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Phytoplankton biomasses and hydrographic conditions during El Niño 1997-1998 in Bahía Concepción, Gulf of California, Mexico

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RESUMEN

Los cambios en las condiciones físico-químicas y los pigmentos fitoplanctónicos, en Bahía Concepción, Golfo de California, se analizan para el periodo 1997 a 1999 con el objetivo de observar el efecto de El Niño 1997-1998 en esta bahía. Tres diferencias notables en los parámetros medidos ocurrieron durante 1998: Temperaturas mayores en la columna de agua, un retrazo de 2-3 meses en el inicio del período de la estratificación y concentraciones menores de nutrientes (nitratos y fosfatos) y peridinina. Estos datos sugieren la presencia de Agua Ecuatorial Superficial (altas temperaturas y baja concentración de nutrientes) con un efecto negativo en la proliferación de dinoflagelados. Se discuten las posibles causas de la baja en la concentración de los dinoflagelados.

PALABRAS CLAVE: El Niño, huellas pigmentarias, Bahía Concepción, Golfo de California.

ABSTRACT

The biomass of phytoplankton groups, particularly dinoflagellates as indicated by their signature pigment peridinin, and the physicochemical conditions in Bahía Concepción, Gulf of California are analyzed for the years 1997-1999, in order to observe the changes in phytoplankton and hydrographic structure linked to El Niño 1997-98. Three significant changes occurred in 1998 compared to 1997 and 1999: higher temperatures in the water column, lower nutrient and peridinin concentrations, and a 2 to 3 month delay of the stratification period. These data suggest the influence of Equatorial Surface Water (low nutrients, high temperatures) and a negative effect on the proliferation of dinoflagellate groups during El Niño 1997-98. Possible causes of the low dinoflagellate biomass are discussed.

KEY WORDS: El Niño, pigment signatures, Bahía Concepción, Gulf of California.

INTRODUCTION

In general, the El Niño effects along the American west coast consist of a relaxation of upwelling, a decrease of nutrients, and a decline of primary and secondary productivities (Lynn *et al.*, 1998). A decrease in phytoplankton biomass along the coasts of Chile and Peru (Cowles *et al.*, 1977; Barber *et al.*, 1983; Guillén *et al.*, 1985; Avaria and Muñoz, 1987) and the western coast of Baja California (Torres-Moye and Álvarez-Borrego, 1985; Martínez-López, 1993; Gárate-Lizárraga and Siqueiros-Beltrones, 1998) have been described. In the Gulf of California, the consequences appear to be different. The primary productivity and phytoplankton and zooplankton biomasses increased during El Niño 1982-83 (Baumgartner *et al.,* 1985; Valdéz-Holguín and Lara-Lara, 1987; Bustillos-Guzmán, 1990; Lavaniegos-Espejo and Lara-Lara, 1990; Álvarez Borrego and Lara-Lara, 1991). This response was attributed to a lower grazing pressure and to a higher incidence of tropical and subtropical species during the El Niño (Valdéz-Holguín and Lara-Lara, 1987; Álvarez Borrego and Lara-Lara, 1991). A stronger advection of nutrient-rich subsurface subtropical waters into the Gulf and their transport to the surface by upwelling has also been used to explain the high productivity (Baumgartner and Christensen, 1985; Robles and Marinone, 1987). Thus, the Gulf of California acts as a chemostatic system, where the nutrient supply is provided by the horizontal subsurface flow of nutrients (Baumgartner *et al.*, 1985). Studies based on monthly composites of coastal-zone color-scanner (CZCS) satellite imagery show that, in general, variability of phytoplankton biomass (as chlorophyll concentration) in the northern and central part of the Gulf of California is unrelated to El Niño (Santamaría-del Angel *et al.*, 1994).

Phytoplankton in coastal lagoons around the Gulf of California is clearly influenced by Gulf waters (Gilmartin and Revelante, 1978; Martínez-López and Gárate-Lizárraga, 1997). Thus, an effect may also be expected during El Niño events, but long time-series data are unavailable as yet to test this hypothesis. For Bahía Mazatlán, near the mouth of the Gulf of California, a decrease in the frequency and duration of red tides has been noted (Cortés-Altamirano, 1987; Cortés-Altamirano *et al.*, 1995; Cortés-Altamirano and Alonso-Rodríguez, 1997). In this study, we analyze the physicochemical conditions and phytoplankton biomass of Bahía Concepción during El Niño 1997-98.

