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Annual cycle of microphytoplankton from the coasts of the tropical Mexican Pacific

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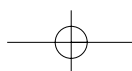
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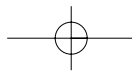
Abstract: Despite the length of littorals, studies of annual cycles for phytoplankton in the Mexican Pacific are rare, especially in tropical areas. A study of the phytoplankton (basically microphytoplankton) was realized in six locations off the States of Jalisco and Colima, from June, 2001 to May, 2002. A total of 286 taxa belonging to the taxonomic groups diatoms, dinoflagellates, cyanophyceae and silicoflagellates were identified. The best represented groups were dinoflagellates (157 taxa) and diatoms (119 taxa). Moreover, the study included a small fraction (15-25 %) of the diatom planktonic flora and 43% of the dinoflagellate flora from the Mexican Pacific. The flora showed a strong tropical-subtropical affinity. Dinoflagellate species appeared to be more important in late spring and early summer, whereas relative abundance of diatoms was higher most of the year of study. Five new records of dinoflagellates for the Mexican Pacific are annotated: *Amphisolenia palmata*, *Amphisolenia truncata*, *Gonyaulax jollifei*, *Kofoidinium splendens* and *Protoperidinium divaricatum*, from which only one is a non-thecate form; these findings may be due to the lack of previous detailed floristic studies in the area. No clear relation existed between microplankton and other variables found in the literature, such as chlorophyll *a* and nutrients. However, several patterns of phytoplankton succession were detected during our study: three stages were recognized, although they did not correspond with the diversity index values calculated.

Résumé : *Cycle annuel du microphytoplancton des côtes tropicales pacifiques du Mexique.* Malgré l'importance des côtes au Mexique, façade de l'Océan Pacifique, les travaux sur les cycles annuels du phytoplancton sont très rares, particulièrement dans la région tropicale. Le cycle annuel du phytoplancton est décrit, essentiellement celui du microplancton, pour 6 localités des côtes tropicales pacifiques du Mexique (régions de Jalisco et Colima) de Juin 2001 à Mai 2002. 286 taxa appartenant aux groupes des diatomées, dinoflagellés, cyanophycées et silicoflagellés ont été trouvée. Les groupes les plus représentés sont les dinoflagellés (157 taxa) et les diatomées (119 taxa). Une petite fraction (15 à 25 %) des diatomées et 43% des dinoflagellés de la flore planctonique déjà décrite est représentée dans cette étude. La flore planctonique montre une très forte affinité tropicale/subtropicale. Les espèces de dinoflagellés sont plus nombreuses vers la fin du printemps et le début de l'été, tandis que les diatomées sont relativement abondantes tout au long du cycle annuel. Cette étude a permis de signaler cinq nouvelles espèces de dinoflagellés pour ces côtes : *Amphisolenia palmata*, *Amphisolenia truncata*, *Gonyaulax jollifei*, *Kofoidinium splendens* et *Protoperidinium divaricatum*, avec un seule espèce nue (sans thèque); Ces nouvelles récoltes sont probablement dues à l'absence d'études floristiques préalables dans cette zone. Le microplancton ne montre pas relation visible avec les autres variables trouvées dans la bibliographie, comme la chlorophylle *a* et les sels

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nutritifs. Quelques patrons de succession ont été détectés dans cette étude: trois stades ont été identifiés, bien que ceux-ci ne correspondent pas à des variations significatives de l'indice de diversité.

Keywords: Diatoms, Dinoflagellates, Diversity, Net phytoplankton, Succession, Tropical Mexican Pacific.

Introduction

Phytoplankton in coastal waters has shown to have a particular dynamics, mainly due to environmental conditions such as mixing processes, upwellings, coastal currents and tides; under these conditions the microphytoplankton (cells larger than 20 μm) fraction generally predominates (Malone, 1971, 1980a, 1980b; Durbin et al., 1975; Mullin, 1998).

The tropical Mexican Pacific (TMP) represents an area of great interest, because it is a transitional zone, where three current systems converge, affecting the surface layers, up to 500 m depth (De la Lanza, 1991): the California current, which is cold and with a low salinity, flowing southward, the Costa Rica current, running northward, and the Gulf of California water, warm and dense, that is transported southward. These systems also converge to join the North equatorial countercurrent (Wyrski, 1965a). The transitional zone has an annual variation, with a latitudinal movement: in winter it is located more to the south, whereas in summer it is displaced to the north (Fernández-Eguiarte et al., 1993).

In the region located between 16° and 21° N, in the TMP, various studies on the composition and distribution of the phytoplankton have been made (Santoyo, 1974; León-Alvarez, 1983; Colombo Rivas, 1986; Hernández-Becerril, 1987; Ceballos-Corona, 1988; Gómez-Aguirre & Gómez-Noguera, 1993; Hernández-Becerril et al., 1993; Aké-Castillo et al., 1999; Bravo-Sierra, 1999; Meave et al., 2001), whereas other authors have reported red tides events (Figuroa-Torres & Zepeda, 2000; Morales-Blake et al., 2001). However, most of these works refer to sporadic investigations, which do not sufficiently describe the structure and distribution of the planktonic flora.

There are some medium-to-long-term studies of the phytoplankton, and they have been carried out in coastal lagoons of more temperate areas (Nienhuis & Guerrero, 1985; Gárate-Lizárraga & Siqueiros-Beltrones, 1998; Gárate-Lizárraga et al., 2001), with very few made in tropical areas (Otero-Dávalos, 1981; León-Alvarez, 1983; Cortés-Altamirano & Núñez-Pastén, 1992). Accordingly, we have planned to study the spatial and temporal variation of the phytoplankton (mainly formed by the microphytoplankton fraction) from a central area of the TMP, during the annual cycle 2001-2002. We would expect that in the

coastal zone large-sized diatoms become dominant in diversity and abundance (either absolute or relative abundance), but the contribution by dinoflagellates may also be important, especially on warmer seasons, as documented in previous papers of the area (e.g. Cortés-Altamirano & Núñez-Pastén, 1992).

