Phytoplankton of the Sontecomapan Lagoon, Veracruz, Mexico

María Guadalupe Figueroa Torres,* Saúl Almanza Encarnación,* María Jesús Ferrara-Guerrero* & Marc Pagano**

Abstract: Phytoplankton plays a key role in aquatic ecosystems as an oxygen producer, a CO_2 trap, a primary source of food in trophic chains and as an indicator of changes in the environment. However, despite this positive importance, it can also develop into harmful algal blooms. With the aim of increasing knowledge about this group of microorganisms in Mexican aquatic ecosystems, a list of the phytoplankton species of the Sontecomapan Lagoon was made indicating those that potentially can provoke red tides. Besides, the distribution and abundance of these species was studied in two seasons, the rainy one (June, 2015) and the dry one (February, 2016), on eight sampling stations. Phytoplankton samples were collected with a Van Dorn bottle to measure environmental factors (transparency, salinity, temperature, pH and dissolved oxygen). A list with 357 species with a clear dominance of diatoms (67.8%) and dinoflagellates (20.16%) was obtained from literature review and materials derived from this study. Among them, 19.88% can potentially form red tides, and some of them are toxic. From the samples collected, 102 species of phytoplankton were recorded; 42 of them during the rainy season, 65 during the dry one and 7 presents in both. Among these species, 17 can potentially form red tides and from these, only two can be toxic for

* Universidad Autónoma Metropolitana, Unidad Xochimico. Departamento El Hombre y su Ambiente. Calzada del Hueso 1100, Col. Villa Quietud, C.P. 06090, CDMX. figueroa@correo.xoc.uam.mx. Phone number +(5255)54837000 ext. 7174. Fax number (5255) 54837465.

** Aix Marseille Université, Université de Toulon, CNRS, IRD, OSU PYTHEAS, Mediterranean Institute of Oceanography, MIO, UM 110, 13288, Marseille, Cedex 09, France.

humans: *Dinophysis caudata* and *Lyngbya majuscula*. The cluster analysis of the environmental factors showed the formation of four groups in the rainy season and three in the dry season, associated to the salinity gradients.

KEYWORDS: Red tides, Harmful Algal Blooms (HAB), tropical coastal lagoon, Mexico.

Introduction

The phytoplankton of the Sontecomapan lagoon has been studied by Suchil (1990), who carried out a seasonal sampling of communities and reported a succession of diatom and dinoflagellates blooms. Guerra-Martínez (1996) studied the variations in nano and microplankton biomass at the lagoon mouth in 1992 and 1993; Meave del Castillo & Lara-Villa (1997) made an inventory of planktonic diatoms and Figueroa-Torres *et al.* (2009) made another one on the thecate dinoflagellates from the lagoon. Camacho *et al.* (1994) studying the circadian rhythms of phytoplankton in October 1993, recorded 90 taxa of which *Skeletonema subsalsum* was the dominant throughout the cycle. Muciño-Márquez *et al.* (2011) studied phytoplankton populations in October, 1999 and reported 179 species, from which *Fragilaria exigua*, *F. tenuicollis*, *F. ulna var ulna*, *Prorocentrum gracile* and *Scrippsiella trochoidea* were the dominant ones. Both studies agreed that diatoms and dinoflagellates were the most abundant and frequent groups in their samples. On the other hand, Muciño-Márquez *et al.* (2012), at the same period, recorded 27 red tide-forming species in this lagoon. Specific taxonomic aspects of some species have been studied by others investigators in this lagoon; Aké-Castillo *et al.* (1995) reported morphological variations of some species from the *Skeletonema* genus (*S. subsalsum, S. pseudocostatum* and *S. costatum)* while Aké-Castillo *et al.* (2000, 2004) reported species from the *Chaetoceros* genus (*Chaetoceros subtilis* var *abnormis* f. *abnormis, Chaetoceros subtilis* var *abnormis* f. *simplex*). Aké-Castillo & Vázquez-Hurtado (2011) described the presence of *Peridinium quinquecorne* var *trispiniferum* and Aké-Castillo (2015) reported the *Thalassiosira cedarkeyensis* species. In summary, according to the different studies, a very great variability in composition and abundance of phytoplankton species has been observed at different sampling stations and seasons at Sontecomapan Lagoon with no clear distribution patterns.

Therefore, this work is a contribution to the phytoplankton studies of the Sontecomapan Lagoon by developing an up-to-date list of species with new sampling observations at rainy and dry seasons. Also, this work is a plea for a constant monitoring of the phytoplankton in the lagoon in order to analyze time-changes in the species' composition and detect the eventual presence of toxic species in the ecosystem to prevent damage to human health.

Materials and Methods

The Sontecomapan Lagoon is a tropical coastal ecosystem characterized by three zones according to the horizontal salinity gradients: fresh, brackish and marine waters; with two-layer flows and vertical mixtures, associated with the climatic conditions of the region (Lankford, 1977). The average depth is 1.5 meter. The combination of physical and chemical factors leads to the formation of zones with different microenvironmental conditions of location and variable dimensions, which favor the differential development of phytoplankton species. Eight sampling stations were set up along the lagoon: La Boya, Río La Palma, El Real, Estero El Fraile, Punta Levisa, El Chancarral, Río Sábalo and Río Basura (Fig. 1). Sampling was performed in June, 2015 (rainy season) and February, 2016 (dry season).

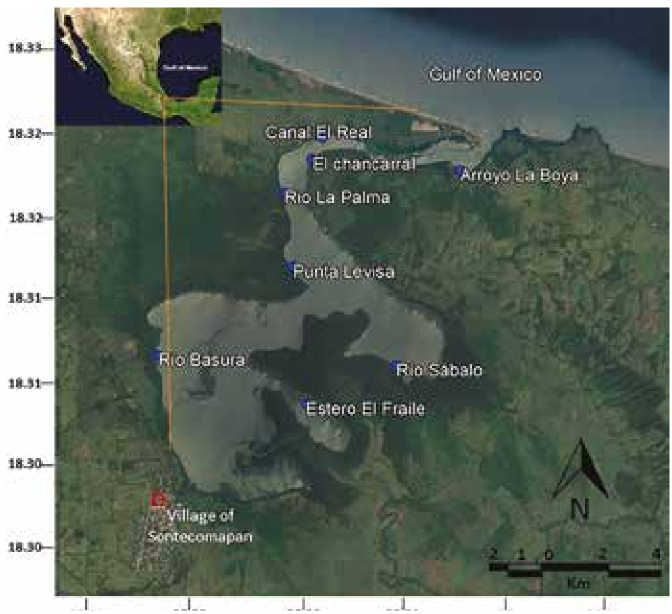

Figure 1. Location of the Sontecomapan Lagoon and sampling stations (Modified from Image @DogotalGlobe, Image@2016TerraMetrics)

Sixteen phytoplankton samples were collected at subsurface level of the water column using a Van Dorn bottle and were placed in 500 ml glass bottles preserved with acetate-lugol at 1%. To perform the counts, samples were homogenized and placed in one-milliliter chambers to be checked under a Zeiss Axiovert 135 inverted microscope, by triplicate. For taxonomic determination, the keys and descriptions by Taylor (1976), Dodge (1982), Balech (1988), Fukuyo *et al.* (1990), Licea *et al.* (1995), Bravo (2004), Okolodkov (2010), Gómez (2010, 2013) and García–Mendoza *et al.* (2016) among others, were consulted. Nomenclature was updated based on the work of Guiry & Guiry (2017).

Salinity was measured with an Atago SMill-E refractometer series 0183181, pH with an Orion pH meter 250A series 017210; depth and transparency with a Secchi disk, water temperature with a cuvette thermometer (0-100 °C ± 1 °C) and the dissolved oxygen concentration was calculated according to Winkler's technique (Strickland & Parsons, 1972).

A cluster analysis was performed using the Statistica 8 software, for the environmental conditions of the lagoon.

Results

Physical and chemical factors

During the rainy season, water depth was greater in stations Canal el Real, Río Sábalo, El Chancarral and La Boya with values of 230, 200, 105 and 100 cm respectively, compared to the dry season, which was shallower, with depths of 73, 180, 44 and 15 cm. Spatially, the deepest stations were recorded far from the mouth at Río Basura and Río Sábalo with values of 320 and 200 respectively in rainfall and 340 and 180 cm in dry. It is clear that the rains and the continental water contributions have a great influence on the depth increase throughout the system (Fig. 2A).

Transparency was generally high in the two sampling periods, with the exception of Río Basura where transparency was 85 cm in the rainy season and 90 cm in the dry season (Fig. 2B).

The water temperature ranged between 25 and 33.5 °C and was higher in the rainy season, where the highest value was obtained in El Fraile (33.5 °C) and the minimum in Río La Palma (25.9 °C). In the dry season, it varied very little: from 25 to 27°C at the different sampling sites (Fig. 2C).

As for pH, it remained close to neutrality in both seasons (Fig. 2D); in the rainy season the maximum value was 7.9 at El Real and the minimum at Río Sábalo with a 6.0 value. In the dry season, Río Sábalo showed the maximum value (7.65) and Río La Palma the minimum (6.7). Río Sábalo, El Fraile and La Boya presented the highest pH values in the dry season and the lowest in the rainy season.

Concentrations of dissolved oxygen showed a spatial variation in the rainy season with highest values at El Chancarral (11.6 mg/L) and Río La Palma (8.8 mg/L) and lowest values at La Boya and Río Sábalo (3.3 mg/L both). In the dry season, values were more homogeneous and varied between 7.8 mg/L at El Chancarral and 5.3 mg/L at Punta Levisa (Fig. 2E).

Salinity presented great fluctuations, from 0 to 20 psu (Fig. 2F). During the rainy season, maxima of 18 and 19 psu were observed at La Boya and El Real, near the mouth of lagoon, and a minimum of 0 psu in Río La Palma and Río Basura, which are further away from the lagoon's mouth. It is worth noting that in this season (although not shown in the figures) salinity of the bottom water at El Chancarral and El Real showed values of 35 and 34 psu respectively, forming a wedge-like halocline. In the dry season the highest salinity (20 psu) was recorded at Río Sábalo, although this station is distant from the mouth of the lagoon, whereas the lowest (3 psu) was recorded at Río Basura.

