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Structure of Benthic Diatom Assemblages from a Mangrove Environment in a Mexican Subtropical Lagoon[1]

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ABSTRACT

The taxonomic list and the structure of benthic diatom assemblages occurring in fine sediments (silt and sand) from the mangrove forest of the Balandra lagoon in Baja California Sur, México was determined based on seasonal samplings for one year. Assemblage structure was analyzed using several ecological indices for estimating diversity (*H'*), dominance (REDI), equitability, and similarity. A total of 230 diatom taxa were identified and include 109 new records for the Baja California peninsula coast. Taxa representative of highly productive and hypersaline environments were common. Assemblages were characterized by a few abundant species and many uncommon or rare taxa. High diatom diversity estimates at all sampling sites during all seasons suggest that diatom assemblages in sediments of the Balandra lagoon represent a quasi-pristine environment.

RESUMEN

Se determinó la lista taxonómica y la estructura de las asociaciones de diatomeas bentónicas presentes en sedimentos de la laguna de Balandra, con base en muestreos estacionales durante un año. La estructura de las asociaciones se analizó mediante varios índices ecológicos utilizados para estimar diversidad (H'), dominancia (REDI), equitabilidad, y similitud. Se registraron un total de 230 taxa de diatomeas, que incluyen 109 nuevos registros para las costas de la Península de Baja California. Taxa representativos de ambientes productivos y extremosos fueron comunes en las asociaciones. Estas se caracterizaron por la presencia de pocas especies abundantes y muchas especies raras y poco comunes. Las estimaciones altas de diversidad en todos los sitios de muestreo durante todas las estaciones del año, sugieren que en sedimentos de la laguna de Balandra proliferan asociaciones estables de diatomeas, las cuales representan un ambiente no perturbado.

Key words: *Baja California peninsula; benthic diatoms; diversity; mangrove.*

THE IMPORTANCE OF BENTHIC DIATOMS to littoral primary production in estuaries and intertidal zones is well recognized (Admiraal *et al.* 1982, Varela & Penas 1985, Delgado 1989, Moncreiff *et al.* 1992; Pinckney & Zingmark 1993a, b). They are a food source for many grazers (Lee *et al.* 1975, Fenchel & Kofoed 1976, Admiraal 1984) and filter feeders (Hendey 1964, Varela & Penas 1985, Shaffer & Sullivan 1988). The photosynthetic activities of benthic diatoms may alter significantly both pH and redox potential, and influence nutrient fluxes in and out of interstitial waters (Sundbäck & Granéli 1988, Seitzinger 1991). Nutrients being consumed by benthic diatoms (and made available to phytoplankton) also sustain monospecific proliferations of a few highly opportunistic forms in the sediments. These forms have been observed as being responsible for high primary production in sediments (Moncreiff *et al.* 1992; Pinckney & Zingmark 1993a, b).

Few studies, though, have attempted to relate the functional attributes of benthic diatom and species composition (Lee *et al.* 1975, Colijn & Dijkema 1981, Cahoon & Laws 1993). Many ecological or biogeographical studies require precise taxonomic determinations. In some cases, sufficient taxonomic support is available for doing biogeographical, ecological, or ecophysiological research, but more taxonomic surveys of benthic marine diatoms are still needed. In some tropical and subtropical regions, taxonomic studies on benthic diatoms are still lacking. For example, Siqueiros Beltrones (1994) summarized the few studies that have been made in México, all exclusively in the Baja California peninsula.

The Baja peninsula extends over both temperate regions and subtropical areas, including a transitional zone where tropical influences can be detected (Brusca 1980). It exhibits a wide variety of littoral habitats, including harsh environments

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characterized by extreme salinity and temperatures where benthic diatoms thrive within microbial mats dominated by filamentous cyanophytes (Brown *et al.* 1985; Siqueiros Beltrones 1988, 1990a). Highly productive environments are common along the peninsula. Along the north coast, there are extensive beds of eelgrass hosting many species of epiphytic diatoms (Siqueiros Beltrones & Ibarra Obando 1985, Siqueiros Beltrones *et al.* 1985). In the southern part of the peninsula, mangroves are the most conspicuous macrofloral components. Local studies on planktonic diatoms have suggested the importance of benthic diatoms that occur abundantly in water samples, but taxonomic analysis has focused only on planktonic forms (Verdugo Díaz 1993, Gárate Lizárraga & Siqueiros Beltrones 1998).

The ecological significance of mangroves has been well documented (Lugo & Snedaker 1974, Dawes 1991), including Bahía de La Paz, México (Jiménez Quiroz 1991). Nevertheless, much of the information on interactions among micro- and macrobiota is still not available. Closer analysis of these interactions will help elucidate the importance of certain taxa in the food web and nutrient dynamics in mangrove sediments. The microbiota in mangrove environments are very complex. Common microorganisms include purple photosynthetic bacteria, diazotrophic cyanophytes, bacteria (Sheridan 1991, Vethanayagam 1991, Holguin *et al.* 1992), and filamentous cyanophytes. Numerous filamentous macroalgae are also present, some of which have been reported for mangroves elsewere (Almodóvar & Pagán 1971, Dawes 1991).

Little taxonomic work has been done in mangrove environments in general. This is the first study to focus specifically on benthic diatoms from a subtropical (or tropical) mangrove environment in Mexico. Elsewere, accounts of epiphytic diatoms associated with mangrove prop roots have revealed rich diatom assemblages and probable host-epiphyte relations (Navarro & Torres 1987). Our purpose here was to determine the taxonomic composition and structure of benthic diatom assemblages in sediments from the mangrove forest in the protected area of Balandra lagoon.

MATERIALS AND METHODS

STUDY AREA.—Balandra is a protected area in Bahía de La Paz, 19 km north of La Paz, between 24°18′30″-24°19′45″N, and 110°19′45″-110°18′15″W (Fig. 1). Two distinct habitats occur: (1) a cove *ca* 250 × 1150 m with sediments of coarse and medium-coarse sand (ϕ 1 and 2); and (2) a lagoon *ca* 324 × 990 m with a 180-m wide mouth and a channel of 1.1-m in mean depth. Lagoon sediments are mainly medium- coarse sand with organic matter and clastic sediments decreasing toward the mouth.

Hydrological characteristics are determined by mixed semidiurnal tides. The lagoon is bordered by three types of small- and medium-size mangrove trees: red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), and white mangrove (*Laguncularia racemosa*), as in the rest of the Bahía de La Paz (Gallo *et al.* 1982, Jiménez Quiroz 1991). Many crabs and snails (*Uca crenulata* and *Cerithidia mazatlanica*) graze upon the mangrove sediments throughout the year.

Balandra is visited regularly by tourists, and the beaches show signs of disturbance (*e.g.*, litter). In spite of the recent paving of the access road, impact is still not severe. Most of our sampling sites were located within the mangroves (Fig. 1) where people rarely go. At the time this study was made, the area could still be considered a quasi-pristine ecosystem.

SAMPLING DESIGN.—Sampling was done seasonally in 1992 (winter [14 February]., spring [25 April], summer [26 July], and autumn [23 October]) during low tide, at four sites subjected to different exposure periods along the flood channel mudflats. Three of the sites consisted of muddy sediments of the intertidal zone within the mangroves. Sites one and two were within the white mangrove pneumatophore area and incipient microbial mats; site three was within the red mangrove prop root area. These three sites were separated by *ca* 100 m. Site four was on a sandy beach in the lagoon (Fig. 1).

At each site, three 20 cm^2 samples of sediments and associated diatoms (1-cm thick) were collected in petri dishes from *ca* 3-m^2 area. The dishes were sealed and transported on ice back to the laboratory. Sediments were analyzed as composite samples from each site to dampen the effect of the patchy distribution of diatoms (McIntire & Moore 1977, Oppenheim 1987).

Three salinity measurements were taken at each sampling site using a Reichert-Jung refractometer (0–100 ppt ± 0.5). To do this, a drop of interstitial water was squeezed through filter paper with a syringe. Separate samples were collected in plastic bags at each site for sediment analyses. Texture for coarser sediments was determined using the granulometric method and, for finer sediments, the hydrometer method (Folk 1974, Brower & Zar 1979).

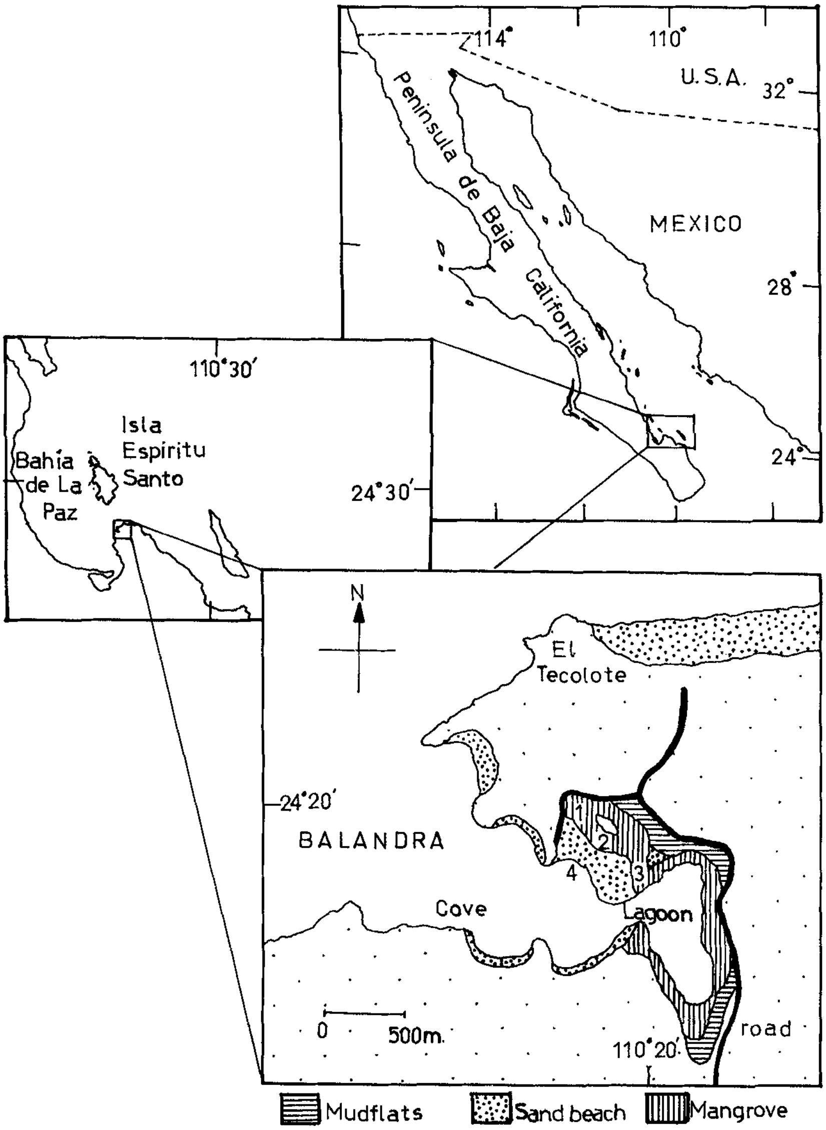

FIGURE 1. Location of sampling sites in the mangrove system of Balandra lagoon of the Baja peninsula, México. Modified after Holguin *et al.* (1992).

Diatom sample analysis.—Subsamples (*ca* 100 cells) were inspected without treatment to attain a gross estimate of the percentage of live cells. The remaining composite samples were treated with acid and heat (Patrick & Reimer 1966). Clean diatom frustules were mounted on glass slides using Cumar R-9 resin (Holmes *et al.* 1981). The permanent diatom slides were analyzed qualitatively solely for taxonomic purposes, and quantitatively to determine relative abundances of species to analyze the structure of diatom assemblages.