Study area

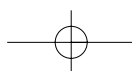
The coastal zone of the Mexican States Jalisco and Colima (Fig. 1) is characterized by the great diversity of natural resources and a considerable number of natural habitats, such as bays, estuaries and coastal lagoons (Ruíz-Durá, 1985). Many rivers flow to the coast and to coastal lagoons: Ameca, Pitillal, Cuale, Tecomala, Tomatlán, San Nicolás, Cutzmalá and Purificación, in Jalisco, and Cihuatlán, Río Seco, Armería and Coahuayana, in Colima.

Average air temperature is 22°C, with the maximum values from May to August, and the minimum ones from January to February (Yáñez-Rivera, 1989). The average annual rainfall range from 800 and 1500 mm, with the maximum rain occurrences from June to September, due to the influence of hurricanes and tropical storms (Reguero & García Cubas, 1989), whereas the minimum ones are from February to April. The continental shelf is rather heterogeneous and not very extensive; for this study only the zone with isobaths of 100 m was considered.

The surface water temperature varies from 23.3 to 30.0°C, with extreme values on March and September, respectively (Robinson, 1973). By winter and spring, marked decrease of the temperature (up to 20°C) is caused by upwellings in the Bahía de Banderas (Roden & Groves, 1959; Griffiths, 1968); this affects the depth of the thermocline, which then may be found at 20 m (Wyrski, 1965b; Griffiths, 1968; Fiedler, 1992). Larger-scale events such as El Niño (ENSO) affect the usual hydrographic conditions: rise in temperature and fall of salinity (Filonov et al., 2003).

Material and methods

Samples were taken monthly, from June, 2001 to May, 2002, in six fixed stations along the coasts of Jalisco and Colima (Fig. 1). Vertical hauls, from 20 m, were made with a net of 64 μm mesh and 31 cm diameter on each station;



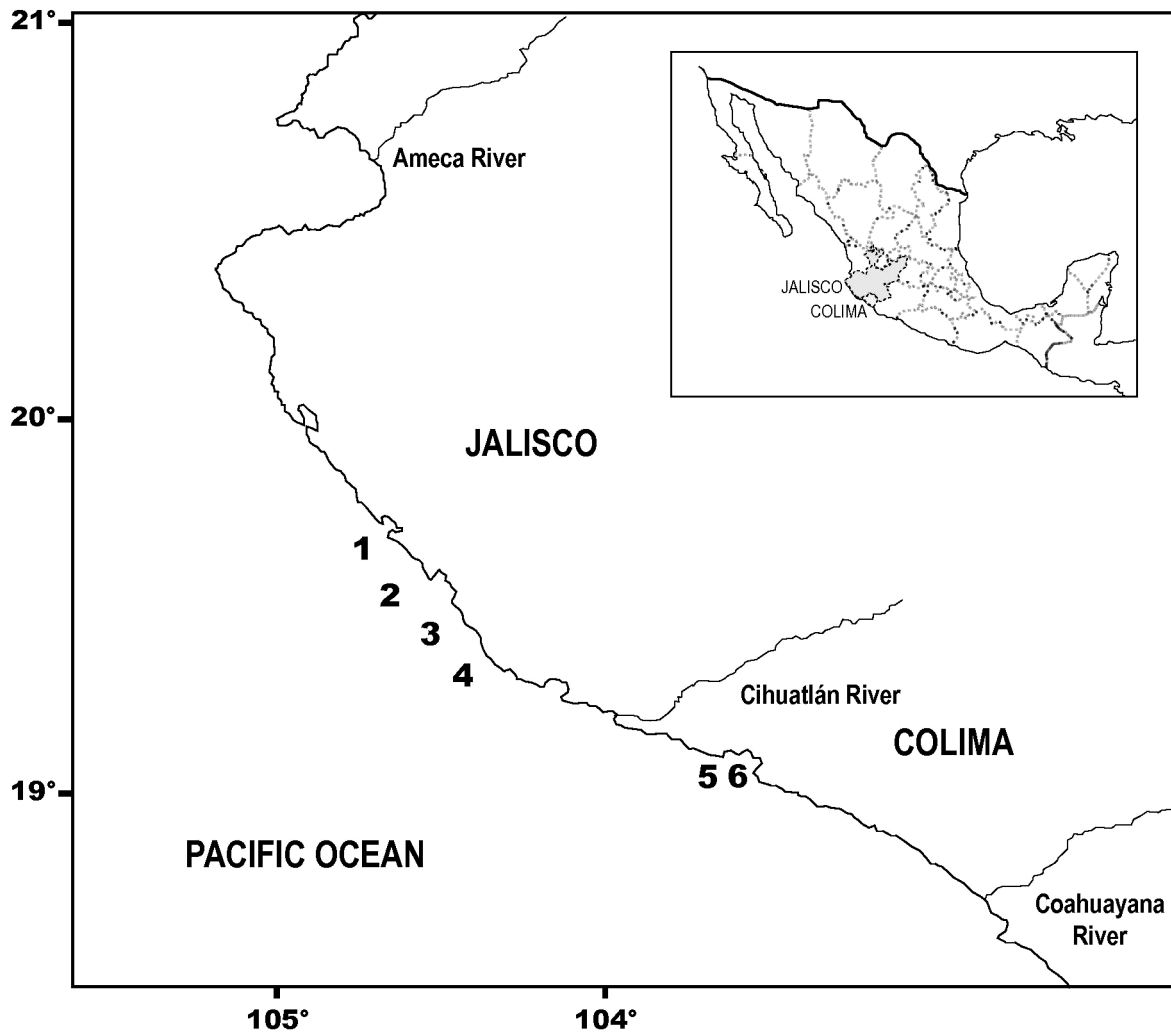


Figure 1. Location of fixed sampling points for this study. 1 = La Soledad, 2 = El Púlpito, 3 = Isla Pajarera, 4 = Careyes, 5 = Bahía Santiago, 6 = Bahía Manzanillo.

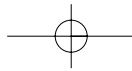
Figure 1. Localisation des stations d'échantillonnage de l'étude. 1 = La Soledad, 2 = El Púlpito, 3 = Isla Pajarera, 4 = Careyes, 5 = Bahía Santiago, 6 = Bahía Manzanillo.

this depth was considered to be the euphotic zone, according to the Secchi disc readings. Samples were immediately fixed with 4% formalin. Temperature was additionally measured at surface and 20 m. Data of chlorophyll *a* and nutrients were obtained, but although they are not included here, some discussion elements will be used.

