

Phytoplankton of the northern coastal and shelf waters of the Yucatan Peninsula, southeastern Gulf of Mexico, Mexico

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ABSTRACT: Based on long-term monitoring (2001-2012) and four oceanographic cruises (2010-2012) in the coastal and shelf waters of the Yucatan Peninsula, SE Gulf of Mexico, a list of 306 strictly phytoplanktonic and tycho planktonic species from 131 genera is presented: centric diatoms (83 species), raphid diatoms (47), araphid diatoms (22), Dinoflagellata (124), Cyanoprokaryota (18), Ebriacea (2), Chlorophyceae (3), Dictyochophyceae (2), Euglenophyceae (2), Cryptophyceae (1), Prymnesiophyceae (1), and Raphidophyceae (1). Diatoms also dominated the number of genera (80) followed by dinoflagellates (39) and cyanobacteria (11). The genera most abundant in species were *Chaetoceros* Ehrenb. (23 species), *Protoperidinium* Bergh (23) and *Ceratium* Schrank (17). The relative richness in species of the genus *Oxytoxum* (11 species) is related to the tropical affiliation of the phytoplankton community. Most of the tycho planktonic diatoms (57 species out of a total of 152 diatoms, or 37.5%) were observed principally from coastal samplings. Eighteen potentially toxic species were found.

INTRODUCTION

While there are checklists of both diatoms and dinoflagellates found in the Gulf of Mexico as a whole (Krayevsky *et al.* 2009, Steidinger *et al.* 2009) and a checklist of dinoflagellates of the southern Gulf of Mexico (Licea *et al.* 2004), information on planktonic algae of the Yucatan waters is scarce. Some data can be found in recently published literature (Licea *et al.* 2004; Troccoli Ghinaglia *et al.* 2004; Álvarez-Góngora and Herrera-Silveira 2006; Herrera-Silveira and Morales-Ojeda 2009; Álvarez-Góngora *et al.* 2012) and in a number of unpublished bachelors, masters and doctoral theses; the latter are considered gray literature and are not cited here.

To provide a preliminary list of both planktonic and tycho planktonic microalgae found in the coastal waters of the northern Yucatan Peninsula, based on original water-bottle samples, was the main purpose of this study.

MATERIALS AND METHODS

A dry warm climate characterizes the study area. Three seasons can be distinguished: a dry season from March to early June, a rainy season from June to October, and the “nortes” (northerly winds) season with short periods of storms and strong winds coming from the north, from November to February (Herrera-Silveira 1993).

Study area and sampling

Phytoplankton was sampled using a Van Dorn bottle during the coastal monitoring surveys in 2001-2012 and on four oceanographic cruises (Table 1). For this study, all the stations located on the continental platform of the northern part of the Yucatan Peninsula and some

stations beyond the 200-m isobath were considered. Coastal samples were collected at 17 sites along the coast line between Chuburná and Dzilam de Bravo (Figure 1). Sea water was taken at 0.5-1.0 m depth, 10-20 m from the beach; the water temperature ranged from 20.3 to 35.9°C and salinity ranged from 27.0 to 39.4 (down to 15.0 in the marina of Dzilam de Bravo). The samples were analyzed quantitatively using the Utermöhl method (Hasle 1978). Carl Zeiss Axiovert 100 and Olympus CK2 inverted microscopes were used.

Identifications were principally made at the species level when possible; otherwise, identification was at the generic level. Tycho planktonic species were also included. Information about the main habitat for some species of cyanobacteria, chlorophytes and pennate diatoms such as *Haslea* spp. remain unknown. AlgaeBase was consulted to verify currently accepted taxonomic names (Guiry and Guiry 2012). Abbreviations of authors of scientific names are used according to Brummit and Powell (1992) unless they were not listed in the book. The major eukaryotic groups are ordered in the list according to Adl *et al.* (2012). For diatoms, the division into three classes by Round *et al.* (1990) was followed, taking into account the most recently published catalogue of diatom genera (Fourtanier and Kociolek 1999).

RESULTS AND DISCUSSION

In total, 306 obligatorily phytoplanktonic and tycho planktonic species from 131 genera were found (Table 2): centric diatoms (83 species), pennate raphid diatoms (47), pennate araphid diatoms (22), Dinoflagellata (124), Cyanoprokaryota (18), Ebriacea (2), Chlorophyceae (3),

Dictyochophyceae (2), Euglenophyceae (2), Cryptophyceae (1), Prymnesiophyceae (1), and Raphidophyceae (1) (Figure 2). At least 24 species remained unidentified to the species level. The genera most abundant in species number were *Chaetoceros* Ehrenb. (23 species), *Protoperdinium* Bergh (23) and *Ceratium* Schrank (17). The prevalence of the former two genera is characteristic for both temperate and tropical regions. Furthermore, the following genera were well represented: *Prorocentrum* Ehrenb. (12 species), *Oxytoxum* F. Stein (11), *Amphora* Ehrenb. ex Kütz. (9), and *Nitzschia* Hassall (8). The genus *Amphora* is represented exclusively by tycho planktonic species. The relative richness in species of the genus *Oxytoxum* is related to the tropical affiliation of the phytoplankton community. Diatoms also dominated in the number of genera (80) followed by dinoflagellates (39), and cyanobacteria (11), with the rest of the major taxonomic groups contributing only one, two or three genera each.

Based on recently published literature on diatoms and dinoflagellates (Okolodkov *et al.* 2007; 2011a; Okolodkov, 2008; 2010; Krayevsky *et al.* 2009; Steidinger *et al.*

2009; Aké *et al.* 2012) and Wood (1968), new records for the Gulf of Mexico were revealed (Table 2). Based on the list of diatom species by Krayevsky *et al.* (2009), five diatom species are new records for the Gulf of Mexico, although we prefer to consider them new records for the southern (Mexican) Gulf of Mexico (Table 3) because we are unaware of the most recent advances in the diatom floristics in the northern/U.S. territorial waters of the Gulf of Mexico. Out of five new records of diatom species, four are tycho planktonic. The dinoflagellates *Oxytoxum constrictum* and *O. tessellatum* are absent in the list of Steidinger *et al.* (2009); however, they were reported from the Straits of Florida and the Caribbean Sea (Wood 1968). Thus they can be considered new records for the southern Gulf of Mexico. The highest occurrences were shown by *Neostreptothea subindica* and *Oxytoxum tessellatum*; four species were found exclusively during coastal surveys (Table 3). *Scrippsiella spinifera*, originally described from the Mediterranean, was also observed in the northern Yucatan waters as a relatively common species accompanying a bloom caused by *S. trochoidea*

TABLE 1. Hydrological (at 10 m depth) and bathymetrical data on oceanographic cruises around the northern Yucatan Peninsula.