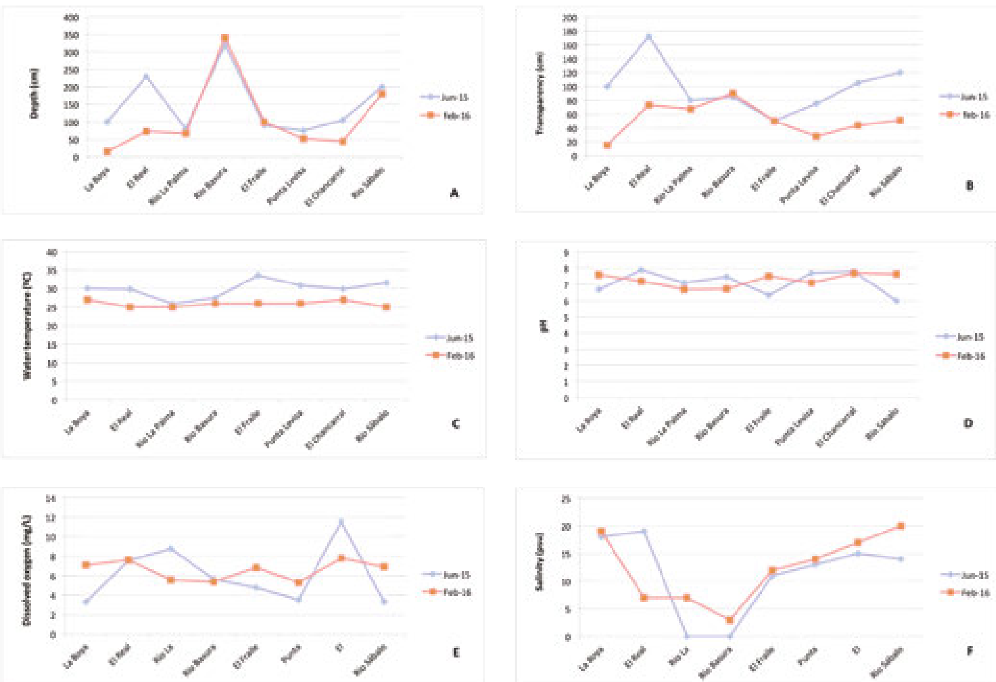

Figure 2. Environmental variables registered in the Sontecomapan Lagoon, Veracruz in rainy season (June, 2015) and dry season (February, 2016). A) depth, B) transparency, C) temperature, D) pH, E) dissolved oxygen and F) salinity.

The cluster analyses based on physical and chemical data (Fig. 3A-B) established clusters (corresponding to geographic zones) at a link distance of 50. The rainy season was more heterogeneous with four clusters, while the dry season formed three. In the dendrogram corresponding to the rainy season (Fig. 3A), the Río Sábalo and the Canal El Real sampling stations were separated in spite of having the highest values of depth and transparency, salinity, pH and temperature. Probably the morphology of the basins was the main factor since Río Sábalo is more isolated from the zone under tidal influence and therefore, with more stagnant waters, while El Real is under oceanic coastal waters influence and high hydrodynamic conditions. Río Basura that has the lowest salinity formed the third zone and all other sampling stations the fourth zone. In the dry season, Río Basura also formed a single cluster characterized by the lowest salinity, as well as Río Sábalo characterized by the highest. The third cluster grouped the rest of the sampling stations with intermediate salinities. Apparently, the other factors were less important than salinity in this season. However, we can point that at both seasons Río Sábalo, which correspond to the more confined zone, clearly distinguished from all the other stations.

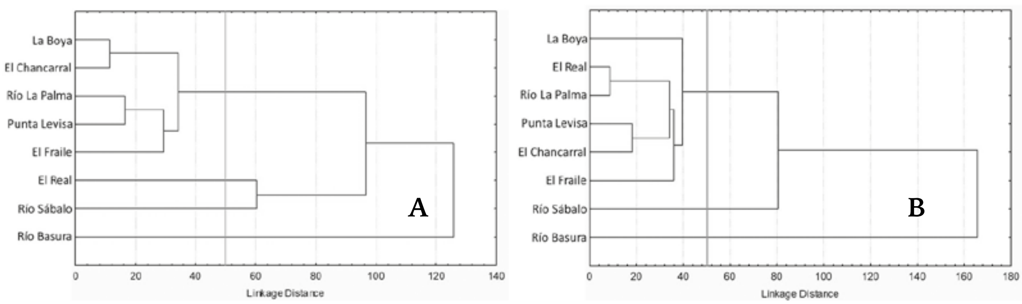

Figure 3 A-B. Dendrograms of Sontecomapan Lagoon, Veracruz, based on physical and chemical data: A) rainy season (June, 2016) and B) dry season (February, 2016)

Phytoplankton

From literature revision and this study, a list of 357 species was generated for the lagoon (Table 1), from which 241 (67.8%) were Diatoms, 72 (20.16%) Dinoflagellates, 13 (3.64 %) Chlorophytes, 11(3.08%) Euglenophytes, 16 (4.20%) Cyanoprokariotes, 2 (0.56%) Raphydophyceae and 2 (0.56%) Silicoflagellates.

We observed that 46 (12.88%) from the species registered in the general list, are potentially red tide forming (Table 2), and are mainly represented by Dinoflagellates with 20 species (43.48%) and Diatoms with 19 (41.30%).

Among them, 12 species are toxic and five affect humans: *Pseudo-nitzschia pungens*, *Pseudo-nitzschia pungens var atlántica* and *Pseudo-nitzschia seriata* diatoms, which produces domoic acid that causes amnesic poisoning by consumption of contaminated shellfish, *Dinophysis caudata* dinoflagellate that causes diarrhea and Cyanoprocariota *Lyngbya majuscula* that produces dermatitis and respiratory diseases.

Five other species affect the marine fauna: dinoflagellates *Gonyaulax spinifera*, producer of yessotoxin that can kill fish and invertebrates, *Phalacroma rotundatum* that may cause problems to salmon in captivity, *Prorocentrum gracile* that causes fish mortality, *Prorocentrum micans* that produces verupine (hepatoxin) toxin affecting clams and shellfish, and *Tripos furca* which may cause great mortality of tuna in captivity. Likewise, the Cyanoprokariota *Anabaenopsis circularis* has been reported as toxic, but not enough information is available, as well as the Raphydophycea *Olisthodiscus luteus*, which seems to cause red blood cells lysis.

From the water samples analyzed in this study, 102 phytoplankton species (Table 1, Plates 1 to 3) were recorded, of which 61 are reported for the first time in the lagoon. Among these 102 species, 69 (67.64%) belong to the group of diatoms, 17 (16.67%) to Dinoflagellates, 10 (9.80%) to Cyanoprokaryotes, 4 (3.93%) to Euglenophytes and 2 (1.96%) to Chlorophytes. It was detected that 17 of these species are potentially red tide forming, eight of them being Diatoms, six Dinoflagellates and three Cyanoprokariotes. Only two are toxic for humans: *Dinophysis caudata* dinoflagellate, that causes diarrhea from contaminated shellfishes consumption, and cyanoprocariota *Lyngbya majuscula*, which may cause dermatitis and respiratory irritation.

Fourty two (42) species were collected in the rainy season and 65 in the dry season (Fig. 4A); 7 species were common to both seasons.

In the dry season, La Boya had the highest richness with 31 species, followed by Río Basura with 29 and El Fraile with 27. In the rainy season, the greatest species richness was registered at Punta Levisa with 18 and Río Sábalo with 14. It is noteworthy that at this season, only two species were registered at El Chancarral.

Phytoplankton abundance reached values up to 300 x 10^4 cells/l (Fig. 4B), but mats of the cyanoprokaryote *Merismopedia convoluta* were also observed in the dry season at El Fraile sampling station with 1600 x 10^4 cells/l; this value was discarded in the graph (Fig. 4B) because it gives the impression of a massive bloom. However, this species is very small (3-5 µm in diameter), hardly perceptible in site and sample (Plate 3, Fig. 24), considering that most of the phytoplankton organisms measure more than 50 μm, which is 15 times greater than *M. convoluta*, and with biovolumes 3,000-fold higher.

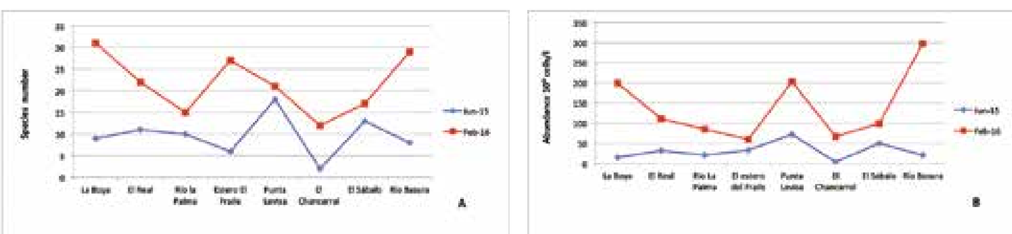

Figure 4 A-B. Phytoplankton species richness and abundance in Sontecomapan Lagoon, Veracruz, in the rainy (June, 2015) and dry (February, 2016) seasons

Table 1. Phytoplankton of the Sontecomapan Lagoon, Veracruz, Mexico

Taxa	Previous records in the lagoon	This study		Taxa	Previous records in the lagoon	This study	
		Jun 2015	Feb 2016			Jun 2015	Feb 2016
Diatoms				*Biddulphia tuomeyi* (J. W. Bailey) Roper	*13*		
Actinocyclus curvatulus Janisch	*8*			*Biddulphia* sp.	*14*		
Actinocyclus sp.	*13*			*Biddulphia* sp. *1*	*13*		
Actinoptychus splendens (Shadbolt) Ralfs	*8*			*Biddulphia* sp. *2*	*13*		
Amphiprora angustata Hendey	*14*			*Brachysira procera* Lange-Bertalot & Gerd Moser	*none*		*X*
Amphora pediculus (Kützing) Van Heurck	*14*			*Caloneis permagna* (Bailey) Cleve	*8*		
Amphora proteus Gregory	*15*			*Campylodiscus echeneis* Ehrenberg ex Kützing	*13*		
Amphora sp.	*14*			*Campylodiscus* sp.	*13*		
Amphicocconeis disculoides (Hustedt) Stefano & Marino	*14*			*Cerataulina pelágica* (Cleve) Hendey	*13*		
Anemastus tuscula (Ehrenberg) D. G. Mann & A. J. Stickle	*14*			*Cerataulus smithii* Ralfs	*13, 17,*		*X*
Asterionellopsis glacialis (Castracane) Round	*8,13*			*Chaetoceros affinis* Lauder	*13*		
Aulacoseira granulata (Ehrenberg) Simonsen	*none*	*X*	*X*	*Chaetoceros atlanticus* Cleve	*10, 14,16*		
Aulodiscus sp.	*14*			*Chaetoceros compressus* Lauder	*13*		
Bacillaria paxillifera (O. F. Müller) T. Marsson	*5,14,16,*		*X*	*Chaetoceros curvisetus* Cleve	*13*		
Bacteriastrum delicatulum Cleve	*14*			*Chaetoceros cf debilis* Cleve	*14, 16*		
Bacteriastrum hyalinum Lauder	*13, 14*			*Chaetoceros denticulatus* H. S. Lauder	*13*		
Bacteriastrum sp.	*14*			*Chaetoceros holsaticus* F. Schütt	*5, 11*		
Bellerochea sp.	*13*			*Chaetoceros laevis* Leuduger-Fortmorel	*13*		
Biddulphia biddulphiana (J. E. Smith) Boyer	*14*			*Chaetoceros lorenzianus* Grunow	*8,13*		
Biddulphia biddulphiana (J. E. Smith) Boyer	*14*			*Chaetoceros aff muelleri* Lemmermann	*13*		
Chaetoceros peruvianus Brightwell	*13*			*Coscinodiscus pavillardii* Forti	*13*		
Chaetoceros aff subtilis Cleve	*13*			*Coscinodiscus aff radiatus* Ehrenberg	*14,*		*X*
Chaetoceros subtilis var abnormis f abnormis Proschkina-Lavrenko	*2*			*Coscinodiscus* sp.	*13*		*X*
Chaetoceros subtilis var abnormis f simplex Proschkina-Lavrenko	*2*			*Coscinodiscus* sp. *1*	*13*		

Table 1. (Continuation)