Species identification was done using two light microscopes: one with bright field and another with phase contrast and bright and dark fields (Carl Zeiss AxioLab). Fresh slides were observed, some of which were added trypan blue or Sodium hypochloride to aid identification for thecate dinoflagellates. A minimum volume of subsampling was determined (Brower et al., 1998) and counting up to

100 cells was made on each sample, to obtain relative abundance of species and to calculate values of the Diversity index (Shannon-Wiener, H'). Also, permanent slides were made, using rinsed or cleaned material, for detailed observations of diatoms (following recommendations by Hasle, 1978). Samples were analyzed by SEM (JEOL JMS), once they were rinsed, mounted, dried and coated with gold, and by TEM (JEOL JEM-1200), using just cleaned material, both to confirm species identification. Net samples do not yield confident calculations of absolute cells densities, and only relative abundances were obtained.

Records of the presence or absence of species were used to perform analyses of similarity (Sørensen's index), to



compare assemblages along the annual cycle, among stations and also among climatic seasons, using a computer program, Past version 0.68.

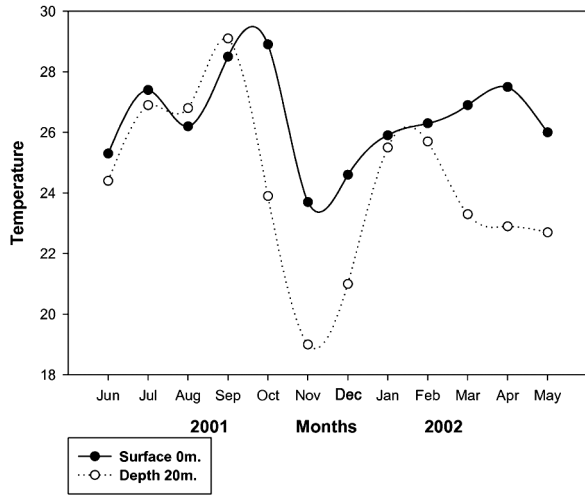


Figure 2. Average water temperatures at surface and 20 m depth along the annual cycle.

Figure 2. Températures moyennes de l'eau en surface et à 20 m de profondeur pendant le cycle annuel.

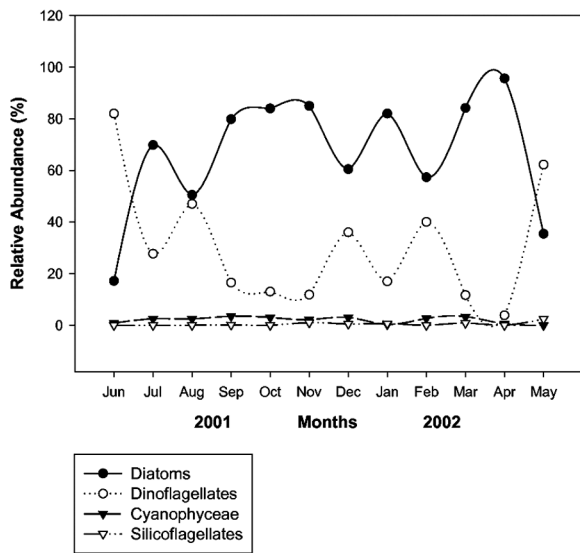


Figure 3. Relative abundances (%) of the taxonomic groups in the annual cycle.

Figure 3. Abondances relatives (%) des groupes taxonomiques pendant le cycle annuel.

Results

Average temperature at surface and 20 m through the year study showed higher values in September, 2001, whereas lower values were recorded by November, 2001 (Fig. 2). Temperature was generally lower at 20 m than at surface (Fig. 2). The temperature field appears to be usual for this year (i.e. no effect of El Niño).

The net phytoplankton community was formed by 286 taxa, divided in 119 diatoms (Bacillariophyceae), 157 dinoflagellates (Dinophyceae), 6 Cyanophyceae (Cyanobacteria) and 4 silicoflagellates (Dictyochophyceae) (Table 1). Thecate dinoflagellates were represented by 149 taxa and Centric diatoms by 94 taxa, the most diverse genera were: *Ceratium*, *Chaetoceros*, *Protoperidinium* and *Rhizosolenia* (Table 1).

Diatoms were the most common and relatively abundant group in all localities and seasons, especially in April, 2002, being relatively low by June, 2001 and decreasing by May, 2002, where dinoflagellates were relatively more abundant (Fig. 3). Cyanophyceae and silicoflagellates were not relatively abundant (Fig. 3): the presence of *Richelia intracellularis* (Cyanophyceae) was commonly recorded as symbiont in the diatoms *Rhizosolenia clevei* and *Guinardia cylindrus* (although in this case was only in November).

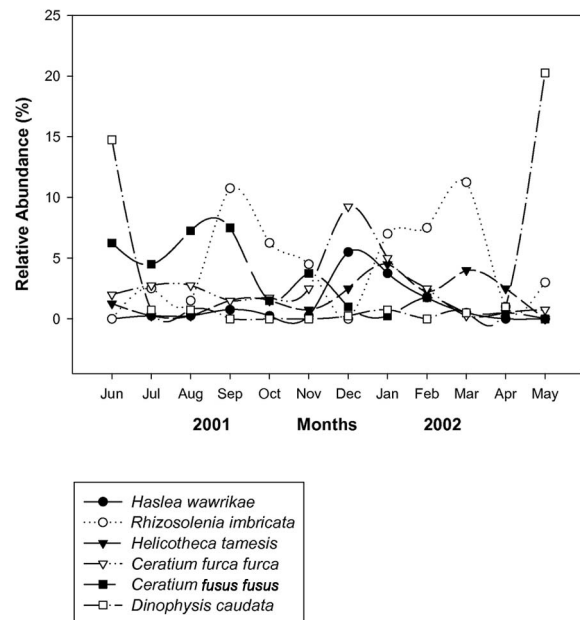
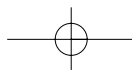
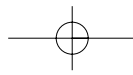


Figure 4. Relative abundances (%) of some dominant/important species along the annual cycle.

Figure 4. Abondances relatives (%) des espèces dominantes pendant le cycle annuel.