Taxonomic determinations.—Taxonomic analysis based on frustule morphology was done at 1000X using phase contrast microscopy. Keys and references used were Peragallo (1891), Van Heurck (1896), Peragallo and Peragallo (1908), Hustedt (1930, 1955, 1959), Hendey (1964), Cleve-Euler (1968), and more recent literature (*e.g.*, Navarro 1983, Siqueiros Beltrones & Ibarra Obando 1985, Simonsen 1987, Siqueiros Beltrones 1988, Round *et al.* 1990).

Drawings were made of all taxa, their location

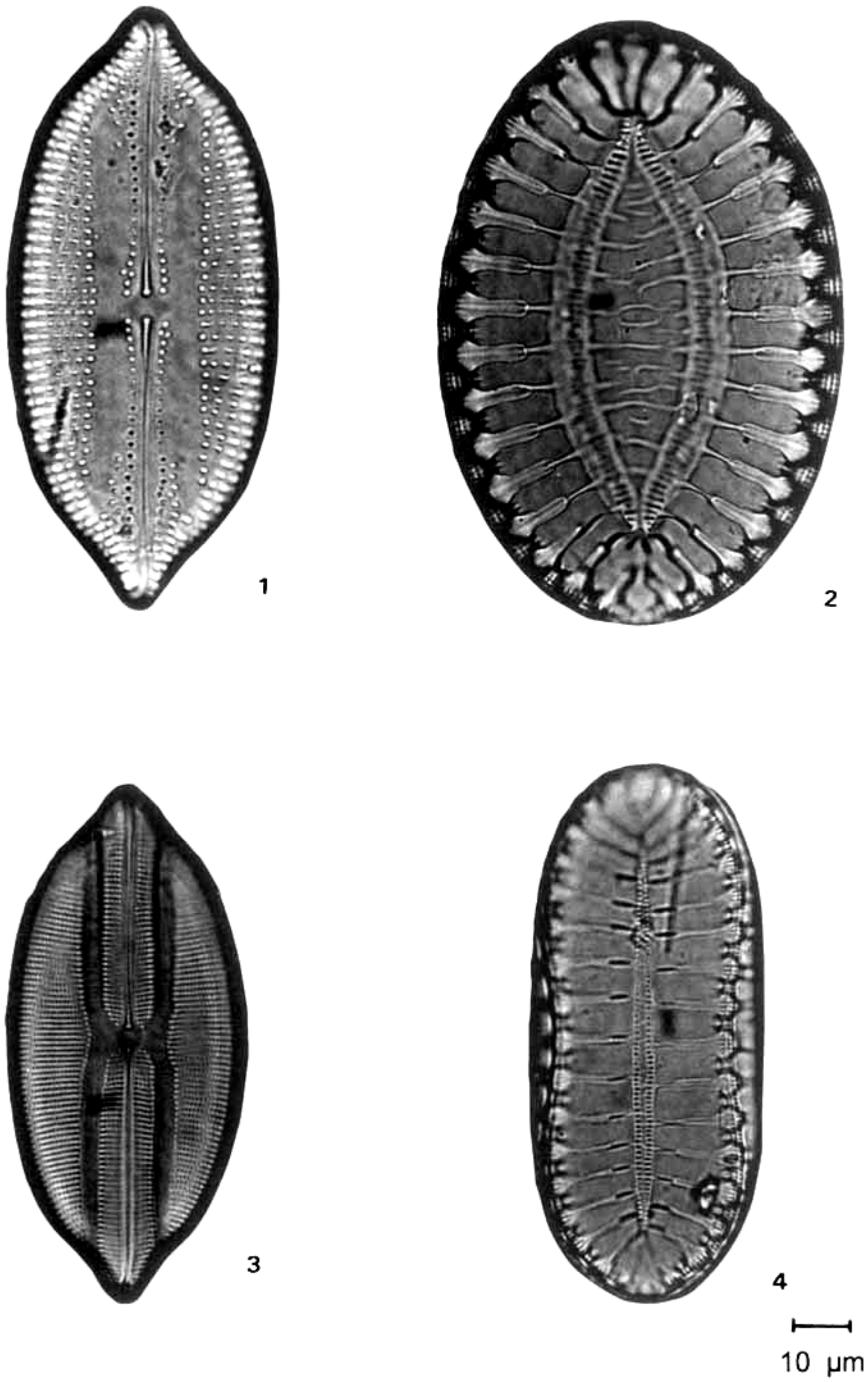

PLATE I. 1. *Lyrella irrorata* (Grev.) D. G. Mann.; 2. *Surirella fastuosa* Ehr.; 3. *Lyrella subtypica* (A. S.) D. G. Mann.; 4. *Surirella hybrida* v. *contracta* Per.

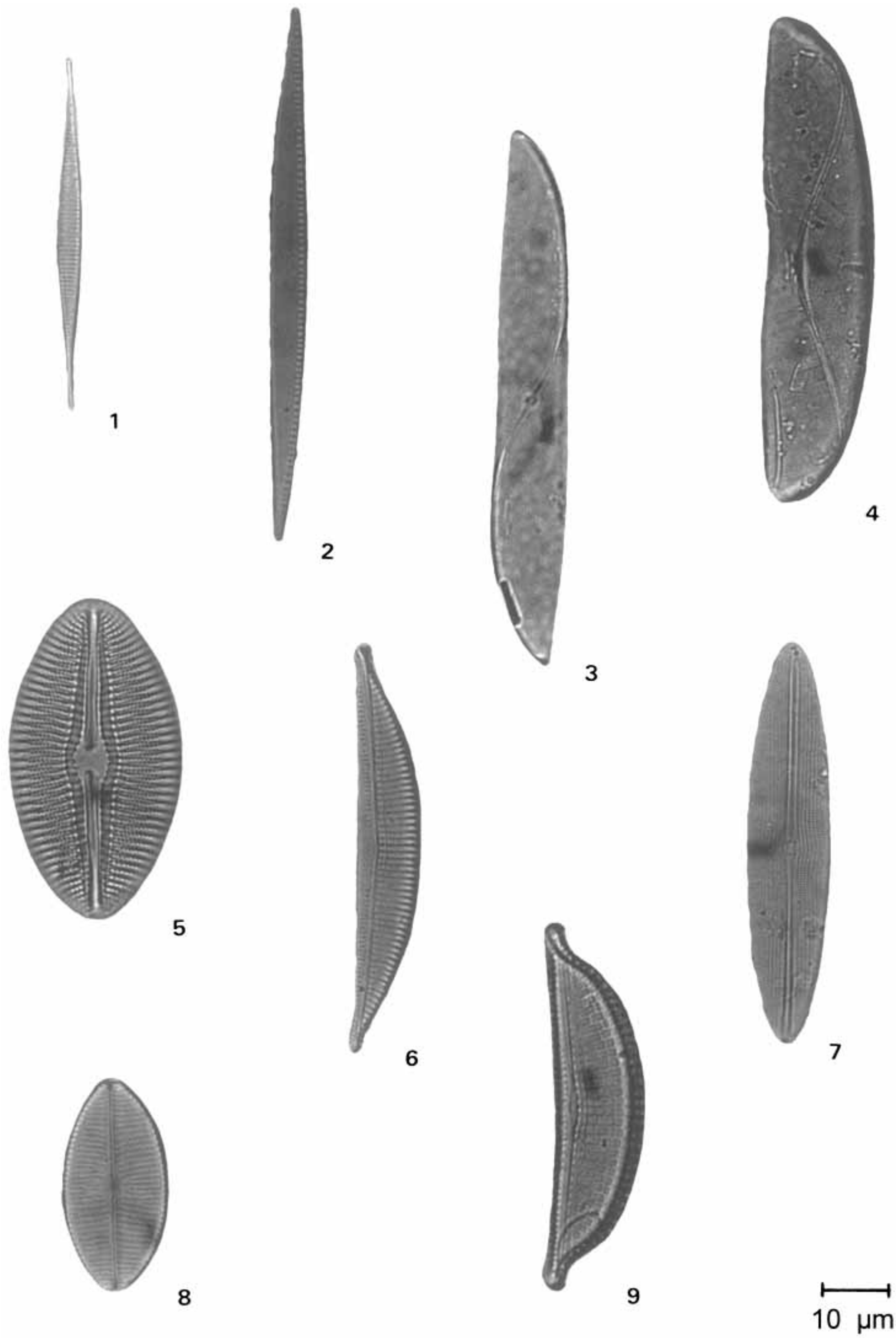

PLATE II. 1. *Nitzschia lorenziana* v. *subtilis* Grun.; 2. *Nitzschia sigma* v. *rigidula* Grun.; 3. *Donkinia thumii* Cl.; 4. *Amphora obtusa* v. *oceanica* Castr.; 5. *Diploneis smithii* (Breb.) Cl.; 6. *Amphora acutiuscula* Kz.; 7. *Frustulia* sp. 1.; 8. *Navicula* sp. 14.; 9. *Amphora costata* W. Sm.

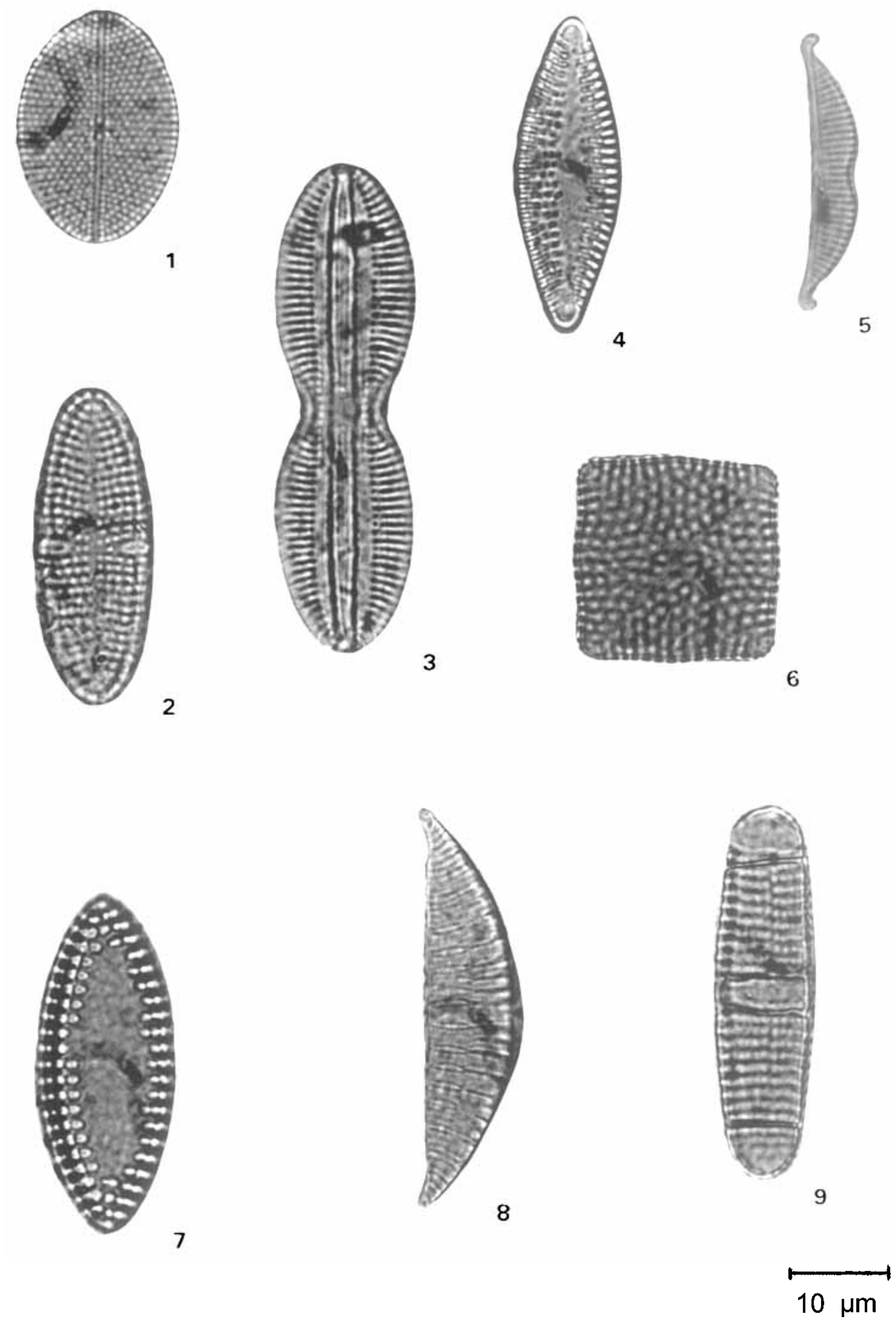

PLATE III. 1. *Mastogloia binotata* (Grun.) Cl.; 2. *Achnanthes* sp. 2.; 3. *Diploneis interrupta* (Kg.) Cl.; 4. *Dimeregramma minor* v. *genuina* A. Cl.; 5. *Amphora angulosa* Grun. 6. *Perisonoe cruciata* (Jan. & Raben.) Andr. & Stoet. 7. *Dimeregramma marina* v. *lanceolata* (Per.) Hust. 8. *Rhopalodia musculus* v. *constricta* W. Sm. 9. *Plagiogramma pulchellum* v. *pygmaea* Grev.

