups, dominated by holoplanktonic forms, and Castellanos-Osorio and Suárez-Morales (1997) described 30 groups from Mahahual, Quintana Roo. Plankton nets and light traps have been shown to collect a similar array of zooplankton elsewhere. For example, in Costa Rica, Morales and Murillo (1996) collected 17 groups in plankton nets while in Australia, Sale et al. (1978) collected 26 groups using light traps. In our study, the pump method was useful for collecting zooplankton in shallow reef patches where standard tows were difficult to operate. It is probable that the difference in zooplankton abundance is more influenced by natural variation rather than the gear type used to collect samples.

Copepods (46%), fish eggs (18%), foraminiferans (21%), gastropod larvae (5%), decapod larvae (1%), and fish larvae (0.33%) were the most abundant groups in our survey. Similarly, Morales and Murillo (1996) reported a predominance of copepods year round (32 to 95%), followed by foraminiferans (1 to 34%), fish larvae and eggs (1 to 28%), and chaetognaths (1 to 6.5%). A similar pattern was observed by Ferraris (1982) at Carrie Bow Cay Belize, where copepods represented 53% of the catch and at Mahahual Quintana Roo where copepods represented 43% of the catch (Castellanos-Osorio and Suárez-Morales 1997).

The relatively higher taxonomic richness and density in CHB might be related to the strong oceanic influence over the bank. Many organisms were holoplanktic (68.4%) and zooplankton density increased because of vertically migrating meroplankton at night

Table 2

Zooplankton density (No.10 m^{-3}) in Chinchorro Bank (CHB), South Coast (SC) and Hol-Chan (HCH).

	CHB						SC						HCH				
Taxa	Apr	Jul	Sep	Nov	Mean	SD	May	Jul	Sep	Nov	Mean	SD	Aug	Oct	Dec	Mean	SD
Copepods	264	912	4561	845	1645.5	1965.32	52	128	519	0	174.7	235.44	74	2550	587	1070.3	1308.85
Fish eggs	582	89	2063	1895	1157.2	972.4	0	0	129	0	32.5	64.50	10	544	766	440.0	388.58
Foraminiferans	189	118	193	724	306.0	280.7	85	32	88	80	71.2	26.37	146	554	766	488.7	315.12
Decapod larvae	588	237	237	56	279.5	222.6	14	50	38	359	115.2	163.19	17	47	17	27.0	17.32
Gastropod larvae	30	25	165	150	92.5	75.3	32	12	28	41	28.2	12.12	12	284	40	112.0	149.61
Fish larvae	4	5	26	0	8.7	11.7	0	23	1	825	212.2	408.64	22	1	0	7.7	12.42
Chaetognatha	2	55	66	17	35.0	30.4	0	0	6	12	4.5	5.74	1	188	1	63.3	108.0
Apendicularians	0	7	152	0	39.7	74.9	0	0	11	12	5.7	6.65	0	0	0	0	0
Siphonophora	2	1	20	6	7.2	8.7	0	0	0	40	10.0	20.00	0	128	0	42.7	73.90
Bivalves	0	11	12	0	5.7	6.6	0	0	12	32	11.0	15.09	0	98	0	32.7	56.58
Polychaeta	17	8	26	30	20.2	9.8	3	0	8	3	3.5	3.31	0	14	0,6	4.9	7.91
Isopods	6	1	13	0	5.0	5.9	15	20	20	0	13.7	9.46	10	27	8	15.0	10.44
Pteropods	0.6	34	19	6	14.9	14.8	0	0	0	0	0	0	0	15	0	5.0	8.66
Ostracods	0	0	0	0	0	0	0	0	0	0	0	0	0,6	20	0	6.9	11.37
Amphipods	2	6	3	7	4.5	2.3	0	0	0	0	0	0	0	0	0	0	0
Salps	2	0	0	0	0.5	1.0	0	0	5	3	2.0	2.44	0	0	0	0	0
Euphausiacea	1	0	6	0	1.7	2.8	0	0	0	0	0	0	0	0	0	0	0
Echinodermata	0	0	0.6	0	0.15	0.3	4	0	0	0	1.0	2	0	0	0	0	0
Nematoda	0	0	2	0	0.5	1.0	0	0	1	0	0.2	0.50	0	2	0	0.7	1.15
Stomatopoda	0	1	0	0	0.25	0.5	0	0	0	0	0	0	0	0	0	0	0