**Table 1.** List of taxa of net phytoplankton from Jalisco and Colima. (*) New records in the Mexican Pacific.**Tableau 1.** Liste des taxons du phytoplancton de Jalisco & Colima (*) Nouvelles espèces dans la partie Mexicaine du Pacifique.**Class Bacillariophyceae**

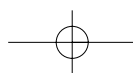
Actinocyclus octonarius var. *tenellus* (Brébisson) Villareal & Fryxell
Actinoptychus parvus ? Mann
Amphiprora sp.
Asterionellopsis glacialis (Castracane) Round
Asteromphalus flabellatus (Brébisson) Grev.
Asteromphalus heptactis (Brébisson) Ralfs
Bacteriastrum comosum ? Pavillard
Bacteriastrum delicatulum Cleve
Bacteriastrum elegans Pavillard
Bacteriastrum elongatum Cleve
Bacteriastrum hyalinum Lauder
Bacteriastrum varians var. *hispidum* (Castrac) Schröder
Biddulphia alternans (Bailey) Van Heurk
Biddulphia obtusa Kützing
Cerataulina pelagica (Cleve) Hendey
Climacodium fraunfeldianum Grunow
Corethron hystrix Hensen
Coscinodiscus asteromphalus Ehrenberg
Coscinodiscus centralis Ehrenberg
Coscinodiscus concinnus Smith
Coscinodiscus curvatus Grunow
Coscinodiscus granii (Gough) Gough
Coscinodiscus radiatus Ehrenberg var. *radiatus*
Coscinodiscus waillesii Gran & Angst
Coscinodiscus sp.
Cylindrotheca closterium (Ehrenberg) Reimann & Lewin
Chaetoceros affinis Lauder var. *affinis*
Chaetoceros affinis var. *circinalis* (Meunier) Hustedt
Chaetoceros brevis Schütt
Chaetoceros coarctatus Lauder
Chaetoceros compressus Lauder
Chaetoceros curvisetus Cleve
Chaetoceros debilis Cleve
Chaetoceros decipiens Cleve f. *decipiens*
Chaetoceros denticulatus Lauder
Chaetoceros didymus Ehrenberg var. *didymus*
Chaetoceros didymus var. *protuberans* (Lauder) Gran & Yendo
Chaetoceros difficilis ? Cleve
Chaetoceros diversus Cleve
Chaetoceros filiferus Karsten
Chaetoceros laciniosus Schütt
Chaetoceros lorenzianus Grunow
Chaetoceros messanensis Castracane
Chaetoceros peruvianus Brightwell
Chaetoceros pseudocurvisetus Mangin
Chaetoceros socialis Lauder
Chaetoceros tortissimus ? Gran
Chaetoceros sp. 1
Chaetoceros sp. 2
Dactyliosolen fragilissimus (Bergon) Hasle & Syvertsen
Dactyliosolen puketensis (Sundström) Hasle
Delphineis surirella (Ehrenberg) Andrews
Detonula pumila (Castracane) Gran

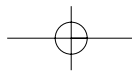
Ditylum brighthwelli (West) Grunow
Eucampia cornuta (Cleve) Grunow
Eucampia zodiacus Ehrenberg
Guinardia cylindrus (Cleve) Hasle
Guinardia delicatula (Cleve) Hasle
Guinardia flaccida (Castracane) Peragallo
Guinardia striata (Stolterfoth) Hasle
Haslea wawriakae (Hustedt) Simonsen
Haslea sp.
Hemidiscus cuneiformis Wallich
Hemiaulus haucki Grunow
Hemiaulus membranaceus Cleve
Hemiaulus sinensis Greville
Helicotheca tamesis (Shrubsole) Ricard
Leptocylindrus danicus Cleve
Leptocylindrus mediterraneus (Perag.) Hasle
Leptocylindrus minimus ? Gran
Licmophora abbreviata Agardh
Lithodesmium undulatum Ehrenberg
Lioloma pacificum (Cupp) Hasle
Meuniera membranacea (Cleve) Silva
Navicula sp. 1
Navicula sp. 2
Navicula sp. 3
Neocalyptrella robusta (Norman) Hernández-Becerril & Meave
Neostreptothea sp. ?
Nitzschia americana Hasle
Nitzschia bicapitata Cleve
Nitzschia longissima (Brébisson) Ralfs
Odontella aurita (Lyngbye) Agardh
Odontella longicuris (Greville) Hoban
Odontella mobiliensis (Bailey) Grunow
Odontella regia (Schultze) Simonsen
Pachyneis gerlachii Simonsen
Planktoniella sol (Wallich) Schütt
Proboscia alata (Brightwell) Sundström
Proboscia alata f. *gracillima* (Cleve) Licea-Durán & Moreno
Proboscia indica (Peragallo) Hernández-Becerril
Pseudo-nitzschia delicatissima (Cl.) Heiden
Pseudo-nitzschia fraudulenta (Cleve) Hasle
Pseudo-nitzschia pseudodelicatissima (Hasle) Hasle
Pseudo-nitzschia pungens (Grun.ex Cl.) Hasle
Pseudo-nitzschia sp.
Pseudosolenia calcar-avis (Schultze) Sundström
Rhizosolenia bergonii Peragallo
Rhizosolenia castracaneii Peragallo
Rhizosolenia clevei var. *communis* Sundström
Rhizosolenia crassispina Schröder
Rhizosolenia hyalina Ostefeld
Rhizosolenia imbricata Brightwell
Rhizosolenia temperi Peragallo
Roperia tessellata (Roper) Grun. ex Pelletan
Skeletonema costatum (Greville) Cleve
Stephanopyxys palmeriana (Grev.) Grunow
Stephanopyxys turris (Arnott & Grev.) Ralfs
Stigmaphora rostrata Wallich

Thalassionema frauenfeldii (Grun.) Hallegraeff
Thalassionema nitzschioides (Grunow) Hustedt
Thalassiosira eccentrica (Ehrenberg) Cleve
Thalassiosira leptopus (Grun.) Hasle & Fryxell
Thalassiosira oestrupii (Ostefeld) Hasle
Thalassiosira sp. 1
Thalassiosira sp. 2
Thalassiosira sp. 3
Thalassiosira sp. 4
Thalassiothrix sp.