STUDY AREA

Bahía Concepción is on the west coast of the Gulf of California ((26° 33' - 26° 53' N; 111° 42' - 112° 56' W). It is approximately 45 km long by 10 km at the widest part. The depth in the central channel is 30 m (Ramírez-Guillén, 1983). From May to October the prevailing winds are weak and primarily from the south. In late fall through early spring, the winds are strong and from the north (Baqueiro-Cárdenas *et al.,* 1978; Thunell *et al.,* 1994). This bay has anti-estuarine features, and the mean annual surface temperature is 24.9 °C, with a lowest mean of 17.5°C (January) and a maximum mean of 32.1 °C (September). Salinity has an annual mean of 35.3 psu, with a minimum and maximum of 34.6 and 37 psu (Félix-Pico and Sánchez, 1976). The concentrations of dissolved oxygen range from 5.4 mL/L in Spring to 5.95 mL/L in Winter. However, at the bottom anoxic or hypoxic conditions have been observed (Gilmartin and Revelante, 1978; Lechuga-Devéze and Morquecho-Escamilla, 1998; Lechuga-Devéze *et al.*, 2000).

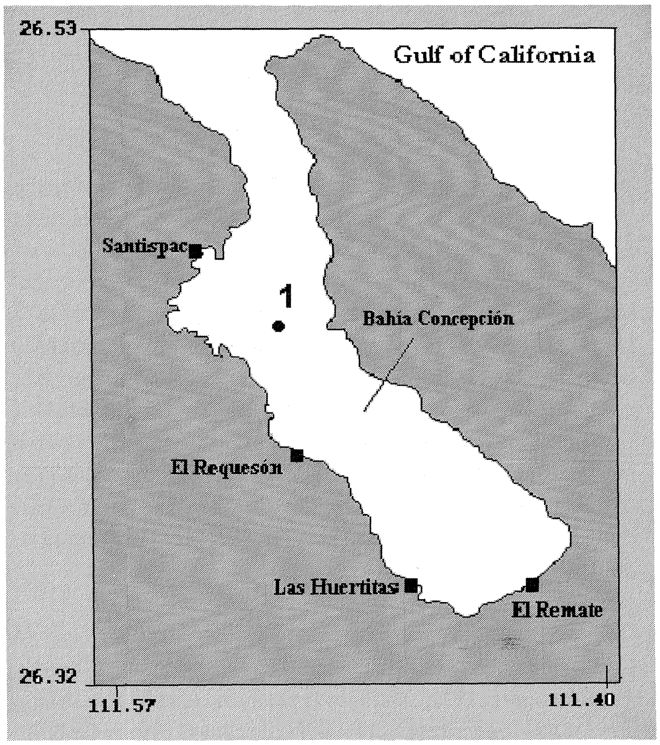

Fig. 1. Location of the study area and sampling station in Bahía Concepción, Gulf of California.

MATERIAL AND METHODS

During 1997, 1998, and 1999 a sampling program was done at a fixed sampling station in the central part of Bahía Concepción (Figure 1). Water samples were obtained at 0, 5, 10, 15, 20, 25, and 27 m depth with a Van-Dorn bottle to determine temperature, dissolved oxygen, nitrates and phosphates, and photosynthetic pigments. Sampling intervals were 3 to 5 days in 1997 (February to May), 3 days in 1998 (February to November), and biweekly in 1999 (January to December).

Seawater temperature was measured with a bucket thermometer. Dissolved oxygen, nitrates, and phosphates were determined following methods described by Strickland and Parson (1972). Photosynthetic pigments were measured by HPLC (Vidussi *et al.*, 1996). Identification and quantification of pigments were made as described by Bustillos-Guzmán *et al.* (1995). The thermal stratification index (ST: °C/m) was computed as the difference of temperature m^{-1} (0 to 27 m) calculated from each 5 m data. Homogenous water-column (ST= <0.05); Transition period (> 0.05 < 0.2); Stratified water column (> 0.2) (Bustillos-Guzmán *et al.*, 1995).

RESULTS

Temperature

A homogeneous water column with temperature of 18 °C was recorded in February 1997. At the end of March, temperature increased to 20 °C (Transition period). In May, the thermocline was completely developed between 10 and 20 m and the surface temperature reached 27 °C. A stratified water column is observed (Figure 2A). From January to May 1998, water column temperatures were vertically homogeneous (19 to 25 °C). From middle April to the end of June the first transition period was observed. In June, stratification was present again and it remained until September. During this period, water column temperatures were between 24 and 31 °C and the thermocline was found between 10- and 20-m depth. Surface temperature reached 31 °C (Figure 2B). Second transition period during 1998 was observed from middle September to early October.

