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Chaetognatha in the Bahía Magdalena lagoon complex, Baja California Śur, México: Species composition and assemblages

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Abstract

The chaetognaths from 187 zooplankton samples collected from the Bahía Magdalena lagoon complex, Baja California Śur, México during March, June, July, August, September, November, and December 1982 were studied. Twelve species belonging to two genera were identified. *Sagitta euneritica* and *S. enflata* were the most abundant and most frequent species with maximum abundance in July (40,000 org/100 m^3 and 6100 org/100 m^3 respectively). *Sagitta pacifica, S. regularis* and *S. pseudoserratodentata* were stenothermic (21 to 25°C), whereas the rest of the species were eurythermic (15.5 to 29.5°C). *Sagitta euneritica* contributed considerably to the zooplanktonic biomass, increasing the density in particular in Bahía Almejas. The analysis of the species assemblages (Morisita index) showed that *S. pacifica* and *S. regularis* interact more frequently in August when there is a change of the water masses that converge in this zone during summer, when the California Countercurrent predominates. The composition of taxa during winter is characterized by the dominance of *S. euneritica*. Entering the warm period, an abrupt change occurs in taxa composition of the three zones studied: channels, Bahía Magdalena, and Bahía Almejas. The amplitude and distribution of *S. peruviana* was influenced possibility by the oceanographic conditions of ENSO 1982.

Key words

Chaetognaths assemblages, Seasonality, ENSO, Bahia magdalena, Mexico

Introduction

The Chaetognaths contribute substantially to the zooplaktonic biomass in the ocean (Bone et. al., 1991). They are strictly carnivorous (Feigenbaum and Maris, 1984). The distribution of these organisms depends on the water temperature and the movement of the water masses (Boltovskoy, 1981 and Alvarino, 1983). A decisive factor in their distribution is the abundance of their prey (Alvarino, 1975). Alvariño was one of the pioneering investigators of the California Current and worked on the description and distribution of several species. Alvariño (1965) published an atlas of the distribution of 24 species of chaetognaths in the California Current region based on the CalCOFI cruises (1954 and 1958) to determine the distribution of the species and their association to different water masses. The Bahia Magdalena Lagoon Complex (BMLC) located in the southwest part of the Baja California Peninsula, México is subject to strong seasonal environmental changes influenced by oceanic currents converging in the area along with other oceanographic features such as coastal upwelling activity, which was more intense during the spring–summer period (Zaitsev *et al*. 2003 and Sánchez-Montante 2004). During winter-spring the California Current (CC) is dominant, bringing colder water from the north, while in summer-autumn warmer water from the equatorial countercurrent brings subtropical conditions to Magdalena Bay (Lynn and Simpson, 1987). The influence of both currents is reflected by the change in planktonic species composition within the BMLC, carried in by tidal movements, (Palomares, 1992). Few studies are available concerning the distribution and abundance of zooplankton species in the area. Funes-Rodríguez (1985) reported on the siphonophora. The most abundant appear as the polygastric stage of *Muggiaea atlantica*. Palomares-García and Gómez-Gutiérrez (1996) analyzed changes in the community structure of copepods from 1983 to 1985. During summer and autumn 1983 (El Niño peak), an unusual increase of tropical-equatorial copepod species were found, with the resident species *Acartia clausi* replaced by *A. tonsa*. The chaetognath species composition for BMLC has characteristics of a coastal lagoon, with low diversity and high dominance of two species (*Sagitta euneritica* and *Sagitta enflata*; Cota-Meza *et al*., 1992). Their study was done in the cold years (1988-1989) whereas the present research includes the onset of El Niño 1982-1983. The aim of this study was to analyze the seasonal variability in the populations of Chaetognatha in the Bahía Magdalena lagoon complex and their relation to temperature and zooplanktonic biomass during 1982.