Class Dinophyceae

Alexandrium catenella (Whedon & Kofoid) Balech
Amphisolenia bidentata Schröder
Amphisolenia lemmermanni Kofoid
 * *Amphisolenia palmata* Stein
Amphisolenia schroederi Kofoid
 * *Amphisolenia truncata* Kofoid & Michener
Balechina coerulea (Dogiel) Taylor
Ceratocorys bipes Cleve
Ceratocorys horrida Stein
Ceratium breve (Ostefeld & Schmidt) Schröder
Ceratium belone Cleve
Ceratium candelabrum (Ehrenberg) Stein
Ceratium carriense Gourret var. *carriense*
Ceratium concilians Jörgensen
Ceratium contortum (Gourret) Cleve var. *contortum*
Ceratium contortum var. *robustum* (Karsten) Sournia
Ceratium contrarium (Gourret) Pavillard
Ceratium declinatum (Karsten) Jörgensen
Ceratium deflexum ? (Kofoid) Jörgensen
Ceratium digitatum Schütt
Ceratium divaricatum (Lemm.) Kofoid
Ceratium eucarvatum Jörgensen
Ceratium extensum (Gourret) Cleve
Ceratium falcatum (Kofoid) Jörgensen
Ceratium furca (Ehrenberg) Claparède & Lachmann var. *furca*
Ceratium furca var. *eugrammum* (Ehr.) Schiller
Ceratium furca var. *hircus* (Schröder) Margalef ex Sournia
Ceratium fusus (Ehrenberg) Dujardin var. *fuscus*
Ceratium fusus var. *seta* (Ehrenberg) Sournia
Ceratium fusus var. *schuetii* ? Lemmermann
Ceratium gibberum var. *dispar* (Pouchet) Sournia
Ceratium gibberum var. *subaequale* Jörg.
Ceratium hexacanthum var. *contortum* Lemm.
Ceratium horridum var. *buceros* (Zacharias) Sournia
Ceratium horridum var. *horridum* Sournia
Ceratium incisum (Karsten) Jörgensen
Ceratium inflatum (Kofoid) Jörgensen
Ceratium kofoidii Jörgensen
Ceratium limulus Gourret
Ceratium lineatum (Ehrenberg) Cleve
Ceratium longirostrum Gourmet
Ceratium longissimum (Schröder) Kofoid





