

ARTICULO ORIGINAL

DIVERSITY AND DISTRIBUTION OF PHYTOPLANKTON IN COASTAL AND OCEANIC WATERS OFF HAVANA CITY

Diversidad y distribución del fitoplancton en aguas costeras y oceánicas de la Ciudad de La Habana

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ABSTRACT

The diversity of phytoplankton species has become relevant for assessing environmental disturbances in marine habitats because its relationship with harmful algal blooms (HABs). The scientific expedition on board of the R/V Race for Water in August 2017 gave us the opportunity for sampling the phytoplankton off Havana City. The aims were (i) to describe the diversity and composition of phytoplankton testing for differences between coastal and oceanic waters, and (ii) to explore the occurrence of potentially harmful phytoplankton species. Twelve sites were selected between Havana Bay and the entrance of Almendares River. Superficial samples of water were taken with a 20 µm plankton net. We identified 71 phytoplankton species belonging to five taxa: 63 Dinophyta, five Bacillariophyta, one Chlorophyta, one Charophyta and one Cyanobacteria. There were 21 phytoplankton species reported by first time for Cuban waters. The observed richness was statistically the same for both coastal and oceanic sites (44 and 52 species respectively). However, the clustering patterns in the MDS plot indicated different species composition between coastal and oceanic waters. Fifteen recorded species may be involved in HABs: *Coscinodiscus* spp., *Dinophysis caudata*, *Gambierdiscus* sp., *Gonyaulax polygramma*, *Gonyaulax spinifera*, *Gymnodinium* sp. 2, *Lingulodinium polyedra*, *Peridinium quadridentatum*, *Phalacroma mitra*, *Phalacroma rotundatum*, *Prorocentrum* cf. *compressum*, *Thalassiosira* spp., *Tripos fusus*, *Tripos furca* and *Trichodesmium thiebautii*. The occurrence of these species pointed to the necessity of a monitoring program in waters of Havana City since its large vulnerability to HABs.

KEY WORDS: marine phytoplankton, diversity, new reports, harmful algae, Race for Water

RESUMEN

La diversidad de especies de fitoplancton se ha utilizado en la evaluación de disturbios ambientales en hábitats marinos por su relación con los florecimientos algales nocivos (FANs). En agosto del 2017, la expedición científica a bordo del Race for Water brindó la oportunidad de muestrear el fitoplancton frente a la costa de la Ciudad de La Habana, teniendo como objetivos: (i) describir la diversidad y composición del fitoplancton comparando aguas costeras y oceánicas, y (ii) explorar la ocurrencia de especies potencialmente dañinas. Se seleccionaron doce sitios de muestreo entre la Bahía de La Habana y la desembocadura del Río Almendares, donde se tomaron muestras superficiales de agua con una red de plancton de 20 µm de apertura de malla. Se identificaron 71 especies de fitoplancton, pertenecientes a cinco taxa: 63 Dinophyta, cinco Bacillariophyta, una Chlorophyta, una Charophyta y una Cyanobacteria. Se registraron 21 especies de fitoplancton por primera vez para aguas cubanas. La riqueza de especies observada fue estadísticamente similar para las muestras costeras y oceánicas (44 y 52 especies respectivamente). Sin embargo, los patrones de agrupación del análisis MDS indicaron diferencias en la composición de especies entre las aguas costeras y oceánicas. Quince de las especies identificadas pudieron estar implicadas en FANs: Coscinodiscus spp., Dinophysys caudata, Gambierdiscus sp., Gonyaulax polygramma, Gonyaulax spinifera, Gymnodinium sp. 2, Lingulodinium polyedra, Peridinium quadridentatum, Phalacroma mitra, Phalacroma rotundatum, Prorocentrum cf. compressum, Thalassiosira spp., Tripos fusus, Tripos furca and Trichodesmium thiebautii. La presencia de estas especies sugiere la necesidad de un programa de monitoreo en las aguas cercanas a la Ciudad de La Habana, pues posee alta vulnerabilidad a FANs.

PALABRAS CLAVE: *fitoplancton marino, diversidad, nuevos registros, algas dañinas, Race for Water*

INTRODUCTION

The phytoplankton is a diverse group adapted to floating or swimming in aquatic

ecosystems; phytoplankters typically include cyanobacteria and microalgae. Most phytoplankton species have photosynthetic pigments such as chlorophyll α , which enable them to use sunlight energy for producing carbohydrates. As primary producers, these organisms constitute the base of the food webs in the open ocean. Importantly, photosynthesis by marine phytoplankton contributes to the sequestering of carbon dioxide released into the atmosphere by natural (e.g. respiration) and anthropogenic processes (e.g. burning of fossil fuels and agriculture) (Graham *et al.*, 2016).

Phytoplanktonic communities are distributed globally from tropical to polar waters with distinctive regional features. Furthermore, the composition and abundance of phytoplankton show significant variations through space and time despite the continuity of the marine water masses. Coastal shelf waters may be distinguished from oceanic waters by the potential to support higher diversity, abundance, biomass, and primary production of phytoplankton. This is because coastal waters usually have larger nutrient supply from bottom by mineralization and/or from land by runoff (Reynolds, 2006).