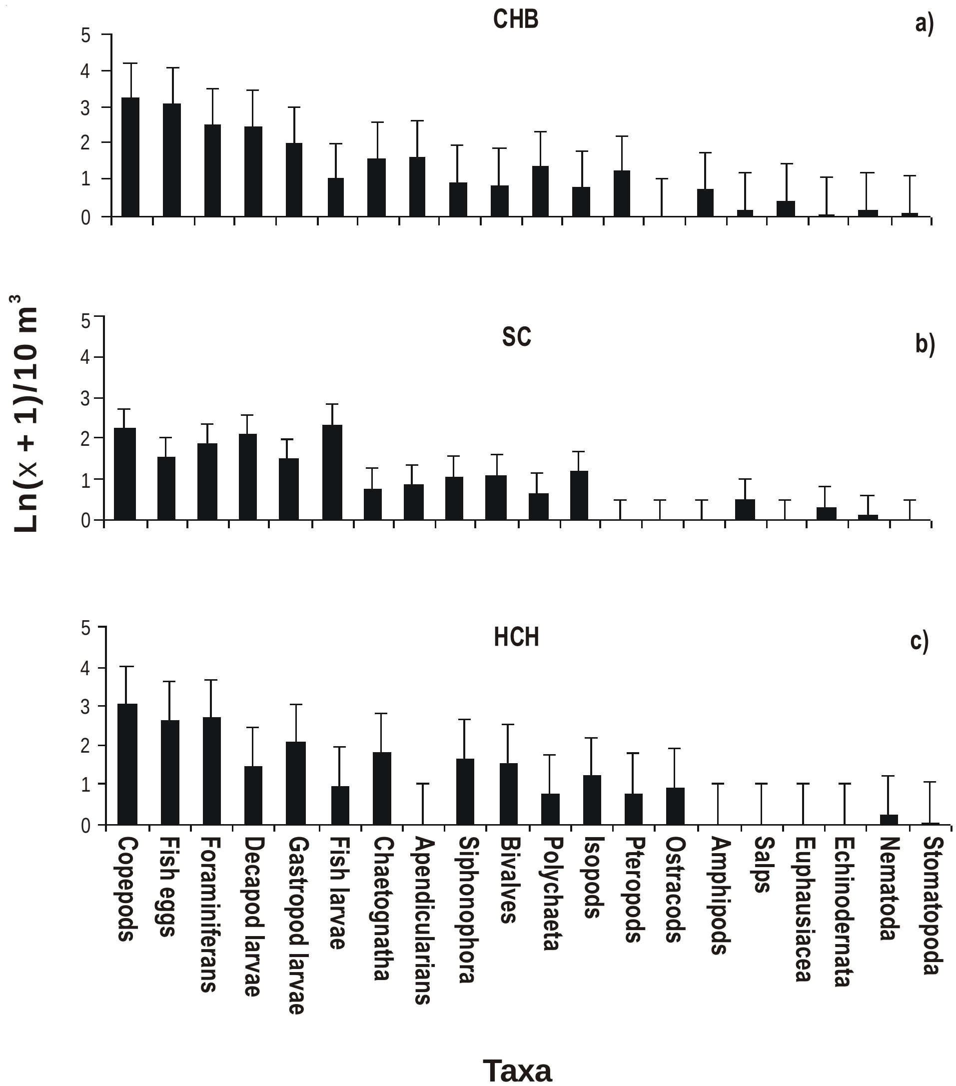

Figure 2. Zooplankton ($\bar{X}$ ± SD) densities. a = Chinchorro Bank (CHB); b = South Coast (SC); c = Hol-Chan (HCH).

(Suárez-Morales and Gasca 1990) or by the zooplankton transport by internal bores in the tidal channels (Pineda 1995, Shanks 1998). An increase in the zooplankton densities were observed in rainy and cold seasons (July–October and November–March) within the 3 areas. Glynn (1973) found higher zooplankton densities after a hurricane in Puerto Rico, and Morales and Murillo (1996) recorded increases in zooplankton numbers at the beginning of the rainy season, probably related to increased availability of food.

Ichthyoplankton were abundant both at CHB and HCH but exhibited a low density at SC. It is a well-known fact that some fishes select particular spawning sites within or near the reef for larval retention (Johannes 1978, Lobel 1989, Vázquez-Yeomans 2000).