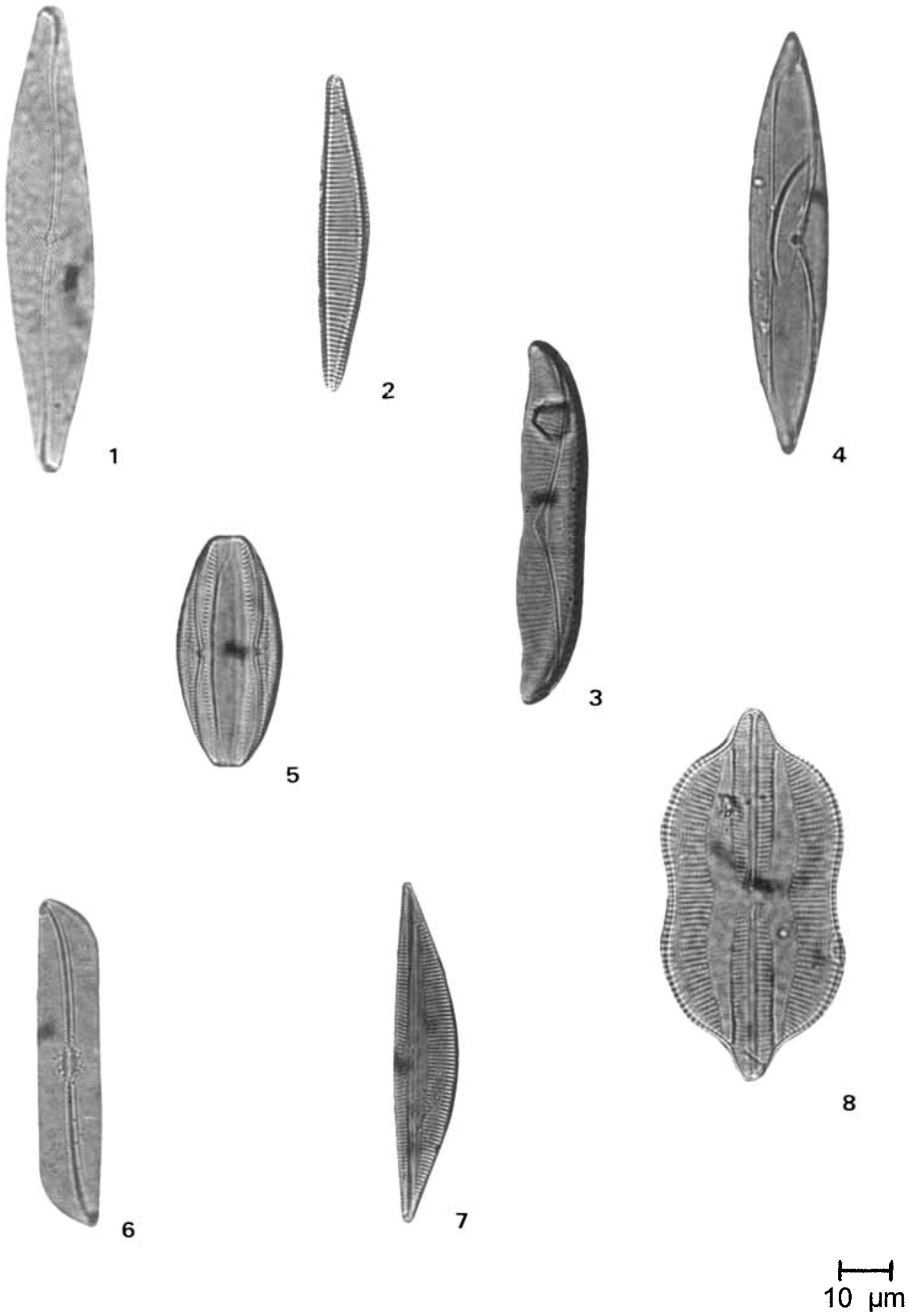

PLATE IV. 1. *Pleurosigma naviculaceum* Breb.; 2. *Pseudoeunotia doliolus* (Wall.) Grun.; 3. *Amphora spectabilis* Greg. 4. *Plagiotropis vitrea* v. *genuina* A. Cl.; 5. *Amphora proteus* v. *contigua* Cl.; 6. *Gyrosigma scalproides* v. *eximium* (Thw.) Cl.; 7. *Lyrella exsul* (A. S.) D. G. Mann.

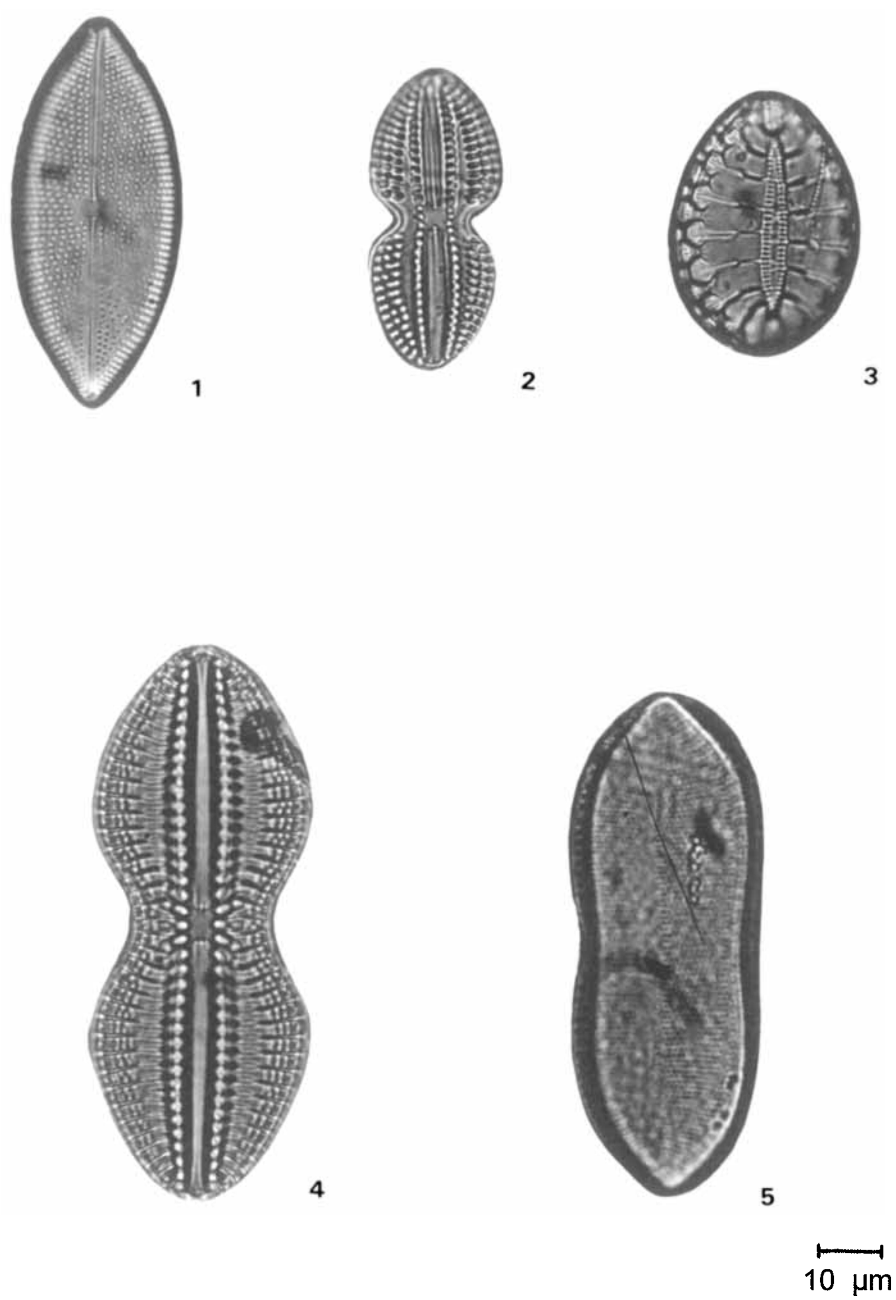

PLATE V. 1. *Petroneis granulata* (Bail.) D. G. Mann.; 2. *Diploneis gruendleri* (A. S.) Cl.; 3. *Surirella fastuosa* v. *cuneata* A. S.; 4. *Diploneis crabro* v. *separabilis* (A. S.) Cl.; 5. *Psammodictyon panduriformis* v. *abrupta* Per.

within the slides recorded, and photographs of representative specimens were taken. All slides were deposited in the diatom collection (Diatomario) of the Museum of Natural History at the Universidad Autónoma de Baja California Sur (MHNUABCS).

ASSEMBLAGE STRUCTURE.—The structure of the assemblages was analyzed according to methods of Brower and Zar (1979), Siqueiros Beltrones and Ibarra Obando (1985), Magurran (1988), and Siqueiros Beltrones (1990b, 1994). Several ecological indices were used to estimate species diversity, equitability, and dominance, [*e.g.*, Margalef (*Da*); Shannon-Wienner (H', $\log_2$); Simpson (λ and $1-\lambda$); Pielou (J'); Redundancy index (REDI)]. The use of several indices to measure diversity yields a better interpretation of the estimated values that respond distinctively to species proportions, thus permitting a more thorough description of the assemblage structure (Siqueiros-Beltrones 1990b).

The biological value index (BVI; Sanders 1960) for 85 percent of the total abundance in the samples, and niche breadth (*B*i) were estimated to identify the important species. Finally, the similarity between samples was measured using the indices of Jaccard (Clifford & Stephenson 1975) and Stander (1970). This combination was used to determine how assemblages resemble each other based solely on presence/absence of species and on the relative abundance of the shared taxa in each site. In this way, a better comparison is accomplished between samples (sites) in terms of the important and rare taxa distribution. Sample size for estimating index values was set at 500 frustules, based on McIntire and Overton (1971) and Siqueiros Beltrones *et al.* (1985, 1991). This sample size is appropiate considering the high species richness observed in the Balandra sediments.

STATISTICAL ANALYSIS.—Nonparametric statistics were applied to measurements of salinity, species numbers, and diversity index values for each sample (site-season). A Friedman two-way ANOVA was used to test for significant differences between sample values, and a Spearman rank analysis to look for correlation between salinity and the assemblage structure parameters.

RESULTS

TAXONOMIC ANALYSIS.—During our taxonomic analysis, a total of 230 taxa were determined, including species and varieties belonging to 48 genera, of which 109 species are new records for the Baja California peninsula (Appendix). The genera represented by most species were: *Navicula* (39), *Amphora* (30), *Nitzschia* (27), *Achnanthes* (14), and *Diploneis* (12). Species level for 34 taxa could not be determined using the available literature. Thus, an identification number was assigned for further analysis. Some of these were rare species but others were abundant.

