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Structure and Composition of the Polychaete Community from Bahia San Quintin, Pacific Coast of Baja California, Mexico

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Abstract.—The diversity patterns of the polychaete fauna from a Pacific coastal lagoon were described. Polychaetes were collected in 1995 and 1998. This lagoon is formed by 2 arms: the western arm named Bahia Falsa and the eastern arm named Bahia San Quintin. 46 stations were sampled with a geological box corer. A total of 3,275 polychaetes, 28 families, 56 genera, and 104 species were identified in 1995, and 3,168 polychaetes were collected in 1998, 21 families, 39 genera and 65 species. From all the macrofauna collected in both surveys, polychaetes represented 45.2%. From the species collected, 55% correspond to new records for the area. Families Dorvilleidae, Polynoidae, Oweniidae, Scalibregmatidae, Sternapsidae and Sigalionidae present in 1995, were not in 1998 survey.

The stations with higher abundances (> 100 specimens/0.02 m^2) were located on the southern half of Bahia San Quintin. Species richness and diversity were also higher in San Quintin Bay. From the 30 families previously reported for San Quintin lagoon, 23 have been collected and 6 families were added: Ampharetidae, Oweniidae, Scalibregmatidae, Sternapsidae, Dorvilleidae and Sigalionidae. Families not found in both surveys were: Paraonidae, Magelonidae, Apistobranchidae, Sphaerodoridae, Trichobranchidae, Chrysopetalidae and Arenicolidae.

Results showed slightly lower redox potential values (−336 to +187 mV), slightly higher sediment temperatures (19.8°–22.1°C) and organic matter contents (0.3–4.1%) in 1998.

From 1995 to 1998 a change in the composition and structure of the polychaete communities was noted; species richness diminished from 104 to 65 species. The trophic complexity changed with an increase of deposit-feeders, the abundance of other trophic categories decreased, indicating a loss of complexity. Significant changes in the abundance of some families were detected, some increased their abundances: Spionidae from 17% to 48%, Orbiniidae from 4% to 13%; other families decreased in terms of abundance and number of species: Lumbrinereidae from 11% to 1.4%, Nereididae from 9% to 1% and Sabellidae from 14% to 5%. These modifications altered the composition and structure of the polychaete communities in this lagoon. Increased anthropogenic disturbance (oyster culture, agriculture) and environmental variability due to the ENSO 97–98 may have affected recruitment and survival of some polychaete species.

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Introduction

Some lagoons, located along the Pacific coast of Mexico, present ideal hydrological and sedimentary characteristics which make them potential sites for aquaculture. The San Quintin complex is one of these coastal lagoons that favor the development of bivalve aquaculture. It is considered ecologically important because it is a nursery area for several fish species, a resting site for migrating birds which have lost most of their resting and feeding areas in the United States, and its high productivity and diversity, in part due to upwellings which supply nutrients periodically. It is environmentally important to obtain baseline scientific data that help understand how benthic communities function and how they change during different climatological conditions.

The hydrology of San Quintin lagoon has been studied (Alvarez-Borrego & Chee-Barragán 1976; Alvarez-Borrego et al. 1975; del Valle & Cabrera-Muro 1981 a, b; Farfán & Alvarez-Borrego 1983). In contrast, there is a lack of information on macrofauna. One of the most neglected, major groups of marine invertebrates may be the polychaetous annelids that could be useful as indicators of varying degrees of marine pollution (Tsutsumi 1990; Pocklington & Wells 1992). Only three polychaete surveys were found on the literature: Reish (1963) 90 stations sampled in 1960 in Bahía San Quintín (BSQ eastern arm), Calderón-Aguilera & Jorajuría-Corbo (1986) 11 stations sampled in 1981–82, 8 in BSQ and 3 in Bahía Falsa (BF western arm); and Díaz-Castañeda & Rodríguez Villanueva (1998) 39 stations sampled in December 1992, 13 in BF and 26 in BSQ.

Coastal marine benthic communities are threatened by human activities, and the present rate of habitat degradation is alarming. Given that only a small fraction of the benthic organisms that reside on or are buried in sediments have been described, it is likely that species are being lost without ecologists knowing they existed (Snelgrove 1999). Polychaetes constitute an important macrofaunal group in this lagoon comprising about 70% of the benthic biomass and individuals (Barnard 1970; Calderón-Aguilera & Jorajuría-Corbo 1986). More than 1,450 polychaete species are known from Mexico (Salazar-Vallejo et al. 1989; Díaz-Castañeda & Rodríguez-Villanueva 1998). Polychaetes are a significant component of all marine ecosysytems, they dominate soft-bottoms communities in terms of numbers of species and individuals. These annelid worms are important in food webs and in energy transference, both as predators and as important prey items for other animals, including crustaceans, fish and wading birds (Knox 1960). They present different feeding modes (carnivores, herbivores, omnivores, deposit-feeders, symbiotic chemoautotrophic bacteria), this plasticity could be the reason of their success in many environments (Beesley et al. 2000). Many species are important bioturbators of sediment and facilitate the incorporation of organic matter into sediments. Polychaetes show a spectacular diversity of reproductive and developmental modes which allow them to live in different environments (Wilson 1991; Giangrande 1997). Because of their cosmopolitan distribution, polychaetes can be used as indicators of pollution and the "state of health" of a benthic community (Pearson & Rosenberg 1978; Reish 1980; Bellan et al. 1988; Pocklington & Wells 1992; Lardicci & Rossi 1998).

From a management perspective, they are useful organisms for identifying problem sites and for the assessment of the severity of the problem. They respond to disturbance induced by different kinds of pollution, by exhibiting quantitative changes in assemblage distribution. Polychaetes can also be used as indicators of recovery of benthic environments from perturbations since in many cases they are major elements of the recolonization process (Díaz-Castañeda et al. 1989; Díaz-Castañeda & Almeda-Jauregui 1999).

In spite of their importance in benthic communities few faunal studies have occurred in Mexico, in part because of identification problems due to lack of proper identification keys as well as the low number of polychaetologists (Salazar-Vallejo et al. 1989; Pocklington & Wells 1992).

El Niño is an important phenomenon throughout the world. Its effects on marine ecosysytems and organisms may go beyond temperature change. Invertebrates have complex life cycles in which certain life stages, and therefore the dynamics of entire populations, are at the mercy of various physical processes acting within the ocean-atmosphere system (Arntz & Tarazona 1990; Bakun 1996; Escribano et al. 2004). During El Niño Southern Oscillation (ENSO) 1997–1998, high temperatures and low nutrient concentrations resulted in widespread mortality of giant kelp forests (*Macrocystis pyrifera*) (Tegner & Dayton 1987) and other marine organisms in the region. Temperature anomalies greater than 1°C persisted continuously for 8 months in the west coast of Baja California, in some cases anomalies attained +3°C (Dayton et al. 1992).

The purpose of this study is to describe the composition and structure of polychaete communities in San Quintín lagoon in 1995 and 1998 before and after the El Niño 1997–98.

Study Area

San Quintin complex is a slightly hypersaline, highly productive coastal lagoon located between 30°24′–30°30′ N and 115°57′–116°01′ W in the Pacific coast of Baja California (Fig. 1). This lagoon has an area of 42 Km^2 (4,200 hectares) and around 80% of it is covered by the eelgrass *Zostera marina* (Inclán-Rivadeneyra & Acosta-Ruiz 1988; Poumian-Tapia & Ibarra-Obando 1999). It has been exploited for many years (mariculture) but it can still be considered a relatively non disturbed area, although oyster culture is increasing. The region is arid, with a mean annual rainfall of about 150 mm. About 90 percent of the rainfall occurs between October and March.

Seagrass beds are important nursery areas for many species of fish and invertebrates, including several of economic importance (Stoner 1980 a, b; Orth & van Montfrans 1984, 1990). They also help to stabilize sediments thus reducing coastal erosion and are responsible for the composition and diversity of the seagrass infauna.