Taxa	Previous records in the lagoon	This study		Taxa	Previous records in the lagoon	This study	
		Jun 2015	Feb 2016			Jun 2015	Feb 2016
Chaetoceros throndsenii var trondsenia (Marino, Montresor & Zingone) Marino, Montresor & Zingone	2			*Coscinodiscus* sp. 2	13		
Chaetoceros throndsenii var trisetosa Zigone	2			*Coscinodiscus* sp. 3			X
Chaetoceros sp. 1	none	X		*Coscinodiscus* sp. 4			X
Chaetoceros sp. 2	none	X		*Craticula cuspidata* (Kützing) D. G. Mann	8, 13		
Chaetoceros sp. 3	14			*Cyclotella meneghiniana* Kützing	13, 14,16	X	
Cocconeis placentula Ehrenberg	14,	X		*Cyclotella* sp.	none		X
Cocconeis scutellum var scutellum Ehrenberg	8, 14			*Cyclotella* sp. 1	13		
Cocconeis sp.	14			*Cyclotella* sp. 2	13		
Corethron hystrix Hensen	8,13			*Cylindrotheca closterium* (Ehrenberg) Reimann & J. C. Lewin	8, 13, 14,	X	
Coscinodiscus af. asteromphalus Ehrenberg	none	X		*Cymatopleura solea* (Brébisson) W. Smith	8, 16		
Coscinodiscus centralis Ehrenberg	8, 14, 16		X	*Cymbella minuta* Hilse	none		X
Coscinodiscus concinnus W. Smith	13, 14, 16			*Cymbella prostata* (Berkeley) Cleve	none		X
Coscinodiscus curvatulus	14			*Cymbella* sp.	none		X
Coscinodiscus granii L. F. Gough	13, 14,16			*Denticula elegans* Kützing	14		
Coscinodiscus jonesiana (Greville) E. A. Sar & I. *Sunesen*	13, 17,		X	*Detonula pumila* (Castaracane) Schütt	13		
Diatoma sp.	14			*Fragilaria goulardii* (Brébisson ex Cleve) Lange-Bertalot	13, 14		
Diploneis bombus (Ehrenberg) Ehrenberg	14			*Fragilaria tenuicollis* Heib.	13		
Diploneis ovalis (Hilse) Cleve	14			*Fragilaria ulna var ungeriana* (Grunow) Lange-Bertalot	13		
Diploneis puella (Schumann) Cleve	none		X	*Fragilaria* sp. 1	none		X
Diploneis smithii (Brébisson) Cleve	none	X		*Fragilaria* sp. 2	13, 14		
Diploneis sp.	14			*Fragilaria* sp. 3	13,14		
Ditylum brightwellii (T. West) Grunow	14			*Fragilaria* sp. 4	14		
Encyonema neomesianum Krammer	14			*Fragilaria* sp. 5	14		

Table 1. (Continuation)

Taxa	Previous records in the lagoon	This study		Taxa	Previous records in the lagoon	This study	
		Jun 2015	Feb 2016			Jun 2015	Feb 2016
Entomoneis alata (Ehrenberg) Ehrenberg	*13*		*X*	*Fragilariforma exigua* (Grunow) M. G. Kelly	*14*		
Entomoneis ornata (Bailey) Reimer	*none*	*X*		*Gomphoneis clevei* (Frike) Gil	*8*		
Entomoneis paludosa (W. Smith) Reimer	*14*			*Gomphoneis herculeana var robusta* (Grunow) Cleve	*14*		
Eunotia sp.	*none*		*X*	*Gomphonema parvulum* (Kützing) Kützing	*none*	*X*	*X*
Eupodiscus radiatus Bailey	*13, 17*			*Guinardia flaccida* (Castracane) H. Peragallo	*none*		*X*
Fallacia pygmaea (Kützing) Stickle & D. G. Mann	*14*			*Guinardia striata* (Stolterfoth) Hasle	*13*		
Fragilaria acus (K¨tzing) Lange-Bertalot	*14*			*Gyrosigma acuminatum* (Kützing) Rabenhorst	*none*	*X*	
Fragilaria capucina Desmasières	*14*			*Gyrosigma attenuatum* (Kützing) Rabenhorst	*14*	*X*	*X*
Tabularia af fasciculata (C. Agardh) D. M. Williams & Round	*13*			*Gyrosigma balticum* (Ehrenberg) Rabenhorst	*13*	*X*	*X*
Gyrosigma distortum (W. Smith) Griffith & Henfrey	*13*			*Mastogloia pusilla* Grunow	*14*		
Gyrosigma eximium (Thwaites) Boyer	*none*	*X*		*Mastogloia* sp.	*none*		*X*
Gyrosigma fasciola (Ehrenberg) J. W. Griffith & Henfrey	*14*		*X*	*Melosira moniliformis* (O. F. Müller) C. Agardh	*none*	*X*	*X*
Gyrosigma af scalproides (Rabenhorst) Cleve	*none*	*X*		*Melosira nummuloides* C. Agardh	*13*	*X*	*X*
Gyrosigna sp.	*13*			*Navicula capitatoradiata* H. Germain	*14*	*X*	
Gyrosigma sp. *1*	*13*			*Navicula cincta* (Ehrenberg) Ralfs	*8*		
Halamphora clara (A. Schmidt) Levkov	*14*			*Navicula cryptocephala* Kützing	*14*		
Hantzchia amphioxys (Ehrenberg) Grunow	*14*			*Navicula veneta* Kützing	*14*		
Hantzschia sp.	*13*			*Navicula distans* (Wm Smith) Ralfs	*8*		
Helicotheca tamesis (Shrubsole) M. Ricard	*13*			*Placoneis grastrum* (Ehrenberg) Kützing	*14*		
Hemiaulus sinensis Greville	*13*			*Navicula gottlandica* Grunow	*14*		
Hyalodiscus scoticus (Kützing) Grunow	*8*			*Navicula menisculus* Schumann	*8*		
Hyalodiscus sp.	*13*			*Navicula*	*14*		
Hyalodiscus sp. *1*	*13*			*Navicula pennata* A. Schmidt	*8*		*X*
Lauderia annulata Cleve	*13*			*Navicula platyventris* Meister	*14*		*X*
Lithodesmium undulatum Ehrenberg	*13, 14*			*Navicula rhynchocephala* Kützing	*14*		*X*

Table 1. (Continuation)

Taxa	Previous records in the lagoon	This study		Taxa	Previous records in the lagoon	This study	
		Jun 2015	Feb 2016			Jun 2015	Feb 2016
Luticola mutica (Kützing) D. G. Mann	*14*			*Navicula tenella* Brébisson ex Kützing	*14*		
Lyrella lyra (Ehrenberg) Karajeva	*none*		*X*	*Navicula veneta* Kützing	*none*	*X*	
Navicula sp. *1*	*none*		*X*	*Odontella af longicruris* (Greville) M. A. Hoban	*none*		*X*
Navicula sp. *2*	*8*	*X*		*Odontella mobiliensis* (J. W. Bailey) Grunow	*8, 13, 14*		*X*
Navicula sp. *3*	*14*			*Odontella* sp.	*13*		
Navicula sp. *4*	*14*			*Palmerina hardmaniana* G. R. Hasle	*13*		
Navicula sp. *5*	*14*			*Paralia sulcata* (Ehrenberg) Cleve	*14*		
Neocalyptrella robusta (G. Norman ex Ralfs) Hernández-Becerril & Meave del Castillo	*13*			*Paraplaconeis placentula* (Ehrenberg) M. S. Kulikovskly & Lange-Bertalot	*14*		
Neostreptotheca subindica Van Stosch	*13*			*Petrodictyon gemma* (Ehrenberg) D. G. Mann	*13*		
Nitzschia angularis W. Smith	*14*			*Petroneis humerosa* (Brébisson ex W. Smith) Stickle & D. G. Mann	*14*	*X*	
Nitzschia longissima (Brebisson) Ralfs	*8, 13,14*			*Pinnularia borealis var scalaris* (Ehrenberg) Rabenhorst	*8*		
Nitzschia macilenta W. Gregory	*none*		*X*	*Pinnularia lata* (Brébisson) W. Smith	*14*		
Nitzschia marginata Hustedt	*8*			*Pinnularia mesolepta* (Ehrenberg) W. Smith	*14*		
Nitzschia obtusa W. Smith	*8*			*Pinnularia nobilis* (Ehrenberg) Ehrenberg	*14*		
Nitzschia sigma (Kützing) W. Smith	*13*		*X*	*Pinnularia* sp.	*8*		*X*
Nitzschia sigmoidea (Nitzsch) W. Smith	*none*		*X*	*Pinnularia* sp. *1*	*14*		
Nitzschia vidovichii (Grunow) Grunow	*14*			*Pinnularia* sp. *2*	*14*		*X*
Nitzschia sp.	*14*			*Placoneis disparilis* (Hustedt) Metzeltin & Lange-Bertalot	*14*		
Nitzchia sp. *1*	*13*			*Plagiotropis lepidoptera* (W. Gregory) Kuntze	*none*	*X*	
Nupela poconoensis (Patrick) Potapova	*14*			*Plagiotropis vitrea* (W. Smith) Grunow	*none*		*X*
Plagiotropis sp. *1*	*none*		*X*	*Rhizosolenia acuminata* (H. Peragallo) H. Peragallo	*14*		
Plagiotropis sp. 2	*none*		*X*	*Rhizosolenia bergonii* H. Peragallo	*14*		
Planothidium lanceolatum (Brébisson ex Kützing) Lange- Bertalot	*14*			*Rhizosolenia castracanei* H Peragallo	*8*		

Table 1. (Continuation)

Taxa	Previous records in the lagoon	This study		Taxa	Previous records in the lagoon	This study	
		Jun 2015	Feb 2016			Jun 2015	Feb 2016
Pleurosigma fasciolata var closterioides (Grunow) Peragallo	*13*			*Rhizosolenia imbricata* Brightwell	*13*		
Pleurosigma rigidum var incurvatum Brun	*14*			*Rhizosolenia setigera* Brightwell	*13*		
Pleurosigma sp.	*13*			*Rhizosolenia* sp.	*13*		
Pleorosigma sp. *1*	*13*			*Rhoicosphenia curvata* (Kützing) Grunow	*none*	*X*	
Pleurosira laevis (Ehrenberg) Compère	*none*		*X*	*Rhopalodia* sp.	*14*		
Pleurosira sp.	*13*			*Sellaphora americana* (Ehrenberg) D. G. Mann	*14*		
Proboscia alata (Brightwell) Sundström	*13,14,16*			*Skeletonema costatum* (Greville) Cleve	*3, 8, 13*		*X*
Proboscia sp.	*14*			*Skeletonema pseudocostatum* Medlin	*3*		
Psammodictyon panduriforme (W. Gregory) D. G. Mann	*14*			*Skeletonema subsalsum* (Cleve-Euler) Bethge	*3, 4, 7, 13*		
Pseudo-nitzchia delicatissima (Cleve) Heiden	*8*			*Skeletonema tropicum* Cleve	*3*		
Pseudo-nitzschia pungens (Grunow ex Cleve) Hasle	*14,16*			*Staurosira construens* Ehrenberg	*14*		
Pseudo-nitzschia pungens var atlantica (Cleve) Moreno & Licea	*8, 10, 14*			*Staurosirella pinnata* (Ehrenberg) D. M. Williams & Round			*X*
Pseudo-nitzschia seriata (Cleve) H. Peragallo	*10, 14, 16*			*Stenoneis insconpicua* (W. Gregory) Cleve	*14*		
Pseudosolenia calcar-avis (Schultze) B. G. Sundström	*13*			*Stephanopyxis palmeriana* (Greville) Grunow	*13*		
Pseudostaurosira parasítica (W. Smith) E. Morales	*14*			*Surirella af guatemalensis* Ehrenberg	*none*		*X*
Surirella fastuosa var cuneata O. Witt	*13*		*X*	*Thalassiosira* sp.	*13,14*		
Surirella febigerii F. W. Lewis	*13*		*X*	*Trieres regia* (M. Schultze) M. P. Ashworth & E. C. Theriot	*13*		
Surirella gemma (Ehrenberg) Kützing	*none*		*X*	*Tryblionella compressa* (J. W. Bailey) Poulin	*14*		
Surirella minuta Brébisson ex Kützing	*8*			*Ulnaria ulna* = (Nitzch) CompèreSynedra ulna	*14*		
Surirella splendida (Ehrenberg) Kützing	*none*		*X*	*Zigoceros ehrenbergii* E. A. SAr	*13*		
Surirella striatula Turpin	*8,14*			*Dinoflagellates*			
Synedra superva Kützing	*none*	*X*		*Achradina* sp.	*14*		