A total of 8386 frustules were counted. Only 181 of the previously determined taxa were included. These comprised 28 rare species represented by only 1 individual, 70 taxa by ≤ 10 (uncommon), 65 common species (≤ 100), and 18 abundant taxa with ≥ 100 individuals. Forty-nine of the determined taxa did not appear during the subsequent quantitative analysis, but 29 not previously accounted for were observed, including 10 common and 3 abundant taxa. A representative array of diatom taxa from the sediments of Balandra lagoon is shown in the appendix.

Species richness from season to season, summing all samples, ranged from 102 in winter to 107 in summer. However, the number of species among sites and seasons (Table 1) showed significative differences ($P = 0.05$, df $= 3$). Site two showed a higher number of taxa throughout the sampling period. The number of species coincided with the variation in salinity values [*e.g.*, site one, with a range of 27–39 (total 54) taxa and a salinity variation of 36.5 ppt; site two, with a range of 57–69 (total 109) taxa and a salinity variation of only 3 ppt]. Nonetheless, no significant differences among the salinity values were detected, and no significant correlation was seen between the two variables ($rs = -0.29$; 0.05, $N = 16$).

Cyanophytes of several genera were abundant in the sediments at site two (*Gomphosphaeria, Chroococcus, Johanepbastita, Entophysalis, Microcoleus,* and *Oscillatoria*), but were rare at site one. The most abundant species was *Staurosirella (Fragilaria) pinnata* (2654 individuals) comprising 31.6 percent of the total diatom individuals (Table 2). Although an araphid form considered epipsammic (and a freshwater form), it was abundant in the mangrove mudflats and scarce at site four, which was 100 percent sand. *Opephora pacifica,* another epipsammic form, was rare at site one. Both species formed mucilaginous colonies. At site one, characterized by high salinities and a high percentage of silt and clay, *Nitzschia punctata* was (almost exclusively) very common, as expected.

ASSOCIATION STRUCTURE.—The estimated index values (H' and $1-\lambda$) show that the highest species di-

TABLE 1. *Mean salinity values (n = 3) and number of species (S) for each sample and percentage of sediment type by station at Balandra lagoon.*

	Stat. 1		Stat. 2		Stat. 3		Stat. 4	
	%°	S	%°	S	%°	S	%°	S
Season								
Winter	52.5	(39)	38	(62)	37.5	(47)	35	(28)
Spring	83.5	(28)	36.5	(64)	40.5	(39)	40	(35)
Summer	47	(27)	38	(69)	42.5	(53)	36.5	(27)
Autumn	48	(29)	35	(57)	35.5	(52)	51.5	(48)
Sediment								
Sand	46		44		41		100	
Clay	21		23		20		0	
Silt	33		34		39		0	

versity occurred at site four during autumn (Table 3), although species richness was not the highest ($S = 48$). Equitability and dominance values indicate more taxa were well represented numerically in the sample, causing a more homogeneous distribution. The main reason is that *S. pinnata* did not bloom at site four as it did at the other sites, where it was the most numerous. Thus, dominance (λ and REDI) was low. A similar situation was observed during spring, but species richness at site four in other seasons responded otherwise.

The observed diversity values suggest a patchy distribution of diatom taxa, but differences between values were not statistically significant (0.05, 3). Also, no significant correlation was detected between salinity and the structure parameter values (0.05, 16). At site two, the dominant presence of *S. pinnata* (high dominance) damped the effect of a high species richness on the diversity estimates of most samples. At site one, the combined dominance of *S. pinnata, N. punctata,* and *Seminavis* sp. caused a low diversity estimate in spring, whereas one or more codominant taxa in the other seasons increased it. At site three, even when diversity estimates were relatively high, the lowest value for H' was measured. Here the dominance by *S. pinnata* was the highest overall and *Seminavis* sp. was absent.

The numerical dominance of *S. pinnata* was associated with a high *Bi* value (Table 2). This taxon was constant in most samples, whereas other abundant taxa (*e.g., N. punctata* and *O. pacifica*) had low *Bi* values because of their narrow distributions. *Amphora* sp. 5 had the second highest *B*i value indicating a homogeneous distribution in all stations, although it was not one of the ten most abundant species. Other species behaved likewise. Diatom species with high BVI values but lower *Bi* values are indicative of a more heterogeneous distribution. The BVI (Table 4) weighs relative abundance and frequency of occurrence, but relies more on the abundance. *Bi* is more sensitive to constancy. *S. pinnata, N. punctata,* and *O. pacifica* also had high BVI values; *Achnanthes lanceolata* v. *genuina* f. *diminuta* and *Cocconeis disculus* behaved likewise. Along with ten other taxa, they can be considered the most representative diatom species for the study area, albeit exhibiting a marked patchy distribution.

Similarity between samples.—The mean value of the Stander similarity index (0.59) indicated, in general, that numerically important taxa are distributed among the four sites (Table 5a). Thus, the weighed species composition from sites two and three were very similar. Values were frequently >0.95, indicating that the main conditions determining taxonomic composition were similar for both sites. Comparison of these two with site one shows a higher similarity related to closeness and thus to sediment type and longer exposure periods during low tide. Values (±0.8) were higher for the winter samples among all sites. The homogeneous distributions of *S. pinnata, A. lanceolata* v. *genuina* f. *diminuta,* and *O. pacifica* were responsible for such similarity, but mostly because of the low *S* in general.

The Stander index values in the spring, summer, and autumn samples from site four differed markedly from the other three sites (Table 5a) with similarity values ranging from 0.01–0.53. This can be attributed mainly to the absence of *S. pinnata* and *N. punctata,* and the almost exclusive presence of *Navicula salinarum, Achnanthes hauckiana* v. *elliptica,* and *Fallacia vittata* at site four. The winter samples from this site, however, showed high sim-

TABLE 2. *Abundances by sample and computed Bi values for 41 taxa of benthic diatoms from Balandra lagoon;* N = *500.*

	Seasons/Sites																
	Winter				Spring				Summer				Autumn				
Species	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	*Bi*
1 *Staurosirella pinnata*	175	282	223	180	210	202	300	20	138	223	93	2	141	264	159	42	13.4
2 *Amphora* sp. 5	0	9	16	11	2	9	5	0	24	10	1	11	35	9	4	10	10.7
3 *Navicula ammophila* v. *intermedia*	18	8	1	5	14	1	1	16	14	7	0	0	17	17	1	31	9.9
4 *Achnanthes lanceolata* v. *genuina* f. *diminuta*	7	23	2	54	11	3	3	70	9	2	8	23	20	3	14	29	9.9
5 *Cocconeis disculus*	0	11	26	31	0	21	10	21	0	10	11	0	0	9	23	4	9.6
6 *Nitzschia punctata* v. *coarctata*	2	5	2	0	1	7	2	13	0	7	1	1	0	5	7	2	9.6
7 *Opephora pacifica*	0	40	53	25	2	44	45	8	0	40	10	0	0	23	8	3	9.0
8 *Paralia sulcata* v. *biseriata*	1	4	1	1	0	3	3	0	0	7	1	0	8	5	0	0	7.7
9 *Nitzschia lanceolata* v. *minima*	0	0	25	0	0	8	14	21	0	2	6	8	0	4	18	2	7.7
10 *Nitzschia dissipata* v. *genuina*	3	3	3	0	0	19	0	1	0	17	4	1	1	9	2	4	7.6
11 *Seminavis* sp.	19	12	0	4	62	10	0	0	50	5	10	2	26	6	4	0	7.5
12 *Navicula* sp. 20	0	10	60	0	0	25	37	0	0	8	2	0	0	15	23	38	6.9
13 *Achnanthes submarina*	9	7	0	0	2	3	0	0	2	4	0	0	2	5	0	0	6.9
14 *Cocconeis distans*	0	1	1	0	0	2	0	1	0	1	2	0	0	2	5	0	6.7
15 *Rhaphoneis* sp. 1	0	1	1	0	0	2	2	2	0	1	2	0	0	0	0	0	6.6
16 *Nitzschia socialis* v. *massilensis*	1	9	5	0	0	10	2	0	1	13	1	0	0	22	4	0	6.6
17 *Nitzschia pellucida*	2	2	1	0	0	1	0	0	1	0	0	3	0	0	0	1	6.3
18 *Fallacia forcipata*	18	2	0	0	1	8	0	1	0	4	10	0	1	2	1	0	6.0
19 *Nitzschia frustulum* v. *genuina*	0	3	0	26	5	2	23	0	2	6	0	0	1	0	12	1	6.0
20 *Trachyneis clepsydra*	0	0	1	0	0	1	0	0	0	4	1	0	0	1	1	1	5.7
21 *Cocconeis disrupta* v. *flexella*	0	7	5	2	0	2	1	0	0	4	0	0	0	0	1	0	5.6
22 *Nitzschia frustulum* v. *perminuta*	0	0	24	14	0	4	0	53	0	0	10	0	0	2	15	9	5.6
23 *Rhopalodia musculus* v. *constricta*	0	0	0	0	3	0	6	0	2	0	5	0	5	0	0	1	53
24 *Nitzschia macilenta*	0	6	1	0	0	3	0	0	0	2	0	0	0	2	4	0	5.2
25 *Nitzschia closterium*	0	0	3	0	0	2	1	0	0	1	0	0	0	4	1	0	5.1
26 *Nitzschia insignis* v. *spathulifera*	0	1	0	0	0	0	0	2	0	1	1	3	0	0	1	7	5.1
27 *Amphora proteus* v. *contigua*	0	5	2	0	0	0	2	1	0	0	0	0	0	2	1	0	5.1
28 *Amphora angusta* v. *ventricosa*	0	4	1	14	0	2	3	0	1	0	0	0	0	2	1	0	4.9
29 *Navicula clamans*	7	3	0	0	2	0	0	0	7	0	0	0	13	0	0	3	4.9
30 *Navicula salinarum*	5	2	5	6	1	8	5	15	0	0	1	10	0	8	0	91	4.9

TABLE 2. *Continued.*

Species	Winter 1	Winter 2	Winter 3	Winter 4	Spring 1	Spring 2	Spring 3	Spring 4	Summer 1	Summer 2	Summer 3	Summer 4	Autumn 1	Autumn 2	Autumn 3	Autumn 4	*Bi*
31 *Achnanthes hauckiana* v. *subrhombica*	22	1	1	1	3	1	2	0	5	0	17	0	45	0	2	0	4.9
32 *Navicula parva*	2	0	0	0	2	0	0	0	6	3	0	0	1	0	0	1	4.9
33 *Cocconeis diminuta*	0	3	5	7	0	4	0	0	0	0	3	0	0	0	0	0	4.7
34 *Diploneis interrupta*	1	0	0	0	0	0	0	1	0	0	6	3	0	0	4	1	4.7
35 *Gyrosigma* sp. 1	0	0	2	0	0	1	1	0	0	3	0	0	0	2	0	0	4.6
36 *Nitzschia* sp. 1	0	0	0	0	0	2	3	0	0	4	0	0	2	6	0	0	4.6
37 *Plagiotropis vitrea* v. *scaligera*	4	2	0	3	0	0	0	0	0	0	0	0	1	0	0	2	4.6
38 *Navicula pennata*	0	3	0	2	0	2	1	0	0	1	25	0	0	3	4	2	4.5
39 *Amphora holsatica*	6	3	0	5	0	0	0	0	0	0	2	0	0	0	1	0	4.3
40 *Nitzschia torenziana* v. *subtilis*	0	0	0	0	0	17	10	0	0	5	1	1	0	7	0	0	4.3
41 *Nitzschia punctata*	52	8	0	2	79	0	0	0	130	0	0	0	62	1	0	0	4.3

TABLE 3. *Values for the ecological indices used to analyze the association structure of benthic diatoms from Balandra lagoon for each site.* N = *number of cells counted;* S = *number of taxa;* H′ = *estimated diversity (Shannon-Wiener's);* λ = *Simpson's dominance;* 1 − λ = *Simpson's diversity; REDI* = *redundancy (dominance) index;* J = *Pielou's equitability.*

Sample	*N*	*S*	*H′*	1 − λ	REDI	λ	*J′*
Winter							
1	529	39	3.89	0.86	0.30	0.13	0.73
2	548	62	3.48	0.72	0.51	0.27	0.58
3	535	47	3.32	0.79	0.47	0.20	0.59
4	522	28	3.42	0.83	0.32	0.16	0.71
Spring							
1	532	28	2.95	0.78	0.43	0.21	0.61
2	532	64	4.16	0.83	0.38	0.16	0.69
3	515	39	2.67	0.64	0.57	0.35	0.50
4	544	35	4.07	0.91	0.23	0.08	0.79
Summer							
1	544	27	3.20	0.83	0.36	0.16	0.67
2	505	69	3.98	0.79	0.45	0.20	0.65
3	533	53	4.36	0.91	0.29	0.08	0.76
4	505	27	3.07	0.83	0.39	0.17	0.64
Autumn							
1	515	29	3.73	0.88	0.26	0.11	0.76
2	508	57	3.45	0.72	0.50	0.28	0.59
3	510	52	4.26	0.88	0.30	0.11	0.74
4	509	48	4.52	0.93	0.23	0.06	0.81
$\bar{x}$			3.66	0.82	0.37	0.17	0.68

ilarity with the other sites, mainly because of the presence of *O. martyi, N. frustulum* v. *genuina, N. frustulum* v. *perminuta,* and the most abundant taxa.