The lagoon has the shape of an inverted "Y", it consists of two sub-basins: BF (west) and BSQ (east). BF has an average depth of 4 m whereas BSQ has an average depth of 8 m. The bay has extensive intertidal and shallow subtidal shoals and channels up to about 10 m deep extending along the length of each basin. It has a permanent entrance and exchanges water with the coastal ocean. During low tides around 20% of the seafloor is exposed. An important aspect of the marine environment is the pattern of coastal upwelling, which is strongest between May and August (Aguirre-Muñoz et al. 1999). The granulometric studies show that in shallow areas as well as to the north of both arms clay and silty-sand

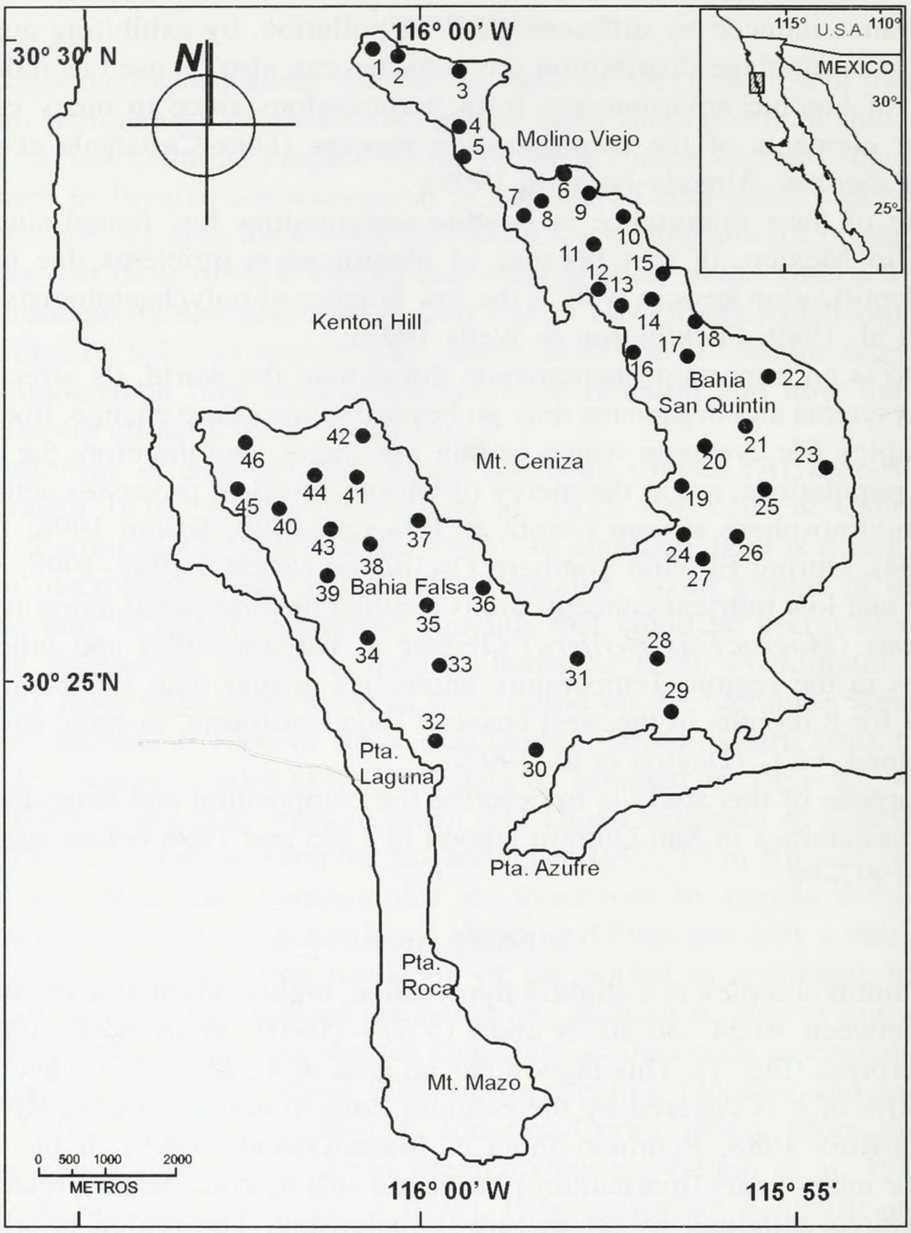

Fig. 1. Location of San Quintin lagoon on the Pacific coast of Baja California and sampling stations.

predominate, whereas near the mouth very fine sands are more abundant. The channel sediments are highly diverse, going from medium to fine sand and silt (Calderón-Aguilera 1992; Camacho-Ibar et al. 1997; Poumian-Tapia & Ibarra-Obando 1999). The lagoon margins present a typical saltmarsh flora with *Spartina foliosa* and *Salicornia virginica* and other vascular plants (Dawson 1962; Barnard 1970).

Material and Methods

Forty six stations were sampled in December 1995 and April 1998, including 15 stations in BF and 31 in BSQ (Fig. 1). Samples were collected using a box corer (16 cm internal diameter, 13 cm depth, sampling area of 0.02 m^2). Temperature and redox potential were measured immediately after collection of each sample by probing 2–3 cm inside the sediments an electrode coupled to a field potentiometer and a thermometer. Sediments were sieved in the field using a 1.0 mm mesh size and retained material was fixed in 10% buffered formaldehyde. In the laboratory, samples were washed and transferred to 70% isopropanol. Different zoological groups and particularly polychaetes were then sorted and identified at species level whenever possible.

Organic matter (percent of dry weight) was evaluated by ignition loss (Byers et al. 1978). Statistical methods were used to describe the structure and organization of the polychaete communities within the bay. Shannon diversity index and Pielou equitability were calculated in order to study the structure and degree of organization of the communities (Shannon & Weaver 1963; Frontier 1985; Pielou 1977). Trophic groups were determined using Fauchald & Jumars (1979) and Rouse & Pleijel (2001).

Olmstead and Tukey's test (Sokal & Rohlf 1995) was applied to analyze spatial distribution of polychaetes. This technique plots the frequency of appearance in each site sampled expressed as percentage against the density of organisms for each species. A mean average was calculated for both axes, resulting in four quadrants: I Frequent and abundant species, II Non frequent and abundant species, III Non frequent and non abundant species and IV Frequent and non abundant species.

Stress predictability (Alcolado 1992) modeling was applied to establish the level of environmental stress existing in the bay. Environmental severity or stress was predicted based on values of diversity (H') and evenness (J'), coupled with redox potential values.

Ordination and classification methods were used to detect spatial patterns among the polychaete fauna. The relationship between sample stations is reflected by the position they display in factorial space; when the two stations were close to each other, they had more similar faunistic profiles (Frontier & Pichod-Viale 1993; Díaz-Castañeda et al. 1993). A factorial correspondence analysis was carried out on the faunistic data: abundance of species and 46 stations. Cluster analysis using Pearson and Bray-Curtis coefficients (Bray & Curtis 1957; Sokal & Rohlf 1995) was employed to evaluate the level of association of different stations and species. A non-metric multidimensional scaling (MDS) method was used for the community ordination (Program PRIMER 5.1.1 for windows) since this technique has demonstrated to be suitable for multiple ecological purposes (Clarke 1993; Clarke & Green 1988). The MDS is based on the calculation of similarity/dissimilarity coefficients among samples, in this case, the similarity coefficient of Bray-Curtis. One data matrix was created for each sampling period using abundance per species. Data were treated using Primer Program 5.1.1 for windows and Statistica v. 5.0, after transformation to $\log_{10}(X + 1)$ as suggested by Frontier (1983) and Legendre & Legendre (1984).

Results

In 1995, the redox potential values (Eh) were negative in most of the stations. In the eastern arm they varied between −340 and +162 mV; BF presented values between − 320 to +161 mV. Sediment temperatures oscillated between 19.1 and 22.0°C. Organic matter values varied between 0.3 to 3.4% in BSQ and 0.1 to 3.1% in BF. In 1998 only 43% of stations were measured for Eh and temperature.

Table 1. Physico-chemical values of San Quintín lagoon sediments.