From January to April 1999, the water column was homogeneous with temperatures between 16.0 and 21.5 °C. First transition period was observed from late April to late May. Water column stratification was detected during the first days of May. From June to September, the water column remained well-stratified with temperatures between 22.0 and 31.0 °C. Second transition period was observed from middle to end of September. Homogeneous water

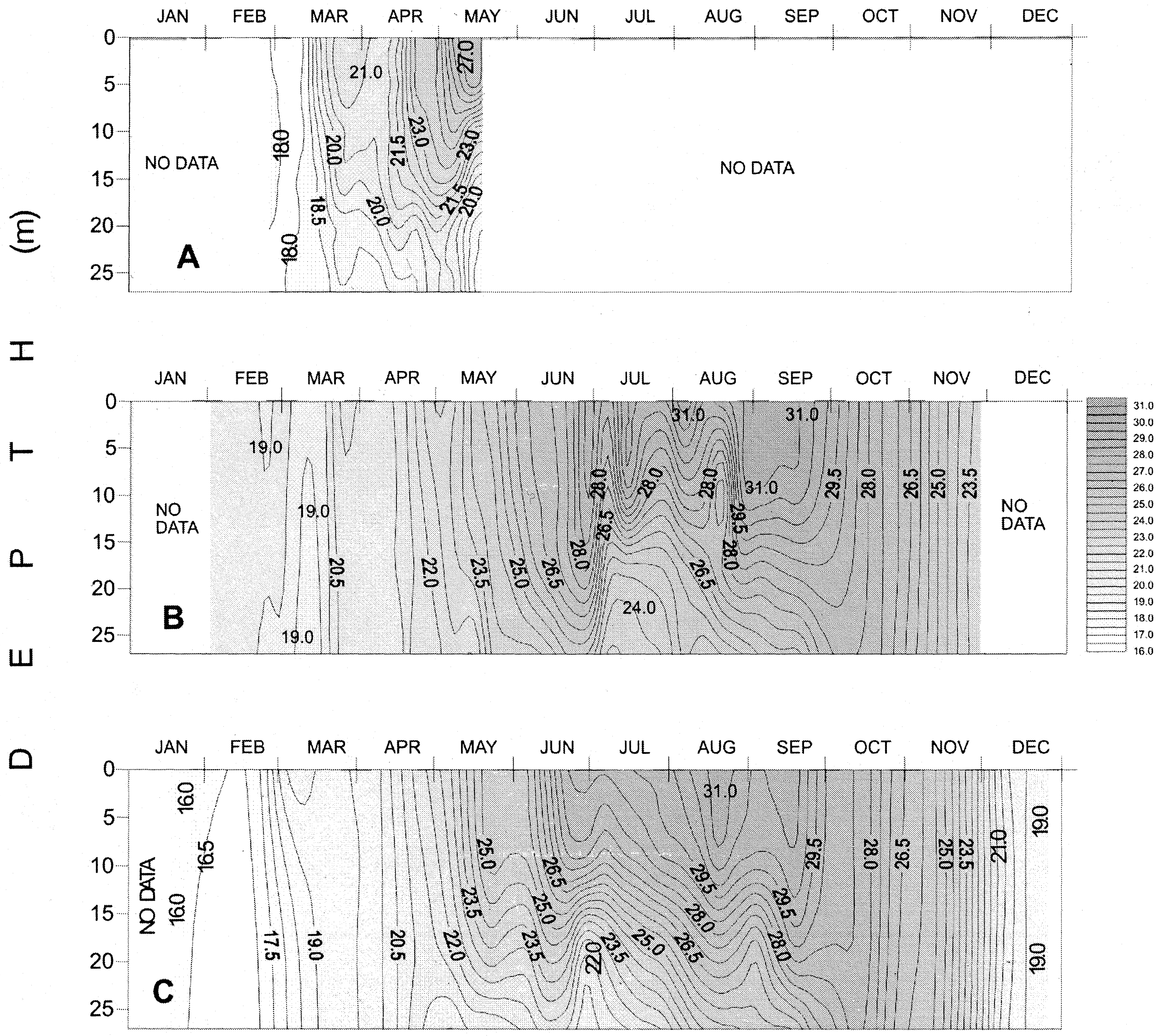

Fig. 2. Variation of temperature (°C) during 1997 (A), 1998 (B), and 1999 (C) in Bahía Concepción, Gulf of California.