TABLE 4. *Highest 15 values for the BVI estimated using 85 percent total abundance of benthic diatoms from Balandra lagoon.*

Species	BVI
1 *Staurosirella pinnata*	186
2 *Opephora pacifica*	79
3 *Navicula* sp. 20	75
4 *Achnanthes lanceolata* v. *genuina* f. *diminuta*	73
5 *Cocconeis disculus*	73
6 *Amphora* sp. 5	60
7 *Achnanthes hauckiana* v. *elliptica*	52
8 *Nitzschia punctata*	52
9 *Navicula ammophila* v. *intermedia*	51
10 *Seminavis* sp.	48
11 *Nitzschia lanceolata* v. *minima*	38
12 *Nitzschia socialis* v. *perminuta*	36
13 *Navicula cryptocephala* v. *perminuta*	33
14 *Navicula salinarum*	33
15 *Amphora acutiuscula*	32

TABLE 5. *Similarity values using Stander (A) and Jaccard (B) indices between all samples from Balandra lagoon.*

(A)																
W1								$\bar{x}$ = 0.59								
W2	0.9															
W3	0.82	0.94														
W4	0.78	0.89	0.84													
S1	0.92	0.86	0.78	0.76												
S2	0.86	0.97	0.96	0.86	0.82											
S3	0.87	0.98	0.96	0.87	0.83	0.98										
S4	0.14	0.18	0.2	0.29	0.14	0.17	0.15									
Su1	0.83	0.66	0.58	0.58	0.85	0.61	0.62	0.11								
Su2	0.87	0.98	0.94	0.86	0.83	0.98	0.98	0.16	0.62							
Su3	0.57	0.61	0.6	0.55	0.55	0.6	0.6	0.37	0.41	0.6						
Su4	0.01	0.03	0.3	0.23	0.03	0.03	0.02	0.32	0.03	0.03	0.04					
A1	0.9	0.82	0.74	0.76	0.88	0.77	0.78	0.17	0.85	0.79	0.53	0.08				
A2	0.89	0.99	0.94	0.86	0.85	0.97	0.98	0.16	0.64	0.99	0.6	0.02	0.8			
A3	0.82	0.92	0.93	0.85	0.78	0.91	0.92	0.35	0.59	0.91	0.65	0.11	0.75	0.92		
A4	0.35	0.35	0.4	0.37	0.29	0.37	0.36	0.53	0.23	0.34	0.36	0.15	0.31	0.37	0.44	
	W1	W2	W3	W4	S1	S2	S3	S4	Su1	Su2	Su3	Su4	A1	A2	A3	A4
(B)																
W1								$\bar{x}$ = 0.24								
W2	0.29															
W3	0.16	0.3														
W4	0.24	0.32	0.29													
S1	0.39	0.29	0.15	0.3												
S2	0.16	0.35	0.4	0.23	0.18											
S3	0.13	0.33	0.3	0.29	0.19	0.34										
S4	0.17	0.2	0.26	0.14	0.14	0.18	0.17									
Su1	0.37	0.26	0.18	0.25	0.58	0.18	0.18	0.07								
Su2	0.15	0.33	0.23	0.14	0.13	0.43	0.32	0.19	0.12							
Su3	0.18	0.29	0.27	0.23	0.21	0.29	0.24	0.33	0.14	0.24						
Su4	0.16	0.14	0.17	0.13	0.14	0.15	0.14	0.38	0.12	0.14	0.29					
A1	0.42	0.28	0.12	0.24	0.46	0.18	0.15	0.1	0.44	0.18	0.24	0.12				
A2	0.16	0.35	0.3	0.21	0.15	0.46	0.39	0.34	0.13	0.45	0.25	0.17	0.18			
A3	0.17	0.29	0.32	0.25	0.17	0.3	0.32	0.36	0.14	0.3	0.44	0.27	0.14	0.33		
A4	0.21	0.21	0.27	0.21	0.21	0.2	0.19	0.39	0.17	0.21	0.35	0.34	0.17	0.22	0.39	
	W1	W2	W3	W4	S1	S2	S3	S4	Su1	Su2	Su3	Su4	A1	A2	A3	A4

During all seasons, species richness for the study area surpassed 100 taxa (mainly rare and uncommon). According to Jaccard's index, these were distributed differentially among the sampling sites, defining discrete assemblages. The mean calculated value (Table 5b) was low (0.24), indicating a patchy distribution of the diatom taxa which accounts for differences among the assemblages. The higher values ranged from 0.37–0.58 and almost exclusively among samples from the same site.

DISCUSSION

In this study we continued to build the taxonomic inventory of benthic diatoms for the Baja California peninsula (Siqueiros Beltrones 1994). We have focused on diatom assemblages associated with mangrove forests. The number of taxa determined in sediments of the Balandra lagoon (230) was similar to that reported for other productive environments along the Baja California peninsula (Siqueiros Beltrones & Ibarra Obando 1985, Siqueiros Beltrones *et al.* 1991, Siqueiros Beltrones 1994). Approximately half of the taxa (109) are new records for the Baja coast relative to the recent inventory by Siqueiros Beltrones (1994). Many taxonomic determinations for this area require specific analyses. For example, *Staurosirella pinnata* has been frequently reported (as *Fragilaria pinnata*) for the Baja California peninsula (Siqueiros Beltrones 1994), but the established freshwater nature of the genus (Round *et al.* 1990) indicates that more work is needed. There was a similar problem with *Opephora pacifica*. Colony formation in this species helped to segregate it from *Martyana* sp., which is also a freshwater form (Round *et al.* 1990). The taxonomic procedure using scale drawings and photographic material, plus the permanent slides in the Diatomario (MHNUABCS), should facilitate further research. Our observations on live material indicated that the acid-treated frustules are reliable representatives of the studied taxocoenosis.

Many different types of environments found along the latitudinal gradient of the peninsula and the temperate western (Pacific) coast, contrast with the tropical characteristics of the eastern (gulf) coast. The transitional characteristics of our study area (Brusca 1980), located within a subtropical region, ensure taxa of different biogeographical affinities and probably a high species richness observed to vary distinctively over different time periods (Rocha Ramírez & Siqueiros Beltrones 1991, Gárate Lizárraga & Siqueiros Beltrones 1998).

The structure analysis revealed a wide range of diversity measurements, most of which were high in the Balandra sediments. Few species are able to tolerate extreme conditions of salinity and desiccation on a permanent basis (Brown *et al.* 1985, Siqueiros Beltrones 1990a); but the hypersaline sediments of Balandra are subject to frequent flooding, thus permitting the proliferation of many more taxa. In site one, however, where hypersaline conditions and desiccation were more severe, species richness resembled those of extreme environments (Brown *et al.* 1985; Siqueiros Beltrones 1988, 1990a). The absence of *S. pinnata* and *Nitzschia punctata,* and the distinctive presence of *Navicula salinarum, Achnanthes hauckiana* v. *elliptica,* and *Fallacia vittata* at site four differentiate it from the other sites. Surprisingly, all of the latter taxa are common inhabitants of silt and clay sediments, even in high salinities, and thus would be expected to occur abundantly at sites one, two, and three.

The differences in species number between sites one and two were recorded by H' estimates, but only reflected typical (nonsignificant) variations among diatom assemblages (Siqueiros Beltrones 1994). Thus, differences among sites one, two, and three, which are located within 300 m may be too subtle for detection against the patchy distribution of common benthic diatoms (Oppenheim 1987), probably determining the differences in the diversity and similarity indices values. As suggested by Siqueiros Beltrones (1990a) for a hypersaline environment, the diatom assemblages from sampling sites one, two, and three should be considered as part of the same association. Although differences in species composition have been explained by salinity gradients, type of sediments, and time of exposure (Whiting & McIntire 1985), a correlation between salinity and diversity was not seen because of the sampling design. Furthermore, the lowest diversity value recorded for site three suggests that other factors also are causing patchiness. This station lies below a mangrove canopy where shade could be determining further variations within the association structure of diatoms by precluding the establishment of certain taxa.

Site four represents part of a different association defined by the coarser grain of the sediments. Variations in the diatom assemblages from the beach site suggest that the number of species is affected by the more dynamic characteristics of the sandy environment. There, the homogeneous distribution of abundances for epipsammic diatom species and other widely distributed taxa yielded relatively high diversity estimates, even with relatively low species numbers.

The opportunistic nature of benthic (epipelic) diatoms is enhanced by variations in the sediments, defining a mosaic of discrete assemblages (McIntire & Moore 1977, Sullivan 1978, Admiraal 1984). The presence or absence of many rare diatom taxa distinguished the assemblages due to the different number of species in the samples. Species richness, together with the differential distribution of common and abundant taxa, accounted for apparent differences in diversity values. Such differences occur because of rapid responses by the assemblages to the extreme variations in physical factors (Oppenheim 1991).

The similar number of species from the winter and summer samples and the different species composition could suggest a continuous replacement of species or succession. Overall differences in the Balandra sediments may also be explained in terms of the euryhaline species, and those adapted to chemical characteristics that can develop at different temperatures during each season. In this case, high BVI and *Bi* values exhibited by the abundant and common taxa indicated their ample distribution both in space and time, suggesting their role as permanent constituents of the local microphytobenthos. Even though the selected sites were apparently homogeneous, and our analyses of composite samples from each site should have served to dampen the effect of patchiness, the low values of similarity indicated a high patchiness. Complicated interactions between diatoms and physicochemical variables (Admiraal 1984) may act as feedback mechanisms for the persistence and replacement of species within microhabitats located in an apparently homogeneous area. Thus, successional events were not evident in the diatom assemblages with the sampling strategy used and variations in association parameters appeared random.

Different combinations of environmental variables influence diatom assemblage structure seasonally (Oppenheim 1991). The separation among samples precludes observing variations over a short time. Longer and more frequent sampling periods are needed to determine the spatiotemporal variations of benthic diatom associations from Balandra lagoon and its surroundings.

Numerically dominant species are considered to be the main food source for many grazers, microfauna, meiofauna, and larger herbivores (Fenchel & Kofoed 1976, Lee *et al.* 1975, Admiraal 1984, Sullivan & Moncreiff 1988). The dominant abundance of few diatom species observed in the lagoon sediment is a common characteristic of the assemblages, as in the case of *S. pinnata, N. punctata,* and *O. martyi.* These are small forms. Some gastropods are known to feed selectively on larger diatoms without affecting the smaller diatoms, thus reducing the population of large-size diatoms (Fenchel & Kofoed 1976). Some diatom taxa may be low in abundance because of intensive selective grazing.