	1995			1998		
Station	Eh(mV)	T°C	% O.M.	Eh(mV)	T°C	% O.M.
2			3.40			
3	−340	21.8	2.03	−336	20.2	4.05
4	155	21.6	1.68	−208	21.1	2.90
5	−106	20.2	2.84			
7	−160	20.9	1.86	−175	21.4	2.04
8	−196	20.8	1.38	−180	21.6	1.35
9	−245	20.8	2.01	−253	20.9	2.14
10	130	21.2	2.19			
11	−73	21.0	1.10			
12	−102	20.3	1.03	−98	20.8	1.66
13	−155	20.2	0.84			
14	−197	21.0	1.32	−144	21.2	1.48
16	−187	19.9	2.35			
17	−167	20.0	1.83			
18	−109	20.1	2.04	−120	21.4	2.40
19	−219	20.6	2.12			
21	−177		1.15	−174	21.5	1.57
22	−82	19.1	1.50	−92	21.4	1.92
24	162	21.7	2.46			
25	−112	21.1	1.27	−126	21.7	1.94
26	−95	21.6	0.80			
28	−62	20.5	1.38	103	21.5	1.45
29	66	21.1	0.91			
30	−43	21.3	0.30	154	19.8	0.50
31	−69	21.5	0.42			
32	−92	21.4	1.30			
33	161	21.7	0.22	187	21.3	0.55
34	−24	21.3	2.14			
35	−128	21.1	2.45			
36	−85	21.6	1.60	−106	21.8	1.66
38	−123	21.6	2.90	−152	21.8	1.87
39	−136	21.2	2.78			
40	−49					
41	33	21.3	2.90	−190	20.9	2.70
42	−176	21.5				
44	−320	21.2	3.27	−277	21.8	2.95
45				−308	22.1	4.11
46	−249	21.4	3.30			

In the eastern arm the Eh varied between −336 mV and +154, while the western arm presented values between − 308 and +187 mV. Sediment temperatures were in the range 19.8 to 22.1°C, while the organic matter content ranged between 0.5 to 4.0% in BSQ and 0.3 to 4.1% in BF (Table 1). These results show slightly lower Eh values and slightly higher temperature and organic matter contents in 1998.

The lists of species found in each survey are given in Table 2. In 1995, a total of 8,680 benthic organisms were collected, of which 38% were polychaetes, 36.5% were crustaceans and 27.4% were molluscs. The 3,275 polychaetes collected and identified belonged to 28 families, 56 genera and 104 species (Table 2).

The families best represented were Capitellidae (19%), Spionidae (17%), Sabellidae (14%), Lumbrinereidae (11%), Nereididae (9%), Cossuridae (8%) and Syllidae (8%). The 10 top dominant species were *Prionospio heterobranchia* (331), *Chone infundiliformis* (295), *Mediomastus californiensis* (264), *Cossura candida* (236), *Scoletoma crassidentata* (222), *Exogone lourei* (206), *Capitella capitata* (147), *Armandia brevis* (130), *Neanthes arenaceodentata* (121), *Chone mollis* (117). The first eight species constitute 55% of the total abundance, the first five have been reported as abundant in previous studies (Reish 1963; Calderón-Aguilera 1986; Díaz-Castañeda & Rodriguez-Villanueva 1998). Reish (1963) found six species that constituted the dominant bay species on the basis of number of specimens. These were, in decreasing order of importance, *Prionospio malmgreni, Exogone verugera, Cossura candida, Capitia ambiseta, Scoloplos acmeceps* and *Fabricia limnicola.* Calderón-Aguilera (1992) reported five numerically dominant species: *Exogone occidentalis, Pseudipolydora kempi, Scoloplos acmeceps, Prionospio heterobranchia* and *Neanthes arenaceodentata.*

In April 1998, a total of 5,584 benthic organisms were collected, of which 56.7% were polychaetes, 27.2% were crustaceans and 7.5% were molluscs. The 3,168 polychaetes identified, belonged to 21 families, 39 genera and 65 species (Table 2). The families best represented were Spionidae (47.6%), Capitellidae (12.3%), Syllidae (10.5%), Paraonidae (7%) and Orbiniidae (6.8%). The first six species constitute around 75% of the total abundance. The ten top dominant species were *Prionospio heterobranchia* (832 specimens), *Polydora websteri* (548), *Scoloplos acmeceps* (370), *Exogone lourei* (291), *Mediomastus californiensis* (273), *Cirriformia spirabrancha* (128), *Capitella capitata* (68), *Chone mollis* (62), *Megalomma pigmentum* (59) and *Fabricinuda limnicola* (50).

The following families present in 1995 were not found in the 1998 survey: Dorvilleidae, Polynoidae, Oweniidae, Scalibregmatidae, Sternapsidae and Sigalionidae. Some of these families have species that are carnivorous. The increase in temperature in 1998 is related to a diminution of prey items which in turn may have affected their abundances.

Olmstead & Tukey's graph is only presented at the family level (Fig. 2a), because there were too many species to produce a clear graph. In 1995 and 1998 the polychaete families were placed in three out of four possible categories: dominant, restricted and rare. In 1995, in quadrant I (frequent and abundant), 6 polychaete families were characterized as dominant. Spionidae, Nereididae, Sabellidae, Lumbrinereidae, Capitellidae and Syllidae families displayed high densities and wide distribution throughout the lagoon. The families Spionidae, Capitellidae, and Sabellidae presented the highest densities and combined accounted for 45% of the total abundance of polychaetes. Ten families restricted to certain areas of the lagoon were located in quadrant II (non-frequent and abundant) and corresponded to 32% of all families. Within quadrant III (non-frequent and non-abundant), 12 polychaete families were located, classified as rare or occasional. No families were located in quadrant IV corresponding to frequent and non-abundant families. Approximately 35% of species were located in quadrant I (36 species). In 1998 (Fig. 2b), in quadrant I, only 3 polychaete families were characterized as dominant. The families Spionidae, Orbiniidae and Capitellidae displayed high densities and

Table 2. Polychaete species from San Quintín lagoon, Baja California.

Species	1995	1998
AMPHARETIDAE		
Ampharete labrops Harman, 1961	x	
Ampharete sp	x	
Amphicteis acutifrons Grube, 1850		x
Amphicteis sp Grube, 1850		x
CAPITELLIDAE		
Capitella capitata Fabricius, 1780	x	x
Mediomastus californiensis Hartman, 1944	x	x
Mediomastus sp	x	x
Notomastus magnus Hartman, 1947	x	x
Notomastus tenuis Moore, 1909	x	x
Notomastus sp		x
CIRRATULIDAE		
Aphelochaeta marioni Saint-Joseph, 1894	x	
Aphelochaeta sp	x	
Cirriformia spirabranchia Moore, 1904	x	x
Monticellina tesselata Harman, 1960	x	
Protocirrineris socialis Blake, 1996	x	
Protocirrineris sp		x
COSSURIDAE		
Cossura candida Hartman, 1955	x	x
Cossura sp A	x	x
DORVILLEIDAE		
Dorvillea sp	x	
EUNICIDAE		
Lysidice ninetta Verril, 1900	x	
Marphysa disjuncta Harman, 1961	x	
M. sanguínea Montagu, 1815	x	x
Marphysa sp	x	x
FLABELLIGERIDAE		
Pherusa capulata Moore, 1909	x	x
Piromis arenosus Kinberg, 1867	x	x
Piromis sp		x
GLYCERIDAE		
Glycera americana Leidy, 1855	x	x
G. tenuis Hartman, 1944	x	x
GONIADIDAE		
Goniada brunnea Treadwell, 1906	x	
G. littorea Hartman, 1950	x	x
HESIONIDAE		
Podarkeopsis glabra Hartman, 1961	x	x
Podarke pugettenisis Johnson, 1901	x	x
LUMBRINERIDAE		
Scoletoma crassidentata Fauchald, 1970	x	
S. erecta Moore, 1904	x	
S. monroi Fauchald, 1970	x	
S. tetraura Schmarda, 1860	x	x

Table 2. Continued.