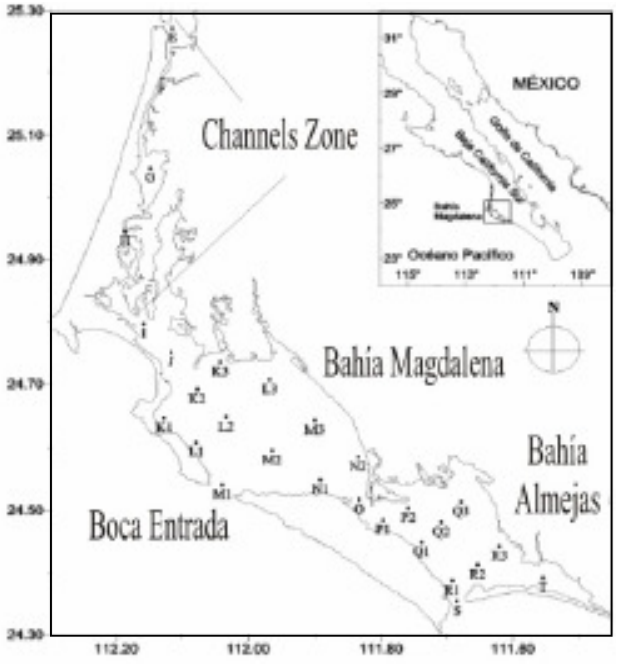

Fig. 1: Survey area and plankton sampling in Bahia Magadalena lagoon compled, Baja California Sur, Mexico

Materials and Methods

Zooplankton sampling was carried out during spring (March and June), summer (July, August and September) and autumn (November and December) of 1982. The sampling grid comprised 28 sampling stations and samples were taken during daylight. The Bahía Magdalena Lagoon Complex (BMLC). (24°15′ to 25°20' N and 111°30' to 112°15' W) is shown in Fig. 1.

This is divided into three zones: the channel zone located in the northwest includes tidal, land and channels, with an average depth of 3.5 m: Bahía Magdalena connected to the Pacific Ocean by a broad mouth with a depth of 38 m, and Bahía Almejas in the southwest with an average depth of 3 m and connected to the open sea by two mouths that do not allow passage by large craft (Fig.1, Alvárez-Borrego *et al*., 1975). Zooplankton samples collected with an open-conical-bridled net (0.60 m diameter, 1 m long and 333 µm mesh net) equipped with a flowmeter in its mouth. The 5 min. trawls were circular and near the surface at about (3.7 km hr^{-1}). The zooplankton captured were fixed in a seawater 4% formaldehyde solution (Steedman, 1976) and neutralized with a saturated solution of sodium borate. The temperature was recorded by a dip thermometer. The salinity was only measured in July, August, and September, using an analytical thermo-salinometer of Beckman Rosemount type, with a precision of 0.1 salinity. In the laboratory, initially there was a general review of the composition of the species in every sample. The zooplankton biomass was estimated a Folsom splitter into 50, 25, 12.5 and 6.25 % to obtain a volume close to 10 mL then divided using the method of displaced volume (Steedman, 1976) and the samples. Samples whose volume was < 15 ml were not divided. Abundance was standardized to (org.) 100 m^{-3} seawater (Fleminger, 1964) and these values were the basis for the statistical analyses. To analyze the association between the chaetognath species and temperature, the relative abundance of each species was calculated throughout the study period and compared with the temperatures at which they were found (to the nearest 0.5°C). To determine the correlation between planktonic biomass and the abundance of chaetognaths, we used a Spearman correlation analysis using the program Statgraphics 5.0. To use the Spearman coefficient, was assumed as null hypothesis that there was no relationship between the abundance of chaetognaths and the zooplankton biomass (p=0.05). The abundances used to estimate the assemblages among species in each month utilized the Morisita's index (Ludwig and Reynolds, 1988) calculated with the program ANACOM (De la Cruz-Aguero, 1994). The abundance of each species was transformed into a logarithm scale; Log (X + 1), where X is equal to the number of organisms for 100 m^{-3}. The similarity among stations was also calculated with Morisita´s index using a matrix of abundance per species. In order to obtain an estimation of the structure of the taxocenosis of the chaetognaths, abundance and relative frequency were graphed. Frequency was defined as the proportion of positive sampling stations for any given species. The graph was divided into one of four quadrants: Quadrant I, dominant species with high abundance and ample distribution; Quadrant II, occasional species with high abundance but with reduced distribution; Quadrant III, rare species with low abundance and reduced distribution; and Quadrant, IV constant species with low abundance but with ample distribution. All the chaetognaths were identified to the species level (Sund, 1961; Alvarino 1963).