CRUISE	DATES	SUBSURFACE WATER TEMPERATURE (°C)	SALINITY	SITE DEPTHS (M)
Xcambo-IV	9 September – 3 October 2010	27.70-30.50	19.00-36.78	4.0-200.0
GOMEX-2010	11-21 September 2010	21.93-30.12	32.65-36.73	15.0-200.0
GOMEX-2011	25 September – 2 October 2011	22.86-31.35	16.42-36.76	13.6-204.0
CO-12	9 July – 5 August 2012	24.70-29.10	36.40-37.20	16.0-256.0

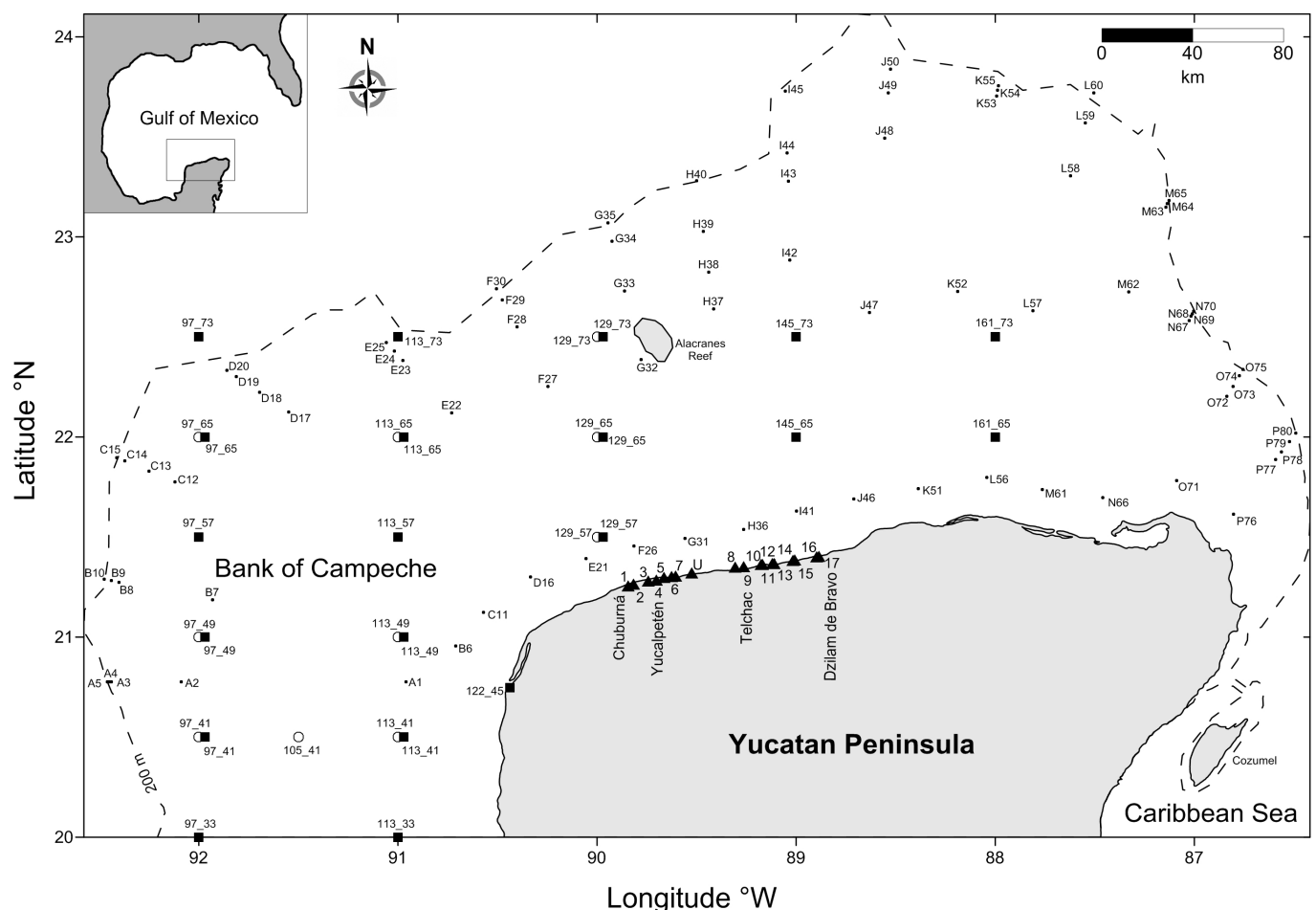


FIGURE 1. Sampling sites around the northern Yucatan Peninsula: filled triangles mean (oceanographic) stations of the coastal surveys (2001-2012), empty circles – Xcambo IV, filled small circles – GOMEX-2010 and GOMEX-2011; filled squares – CO-12.

in the marina of Dzilam de Bravo on 19 May 2009. It has been previously found in Yucatan waters, in the states of Campeche and Quintana Roo (Troccoli Ghinaglia *et al.* 2004), although it is not included in a checklist of dinoflagellates for the Gulf of Mexico published more recently (Steidinger *et al.* 2009). Therefore, we report it here for the first time for the state of Yucatan.

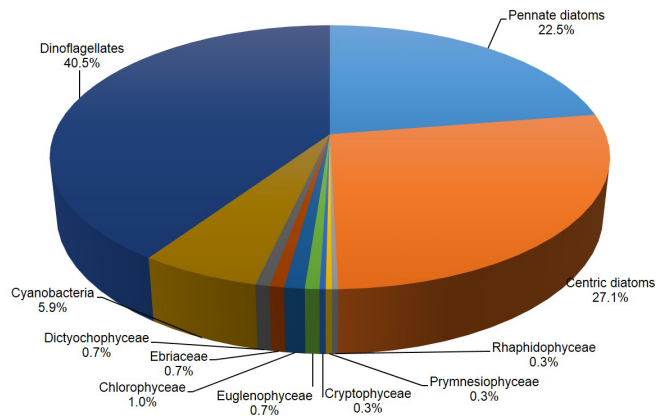


FIGURE 2. Distribution of major taxonomic groups of phytoplankton in the coastal and shelf waters of the northern part of the Yucatan Peninsula, southeastern Gulf of Mexico.

Most of the tycho planktonic diatoms (57 species out of a total of 152 diatoms, or 37.5%) were also observed principally from coastal samplings. The portion of freshwater species (mainly cyanobacteria and chlorophyceans) was pronounced (21 species, or 6.8%); however, they were never observed as abundant or even frequent in terms of the number of cells. The small number of benthic dinoflagellates found in plankton samples, compared to diatoms, can be explained by the rather low species richness of benthic dinoflagellates in general: at the northern Yucatan coast, 20 epiphytic dinoflagellate

species from 12 genera were encountered (Okolodkov *et al.* 2011b). It is widely known that benthic diatoms outnumber benthic dinoflagellates in the number of species both locally and globally.