The accelerated proliferation of planktonic or benthic microalgae species (i.e. “algal bloom”) are subjects of environmental concern. Human activities are responsible for the increased inflow of nutrients in aquatic ecosystems where they may trigger harmful algal blooms (HABs). Some HABs are constituted by species producing toxins which are released into the atmosphere by spray or incorporated into animal tissues where they may accumulate. Even in the case of HABs which apparently do not release toxins, the algal growth can be extensive causing fish mortality

by mechanical damage in the gills. The decomposition of high amounts of phytoplanktonic biomass consumes the oxygen causing hypoxia which in turn affects other aquatic species. There is a worldwide increase of the frequency, intensity and geographical extension of HABs because anthropogenic activities associate to global change (Hallegraeff *et al.*, 2004). This has triggered the interest of the society and scientific community on phytoplankton studies in the last years.

In Cuban Archipelago, the studies about marine phytoplankton gained in importance after 1960 with some relevant contributions from López-Baluja and Vinogradova (1972; 1974), López-Baluja (1978), López-Baluja *et al.* (1980), Borrero *et al.* (1981; 1984), Popowski *et al.* (1982) and Popowski and Campos (1987). Recently, information about phytoplankton species has become a topic of special interest due to the necessity for assessing environmental disturbances in the marine habitats and detecting/preventing HABs. Some relevant studies have been carried out by Leal *et al.* (2001), Pérez de los Reyes *et al.* (2009), Loza and Lugioyo (2009), Loza *et al.* (2009), and Bustamante *et al.* (2016). Also, there are important studies of phytoplankton diversity from bays (e.g. Gómez *et al.*, 2001; Moreira *et al.*, 2007; 2009; 2014) and coastal lagoons (e.g. Moreira *et al.*, 2013). Recent reports of phytoplankton blooms from marine zones around Cuba constitute evidences of the increasing awareness of HABs. Harmless blooms have occurred in Santiago de Cuba Bay (Gómez, 2007), Cayo Largo del Sur (Loza *et al.*, 2013), La Redonda Lagoon in Ciego de Ávila (Moreira & Comas, 2014), Cienfuegos Bay (Moreira, 2009; 2010; Moreira *et al.*, 2014) and

Marina Hemingway in Havana (Delgado *et al.*, 2016). In January 2014, a HAB of *Cochlodinium polykrikoides* Margalef 1961 was detected in Guanaroca Lagoon (Cienfuegos) possibly causing mortality of fishes, oysters and blue crabs (Moreira *et al.*, 2016b). Few months later, a HAB of the benthic dinoflagellate *Vulcanodinium rugosum* Nézan and Chomérat 2011 caused severe skin lesions to people swimming in some beaches of Cienfuegos Bay (Moreira *et al.*, 2016a). In this scenario, the accurate identification of the species involved in these events is essential for the implementation of HAB monitoring and early warning programs at nation-scale.

Havana, the largest city and capital of Cuba, is especially vulnerable to HABs due to eutrophication, urban and industrial contamination and concentration of inhabitants in the coastal zone (Armenteros *et al.*, 2009). Therefore, the knowledge of diversity and composition of phytoplankton is needed for the assessment of potentially harmful species and as a baseline for a HAB monitoring program. In this context, the scientific expedition on board of the R/V Race for Water in August 2017 gave the opportunity to us of sampling the phytoplankton off Havana City. We aimed in this contribution: (i) to describe the diversity and composition of phytoplankton with emphasis in the differences between coastal and oceanic waters and (ii) to explore the occurrence of potentially harmful phytoplankton species.

MATERIALS AND METHODS

The sample campaign was performed on August, 3rd-5th, 2017. Twelve sites were selected off Havana City, between Havana Bay and the mouth of Almendares River (Fig. 1). The geographical coordinates and