The proportion of certain diatom taxa within the assemblages in the Balandra sediments can be determined in part by grazers. Numerous *Uca* and *Cerithidia* were seen grazing in the Balandra lagoon sediments. We assume that many other micro- and meiofaunal herbivores are doing likewise. Certain protozoa, foraminifera, and nematodes show marked preferences, either ingestive or digestive (Lee *et al.* 1975). Information on the population dynamics of such organisms and observations of their feeding behavior are needed to support the apparent influence of grazing on the distribution and structure of benthic diatom assemblages in the Balandra sediments.

In our study, rare species did not cause significant differences in the assemblage parameters, and important species (BVI or *Bi*) were distributed throughout most of the study area. These may serve as indicators of changes in the ecosystem, either individually or as an important influence on assemblage structure. The relatively high diversity estimates of the diatom assemblages in relation to other areas (Siqueiros Beltrones 1990b) and persistence of certain taxa suggest that a stable, undisturbed microphytobenthic community is thriving in the Balandra mangrove system.

Attempts to make Balandra more accessible to visitors may result in disturbance of the mangrove community because of the lack of an effective maintenance program. We assume that the Balandra lagoon is not influenced by urban discharges from La Paz, unlike the mangrove systems located around Ensenada de La Paz. The parameters measured for the diatom assemblages can be monitored to detect environmental impacts caused by pollution or other types of ecological disturbance, either natural or anthropogenic (Siqueiros-Beltrones 1994). A comparison between the two systems may indicate the type of changes that local and regional benthic diatom assemblages can exhibit in response to urban pollution.

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APPENDIX

Taxonomic list of benthic diatoms from sediments in Balandra laggon. *New records for the Baja California peninsula. Source for taxonomic determiniation is given.

1.—*Achnanthes* sp. 1
Valves rhombic-lanceolate, 15.5 μm long, 8.5 μm wide. Raphe not reaching the central nodule, extending only 2/3 of the valve. Striae slightly radial 8-9/10 μm.
2.—*Achnanthes* sp. 2
Valves lanceolate, 31.1 μm long, 12.5 μm wide. Raphe valve showing marginal sulcus and two transapical median hyaline oval zones. Raphe valve with staurus not reaching the valve margins. Striae punctate and radial 11-12/10 μm. Appendix, pl- III, f. 2.
3.—*Achnanthes* sp. 3
Valves elliptical, 37.9 μm long, 13.1 μm wide. Striae slightly radiate 11/10 μm, centra; striae half as long as the rest.
4.—*Achnanthes biasolettiana* (Kz.) Grun. Hustedt (1959), P. II, p. 379, f. 823.
5.—*Achnanthes brevipes* Ag. Hustedt (1959), P. II, p. 424, f. 877 a-c.
6.—*Achnanthes brevipes* v. *intermedia* Kz. Cleve (1968) V. III, p. 50, f. 596.
7.—*Achnanthes hauckiana* v. *subrhombica* A. Cl. *
Cleve (1968), V. III, p. 45, f. 582 e, f.
8.—*Achnanthes hauckiana* v. *elliptica* Schulz. *
Cleve (1968), V. III, p. 45, f. 582 c, d.
9.—*Achnanthes lanceolata* v. *genuina f. diminuta* May. Cleve (1968), V. III, p. 45, f. 527 x, y.
10.—*Achnanthes lanceolata* v. *rostrata* Hust. *
Hustedt (1959), P. II, p. 410, f. 863 i-m.
11.—*Achnanthes longpipes* Ag. Hustedt (1959), P. II, p. 427, f. 878.
12.— *Achnanthes manifera* Brun. *
Hustedt (1955), pl. 6, p. 18, f. 1-8.

13.—*Achnanthes marginulata* v. *typica* A. Cl. *
Cleve (1968), V. III, p. 33, f. 537 a-d.
14.—*Achnanthes submarina* Hust. *
Simonsen (1987), pl. 652, f. 12-24.
15.—*Actinoptychus undulatus* Ehr. Peregallo (1908), pl. 111, p. 407, f. 1.
16.—*Amphora* sp. 4
Valves 27.9 μm long, 6.4 μm wide. Raphe straight valve ends slightly acute. Striae straight but curving towards the center 20/10 μm.
17.—*Amphora* sp. 5
Similar to *Amphora holsatica* Hust. Cleve (1968), V. III, p. 99, f. 688, but with higher number of striae 18-19/10 μm.
18.—*Amphora* sp. 7
Valves 20.9 μm long, 2.6 μm wide. Raphe straight, ends slightly capitate. Dorsal striae straight 20/10 μm. No ventral striae.
19.—*Amphora* sp. 13
Valves 10.5 μm long, 3.9 μm wide. Central part of the valve convex, ends capitated. Striae straight 20-22/10 μm.
20.—*Amphora acutiuscula* Kz. Cleve (1968), V. III, p. 98, f. 686 a-b. Appendix, pl. II, f. 6.
21.—*Amphora angulosa* Grun. *
Peragallo (1908), pl. 50, p. 229, f. 13. Appendix, pl. III, f. 5.
22.—*Amphora angusta* (Greg.) Cl. *
Peragallo (1908), pl. 50, p. 231, f. 37.
23.—*Amphora angusta* v. *ventricosa* (Greg.) Cl. *
Hustedt (1955), pl. 16, p. 42, f. 26. Appendix pl. IV, f. 7.
24.—*Amphora binodis* v. *bigibba* Grun. Peragallo (1908), pl. 50. p. 227, f. 36.
25.—*Amphora coffaeiformis* v. *borealis* (Kz.) Cl.
Cleve (1968), V. III, p. 97, f. 695 b-d.
26.—*Amphora coffaeiformis* v. *perpusilla* Grun. Cleve 91968), V. III, p. 98.
27.—*Amphora coffaeiformis* v. *salina* (W. Sm.) A. Cl. *
Cleve (1968), V. III, p. 97, f. 685 a.
28.—*Amphora costata* W. Sm. Cleve (1968), V. III, p. 99, f. 690.
Appendix pl. II, f. 9.
29.—*Amphora crassa* v. punctata A. S. *
Peragallo (1908), pl. 46, p. 208, f. 8.
30.—*Amphora decussata* Grun. Peragallo (1908), pl. 49, p. 222, f. 24; Hendey (1964) pl. 37, p. 266, f. 9.
31.—*Amphora exigua* Greg. Peragallo (1908), pl. 50, p.230, f. 30, 31; Cleve (1968), V. III, p. 99, f. 686 e.
32.—*Amphora holsatica* Hust. Cleve (1968), V. III, p. 99, f. 688.
33.—*Amphora hyalina* Kz. *
Peragallo (1908), pl. 50, p. 226, f. 7.
34.—*Amphora laevis* Greg.
Cleve (1968), V. III, p. 102, f. 698 (a-d); Van Heurck (1896), p. 139, f. 693.
35.—*Amphora laevis* v. *laevissima* (Greg.) Cl. Peragallo (1908), pl. 49, p. 221, f. 11.
36.—*Amphora libyca* v. *baltica* (Br.) A. Cl. *
Cleve (1968), V. III, p. 90, f. 666 e-h.
37.—*Amphora obtusa* v. *oceanica* Castr. *
Peragallo (1908), pl. 48, p. 216, f. 4. Appendix pl. II, f. 4.
38.—*Amphora ostrearia* Bréb. *
Peragallo (1908), pl. 49, p. 219, f. 13.
39.—*Amphora ostrearia* v. *vitrea* Cl. *
Peragallo (1908) pl. 49, p. 220, f. 14, 15.
40.—*Amphora proteus* Greg. Peragallo (1908) pl. 44, p. 200, f. 23.
41.—*Amphora proteus* v. *contigua* Cl. Peregallo (1908), pl. 44, p. 201, f. 24, 25.
Appendix pl. IV, f. 5.
42.—*Amphora proteus* v. *kariana* Grun. *
Cleve (1968), V. III, p. 93, f. 637 b, c.
43.—*Amphora rhombica* Kitton *
Peregallo (1908), pl. 50, p. 224, f. 4.
44.—*Amphora spectabilis* Greg. *
Cleve (1968), V. III, p. 102, f. 701; Peregallo (1908), pl.48, p. 216, f. 8.
Appendix pl. IV, f. 3.
45.—*Amphora tenerrima* Al. *et* Hust. Hustedt (1955), pl. 4, p. 9, f. 23, 24.
46.—*Anaulus americanum* Hust. *
Hustedt (1955) pl. 4, p. 9, f. 23, 24.
47.—*Berkeleya rutilans* (Trent.) Cl. Hustedt (1959), P. II, p. 720, f. 1093 (a-b);
Hendey (1964), p. 240.
48.— *Caloneis linearis* (Grun.) Boyer.*
Hendey (1964), pl. 29, p. 230, f. 3.
49.—*Campylodiscus brightwellii* Grun. *

Navarro (1983), p. 395, f. 50, 51.
50.—*Campylodiscus ecclesianus* Grev. *
Peregallo (1908) pl. 53, p. 239, f. 3.
51.—*Campylodiscus thuretii* Breb. Van Heurck (1896), p. 378, f. 595.
52.—*Cocconeis convexa* Giffen. *
Navarro (1982), p. 322, f. 10-13.
53.—*Cocconeis diminuta* Pant. Hustedt (1930), p. 190, f. 265.
54.—*Cocconeis dirupta* Greg. Hustedt (1959), P. II, p. 354, f. 809 a-c.
55.—*Cocconeis dirupta* v. *flexella* (Jan.) Rbh. Hustedt (1959), P. II, p. 355, f. 809.
56.—*Cocconeis disculoides* Hust. hendey (1964), pl. 28, p. 178, f. 20, 21.
57.—*Cocconeis disculus* (Schum) Cl. Hendey (1964), pl. 28, p. 178, f. 19.
58.—*Cocconeis distans* Greg. Hustedt (1959), P. II, p. 344, f. 797.
59.—*Cocconeis pediculus* Ehr. *
Hustedt (1959), P. II, p. 350, f. 804.
60.—*Cocconeis scutellum* Ehr. *
Hustedt (1959), P. II, p. 338, f. 790; Hendey (1964), pl. 27, p. 180, f. 8.
61.—*Cylindrotheca gracilis* v. *major* Grun. *
Cleve (1968), V. V, p. 95, f. 1518 a.
62.—*Cymatoneis* sp. 1
Valves lanceolate with capitate ends, 30 μm long, 21.4 μm wide. Valve divided in four parts by longitudinal lineolae. Striae punctate, longitudinally and transapically arranged 16/1101 μm.
63.—*Cymbella* sp. 1
Similar in form to *C. amphicephala* v. *genuina* May, Cleve (1968), V. IV, p. 151, f. 1223 a, b. but smaller, 14.9 μm long and 4.0 μm wide, with more striae ± 30/10 μm.
64.—*Cymbella gracilis* v. *linata {cf1}(W. Sm.) A. Cl.* *
Cleve (1968), V. V, p. 33, f. 1405 a, g-1.
65.—*Denticula tenuis* v. *genuina* Grun. *
Cleve (1968), V. V, p. 33, f. 1405 a, g-1.
66.—*Dimeregramma marina* v. *lanceolata* (Per.) Hust.
Cleve (1968), V. II, p. 26, f. 333 e. Appendix, pl. III, f.7.
67.—*Dimeregramma minor* v. *elliptica* A. Cl. *
Cleve (1968) V. II, p. 27, f. 334 f.
68.—*Dimeregramma minor* v. *genuina* A. Cl.
Cleve (1968), V. II, p. 27, f. 334 a, b. Appendix, pl. III, f.4.
69.—*Dimeregramma minor* v. *nana* (Greg.) Ralfs. *
Cleve (1968), V. II, p. 27, f. 334 c, d.
70.—*Diploneis crabro* v. *separabilis* (A. S.) Cl.*
Cleve (1968), V. III, p. 86, f. 660 c. Appendix, pl. V, f. 4.
71.—*Diploneis didyma* Ehr. Hustedt (1959), P. II. p. 685, f. 1075 a, b.
72.—*Diploneis eudoxia* (A. S.) Mills *
Hustedt (1959), P. II, p. 595, f. 1013.
73.—*Diploneis gruendleri* (A. S.) Cl. Hustedt (1959), P. II, p. 702, f. 1084.
Appendix, pl V, f. 2.
74.—*Diploneis interrupta* (Kg.) Cl. *
Hustedt (1959), P. II, p. 602, f. 1019 a. Appendix, pl. III, f. 3.
75.—*Diploneis littoralis* v. *clathrata* (Östr.) Cl. *
Hustedt (1959), P. II, p. 665, f. 1062 b, c.
76.—*Diploneis papula* v. *constricta* Hust. *
Hustedt (1959), P. II, p. 679, f. 1071 d.
77.—*Diploneis smithii* (Bréb.) Cl. Hustedt (1959), P. II, p.647, f. 1051.
Appendix, pl. II, f. 5.
78.—*Diploneis smithii* v. *pumila* (Grun.) Hust. *
Hustedt (1959), P. II, p. 650, f. 1052 d, e.
79.—*Diploneis subadvena* Hust. *
Hustedt (1959), P. II, p. 633, f. 1042.
80.—*Diploneis suborbicularis* v. *intermedia* A. Cl. *
Cleve (1968), V. III, p. 69, f. 626 c.
81.—*Diploneis vacillans* (A.S.) Cl. Hustedt (1959), P. II, p. 798, f. 1060 a-d.
82.—*Donkinia thumii* Cl. *
Peragallo (1891), pl. 9, p. 30, f. 10. Appendix pl. II, f. 3.
83.—*Entomoneis alata* Ehr. Peragallo (1908), pl. 37, p. 184, f. 6, 7.
84.—*Entomoneis alata* f. *minor* Ehr. *
Peragallo (1908), pl. 37, p. 37, f. 8, 9.
85.—*Entomoneis paludosa* v. *duplex* (Donk.) Cl. *
Clebe (1968), V. V, p. 31, f. 1400 e.
86.—*Eunotogramma* sp.