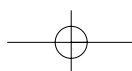
<i>Ceratium lunula</i> (Schimper ex Karsten) Jörgensen	<i>Gonyaulax monspina</i> ? Rampi	<i>Protoberidinium mediterraneum</i> (Kofoid) Balech
<i>Ceratium macroceros</i> var. <i>gallicum</i> (Kofoid) Sournia	<i>Gonyaulax pacifica</i> Kofoid	<i>Protoberidinium oblongum</i> (Aurivillius) Parke & Dodge
<i>Ceratium macroceros</i> (Ehrenberg) Vanhöffen var. <i>macroceros</i>	<i>Gonyaulax polygramma</i> Stein	<i>Protoberidinium obtusum</i> (Karsten) Parke & Dodge
<i>Ceratium massiliense</i> (Gourret) Karsten	<i>Gonyaulax spinifera</i> (Claparède & Lachmann) Diesing	<i>Protoberidinium oceanicum</i> (Vanhöffen) Balech
<i>Ceratium paradoxides</i> Cleve	<i>Gonyaulax turbynei</i> Murray & Whitting	<i>Protoberidinium oviforme</i> ? (Dangeard) Balech
<i>Ceratium pavillardii</i> Jörgensen	<i>Gonyaulax</i> sp.	<i>Protoberidinium paviventer</i> ? Balech
<i>Ceratium pentagonum</i> var. <i>subrobustum</i> Jörgensen	<i>Gotius abei</i> Matsuoka	<i>Protoberidinium pellucidum</i> Bergh
<i>Ceratium porrectum</i> Karsten Jörgensen	<i>Gymnodinium catenatum</i> Graham	<i>Protoberidinium pentagonum</i> (Gran) Balech
<i>Ceratium praelongum</i> (Lemmermann) Kofoid ex Jörgensen	<i>Gymnodinium</i> sp.	<i>Protoberidinium punctulatum</i> (Paulsen) Balech
<i>Ceratium ranipes</i> Cleve	<i>Histioneis mitchellana</i> Murray & Whitting	<i>Protoberidinium pyriforme</i> (Paulsen) Balech
<i>Ceratium reflexum</i> Cleve	* <i>Kofoidinium splendens</i> Pavillard	<i>Protoberidinium pyriforme</i> subsp. <i>breve</i> (Paulsen) Balech
<i>Ceratium schmidtii</i> ? Jörgensen	<i>Noctiluca scintillans</i> (Macartney) Kofoid & Swezy	<i>Protoberidinium schilleri</i> ? (Paulsen) Balech
<i>Ceratium schröderi</i> B. Schröder	<i>Ornithocercus heteroporus</i> Kofoid	<i>Protoberidinium steinii</i> (Jörgensen) Balech
<i>Ceratium symmetricum</i> var. <i>symmetricum</i> Graham & Bronikowsky	<i>Ornithocercus magnificus</i> Stein	<i>Protoberidinium subpyriforme</i> ? (Dangeard) Balech
<i>Ceratium teres</i> Kofoid	<i>Ornithocercus splendidus</i> Schütt	<i>Protoberidinium tenuissimum</i> (Kofoid) Balech
<i>Ceratium trichoceros</i> (Ehrenberg) Kofoid	<i>Ornithocercus steinii</i> Schütt	<i>Protoberidinium trystilum</i> (Stein) Balech
<i>Ceratium tripos</i> var. <i>atlanticum</i> (Ostenfeld) Paulsen	<i>Ornithocercus thumii</i> (Schmidt) Kofoid & Skogsberg	<i>Protoberidinium venustum</i> (Matzenauer) Balech
<i>Ceratium tripos</i> var. <i>pulchellum</i> (Schröder) López ex Sournia	<i>Oxytoxum reticulatum</i> (Stein) Schütt	<i>Protoberidinium</i> sp. 1
<i>Ceratium vultur</i> Cleve	<i>Oxytoxum sceptrum</i> (Stein) Schröder	<i>Protoberidinium</i> sp. 2
<i>Ceratium vultur</i> f. <i>summatranum</i> (Karsten) Sournia	<i>Oxytoxum scolopax</i> Stein	<i>Pselodinium vaubanii</i> Sournia
<i>Ceratium</i> sp.	<i>Podolampas bipes</i> Stein	<i>Pyrocystis fusiformis</i> Thomson & Blackmann
<i>Dinophysis amandula</i> Sournia	<i>Podolampas spinifera</i> Okamura	<i>Pyrocystis lunula</i> (Schütt) Schütt
<i>Dinophysis argus</i> (Stein) Abé	<i>Preperidinium</i> sp.	<i>Pyrocystis noctiluca</i> Murray ex Haeckel
<i>Dinophysis caudata</i> Saville-Kent	<i>Prorocentrum compressum</i> (Bailey) Abé ex Dodge	<i>Pyrocystis robusta</i> Kofoid
<i>Dinophysis doryphora</i> (Stein) Abé	<i>Prorocentrum gracile</i> Schütt	<i>Pyrophacus horlogium</i> Stein
<i>Dinophysis fortii</i> Pavillard	<i>Prorocentrum maximum</i> (Gourret) Schiller	<i>Pyrophacus steinii</i> (Schiller) Wall & Dale
<i>Dinophysis hastata</i> Stein	<i>Prorocentrum micans</i> Ehrenberg	<i>Scrippsiella trochoidea</i> (Stein) Steidinger & Balech
<i>Dinophysis hindmarchii</i> (Murray & Whitting) Balech	<i>Prorocentrum rostratum</i> Stein	<i>Shuettiella mitra</i> (Schütt) Balech
<i>Dinophysis mitra</i> (Schütt) Abé	<i>Prorocentrum sigmoides</i> Böhm	<i>Spiraulax kofoidii</i> Graham
<i>Dinophysis odiosa</i> (Pavillard) Tai & Skogsberg	<i>Prorocentrum triestinum</i> Schiller	
<i>Dinophysis porodictyum</i> (Stein) Abé	<i>Protoberidinium abei</i> (Paulsen) Balech	Class Cyanophyceae
<i>Dinophysis rapa</i> (Stein) Abé	<i>Protoberidinium brevipes</i> (Paulsen) Balech	<i>Trichodesmium contortum</i> Wille
<i>Dinophysis schuettii</i> Murray & Whitting	<i>Protoberidinium brochii</i> (Kofoid & Swezy) Balech	<i>Trichodesmium erythraera</i> Ehrenberg
<i>Diplopsalopsis bomba</i> Stein	<i>Protoberidinium cerasus</i> (Paulsen) Balech	<i>Trichodesmium hildebrandtii</i> Gomont
<i>Goniodoma polyedricum</i> (Pouchet) Jörgensen	<i>Protoberidinium claudicans</i> (Paulsen) Balech	<i>Anabaena</i> sp.
<i>Goniodoma sphaericum</i> Murray & Whitting	<i>Protoberidinium conicum</i> (Gran) Balech	<i>Nodularia</i> sp.
<i>Gonyaulax diegensis</i> Kofoid	<i>Protoberidinium crassipes</i> (Kofoid) Balech	<i>Richelia intracellularis</i> Schmidt
<i>Gonyaulax digitalis</i> (Pouchet) Kofoid	<i>Protoberidinium depressum</i> (Bailey) Balech	
<i>Gonyaulax grindleyi</i> Reinecke	* <i>Protoberidinium divaricatum</i> (Meunier) Balech	Class Dictyochophyceae
* <i>Gonyaulax jollifei</i> Murray & Whitting	<i>Protoberidinium divergens</i> (Ehr.) Balech	<i>Dictyocha calida</i> Poelchau
	<i>Protoberidinium elegans</i> (Cleve) Balech	<i>Dictyocha californica</i> Schrader & Murray
	<i>Protoberidinium grande</i> (Kofoid) Balech	<i>Dictyocha fibula</i> Ehrenberg
	<i>Protoberidinium grani</i> (Ostenfeld) Balech	<i>Dictyocha octonaria</i> Ehrenberg
	<i>Protoberidinium latidorsale</i> ? (Dangeard) Balech	
	<i>Protoberidinium latispinum</i> (Manguin) Balech	
	<i>Protoberidinium leonis</i> (Pavillard) Balech	

The most abundant (relative abundance) species were the diatoms *Haslea wawriake* (December and January), *Helicotheca thamesis* (December, January to April) and *Rhizosolenia imbricata* (September to November, and January to March), and the dinoflagellates *Ceratium fusus* var. *fuscus* (June to September) and *Ceratium furca* var. *furca* (January); by June, 2001 and May, 2002, the relative abundance of the dinoflagellate *Dinophysis caudata* was considerable (Fig. 4).

Species richness varied from 34 species in May (El

Púlpito) to 87 species in November (Bahía Manzanillo). The calculated values of the diversity (H') ranged from 0.73 (April, I. Pajarera) to 3.55 (July, La Soledad). H' values were relatively homogeneous from June to December, 2001, but decreased by January, 2002, then increased slightly by February and March and in April they decreased, to finally rise again by May (Fig. 5).

The analysis of similarity showed the presence of high affinity between four localities: El Púlpito, Is. Pajarera and B. Manzanillo, B. Santiago, remaining two other associated



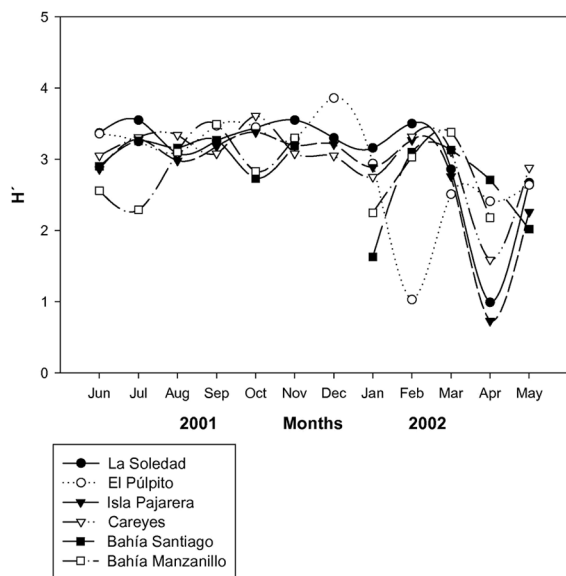
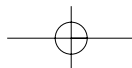


Figure 5. Diversity index values (H') along the annual cycle.