Due to the optical limitations of inverted microscopes, we failed to identify *Pseudo-nitzschia* species. Nevertheless, our findings in coastal waters of the State of Veracruz (Parsons *et al.* 2012) imply the occurrence of at least five toxic species that can cause amnesic shellfish poisoning. In contrast, among dinoflagellates the potentially toxic species were easier to identify. Most of these species were rare in the samples. Only *Prorocentrum minimum* was observed in high abundances in marinas (particularly in Chuburná, Yucalpetén, Telchac y Dzilam de Bravo; stations 1, 4, 9 and 17 of the coastal surveys; (Figure 1), up to 7.1×10^7 cells l^{-1} (Merino-Virgilio *et al.* 2011a). Another species, *Pyrodinium bahamense* var. *bahamense*, considered potentially toxic only due to a single report on the toxicity of var. *bahamense* in the coastal waters of East Florida (Landsberg *et al.* 2006), reached the population density of 1.8×10^5 cells l^{-1} (Merino-Virgilio *et al.* 2011b). In total, 18 potentially toxic species (16 dinoflagellates and two cyanobacteria) were found.

The presented list can be considered preliminary. Among planktonic diatoms, we expect to identify more *Thalassiosira* Cleve and *Coscinodiscus* Ehrenb. species, as well as even more tycho planktonic diatoms, above all, from the genera *Licmophora* C. Agardh, *Amphora* Ehrenb. ex Kütz., *Nitzschia* Hassall, *Navicula* Bory, *Pleurosigma* W. Sm., *Cocconeis* Ehrenb. and some others that escaped our attention during routine counts and that need a thorough examination of frustule morphology. As regarding flagellates, the species diversity, first of all, of naked dinoflagellates from the order Gymnodiniales and nanophytoflagellates was underestimated due to methodological problems.

TABLE 2. List of phytoplankton species of the northern coastal and shelf waters of the Yucatan Peninsula (2002-2012) from water-bottle samples (b – benthic or tycho planktonic marine (epiphytic, epipelagic or epilithic), f – freshwater (sometimes brackish-water) planktonic, t – potentially toxic).

TAXA	COASTAL SURVEYS	XCAMBO-IV	GOMEX 2010	GOMEX 2011	CO-12
CYANOPROKARYOTA					
<i>Anabaena</i> sp. ^f					+
<i>Aphanothece</i> sp. ^f	+				
<i>Arthrospira</i> sp. ^f	+				
<i>Chroococcus</i> sp.	+				
<i>Gloeocapsa gelatinosa</i> Kütz. ^f	+				
<i>Merismopedia convoluta</i> Bréb. ex Kütz. ^f	+				
<i>Merismopedia glauca</i> (Ehrenb.) Kütz. ^f	+				
<i>Merismopedia punctata</i> Meyen ^f	+				
<i>Merismopedia elegans</i> A. Braun ex Kütz. ^f	+				
<i>Oscillatoria limosa</i> C. Agardh ex Gomont ^f	+				
<i>Oscillatoria tenuis</i> C. Agardh ex Gomont ^f	+				
<i>Spirocoleus fragilis</i> (Menegh.) P. C. Silva ^f	+				
<i>Spirulina</i> sp.	+				
<i>Trichodesmium erythraeum</i> Ehrenb. ^t				+	
<i>Trichodesmium thiebautii</i> Gomont ex Gomont ^t	+	+		+	
DICTYOCOPHYCEAE					
<i>Dictyocha fibula</i> Ehrenb.		+	+		+
<i>Mesocena polymorpha</i> Lemmerm.					+
RAPHIDOPHYCEAE					
<i>Chattonella</i> cf. <i>subsalsa</i> Biecheler			+	+	

TABLE 2. CONTINUED.

TAXA	COASTAL SURVEYS	XCAMBO-IV	GOMEX 2010	GOMEX 2011	CO-12
BACILLARIOPHYTA: COSCINODISCOMPHYCEAE					
<i>Actinopterychus senarius</i> (Ehrenb.) Ehrenb. ^b	+				
<i>Bacteriastrum delicatulum</i> Cleve	+				
<i>Bacteriastrum elongatum</i> Cleve	+				
<i>Bacteriastrum furcatum</i> Shadbolt			+	+	
<i>Bacteriastrum hyalinum</i> Lauder	+		+	+	
<i>Belleriochea malleus</i> (Brightw.) Van Heurck	+				
<i>Biddulphia alternans</i> (Bailey) Van Heurck ^b	+				
<i>Biddulphia biddulphiana</i> (W. Sm.) Boyer ^b	+			+	
<i>Biddulphia rhombus</i> (Ehrenb.) W. Sm. ^b	+				
<i>Cerataulina pelagica</i> (Cleve) Hendey	+		+	+	+
<i>Chaetoceros affinis</i> Lauder	+		+	+	+
<i>Chaetoceros anastomosans</i> Grunow	+				
<i>Chaetoceros brevis</i> F. Schütt	+				
<i>Chaetoceros coarctatus</i> Lauder			+	+	
<i>Chaetoceros compressus</i> Lauder	+		+		+
<i>Chaetoceros costatum</i> Pavill.	+	+		+	
<i>Chaetoceros curvisetus</i> Cleve				+	
<i>Chaetoceros debilis</i> Cleve	+				
<i>Chaetoceros decipiens</i> Cleve	+	+	+	+	
<i>Chaetoceros dicaeta</i> Ehrenb.	+		+	+	
<i>Chaetoceros didymus</i> Ehrenb.	+		+	+	+
<i>Chaetoceros difficilis</i> Cleve	+				
<i>Chaetoceros diversus</i> Cleve		+	+	+	+
<i>Chaetoceros laciniosus</i> F. Schütt	+		+		
<i>Chaetoceros lorenzianus</i> Grunow	+			+	
<i>Chaetoceros messanensis</i> Castrac.				+	+
<i>Chaetoceros pelagicum</i> Cleve	+				
<i>Chaetoceros pendulus</i> G. Karst.		+	+	+	
<i>Chaetoceros peruvianus</i> Brightw.	+		+	+	
<i>Chaetoceros pseudocurvisetus</i> Mangin	+			+	
<i>Chaetoceros socialis</i> Lauder				+	
<i>Chaetoceros teres</i> Cleve	+		+	+	
<i>Chaetoceros tortissimus</i> Gran	+				
<i>Climacodium biconcavum</i> Cleve				+	
<i>Climacodium frauenfeldianum</i> Grunow			+	+	
<i>Corethron hystrix</i> Hensen	+			+	
<i>Coscinodiscus centralis</i> Ehrenb.	+				
<i>Coscinodiscus perforatus</i> Ehrenb.	+	+		+	
<i>Coscinodiscus wailesii</i> Gran et Angst	+				
<i>Cyclotella antiqua</i> W. Sm. ^f	+				
<i>Cyclotella marina</i> (Tanimura, Nagumo et Kato) Aké-Castillo, Okolodkov et Ector in Aké-Castillo et al.	+				
<i>Cymatosira lorenziana</i> Grunow ^b	+		+	+	+
<i>Dactyliosolen fragilissimus</i> (Bergon) Hasle	+			+	
<i>Ditylum brightwellii</i> (T. West) Grunow				+	
<i>Eucampia cornuta</i> (Cleve) Grunow		+	+	+	
<i>Eucampia zodiacus</i> Ehrenb.	+		+	+	+
<i>Guinardia cylindrus</i> Cleve			+		
<i>Guinardia delicatula</i> (Cleve) Hasle	+	+	+	+	+
<i>Guinardia flaccida</i> (Castrac.) H. Perag.	+		+	+	+
<i>Guinardia striata</i> (Stolterf.) Hasle	+	+	+	+	+
<i>Helicotheca tamesis</i> (Shrubsole) Ricard	+	+	+	+	
<i>Hemiaulus hauckii</i> Grunow in Van Heurck	+	+	+	+	
<i>Hemiaulus membranaceus</i> Cleve		+			
<i>Hemiaulus sinensis</i> Grev.	+	+	+	+	+
<i>Isthmia enervis</i> Ehrenb. ^b	+			+	
<i>Lauderia annulata</i> Cleve	+				
<i>Leptocylindrus danicus</i> Cleve	+	+	+	+	+
<i>Lithodesmium undulatum</i> Ehrenb.	+				