Table 1. (Continuation)

Taxa	Previous records in the lagoon	This study		Taxa	Previous records in the lagoon	This study	
		Jun 2015	Feb 2016			Jun 2015	Feb 2016
Synedra tabulata (C. Agardh) Kützing	*none*		*X*	*Akashiwo sanguínea* (K. Hirasaka) G. Hansen & Moestrup	*14, 16*		*X*
Synedra ulna var ulna (Nitzsch) Ehrenberg	*8*			*Ceratium horridum var buceros* (Zacharias) Sournia	*9*		
Synedra sp.	*13*			*Ceratium massiliense f armatum* (Karsten) Schiller	*9*		
Tabularia fasciculata (C. Agardh) William & Round	*none*	*X*		*Ceratium tripos var atlanticum* (Ostenfeld) Paulsen	*9*		
Terpsinoë musica Ehrenberg	*13*		*X*	*Ceratium* sp.	*14*		
Thalassionema frauenfeldii (Grunow)Tempère & Peragallo	*13*			*Ceratium* sp. *1*	*14*		
Thallasionema nitzschiodes (Grunow) Mereschkowsky	*13*	*X*		*Cuneolus aff skvortzowii* (Nikolae) Medlin	*13*		
Thalassionema nitzschioides var lanceolata Grunow	*14*			*Dinophysis caudata* Saville-Kent	*5; 9, 10, 14, 16*		*X*
Thalassiosira cedarkeyensis A.K.S.K. Prasad	*1*			*Dinophysis* sp.	*14*		
Thalassiosira plicata Schrader inc.	*14*			*Diplopsalis* sp.	*13,14*		
Glenodinium sp.	*14*			*Oxytoxum sceptrum* (Stein) Schröder	*9*		
Goniodoma sphaericum Murray & Whitting	*14*		*X*	*Peridiniella danica* (Paulsen) Y. B. Okolodkov & J. D. Dodge	*14*		
Gonyaulax digitalis (Pouchet) Kofoid	*9*			*Peridiniopsis polonica* (Woloszynska) Bourrelly	*14*		
Gonyaulax polygramma Stein	*9*		*X*	*Peridinium quadridentatum* (F. Stein) Gert Hansen	*5, 6*		
Gonyaulax spinifera (Claparède et lachmann) Diesing	*9*			*Petroneis humerosa* (Brébisson ex Smith) Stickle & D. G. Mann	*13*		
Gonyaulax turbynei Murray & Whitting	*14, 16*			*Phalacroma rotundatum* (Claparède et Lachmann) Kofoid & Michener	*5, 916*		
Gymnodinium sp.	*14*			*Podolampas bipes Stein*	*9*		
Gymnodinium sp. *1*	*14*			*Podolampas bipes var reticulata* (Kofoid) Taylor	*14*		
Gyrodinium fusiforme Kofoid & Swezy	*14*			*Podolampas palmipes* Stein	*9*		
Gyrodinium spirale (Bergh) Kofoid & Swezy	*14, 16*			*Prorocentrum cordatum* (Ostenfeld) Dodge	*1*		
Noctiluca scintillans (Macartney) Kofoid & Sweay	*5, 14, 16*			*Prorocentrum gracile* Schütt	*5; 9, 14,15, 16*		
Operculodinium israelianum (M. Rossignol) Wall	*14*			*Prorocentrum mexicanum* Osorio-Tafall	*14, 15*		

Table 1. (Continuation)

Taxa	Previous records in the lagoon	This study		Taxa	Previous records in the lagoon	This study	
		Jun 2015	Feb 2016			Jun 2015	Feb 2016
Ornithocercus magnificus Stein	*9*			*Prorocentrum micans* Ehrenberg	*5, 9, 14, 15, 16*		
Ostreopsis sp.	*14*			*Prorocentrum scutellum* Schröder	*14, 15*		
Oxyrrhis marina Dujardin	*none*	*X*		*Prorocentrum* sp.	*14*		
Oxytoxum globosum Schiller	*14*			*Protoperidinium argentinense* Balech	*none*	*X*	
Oxytoxum mediterraneum Schiller	*14*			*Protoperidinium brevipes* (Paulsen) Balech	*none*	*X*	
Protoperidinium brochii (Kofoid &Swezy) Balech	*9*			*Protoperidinium thulesence* (Balech) Balech	*none*	*X*	
Protoperidinium claudicans (Paulsen) Balech	*9*			*Pyrocystis lunula* (Schütt) Schütt	*14*		
Protoperidinium corniculum Kofoid et Michener	*9*			*Pyrophacus* horologium Stein	*9, 14*		
Protoperidinium crassipes (Kofoid) Balech	*9*	*X*		*Pyrophacus steinii* (Schiller) Wall & Dale	*9*		
Protoperidinium curtipes (Jørgensen) Balech	*none*		*X*	*Scrippsiella acuminata* (Ehrenberg) Kretschmann, Elbrächter, Zinssmeister, Soehner, Kirsch, Kusber & Gottschling	*14, 16,*		*X*
Protoperidinium depressum (Bailey) Balech	*9, 14, 16*		*X*	*Tripos deflexus* (Kofoid) F. Gómez	*9*		
Protoperidinium divergens (Ehrenberg) Balech	*9*			*Tripos furca* (Ehrenberg) F. Gómez	*9, 10, 11, 14*		
Protoperidinium oceanicum (Vanhöffem) Balech	*9*			*Tripos fusus* (Ehrenberg) F. Gómez	*9, 10, 14, 16*		
Protoperidinium ovatum Pouchet	*14*			*Tripos hircus* (Schröder) F Gómez	*1, 9, 11, 12*		*X*
Protoperidinium paulseni Abe	*none*		*X*	*Tripos lunula* (Schimper ex Karsten) F. Gómez	*9*		
Protoperidinium pentagonum (Gran) Balech	*9*			*Tripos teres* (Kofoid) Gómez	*9*		
Protoperidinium puntulatum (Paulsen) Balech	*14*	*X*		*Tripos tripos* (O. F. Müller) F Gómez	*14*		*X*
Protoperidinium thorianum (Paulsen) Balech	*none*	*X*		*Tryblionella compressa* (J. W. Bailey)	*14, 15,16*		
Zygabikodinium lenticulatum Loeblich Jr et Koeblich III	*9, 14*			*Euglena cf stellata* Mainx	*14,16*		
CHLOROPHYTES				*Euglena cf viridis* (O. F. Müller) Ehrenberg	*14, 16*	*X*	
Actinastrum hantzschii Lagerheim	*14*			*Euglena* sp.	*14*		
Ankistrodesmus gracilis (Reinsch) Korshikov	*14*			*Euglena* sp. *1*	*14*		
Closterium moniliferum Ehrenberg ex Ralfs	*none*		*X*	*Euglena* sp. 2	*14*		
Coelastrum microporum Nägeli	*none*	*X*		*Pleuromonas* sp.	*14*		

Table 1. (Continuation)

Taxa	Previous records in the lagoon	This study		Taxa	Previous records in the lagoon	This study	
		Jun 2015	Feb 2016			Jun 2015	Feb 2016
Pandorina morum (O. F. Müller) Bory	*14*			*Trachelomonas hispida* (Perty) F. Stein	*none*	*X*	
Raphidonema nivale Lagerheim	*14*			*Trachelomonas lefebrei* Deflandre	*none*	*X*	
Scenedesmus arcuatus (Lemmermann) Lemmermann	*14*			*Trachelomonas volvocina* (Ehrenberg) Ehrenberg	*none*	*X*	
Scenedesmus acuminatus (Lagerheim) Chodat	*14*			*Trachelomonas* sp.	*14*		
	14			*Cyanoprokaryotes*			
Scenedesmus maximus (West & G. S. West) Chodat	*14*			*Anabaenopsis circularis* (G. S. West) Woloszynska & V. Miller	*none*	*X*	
Staurastrum leptocladum Nordstedt	*14*			*Arthrospira platensis* Gomont	*none*	*X*	*X*
Tetradesmus lagerheimii M. J. Wynne & Guiry	*14*			*Arthrospira subsalsa* (Oersted ex Gomont) W.B. Crow	*none*	*X*	
Ulotrhrix sp.	*14*			*Johannesbaptistia pellucida* (Dickie) W. R. Taylor & Drouet	*14*		
EUGLENOPHYTES				*Limnoraphis hieronymusii* (Lemmermann) J. Komárek, E. Zapomelová, J. Smarda, J. Kopecky, E. Rejmánková, J. Woodhouse, B. A. Neilan & J. Kommárková	*none*		*X*
Euglena polymorpha P. A. Dangeard	*14*			*Lyngbya majuscula* Harvey ex Gomont	*none*		*X*
Merismopedia convoluta Brébisson ex Kützing	*none*		*X*	*Phormidium retzii* Kützing ex Gomont	*14*		
Merismopedia elegans A. Braun ex Kützing	*14*			*Spirulina nordstedtii* Gomont	*14*		
Merismopedia glauca (Ehrenberg) Kützing	*14*			*Silicoflagellate*			
Mersimopedia sp.	*14*			*Dictyocha fibula* Ehrenberg	*14, 16*		
Oscillatoria aff limosa C. Agardh ex Gomont	*none*		*X*	*Dictyocha* sp.	*14*		
Oscillatoria obtusa N. L. Gardner	*none*		*X*	*Raphidophyceae*			
Oscillatoria sp.	*none*	*X*		*Chatonella* sp.	*14*		
Phormidium nigroviride (Thwaites ex Gomont) Anagnostidis & Kpmárek	*none*	*X*		*Olisthodiscus luteus* N. Cartes	*14, 16*		

(1) Aké-Castillo 2015, (2) Aké-Castillo *et al*. 2004, (3) Aké-Castillo *et al*. 1995, (4) Aké-Castillo *et al*. 1997, (5) Aké-Castillo & Vázquez-Hurtado 2008, (6) Aké-Castillo & Vázquez-Hurtado 2011, (7) Camacho *et al*. 1994, (8) Carbajal 2009, (9) Figueroa-Torres *et al*. 2009, (10) Guerra-Martínez 1996, (11) Guerra-Martínez & Lara-Villa (1996), (12) Guerra-Martínez & Meave del Castillo (1997), (13) Meave del Castillo & Lara-Villa 1997, (14) Muciño-Márquez *et al*. 2011 a, (15) Muciño-Márquez *et al*. 2011 b, (16) Muciño-Márquez *et al*. 2012, (17) Meave del Castillo & Moreno-Ruiz (1997).