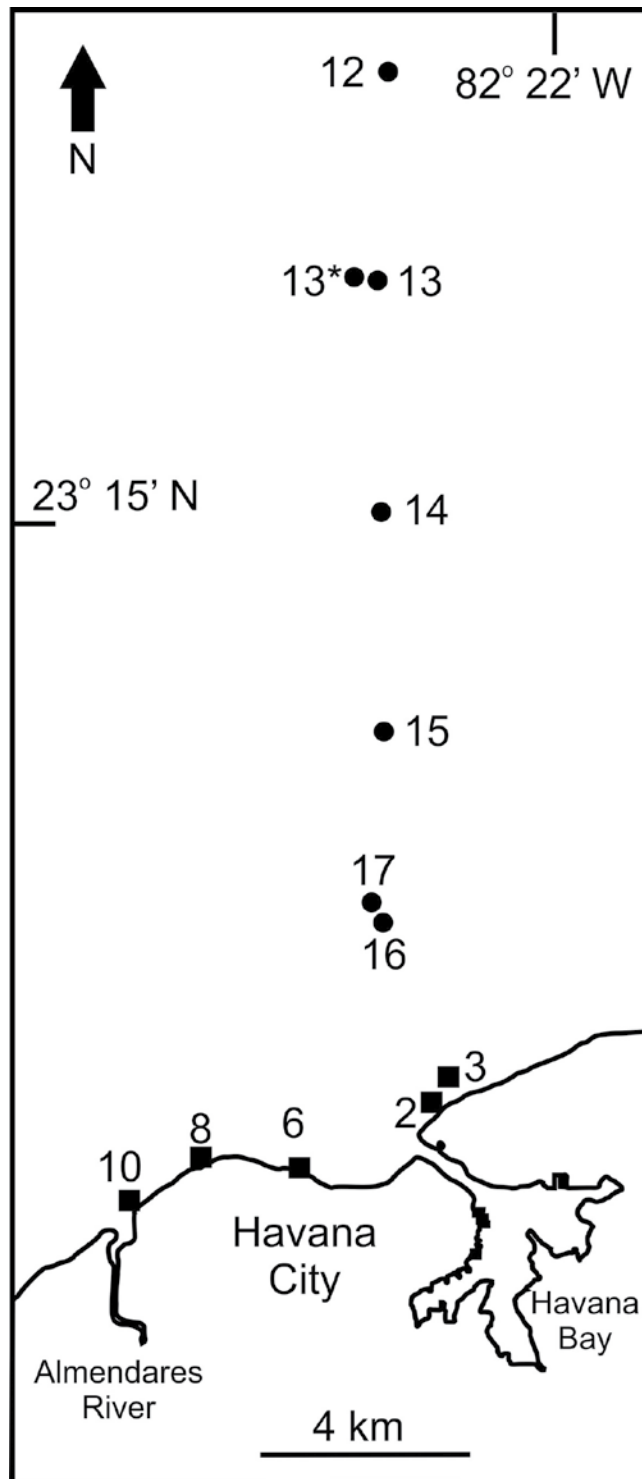


Fig. 1. Map of the study zone indicating the locations of the sampling sites of phytoplankton. Squares and circles indicate coastal and oceanic water sites respectively.

depth were obtained from the vessel navigation system (Table 1). Samples were clustered in coastal (5 sites) versus oceanic (7 sites) waters on basis of depth and distance from shore.

Single superficial samples (1-2 m depth) of water were taken for phytoplankton analyses in eleven sites. The samples were taken with a plankton net (mesh of 20 μm) from an oblique haul during 10 minutes while the vessel was moving slowly. In another site was performed a vertical haul from 7 m depth to surface. All the samples were conserved in 250 mL plastic jars with 3% formaldehyde.

Sample jars were gently shaken for homogenize the content and a drop was extracted with a dropper. Several drops were extracted at several levels of the jars including the material deposited at bottom. Each drop was placed in a temporary preparation and examined under an optical microscope Olympus CX41 at 400x and 1000x of magnification. The stopping criterion for the examination of each sample was that no new record of species occurred in a drop. The phytoplankton species were identified using the taxonomic literature by Gomont (1893), Taylor (1976), Balech (1988), Janson *et al.* (1995), Tomas (1997), Larsen and Nguyen (2004), Hallegraeef *et al.* (2004), and Komárek and Anagnostidis (2005). Taxonomic nomenclature was checked and updated using the online database Algaebase (Guiry & Guiry, 2018).

The processing of samples yielded a qualitative (presence/absence) database of species \times samples. Descriptive statistics of diversity were computed using the software EstimateS 9.0 (Colwell,

Table 1. Data of phytoplankton sampling with sample codes and geographical coordinates of starting points for net tows. S depth indicates depth of sampling, and B depth indicates depth bottom

Site	Sample code	Coordinates	S depth (m)	B depth (m)
2	RFWCUBA030817E2FIT4	23°09,428 N 82°21,124 W	1	10
3	RFWCUBA030817E3FIT8	23°09,558 N 82°21,098 W	1	20
6	RFWCUBA030817E6FIT11	23°08,717 N 82°22,689 W	1	10
8	RFWCUBA030817E8FIT14	23°08,794 N 82°23,753 W	1	15
10	RFWCUBA030817E10FIT17	23°08,404 N 82°24,491 W	1	20
12	RFWCUBA040817E12FIT21	23°19,428 N 82°21,772 W	1	1660
13	RFWCUBA040817E13FIT24	23°17,384 N 82°21,896 W	1	1660
13*	RFWCUBA040817E13FIT26	23°17,435 N 82°22,178 W	7	1660
14	RFWCUBA040817E14FIT29	23°15,124 N 82°21,829 W	1	1500
15	RFWCUBA040817E15FIT31	23°12,982 N 82°21,797 W	1	1300
16	RFWCUBA040817E16FIT34	23°11,265 N 82°21,913 W	1	800
17	RFWCUBA050817E17FIT37	23°11,315 N 82°21,925 W	1	800

* Vertical haul from 7 m to surface

2013). An ordination of samples was made using a non-metric multidimensional scaling with Sorensen index in the program PRIMER 6.1 (Clarke & Gorley, 2006). The procedure SIMPER was used to detect those species that most contribute to the differences between groups.

RESULTS

DIVERSITY

We identified 71 species of phytoplankton belonging to five taxonomic groups (in parentheses the percent of total): 63 Dinophyta (89%), five Bacillariophyta (7%), one Chlorophyta (1%), one Charophyta

(1%), and one Cyanobacteria (1%). The most diverse genera were *Triplos* and *Protoperidinium*, with 20 and 9 infrageneric taxa respectively. There were 21 phytoplankton species reported by first time for Cuban waters (Table 2).

