

*Full Length Research Paper*

# Species composition and abundance of phytoplankton communities in Acapulco Bay, Mexico

Agustín A. Rojas-Herrera, Juan Violante-González, Víctor M. G. Sevilla-Torres, Jaime S. Gil-Guerrero, Pedro Flores-Rodríguez, José Antonio Rendón-Dircio.

Unidad Académica de Ecología Marina, Universidad Autónoma de Guerrero, Gran Vía Tropical No. 20, Fracc. Las Playas, 39390 Acapulco, Guerrero, Mexico.

## Abstract

Phytoplankton community species composition and abundance over time in Acapulco Bay, Mexico, were quantified from September 2009 to April 2010. Monthly phytoplankton samples and physicochemical measurements (water temperature, pH, salinity and nutrient concentrations) were taken monthly. A total of 102 species were identified: 51 dinoflagellates, 42 diatoms, 4 cyanobacteria, 2 silicoflagellates, 2 chlorophytes and 1 charophyte. Community structure was determined principally by adiphoric species, that is, those adapted to neritic and oceanic environments. The diatoms *Chaetoceros affinis*, *Rhizosolenia hebetata*, *R. alata* and *Chaetoceros* sp. dominated during the rainy season (September-November 2009) and early dry season. The dinoflagellate *Neoceratium deflexum* dominated during the dry season. Variations in phytoplankton community composition and abundance responded mainly to fluctuations in water nutrient concentrations. At least eight potentially toxic dinoflagellate species were recorded which could generate harmful algal blooms (HABs) if bay environmental conditions are altered.

**Keywords:** Marine phytoplankton, species composition, Acapulco Bay, Mexico.

## INTRODUCTION

Marine phytoplankton form rich and diverse microalgae communities containing species with different ecophysiological and morphological characteristics, resource requirements, growth rates and sinking velocities (Silver and Platt, 1978; Reynolds, 2006; Winder and Hunter, 2008). Phytoplankton community composition and structure are governed by environmental factors such as vertical mixing processes, temperature, and light and nutrient availability. Fluctuations in nutrient availability over time may cause significant changes in community composition and structure (Reynolds, 2006; Winder and Hunter, 2008; Rojas-Herrera et al., 2012).

Under very specific environmental conditions, some microalgae species of different groups may proliferate massively, forming harmful algal blooms (HAB) also known as "red tides". A global phenomenon, HAB mainly contain dinoflagellate species, and occasionally diatom,

haptophyte, raphidophyte, cyanophyte and pelagophyte groups (Zingone and Oksfeldt, 2000; Garces et al., 2002). Red tides are a biological phenomenon that occurs in sites near coasts, usually during warm seasons and rainy periods in tropical environments (Cabrera-Mancilla et al., 2000; Garate-Lizarraga et al., 2008). They can be caused by increased anthropogenic nutrient discharge into coastal oceans, transport of toxigenic species in ship ballast water or large-scale climate changes (e.g. global warming) (Cabrera-Mancilla et al., 2000; Garate-Lizarraga et al., 2008; Bauman et al., 2010). Harmful algal blooms pose a health threat to human coastal populations and can damage the environment. Individual phytoplankton species abundance is not homogeneous in HAB and communities can consist of species with different biological and physiological characteristics (Smayda, 1997). Toxic red tides have been increasingly frequent in recent years, negatively impacting economic activities in coastal zones and threatening public health.

The limited literature on marine phytoplankton in Mexico consists mostly of species checklists (Licea et al.,

\*Corresponding Author E-mail: [viojuang@yahoo.com.mx](mailto:viojuang@yahoo.com.mx)

1995), or focuses only species found in HAB (Cabrera-Mancilla et al., 2000; Garate-Lizarraga et al., 2008). The only study done in Acapulco Bay to date is a quantitative analysis of the phytoplankton community (Rojas-Herrera et al., 2012). The present study aim was to increase understanding of phytoplankton composition and community structure in Acapulco Bay and how it changes over time.

## MATERIALS AND METHODS

Phytoplankton samples were taken between September 2009 and April 2010 at five sites in Acapulco Bay: 1) Club de Yates (16°50'N, 99°54'W); 2) Islote del Morro (16°51'N, 99°53'W); 3) Naval Base (16°51'N, 99°51'W); 4) Casa de Diaz Ordaz (16°50'N, 99°51'W); and 5) Centro de la Bahía (16°49'N, 99°53'W). Samples were collected using a nylon mesh plankton net (150  $\mu$  aperture) for 5 min at water surface at each site. Water temperature ( $^{\circ}$ C), pH and salinity were measured in situ with an YSI probe. Water samples (500 ml) were taken at each station to quantify nutrient (nitrates, ammonium, and phosphates) concentration following a standard colorimetric method (Hanna equip). Phytoplankton species were identified based on specialized bibliography (Round et al., 1990; Licea et al., 1995; Moreno et al., 1995).

Using published phytoplankton species records for Mexico and other countries, we developed a source-based classification: estuarine (ES); neritic (NE); adiabatic (AD) and oceanic (OC). We applied the Olmstead-Tukey association test (Sokal and Rohlf, 1998) to classify identified phytoplankton species based on occurrence frequency and mean abundance parameters: dominant (abundant and frequent) (D); common (low abundance but frequent) (C); occasional (abundant but low frequency) (O); and rare (low abundance and low frequency) (R). Significant differences in monthly parameters (temperature, pH and salinity) and nutrient concentrations between stations were identified with a one-way ANOVA. When significant deviations from normality were identified, parameters and concentration data were log-transformed ( $\log x+1$ ) to meet normality and homoscedasticity requirements. A  $\chi^2$  test was applied to identify significant differences in mean phytoplankton group abundance between months.