Gastropod larvae were most abundant in CHB followed by HCH and this could be related to increased depth and greater oceanic influence in those areas compared to SC. All gastropod larvae found were actaeplanic larvae according to Scheltema's (1989) definition. These larvae spend a maximum of 6 weeks in the water column and primarily are coastal species. Almost all gastropod larvae found here have a small size in the adult stage (3 cm maximum shell length) and species such as *Natica* sp. 1, *Rissoina* sp. 1, and *Epitonium* sp. 1 were widely distributed in the study area. The exceptions were *Strombus raninus* and *S. gigas*, which attain large sizes as adults (7 and 30 cm shell length, respectively) and are commercially exploited in the region. *Strombus raninus* larvae were collected only at SC, whereas *S. gigas* were collected at CHB. No *S. gigas* larvae were collected from HCH, and this could be related to a reproductive failure of *S. gigas* adults in environments near shore, mediated by some environmental component (McCarthy et al.

Table 3

Gastropod larvae abundance (No.10 m^{-3}) at Chinchorro Bank (CHB), South Coast (SC) and Hol-Chan (HCH).

	CHB						SC						HCH				
Species	Apr 23/96	Jul 11/96	Sep 4/96	Nov 28/96	Mean	SD	May 23/96	Jul 26/96	Sep 25/96	Nov 25/96	Mean	SD	Aug 13/96	Oct 15/96	Dec 10/96	Mean	SD
Natica sp. 1	1	1.4	17.0	19.0	9.6	9.74	5.0	2.5	1.2	1.2	2.5	1.79	0.8	0	17.5	6.1	9.88
Natica sp. 2	0	0.7	0.7	3.5	1.3	1.55	0	0	1.2	0	0.3	0.6	0	0	0	0	0
Natica sp. 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.3	1.1	1.91
Rissoina sp. 1	2.1	2.8	6.4	0	2.8	2.66	22.5	5.0	0	2.5	7.5	10.21	0	6.6	0.5	2.4	3.67
Rissoina sp. 2	0	0	0	0	0	0	0	0	0	2.5	0.6	1.25	0	25.0	0.5	8.5	14.29
Mitrella sp. 1	0	0.7	0	2.1	0.7	0.99	7.5	0	0	1.2	2.2	3.59	1.6	2.5	1.6	1.9	0.52
Mitrella sp. 2	0	0	0	0	0	0	0	0	0	0	0	0	0	5.0	0	1.6	2.88
Cerithiopsis hero	0	0	9.2	0	2.3	4.60	0	0	0	0	0	0	0.8	2.5	2.5	1.9	0.98
Cerithiopsis sp. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	3.3	0.8	1.4	1.72
Cerithiopsis sp. 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cerithium atratum	0	0	0	0	0	0	0	0	0	1.2	0.3	0.60	0	23.3	0	7.7	13.45
Alaba sp.	0	0	0	0.7	0.2	0.35	0	0	0	0	0	0	0	35.8	4.1	13.3	19.59
Epitonium sp. 1	0	0	2.5	0	0.6	1.25	0	0	0	1.5	0.4	0.75	0	25.0	1.6	8.9	13.99
Epitonium sp. 2	0	0	0	0	0	0	0	0	0	2.5	0.6	1.25	0	4.1	0	1.4	2.37
Epitonium sp. 3	0	0	0	0	0	0	0	0	0	0	0	0	0	11.6	0	3.9	6.70
Simnia acicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0.3	0.46
Aporrhais sp.	0	0.7	0	0	0.2	0.35	1.2	0	0	0	0.3	0.60	0	0	0	0	0
Creseis acicula	0	2.1	6.4	2.8	2.8	2.66	0	0	0	0	0	0	0	5.8	0	1.9	3.35
Strombus gigas	0	5.7	0	0	1.4	2.85	0	0	0	0	0	0	0	0	0	0	0
Strombus raninus	0	0	0	0	0	0	0	0	1.2	0	0.3	0.60	0	0	0	0	0
Seila sp.	0	0	0	0	0	0	0	0	0	1.2	0.3	0.60	0	0	0	0	0
Bittium sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	5.8	0	1.9	3.35
Lunatia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0.3	0.46
Atlanta sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	10.0	0	3.3	5.77
Limacina sp. 1	0.7	0	2.1	7.1	2.5	3.21	0	0	0	1.4	0.4	0.70	0	3.3	0.8	1.4	1.72
Limacina sp. 2	0	0	5.7	0	1.4	2.85	0	0	0	0	0	0	0	0	0.8	0.3	0.46
Limacina sp. 3	0	0	0	0	0	0	0	0	0	3.3	0.8	1.65	0	80.8	4.1	28.3	45.51