In some samples occurred a high number of phytoplankton, zooplankton and foraminifera associated to detritus or micro-plastic fibers. An athecate chain-forming dinoflagellate of four cells was identified as *Gymnodinium* sp. 2 but its shape was deformed due to preservation. Two freshwater species were identified in the samples: *Monactinus simplex* and *Staurastrum* sp.

Table 2. List of phytoplankton taxa, the frequency of occurrence (# of sites where occurred / 12 sites) and new reports for Cuban waters.

Group	Taxon	Frequency (%)	New report
Bacillariophyta	<i>Asterolampra</i> cf. <i>marylandica</i> Ehrenberg 1844	8	
	Bacillariophyceae	8	
	<i>Coscinodiscus</i> spp.	92	
	<i>Pleurosigma</i> sp.	8	
	<i>Thalassiosira</i> spp.	17	
Dinophyta	<i>Ceratocorys horrida</i> Stein 1883	25	
	<i>Citharistes regius</i> Stein 1883	8	X
	<i>Cladopyxis brachiolata</i> Stein 1883	25	X
	<i>Corythodinium constrictum</i> (Stein) Taylor 1976	8	
	<i>Corythodinium tessellatum</i> (Stein) Loeblich Jr. & Loeblich III 1966	8	X
	<i>Dinophysis caudata</i> Saville Kent 1881	8	
	<i>Dinophysis mucronata</i> (Kofoid & Skogsberg) Balech 1944	8	X
	<i>Gambierdiscus</i> sp.	8	
	<i>Gonyaulax</i> cf. <i>sphaeroidea</i> Kofoid 1911	8	X
	<i>Gonyaulax polygramma</i> Stein 1883	67	
	<i>Gonyaulax spinifera</i> (Claparède & Lachmann) Diesing 1866	42	
	<i>Gymnodinium</i> sp. 1	17	
	<i>Gymnodinium</i> sp. 2	8	
	<i>Histioneis inclinata</i> Kofoid & Michener 1911	8	X
	<i>Lingulodinium polyedra</i> (Stein) Dodge 1989	25	
	<i>Omithocercus magnificus</i> Stein 1883	25	
	<i>Omithocercus steinii</i> Schütt 1900	17	
	<i>Oxytoxum</i> cf. <i>mediterraneum</i> Schiller 1937	8	
	<i>Oxytoxum sceptrum</i> (Stein) Schröder 1906	8	X
	<i>Oxytoxum scolopax</i> Stein 1883	17	
	<i>Oxytoxum sphaeroideum</i> Stein 1883	8	
	<i>Oxytoxum subulatum</i> Kofoid 1907	8	X
	<i>Peridiniella sphaeroidea</i> Kofoid & Michener 1911	8	X
	<i>Peridinium quadridentatum</i> (Stein) H. Hansen 1995	33	
	<i>Phalacroma doryphorum</i> Stein 1883	17	
	<i>Phalacroma favus</i> Kofoid & Michener 1911	8	X
	<i>Phalacroma mitra</i> Schütt 1895	8	X
	<i>Phalacroma rotundatum</i> (Claparède & Lachmann) Kofoid & Michener 1911	8	
	<i>Podolampas palmipes</i> Stein 1883	50	
	<i>Podolampas reticulata</i> Kofoid 1907	8	X
	<i>Prorocentrum</i> cf. <i>compressum</i> (Bailey) Abé ex Dodge 1975	17	
	<i>Prorocentrum gracile</i> Schütt 1895	58	

	<i>Prorocentrum</i> sp.	17	
	<i>Protoperidinium cerasus</i> (Paulsen) Balech 1973	8	
	<i>Protoperidinium</i> cf. <i>cassum</i> (Balech) Balech 1974	17	X
	<i>Protoperidinium</i> cf. <i>conicum</i> (Gran) Balech 1974	17	
	<i>Protoperidinium</i> cf. <i>mastophorum</i> (Balech) Balech 1974	8	X
	<i>Protoperidinium</i> cf. <i>nudum</i> (Meunier) Balech 1974	8	X
	<i>Protoperidinium depressum</i> (Bailey) Balech 1974	42	
	<i>Protoperidinium obtusum</i> (Karsten) Parke & Dodge 1976	8	X
	<i>Protoperidinium</i> sp. 1	33	
	<i>Protoperidinium</i> sp. 2	8	
	<i>Pyrophacus horologium</i> Stein 1883	42	
	<i>Tripos candelabrus</i> (Ehrenberg) F. Gómez 2013	8	
	<i>Tripos carriensis</i> (Gourret) F. Gómez 2013	17	
	<i>Tripos contortus</i> (Gourret) F. Gómez 2013	8	
	<i>Tripos declinatus</i> (Karsten) F. Gómez 2013	17	
	<i>Tripos extensus</i> (Gourret) F. Gómez 2013	42	
	<i>Tripos falcatifformis</i> (Jørgensen) F. Gómez 2013	8	X
	<i>Tripos furca</i> (Ehrenberg) F. Gómez 2013	92	
	<i>Tripos fusus</i> (Ehrenberg) F. Gómez 2013	50	
	<i>Tripos fusus</i> var. <i>seta</i> (Ehrenberg) F. Gómez 2013	8	
	<i>Tripos hexacanthus</i> (Gourret) F. Gómez 2013	8	
	<i>Tripos macroceros</i> var. <i>gallicus</i> (Kofoid) F. Gómez 2013	42	
	<i>Tripos massiliensis</i> (Gourret) F. Gómez 2013	33	
	<i>Tripos muelleri</i> Bory 1825	25	
	<i>Tripos muelleri</i> var. <i>tripodioides</i> (Jørgensen) F. Gómez 2013	8	X
	<i>Tripos pentagonus</i> (Gourret) F. Gómez 2013	33	
	<i>Tripos pentagonus</i> var. <i>tenerus</i> (Jørgensen) F. Gómez 2013	17	X
	<i>Tripos</i> sp.	8	
	<i>Tripos strictus</i> (Okamura & Nishikawa) F. Gómez 2013	8	X
	<i>Tripos teres</i> (Kofoid) F. Gómez 2013	83	
	<i>Tripos vultur</i> var. <i>japonicus</i> (Schröder) F. Gómez 2013	8	X
Chlorophyta	<i>Monactinus simplex</i> (Meyen) Corda 1839	42	
Charophyta	<i>Staurastrum</i> sp.	17	
Cyanobacteria	<i>Trichodesmium thiebautii</i> Gomont ex Gomont 1890	42	