Figure 5. Valeurs de l'indice de diversité pendant le cycle annuel.

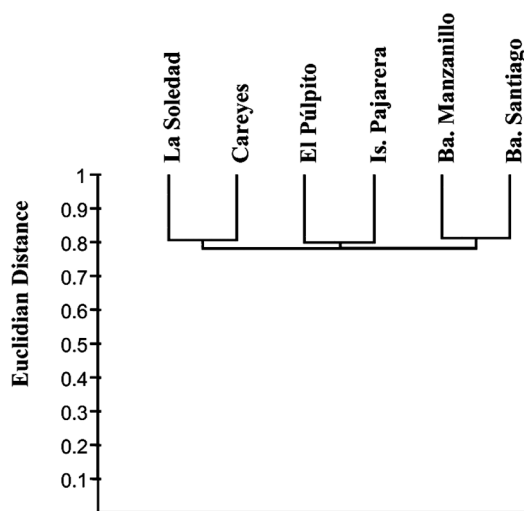


Figure 6. Dendrogram of the analysis of similarity among stations.

Figure 6. Dendrogramme de l'analyse de similarité entre stations.

between them: La Soledad and Careyes (Fig. 6). The analysis also showed different communities for Summer/Fall and for Winter/Spring (Fig. 7), with a significant value.

Five new records of dinoflagellates are annotated for the Mexican Pacific: *Amphisolenia palmata*, *Amphisolenia truncata*, *Gonyaulax jollifei*, *Kofoidinium splendens* and *Protoperidinium divaricatum* (Table 1). From all of them, only *Kofoidinium splendens* is a non-thecate form.

Discussion

Phytoplanktonic composition

Phytoplankton composition in our study was better represented by diatoms and dinoflagellates, in terms of diversity and relative abundance, as expected for the microplankton fraction in coastal waters. However, species richness was higher in dinoflagellates (157 taxa) than in diatoms (119 taxa). Results from other authors for near areas showed that diatoms were the richest and most abundant group (in terms of relative and absolute abundance) (Otero-Dávalos, 1981; León-Álvarez, 1983; Bravo-Sierra, 1999).

Diatoms were the most abundant (relative abundance) group along the year of study, especially by April, 2002 (Fig. 3). The assemblages showed the presence of medium to large-sized species (Table 1), but the species richness (119 taxa) was not as high as expected. By September, 2001 and March, 2002 the diatom *Rhizosolenia imbricata* repre-

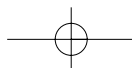
sented 12 % (Fig. 4). This species has also been recorded as abundant and dominant (23 to 90 % of the abundance in the community) in close zones as the Gulf of California by July (Bustillos-Guzmán, 1986).

In June, 2001 and in May, 2002, dinoflagellates were more abundant than diatoms, indicating that dinoflagellates are more important in late spring and early summer (Fig. 3), and this increase was related to the high relative abundance (between 15 and 20 %) of *Dinophysis caudata* (Fig. 4). The number of taxa identified here is considered to be high (157 taxa). Dinoflagellates are also a major component in the planktonic flora from the Gulf of Tehuantepec (Meave & Hernández-Becerril, 1998), another zone relatively close to our study area (to the south), with similar climatic characteristics.

Species assemblages were relatively homogeneous in all stations, although differences in species composition were also noted among stations (Fig. 6), with stations located closer (B. Manzanillo and B. Santiago, Fig. 1) having a higher association.

Diatoms encountered in our study represent only a small fraction of the total listed for the Mexican Pacific, between 15-25 % (Meave et al., 2003), although that list also includes "tychoplanktonic" forms. In the case of the dinoflagellates, about 43 % of the flora reported for the Mexican Pacific is included here (Hernández-Becerril, 2003).

Two species of Cyanophyceae appeared in all localities and along the whole year of study: *Trichodesmium erythraera* and *Anabaena* sp., whereas *Richelia intracellularis*



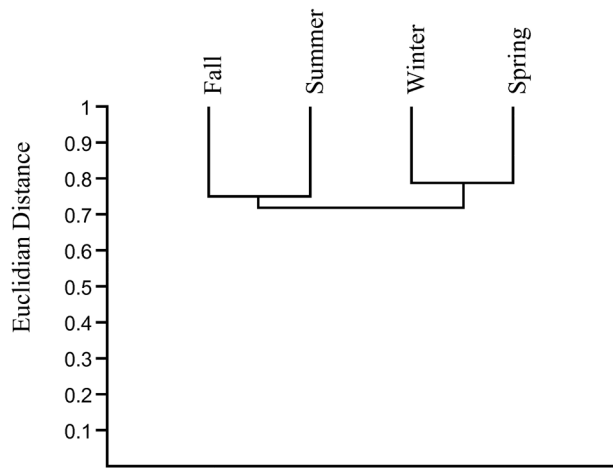
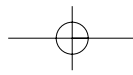


Figure 7. Dendrogram of the analysis of similarity among climatic season.

Figure 7. Dendrogramme de l'analyse de similarité entre saisons.

was found as common symbiont in two species of diatoms: *Rhizosolenia clevei* and *Guinardia cylindrus*. Also two species of silicoflagellates (*Dictyocha fibula* and *D. californica*) occurred in all localities and during the whole year of study.

A considerable amount of species found in our study are referred to as tropical/subtropical forms, with another important component of temperate and cosmopolitan forms. This reflects the nature of the communities in a transitional area. Species considered oceanic were also found, nearly in the same proportion as the neritic forms. A total of 92 taxa were present along the whole year of study, about 31 % of the total 286 taxa. This may be interpreted as these species that represent the "base community" of microphytoplankton in the area.