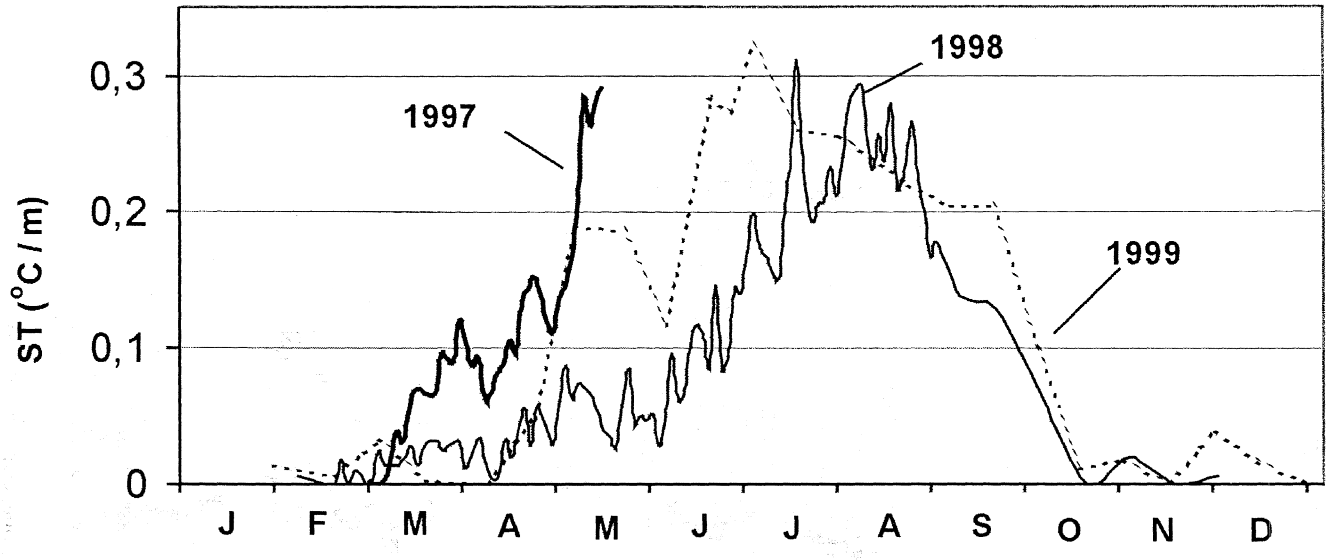

Fig. 3. Stratification index (ST) during 1997, 1998, and 1999 in Bahía Concepción, Gulf of California.

column conditions were again reached between October and December (19.0 and 28.0 °C) (Figure 2C).

The stratification index showed that during 1997 stratification was reached earlier. The delay period of about 2 months is evident in 1998. In 1999 stratification began in between the time of stratification in 1997 and 1998. The end of the stratification was similar in 1998 and 1999, therefore 1998 has a shorter stratification period (Figure 3).

Phosphates and nitrates

In general, values of phosphate and nitrate concentration increased with stratification, although lower values were clearly recorded in 1998 (Figure 4). The phosphate concentration was higher in 1999 when the value reached 30 mM/m^2, in contrast with the low values found in 1998 (< 10 mM/m^2 for the same period) (Figure 4A). Peak values on nitrates were around 20 mM/m^2 during 1998, whereas peak values for 1997 were 30 and for 1999 were 40 mM/m^2 (Figure 4B).

Phytoplankton pigments

In general, an increase of pigments occurred during the hydrographic transitional periods (Figure 5). Chlorophyll *a* values were similar form year to year, and with the exception of peak values (> 70 mg m^{-2}) that occurred (3 for 1997, 1 for 1998, and 1 for 1999), they were lower than 40 mg m^{-2} (Figure 5A). For peridinin concentrations, the outstanding feature is the low value during 1998 (in general lower than 1.5 mg/m^2) and peak values found during July 1999 (Figure 5B) caused by a dinoflagellate bloom. Fucoxanthin was the most important carotenoid and closely followed the variation of the chlorophyll *a,* suggesting that diatoms are responsible for most of the phytoplankton biomass changes in the bay (Figure 5C). The chlorophyll *b*-containing groups (Chlorophyceae and Prasinophyceae) show no important differences from one year to the next (Figure 5D).