Community level parameters included total number of species (richness); total number of cells; the Shannon-Wiener diversity index (H); species evenness (J); and the Berger-Parker index (BPI) as a measurement of species numerical dominance (Magurran, 1991; Krebs, 1999). The qualitative Jaccard similarity index was used to evaluate similarity or difference in species composition between months. The Student's *t*-test was applied to identify differences between community parameters, and correlations calculated using the Spearman range

coefficient ( $r_s$ ) were used to identify the parameters that determined observed species distribution and composition patterns.

## RESULTS

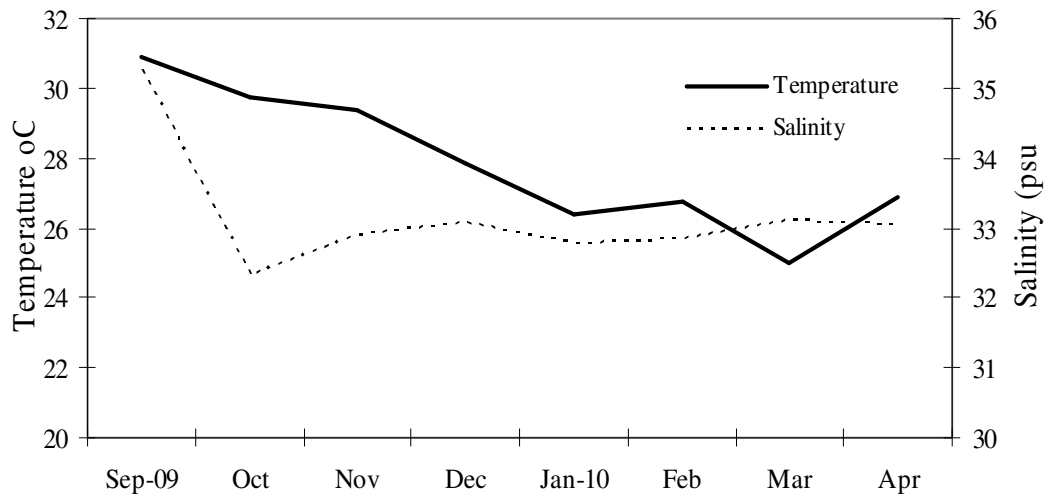
Mean temperature values varied significantly between months:  $30.88 \pm 0.44$  to  $24.99 \pm 1.62$   $^{\circ}$ C (ANOVA,  $F = 208.55$ ,  $P < 0.05$ ). The lowest temperature was registered in March 2010 and the highest in September 2009 (Figure 1). Salinity also varied significantly ( $32.3 \pm 0.48$  to  $35.26 \pm 2.14$  psu (ANOVA,  $F = 66.43$ ,  $P < 0.05$ ) (Figure 1), while pH values ranged from  $7.78 \pm 0.46$  to  $8.4 \pm 0.2$  (ANOVA,  $F = 17.14$ ,  $P < 0.05$ ). No significant variations in environmental parameters were recorded between sampling stations, allowing the data to be pooled in all subsequent analyses.

Concentrations of the three analyzed nutrients varied significantly ( $P < 0.05$ ) during the study period: nitrates ( $\text{NO}_3^-$ ) increased from October 2009 to January 2010; phosphate ( $\text{PO}_4^{3-}$ ) concentrations were higher between October and December 2009; and ammonium ( $\text{NH}_4^+$ ) peaked in February 2010 (Figure 2). Only phosphate concentrations exhibited significant variation between stations (ANOVA,  $F = 3.39$ ,  $P < 0.05$ ), the highest overall concentration being recorded in December 2009 at Station 1 (Club de Yates).

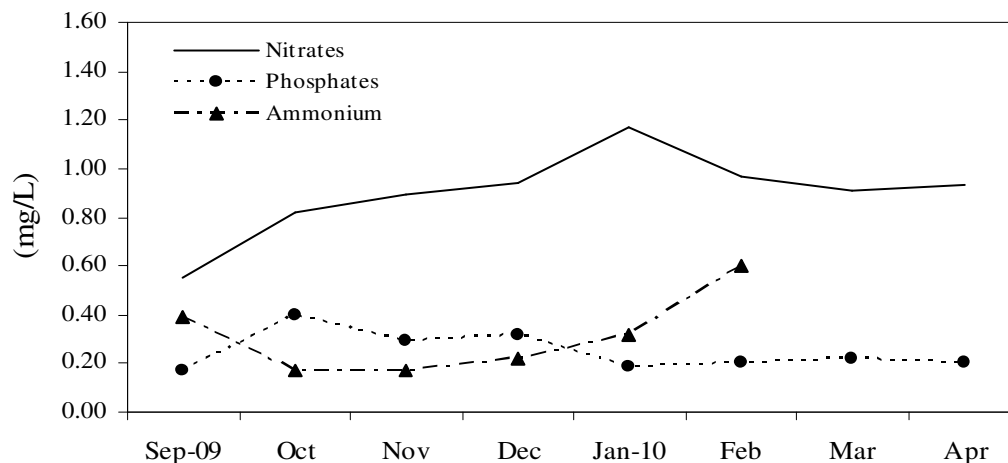
A total of 102 phytoplankton species were collected from Acapulco Bay: 51 dinoflagellates (Dinophyta); 42 diatoms (Bacillariophyta); 4 cyanobacteria (Cyanobacteria); 2 silicoflagellates (Heterokontophyta); 2 chlorophytes (Chlorophyta); and 1 charophyte (Charophyta) (Table 1). Diatom species numbers were relatively lower than the remaining phytoplankton species groups, but this group's total cell abundance represented 52% of total cells collected during the sampling period. The most important Dinoflagellate genera were: *Neoceratium* (27 species); *Protoperdinium* (9); and *Dinophysis* (4 species). Diatom genera included *Chaetoceros* (11 species); *Nitzschia* (5); and *Guinardia* (4 species).