TABLE 2. CONTINUED.

TAXA	COASTAL SURVEYS	XCAMBO-IV	GOMEX 2010	GOMEX 2011	CO-12
<i>Melosira nummuloides</i> C. Agardh ^b	+				
<i>Neocalyptrella robusta</i> (G. Norman ex Ralfs in A. Pritch.) Hernández-Becerril et Meave del Castillo		+	+	+	+
<i>Neostreptothea subindica</i> Stosch	+		+	+	
<i>Odontella aurita</i> (Lyngb.) C. Agardh ^b	+		+	+	
<i>Odontella mobiliensis</i> (Bailey) Grunow ^b	+				
<i>Odontella tuomeyi</i> (Bailey) F. C. S. Roper ^b	+				
<i>Paralia fenestrata</i> Sawai et Nagumo ^b	+		+	+	+
<i>Plagiogrammopsis vanheurckii</i> (Grunow) Hasle, Stosch et Syvertsen				+	
<i>Planktoniella sol</i> (G. C. Wall.) F. Schütt				+	+
<i>Proboscia alata</i> (Brightw.) Sundström	+	+		+	+
<i>Proboscia indica</i> (H. Perag.) Hernández-Becerril	+		+		
<i>Pseudosolenia calcar-avis</i> (Schultze) B. G. Sundström	+	+	+	+	
<i>Rhizosolenia acuminata</i> (H. Perag.) H. Perag in H. Perag. et Perag.	+			+	
<i>Rhizosolenia bergonii</i> H. Perag.	+		+	+	
<i>Rhizosolenia hebetata</i> Bailey var. <i>semispina</i> (Hensen) Gran	+	+	+	+	+
<i>Rhizosolenia imbricata</i> Brightw.	+		+	+	+
<i>Rhizosolenia setigera</i> Brightw.	+	+	+	+	+
<i>Rhizosolenia styliformis</i> Brightw.	+		+	+	+
<i>Skeletonema costatum</i> (Grev.) Cleve				+	
<i>Stephanopyxis palmeriana</i> (Grev.) Grunow	+			+	
<i>Thalassiosira eccentrica</i> (Ehrenb.) Cleve				+	
<i>Thalassiosira</i> sp.	+				
<i>Triceratium favus</i> Ehrenb. ^b	+				
<i>Triceratium pentacrinus</i> (Ehrenb.) G. C. Wall.	+			+	
<i>Triceratium reticulatum</i> Grev. ^b	+			+	
BACILLARIOPHYTA: FRAGILARIOPHYCEAE					
<i>Asterionella formosa</i> Hassal	+				
<i>Asterionella gracillima</i> (Hantzsch) Heib.	+				
<i>Asterionellopsis glacialis</i> (Castrac.) Round	+				+
<i>Climacosphenia</i> sp. ^b	+			+	
<i>Grammatophora marina</i> (Lyngb.) Kütz. ^b	+		+	+	
<i>Grammatophora oceanica</i> Ehrenb. ^b				+	
<i>Hyalosira interrupta</i> (Ehrenb.) Navarro ^b	+		+	+	
<i>Licmophora</i> spp. ^b	+		+	+	
<i>Lioloma delicatulum</i> (Cupp) Hasle	+				
<i>Podocystis perrinensis</i> Ricard ^b	+				
<i>Rhabdonema adriaticum</i> Kütz. ^b	+		+	+	+
<i>Striatella delicatula</i> (Kütz.) Grunow ex Van Heurck ^b	+			+	
<i>Striatella unipunctata</i> (Lyngb.) C. Agardh ^b	+		+	+	
<i>Synedra crystallina</i> (C. Agardh) Kütz. ^f	+				
<i>Synedra formosa</i> Hantzsch ^f	+				
<i>Synedra fulgens</i> (Grev.) W. Sm. ^f	+				
<i>Synedra ulna</i> (Nitzsch) Ehrenb. var. <i>ulna</i> ^f	+				
<i>Tabellaria</i> sp. ^f	+				
<i>Thalassionema frauenfeldii</i> (Grunow) Tempère et H. Perag.	+	+	+	+	+
<i>Thalassionema nitzschioides</i> (Grunow) Mereschk.	+	+	+	+	+
<i>Thalassiothrix</i> sp.	+				
<i>Toxarium undulatum</i> Bailey ^b	+				
BACILLARIOPHYTA: BACILLARIOPHYCEAE					
<i>Amphora angusta</i> W. Greg. ^b	+				
<i>Amphora arenaria</i> Donkin ^b	+				
<i>Amphora crassa</i> W. Greg. ^b	+				
<i>Amphora decussata</i> Grunow ^b			+	+	
<i>Amphora inflata</i> Grunow ^b	+				
<i>Amphora laevis</i> W. Greg. ^b	+		+	+	
<i>Amphora lineolata</i> Ehrenb. ^b	+				
<i>Amphora ostrearia</i> Bréb. ^b	+		+	+	
<i>Amphora ovalis</i> (Kütz.) Kütz. ^b	+				
<i>Bacillaria paxillifera</i> (O. F. Müll.) T. Marsson ^b	+			+	

TABLE 2. CONTINUED.