Results and Discussion

Species composition: Twelve chaetognath species were identified; 11 in the genera *Sagitta* (Slabber, 1778), and 1 in *Pterosagitta* (Ritter-Zahony, 1911). *S. bipunctata* (Quoy and Gaimard, 1827) and *P. draco* (Krohn, 1853) were recorded for the first time in the Bahía Magdalena Complex, and were associated with habitats typical for them and in low abundances (< 8 org. 100 m^{-3}). A species of *Pterosagitta*, two species of *Krohnitta* and fourteen of the *Sagitta* genera have previously been reported in the Mexican Pacific (Sund, 1961), but not S. *peruviana* (in the BMLC having values > 6,000 org. 100 m^{-3} during summer). *S. peruviana* was first described near Puerto Talara (North of Perú) and in the adjacent regions along the Peruvian coasts (Sund, 1961), in the Bay of Panama (Pineda-Polo, 1978), Costa Rica and Guatemala (Alvarino, 1972). However, the only previous reports for this species in México are by Alvariño (1972) who recorded high abundance of *S. peruviana* in the Gulf of Tehuantepec (México) and Esquivel (1987) who detected this species in the north of the Gulf of California. Its record in the Gulf of California and in the Magdalena Bay Lagoon Complex extends the knowledge of its distribution in the northern region of the Eastern Tropical Pacific (Cota-Meza and Fernández-Álamo 1998). Along the western coast of Baja California Śur, México, the temperature and salinity were different during "El Niño" 1983 compared to previous non El Niño years The warmer waters seemed to affect the local siphonophore community causing a decrease in the abundance of the temperate

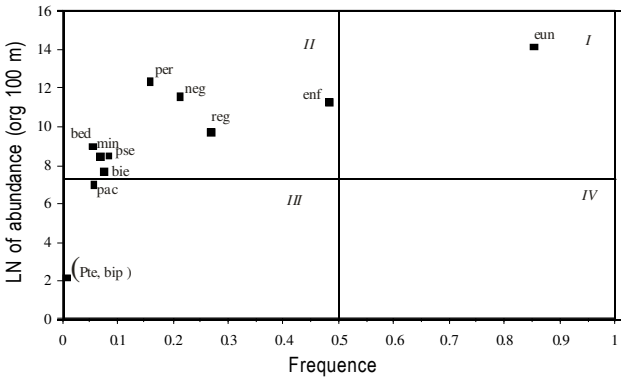

Fig. 2: Frequency and total abundance of chaetognaths in 1982. eun=*S. euneritica*, enf=*S. enflata*, reg = *S. regularis*, neg=*S. neglecta*, per= *S. peruviana*, bie= *S. bieri*, pse =*S. pseudoserratodentata*, min=*S. minima*, bed = *S. bedoti,* pac = *S. pacifica*, Pte = *P. draco*, bip = *S. bipunctata*

Table - 1: Sea surface temperature (°C) with chaetognath abundances

Species	Min	Max	Max Abundances
S. bedoti	15.5	26.5	18.0, 20.0 and 26.5
S. bierii	22.0	28.5	24.0
S. enflata	17.0	29.0	21.5, 22.5, and 24.5
S. euneritica	15.5	29.5	24.0
S. minima	15.5	25.5	17.5, 23.0 and 25.0
S. neglecta	19.5	27.5	26.0
*S. pacifica**	21.0	25.0	24.0
*S. regularis**	20.5	25.0	22.5, 23.5
S. peruviana	22.0	29.0	25.5 and 28.0
*S. pseudo serratodentata**	22.0	24.5	23.5

Temperature (°C, *Stenothermic)

Table - 2: Abundance of chaetognaths and Correlations for ranges of spearman (rs) between the abundance of chaetognaths and the biomass planktonic in three zones of the complex lagoon of Bahía Magdalena during 1982, significant correlations in a level of p=0.05

Date	Channels zone	Magdalena bay	Almejas bay
03-82	-0.4	0.30	0.56
06-82	0.63	0.23	0.73*
07-82	0.80	0.61*	0.51
08-82	0.6	0.21	0.47
09-82	0.0*	-0.165	0.69*
11-82	1.0*	0.6*	0.64*
12-82		0.11	0.84*

* Significativas

species *Muggiaea atlantica* and an increase in the abundance of *Chelophyes contorta*, a tropical species.(Gasca and Suárez, 1992).

The surface temperature varied widely monthly in the three areas of BMLC. In general, the values were lower in the lagoon mouths and higher in Channel zones and Almejas Bay. The lowest temperatures were recorded in March (15.5°C to 21.6°C) and the highest during September (23.7°C to 29.2°C). In general, chaetognaths are eurythermic (8-28°C) (Sund and Renner, 1959). In Bahía Magdalena, we frequently found higher abundances of *S. pacifica*, *S. regularis*, and *S. psudoserratodentata* associated with narrow temperature intervals (21°C to 25°C), which may be associated to the entrance of tropical waters into the bay (Table 1).