Species group differentiation showed that diatoms were more abundant from September 2009 to January 2010, while dinoflagellates dominated numerically from February to April 2010 (Figure 3). Weak positive relationships were observed between nitrate concentration and dinoflagellate monthly abundance and total monthly phytoplankton cells (all groups), although these were not significant ( $P > 0.05$ ). However, these same parameters registered a strong positive correlation with the ammonium concentrations ( $r_s = 0.827$ ,  $r_s = 0.900$ ,  $P < 0.05$ ; respectively)

Six dinoflagellate species (*Neoceratium furca*, *N. fusus*, *N. ibidem*, *N. macroceros*, *N. trichoceros*, and *N. tripos*), 6 diatom species (*Chaetoceros affinis*, *Ch. curvisetus*, *Ch. didymus*, *Chaetoceros* sp., *Coscinodiscus*



**Figure 1.** Monthly temperature and salinity values in Acapulco Bay, Mex. (September 2009- April 2010 period)



**Figure 2.** Monthly nutrient concentrations (mg/L) in Acapulco Bay, Mex.

*heteroporus*, and *Rhizosolenia hebetate*), as well as the cyanobacteria *Phormidium limosum* occurred in all months (Table 1). Five species numerically dominated the sampled phytoplankton communities: 1 dinoflagellate (*Neoceratium deflexum*) and 4 diatoms (*Chaetoceros* sp., *Ch. affinis*, *Rhizosolenia hebetate*, and *R. alata*) (Table 2). These species represented 25% of total estimated cell counts in all samples.

Phytoplankton species distribution analysis showed over 60% of the dinoflagellate and diatom species to be adiaphoric species (i.e. occurring in neritic and oceanic areas; Figure 4). Frequency-abundance graphics indicated 36% of the microalgae species to be dominant (i.e. abundant and frequent) and 50% to be rare. No

differences ( $P > 0.05$ ) in phytoplankton abundance (cell/L) were observed between the 5 sampled stations.

Species richness varied significantly ( $t$ -test = 11.11,  $P < 0.05$ ) from 26 species (November 2009) to 55 (February and March 2010), while monthly total abundance ranged from 1695 cells (November 2009) to 8196 cells (February 2010). The monthly diatom cell counts were higher than other phytoplankton groups from September 2009 to January 2010, while dinoflagellate cell counts were higher from February to April 2010 (Table 2). Shannon-Wiener diversity index values were  $\geq 3$  bits/ind. in all months, and they differed between months ( $t$ -test = 29.35,  $P < 0.05$ ). Evenness ranged from 0.60 to 0.75, and also differed between months ( $t$ -test =

**Table 1.** Abundance of phytoplankton species (cell/L) in Acapulco Bay, Mexico. Distribution: 1 = Estuarine, 2 = Neritic, 3 = Adiaphoric, 4 = Oceanic. Classification: (D) dominant, (C) common, (O) occasional), (R) rare.

Species	Sep. 09	Oct.	Nov.	Dec.	Jan. 10	Feb.	Mar.	Apr.
<b>Dinophyta</b>								
<i>Amphisolenia bidentata</i> <sup>3 (R)</sup>								2
<i>Amphisolenia lemmermanni</i> <sup>3 (R)</sup>								1
<i>Amphisolenia</i> sp. <sup>(R)</sup>								2
<i>Ceratocorys horrida</i> <sup>3 (R)</sup>						1		
<i>Dinophysis caudata</i> <sup>3 (D)</sup>	4				1	3	112	97
<i>Dinophysis rotundata</i> <sup>3 (R)</sup>	2						1	
<i>Dinophysis tripos</i> <sup>3 (R)</sup>						1		
<i>Dinophysis</i> sp. <sup>3 (R)</sup>						1		
<i>Gonyaulax polyedra</i> <sup>2 (R)</sup>					1	6		
<i>Gonyaulax polygramma</i> <sup>3 (R)</sup>						3		
<i>Gonyaulax</i> sp. <sup>(D)</sup>						5	53	100
<i>Neoceratium arietinum</i> <sup>3 (R)</sup>	1	1						
<i>Neoceratium candelabrum</i> <sup>3 (D)</sup>					100	110	47	72
<i>Neoceratium carriense</i> <sup>3 (D)</sup>			3	8	25	64	59	2
<i>Neoceratium concilians</i> <sup>3 (R)</sup>						7		
<i>Neoceratium contortum</i> <sup>3 (R)</sup>						13	1	1
<i>Neoceratium contrarium</i> <sup>3 (R)</sup>			1					
<i>Neoceratium deflexum</i> <sup>3 (D)</sup>		178	86	43	391	2453	666	1214
<i>Neoceratium dens</i> <sup>3 (D)</sup>						6	1	251
<i>Neoceratium extensum</i> <sup>2 (R)</sup>				4		4		
<i>Neoceratium furca</i> <sup>2 (D)</sup>	11	14	11	19	34	146	62	166
<i>Neoceratium fusus</i> <sup>2 (D)</sup>	36	123	79	55	39	308	43	67
<i>Neoceratium ibidems</i> <sup>3 (D)</sup>	2	61	18	37	101	519	249	141
<i>Neoceratium incisum</i> <sup>3 (R)</sup>							4	
<i>Neoceratium inflatum</i> <sup>3 (D)</sup>		1	1			24	6	3
<i>Neoceratium kofoidii</i> <sup>3 (R)</sup>		1	1			24	6	3
<i>Neoceratium lineatum</i> <sup>3 (R)</sup>							1	
<i>Neoceratium longirostrum</i> <sup>3 (D)</sup>			1	44	3	17	6	6
<i>Neoceratium lunula</i> <sup>3 (D)</sup>					6	90	17	23
<i>Neoceratium macroceros</i> <sup>3 (D)</sup>	11	171	15	12	5	57	7	8
<i>Neoceratium massiliense</i> <sup>4 (O)</sup>						72		
<i>Neoceratium pentagonum</i> <sup>3 (R)</sup>							1	
<i>Neoceratium ranipes</i> <sup>4 (R)</sup>						5	3	4