DISCUSSION

Hydrographic conditions were similar to those reported previously (Reyes-Salinas, 1994; Lechuga-Devéze and Morquecho-Escamilla, 1999). Dominance of diatoms and dinoflagellates is a community phytoplankton feature for Bahía Concepción (Martínez-López and Gárate-Lizárraga, 1994; 1997), as confirmed by the high concentration of fucoxanthin and peridinin (Figure 5). Additionally, the pigment signatures showed an important contribution of the chlorophyll *b*-containing groups. Warmer temperatures at depth as well as a time-delay in the stratification were noted during 1998. These differences could be caused by the normal annual and interannual surface temperature variability in the Gulf of California (Soto-Mardones *et al.*, 1999) and the wind effect on the hydrographic patterns (Santa-María del Angel *et al.*, 1994). These differences were also accompanied by a lower concentration of phosphate, nitrate, and chlorophyll a, suggesting that they can be linked to the El Niño 1997/1998 phenomenon. Let us explore this possibility.

Evidence of El Niño off the Mexican coastal zone, in the form of surface Tropical Pacific water (Durazo and

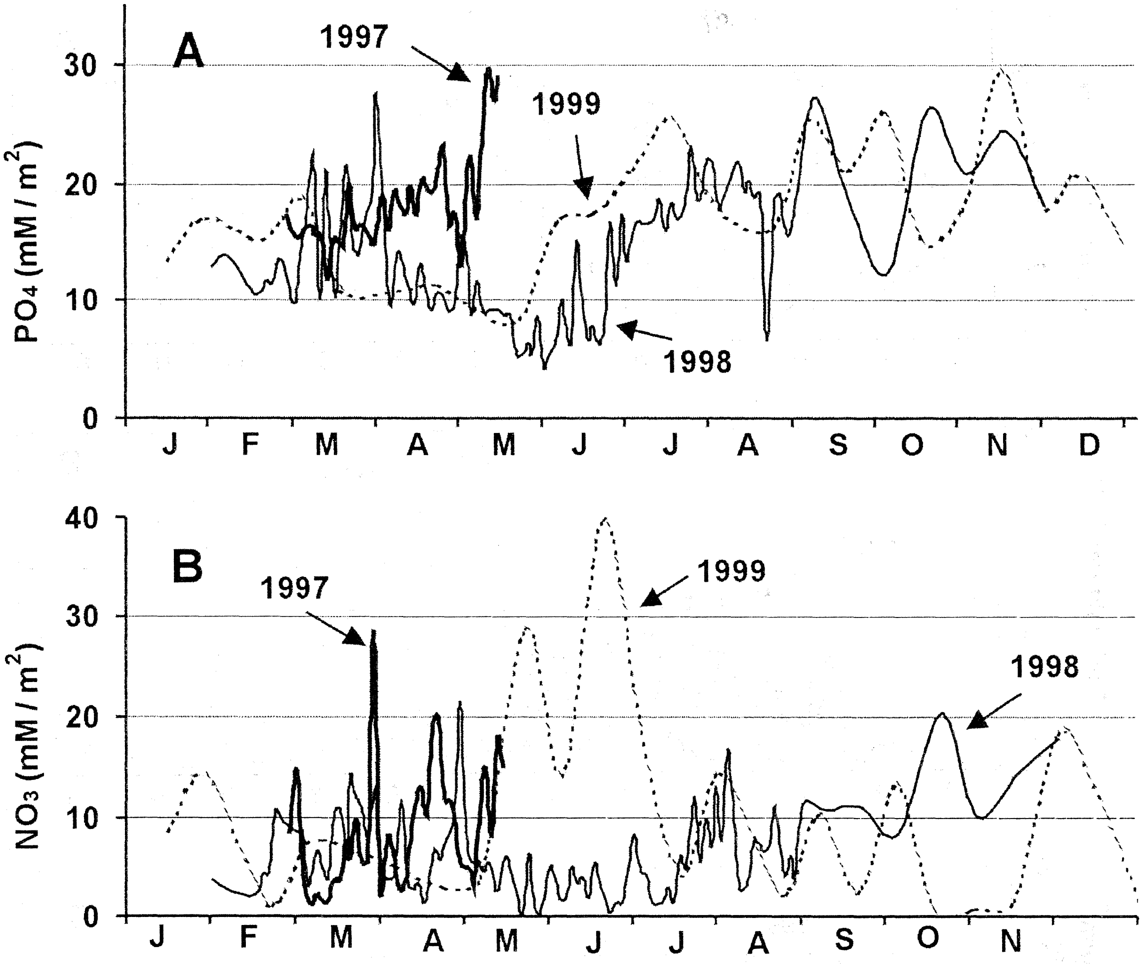

Fig. 4. Integrated values of phosphate (A) and nitrate (B) concentration during 1997, 1998, and 1999 in Bahía Concepción, Gulf of California.