DISTRIBUTION

The observed richness was 44 and 52 species for the coastal and oceanic sites respectively. There were not significant differences of species richness between the coastal and oceanic sites as indicates by the broad overlapping of

the 0.95 confidence intervals (Fig. 2A). The most frequent families were the same for both type of sites. The families Ceratiaceae and Protoperidiniaceae changed their relative importance between the two types of sites: Ceratiaceae was relatively less dominant in

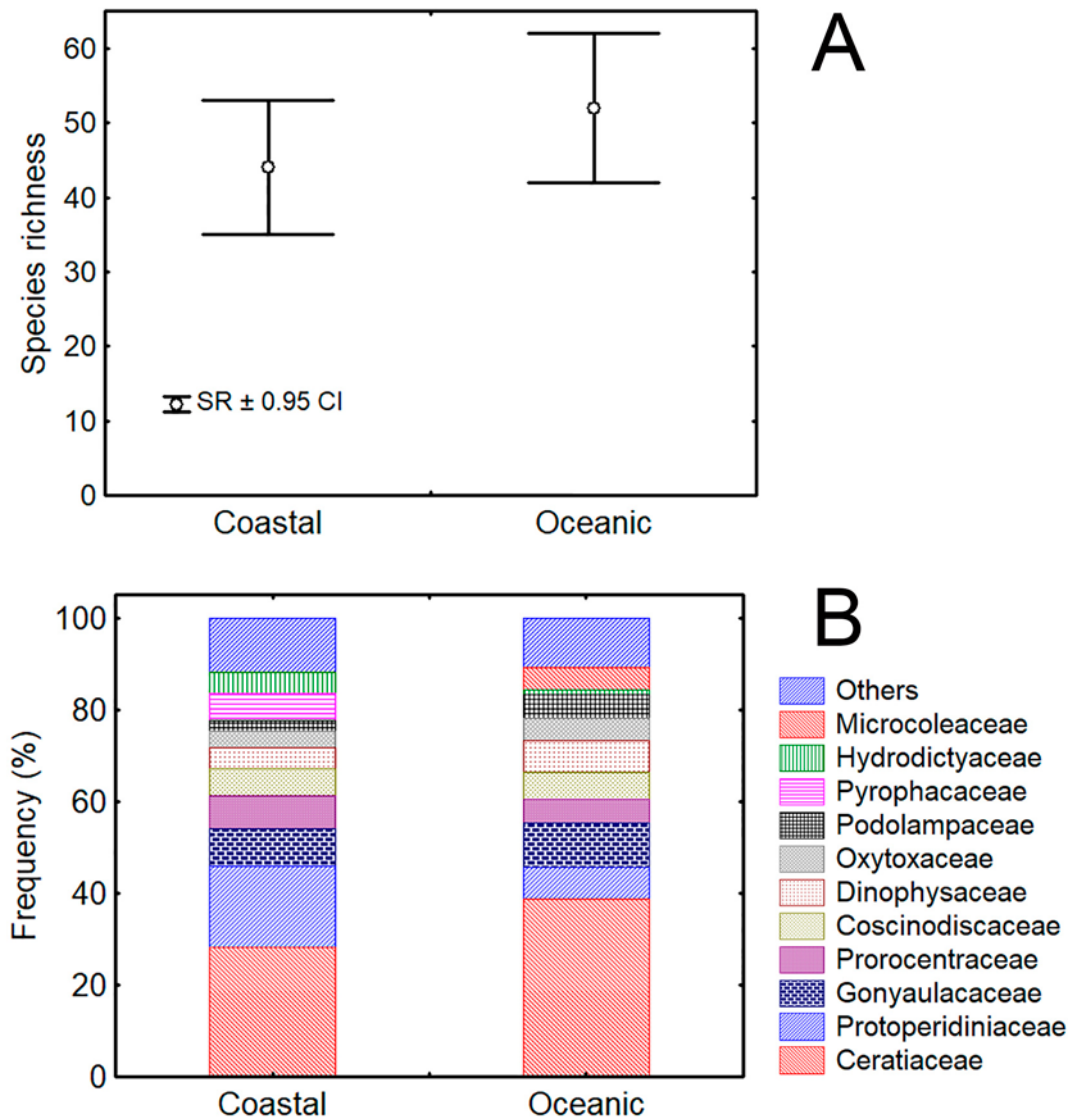


Fig. 2. (A) Species richness of phytoplankton in coastal and oceanic water sites. CI = Confidence intervals. (B) Frequency of the most phytoplankton families. Others include 11 families.

coastal sites when compared with the oceanic ones. Pyrophacaceae occurred only in coastal sites meanwhile Microcoleaceae only in oceanic sites (Fig. 2B).

The most broadly distributed species in the studied area were *Coscinodiscus* spp. and *Tripos furca* that occurring in all sites but one. Other frequent species were: *Tripos teres*, *Gonyaulax polygramma*,

Prorocentrum gracile, *Tripos fusus*, and *Podolampas palmipes* (Table 2). Despite the occurrence of widely distributed species, there was a substantial variation in the species composition among samples as suggested by the clustering patterns in the MDS plot (Fig. 3). The ordination indicated different phytoplankton community composition between coastal and

oceanic waters. The table 3 lists the seven and three species characteristic of coastal and oceanic waters respectively.