TAXA	COASTAL SURVEYS	XCAMBO-IV	GOMEX 2010	GOMEX 2011	CO-12
<i>Caloneis liber</i> (W. Sm.) Cleve ^b	+				
<i>Campylodiscus</i> sp. ^b	+			+	
<i>Climaconeis</i> sp. ^b	+		+	+	+
<i>Cocconeis scutellum</i> Ehrenb. ^b	+			+	
<i>Cylindrotheca closterium</i> (Ehrenb.) Reimann et J. C. Lewin ^b	+	+	+	+	+
<i>Dictyoneis</i> sp. ^b	+				
<i>Diploneis crabro</i> (Ehrenb.) Ehrenb. ^b	+			+	
<i>Entomoneis alata</i> (Ehrenb.) Ehrenb. ^b	+			+	+
<i>Gyrosigma acuminatum</i> (Kütz.) Rabenh. var. <i>acuminatum</i> ^b	+			+	
<i>Gyrosigma acuminatum</i> var. <i>brebissonii</i> (Grunow) Cleve ^b	+				
<i>Gyrosigma balticum</i> (Ehrenb.) Rabenh. ^b	+				
<i>Haslea frauenfeldii</i> (Grunow) Simonsen	+			+	+
<i>Haslea wawriake</i> (Hust.) Simonsen		+	+	+	
<i>Lyrella lyra</i> (Ehrenb.) Karajeva ^b	+				
<i>Mastogloia</i> sp. ^b	+				
<i>Meuniera membranacea</i> (Cleve) P. C. Silva		+			
<i>Navicula cancellata</i> Donkin ^b	+				+
<i>Navicula directa</i> (W. Sm.) Ralfs in A. Pritch. ^b	+			+	
<i>Navicula distans</i> (W. Sm.) Ralfs in A. Pritch. ^b			+	+	+
<i>Nitzschia angularis</i> W. Sm. ^b	+				
<i>Nitzschia dissipata</i> (Kütz.) Grunow	+				
<i>Nitzschia lanceolata</i> W. Sm.	+	+	+		
<i>Nitzschia longissima</i> (Bréb.) Ralfs in A. Pritch.	+	+	+	+	+
<i>Nitzschia reversa</i> W. Sm.	+	+		+	+
<i>Nitzschia sicula</i> (Castrac.) Hust.	+				
<i>Nitzschia sigma</i> (Kütz.) W. Sm.	+		+	+	+
<i>Nitzschia sigmoidea</i> (Nitzsch) W. Sm.	+				
<i>Plagiotropis lepidoptera</i> (W. Greg.) Kuntze ^b	+		+	+	
<i>Pleurosigma angulatum</i> W. Sm. ^b	+		+	+	+
<i>Pleurosigma elongatum</i> W. Sm. ^b	+				
<i>Pleurosigma formosum</i> W. Sm. ^b	+			+	+
<i>Pleurosigma normanii</i> Ralfs ^b	+			+	
<i>Pleurosigma salinarum</i> (Grunow) Grunow ^b	+				
<i>Pseudo-nitzschia</i> cf. <i>delicatissima</i> (Cleve) Heiden	+	+	+	+	+
<i>Pseudo-nitzschia</i> cf. <i>pungens</i> (Grunow ex Cleve) G. R. Hasle	+	+			
<i>Pseudo-nitzschia</i> cf. <i>seriata</i> (Cleve) H. Perag.	+				
<i>Surirella fastuosa</i> Ehrenb. ^b				+	
<i>Trachyneis aspera</i> (Ehrenb.) Cleve ^b				+	
DINOFLAGELLATA					
<i>Akashiwo sanguinea</i> (Hirasaka) G. Hansen et Ø. Moestrup ^f	+	+	+	+	
<i>Alexandrium</i> sp.				+	
<i>Amphidinium carterae</i> Hulburt ^{b,c}	+			+	
<i>Amphisolenia bidentata</i> Schröd.				+	
<i>Amphisolenia bifurcata</i> G. Murray et Whitting				+	
<i>Amphisolenia globifera</i> F. Stein				+	+
<i>Amphisolenia schauinslandii</i> Lemmerm.				+	
<i>Balechina coerulea</i> (Dogiel) F. J. R. Taylor			+		
<i>Centrodinium</i> sp.	+				
<i>Ceratium belone</i> Cleve	+		+		
<i>Ceratium contortum</i> (Gourret) Cleve				+	
<i>Ceratium dens</i> Ostenf. et Schmidt				+	
<i>Ceratium extensum</i> (Gourret) Cleve			+	+	+
<i>Ceratium furca</i> (Ehrenb.) Clap. et Lachm. var. <i>furca</i>	+	+	+	+	+
<i>Ceratium furca</i> var. <i>hircus</i> (Schröd.) Margalef ex Sournia	+			+	+
<i>Ceratium fusus</i> (Ehrenb.) Dujard.	+	+	+	+	+
<i>Ceratium horridum</i> (Cleve) Gran					+
<i>Ceratium karstenii</i> Pavill.		+		+	
<i>Ceratium kofoidii</i> Jörg.			+	+	
<i>Ceratium lineatum</i> (Ehrenb.) Cleve	+	+	+	+	+
<i>Ceratium massiliense</i> (Gourret) Jörg.				+	

TABLE 2. CONTINUED.