Table 1 Sea surface temperature (°C) and chaetognath abundances These chaetognaths species were found during the period of progressive increase in temperature in BMLC (October to December). This is the same temperature interval indicated for the California Current near the coast of Baja California during summer (Badan, 1997).

S. enflata appeared mainly with low abundance associated with low temperatures (17.0-19°C) distributed in the Mouth of Magdalena Bay. *S. enflata* and *S. friderici* (warm-water chaetognath including *S.*

S. friderici, typical of the Moroccan coast, appeared in some areas with temperatures ranging from 18 - 25 Table 1 Sea surface temperature (°C) and chaetognath abundance°C.

This species was never found during winter with prevailing temperatures < 17°C (Raymont 1983). Previously, circumstantial evidence had suggested that *S. enflata* was only widely distributed throughout the bay in summer and autumn when the temperature had increased. *S minima* was mainly associated with lower temperatures, typically < 25°C and at stations near the mouth of Magdalena Bay. In September, when the temperatures increased, the presence of this species indicated regions where low water temperatures still prevailed (Cota–Meza *et al*., 1992),

Biomass and chaetognaths abundances: There was a drastic decrease in phytoplankton biomass during December 1982, coinciding with the increase in sea surface temperature of water related to El Niño 1982-1983 (Gárate-Lizárrage and Siqueiros-Beltrones, 1998). The maximum zooplanktonic biomass occurred in summer (July and August with 35.3 and 13.8 ml m^3 respectively). Palomares-García and Gómez – Gutierrez (1996), stated that the zooplanktonic biomass from 1982 to 1986 related to the seasonal changes in temperature of the sea. They said the low biomass of zooplankton appeared during the first half of the year and both temperature and zooplankton biomass increased in the summer. The phytoplankton blooms occurred mostly in spring in BMLC composed by species like *Rhizosolenia imbricata Odontella mobiliensis*, *Proboscia alata*, *Leptocylindrus danicus*, *Thalassiosira leptopus*, *Thalassionema nitzschiodes*, and *Nitzschia pacifica* (Gárate-Lizárrage and Siqueiros-Beltrones, 1998). The high density of these species probably enhanced the increase in abundance of herbivorous and omnivoros zooplankton, particularly copepods like *Paracalanus* and *Acartia clausi* which usually considered as a resident species (Palomares-García, 1992), dominate during July to September. *S. euneritica* was present (Table 2). It appears that the proportional composition of different taxa of copepods, euphausiids, and chaetognaths is maintained in two sectors of the California Current System (Lavaniegos and Ohman, 2007) and the