Species	1995	1998
MALDANIDAE		
Axiothella rubrocincta Johnson, 1901	x	
Axiothella sp Verril, 1900	x	
Clymenura gracilis Moore, 1923		x
Euclymeninae sp A Ardwidsson, 1906		x
Isocirrus longiceps Moore, 1923	x	
Maldane sp	x	
NEPHTYIDAE		
Nephtys caecoides Hartman, 1938	x	x
Nephtys sp		x
NEREIDIDAE		
Neanthes caudata delle Chiaje, 1828	x	x
Nereis latescens Chamberlin, 1919	x	
N. pelagica Linné, 1758	x	
Nereis sp		x
Platynereis bicanaliculata Baird, 1863	x	
P. marphysa		x
OENONIDAE		
Arabella iricolor Montagu, 1804	x	x
A. pectinata Fauchald, 1970	x	
Drilonereis falcata Moore, 1911	x	
D. longa Webster, 1879	x	
D. mexicana Fauchald, 1970		x
Drilonereis sp		x
Notocirrus californiensis Hartman, 1944		x
ONUPHIDAE		
Kinbergonuphis sp	x	x
OPHELIIDAE		
Armandia bioculata Hartman, 1938	x	
A. brevis Moore, 1906	x	x
Ophelia pulchela Tebble, 1953		x
Polyophthalmus picuts Dujardin, 1839	x	
ORBINIDAE		
Leitoscoloplos mexicanus Fauchald, 1972	x	
L. normalis Day, 1977	x	
Naineris grubei Gravier, 1908		x
Phylo felix Kinberg, 1866	x	
P. ornatus Verril, 1873	x	
Scoloplos acmeceps Chamberlain, 1919	x	x
S. armiger Müller, 1776	x	
S. ohlini Ehlers, 1901		x
S. texana Maciolek & Holland, 1978		x
OWENIIDAE		
Owenia collaris Hartman, 1955	x	
PHYLLODOCIDAE		
Eteone pacifica Hartman, 1936	x	
Eteone sp	x	x
Eulalia bilineata Johnston, 1840	x	
Eumida sp		x

Table 2. Continued.

Species	1995	1998
POLYNOIDAE		
Harmothoe imbricata Linné, 1767	x	
Harmothoe sp		x
SABELLIDAE		
Chone infundibuliformis Kröyer, 1856	x	
C. mollis Bush, 1904	x	x
Fabricinuda limnicola Hartman, 1951	x	x
Megalomma pigmentum Reish, 1963	x	x
SCALIBREGMATIDAE		
Scalibregma sp	x	
SIGALIONIDAE		
Sthenelais fusca Johnson, 1897	x	
SPIONIDAE		
Aporionospio pigmaeus Hartman, 1961	x	
Boccardiella hamata Webster, 1879	x	x
Microspio pigmentata Reish, 1959		x
Minuspio cirrifera Wirén, 1883	x	
Polydora socialis Schmarda, 1861		x
P. websteri Hartman, 1943		x
Prionospio heterobranchia Reish, 1959	x	x
P. lighti Maciolek, 1985	x	x
Pseudopolydora pauchibranchiata Okuda, 1937	x	
Scolelepis squamata Müller, 1806	x	
Spiophanes bombyx Claparéde, 1870	x	
S. duplex Chamberlain, 1919	x	x
S. missionensis Hartman, 1941	x	
Spio pacifica Blake & Kudenov, 1978	x	
Spio sp		x
SYLLYDAE		
Cicese sphaerosylliformis Díaz & San Martín, 2001	x	x
Eusyllis sp	x	
Exogone lourei Berkeley & Berkeley, 1938	x	x
Grubeosyllis mediodentata Westheide, 1974	x	x
Pionosyllis sp	x	x
Sphaerosyllis californiensis Hartman, 1966		x
Syllis aciculata Treadwell, 1945	x	
S. gracillis Grube, 1840	x	x
S. heterochaeta Moore, 1909	x	
Syllis sp		x
TEREBELLIDAE		
Eupolymnia nebulosa Montagu, 1818	x	
Pista alata Moore, 1909	x	x
Pista sp	x	x
Polycirrus sp		x

Table 3. Polychaete species recorded in previous studies at San Quintín lagoon, Baja California. Numbers correspond to the different taxa recorded in the area.

Reish, 1963	
1	*Anaitides ca. multiseriata*
2	*Anaitides williamsi*
3	*Arabella iricolor*
4	*Arenicola cristata*
5	*Armandia bioculata*
6	*Axiothella rubrocincta*
7	*Brania clavata*
8	*Capitella capitata*
9	*Capitita ambiseta*
10	*Chone mollis*
11	*Chrysopetalum occidentale*
12	*Cirriformia luxuriosa*
13	*Cirriformia spirabrancha*
14	*Cossura candida*
15	*Dorvillea articulata*
16	*Eteone dilatae*
17	*Eteone pacifica*
18	*Eulalia bilineata*
19	*Exogone verugera*
20	*Fabricia limnicola*
21	*Glycera americana*
22	*Goniada brunnea*
23	*Hapioscoloplos elongatus*
24	*Lepidonotus caelorus*
25	*Lumbrineris erecta*
26	*Lumbrineris minima*
27	*Marphysa sanguinea*
28	*Megalomma pigmentum*
29	*Nephtys caecoides*
30	*Nereis caudata*
31	*Nerinidaes maculata*
32	*Notomastus magnus*
33	*Onuphis microcephala*
34	*Ophiodromus puggettensis*
35	*Pista alata*
36	*Platynereis bicanaliculata*
37	*Polydora uncata*
38	*Polyophthalmus pictus*
39	*Prionosopio malmgreni*
40	*Prionospio pygmaeus*
41	*Scoloplos (L) ohlini*
42	*Scoloplos acmeceps*
43	*Scyphoproctus oculatus*
44	*Sphaerodorum minutum*
45	*Spiophanes missionensis*
46	*Trypanosyllis gemmipara*
47	*Typosyllis variegata*
48	*Aedicira pacifica*
49	*Aricidea suecica*
	Armandia bioculata
	Axiothella rubrocincta
	Brania clavata
	Chone mollis
	Cirriformia luxuriosa

Table 3. Continued.

50	*Cossura soyeri*
	Eteone dilatae
	Eteone pacifica
	Exogone occidentalis
	Fabricia limnicola
	Kinbergonuphis microcephala
	Leitoscoloplos pugettensis
	Lepidonotus squamatus
	Lumbrineris erecta
	Lumbrineris mimima
51	*Magelona pitelkai*
	Marphisa sanguinea
52	*Mediomastus ambisetus*
53	*Mediomastus californiensis*
	Megalomma pigmentum
	Neanthes arenaceodentata
54	*Nephtys caecoides*
55	*Nephtys ferruginea*
	Notomastus magnus
	Notomastus tenuis
	Pherusa capulata
56	*Phylo felix*
	Pista alata
	Platynereis bicanaliculata
	Polyophtalmus pictus
57	*Prionospio cirrifera*
58	*Prionspio heterobranchia*
59	*Prionospio malmgreni*
60	*Prionospio newportensis*
61	*Pseudopolydora kempi*
	Scolelepis maculata
	Scolopios acmeceps
	Scyphoproctus oculatus
	Spiophanes missionensis
62	*Apistobranchus sp*
	Arabella iricolor
63	*Brada villosa*
	Brania sp.
64	Cirriformia cf. spirabrancha
	Chaetozone sp.
	Chone sp.
65	*Clymenura gracilsis*
	Cossura candida
66	*Euchone sp.*
67	*Exogone dispar*
68	*Exogone lourei*
69	*Goniada maculata*
	Kinbergonuphis cf microcephala
70	*Leitoscoloplos mexicanus*
71	*Lysidice ninetta*
72	*Marphysa sanguinea*
	Megalomma bioculatum
73	*Monticellina tesselata*
	Neanthes acuminata
	Nereis sp.
	Notomastus sp.

Table 3. Continued.

74	*Pionosyllia sp.*
75	*Polydora socialis*
76	*Praxillela sp.*
77	*Prionospio multibranchiata*
	Prionospio (Minuspio) cirrifera
	Prionospio heterobranchia
78	*Scoletoma tetraura*
79	*Scoloplos rubra*
80	*Spio pettiboneae*
81	*Syllis (Syllis) gracilis*

when combined accounted for 70% of the total abundance. Seven families restricted to certain areas of the estuary were located in quadrant II (non-frequent and abundant) and corresponded to 33% of all families. Within quadrant III (non-frequent and non-abundant), 11 polychaete families were located, and corresponded to rare or occasional. No families were located in quadrant IV. 25% of species were located in quadrant I (16 species).