TAXA	COASTAL SURVEYS	XCAMBO-IV	GOMEX 2010	GOMEX 2011	CO-12
<i>Ceratium pentagonum</i> Gourret			+	+	
<i>Ceratium ranipes</i> Cleve			+		
<i>Ceratium teres</i> Kof.		+	+	+	+
<i>Ceratium trichoceros</i> (Ehrenb.) Kof.	+	+	+	+	+
<i>Ceratium tripos</i> (O. F. Müll.) Nitzsch		+	+	+	+
<i>Ceratium vultur</i> Cleve				+	
<i>Ceratocorys horrida</i> F. Stein			+		
<i>Cochlodinium</i> sp.					+
<i>Dinophysis caudata</i> Saville-Kent ^t	+	+	+	+	+
<i>Dinophysis exigua</i> Kof. et Skogsb.				+	
<i>Dinophysis hastata</i> F. Stein			+		
<i>Dinophysis ovum</i> F. Schütt				+	
<i>Dinophysis pusilla</i> Jörg.			+		
<i>Diplopsalopsis bomba</i> (F. Stein ex Jörg.) J. D. Dodge et Toriumi					+
<i>Gambierdiscus</i> sp. ^b	+				
<i>Gonyaulax digitalis</i> (Pouchet) Kof.	+	+		+	
<i>Gonyaulax minuta</i> Kof. et J. R. Mich.	+				
<i>Gonyaulax polygramma</i> F. Stein	+		+	+	
<i>Gonyaulax spinifera</i> (Clap. et Lachm.) Diesing ^t	+		+	+	
<i>Gonyaulax verior</i> Sournia	+				
<i>Gymnodinium flavum</i> Kof. et Swezy				+	
<i>Gymnodinium gelbum</i> Kof.				+	
<i>Gymnodinium gibbera</i> J. Schiller	+				
<i>Gymnodinium mitratum</i> J. Schiller				+	
<i>Gymnodinium rotundatum</i> Klebs	+				
<i>Gymnodinium simplex</i> (Lohmann) Kof. et Swezy	+				
<i>Gymnodinium variabile</i> Herdman	+			+	
<i>Gyrodinium</i> cf. <i>biconicum</i> Kof. et Swezy	+			+	
<i>Gyrodinium</i> cf. <i>fusiforme</i> Kof. et Swezy	+	+	+	+	+
<i>Gyrodinium nasutum</i> (Wulff) J. Schiller			+	+	
<i>Gyrodinium spirale</i> (Bergh) Kof. et Swezy		+	+	+	
<i>Heterocapsa</i> sp.	+	+	+	+	
<i>Karenia brevis</i> (C. C. Davis) G. Hansen et Ø. Moestrup ^t	+			+	+
<i>Karenia papilionacea</i> A. J. Haywood et K. A. Steidinger ^t	+			+	
<i>Katodinium glaucum</i> (Lebour) A. R. Loebl.				+	
<i>Lingulodinium polyedrum</i> (F. Stein) J. D. Dodge				+	
<i>Noctiluca scintillans</i> (Macartney) Kof. et Swezy		+		+	
<i>Ornithocercus steinii</i> F. Schütt				+	
<i>Ostreopsis</i> sp. ^b	+				
<i>Oxyphysis oxytoxoides</i> Kof.	+				
<i>Oxytoxym constrictum</i> (F. Stein) Buetschli					+
<i>Oxytoxym curvatum</i> (Kof.) Kof. et J. R. Michener			+		
<i>Oxytoxym elegans</i> Pavill.				+	+
<i>Oxytoxum globosum</i> J. Schiller				+	
<i>Oxytoxum longiceps</i> J. Schiller		+	+	+	
<i>Oxytoxum milneri</i> J. Murray et Whitting			+	+	
<i>Oxytoxum scolopax</i> F. Stein			+	+	+
<i>Oxytoxum subulatum</i> Kof.				+	
<i>Oxytoxum tessellatum</i> (F. Stein) F. Schütt				+	+
<i>Oxytoxum variabile</i> J. Schiller			+		
<i>Oxytoxum viride</i> J. Schiller				+	
<i>Peridinium quinquecorne</i> T. H. Abé			+	+	+
<i>Phalacroma mitra</i> F. Schütt ^t			+		
<i>Phalacroma ovum</i> F. Schütt				+	
<i>Phalacroma porodictyum</i> F. Stein	+				
<i>Phalacroma rapa</i> F. Stein ^t			+		
<i>Phalacroma rotundatum</i> (Clap. et J. Lachm.) Kof. et J. R. Michener ^t		+	+		+
<i>Podolampas bipes</i> F. Stein			+	+	
<i>Podolampas palmipes</i> F. Stein				+	+
<i>Podolampas spinifera</i> Okamura			+	+	+

TABLE 2. CONTINUED.

TAXA	COASTAL SURVEYS	XCAMBO-IV	GOMEX 2010	GOMEX 2011	CO-12
<i>Polykrikos kofoiidii</i> Chatton			+	+	
<i>Pronoctiluca pelagica</i> Fabre-Domergue				+	+
<i>Prorocentrum compressum</i> (Bailey) T. H. Abé ex J. D. Dodge		+			
<i>Prorocentrum</i> cf. <i>concovum</i> Fukuyo ^f	+		+		
<i>Prorocentrum dentatum</i> F. Stein	+		+		
<i>Prorocentrum gracile</i> F. Schütt	+	+		+	+
<i>Prorocentrum lima</i> (Ehrenb.) F. Stein ^f	+		+		
<i>Prorocentrum mexicanum</i> B. F. Osorio	+		+		
<i>Prorocentrum micans</i> Ehrenb.			+	+	
<i>Prorocentrum minimum</i> (Pavill.) J. Schiller ^f	+	+	+	+	
<i>Prorocentrum rhathymum</i> A. R. Loeb., Sherley et R. J. Schmidt ^{b,t}				+	+
<i>Prorocentrum rostratum</i> F. Stein		+	+		
<i>Prorocentrum scutellum</i> Schröd.	+				+
<i>Protoceratium reticulatum</i> (Clap. et Lachm.) Buetschli ^f	+				
<i>Protoperidinium abei</i> (Paulsen) Balech				+	
<i>Protoperidinium brevipes</i> (P. A. Dang.) Balech	+				
<i>Protoperidinium brochii</i> (Kof. et Swezy) Balech	+		+	+	
<i>Protoperidinium cerasus</i> (Paulsen) Balech	+		+		
<i>Protoperidinium claudicans</i> (Paulsen) Balech			+	+	
<i>Protoperidinium concinnum</i> M. A. Faust	+			+	
<i>Protoperidinium conicum</i> (Gran) Balech	+				
<i>Protoperidinium crassipes</i> (Kof.) Balech			+		
<i>Protoperidinium depressum</i> (Bailey) Balech			+	+	
<i>Protoperidinium divergens</i> (Ehrenb.) Balech	+		+	+	
<i>Protoperidinium</i> cf. <i>globulum</i> (F. Stein) Balech	+	+	+	+	
<i>Protoperidinium granii</i> (Ostenf.) Balech	+	+	+	+	
<i>Protoperidinium hirobis</i> (T. H. Abé) Balech				+	
<i>Protoperidinium longipes</i> Balech	+				
<i>Protoperidinium ovum</i> (J. Schiller) Balech			+	+	
<i>Protoperidinium pallidum</i> (Ostenf.) Balech	+				
<i>Protoperidinium pellucidum</i> Bergh	+			+	
<i>Protoperidinium pentagonum</i> (Gran) Balech	+				+
<i>Protoperidinium pyriforme</i> (Paulsen) Balech subsp. <i>breve</i> (Paulsen) Balech	+			+	
<i>Protoperidinium pyriforme</i> subsp. <i>pyriforme</i>	+		+	+	+
<i>Protoperidinium quarnerense</i> (Schröd.) Balech			+	+	
<i>Protoperidinium sphaericum</i> (J. Murray et Whitting) Balech		+			
<i>Protoperidinium steinii</i> (Jörg.) Balech			+	+	
<i>Protoperidinium subinerme</i> (Paulsen) A. R. Loeb.				+	
<i>Pyrocystis lunula</i> (F. Schütt) F. Schütt			+	+	
<i>Pyrodinium bahamense</i> Plate var. <i>bahamense</i> ^f	+		+	+	
<i>Pyrophacus horologium</i> F. Stein	+		+	+	
<i>Scrippsiella spinifera</i> G. Honsell et M. Cabrini	+		+		
<i>Scrippsiella trochoidea</i> (F. Stein) A. R. Loeb.	+	+	+	+	+
<i>Torodinium robustum</i> Kof. et Swezy	+	+	+		+
Dinoflagellate cysts ^b			+	+	
EBRIACEA					
<i>Ebria tripartita</i> (Schum.) Lemmerm.				+	
<i>Hermesinum</i> sp.				+	
CHLOROPHYCEAE					
<i>Cosmarium</i> sp. ^f	+				
<i>Crucigenia</i> sp. ^f				+	
<i>Scenedesmus</i> sp. ^f				+	
EUGLENOPHYCEAE					
<i>Eutreptia</i> sp.	+				+
<i>Eutreptiella marina</i> da Cunha	+			+	
CRYPTOPHYCEAE					
<i>Rhodomonas pusilla</i> (H. Bachm.) Javorn. ^f	+				
PRYMNESIOPHYCEAE					
<i>Phaeocystis globosa</i> Scherffel				+	