Baumgartner, in press) was detected in June 1997 (Filonov and Tereshchenko, 2000). Positive anomalies of the sea level and sea surface temperature (SST) also linked to the El Niño (Baumgartner and Christensen, 1985) were recorded during July and August 1997 in the Gulf of California (Thunell *et al.*, 1999). SSTs in Bahía Concepción were similar for the three years (Figure 6A) but temperatures below 15 meters were higher during 1998. This is better shown when comparing the mean water column temperature (Figure 6B). Therefore, it is plausible to assume that the warming effect of El Niño was present in Bahía Concepción until October 1998 and began during the second half of 1997. Positive SST anomalies were also recorded in the California waters (Lynn *et al.*, 1998).

Transitional hydrographic periods are important for phytoplankton because an enhancement of their biomass occurs because the increase of the nutrients (Kiørboe, 1993; Townsend *et al.*, 1994; Bustillos-Guzmán *et al.*, 1995; Thunell *et al.*, 1996). These features were recorded in Bahía Concepción, but in 1998 the beginning of the stratification period was delayed for about 3 months (Figure 3). According to Álvarez-Borrego and Lara-Lara (1991), stratification in the Gulf of California begins when the northwest winds diminish. It is plausible that a prolongation of northwest winds was the cause of such a delay (unpublished data).

The stratification period in Bahía Concepción is also important because there is a high organic-matter oxidation and nutrient production in the bottom waters. Lechuga-Devéze *et al.* (2000) calculated that for a "normal" 225 day stratification period, N-Nitrate released by mineralization of organic matter is 68 mmol N-Nitrate $m^{-2}y^{-1}$. Thus, using a stratification period of only 135 days (for 1998), only 40.8 mmol N-Nitrate $m^{-2}y^{-1}$ should be produced (40% less). The shorter mineralization time during 1998 may be linked to the lower NO_3 and PO_4 concentrations.

During the transition period from a well-mixed to a stratified water column, nutrient-rich waters, coming in from