BSQ exhibited a broad range of species richness per station. Values varied between 6–13 species in heads of both estuary arms and 3–26 species in the middle sections of both basins (Fig. 3).

Higher abundance values, more than 100 polychaetes/station were located largely on the southern half of BSQ, only one of these stations was located in the northern part of BF (station 46). In both surveys, SQB presented higher polychaete densities and diversity values, probably the oyster aquaculture in BF although not intensive has produced a certain impact in the benthic communities due to an excess of organic matter.

In 1995, in BSQ several stations presented diversity values higher than 3.50, station 14 had 4.15; three stations (5, 9, 20) reached 25 species. On the contrary, in BF only one station (14) presented a higher value than 3.50 (station 41), seven stations presented diversity values between 3.00 and 3.50, no stations had values higher than 4.00. No station reached an specific richness of 25, the highest value was 19 species in station 22.

From the 30 families already reported by Reish (1959), Calderón-Aguilera (1992), Díaz-Castañeda & Rodríguez-Villanueva (1998), 23 have been found in the present work and six families are added: Ampharetidae, Oweniidae, Scalibregmatidae, Sternapsidae, Dorvilleidae and Sigalionidae. The seven families not found in 1995 and 1998 were: Paraonidae, Magelonidae, Apistobranchidae, Sphaerodoridae, Trichobranchidae, Chrysopetalidae and Arenicolidae.

From the 6,443 polychaetous annelids collected in both cruises, representing 104 species, 53% (55 species) correspond to new records for the area. Thirty species were common to both sampling campaigns. One new genus and a new species was found in the eastern arm, in stations 8, 17 and 23 of BSQ: *Cicese sphaerosylliformis,* reported separately (Díaz-Castañeda & San Martin 2001). From the 104 polychaete species found in 1995, 41% (43 species) are recorded for the first time, whereas from the 65 species collected in 1998, 33% (22 species) correspond to new records. Species richness and diversity were higher in BSQ

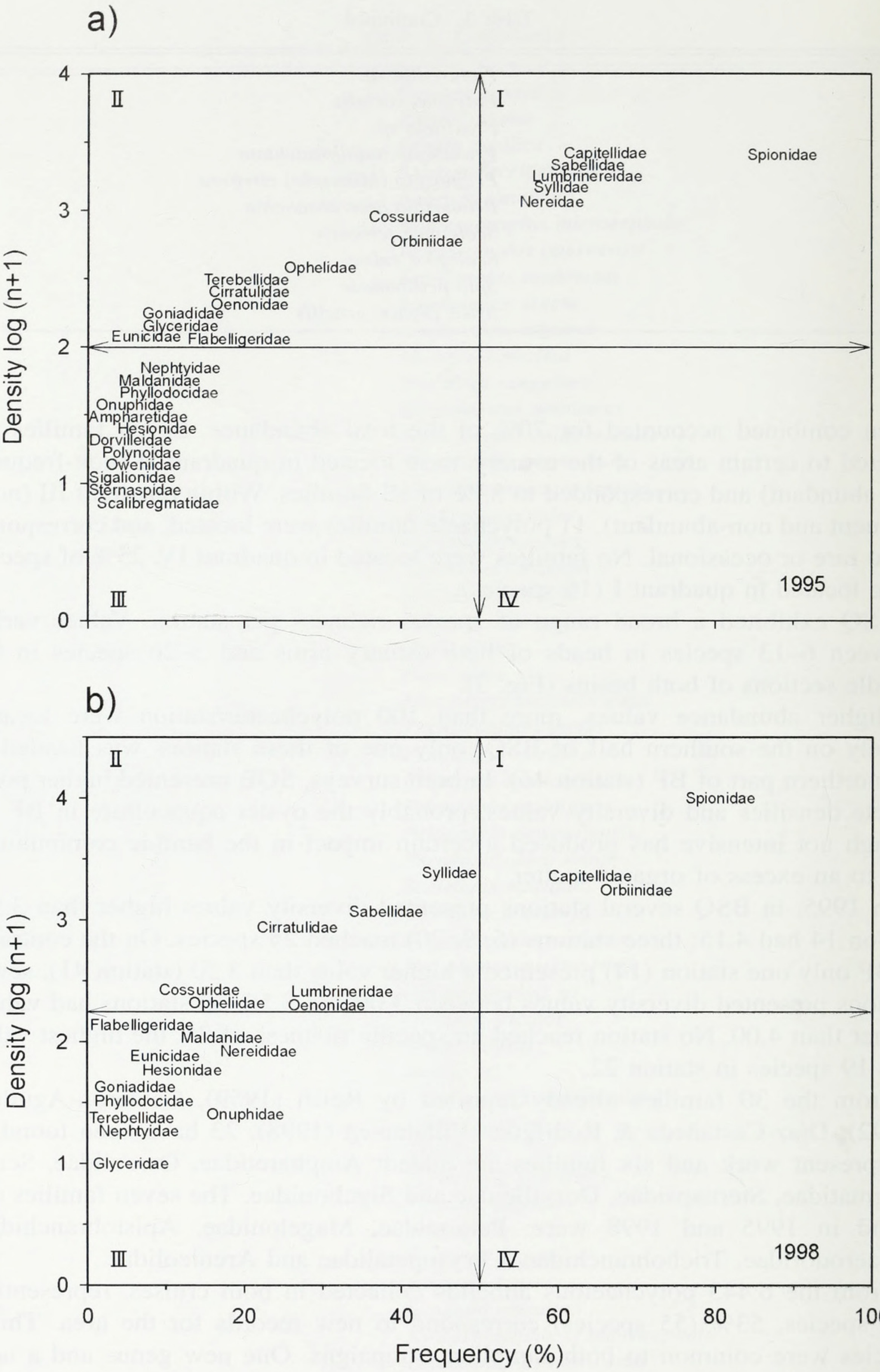

Fig. 2. Relationship between frequency (%) and density (org. 0.1 m^2) of polychaete families using Olmstead and Tukey's technique: a) 1995 B) 1998.