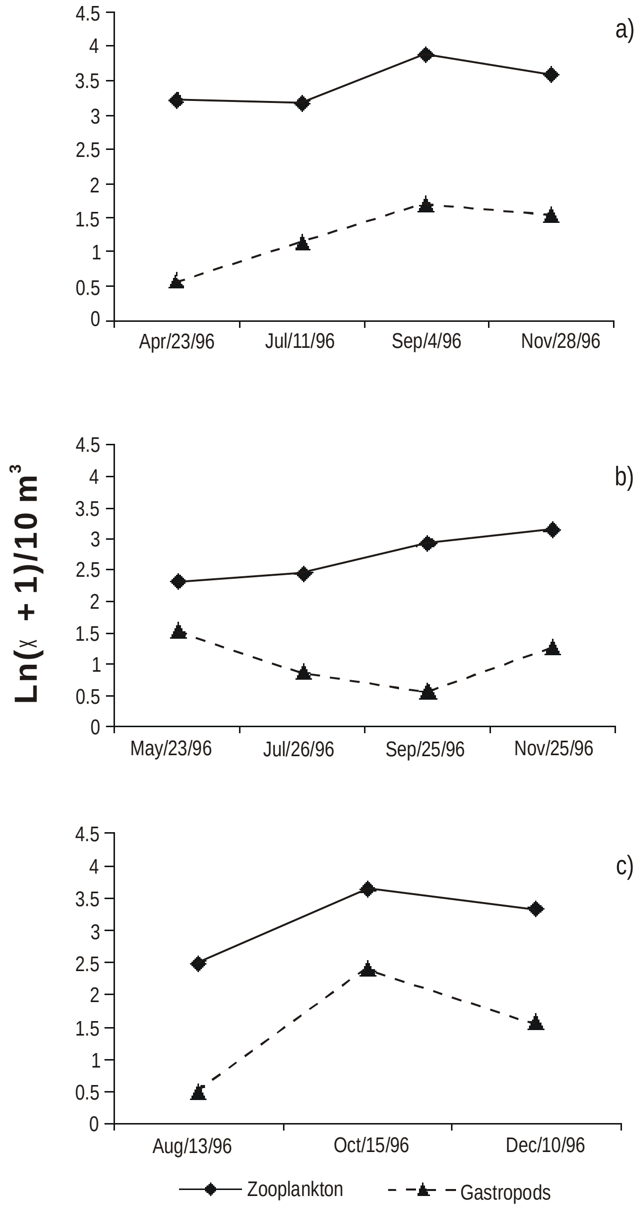

Figure 3. Mean zooplankton and gastropod density variation over time. a = CHB; b = SC; c = HCH.

1999), as has been reported in Florida.

In the region, several species of *Natica* (5), *Rissoina* (7) (Vokes and Vokes, 1983), *Mitrella* (5), *Cerithiopsis* (5), and *Epitonium* (13) have been reported, but there is currently no available information on their larval stages; many of them are reported here for first time. In July, newly hatched veligers of *S. gigas* (5.7/10m^{-3}) were collected at CHB. This value is higher than the 1.2 larvae/10m^{-3} reported from Florida (Stoner et al. 1997) and similar to the density found in the Bahamas (4.5/10m^{-3}, Stoner and Davis 1997). Apparently, CHB is an important site for production of *S. gigas* veligers (Stoner et al. 1997). Samples collected with plankton tows at CHB showed that the reproductive period of strombids is from February to November with a peak in August and October (de Jesús-Navarrete and Aldana-Aranda 2000). Hence, the higher density of gastropods found in the rainy and cold season may be related to the spawning season. In spite of the environmental homogeneity, there were differences in the distribution and abundance of *Strombus* veligers, and this might be related to some water characteristics locally, affecting gastropod reproduction mainly in SC and HCH.

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