87.—*Fallia fenestrella* (Hust.) D. G. Mann. *
Hustedt (1955), pl. 5, p. 30, f. 32.
88.—*Fallacia forcipata* (Grev.) A. J. Stickle & D. G. Mann. *
Hustedt (1955), pl. 7, p. 22, f. 12, 13.
89.—*Fallacia oculiformis* (Hust.) D. G. Mann. *
Hustedt (1959), P. III, p. 539, f. 1575.
90.—*Fallacia pseudoforcipata* (Hust.) D. G. Mann. *
Hustedt (1959), P. III, p. 536, f. 1572.
91.—*Fallacia vittata* (Cl.) D. G. Mann
Hustedt (1955), pl. 8, p. 28, f. 3-5, 12.
92.—*Staurosirella* (*Fragilaria*) *lapponica* v. minuta A. Cl. *
Cleve (1968), V. II, p. 33, f. 345.
93.—*Staurosirella* (*Fragilaria*) *pinnata* Ehr. *
Hustedt (1959), P. II, p. 160, f. 671 a-i.
94.—*Frustulia* sp. 1.
Valves lineal-elliptic, 63.2 μm long, 15.7 μm wide. Striae punctate longitudinally aranged in lineolae 18-20/10 μm. Appendix, pl. II, f. 7.
95.—*Frustulia* sp.2
Sinilar to *F. vitrea* Östr. Cleve (1968), V. V, p. 9, f. 1330, but with a narrow staurus.
96.—*Grammatophora marina* (Lyngb.) Kutz.
Hustedt (1959) P. II, p. 43, f. 569.
97.—*Gyrosigma* sp. 1
Valves lineal-sigmoid with rounded ends, 131 μm long and 6.0 μm wide. Transversal striae 20/10 μm, longitudinal striae hardly visible. Similar to *G. beaufortianum* Hust. Hustedt (1955), pl. 10, p. 34, f. 7, but significantly larger.
98.—*Gyrosigma* sp. 2
Valve lanceolate, 164 μm long, 10 μm wide. Raphe arching towards the ends and bordered by puncta 22-23/10 μm. Longitudinal and tranversal striae 8-10/10 μm.
99.—*Gyrosigma acuminatum* v. *lacustre* (W. Sm.) A. Cl. *
Cleve (1968), V. V, p. 15, f. 1346 a, b.
100.—*Gyrosigma balticum* (Ehr.) Cl. Cleve (1968), V. V, p. 11, f. 1331.
101.—*Gyrosigma distortum* v. *marinum* A. Cl. *
Cleve (1968), V. V, p. 12, f. 1338 a.
102.—*Gyrosigma fasciola* v. *arcuatum* (Donk.) Cl. Cleve (1968)
V. V, p. 13, f. 1339 b.
103.—*Gyrosigma scalproides* v. *eximium* (Thw.) Cl. *
Cleve (1968), V. V, p. 11, f. 1334. Peragallo (1891), pl. 8, p. 24, f. 27.
Appendix, pl. IV, f. 6.
104.—*Gyrosigma wansbeckii* (Donk.) Cl. *
Cleve (1968), V. V, p. 11, f. 1332.
105.—*Gyrosigma peisonis* (Grun.) Hust. Hustedt, 1955, pl. 10, p. 34, f. 4, 5.
106.—*Licmophora flabellata* (Grev.) Agardh.
Van Heurck (1896), p. 342, f. 852; Hustedt (1959) P. II, p. 58, f. 581.
107.—*Licmophora gracilis* v. *anglica* (Kz.) Per. Cleve (1968), V. II, p. 19, f. 327.
108.—*Licmophora remulus* Grun. *
Peragallo (1908) pl. 84, p. 345, f. 3.
109.—*Lyrella clavata* (Greg.) D. G. Mann. *
Peragallo (1908), pl. 24, p. 137, f. 6-8.
110.—*Lyrella clavata* f. *subconstricta* Hust. *
Hustedt (1959), P. III, p. 444, f. 1509 d, e.
111.—*Lyrella exsul* (A. S.) D. G. Mann. *
Hustedt (1959), P. III, p. 444, f. 1515 a, b. Appendix, pl. IV, f. 8.
112.—*Lyrella hennedyi* f. *typica* (A. Cl.) A. J. Stickle & D. G. Mann *
Hustedt (1959), P. III, p. 453, f. 1516 c, e-h.
113.—*Lyrella irrorata* (Grev.) D. G. Mann.
Peragallo (1908) pl. 23, p. 136, f. 12; Hustedt (1955), pl. 8, p. 24, f. 139.
Appendix pl. I, f. 1.
114.—*Lyrella subtypica* (A. S.) D. G. Mann. *
Peragallo (1908) pl. 22, p. 135, f. 2. Appendix, pl. I, F. 3.
115.—*Mastogloia* sp. 1
Valves elliptic-lanceolate, 17.1 μm long, 11.6 μm wide, 5 loculi/10 μm. Striae straight 20/10 μm, showing a small central hyaline area.
116.—*Mastogloia acutiuscula* v. *elliptica* Hust.
Hustedt (1959) P. II, p. 515 f. 947 c.
117.—*Mastogloia apiculata* W. Sm. *
Cleve (1968), V. III, p. 58, f. 605; Peragallo (1908), pl. 5, p. 33, f. 21, 22.
118.—*Mastogloia binotata* (Grun.) Cl. *

Hustedt (1959), P. II, p. 470, f. 889. Appendix pl. III, f. 1.
119.—*Mastogloia exigua* Lewis. Hustedt (1959), P. II, p. 569, f. 1003.
120.—*Mastogloia mediterranea* Hust. *
Hustedt (1959), P. II, p. 570, f. 1005.
121.—*Melosira nummuloides* Ag. *
Hendey (1964), pl. 1, p. 72, f. 1.
122.—*Navicula* sp. 4
Valves elliptic-lanceolate, 21.2 μm long, 7.6 μm wide. Striae slightly radiate, shorter at the median part of the valve 16-17/10 μm.
123.—*Navicula* sp. 7
Valves elliptic, 10μm long, 3.5 μm wide. Striae slightly radiate 18/10 μm.
124.—*Navicula* sp. 11
Valves lanceolate with rounded ends, 20.0 μm long, 6.7 μm wide. Striae punctate radiate 14/10 μm.
125.—*Navicula* sp. 12
Valves elliptic with rostrated ends, 14.9 μm long, 6.4 μm wide. Striae punctate, radiate, shorter to the median part of the valve 12/10 μm.
126.—*Navicula* sp. 14
Fits the description of *N. järnefeltii* Hust. Hustedt (1959), P. III, p. 138, f. 1272, but smaller and with fewer striae 31.8 μm long, 15.5 μm wide. Striae 12/10 μm. Appendix pl. II, f. 8.
127.—*Navicula* sp. 15
Valves lineal-lanceolate, 28.6 μm long, 7.5 μm wide. Punctate striae, slightly radiate 12/10 μm.
128.—*Navicula* sp. 17
Valves lineal-lanceolate, 26.4 μm long, 9.2 μm wide. Striae radial, straight toward the ends, curved at the middle part of the valve 20/10 μm. Wide staurus.
129.—*Navicula* sp. 20
Valves elliptic, 6.9 μm long, 4.1 μm wide. Hyalinous, no visible striae.
130.—*Navicula* sp. 24
Valves elliptic, 31.6 μm long, 11.5 μm wide. Raphe slightly curved toward the ends. Striae punctate, radial 24/10 μm.
131.—*Navicula* sp. 25
Valves lanceolate with a wider middle, ends slightly capitate, 28.9 μm long, 15.4 μm wide. Striae short punctate, radiating toward the ends 8-9/10 μm. Similar to *N. palpebralis* Bréb. Van Heurck (1896) pl. 4, p. 208, f. 179.
132.—*Navicula* sp.26
Valves lineal-elliptic, median margin just visible, 51.1 μm long, 14.4 μm wide. Striae straight, shorter to the middle 26-30/10 μm.
133.—*Navicula* sp. 27
Valves lineal, ends rounded, 20 μm long, 4.3 μm wide. Striae straight 18/10 μm.
134.—*Navicula* sp. 28
Valves lanceolate with capitate ends, 13.9 μm long, 5.1 μm wide. Striae punctate straight 16/10 μm.
135.— *Navicula* sp. 32
Valves slliptic, 15.9 μm long, 7.4 μm wide. Raphe bent at the ends small central hyaline area. Striae punctate radial 24/10 μm.
136.—*Navicula* sp. 34
Valves lineal, 24.1 μm long, 5.3 μm wide. Narrow staurus, striae straight 13/10 μm.
137.—*Navicula ammophila* v. *intermedia* Grun. Cleve (1968) V. III. p. 131, f. 757.
138—.*Navicula cancellata* Donk. Peragallo (1908), pl. 13, p. 101, f. 7, 8.
139.—*Navicula cincta* v. *heufleri* (Grun.) Cl. Cleve (1968), V. III, p. 152, f. 809 d.
140.—*Navicula clamans* Hust. Hustedt (1959), P. III, p. 179, f. 1313.
141.—*Navicula cryptocephala* v. *genuina* A. Cl. Hustedt (1930), p. 295, f. 497 b.
142.—*Navicula cryptocephala* v. *perminuta* Grun. *
Cleve (1968), V. III, p. 154, f. 813 f-h.
143.—*Navicula disserta* Hust. Hustedt (1955), pl. 3, p. 168, f. 9.
144.—*Navicula diversistriata* Hust. Hustedt (1955), pl. 9, p. 28, f. 6-9.
145.—*Navicula gracilus* Ehr. Cleve (1968), V. III, p. 130, f. 756 1-d.
146.—*Navicula gregaria* v. *thruholmensis* (J.-Dannf.) Cl. *
Cleve (1968), V. III, p. 130, f. 755 d.
147.—*Navicula halophilioides* Hust. *
Huestedt (1959), P. III, p. 68, f. 1213.
148.—*Navicula justa* Hust. *
Hustedt (1959), P. III, p. 228, f. 1348.
149.—*Navicula lanceolata* v. *genuina* A. Cl. Cleve (1968), V. III, p. 134, f. 772 a.
150.—*Navicula mayeri* v. *typica* A. Cl. *
Cleve (1968), V. III, p. 153, f. 812 a.
151.—*Navicula menisculus* v. *upsaliensis* Grun. *
Cleve (1968), V. III, p. 150, f. 804 e-g.
152.—*Navicula parva* (Menegh.) A. Cl. Cleve 91968), V. III, p. 130, f. 754 a-d.
153.—*Navicula patrickae* Hust. Hustedt (1955), pl. 8, p. 26, f. 15, 16.