The freshwater species *Monactinus simplex* was observed in four coastal and one oceanic sites. Meanwhile *Staurastrum* sp. occurred once in both coastal and oceanic sites.

DISCUSSION

We observed a high number of phytoplankton taxa and the predominance of dinoflagellates in waters off Havana City. Loza and Lugioyo (2009) presented a list of 181 phytoplankton species from oceanic waters around Cuba, of which 57 species were found in both south and north shores while 79 species were observed only at north coast. Near the Havana City, have been observed 69 and 125 phytoplankton species in 2011 and 2012 respectively in coastal

samples from Playas del Este (Bustamante *et al.*, 2016).

Diatoms and dinoflagellates are the dominant phytoplanktonic groups in the Gulf of Mexico and Caribbean Sea (Okolodkov, 2003). In our study, dinoflagellates were more diverse than diatoms in contrast with other studies in Cuban waters which report diatoms as the most diverse taxa (López-Baluja & Vinogradova, 1974; Borrero *et al.*, 1981; 1984; Popowski *et al.*, 1982; Loza & Lugioyo, 2009; Bustamante *et al.*, 2016). This fact may be explained by three reasons. First, the samples were taken in summer, when relative diversity of dinoflagellates increases. According to Reynolds (2006), seasonal changes mainly related to nutrients availability notably influenced the relative dominance of both taxa. Diatoms are dominant in cool, well-mixed and nutrient-rich waters, which are

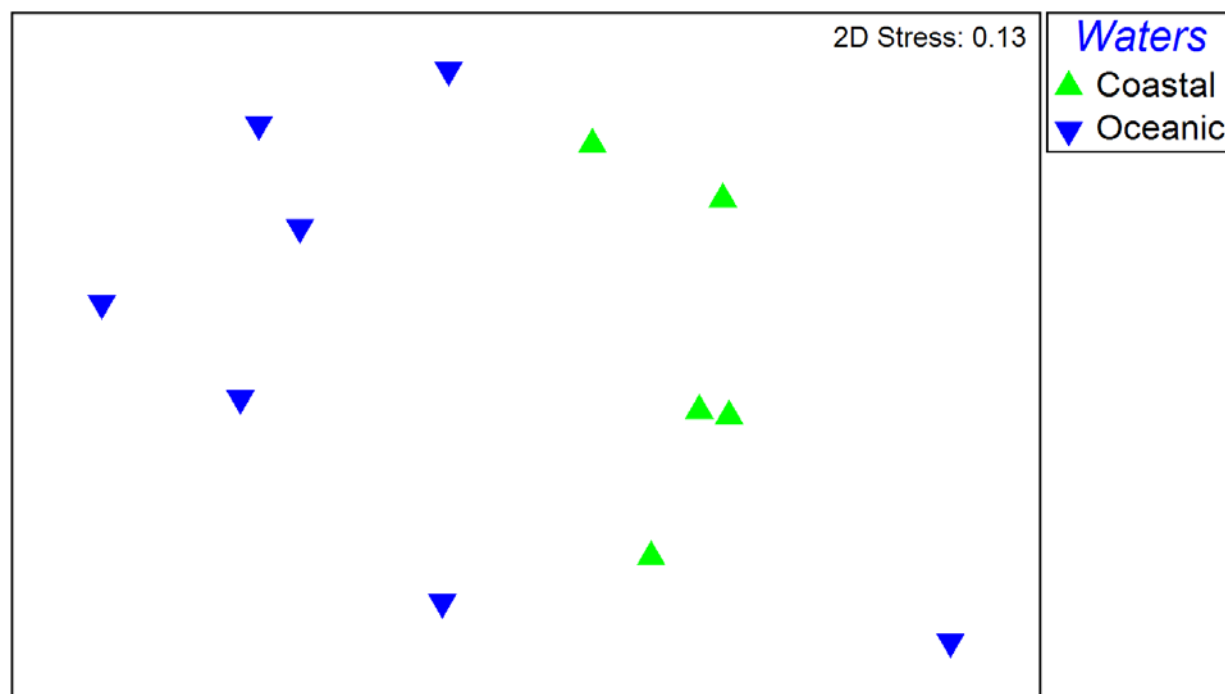


Fig. 3. Ordination of samples based on presence/absence of phytoplankton species and coded by location in coastal or oceanic water sites.