In the rainy season, due to their abundance, only two species dominated: the *Melosira nummuloides* diatom with 21 x10^4 cells/l at Punta Levisa and the euglenophyte *Trachelomonas volvocina* with 23 x10^4 cells/l, at Río Sábalo. In contrast, in the dry season, high abundances of diatoms were observed: *Eunotia* sp. with 87 x10^4 cells/l at Río Basura and 4 x10^4 cells/l at Río La Palma, *Melosira moniliformis* was frequent in all sampling stations and reaching up to 28 x10^4 cells/l, *Gomphonema parvulum* with a high abundance of 26 x 10^4 cells/l present only at Río Basura. At this latter station, *Nitzschia macilenta* was observed with 21 x 10^4 cells/l, although it was also present in seven of the eight sampling stations. Among the dinoflagellates, only *Tripos hircus* can be highlighted, as it was present in seven of the eight sampling stations, reaching its maximum density of 20 x10^4 cells/l at Río Sábalo. The cyanoprokaryote *Oscillatoria* af. *limosa* showed values of 10.2 x10^5 cells/l at La Boya, 61 x10^4 cells/l at El Real, 81 x10^4 cells/l at Punta Levisa and 27 x10^4 cells/l at El Chancarral sampling stations. *Lyngbya majuscula* reached 35 x10^4 cells/l at Estero El Fraile, *Limnoraphis hieronymusii* 29 x10^4 cells/l only at Río Sábalo, and, as already mentioned, *Merismopedia convoluta* reached a very high density of 1600 x10^4 cells/l only at El Fraile.

The cyanoprokaryote *Oscillatoria* af. *limosa* showed values of 10.2 x10^5 cells/l at La Boya, 61 x10^4 cells/l at El Real, 81 x10^4 cells/l at Punta Levisa and 27 x10^4 cells/l at El Chancarral sampling stations. *Lyngbya majuscula* reached 35 x10^4 cells/l at Estero El Fraile, *Limnoraphis hieronymusii* 29 x10^4 cells/l only at Río Sábalo, and as already mentioned, *Merismopedia convoluta* reached a very high density of 1600 x10^4 cells/l only at El Fraile.

Discussion

It was observed that depth varied little in the sampling stations between the two periods, except at El Real which was far deeper in the rainy season (near 230 cm) than in the dry one (73 cm), probably due to erosion caused by currents. The rest of the sampling stations were shallow, reaching only a few centimeters deep, comparable to the mean depth of Mexican lagoons (150 cm; Lankford, 1977).

The temperatures recorded in our study (25 to 33.5 °C) were higher than those reported by Lankford (1977) and García-Cubas & Reguero (1995), with values close to 24 °C. Likewise, we recorded the highest temperatures in the rainy season, whereas Morán (1994) reported highest values in dry season.

The highest salinities found in dry season (20 psu) were similar to those previously reported by Morán (1994). At both seasons, the lowest values (0-7 psu) were observed closed to river outlet (La Palma and Basura rivers) and the highest (18-19 psu) in Arroyo la Boya near the mouth of the lagoon. In Río Sábalo salinity fluctuated from 14 to 20 psu, probably due to water stagnation and evaporation, and the low contribution of fresh water from the river, coinciding with that reported by Lankford (1977) and Muciño-Márquez *et al.* (2012). In this regard, García-Cubas & Reguero (1995) point out that the lagoon is predominantly mesohaline, with frequent fluctuations of 5 to 18 psu.

The lagoon has a pH close to neutrality (from 6.7 to 7.9) and is rather well oxygenated with concentration showing greater fluctuations in the rainy season (3.3. mg/L to 11.6 mg/L) than in the dry season (5.3 mg/L to 7.8 mg/L), remaining within the appropriate intervals for aquatic life. These values coincide with those reported by Carbajal (2009) for this lagoon, and by Contreras & Warner (2004), Contreras *et al.* (2005) and López Ortega *et al.* (2012), for other lagoons in the State of Veracruz.

We did not measure nutrients during this study, but according to Castro-Gutiérrez *et al.* (1985), nutrients are not usually limiting for the development of phytoplankton in the lagoon due to river inputs and contributions of matter from the adjacent vegetation together with the recycling mechanisms and processes.

According to Lankford (1977), Castro-Gutiérrez *et al.* (1985), Martínez (1987), Morán (1994), Figueroa-Torres *et al.* (2009), Muciño-Márquez *et al.* (2011a, 2012) and Esquivel & Soto-Castor (this issue), the Sontecomapan lagoon presents three zones, based on morphology, and on gradients of salinity and nutrient concentration. The first is oligohaline with high fresh water influence and highest nutrient level. The second, in the central channel, is considered as a transition zone between mesohaline and polyhaline water, with the lowest nutrient values and greater salinity variations. The third zone, euhaline, corresponds to the lagoon's mouth. This zone behaves as an area of water masses exchange with the coastal zone and over time, recycling of nutrients has been observed at different scales as a consequence of the process of water mass regeneration and population succession. These processes are directly influenced by climatic seasonal changes, hydrometeorological conditions, and circadian and tidal rhythms, all of them widely recognized as important in the study of phytoplankton (Castro-Gutierrez *et al.*, 1985; Guerra-Martínez, 1996; Figueroa-Torres *et al.*, 2009 & Muciño-Márquez *et al.*, 2011 a, b and 2012), and were also probably important drivers for the variability observed in this study.

The dendrogram showed a spatial arrangement in the dry season very similar to the salinity gradients described above, with three different areas clearly related to salinity. However, in the rainy season our results suggest differences also linked to morphological characteristics of the sites. At this period, the Río Sábalo was separated from El Real probably due to its location in a confined area with little current and evaporation processes, maintaining high salinity values while El Real, located near the mouth of the lagoon, had high seawater influence linked to tidal effect (Muciño-Márquez, 2011a, b). Río Basura, farther from the mouth of the lagoon, has higher hydrodynamic and greater fresh water influence than El Sábalo.

From the samples analyzed in this work, a total of 102 phytoplankton species were recorded. The predominance of diatoms and dinoflagellates agrees with that reported by Muciño-Márquez, (2011a, b). The highest abundance occurred in February, 2017, corresponding to the dry season, in agreement with Suchil (1990) who points out that the dry months produce stability and adequate conditions for the best development of phytoplankton.

Of the species identified, 61 are new records for the lagoon, this suggests that species richness may be underestimated, possibly due to the presence of very diverse microenvironmental conditions and to the constant introduction and species exchange of continental and marine origin by the water currents.

Additionally, in the dry season, it was observed that the richness and abundance of species were very variable throughout stations and sampling sites, with importance of freshwater species in the rainy season and of potentially toxic or harmful algae of marine lineage, aspects that were repeatedly observed in previous studies (Guerra-Martínez & Lara-Villa, 1996; Figueroa-Torres *et al.*, 2009).

The most frequent and abundant species was *Tripos hircus*, especially in the dry season, with a maximum density of 20 x 10^4 cells/l. Guerra-Martínez and Lara-Villa (1996) recorded high densities of this species in the lagoon, at salinities of 13-35 psu and temperatures of 30 to 34 °C. The decrease of its population was associated with the increase of freshwater inputs in the system. Figueroa-Torres (1990), Zamudio-Reséndiz (1998) and Okolodkov (2010), among others, have observed that this species is common in the waters of the Gulf of Mexico, and López (1980) considers it as an indicator of nutrient-rich and warm water.

Within the species recorded, 17 are potentially harmful, and 2 may affect human health: the *Dinophysis caudata* dinoflagellate that may cause diarrhea through consumption of contaminated shellfish and, the cyanoprocariota *Lyngbya majuscula* that may cause dermatitis and respiratory irritation.

By combining our results with historical data, we could establish a current register of 357 phytoplankton species for the Sontecomapan Lagoon. This inventory is dominated by diatoms and dinoflagellates, characteristic of brackish and marine environments, but also includes freshwater microalgae such as chlorophytes and euglenofites showing the polyhaline nature of the lagoon ecosystem.

Among this list 46 species formed algal blooms, and 12 of them are potentially toxic, five species affect humans and five more affect marine fauna.

Table 2. Species of phytoplankton of the Sontecomapan Lagoon, Veracruz, that can form blooms.

	Characteristics	References
DIATOMS		
Bacillaria paxillifera (O. F. Müller) T. Marsson	Abundant in the Sontecomapan lagoon in high salinities. Form macroscopic aggregates of brown colonies	1, 18, 20, **28**
Cerataulus smithii Ralfs	Apparently not toxic	27, **28**
Chaetoceros atlanticus Cleve	Some authors report it as a harmfull species in other bodies of water	12, 18, 20 13, 25
Chaetoceros cf. *debilis* Cleve	May cause anoxia due to high number of organisms	18, 20
Chaetoceros holsaticus F. Schütt	Form spring blooms in the Baltic Sea	22
Coscinodiscus centralis Ehrenberg	Non toxic	18, 20, **28**
Coscinodiscus concinnus W. Smith	Harmful species	13, 18, 20
Coscinodiscus granii L. F. Gough	Form mucilaginous aggregates brown green	7, 18, 20
Coscinodiscus jonesiana (Greville) E. A. Sar & I. Sunesen	Apparently non toxic	27, **28**
Cyclotella meneghiniana Kützing	Not toxic. It is found in eutrophic waters	19, 20, **28**
Eupodiscus radiatus Bailey	Apparently non toxic	27, **28**
Melosira moniliformis (O. F. Müller) C. Agardh	It can form long chains on macroalgae in saline waters, flowering has been reported in Hawaiian Stream Ecosystems	16, **28**
Melosira nummuloides C. Agardh	Forms flowering in other bodies of water	6, **28**
Nitzschia longissima (Brebisson) Ralfs	Forms flowering in other bodies of water	20
Pleurosigma rigidum var. *incurvatum* Brun	Forms flowering in other bodies of water	18
Proboscia alata (Brightwell) Sundström	Apparently non toxic	18, 20
Pseudo-nitzschia pungens (Grunow ex Cleve) Hasle	It forms pale green blooms. It produces domoic acid, causing amnesic poisoning in humans, by the consumption of contaminated molluscs	12, 18, 20
Pseudo-nitzschia pungens var. *atlantica* (Cleve) Moreno & Licea	Toxic, produces domoic acid	12, 18
Pseudo-nitzschia seriata (Cleve) H. Peragallo	Toxic, produces domoic acid Causes amnestic poisoning from contaminated shellfish consumption Flowering of this species has been reported in the bays of Sechura and Pisco, Peru.	12, 18, 20, 24

Table 2. (Continuation)