Table 1 continue

<i>Neoceratium symmetricum</i> <sup>4 (R)</sup>						17	1	21
<i>Neoceratium trichoceros</i> <sup>3 (D)</sup>	1	1	95	70	87	825	79	187
<i>Neoceratium tripos</i> <sup>3 (D)</sup>	82	461	90	135	233	992	122	599
<i>Neoceratium vultur</i> <sup>3 (D)</sup>		40		1	2	17		12
<i>Neoceratium</i> sp. <sup>(D)</sup>						10	218	12
<i>Ornithocercus steinii</i> <sup>3 (D)</sup>	141	4			1	2	1	2
<i>Ornithocercus</i> sp. <sup>(R)</sup>				1		1	1	
<i>Prorocentrum gracile</i> <sup>2 (D)</sup>					2	3	305	53
<i>Protoperidinium cerasus</i> <sup>3 (R)</sup>						1		
<i>Protoperidinium claudicans</i> <sup>3 (D)</sup>	1	1		1	2	11	7	1
<i>Protoperidinium conicum</i> <sup>3 (R)</sup>							5	
<i>Protoperidinium diabolum</i> <sup>3 (R)</sup>					1			
<i>Protoperidinium divergens</i> <sup>3 (D)</sup>	1			1	5	34	12	
<i>Protoperidinium exentricum</i> <sup>3 (R)</sup>	1				1			
<i>Protoperidinium pellucidum</i> <sup>3 (R)</sup>	1							
<i>Protoperidinium pentagonum</i> <sup>3 (R)</sup>						2	3	
<i>Protoperidinium</i> sp. <sup>(D)</sup>			1	1		14	468	155
<i>Pyrocystis fusiformis</i> <sup>4 (D)</sup>							176	200
Subtotal	295	1056	401	432	1040	5844	2737	3404
<b>Bacillariophyta</b>								
<i>Amphiprora gigantea</i> <sup>3 (R)</sup>							2	
<i>Asterionella japonica</i> <sup>3 (R)</sup>				1				
<i>Bacteriastrium delicatulum</i> <sup>4 (R)</sup>						1		
<i>Chaetoceros affinis</i> <sup>3 (D)</sup>	433	35	46	4	22	229	41	24
<i>Chaetoceros constrictus</i> <sup>3 (O)</sup>	57							
<i>Chaetoceros curvisetus</i> <sup>3 (D)</sup>	43	20	25	233	21	14	1	5
<i>Chaetoceros decipiens</i> <sup>3 (D)</sup>	51	47	1	4				
<i>Chaetoceros debilis</i> <sup>3 (R)</sup>	16			1				
<i>Chaetoceros didymus</i> <sup>3 (D)</sup>	400	136	76	101	75	485	32	82
<i>Chaetoceros lorenzianus</i> <sup>2 (D)</sup>	38	4		2				
<i>Chaetoceros socialis</i> <sup>2 (D)</sup>	8			24	5	91	3	
<i>Chaetoceros teres</i> <sup>3 (D)</sup>	311	224		52	1	11	4	6
<i>Chaetoceros tetrastichon</i> <sup>4 (R)</sup>	21							
<i>Chaetoceros</i> sp. <sup>(D)</sup>	22	94	50	888	1131	1319	1001	766
<i>Coscinodiscus heteroporus</i> <sup>3 (D)</sup>	110	145	69	50	19	59	236	173