Table 3. Phytoplankton species that most contribute to the dissimilarity between coastal and oceanic sites. Average dissimilarity between coastal and oceanic groups: 68%.

Species	Coastal	Oceanic
<i>Pyrophacus horologium</i>	X	
<i>Prorocentrum gracile</i>	X	
<i>Monactinus simplex</i>	X	
<i>Protoperidinium depressum</i>	X	
<i>Trichodesmium thiebautii</i>		X
<i>Tripos fusus</i>	X	
<i>Peridinium quadridentatum</i>	X	
<i>Tripos macroceros</i> var. <i>gallicus</i>	X	
<i>Podolampas palmipes</i>		X
<i>Tripos extensus</i>		X

typical of winter season. Meanwhile, dinoflagellates get relative advantages in warm, stratified and nutrient-poor waters, which are typical of summer season. For instance, in southwestern Cuba, seasonal variations of phytoplankton communities were observed, with more diatoms during the cooler months while peridinians predominated in the warmer period (López-Baluja, 1978).

Second, we likely underestimated the diversity of diatoms because some species were difficult to identify only with light microscopy. For instance, we recorded the occurrence of several species within the genera *Coscinodiscus* and *Thalassiosira* but unambiguous species delimitation and identification was not possible. Third, small-sized species could pass through the plankton net, being missed in the samples.

We found different species composition between coastal and oceanic sites likely because water column differences in light availability, temperature, nutrients and currents (Reynolds, 2006). Coastal waters are suitable for small and fast-growth dinoflagellate species of gymnodinioids, peridinians and prorocentroids. Oceanic waters

are preferred by larger dinoflagellates (e.g. ceratians) better adapted to vertical movements in the water column where actively seek the best conditions of light and nutrients (Smayda & Reynolds, 2001).

We reported specialized phytoplankters such as heterotrophic dinophysoids and nitrogen-fixer *Trichodesmium* spp. (Microcoleaceae) which were common inhabitants of oceanic oligotrophic waters (Reynolds, 2006). For instance, *Trichodesmium thiebautii* have been observed frequently from oceanic samples in other studies around Cuban waters (López-Baluja & Vinogradova, 1972; 1974; Borrero *et al.*, 1984; Popowski & Campos, 1987; Loza & Lugioyo, 2009). The family Pyrophacaceae was detected only in coastal sites because of *Pyrophacus horologium* which is a thermophile neritic species (Balech, 1988).

The presence of two freshwater species may be explained by water discharges from land (e.g. Almendares River). The transportation of these species by coastal currents probably caused their occurrence in oceanic samples; although *Monactinus simplex* was one of the characteristic species of coastal waters. In *M. simplex*, always indicators of stress were observed (e.g. contracted cytoplasm, discoloration of cellular content). In *Staurastrum* sp., only cell fragments or empty hemicells could be identified.

We observed more phytoplankton species in the presence of detritus or microplastic fibers in the samples. Recent studies have shown the potential for single phytoplankton cells and residual organic matter to interact with microplastics forming aggregates (Long *et al.*, 2017). Thus, these aggregates could have significant impact on marine biota through transference to phytoplankton grazers of the food web.

Importantly, some identified species could be potentially harmful or bloom-forming. We listed them as follows:

Species of the genera *Coscinodiscus* and *Thalassiosira* have been implicated in HABs, with negative impact due to mucilage production or anoxia (Hallegraeff *et al.*, 2004). For instance, the mucilage generation during a bloom of diatoms including *Coscinodiscus* spp. and *Thalassiosira* sp. affected fishing and sport diving in the Marmara Sea, Turkey (Aktan *et al.*, 2008). Particularly, *Coscinodiscus concinnus* Smith 1856, *C. centralis* Ehrenberg 1839, and *C. wailesii* Gran & Angst 1931 are cosmopolitan species capable of forming harmful masses (revised in Hallegraeff *et al.*, 2004). Two of these species have been recorded in Cuban waters: *C. concinnus* (López-Baluja & Vinogradova, 1974; López-Baluja *et al.*, 1980; Borrero *et al.*, 1981; Popowski *et al.*, 1982) and *C. centralis* (Borrero *et al.*, 1984). Another species that can form gelatinous colonies is *Thalassiosira subtilis* (Ostenfeld) Gran 1900 (revised in Hallegraeff *et al.*, 2004), and it was reported for Cuba in recent years (Loza & Lugioyo, 2009).