	Characteristics	References
DINOFLAGELLATES		
Akashiwo sanguinea (K. Hirasaka) G. Hansen & Moestrup	It forms yellowish brown blooms. It causes anoxia in other bodies of water	18, 20, **28**
Dinophysis caudata Saville-Kent	Causes diarrhea in humans due to consumption of contaminated shellfish	1, 12, 15, 18, 20, **28**
Gonyaulax polygramma Stein	Form harmful flowers in the southern Gulf of Mexico	8, 15, **28**
Gonyaulax spinifera (Claparède et lachmann) Diesing	Producer of yessotoxin, fish and invertebrates were apparently killed by this bloom, which was rapidly dispersed by tides and wind-forcing.	9, 20
Gonyaulax turbynei Murray & Whitting	Causes anoxia in other bodies of water	18, 20
Gyrodinium spirale (Bergh) Kofoid & Swezy	Orange blooms. Abundant in the Sontecomapan lagoon, in high salinity, it causes anoxia in other bodies of water	18, 20
Noctiluca scintillans (Macartney) Kofoid & Sweay	It forms milky pink, pink or orange blooms. It is found in high concentrations of ammonium	1, 18, 20
Peridinium quadridentatum (F. Stein) Gert Hansen	It has been observed in the Sontecomapan lagoon associated with *Tripos hircus* and *Prorocentrum cordatum*	1
Phalacroma rotundatum (Claparède & Lachmann) Kofoid & Michener	Toxic species, can cause problems to the salmon in captivity by its long silicified chains.	3, 10, 20
Prorocentrum cordatum (Ostenfeld) J. D. Dogge	It has been observed in the lagoon of Sontecomapan, associated to *P. quadridentatum* and *Tripos hircus*	1
Prorocentrum gracile Schütt	Abundant in the Sontecomapan lagoon in high salinities. Has caused fish mortality in Tabasco	14, 18, 19, 20, 21
Prorocentrum mexicanum	It forms algae blooms in other bodies of water.	19
Prorocentrum micans Ehrenberg	Pale-brown blooms. A flowering was reported in Bahía Magdalena, in shallow waters. Occasionally causes hyperoxia or anoxia Produces toxin verupine (hepatoxin) affecting clams and shellfish	15, 18, 19, 20, 21
Protoperidinium depressum (Bailey) Balech	Flowering of this species has been reported in the bays of Sechura and Pisco, Peru.	20, 24, **28**
Scrippsiella acuminata (Ehrenberg) Kretschmann, Elbrächter, Zinssmeister, Soehner, Kirsch, Kusber & Gottschling	Coffee Flowering. Abundant in the Sontecomapan lagoon in high salinity, it causes anoxia in other bodies of water	15, 18, 20, **28**
Tripos furca (Ehrenberg) F. Gómez	It forms orange blooms. May cause anoxia. It has been observed in the Sontecomapan lagoon, at the time dry, sometimes associated with *P. quadridentatum* and *Prorocentrum cordatum*. It has been reported as harmful in Puerto Escondido, Baja California, causing great mortality of tuna in captivity.	11, 12, 15, 18, 20, 23

Table 2. (Continuation)

	Characteristics	References
DINOFLAGELLATES		
Tripos fusus (Ehrenberg) F. Gómez	Produces hydrogen sulfide	11, 12, 18,20
Tripos hircus (Schröder) F Gómez	When it is very abundant it produces anoxia	12, **28**
Tripos muelleri Bory	Apparently non-toxic	18
Tryblionella compressa (J.W.Bailey) Poulin	Yellow brown flowering .Apparently non-toxic	18, 19, 20
EUGLENOPHYTES		
Euglena cf. *stellata* Mainx	Apparently non-toxic	18, 20
Euglena cf. *viridis* (O. F. Müller) Ehrenberg	Apparently non-toxic	18, 20
CYANOPROKARYOTES		
Anabaenopsis circularis (G. S. West) Woloszynska & V. Miller	Produces toxins	5, 18, 26, **28**
Arthrospira platensis Gomont	Apparently non-toxic	2, **28**
Lyngbya majuscula Harvey ex Gomont	May cause respiratory dermatitis and irritation	4, **28**
SILICOFLAGELLATE		
Dictyocha fibula Ehrenberg	Causes anoxia in other bodies of water	18, 20
RAPHIDOPHYCEAE		
Chatonella sp	Produces massive blooms	18
Olisthodiscus luteus N. Cartes	Causes anoxia in other bodies of water. Preliminary data show is hemolytic (disintegrates erythrocytes or red blood cells)	17. 18, 20

(1) Aké-Castillo & Vázquez-Hurtado 2008, (2) Arulmoorthy *et al.* 2017, (3) Cassis *et al.* 2002, (4) Chi *et al.* 2012, (5) Churro *et al.* 2009, (6) Dimar 2011, (7) Fukao *et al.* 2009, (8) Gárate-Lizárraga *et al.* 2006, (9) Gárate-Lizárraga *et al.* 2014, (10) González-Gil *et al.* 2011, (11) Guerra-Martínez 1996, (12) Guerra-Martínez & Lara-Villa 1995, (13) Guiry & Guiry 2017, (14) LESP 2005, (15) Licea *et al.* 2002, (16) Mathew 2007, (17) Moestrup 2002, (18) Muciño-Márquez *et al.* 2011 a, (19) Muciño-Márquez *et al.* 2011 b, (20) Muciño-Márquez *et al.* 2012, (21) Muciño-Márquez *et al.* 2015, (22) Nommann & Kaasik 1992, (23) Orellana-Cepeda *et al.* 2002, (24) Orozco *et al.* 2017, (25) Rivera & Sánchez 2011, (26) Walker 2004, (27) Meave y Moreno (1997), (28) this study.

It is worth noting that most of the toxic species were present in the dry season, so special attention should be paid to their presence at this season. It is not possible to rule out the possibility that the above-mentioned species may be present again and in higher concentrations. Besides new harmful and toxic species may also develop because of accelerated processes of eutrophication of anthropic origin in the last years in the coastal lagoons, which can affect economic production, human health and marine biota.

Conclusions

The Sontecomapan lagoon is an ecosystem with marked hydrodynamic processes at different times of the year. Salinity appears as a determinant factor, which confers a polyhaline character to the system, forming three characteristic zones: the first with strong influence of fresh water, the second brackish and the third with more marine influence.

Other physical and chemical factors such as pH, temperature and dissolved oxygen generate particular microenvironmental conditions that drive the distribution and abundance of phytoplankton species, in addition to which the intrinsic characteristics of the species must be considered in order to tolerate certain environmental conditions. However, there are few studies on this subject and so far, no clear behavioral patterns can be established.

From this study, a list of 102 species was obtained, with 61 new records for the area, with only two species toxic to man and none for aquatic fauna. Combining this list with previous historical data, we could establish a current list of 357 phytoplankton species for the lagoon, of which 46 are potentially harmful or toxic.

Due to the importance of this resource, it is necessary to continue sampling and monitoring the phytoplankton of the Sontecomapan Lagoon, since the harmful and toxic species can develop and reach alarming densities at any time, emphasizing the dry season, when more problematic species are present. It is also important to consider that the accelerated process of anthropic origin eutrophication that occurred in the last years in the Mexican coastal lagoons may affect the economic production, human health and marine biota.

Acknowledgements

This study was supported by the 2002-39634-F/A-1 project CONACYT, the Mobility ECOS-ANUIES-CONACYT Program (189448) and the Universidad Autónoma Metropolitana, Unidad Xochimilco. The authors thank Lic. Suny Ramírez Figueroa for her support in the manuscript review.

References

Aké-Castillo, C. J., M. E. Meave del Castillo & D. U. Hernández-Becerril. 1995. Morphology and distribution of species of the diatom genus *Skeletonema* in a tropical coastal lagoon. European Journal of Phycology, 30 (2): 107-115.

Aké Castillo, J. A. & M. E. Meave, 1997. *Skeletonema subsalsum*. In González S., R. Dirzo & R. C. Vogt (eds). Historia Natural de Los Tuxtlas. Parte III: Otros Grupos: Listados. UNAM, Instituto de Biología, Instituto de Ecología, CONABIO, México, pp. 197-199.

Aké-Castillo, C. J., S. L. Guerra-Martínez & M. E. Zamudio-Reséndiz. 2000. Especies de *Chaetoceros* Ehrenberg (Bacillariophyceae) con número reducido de quetas presentes en una laguna costera. In: Ríos, J., E. Juárez, M. Pérez, E. López, E. G. Robles, D. U. Hernández-Becerril & M. Silva (eds). Estudios sobre Plancton en México y el Caribe. Sociedad Mexicana de Planctonología y Universidad de Guadalajara, México, pp. 77-78.

Aké-Castillo, C. J., S. L. Guerra-Martínez & M. E. Zamudio-Reséndiz. 2004. Observations on some species of *Chaetoceros* (Bacillariophyceae) with reduced number of setae from a tropical coastal lagoon. Hydrobiologia, 524 (1-3): 203-213.

Aké-Castillo, C. J. & G. Vázquez-Hurtado. 2008. Phytoplankton variation and its relation to nutrients and allochthonous organic matter in coastal lagoon on the Gulf of Mexico. Estuarine, Coastal and Shelf Science, 78: 705-714.

Aké-Castillo, C. J. & G. Vázquez-Hurtado. 2011. *Peridinium quinquecorne* var *trispiniferum* var nov. (Dinophyceae) from a brackish environment. Acta Botánica Mexicana, 94: 125-140.

Aké-Castillo, C. J. 2015. Descripción morfológica y autoecología de *Thalassiosira cedarkeyensis* A.K.S.K. Prasad (Bacillariophyta: Thalassiosirales), en la laguna de Sontecomapan, Veracruz, México. Cymbella, 1: 12-18.

Arulmoorthy, M. P., S. Vasudevan, V. Ashokprabu & M. Srinivasa. 2017. First Report on the Cyanobacteria *Spirulina platensis* bloom and its effect on the physico-chemical parameters, at Muttukadu backwater, Southeast coast of India. Phykos, 47 (1): 52-58.

Balech, E. 1988. Los Dinoflagelados del Atlántico Sudoccidental. Publicación del Instituto Español de Oceanografía Madrid, España.

Bravo, E. 2004. Fitoflagelados potencialmente tóxicos y nocivos de las costas del Pacífico Mexicano. Biología Tropical, 52 (1):5-16.

Camacho, R., R. Flores, F. Flores, A. Salas, A. Juárez, J. Vega, M. Lara-Villa & S. Licea. 1994. Ciclo circadiano del fitoplancton de la laguna de Sontecomapan, Veracruz (octubre-1993). Resúmenes VII Reunión SOMPAC.

Carbajal, R. F. 2009. Diatomeas de la laguna de Sontecomapan, Veracruz y su importancia como indicadores biológicos. Tesis Maestría en Ciencias Agropecuarias. Universidad Autónoma Metropolitana, Unidad Xochimilco.

Cassis, D., P. Muñoz, S. Avaria. 2002. Variación temporal del fitoplancton entre 1993 y 1998 en una estación fija del seno Aysén, Chile (45º 26' S; 73º 00' W). Universidad de Valparaíso Viña del Mar, Chile. Revista de Biología Marina y Oceanografía, 37(1): 43-65.

Castro-Gutiérrez, A., P. J. Franco, J. R. Nava, C. P. Chinolla & L. E. Portilla. 1985. Relación de nutrimentos y producción secundaria en una laguna costera. Mem. VIII Congr. Nal. Zool., pp. 1034-1036.

Contreras, E. F. & B. G. Warner. 2004. Ecosystem characteristics and management considerations for coastal wetlands in Mexico. Hydrobiología, 511 (1-3): 233-245.