Table 1 continue

<i>Coscinodiscus</i> sp. <sup>(R)</sup>		1						
<i>Ditylum brightwelli</i> <sup>3(D)</sup>	8	44	38	11	11	1	1	
<i>Guinardia delicatula</i> <sup>2(D)</sup>	28			21	65	20	39	136
<i>Guinardia flaccida</i> <sup>3(R)</sup>							1	1
<i>Guinardia striata</i> <sup>3(D)</sup>	4			6	20	14	29	140
<i>Guinardia</i> sp. <sup>(R)</sup>				1				
<i>Gyrosigma peisonis</i> <sup>3(R)</sup>	1							
<i>Hemiaulus sinensis</i> <sup>2(D)</sup>			6	25	6			
<i>Leptocylindrus danicus</i> <sup>3(D)</sup>	115		11	25	26		13	18
<i>Licmophora abbreviata</i> <sup>2(R)</sup>							18	2
<i>Nitzschia closterium</i> <sup>3(R)</sup>							1	
<i>Nitzschia delicatissima</i> <sup>3(C)</sup>	228	23		67	24			
<i>Nitzschia pacifica</i> <sup>3(D)</sup>				10	61		14	10
<i>Nitzschia paradoxa</i> <sup>1(R)</sup>				3				
<i>Nitzschia sigma</i> <sup>1(R)</sup>	2							
<i>Nitzschia seriata</i> <sup>1(R)</sup>				1				
<i>Nitzschia</i> sp. <sup>(D)</sup>	8							59
<i>Pleurosigma normanii</i> <sup>3(R)</sup>				1		1		
<i>Pleurosigma</i> sp. <sup>(R)</sup>								2
<i>Pseudonitzschia delicatissima</i> <sup>3(D)</sup>								
<i>Pseudonitzschia seriata</i> <sup>3(R)</sup>								
<i>Planktoniella sol</i> <sup>4(D)</sup>					1	3	6	14
<i>Rabdonema</i> sp. <sup>(D)</sup>					2	10	119	180
<i>Rhizosolenia alata</i> <sup>3(D)</sup>	308	255	509	49	14		1	23
<i>Rhizosolenia hebetata</i> <sup>3(D)</sup>	378	509	418	947	160	48	924	759
<i>Rhizosolenia setigera</i> <sup>2(R)</sup>	5							
<i>Skeletonema costatum</i> <sup>3(D)</sup>	5	7	6	82	14			2
<i>Stephanopyxis palmeriana</i> <sup>3(D)</sup>		3			110	1		
<i>Thalassionema frauenfeldii</i> <sup>4(R)</sup>				3				
Subtotal	2600	1547	1255	2612	1788	2307	2486	2402
<b>Heterokontophyta</b>								
<i>Dictyocha fibula</i> <sup>4(R)</sup>							1	2
<i>Dictyocha octonaria</i> <sup>4(R)</sup>		9				1		
Subtotal		9				1	1	1
<b>Chlorophyta</b>								
<i>Chlamydomonas</i> sp. <sup>(R)</sup>				1				

Table 1 continue

<i>Volvox</i> sp. <sup>(R)</sup>					1	10		4
Subtotal					1	1	10	4
<b>Charophyta</b>								
<i>Staurastrum</i> sp. <sup>(R)</sup>			4				2	1
Subtotal			4				2	1
<b>Cyanobacteria</b>								
<i>Microcystis aeruginosa</i> <sup>1 (R)</sup>			3					
<i>Phormidium limosum</i> <sup>1 (D)</sup>	4	8	35	9	193	34	171	34
<i>Spirulina</i> sp. <sup>(O)</sup>								71
<i>Trichodesmium</i> sp. <sup>(R)</sup>			2					
Subtotal	4	13	35	9	193	34	171	105
Total abundance	<b>2899</b>	<b>2625</b>	<b>1695</b>	<b>3054</b>	<b>3022</b>	<b>8196</b>	<b>5397</b>	<b>5918</b>

**Table 2.** Characteristics of the phytoplankton community in Acapulco Bay, Mexico. Dino = dinoflagellates, Diat = diatoms; BPI = Berger-Parker Index; H = Shannon-Wiener diversity index; J = evenness.

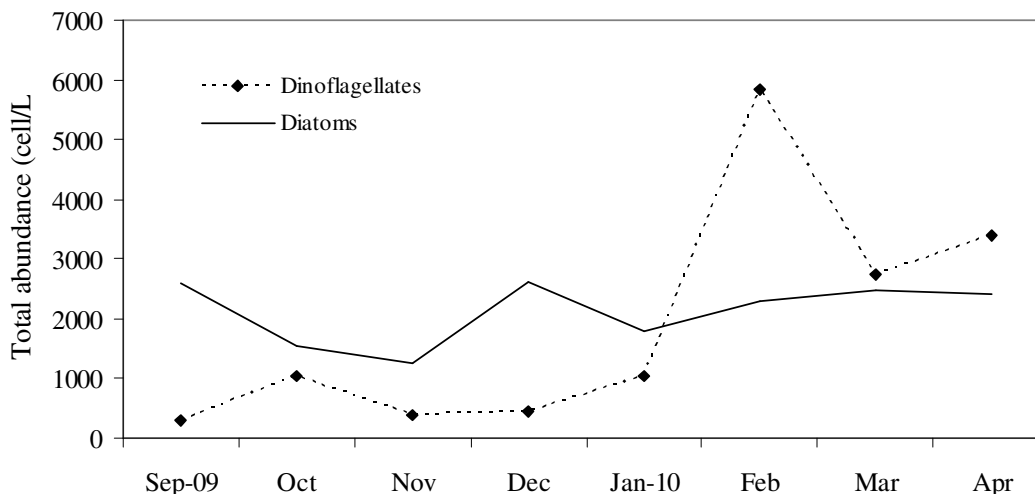
Month	No. of species	Dino. No. cell	Diat. No. cell	Total cell	Dominant specie	BPI	H'	J'
Sep. 09	39	295	2600	2899	<i>Chaetoceros affinis</i>	0.15	3.81	0.72
Oct.	31	1056	1547	2625	<i>Rhizosolenia hebetata</i>	0.19	3.70	0.75
Nov.	26	401	1255	1695	<i>Rhizosolenia alata</i>	0.33	3.07	0.65
Dec.	43	432	2612	3054	<i>Rhizosolenia hebetata</i>	0.31	3.24	0.60
Jan. 10	42	1040	1788	3022	<i>Chaetoceros</i> sp.	0.37	3.46	0.64
Feb.	55	5844	2307	8196	<i>Neoceratium deflexum</i>	0.30	3.42	0.59
Mar.	55	2737	2486	5397	<i>Chaetoceros</i> sp.	0.19	3.93	0.68
Apr.	53	3404	2402	5918	<i>Neoceratium deflexum</i>	0.21	4.06	0.71

32.8,  $P < 0.05$ ). Species composition similarity ranged from 15 to 66% (mean = 38.6%  $\pm$ 14.2) during the sampling period, with the highest values in March and April 2010 (Figure 5).