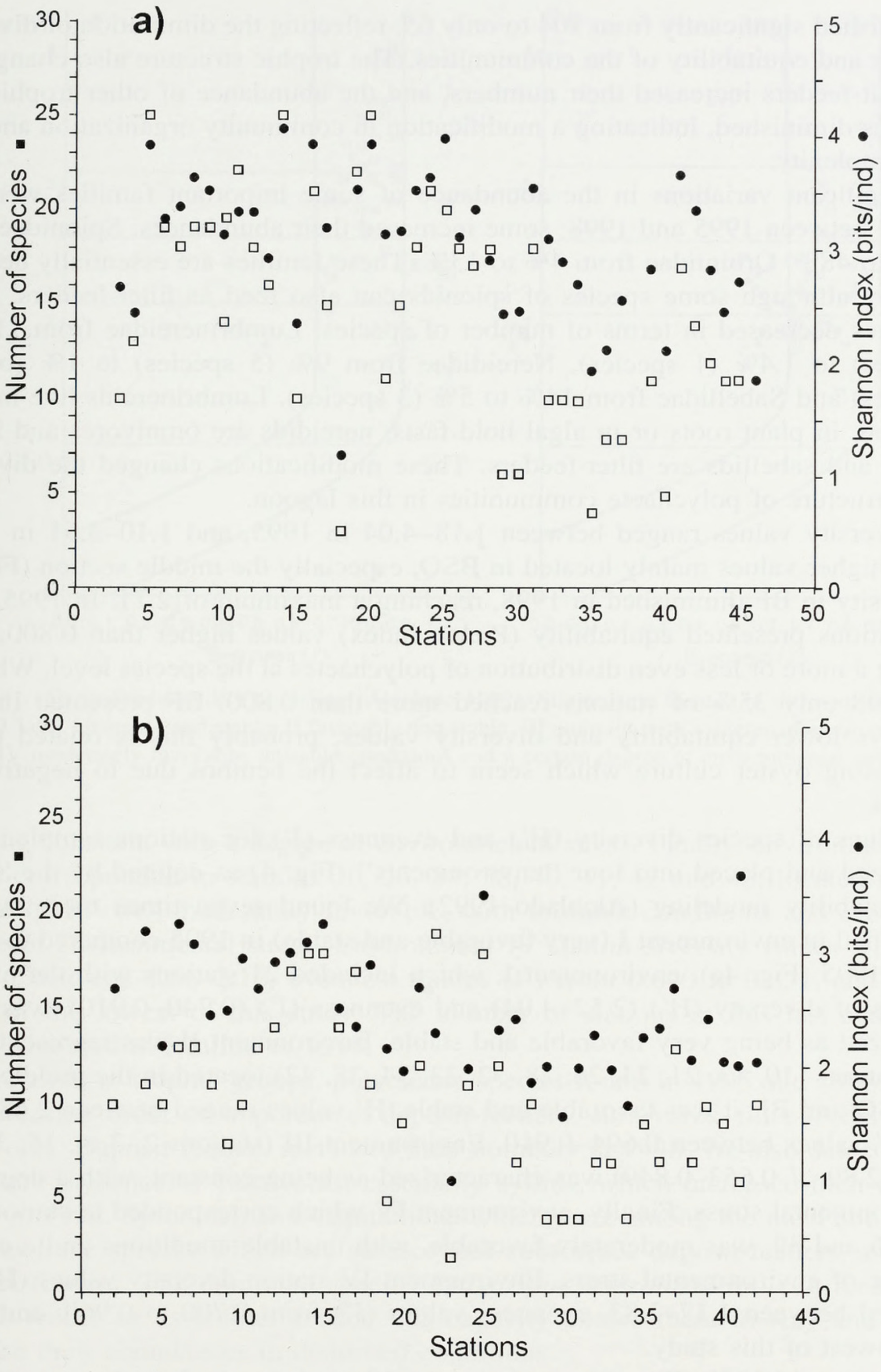

Fig. 3. Diversity (H′) and species richness of polychaetes collected in both surveys: a) 1995, b) 1998.

(Fig. 3), 11 stations in BSQ had diversity values higher than 3.5, only station 40 located in the northern section of BF presented a diversity value higher than 3.5.

Although abundances were similar in 1995 and 1998, we noted a change in the composition and structure of the polychaete communities; species richness diminished signficantly from 104 to only 65, reflecting the diminution of diversity values and equitability of the communities. The trophic structure also changed as deposit-feeders increased their numbers, and the abundance of other trophic categories diminished, indicating a modification in community organization and loss of complexity.

Significant variations in the abundance of some important families were detected between 1995 and 1998; some increased their abundances: Spionidae from 17% to 48%, Orbiniidae from 4% to 13%. These families are essentially deposit-feeders although some species of spionids can also feed as filter-feeders. Other families decreased in terms of number of species: Lumbrinereidae from 11% (4 species) to 1.4% (1 species), Nereididae from 9% (5 species) to 1% (only 2 species) and Sabellidae from 14% to 5% (3 species). Lumbrinereids live in sand or mud, in plant roots or in algal hold-fasts, nereidids are omnivores and herbivores and sabellids are filter-feeders. These modifications changed the diversity and structure of polychaete communities in this lagoon.

Diversity values ranged between 1.18–4.04 in 1995, and 1.10–3.51 in 1998, with higher values mainly located in BSQ, especially the middle section (Fig. 3). Diversity in BF diminished in 1998, reaching a maximum of 2.71. In 1995, 55% of stations presented equitability (Pielou index) values higher than 0.800, indicating a more or less even distribution of polychaetes at the species level. Whereas in 1998 only 35% of stations reached more than 0.800. BF presented in both surveys lower equitability and diversity values, probably this is related to the increasing oyster culture which seem to affect the benthos due to negative Eh values.

Values of species diversity (H′) and evenness (J′) for stations sampled were analyzed and placed into four "environments" (Fig. 4) as defined by the Stress-Predictability modeling (Alcolado 1992). We found seven times more stations classified in environment I (very favorable and stable) in 1995 compared to 1998.

In 1995 (Fig. 4a), environment I, which included 21 stations with the highest values of diversity (H′) (2.52–4.04) and evenness (J′) (0.740–0.910), was characterized as being very favorable and stable. Environment II was represented by 11 stations (10, 13, 21, 24, 26, 28, 32, 33, 34, 38, 42) located in the middle areas of BSQ and BF, it was favorable and stable, H′ values ranged between 2.68–3.62 and J′ values between 0.694–0.910. Environment III (stations 2, 3, 4, 15, 37, H′ 2.41–2.89, J′ 0.653–0.849) was characterized as being constant, with a degree of environmental stress. Finally, environment IV which corresponded to stations 18, 35, 36 and 39, was moderately favorable, with unstable conditions and a certain degree of environmental stress. Environment IV station diversity values (H″) oscillated between 1.17–2.83, evenness values (J″) from 0.700 to 0.960, and were the lowest of this study.

Whereas in 1998 (Fig. 4b), environment I included only 3 stations (6, 15, 25) with the highest values of diversity (H′) (3.24–3.52) and evenness (J′) (0.777–0.878), was characterized as being very favorable and stable. Environment II was constituted by 10 stations (2, 3, 4, 10, 11, 12, 13, 14, 18, 21) situated mainly in the medium section of BSQ, it was favorable and stable, H′ values ranged between 2.42–3.18 and J′ values between 0.723–0.918. Environment III increased with respect to 1995 survey, it was formed by 12 stations located in both arms (5, 8, 9, 16, 19, 26, 27, 32, 35, 36, 39, 43), H′ 2.16–2.51, J′ 0.575–0.836) characterized

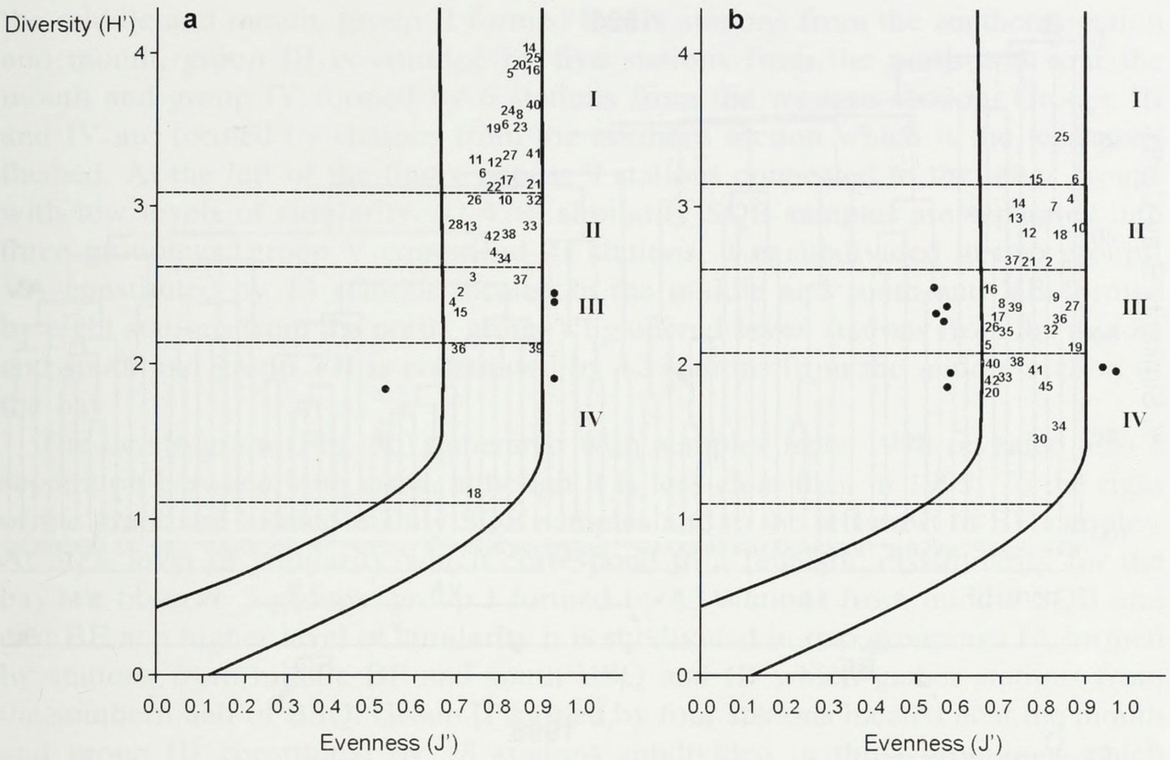

Fig. 4. Stress-Predictability modeling (Alcolado 1992). Stations are located in different environments: I Very favorable and stable, II favorable and stable, III constant with a degree of environmental stress, IV moderately favorable, unstable conditions and a certain degree of environmental stress.

as being constant, with a degree of environmental stress. Finally, environment IV which corresponded to stations 30, 33, 34, 38, 40, 41, 42 and 45, located in the middle of BF was moderately favorable, with unstable conditions and a certain degree of environmental stress. Environment IV station diversity values (H″) oscillated between 1.56–2.16, evenness values (J″) from 0.640 to 0.831, and were some of the lowest of this study. The number of stations in this last category almost doubled in relation to 1995.