Contreras-Espinosa F., N. E. Rivera-Guzmán & R. Segura-Aguilar. 2005. Nutrimentos y productividad primaria fitoplanctónica en una laguna costera tropical intermitente (La Mancha, Ver.) del Golfo de México. Hidrobiológica, 15 (3): 299-310.

Chin, S. L. N., L. J. Ong & L. M. Chou. 2012. *Lyngbya majuscula* blooms in an enclosed marine environment available. Environment Asia, 5(2): 93-98.

Churro, E., C. Alverca, F. Sam-Bento, S. Paulino, V. C. Figueira, A. J. Bento, S. Prabhakar, M. Lobo, A. J. Calado & P. Pereira. 2009. Effects of bacillamide and newly synthesized derivatives on the growth of cyanobacteria and microalgae cultures. Journal of Applied Phycology, 21 (4): 429-442.

Dimar, C. 2011. Catálogo de Fitoplancton de la Bahía de Cartagena, Bahía Portete y Agua de Lastre. Dirección General Marítima, Centro de Investigaciones Oceanográficas e Hidrográficas del Caribe. Dimar, Serie de Publicaciones Especiales CIOH, Vol 5. Cartagena de Indias, Colombia.

Dodge, J. D. 1982. Marine dinoflagellates of the British Isles. London HMSO.

Figueroa-Torres, M. G. 1990. Sistemática y distribución del Género *Ceratium* Schrank 1793 en el sur del Golfo de México (feb-dic. 1987). Tesis de Maestría. Facultad de Ciencias. Universidad Nacional Autónoma de México. México, D. F.

Figueroa-Torres, M. G., J. L. Moreno-Ruiz, M. J. Ferrara-Guerrero, M. A. Zepeda-Esquivel & I. Weiss-Martínez. 2009. Dinoflagelados tecados de la laguna de Sontecomapan, Veracruz, Mexico. In Ayala-Pérez, L., R. Gío-Argaez & N. Trigo-Boix (eds.). Contribuciones Metodológicas al Conocimiento de los Recursos Naturales. Edición especial Universidad Autónoma Metropolitana Xochimilco, Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México y Sociedad Mexicana de Historia Natural, pp. 35-44.

Fukao, T., K. Kimoto, T. Yamatogi, K. Yamamoto, Y. Yoshida & Y. Kotani. 2009. Marine mucilage in Ariake Sound, Japan, is composed of transparent exopolymer particles produced by the diatom *Coscinodiscus granii*. Fishery Science, 75: 1007-1014.

Fukuyo, Y., H. Tahano, M. Chihara & K. Matsuoka. 1990. Red tides organism in Japan. An illustrated taxonomic guide. Rakakuho Tokio.

Gárate-Lizárraga, I., M. S. Muñetón-Gómez & S. Maldonado-López. 2006. Florecimiento del dinoflagelado *Gonyaulax polygramma* frente a la isla Espíritu Santo, Golfo de California, México. Revista de Investigación Marina, 27 (1): 31-39.

Gárate-Lizárraga, I., M. S. Muñetón-Gómez, B. Pérez-Cruz & J. A. Díaz –Ortíz. 2014. Bloom of *Gonyaulax spinifera* (Dinophyceae: Gonyaulacales) in Ensenada de la Paz Lagoon, Gulf of California. CICIMAR Oceánides, 29(1): 11-18.

García-Cubas, A. & M. Reguero. 1995. Moluscos de la laguna de Sontecomapan, Veracruz, México: sistemática y ecología. Hidrobiológica, 5 (1-2): 1-24.

García-Mendoza, E., S. I. Quijano-Scheggia, A. Olivos-Ortiz & E. J. Núñez-Vázquez (eds.). 2016. Florecimientos Algales Nocivos en México. CICESE. Ensenada, México.

Gómez, F. 2010. *Neoceratium* gen. nov, a new genus for all marine species currently assigned to *Ceratium*. Protistology, 161(35-54): 35-54

Gómez, F. 2013. Reinstatement of the dinoflagellate genus *Tripos* to replace *Neoceratium*, marine species of *Ceratium* (Dinophyceae, Alveolata). CICIMAR Oceánides, 28(1): 1-22.

González-Gil, S., G. Pizarro, B. Paz, L. Velo-Suárez & B. Reguera. 2011. Considerations on the toxigenic nature and prey sources of *Phalacroma rotundatum*. Aquatic Microbial Ecology, 64 (1): 197-203.

Guerra-Martínez, S. L. 1996. Variaciones de la biomasa nano y microplanctónica en la boca de la laguna de Sontecomapan Ver (1992-1993). Tesis de licenciatura (Biología), Facultad de Ciencias, UNAM, México.

Guerra-Martínez, S. L. & M. A. Lara-Villa, 1996. Florecimiento de *Ceratium furca* (Peridiniales: Ceratiaceae) en un ambiente salobre: Laguna de Sontecomapan, México. Revista Biología Tropical, 44 (1): 23-30.

Guerra-Martínez, S. L. & M. E. Meave del Castillo. 1997. *Ceratium furca* var *hircus*. In González S., R. Dirzo & R. C. Vogt (eds.). Historia Natural de Los Tuxtlas. Parte III: Otros Grupos: Listados. UNAM, Instituto de Biología, Instituto de Ecología, CONABIO, México, pp. 195-196.

Guiry, M. D. & G. M. Guiry. 2017. AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org. Rearched on 12 October 2017.

Lankford, R. R. 1977. Coastal lagoons of Mexico: their origin and classification. Estuarine Processes, 2: 182-215.

LESP. 2005. Instrucción de trabajo para el muestreo de fitoplancton in Muciño-Márquez, R. E., M. G Figueroa-Torres & A. Aguirre-León. 2015. Cianofitas de los sistemas fluvio-lagunares Pom-Atasta y Palizada del Este, adyacentes a la laguna de Términos, Campeche, México. Polibotánica, 39: 49-78.

Licea, S., J. L. Moreno, H. Santoyo & G. Figueroa. 1995. Dinoflagelados del Golfo de California. Universidad Autónoma de Baja California / SEP / FOMES, México.

Licea, S., M. E. Zamudio, R. Luna, Y. B. Okolodkov & S. Gómez-Aguirre, 2002 Available from: Yuri Okolodkov, Retrieved on: 29 March 2016 Toxic and Harmful Dinoflagellates in the Southern Gulf of Mexico. https://www.researchgate.net/publication/233993871_Toxic_and_harmful_dinoflagellates_in_the_southern_Gulf_of_Mexico. Rearched on 2 October 2017.

López, L. 1980. Distribución fitogeográfica de *Ceratium furca* (Ehrenberg) Claparade y Lachmann var *hircus* (Schröder) Margalef (Dinoflagellatae, Peridinidae). Academia de Ciencias de Cuba. Informe Técnico 121. La Habana, Cuba.

López Ortega, M., G. Pulido Flores, A. Serrano Solís, J. C. Gaytán Oyarzún, W. S. Monks Sheets & M. A. López Jiménez. 2012. Evaluación estacional de las variables físicoquímicas del agua de la Laguna de Tampamachoco, Veracruz, México. Revista Científica UDO Agrícola, 12(3): 713-719.

Martínez, M. G. 1987. Distribución y abundancia estacional del ictioplancton de la laguna de Sontecomapan, Veracruz. Tesis profesional. UNAM, ENEP-Iztacala.

Mathew, L. J. 2007. Why sweat the small stuff: the importance of microalgae in Hawaiian Stream In Evenhuis, N. L. & J. M. Fitzsimons (eds.). Ecosystems Biology of Hawaiian Streams and Estuaries. Bishop Museum Bulletin in Cultural and Environmental Studies, 3: 183–193.

Meave del Castillo, M. E & M. A. Lara-Villa. 1997. Diatomeas planctónicas de la laguna de Sontecomapan. In González S., R. Dirzo & R. C. Vogt (eds.). Historia Natural de Los Tuxtlas. Parte III: Otros Grupos: Listados. UNAM, Instituto de Biología, Instituto de Ecología, CONABIO, México D. F., pp. 209-212.

Meave del Castillo M. E. & J. L. Moreno-Ruiz. 1997. *Coscinodiscus jonesianus*. In González S., R. Dirzo & R. C. Vogt (eds). Historia Natural de Los Tuxtlas. Parte III: Otros Grupos: Listados. UNAM, Instituto de Biología, Instituto de Ecología, CONABIO, México, D. F., pp. 196-197.

Moestrup, O. 2002. Fitoflagelados Potencialmente Toxígenos en el Cono Sur Americano In Ferrario, M. E. & B. Reguera (eds). Floraciones Algales Nocivas en el Cono Sur Americano Sar. Instituto Español de Oceanografía, pp. 145-154.

Morán S. A. 1994. Caracterización hidrológica y espacio-temporal con base en los nutrientes y clorofila a de la laguna de Sontecomapan, Veracruz. Tesis de licenciatura. ENEP-Iztacala. UNAM, 66 pp.

Muciño-Márquez, R. E., M. G. Figueroa-Torres & A. Esquivel-Herrera. 2011a. Variación nictemeral de la comunidad fitoplanctónica y su relación con las especies formadoras de florecimientos algales nocivos en la boca de la laguna costera de Sontecomapan, Veracruz, México. CICIMAR Oceánides, 26(1): 19-31.

Muciño-Márquez, R. E., M. G. Figueroa-Torres & I. Gárate-Lizárraga. 2011b. Variación nictemeral de del género *Prorocentrum* (Dinophyceae) en la laguna de Sontecomapan, Veracruz, UAM-Xochimilco. E-BIOS 1, (1): 3-13.

Muciño-Márquez, R. E., M. G. Figueroa-Torres & I. Gárate-Lizárraga. 2012. Especies fitoplanctónicas formadoras de proliferaciones algales nocivas en la boca de la laguna costera de Sontecomapan, Veracruz, México. Cuadernos de Investigación UNED 3, (2):151-160.

Muciño-Márquez, R. E., I. Gárate-Lizárraga & D. J. López-Cortés. 2015. Variación estacional del Género *Prorocentrum* (Dinophyceae) En dos Granjas Atuneras en la Bahía de La Paz, México. Bogotá, Colombia. Acta Biológica Colombiana, 20(1): 195-206.

Nommann, S. & E. Kaasik. 1992. Hydrodynamical control of phytoplankton succession during the vernal light-limited phase in the Baltic Sea. Marine Ecology Progress Series, 84: 279-292.

Okolodkov, Y. 2010. *Ceratium* Schrank (Dinophyceae) of the National Park Sistema Arrecifal Veracruzano, Gulf of México, whit a key for identification. Acta Botánica Mexicana, 93: 41-101.

Orellana-Cepeda, E., C. Granados-Machuca & J. Serrano-Esquer. 2002. *Ceratium furca*: One possible cause of mass mortality of cultured blue fin tuna at Baja California, Mexico. Proceedings of the 10th International Conference on Harmful Algae, 21-25 October, St. Petesburg Beach, Florida, USA.

Orozco, R., Y. Quispe, A. Lorenzo & M. L. Zamudio. 2017. Asociación de floraciones de algas nocivas y *Vibrio* spp en áreas de pesca y acuicultura de bivalvos en las bahías de Sechura y Pisco, Perú Revista Peruana de Biología, 24(1): 111-116.

Rivera, M. & P. Sánchez. 2011. Diatomeas Planctónicas del Litoral de Andalucía (España). Acta Botánica Malacitana, 36: 5-31.