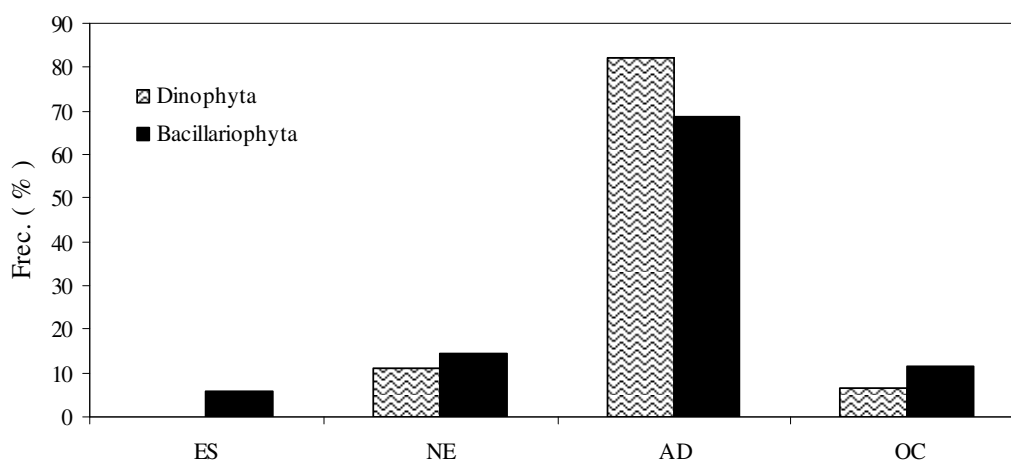
## DISCUSSION

Water temperature decreased steadily from September 2009 to January 2010 (Figure 1),

whereas salinity dropped significantly only in October 2009. Temperature fluctuations in tropical marine areas are not as marked as in temperate or cold latitudes; suggesting that this parameter



**Figure 3.** Temporal variation of total relative abundance (%) of Phytoplankton groups in Acapulco Bay, Mex.



**Figure 4.** Frequency distribution of phytoplankton species in Acapulco Bay, based on its origin. ES: Estuarine, NE: Neritic, AD: Adiaforical, OC: Oceanic

does not have an important effect on species composition in tropical phytoplankton communities (Varona-Cordero and Gutierrez-Mendieta, 2006). In contrast, salinity is known to have a notable effect on phytoplankton community structure, particularly in estuarine and coastal environments (Peña and Pinilla, 2002; Lassen et al., 2004; Troccoli et al., 2004). The observed decrease in salinity in October (Figure 1) can be attributed to freshwater flow into the bay during the rainy season (June to November).

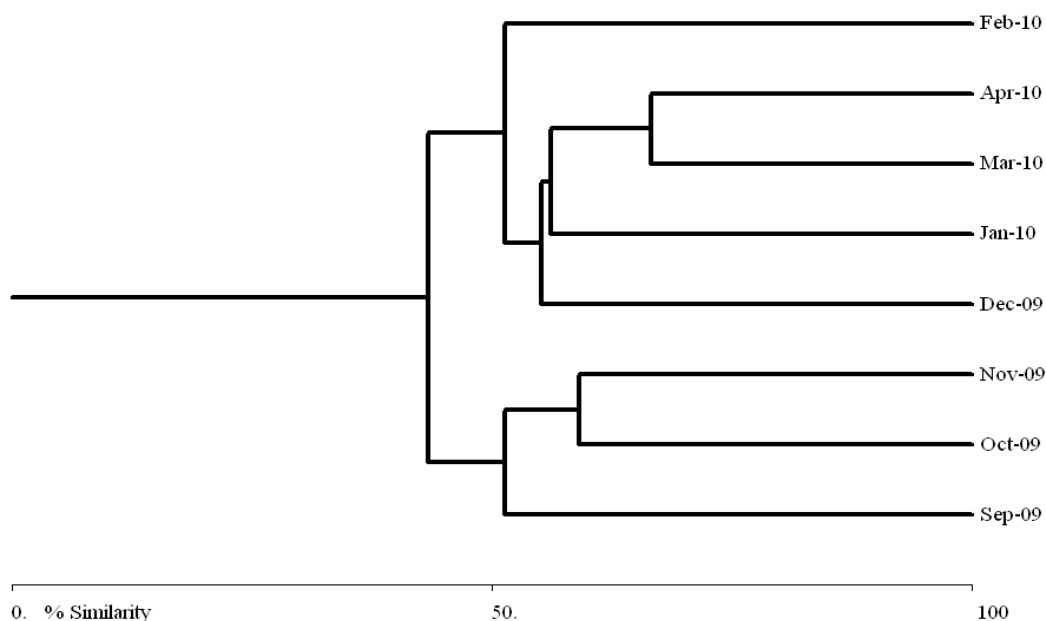
The constant increase in nitrate and phosphate concentrations from October 2009 to January 2010 may also be attributed to rainfall runoff during the rainy season (Moreira et al., 2007). Sewage, as well as substantial amounts of garbage and other solid materials from the Acapulco urban area discharge directly into the bay,

contributing to higher nutrient concentrations and consequently rapid population growth in several phytoplankton species (Varona-Cordero and Gutierrez-Mendieta, 2006; Moreira et al., 2007).