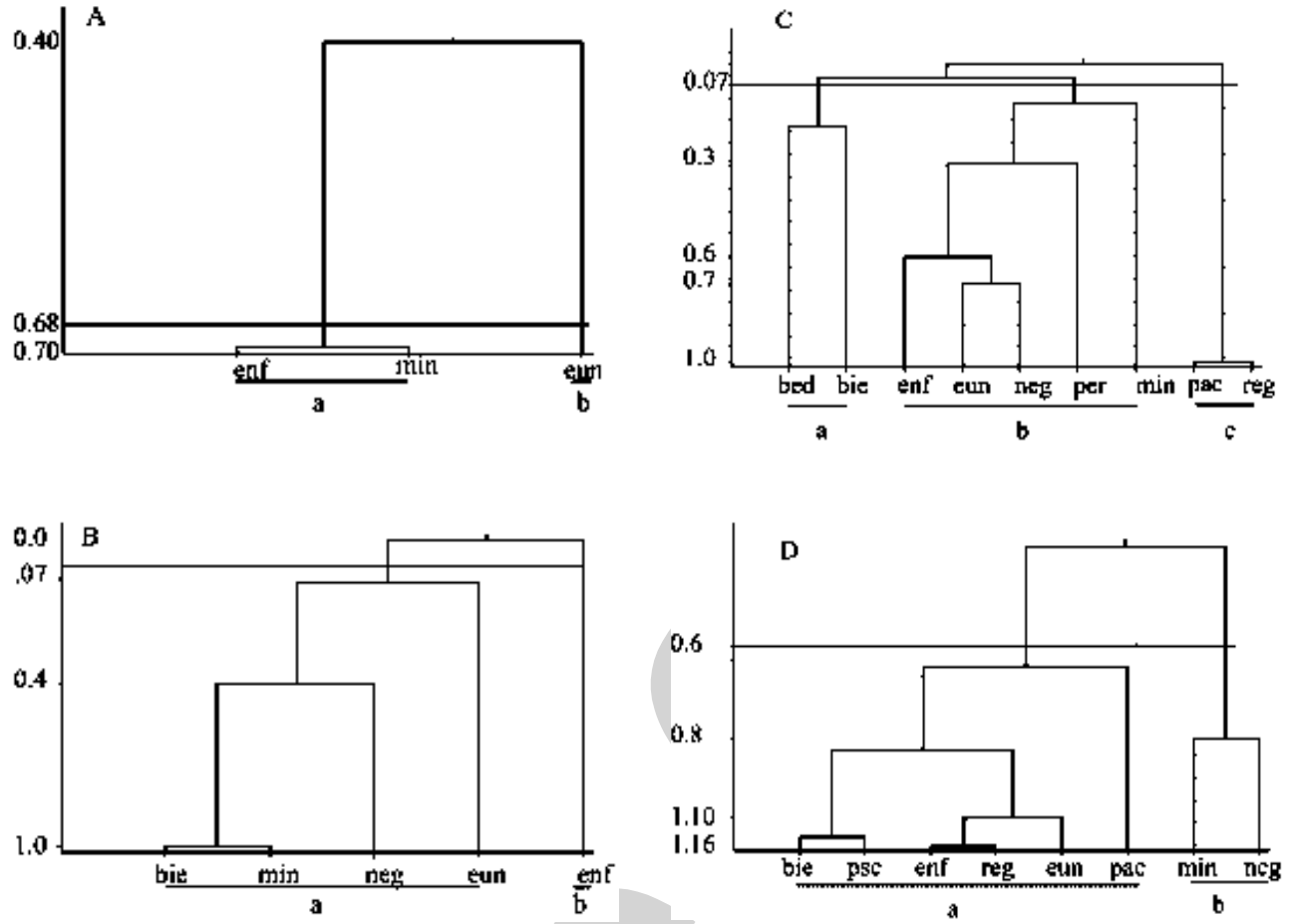

Fig. 3: Assemblages among species in the Bahia Magdalena lagoon, during: A) March association level = 0.68 and B) July association level = 0.07; C)August association level = 0.07 and D) December association level = 0.60; Morisita index (UPGMA)

BMLC (Palomares-García and Gómez-Gutiérrez, 1996). In general, the chaetognaths contributed to an increased biomass in most of the months studied, particularly for the area of Almejas.

Characterization of the taxocenosis of chaetognaths: When graphical the abundance and the frequency of appearance (Fig. 2) settle down three groups that define them next**:** Group I (Dominant): group represented by *S. euneritica* that was but the abundant one and but frequent throughout the period of study. Group II: This group contains to the following species: *S. enflata*, *S. regularis*, *S. neglecta*, *S. peruviana*, *S. pseudoserratodentata*, *S. bierii*, *S. minima*, y *S. bedoti*, which are abundan but little frequent (occasional), excels of *S. enflata* group obtaining a value of 0,48, the rest obtained values below 0.3. The majority of these species keeps relation with their appearance in the period from summer - autumn.

Group III grouped itself to the following species: *S pacifica*., and *Pterosagitta draco*, which were characterized little for being abundances and little frequent in their appearance (rare). All are oceanic. When characterizing the taxocenosis of chaetognaths *S. euneritica* separates considerably of the total of the species found during 1982; this species is of relatively small size and of ample distribution and abundance it confirms his affinity by the areas coasts (García-Zapien 1989).

Associations: The Morisita index was used to define the seasonal clusters of species and stations in Bahia Magdalena lagoon complex in 1982. The groups varied in complexity of taxocenosis, especially during the cold period. Group *a* was formed by oceanic species (*Sagitta enflata* and *S. minima*) and the group *b* was formed by a neritic species (*S. euneritica*). *S. euneritica* was the most abundant species throughout the period of study. Frequently organisms were found with food in their intestines (copepods). This species was recorded in the BMLC as a dominant species in cold years (Cota-Meza *et. al.,* 1992), and dominant in El Niño years. The other group was formed by the oceanic species *S. minima* and *S. enflata* (group *a* Fig. 3A) and were related to the pattern of currents that occur outside Bahía Magdalena. In spring, the CC dominates and is associated with upwelling and the tides *(Sáchez- Montante et al*. 2007). Although the two are considered oceanic, *S minima* usually inhabits deep waters (100 and 300 m). Sund and Renner (1959) found them in high abundance in waters with elevated concentrations of nutrients upwelled to the surface. *S. enflata* like *S minima* can enter into the bay transported by tidal currents, as are some larvae