Strickland, J. & T. Parsons. 1972. A practical handbook of seawater analysis. Fisheries Research Board of Canada. Ottawa, Canada.

Suchil, V. M. A. 1990. Determinación de la variación estacional de fitoplancton, y su relación con los parámetros físicos y químicos de las lagunas de: Sontecomapan y del Ostión, Ver. para el año de 1985. Tesis profesional. Universidad Nacional Autónoma de México, ENEP-Z.

Taylor, F. J. R. 1976. Dinoflagellates from Internacional Indian. Ocean expedition. Bibliotheca Botanica. Srittgart, Germany.

Walker, D. 2004. The Valley of the Sub and tehe central Arizona Basin. Comprehensive Watershed Management: Water Quality Monitoring Report. University of Arizona. https://cals.arizona.edu/limnology/watersheds/reports/Report070704.pdf (Reached on 3 October 2017)

Zamudio-Reséndiz, M. E. 1998. Hidrología y fitoplancton en una región costera al oeste del Golfo de México. Tesis de Maestría. Instituto de Ciencias del Mar y Limnología. Colegio de Ciencias y Humanidades. Universidad Nacional Autónoma de México. México.

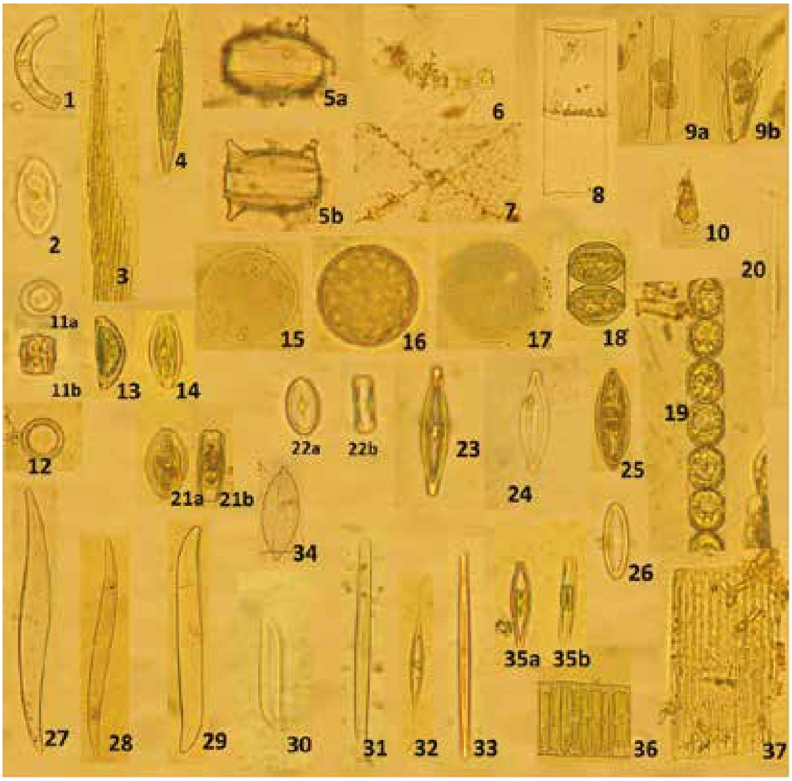

Plate 1 Figures 1. *Aulacoseira granulata*; 2. *Cocconeis placentula*; 3. *Bacillaria paxillifera*; 4. *Brachysira procera*; 5a y b. *Cerataulus smithii;* 6. *Chaetoceros* sp. 1; 7. *Chaetoceros* sp. 2; 8. *Guinardia flaccida*; 9a y b. *Entomoneis alata;* 10. *Entomoneis ornata*; 11a y b. *Cyclotella meneghiniana*; 12. *Cyclotella* sp; 13. *Cymbella minuta;* 14. *Cymbella próstata*; 15. *Coscinodiscus* af *jonesiana*; 16. *Coscinodiscus* af *radiatus*; 17. *Coscinodiscus* sp. 1; 18. *Melosira moniliformis*; 19. *Melosira nummuloides*; 20. *Cylindrotheca closterium*; 21a y b. *Diploneis puella;* 22a y b. *Diploneis smithii;* 23. *Navicula capitatoradiata*; 24. *Navicula veneta*; 25. *Navicula* sp. 1; 26. *Navicula* sp. 2; 27. *Gyrosigma acuminatum;* 28. *Gyrosigma attenuatum;* 29. *Gyrosigma balticum;* 30. *Gyrosigma eximium;* 31. *Gyrosigma* af *scalproides*; 32. *Gyrosigma fasciola*; 33. *Fragilaria* af *fasciculata*; 34. *Lyrella lyra*; 35a y b. *Gomphonema parvulum*; 36. *Eunotia* sp; 37. *Fragilaria* sp.

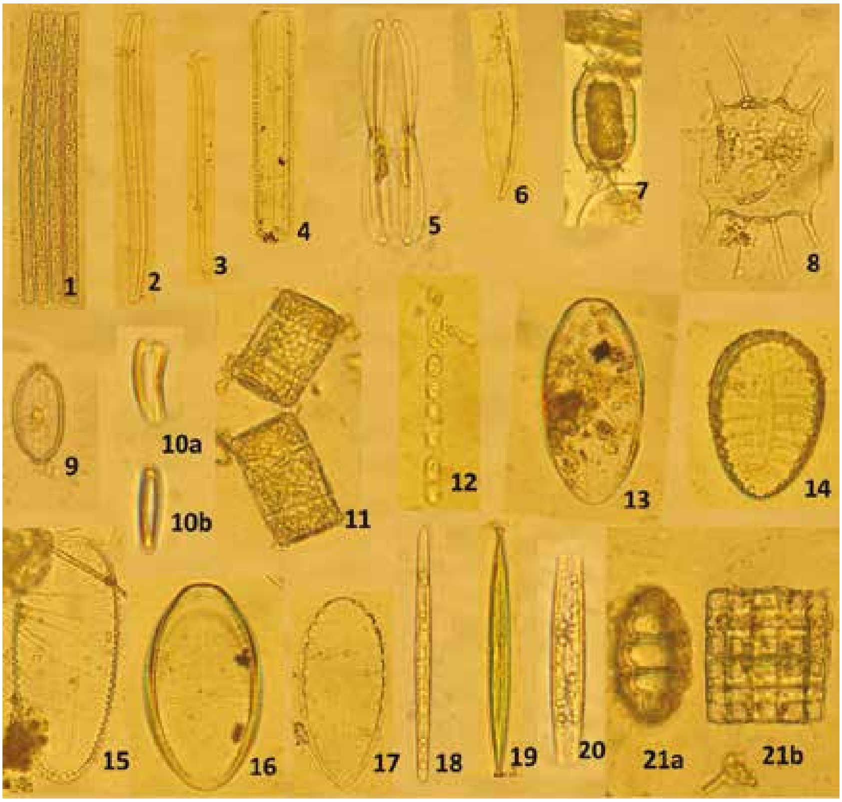

Plate 2 Figures 1. *Nitzschia macilenta*; 2. *Nitzschia sigma*; 3. *Nitzschia sigmoidea*; 4. *Pinnularia* sp; 5. *Plagiotropis lepidoptera*; 6. *Plagiotropis vítrea*; 7. *Odontella longicruris*; 8. *Odontella mobiliensis*; 9. *Petroneis humerosa;* 10. *Rhoicosphenia curvata*; 11. *Pleurosira laevis*; 12. *Skeletonema costatum*; 13. *Surirella* af *guatemalensis;* 14. *Surirella fastuosa* var *Cuneata*; 15. *Surirella febigerii*; 16. *Surirella gemma;* 17. *Surirella splendida*; 18. *Synedra superva;* 19. *Synedra tabulata*; 20. *Thallasionema nitzschioides;* 21a y b. *Terpsinoe musica*.

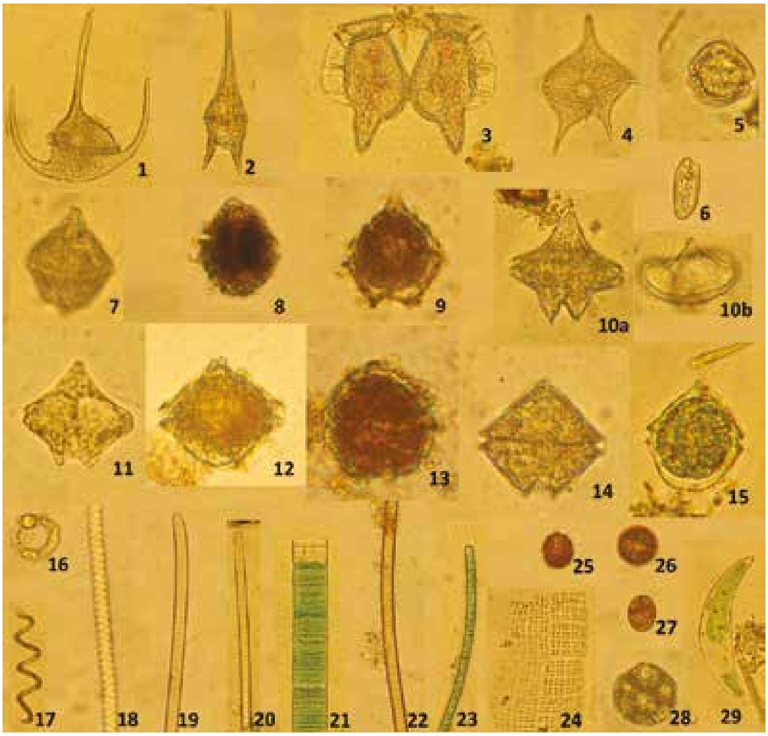

Plate 3 Figures 1. *Tripos tripos*; 2. *Tripos furca* var *hircus*; 3. *Dinophysis caudata*; 4. *Protoperidinium depressum*; 5. *Goniodoma sphaericum*; 6. *Oxyrrhis marina;* 7. *Gonyaulax polygramma*; 8. *Protoperidinium argentinense*; 9. *Protoperidinium brevipes*; 10a y b. *Protoperidinium curtipes*; 11. *Protoperidinium crassipes*; 12. *Protoperidinium punctulatum*; 13. *Protoperidinium thorianum;* 14. *Protoperidinium paulseni*; 15. *Scrippsiella acuminata*; 16. *Anabaenopsis circularis;* 17. *Arthrospira platensis;* 18. *Arthrospira subsalsa;* 19. *Phormidium nigroviride*; 20. *Oscillatoria* af *limosa;* 21. *Oscillatoria obtusa;* 22. *Oscillatoria* sp; 23. *Limnoraphis hieronymusii*; 24. *Merismopedia convoluta*; 25. *Trachelomonas hispida;* 26. *Trachelomonas lefebrei*; 27. *Trachelomonas volvocina;* 28. *Coelastrum microporum*; 29. *Closterium moniliferum*.

Figueroa Torres M.G., Almanza Encarnacion S., Ferrara-Guerrero M.J., Pagano Marc.

Phytoplankton of the Sontecomapan lagoon, Veracruz, Mexico.

In : Castellanos-Paez M.E. (ed.), Esquivel Herrera A. (ed.), Aldeco-Ramirez,J. (ed.), Pagano Marc (ed.). Ecology of the Sontecomapan lagoon, Veracruz. Mexico : UAM, IRD, 2018, p. 107-135.

ISBN 9786072815155