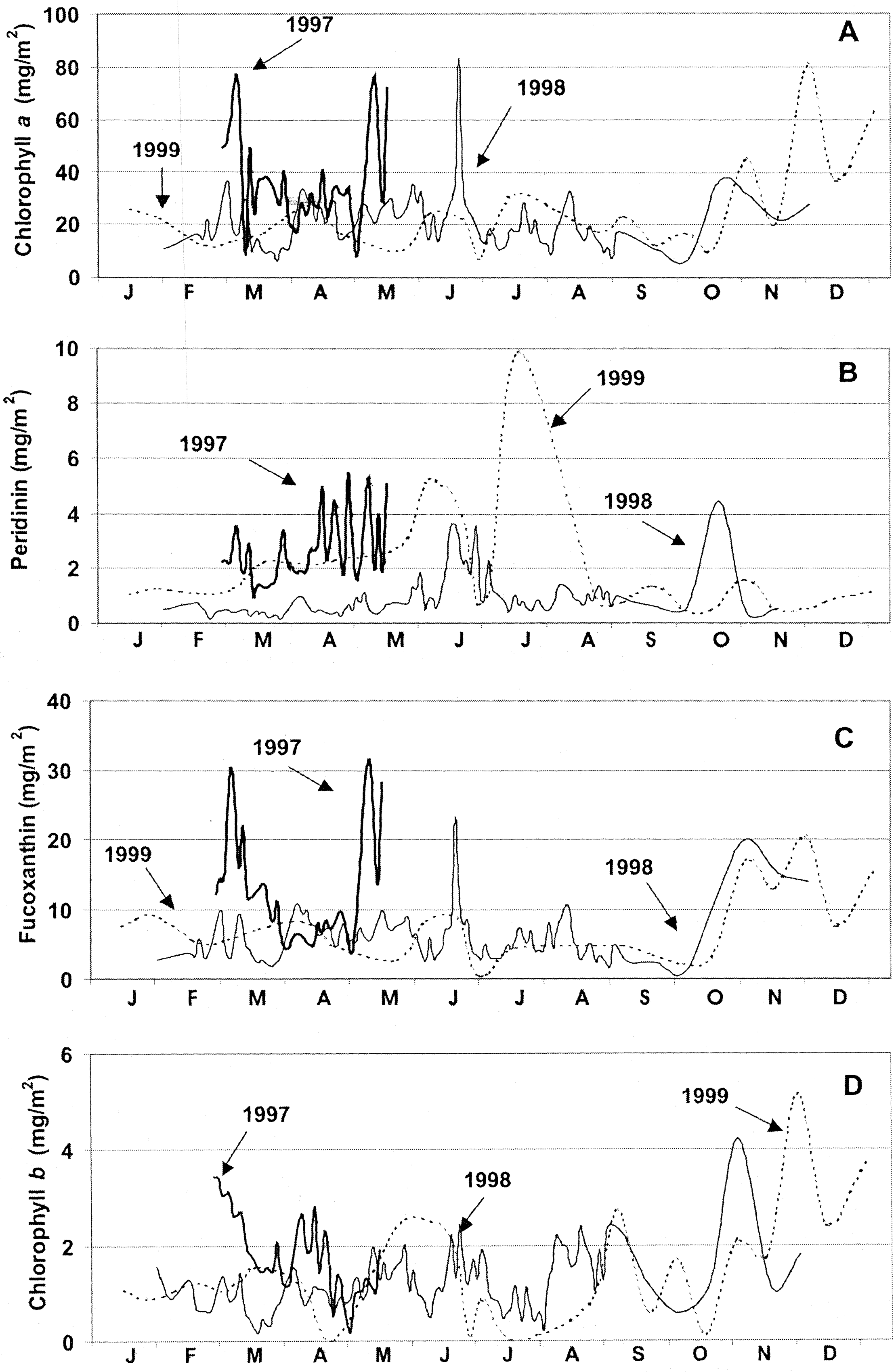

Fig. 5. Integrated values of pigment concentration during 1997, 1998, and 1999 in Bahía Concepción, Gulf of California. A) Chlorophyll *a*. B) Peridinin. C) Fucoxanthin. D) Chlorophyll *b*.