The flora found in this study do share general characteristics with planktonic flora of close areas, such as the Gulf of California (to the north) and the Gulf of Tehuantepec (to the south), which are characterized as subtropical to tropical (Hernández-Becerril, 1987, 2003, Licea et al., 1995, Moreno et al., 1996, Meave & Hernández-Becerril, 1998). Furthermore, proportions of both diatoms and dinoflagellates obtained in our study are similar to those occurred in May, 1989, for the Gulf of Tehuantepec (Meave & Hernández-Becerril, 1998). In a similar study (based on net samples), in a very close zone to our study area (Bahía Banderas), Bravo-Sierra (1999) found similar microplanktonic floras, with more species richness in diatoms than in dinoflagellates and also an important quantity of tropical or subtropical dinoflagellates, but the difference was due to the high proportion of tychoplanktonic (both benthic and epiphytic) diatoms.

The flora described here may well represent the net phytoplankton, but no much information about the nano and picoplankton fractions (that very often contain fragile cells and are smaller than 20 micrometers) is provided; however, relative small forms could be found in a clogged net.

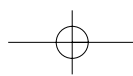
Five new records of dinoflagellates are annotated for the Mexican Pacific in this paper. These are: *Amphisolenia palmata*, *Amphisolenia truncata*, *Gonyaulax jollifei*, *Kofoidinium splendens* and *Protoberidinium divaricatum*. Two of them belong to the genus *Amphisolenia*, of the Order Dinophysiales, species of large size, which generally occur in very low densities. Only one species is a non-thecate (naked) form, *Kofoidinium splendens*, which is a relatively large species and it may have been ignored in previous studies, especially in preserved samples that may deteriorate it. We may speculate that due to the lack of detailed floristic and taxonomic studies in the area, we were able to find such new records, and further studies might yield not only new records but also new species (Hernández-Becerril et al., 2004).

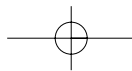
Temporal dynamics of the net phytoplankton

Diatoms appeared as the more important group in relative abundance throughout the year studied, and only by June, 2001 and May 2002 dinoflagellates were more important. This supports other results in closer areas (Mazatlán, Sinaloa, Mexico) where dinoflagellates become more abundant in warmer seasons, including cases of red tides (Cortés-Altamirano & Núñez-Pastén, 1992).

Water temperature throughout the annual cycle (Fig. 2) did not appear to have affected the microphytoplankton community: those two major rises of the dinoflagellates' relative abundances (involving *Dinophysis caudata*) are not directly related to an increase in temperature. Additionally, results of chlorophyll *a* and nitrate concentrations in the area (not reported here, e.g. Blanco Alonso & Madrid Hernández, 2004), showed maximum values by November, 2001 and March, 2002, which could be more related to high diatom relative abundance, however water samples for those analyses were not separated by fractions thus the chlorophyll *a* content might also be supplied by other phytoplankton fractions or groups (e.g. nano and picoplankton, phytoflagellates).

Some succession patterns (Margalef, 1958, 1967, 1968, 1974; Smayda, 1980; Reynolds, 1995) in the phytoplankton were observed. Species considered pioneers in the succession process (stage 1) were recorded during August, September and October, such as the diatoms *Chaetoceros affinis* var. *circinalis*, *C. didymus*, *C. diversus*, *C. lacinosus*, *C. lorenzianus*, *Pseudo-nitzschia delicatissima*, *Skeletonema costatum* and *Thalassionema nitzschioides*. In November and December, we found a community mixed, composed by pioneer species together with larger forms,





considered as part of the second stage (stage 2) of the phytoplanktonic succession: *Chaetoceros curvisetus*, *C. messanensis*, *C. tortissimus*, *Pseudo-nitzschia pungens*, *Skeletonema costatum*, *Thalassionema nitzschioides* *Thalassiosira* sp., and *Guinardia cylindrus*, *Proboscia alata* f. *alata*, *Pseudosolenia calcar-avis*, *Rhizosolenia crassispinata*, *R. imbricata* (all diatoms).

In January, species such as *Coscinodiscus* ssp., *Leptocylindrus danicus*, *Rhizosolenia imbricata*, *Pseudosolenia calcar-avis* and the dinoflagellate *Ceratium furca* were more abundant and represented the stage 2, whereas in February dinoflagellate species became more important: *Ceratium declinatum*, *C. furca*, *C. fusus*, *C. macroceros*, *Dinophysis caudata*, *Protoperidinium depressum*, *P. grani*, *P. pentagonum*, *P. pellucidum*, indicating the tertiary stage (stage 3) of the succession. By March and April no clear trend was detected, possibly due to the mix of water of different origins, but still diatoms dominated the communities. The unidirectional trend of the species succession may be easily modified according to meso-scale and local oceanographic and climatic events.

Unfortunately, the successional patterns do not follow any correspondence with the indices of diversity calculated (Fig. 5), which showed moderate to relative high values, from June to December, and decreased by January. Following the ecological theory, the values of the index should increase with more complex communities, or in stages 3 and 4 (Margalef, 1968, 1974).

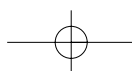
Community changes of the microphytoplankton were also shown by the analysis of similarity, which helped to define two distinct assemblages: one for Summer/Fall and the other for Winter/Spring (Fig. 7). The communities found in winter and spring indicated that there were 134 similar species between these two seasons, from which 83 are tropical or subtropical forms, such as the diatoms: *Asteromphalus heptactis*, *Bacteriastrum elongatum*, *Cylindrotheca closterium*, *Chaetoceros filiferus*, *Dactyliosolen phuketensis*, *Detonula pumila*, *Guinardia flaccida*, *Haslea wawrikan*, *Helicotheca tamesis*, *Hemidiscus cuneiformis*, *Meuniera membranacea*, *Pseudo-nitzschia pseudodelicatissima*, *Thalassionema nitzschioides*, and the dinoflagellates: *Alexandrium catenella*, *Ceratium digitatum*, *C. extensum*, *C. falcatum*, *C. gibberum* var. *subecuale*, *C. horridum* var. *buceros*, *C. incisum*, *C. lunula*, *Dinophysis porodyctium*, *D. rapa*, *Gonyaulax digitalis*, *G. monospina*, *G. spinifera*, *Kofoidinium splendens*, *Protoperidinium divaricatum*, *P. elegans*, *P. latispinum*, *P. oceanicum*, *P. trystilum*, *P. venustum*. These two different phases of the community may be associated to local oceanographic and climatic factors, such as circulation patterns, presence of upwellings, changes in temperature and rain incidence.

Acknowledgements

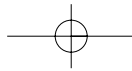
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