In relation to trophic groups, polychaete species found in 1995 and 1998 were in decreasing order of importance: deposit-feeders, carnivores, filter-feeders and herbivores. Deposit-feeders increased their numbers in 1998. We also detected an important presence of carnivores, essentally syllids, which increased their abundance in 1998. Spionidae and Capitellidae which were among the most abundant families have species which are surface and subsurface deposit-feeders, as well as filter-feeders. The dominant species *Prionospio heterobranchia* can feed as a deposit-feeder or as a filter feeder, this capacity allows them to stay and even increase their abundances in disturbed conditions.

The families best represented in 1995, by decreasing order of importance were Capitellidae, Spionidae, Sabellidae, Lumbrinereidae and Nereididae, they changed in 1998: Spionidae, Orbiinidae, Capitellidae, Syllidae, Sabellidae.

Bray-Curtis coefficient of similarity was used to measure the level of association of samples. The dendrogram (Fig. 5a) generated with samples and replicates from 1995 revealed a clear separation between both arms, to the right of the graph are located BSQ samples and to the left BF samples (except stations 4 and 15). BF revealed four groups at 30% level of similarity: group I with 6 stations from

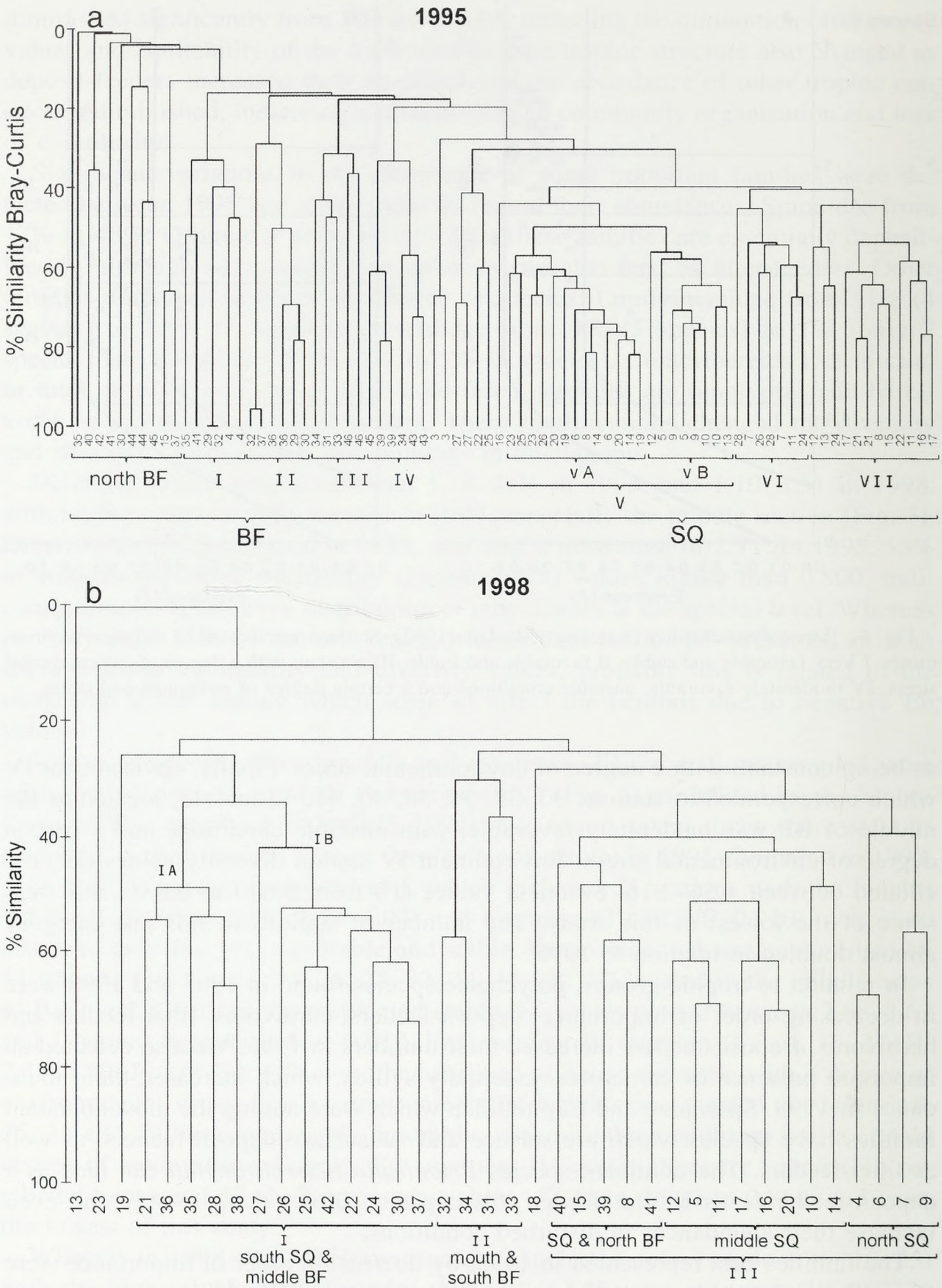

Fig. 5. Bray-Curtis dendrogram showing classification of stations sampled in 1995 (a) and 1998 (b).

the middle and mouth, group II formed by six stations from the southern section and mouth, group III constituted by five stations from the north and near the mouth and group IV formed by 6 stations from the western section. Groups III and IV are formed by stations from the northern section which is the least well flushed. At the left of the figure appear 9 stations connected to the other groups with low levels of similarity. At 42% similarity SQB samples are separated into three groupings: group V comprised 21 stations, it is subdivided in two groups, VA constituted by 13 stations located in the middle and south and VB formed by eight stations from the north, group VI gathered seven stations from the middle and south and group VII is constituted by 12 stations from the middle section of the bay.

The dendrogram (Fig. 5b) generated with samples from 1998 revealed also a separation between both arms, although it is less clear than in 1995. To the right of the graph are located mainly SQB samples and to the left most of BF samples. At 30% level of similarity which correspond to a faunistic dissimilarity for the bay we observe 3 groups: group I formed by 13 stations from middle SQB and east BF, at a higher level of similarity it is subdivided in two groupings IA formed by stations from middle BF and south BSQ and IB which gather stations from the southern half of BSQ. Group II formed by four stations located near the mouth and group III constituted by 18 stations subdivided in three groupings which represent respectively north BF and middle BSQ, middle BSQ and north BSQ.

Factorial Correspondence Analysis (FCA) and non metric MDS were applied to a matrix of 104 species and 45 stations in 1995, and a matrix of 65 species and 42 stations in 1998. Data treated correspond to the polychaete species abundances. Some representative graphics were selected.