TABLE 3. New records of microalgae for the southern Gulf of Mexico (CS – coastal surveys).

TAXA	CRUISE OR SURVEY	STATIONS
Diatoms:		
<i>Neostreptothea subindica</i>	GOMEX-10	A4, B6, N67, N68, N69, P77
	GOMEX-11	A4, B6, N67, N69, P77
<i>Odontella tuomeyi</i>	CS	
<i>Pleurosigma formosum</i>	GOMEX-11	N66
	CO-12	113_49
<i>Podocystis perrinensis</i>	CS	
<i>Triceratium reticulatum</i>	CS	
Dinoflagellates:		
<i>Oxytoxym constrictum</i>	CO-12	97_57, 129_73
<i>Oxytoxum tessellatum</i>	GOMEX-10	A2, B9, B10, C11, C14, J46, J47, L59, M62, M63, P76

ACKNOWLEDGMENTS: We are grateful to the project (cruise) coordinators Arturo Mendoza-Quintero and Miguel Herrera-Rodríguez (PEMEX), Víctor Enriquez-Avedoy (Instituto Nacional de Ecología), Omar Zapata-Pérez, Gerardo Gold-Bouchot and Pedro Ardisson-Herrera (CINVESTAV-IPN) for financial and logistical support in sampling. Eberto Novelo-Maldonado from Universidad Nacional Autónoma de México gave us valuable comments on green algae and cyanobacteria, and José A. Aké-Castillo from Universidad Veracruzana on diatoms. The help of our colleagues and students who participated in sampling is very much appreciated. Among them are Sara M. Morales-Ojeda, Mercy N. López-Herrera, Iliana Osorio-Moreno, Ricardo Ortegon-Herrera y Giuliana Cruz-Trejo. Marcia M. Gowing from the University of California at Santa Cruz, California, kindly improved the writing style. Critical comments on our manuscript by two anonymous reviewers are very much appreciated. Financial support for the following projects is much appreciated: (1) "Evaluación de daños en las zonas costeras de la Península de Yucatán por el huracán Isidoro" (SISIERRA-CONACYT, 2000-2004, responsible: J. I. Euán-Ávila), (2) "Coastal evolution of the western littoral of the Yucatán Peninsula: erosion and water quality" (CONACYT, 2000-2005, responsible: L. R. A. Capurro-Filigrasso), (3) "Mareas rojas de Yucatán: caracterización de factores de disparo y dispersión" (FOMIX CONACYT-Gobierno del Estado de Yucatán, 2006-2007, responsable: JAHs), (3) "Monitoreo de la marea roja de Yucatán para la prevención y comunicación de riesgos" (CINVESTAV-Fundación PRODUCE, A.C., 2009, responsable: JAHs), and (4) "Análisis de las causas, dispersión y consecuencias ambientales de la marea roja en Yucatán" (FOMIX CONACYT-Gobierno del Estado de Yucatán, 2009-2011, responsable: JAHs) and some others.