Dinoflagellates (51 species) dominated the Acapulco Bay phytoplankton community in terms of species richness (Table 1), although total dinoflagellate abundance was similar to that of diatoms (Table 2). This contrasts with the numerical dominance of diatoms in species number reported in other phytoplankton composition studies done at tropical latitudes (Peña and Pinilla, 2002; Ochoa and Tarazona, 2003; Varona-Cordero and Gutierrez-Mendieta, 2006; Moreira et al., 2007). However, our results coincide with a previous study from the same area (Rojas-Herrera et al., 2012).

Phytoplankton species groups are considered good





**Figure 5.** Similarity percentages for monthly phytoplankton samples in Acapulco Bay, Mexico.

indicators within marine environment water masses (Castillo and Vidal, 1982). Dinoflagellates are better adapted to the oceanic environment, while diatoms are more adapted to coastal environments (Castillo, 1984; Peña and Pinilla, 2002). The presence of variation in the monthly cell abundances of these two important microalgae groups throughout the year (Figure 3), suggests that environmental conditions in Acapulco Bay change during the year in response to variations in several physicochemical parameters. Changes in the bay's water masses are probably reflected in the changing nature of its phytoplankton community; for example, more than 60% of the dinoflagellate and diatom species recorded in the present study are adiaborphic (adapted to neritic or oceanic environments) (Peña and Pinilla, 2002) (Figure 4).

Different species dominated numerically in each month, indicating wide variability in species composition over time. The diatoms *Chaetoceros affinis*, *Rhizosolenia hebetata*, *R. alata*, and *Chaetoceros* sp. dominated during the rainy season (September–November 2009), and early dry season (Table 2). While the dinoflagellate *Neoceratium deflexum* dominated during the dry season. Some studies indicate that changes in phytoplankton community structure can be associated with small changes in water temperature (Varona-Cordero and Gutierrez-Mendieta, 2006; Ochoa and Tarazona, 2003) or with the different strategies used by phytoplankton groups to absorb available nutrients in the water column (Langlois and Smith, 2001).

The decrease in water temperature from September 2009 to January 2010 may have affected dinoflagellate

abundance during this period since this microalgae group is highly sensitive to minor drops in water temperature (Varona-Cordero and Gutierrez-Mendieta, 2006; Ochoa and Tarazona, 2003; Moreira et al., 2007). Diatoms, in contrast, are less sensitive to slight shifts in water temperature and can respond more rapidly to increases in available nutrient concentrations (Örnólfsson et al., 2004), as occurred at the end of the rainy season (Figure 3).

The higher monthly diatom abundance in the late rainy season (December 2009) can be attributed to a higher abundance of *Rhizosolenia hebetata* (Tables 1 and 2), a large diatom (Moreira et al., 2007) that represented 36% of total cells in this microalgae group for this month.

In contrast, *Neoceratium deflexum* was largely responsible for the notable increase in dinoflagellate abundance in February 2010 (Tables 1 and 2); indeed, this high abundance was probably caused almost entirely by *Neoceratium* genus dinoflagellates. Under the proper environmental conditions, these can form long multi-cell chains and accumulate in large populations (Vargas-Montero et al. 2008). The strong influence of the rainy and dry seasons on phytoplankton composition and abundance in Acapulco Bay coincides with many other studies done in tropical regions (Moreira et al., 2007).

Of the 51 dinoflagellate species identified here, at least eight (*Dinophysis caudata*, *D. rotundata*, *D. tripos*, *Gonyaulax polygramma*, *G. spinifera*, *Neoceratium furca*, *N. fusus* and *N. tripos*) have been linked to harmful algal blooms (HABs) in other locations in Mexico (Cortes-Altamirano, 1998). In the present case, however, only the dinoflagellates *Neoceratium furca*, *N. fusus* and *N. tripos*

were frequent, although they did not numerically dominate any of the samples (Table 1).

The phytoplankton community species distribution pattern in Acapulco Bay was similar to that reported for other marine or estuarine communities. Community structure was determined by a low number of dominant species (36%), which contributed over 90% of total abundance, as well as a high number of occasional and rare species (62%).

Total richness (102 species) and diversity values (3.07 to 4.06 bits/ind) registered in the study area were within ranges previously reported in the same area (Rojas-Herrera et al., 2012), as well as for other areas of Mexico (Varona-Cordero and Gutierrez-Mendieta, 2006) and other countries with similar climate conditions (Peña and Pinilla, 2002; Ochoa and Tarazona, 2003; Moreira et al., 2007). The low similarity values observed here (mean = 39%) suggest that species composition differed between months in response to variability in environmental conditions over time.

Overall, the results indicate that phytoplankton composition and species abundance in Acapulco Bay varied temporally in response to fluctuations in environmental conditions. Primary among these fluctuations were the different levels of water nutrient concentrations caused by differing rainfall discharge levels into the bay during the rainy season (June to November). Higher nutrient concentrations and slight variations in water temperature promoted population growth in some dinoflagellate or diatom species at different times during the year.

## ACKNOWLEDGEMENTS

The research reported here was partially financed by the Conacyt and the State of Guerrero through the project "Estudio ecológico de la Bahía de Acapulco" (FOMIX 2008-01). It was also partially financed through the projects: "Diversidad de peces de sustrato rocoso, en la bahía de Acapulco, Gro". and "Parásitos de rayas de importancia económica y ecológica en la Bahía de Acapulco, Guerrero, Mex."