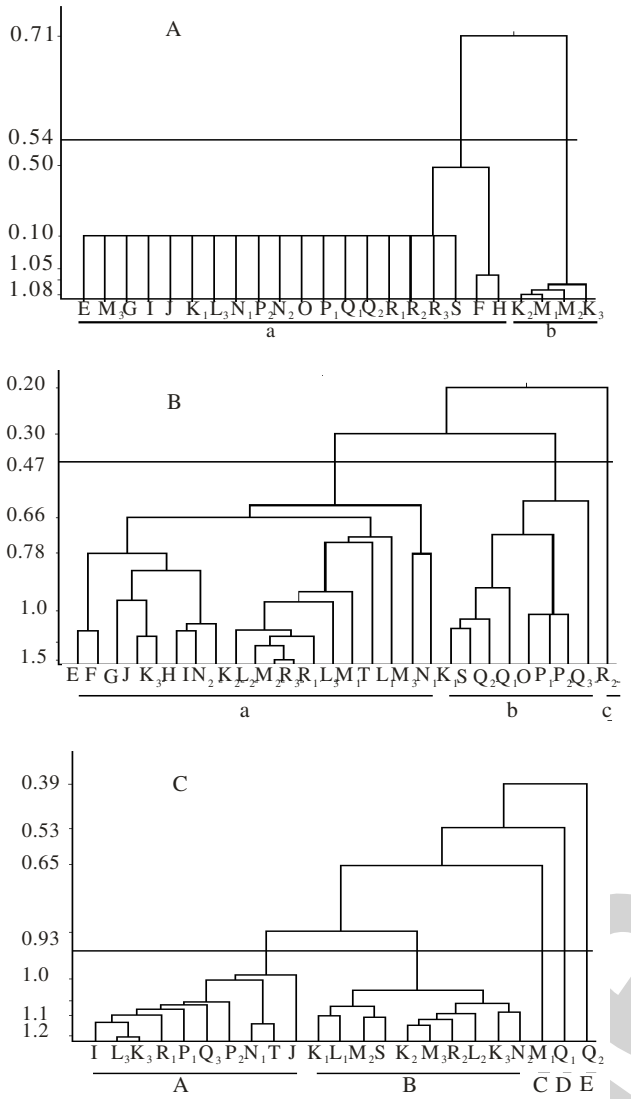

Fig. 4: Similarity among stations in the Bahia Magdalena lagoon during A) June association level = 0.54 Group conformation a and b; B) August association level = 0.47 Group conformation a, b and c; C) December association level = 0.93 Group conformation a, b, d and e; Coefficient of association, Morisita index (UPGMA)

of fish that are associated with the dynamics of the tides (Aceves-Medina *et al*., 1992). In spring, and early summer, *S. minima* and *S. bedoti* was recorded with *S. bierii* (***a***) in regions where plankton were accumulated due to the tides (Fig 3B). (On July 20th, there was a very big tide). In summer (August Fig. 3C) the following were found; *S enflata*, *S. euneritica, S. neglecta*, *S. peruviana*, and *S. minima* , the first three being found in Bahia Matanchen, San Blas, Nayarit (García-Zapien, 1989), at La Boca Barron Botadero and Chametla, Sinaloa, México (Pantoja, 1973), and the southern Gulf of California (Medina-Rendón, 1989). *Sagitta enflata* was associated with *S. regularis* (group b was).There were also association between some rare species in the bay, *e.g. S. pacifica* and *S. regularis*.

Similarity: The cold period was characterized by a homogeneous chaetognatha community with a dominance of *Sagitta euneritica*, except in deep zones (stations K_2 and M_1) where oceanic species like *S. enflata* and *S. minima* dominated (Fig. 4A).

During the warm period, there was an abrupt change in the clustered stations. Heterogeneity in the taxocenosis was related to three zones of Bahía Magdalena (Fig.4B, C). The three sampling areas were in agreement: 1) zone of channels 2) the deep zones (Magdalena Bahía and 3) the zone of Bahía Almejas, *S.euneritica* was dominant in BMLC in abundance and distribution being more , abundant in spring-summer. *S. enflata*. was the second most dominant species. The association is characterized in spring by *S. minima, S enflata*. and *S., euneritica*. The distribution of *S. peruviana* was possibly influenced by the oceanographic conditions of ENSO 1982. Changes associated with El Niño warming modified spawning activity of small pelagic fishes, phytoplankton and zooplankton composition (Avendaño-Ibarra *et al*., 2004).

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