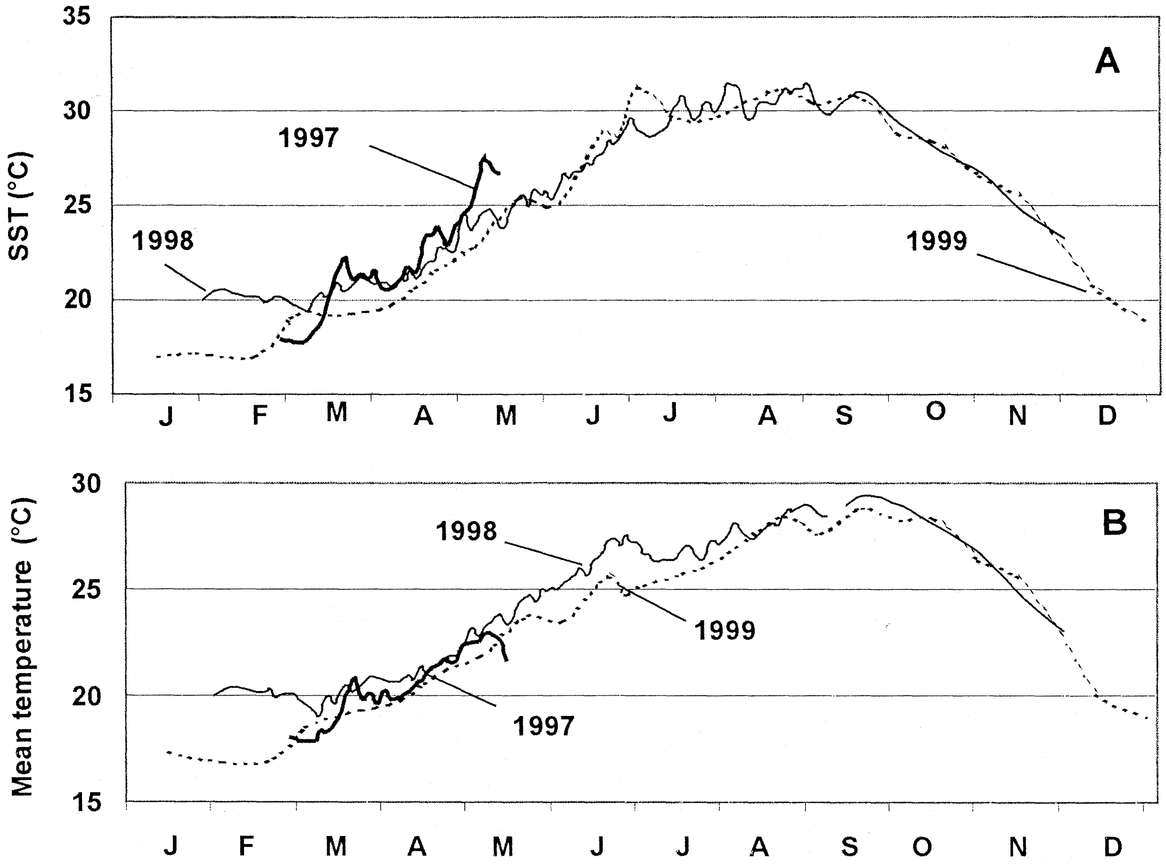

Fig. 6. Sea surface temperature (SST) (A) and mean temperature (B) during 1997, 1998, and 1999 in Bahía Concepción, Gulf of California.

the Gulf of California, and nitrate and nitrite production inside the bay provide an optimum environment for phytoplankton, mainly diatoms and dinoflagellates (Martínez-López and Gárate-Lizárraga, 1997). The association between this transitional period with high nutrient and pigment concentrations is clearly observed in our data. According to Álvarez-Borrego and Schwartzlose (1979), during spring and summer the central part of the Gulf of California is influenced on the surface mainly by the Equatorial Surface Water (ESW), characterized by low salinity (<35.0 psu) and low nutrient concentrations. Additionally, the ESW flow into the Gulf is intensified and remains for longer periods when the El Niño is present (Torres-Orozco, 1993; Castro *et al.,* 2000; Lavin, 2002). Flow intensification and a longer permanence of ESW in the area may also be the cause of the low nutrients recorded during 1998.

Important blooms of dinoflagellates have been recorded in Mazatlán, Guaymas, and Bahía de La Paz during the upwelling periods (Cortés-Altamirano *et al.*, 1995; Gárate-Lizárraga *et al.*, 2001). But the decrease in the intensity of upwelling that occurred during El Niño conditions (Santamaría-del Angel *et al.*, 1994) has a negative effect on the dinoflagellate blooms (Cortés-Altamirano 1987; Manrique and Molina, 1997). According to the above results and our data (high temperatures and the low nutrient concentration during 1998), it is plausible to assume that the 1997-1998 El Niño caused environmental conditions that negatively affected the dinoflagellate group. Phytoplankton biomass was reestablished in 1999 together with hydrographic conditions.

The main dinoflagellate blooming species in Bahía Concepción is *Noctiluca scintillans,* and toxic species from the genera *Alexandrium*, *Dinophysis*, *Prorocentrum,* and *Gymnodinium* have been also reported (Gárate-Lizárraga, 1991; Lechuga-Devéze and Morquecho-Escamilla, 1998; Gárate-Lizárraga *et al.*, 2001). The highest dinoflagellate concentrations occurred during the mixed-stratified hydrographic period under a narrow temperature window of 23 to 26 °C (Lechuga-Devéze and Morquecho-Escamilla, 1998; Lechuga-Devéze *et al.*, 2000). In 1998, temperatures were in the upper limit of this range and therefore could be linked to the low dinoflagellate biomass. Two dinoflagellate species bloomed during 1999 in Bahía Concepción, *Gymnodinium catenatum* (May) and *Alexandrium affine* (July) (Gárate-Lizárraga *et al.*, 2002). These species were responsible for the elevated peridinin concentration (Figure 6B). Although the SST was high, both species were located below the thermocline, mainly above the oxycline, where temperature is lower (22 to 24 ºC). Nutrients could be supplied by a diffusion mechanism from the anoxic zone as suggested by Bustillos-Guzmán *et al.* (2000).

CONCLUDING REMARKS

Differences in magnitude as well as environmental conditions previous and post the El Niño event make difficult a direct comparison between an event and other. This hold particularly true when time series data are not available as is our case. However, our data set suggest that conditions present in Bahía Concepción during the El Niño 1997-1998, did not favored the proliferation of dinoflagellates because the high temperatures and low nutrient conditions. This effect, however, have to be corroborated with longer time-series data.

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