## REFERENCES

- Bauman AG, Burt JA, Feary DA, Marquis E, Usseglio P (2010). Tropical harmful algal blooms: an emerging threat to coral reef communities?. *Mar. Pollut. Bull.* 60: 2117–22.
- Cabrera-Mancilla E, Ramírez-Camarena C, Muñoz-Cabrera L, Monreal-Prado A (2000). Primer registro de *Gymnodinium catenatum* Graham (Gymnodiniaceae) como causante de marea roja en la Bahía de Acapulco, Gro. México. In: Ríos-Jara, E., E. Juárez-Carillo, M. Pérez-Peña, E. López-Uriarte, E. G. Robles-Jarero, D. U. Hernández-Becerril, M. Silva-Briano (eds.). *Estudios sobre plancton en México y el Caribe*. Sociedad Mexicana de Planctonología y Universidad de Guadalajara. p. 85–86.
- Castillo F (1984). Fitoplancton del Pacífico colombiano como indicador de masas de agua. *Erferen IV. Biol. Pesq.* 13: 67–70.
- Castillo F, Vidal A (1982). Fitoplancton del Pacífico colombiano como indicadores de masas de agua. Fase CIOH, Cartagena. p. 1–57.
- Cortés-Altamirano R (1998). Informe regional sobre mareas rojas en México. IOC/ARIBE-ANCA. II Taller regional, Ciudad de la Habana, Cuba. 4 p.
- Gárate-Lizárraga I, Pérez-Cruz B, Díaz-Ortiz J, Band-Schmidt CJ (2008). Microalgas y biotoxinas marinas en las costas mexicanas. *Conver.* 9: 22–26.
- Garcés E, Zingone A, Montresor M, Reguera B, Dale B (2002). *Lifehab: Life histories of microalgal species causing harmful blooms*. (eds.). Office for the Official Publications of the European Communities, Luxemburgo. 220 p.
- Krebs CJ (1999). *Ecological methodology*. Addison-Wesley Educational Publishers, Inc. Boston, Massachusetts 654 p.
- Langlois GW, Smith P (2001). *Phytoplankton In: Biology and Ecological Niches in the Gulf of the Farallones*: U.S. Geological Survey, Reston, Virginia. p. 32–35.
- Lassen MF, Bramm ME, Richardson K, Youssof F, Shariff M (2004). *Estuaries*. 27: 716–727.
- Licea S, Moreno JL, Santoyo H, Figueroa G (1995). *Dinoflagelados del Golfo de California*. México. Universidad Autónoma de Baja California Sur, México 165 p.
- Magurran A (1991). *Ecological diversity and its measurement*. Princeton University Press, Princeton, New Jersey, 178 p.
- Moreno JL, Licea S, Santoyo H (1995). *Diatomeas del Golfo de California*. México. Universidad Autónoma de Baja California Sur, México 273 p.
- Moreira A, Seisdedo M, Leal S, Comas A, Delgado G, Regadera R, Alonso C, Muñoz A, Abatte M (2007). Composición y abundancia del fitoplancton de la Bahía de Cienfuegos, Cuba. *Rev. Invest. Mar.* 28:97–109.
- Ochoa N, Tarazona J (2003). Variabilidad temporal de pequeña escala en el fitoplancton de Bahía Independencia, Pisco, Perú. *Rev. Peru. Biol.* 10: 59–66.
- Örnólfssdóttir EB, Lumsden E, Pinckney JL (2004). Phytoplankton community growth-rate response to nutrient pulses in a shallow turbid estuary, Galveston Bay, Texas. *J. Plank. Res.* 26: 325–339.
- Peña V, Pinilla GA (2002). Composición, distribución y abundancia de la comunidad fitoplanctónica de la ensenada de Utría, Pacífico colombiano. *Rev. Biol. Mar. Oceanogr.* 37: 67–81.
- Reynolds CS (2006). *Ecology of phytoplankton*. Cambridge University Press.
- Rojas-Herrera AA, Violante-González J, García-Ibáñez S, Sevilla-Torres VMG, Gil-Guerrero JS, Flores-Rodríguez P (2012). Temporal variation in the phytoplankton community of Acapulco Bay, Mexico. *Microbiol. Res.* 13-19.
- Round FE, Crawford RM, Mann DG (1990). *The Diatoms. Biology and morphology of the genera*. Cambridge University Press. 747 p.
- Silver W, Platt T (1978). Energy flux in the pelagic ecosystem: A time-dependent equation. *Limnol. Oceanogr.* 23: 813–816.
- Smayda TJ (1997). Harmful algal blooms: Their ecophysiology and general relevance to phytoplankton blooms in the sea. *Limnol. Oceanogr.* 5: 1137-1153.
- Sokal RR, Rohlf FJ (1998). *Biometry*, 2nd ed. W. H. Freeman and Company, San Francisco, California, 859 p.
- Trocchi LG, Herrera-Siveira JA, Comín F (2004). Structural variations of phytoplankton in the coastal seas of Yucatán, México. *Hidrobiol.* 519: 85–102.
- Vargas-Montero M, Bustamante EF, Guzmán JC, Vargas JC (2008). Florecimientos de dinoflagelados nocivos en la costa Pacífica de Costa Rica. *Hidrobiol.* 18: 15–23.
- Varona-Cordero F, Gutiérrez-Mendieta FJ (2006). Composición estacional del fitoplancton de dos lagunas del Pacífico tropical. *Hidrobiol.* 16: 159–174.
- Winder M, Hunter DA (2008). Temporal organization of phytoplankton communities linked to physical forcing. *Oecol.* 156: 179–192.
- Zingone A, Oksfeldt EH (2000). The diversity of harmful algal blooms: A challenge for science and management. *Ocean. Coast. Manag.* 43: 725–748.