In 1995, the first two axis extracted 45.5% of total inertia. In the factorial plane 1–2 we observed that samples from each lagoon arm gathered, forming BF and BSQ two separate groups in the factorial space (Fig. 6a). Most of the stations of BSQ were located on the positive side of axis 2 whereas all stations of BF were situated in the negative side of this axis which indicate that polychaete communities inhabiting each lagoon arm are not exactly the same, even if the species list is similar, the proportion between species change. This can be explained by the fact that hydrological conditions are not the same in both arms, depth averages are 4 and 8 m in BF and BSQ respectively. Conditions in BF can favor the development of more sensible species, those that can not tolerate very low oxygen concentrations and/or very negative Eh values because in this arm the water exchange with the sea is faster (Díaz-Castañeda & Rodriguez-Villanueva 1998). However if oyster aquaculture increases, it may cause a negative effect in the water and sediment quality, affecting these species.

In 1998, the first two axes extracted 55.2% of total inertia. In the factorial plane 1–2 (Fig. 6b), BF stations appear together, forming two groups. One of the groups is located on the positive side of axis 2, the second group which correspond to the southern section is situated on the negative side of this axis, near the stations from north BSQ. BSQ stations form a group that extends along axis 1, the stations from the north (negative side of axis 2), middle and southern sections differentiate.

Polychaete communities were also examined using non metric multidimensional scaling. This analysis also provided evidence of a separation between samples of the eastern and western arms of the bay. MDS analysis applied to data from

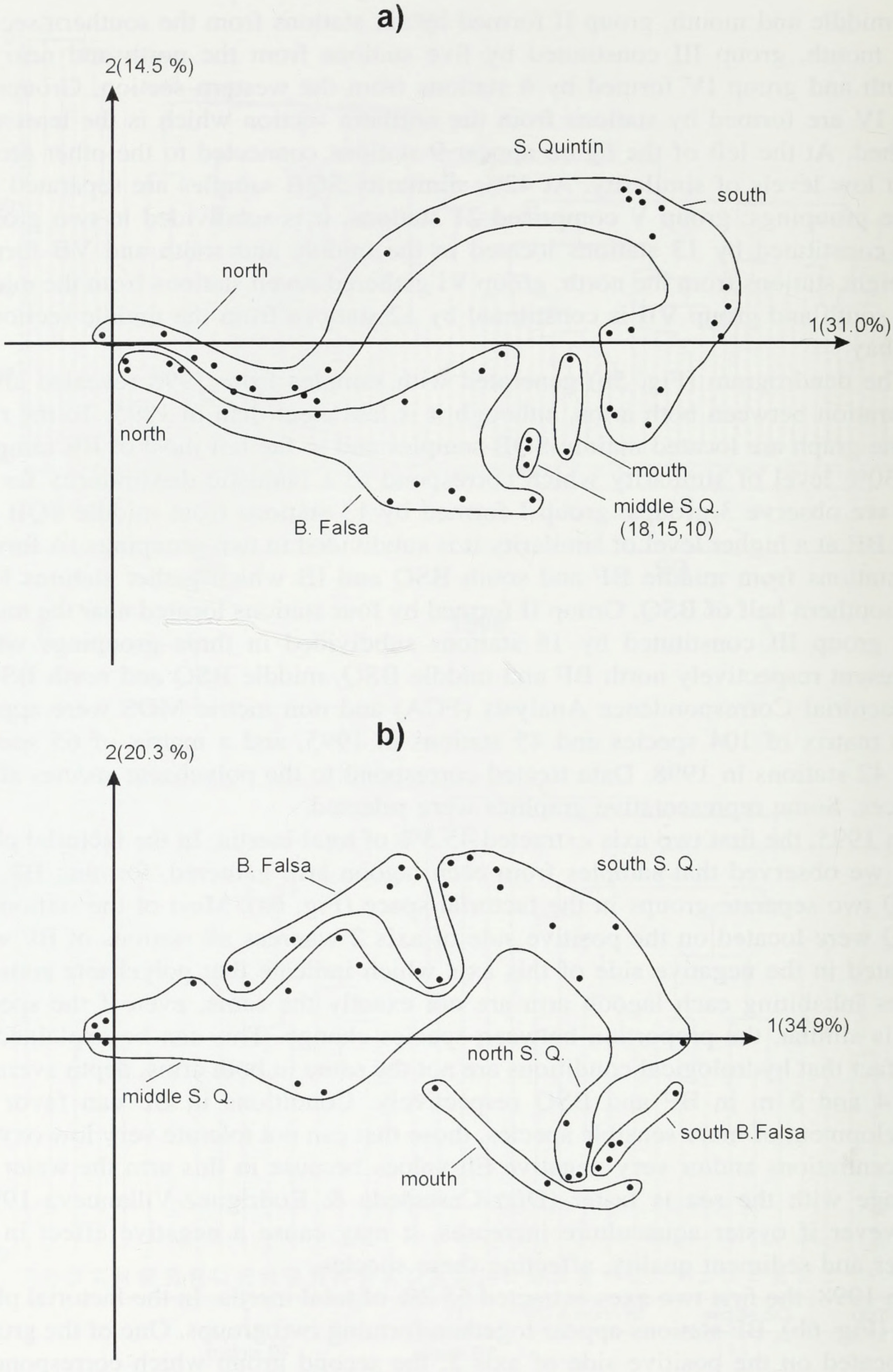

Fig. 6. Factorial Correspondance Analysis (FAC) ordination of sampled stations in Bahía San Quintín.

Fig. 7. Non-metric multidimensional scaling (MDS) ordination of stations sampled in 1995 (a) and 1998 (b).

1995 (Fig. 7a) revealed a group of stations located in the center which correspond to BSQ; to the right are located stations from the northern area. Around these stations are located those from BF. The stations near the mouth are surrounded by a dotted circle. Stress value (0.15) indicated that the configuration was a good representation of the faunistic similarities between stations. In 1998 (Fig. 7b) the separation between stations from BSQ and BF is also observed but not so clearly, stations from north BSQ are situated in the right and upper section. Most BSQ stations are located in the right side, while BF are mainly in the left. Stress value is 0.13. The mouth stations are essentially located in the same position than in 1995.

In conclusion, the study of polychaete communities in both arms of San Quintin lagoon showed in both surveys differences in species diversity, composition of species and abundances. Polychaete communities seemed to have balanced according to the physico-chemical characteristics prevailing in the area in 1995 and 1998. The proportion of families changed, some families disappeared completely in the 1998 survey: Dorvilleidae, Polynoidae, Oweniidae, Scalibregmatidae, Sternapsidae, Sigalionidae. Seven families found in 1992 (Díaz-Castañeda & Rodríguez-Villanueva 1998) were not collected in 1995 or 1998: Paraonidae, Magelonidae, Apistobranchidae, Sphaerodoridae, Trichobranchidae, Chrysopetalidae and Arenicolidae.

The eastern arm (SQB) presented in both surveys, higher polychaete densities and diversity values, probably the oyster aquaculture in Falsa Bay although not intensive has produced a certain impact in the benthic communities due to an excess of organic matter, resulting in negative Eh values and reduction of abundance and diversity. Comparing the polychaete composition and the values of some ecological indexes (Shannon Index, Pielou, Simpson dominance) between 1995 and 1998 we detected an important diminution of the species richness and diversity.

In BSQ several stations presented diversity values higher than 3.50, one station had more than 4.0; in BF only one station presented a higher value than 3.50, no stations had values higher than 4.0. Higher species richness values were located in BSQ (up to 26/station), indicating that this is an adequate environment for polychaetes development. It seems that the physico-chemical characteristics prevailing in each arm, as well as water exchange rates influence benthic communities development. The mathematical methods applied allowed a better global vision of the organization and structure of these populations.

Increased environmental variability due to the ENSO 97–98 probably may have affected recruitment, survival and reproductive patterns of polychaete species, modifying the composition and structure of polychaete communities between 1995 and 1998. In Chile, Escribano et al. (2004) found increased benthic bioturbation during the same period. Probably there was seagrass reduction (*Zostera marina*) in 1998 that could have indirectly affected zoobenthic recruitment, which is partially driven by the hydrodynamic environment modified by seagrass meadows, as has been observed by other authors (Bostrom & Bonsdorff 2000).

Finally, in San Quintin lagoon more than 50% of stations had relatively high values of diversity and evenness, indicative of healthy benthic communities. In general, the bay is characterized by high diversity values and approximately 70% of stations were favorable and constant environments for polychaetes, especially in the southern area of BF where the bivalve culture takes place and the middle section of BSQ.

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