154. —*Navicula pennata* Schm. Hendey (1964), pl. 30, p. 203, f. 21.
155.—*Navicula pseudogracilis* Hust. *
Cleve (1968), V. III, p. 140, f. 785 a.
156.—*Navicula radiosa* v. *tenella* (Breb.) V. H. *
Cleve (1968), V. III, p. 156, f. 816 m, n.
157.—*Navicula salinarum* Grun. *
Peragallo (1908), pl. 12, p. 99, f. 33.
158.—*Navicula schonfeldii* Hust. *
Hustedt (1930), p. 300, f. 520.
159.—*Navicula sparsistriata* Hust. *
Hustedt (1959), P. III, p. 547, f. 1585.
160.—*Navicula stundlii* Hust. *
Simonsen (1987), pl. 687, f. 5-11.
161.—*Nitzschia* sp. 1
Valves semilanceolate, 21.9 μm long, 5.8 μm wide. No visible striae or intercalary bands, with 9/10 μm keel puncta.
162.—*Nitzschia* sp. 2
Valves lineal-lanceolate, 47.9 μm long, 5.2 μm wide. Hyalinous without visible striae, with 3-4/10 μm keel puncta.
163.—*Nitzschia acicularis* v. *typica* a. Cl. *
Cleve 91968), V. V, p. 92, f. 1509 a-c.
164.—*Nitzschia acuminata* (W. Sm.) Grun. *
Cleve (1968), V. V, p. 61, f. 1436 a; Peragallo (1908), pl. 70, p. 271, f. 18-21.
165.—*Nitzschia apiculata* (Greg.) Grun. *
Cleve (1968), V. V, p. 61, f. 1437; Peragallo (1908), pl. 70, p. 271, f. 24, 25.
166.—*Nitzschia circumsuta* (Bail.) Grun. Cleve (1968), V. V, p. 62, f. 1440.
167.—*Nitzschia closterium* W. Sm. Hustedt (1955), pl. 16, p. 48, f. 16-18.
168.—*Nitzschia dissipata* v. *genuina* A. Cl. Cleve (1968), V. V, p. 71, f. 1463 a-d.
169.—*Nitzschia filiformis* v. *genuina* A. Cl. Cleve (1968), V. V, p. 78, f. 1478 a, b.
170.—*Nitzschia fustulum* v. *genuina* May. Cleve (1968), V. V, p. 87, f. 1478 a, b.
171.—*Nitzschia frustulum* v. *perminuta* Grun. Cleve (1968) V. V, p. 71, f. 1463 e.
172.—*Nitzschia insignis* Greg. Peragullo (1908), pl. 75, p. 295, f. 7-9.
173.—*Nitzschia insignis* v. *spathulifera* Grun. *
Cleve (1968), V. V, p. 68, f. 1454 a; Peragallo (1908), pl. 75, p. 296, f. 7-9.
174.—*Nitzschia lanceolata* v. *minima* Grun. Cleve (1968), V. V, p. 84, f. 1491 e-i; Peragallo (1908), pl. 73, p. 285, f. 19.
175.—*Nitzschia longissima* v. *costata* (Whiting 1983, Siqueiros-Beltrones & Ibarra Obando 1985).
176.—*Nitzschia lorenziana* v. *subtilis* Grun. *
Cleve (1968), V. V, p. 93, f. 1510; Peragallo (1908), pl. 74, p. 294, f. 24. Appendix pl. II, f. 1.
177.—*Nitzschia macilenta* Greg. Cleve (1968), V. V, p. 73, f. 1465; Peragallo (1908), pl. 72, p. 279, f. 1, 2.
178.—*Nitzschia microcephala* Grun. *
Cleve (1968), V.V, p. 88, f. 1499 a, b.
179.—*Nitzschia ovalis* Arnott. *
Cleve (1968), V. V, p. 89, f. 1502
180.—*Nitzschia pellucida* Grun. *
Cleve (1968), V. V, p. 65, f. 1448, a, b, e, f.
181.—*Nitschia punctata* (W. Sm.) Grun. *
Peragallo (1908), pl. 69, p. 267, f. 22-24; Van Heurck (1896), p. 384, f. 491.
182.—*Nitzschia punctata* v. *coarctata* Grun. *
Peragallo (1908), pl. 69, p. 268, f. 25-30.
183.—*Nitzschia rhopalodioides* Hust. Hutedt (1955), pl. 15, p. 45, f. 16.
184.—*Nitzschia sigma* v. *genuina* Grun. Cleve (1968), V. V, p. 74, f. 1470, a, b.
185.—*Niztschia sigma* v. *rigidula* Grun. Cleve (1968) V. V, p. 75, f. 147 k;
Van Heurck (1896), p. 396, f. 534. Appendix pl. II, f. 2.
186.—*Nitzschia socialis* v. *massiliensis* Grun. *
Peragallo (1908), pl. 72, p. 280, f. 10.
187.—*Nitzschia tryblionella* v. *suborbicularis* A. Cl. *
Cleve (1968), V. V, p. 58, f. 1430 h.
188.—*Odontella aurita* Breb. Peragallo (1908), pl. 98, p. 381, f. 4.
189.—*Opephora pacifica* (Grun.) Pet.
Hustedt (1959), P II, p. 135, f. 655.
190.—*Paralia sulcata* v. *biseriata* Grun. Peragallo (1908), pl. 119, p. 448, f. 14.
191.—*Perissonoe cruciata* (Jan. & Raben.) ANdrews & Stoezel. *
Andrews * Stoelzel (1984), pl. 1, p. 226, f. 1-8. Appendix pl. III, f. 6.
192.—*Petrodycton gemma* (Ehr.) D. G. Mann, Cleve (1968), V. V, p. 117. f. 1555.
193.—*Petroneis granulata* (Bail.) D. G. Mann. *
Hustedt (1959), P. III, p. 702, f. 1696. Appendix pl. V, f. 1.
194.—*Pinnularia minuta* v. *typica* A. Cl. *
Cleve (1968), V. IV, p. 29, f. 1031 b-e.

195.—*Plagiogramma laeva* (Greg.) Ralfs. *
Hustedt (1959), p. 112, f. 637.
196.—*Plagiogramma pulchellum* Grev. Peragallo (1908), pl. 82, p. 338, f. 1, 2.
197.—*Plagiogramma pulchellum* v. *pygmaea* Grev. *
Peragallo (1908), pl. 82, p. 338, f. 3. Appendix pl, III, f. 9.
198.—*Plagiotropis vitrea* v. *genuina* A. Cl. *
Cleve (1968), V. V, p. 28, f. 1388 a, b. Appendix pl. VI, f. 4.
199.—*Plagiotropis vitrea* v. *scaligera* (Grun.) Cl. *
Cleve (1968), V. V, p. 28, f. 1388 c.
200.—*Pleurosigma angulatum* v. *genuinum* (Quek.) W. Sm. Cleve (1968), V. V, p. 23, f. 1372.
201.—*Pleurosigma cuspidatum* Cl. * Peragallo (1908), pl. 33, p. 165, f. 8.
202.—*Pleurosigma formosum* W. Sm. Cleve (1968) V. V, p. 20, f. 1360; Peragallo (1891), pl. V, p. 4, f. 3-5.
203.—*Pleurosigma intermedium* W. Sm. Peragallo (1891), pl. V, p. 13, f. 27-28.
204.—*Pleurosigma naviculaceum* Breb.*
Hustedt (1955), pl. 11, p. 35, f. 6. Appendix, pl. IV, f. 1.
205.—*Pleurosigma rigidum v. genuinum* W. Sm.*
Cleve (1968), V.V, pl 21, f. 1363.
206.—*Pleurosigma strigosum* v. *genuina* A. Cl.*
Cleve (1968), V. V, p. 22, f. 1369 a; Peragallo (1908), pl. 32, p. 163, f. 22.
207.—*Proschkinia complanatoides* (Hust. ex Simonsen) D. G. Mann.
Hustedt (1959), P. III, p. 340, f. 1461.
208.—*Psamodictyon panduriformis* v. *abrupta* (Per.) D. G. Mann.
Peragallo (1908), pl. 70, p. 269, f. 7. Appendix, pl. V, f. 5.
209.—*Psamodictyon panduriformis* v. *delicatula* (Grun.) D. G. Mann.*
Peragallo (1908), pl. 70, p. 269, f. 13.
210.—*Psamodictyon panduriformis* v. *lata* (Witt.) D. G. Mann.
Peragallo (1908), pl. 70, p. 269, f. 1.
211.—*Psamodictyon panduriformis* v. *peralbata (Per.) D. G. Mann.*
Peragallo (1908), pl. 70, p. 269, f. 2.
212.—*Pseudoeuntia doliolus* (Wall.) Grun.*
Peragallo (1908), pl. 82, p. 306, f. 27.Appendix, pl. IV, f. 2.
213.—*Rhaphoneis* sp. 1
Valves elliptic, 20 µm long, 16.4 µm wide. Pseudoraphe evident, widened in the middle. Striae punctate, radial 7/10 µm.
214.—*Rhaphoneis surirella* v. *australis* Petit. Peragallo (1908), pl. 83, p. 330, f. 30; Van Heurck (1896), p. 330, f. 398.
215.—*Rhopalodia musculus* v. *constricta* W. Sm. Peragallo (1908), pl. 77, p. 303, f. 11-17. Appendix, pl. III, f. 8.
216.—*Seminavis* sp.
Similar to *S. gracilenta* (Grun. ex A. Schmidt) D. G. Mann, but smaller, 20 µm long, 4.1 µm wide. Striae straight 17/10 µm.
217.—*Stauroneis gregorii* Ralfs.*
Cleve (1968), V. III, p. 213, f. 950 a, b.
218.—*Surirella fastuosa* Ehr. Peragallo (1908), pl. 58, p. 253, f. 2,3. Appendix, pl. V, f. 2.
219.—*Surirella fastuosa* v. *cuneata* A. S. Peragallo (1908), pl. 58, p. 253, f. 2, 3.
Appendix, pl. V, f.1.
220.—*Surirella hybrida* v. *contracta* Per.*
Peragallo (1908), pl. 64, p. 253, f. 5,6. Appendix, pl. I, f. 4.
221.—*Surirella intermedia* A. Cl.*
Cleve (1968), V. V, p. 126, f. 1572.
222.—*Surirella ovata* Kz. Hustedt (1930), p. 442, f. 863, 864.
223.—*Surirella ovata* v. *minuta* (Bréb) A. Cl.*
Cleve (1968), V. V, p. 122, f. 1566 d.
224.—*Synedra formosa* Hantzsch.*
Peragallo (1908), pl. 78, p. 310, f. 6.
225.—*Synedra fulgens* v. *mediterranea* Grun.*
Hustedt (1959), P. II, p. 230, f. 717 d, e.
226.—*Synedra nana* v. *genuina* A. Cl.*
Cleve (1968), V. II, p. 57, f. 374 a-e.
227.—*Synedra tabulata* (Ag.) Kg. Hustedt (1959), p. 218, f. 710 a-d.
228.—*Synedra tenera* v. *genuina* A. Cl.*
Cleve (1968), V. II, p. 57, f. 375 a-c.
229.—*Trachyneis aspera* v. *intermedia* (Grun.) Cl. Peragallo (1908), pl. 29, p. 150, f. 5, 6.
230.—*Trachyneis clepsydra* (Donk.) Cl. Peragallo (1908), pl. 29, p. 151, f. 11, 12.