LITERATURE CITED

- Adl, S.M., A.G.B. Simpson, C.E. Lane, J. Lukeš, D. Bass, S.S. Bowser, M.W. Brown, F. Burki, M. Dunthorn, V. Hampl, A. Heiss, M. Hoppenrath, E. Lara, L. Le Gall, D.H. Lynn, H. McManus, E.A.D. Mitchell, S.E. Mozley-Stranridge, L.W. Parfrey, J. Pawlowski, S. Rueckert, L. Shadwick, C.L. Schoch, A.V. Smirnov and F.W. Spiegel. 2012. The revised classification of eukaryotes. *Journal of Eukaryotic Microbiology* 59(5): 429-493.
- Aké-Castillo, J.A., Y.B. Okolodkov, S. Espinosa-Matías, F. del C. Merino-Virgilio, J.A. Herrera-Silveira and L. Ector. 2012. *Cyclotella marina* (Tanimura, Nagumo et Kato) Aké-Castillo, Okolodkov et Ector comb. et stat. nov. (Thalassiosiraceae): a bloom-forming diatom in the southeastern Gulf of Mexico. *Nova Hedwigia, Beiheft* 141: 263-274.
- Álvarez-Góngora, C. and J.A. Herrera-Silveira. 2006. Variations of phytoplankton community structure related to water quality trends in a tropical karstic coastal zone. *Marine Pollution Bulletin* 52: 48-60.
- Álvarez-Góngora, C., M. de los A. Liceaga-Correa and J.A. Herrera-Silveira. 2012. Variaciones estacionales de la estructura comunitaria del fitoplancton en zonas de descarga de agua subterránea en la costa norte de la Península de Yucatán. *Revista de Biología Tropical* 60(1): 157-172.
- Brummit, R.K. and C.E. Powell (ed.). 1992. *Authors of plant names. A list of authors of scientific names of plants with recommended standard forms of their names, including abbreviations*. London: Royal Botanical Gardens, Kew. 732 p.
- Fourtanier, E. and P. Kociolek. 1999. Catalogue of the diatom genera. *Diatom Research* 14(1): 1-190.
- Guiry, M.D. and G.M. Guiry. 2012. *AlgaeBase. World-wide electronic publication*. National University of Ireland, Galway. Electronic database accessible at <http://www.algaebase.org/>. Captured on 18 November 2012.
- Hasle, G.R. 1978. The inverted-microscope method; p. 88-96 *In* Sournia, A. (ed.). *Phytoplankton manual*. Paris: UNESCO.
- Herrera-Silveira, J.A. 1993. *Ecología de los productores primarios en la laguna de Celestún, México. Patrones de variación espacial y temporal*. Ph.D. thesis. Barcelona: Universitat de Barcelona. 233 p.
- Herrera-Silveira, J.A. and S.M. Morales-Ojeda. 2009. Evaluation of the health status of a coastal ecosystem in southeast Mexico: Assessment of water quality, phytoplankton and submerged aquatic vegetation. *Marine Pollution Bulletin* 59: 72-86.
- Krayevsky, D.M., E. Meave del Castillo, E. Zamudio, J.N. Norris and S. Frederique. 2009. Diatoms (Bacillariophyta) of the Gulf of Mexico; p. 155-186 *In* Tunnel, J.W.Jr., D.L. Felder and S.A. Earl (ed.). *Gulf of Mexico origin, waters, and biota. Vol. 1. Biodiversity*. Corpus Christi: Harte Research Institute for Gulf of Mexico Studies Series, Texas A&M University Press.
- Landsberg, J.H., S. Hall, J.N. Johannessen, K.D. White, S.M. Conrad, S.M., J.P. Abbott, L.J. Flewelling, R.W. Richardson, R.W. Dickey, E.L.E. Jester, S.M. Etheridge, J.R. Deeds, F.M. Van Dolah, T.A. Leighfield, Y. Zou, C.G. Beaudry, R.A. Benner, P.L. Rogers, P.S. Scott, K. Kawabata, J.L. Wolny and K.A. Steidinger. 2006. Saxitoxin puffer fish poisoning in the United States, with the first report of *Pyrodinium bahamense* as the putative toxin source. *Environmental Health Perspectives* 114: 1502-1507.
- Licea, S., M.E. Zamudio, R. Luna and J. Soto. 2004. Free-living dinoflagellates in the southern Gulf of Mexico: Report of data (1979-2002). *Phycological Research* 52: 419-428.
- Merino-Virgilio, F. del C., A.C. Aguilar-Trujillo, I. Osorio-Moreno, Y.B. Okolodkov and J.A. Herrera-Silveira. 2011a. Primeros florecimientos de *Prorocentrum minimum* en el sur del Golfo de México; p. 63 *En Resúmenes del 1er Congreso Nacional de la Sociedad Mexicana para el Estudio de Florecimientos Algaes Nocivos. Mazatlán, Sinaloa, 16-18 de noviembre de 2011*.
- Merino-Virgilio, F. del C., A.C. Aguilar-Trujillo, I. Osorio-Moreno, Y.B. Okolodkov, J.A. Herrera-Silveira and S. Espinosa-Matías. 2011b. *Pyrodinium bahamense* var. *bahamense* en el norte de la península de Yucatán; p. 50 *En Resúmenes del 1er Congreso Nacional de la Sociedad Mexicana para el Estudio de Florecimientos Algaes Nocivos. Mazatlán, Sinaloa, 16-18 de noviembre de 2011*.
- Okolodkov, Y.B. 2008. *Protophydinium* Bergh (Dinophyceae) of the National Park Sistema Arrecifal Veracruzano, Gulf of Mexico, with a key for identification. *Acta Botanica Mexicana* 84: 93-149.
- Okolodkov, Y.B. 2010. *Ceratium* Schrank (Dinophyceae) of the National Park Sistema Arrecifal Veracruzano, Gulf of Mexico, with a key for identification. *Acta Botanica Mexicana* 93: 41-101.
- Okolodkov, Y.B., G. Campos-Bautista, I. Gárate-Lizárraga, J.A.G. González-González, M. Hoppenrath M. and V. Arenas. 2007. Seasonal changes of benthic and epiphytic dinoflagellates in the Veracruz reef zone, Gulf of Mexico. *Aquatic Microbial Ecology* 47(3): 223-237.
- Okolodkov, Y.B., J.A. Aké-Castillo, M.G. Gutiérrez-Quevedo, H. Pérez-España and D. Salas-Monreal. 2011a. Annual cycle of the plankton biomass in the National Park Sistema Arrecifal Veracruzano, southwestern Gulf of Mexico; p. 63-88 *In* Kattel, G. (ed.). *Zooplankton and phytoplankton: Types, characteristics and ecology*. Hauppauge, New York: Nova Science Publishers, Inc.
- Okolodkov, Y.B., F. del C. Merino-Virgilio, A.C. Aguilar-Trujillo, I. Osorio-Moreno, J.A. Herrera-Silveira and C. Galicia-García. 2011b. Riesgo de la ciguatera en la costa norte y este de la península de Yucatán, Golfo de México y Caribe; p. 56 *En Resúmenes del 1er Congreso Nacional de la Sociedad Mexicana para el Estudio de Florecimientos Algaes Nocivos. Mazatlán, Sinaloa, 16-18 de noviembre de 2011*.
- Parsons M.L., Y.B. Okolodkov and J.A. Aké-Castillo. 2012. Morphology of the species of *Pseudo-nitzschia* (Bacillariophyta) of the National Park Sistema Arrecifal Veracruzano, SW Gulf of Mexico. *Acta Botanica Mexicana* 98: 51-72.
- Round, F.E., R.M. Crawford and D.G. Mann. 1990. *The diatoms: biology and morphology of the genera*. Cambridge, New York, Port Chester, Melbourne, Sydney: Cambridge University Press. ix+747 p.
- Steidinger, K.A., A.M. Faust and D.U. Hernández-Becerril. 2009. Dinoflagellates (Dinoflagellata) of the Gulf of Mexico; p. 131-154 *In* Tunnel, J.W.Jr., D.L. Felder and S.A. Earl (ed.). *Gulf of Mexico origin, waters, and biota. Vol. 1. Biodiversity*. Corpus Christi: Harte Research Institute for Gulf of Mexico Studies Series, Texas A&M University Press.
- Troccoli Ghinaglia, L., J.A. Herrera-Silveira and F.A. Comín. 2004. Structural variations of phytoplankton in the coastal seas of Yucatan. *Hidrobiologia* 519: 85-102.
- Wood, E.J.F. 1968. *Dinoflagellates of the Caribbean Sea and adjacent seas*. Coral Gables: University of Miami Press. 143 p.

RECEIVED: December 2012

ACCEPTED: June 2013

PUBLISHED ONLINE: August 2013

EDITORIAL RESPONSIBILITY: Luciana Gomes Barbosa