Dinophysis caudata distributes in tropical and temperate waters and is frequently involved in blooms with others species of *Dinophysis* causing Diarrheic Shellfish Poisoning (DSP). For example, some studies have detected high levels of toxins in Asian Green mussel (*Perna viridis* Linnaeus 1758) from Philippines due to the presence of *D. caudata* and *D. miles* Cleve 1900. *D. caudata* can produce okadaic acid (OA) and pectenotoxin-2 (PTX-2) (Reguera *et al.*, 2014). This species was observed co-occurring with other harmful species during blooms or red tides events in Cienfuegos Bay (Moreira, 2009; 2010; Moreira *et al.*, 2009; 2016a).

Phalacroma mitra potentially produces the toxin dinophysistoxin-1 (DTX-1) but there is no evidence yet of link between occurrence of the species and algal blooms or DSP outbreaks (Reguera *et al.*, 2014). However, *Phalacroma rotundatum* is a heterotrophic species that does not produce toxin. Even more, toxicological studies suggest that *P. rotundatum* is a vector of DSP toxins transferred through the trophic web from toxic *Dinophysis* to ciliates to *Phalacroma* (Reguera *et al.*, 2014).

The genus *Gambierdiscus* is frequently involved in HABs, specifically in the Ciguatera fish poisoning (Hallegraeff *et al.*, 2004). Several species produce ciguatoxins (CTXs) and maitotoxins (MTXs), which are very potent marine biotoxins (Pisapia *et al.*, 2017). Although the genus is mostly benthic, there are species occurring in the plankton (Parsons *et al.*, 2012) probably as result of resuspension (Stanca & Parsons, 2017). Bustamante *et al.* (2016) also observed *Gambierdiscus* sp. from coastal samples, near the study area.

There are reports of *Gonyaulax polygramma* blooms causing mortality to the marine fauna due to oxygen depletion in Hong Kong and South Africa (Hallegraeff *et al.*, 2004). Blooms involving *G. polygramma* and others species as *G. spinifera* have been detected in eutrophic zones of Cienfuegos Bay (Moreira, 2010). Unlike *G. polygramma*, toxicological studies have proved the production of yessotoxin by *G. spinifera* (Rhodes *et al.*, 2006).

Lingulodinium polyedra is a potentially bloom-forming dinoflagellate, capable of producing yessotoxins (Paz *et al.*, 2004). *L. polyedra* has been related with fish and lobsters killings during a red tide event in Bahía Culebra, Costa Rica (Morales-Ramírez *et al.*, 2001).

Peridinium quadridentatum and *Prorocentrum compressum* have been involved frequently in non-toxic blooms in Cienfuegos Bay. These events were probably caused by nutrient inputs from land (Moreira *et al.*, 2009; Moreira, 2010).

Blooms of the common non-toxic species *Tripos fusus* and *T. furca* can produce hypoxia, water discoloration and physical damage to gills of marine animals (Marshall, 2016). For instance, high cell densities of *T. fusus* can cause gill irritation of oyster larvae and shrimps (revised in Hallegraeff *et al.*, 2004). This species was involved in a mixed bloom with two other dinoflagellates in Santiago de Cuba Bay but without harmful effects (Gómez, 2007). In 1994, a bloom of *Tripos furca* and *Prorocentrum micans* Ehrenberg 1834 caused massive fish mortality due to oxygen depletion in St. Helena Bay, South Africa (GEOHAB, 2001). Furthermore, a bloom of *T. furca* affected farmed fishes, lobsters and snails as well as wild fishes in Van Phong Bay, Viet Nam likely due to gill damage observed in dead fishes collected (Doan-Nhu & Nguyen-Ngoc, 2017). *T. furca* have been frequently observed in samples from Cuban waters but not harmful events have been reported regarding this species (e.g. Loza & Lugioyo, 2009; Moreira *et al.*, 2007; 2009; 2013; 2016a).

The species identified as *Gymnodinium* sp. 2 was likely *G. catenatum*, which has been reported from north and south Cuban waters (e.g. Leal *et al.*, 2001; 2003; Moreira, 2009; 2010; Moreira *et al.*, 2013). The bloom-forming *G. catenatum* is distinguished from most other species of *Gymnodinium* by its chain-forming shape and cell size (Larsen & Nguyen, 2004). This species can produce paralytic shellfish toxins (Oshima *et al.*, 1987).

Trichodesmium thiebautii has wide distribution in tropical and subtropical seas and its blooms can be harmful because the synthesis of neurotoxins with effects similar to anatoxin *a* (Hallegraeff *et al.*, 2004). The species can be confused with the also potentially toxic *Trichodesmium erythraeum* Ehrenberg ex Gomont 1892. We described the colonies as variable in shape, approximately 2 mm long, with parallel trichomes or mostly rope-like twisted, trichomes not constricted at the cross walls and sometimes with calyptras at the end, with isodiametric cells (11–14 μm wide and 11–15 μm long). Thus, the description agreed with Hallegraeff *et al.* (2004), Larsen and Nguyen (2004), and Komárek and Anagnostidis (2005).

In summary, the phytoplankton associated to neritic and oceanic waters off the Havana City was highly diverse with 71 species (or infrageneric taxa). Twenty-one phytoplankton species were reported by first time for Cuba. There was different community composition between coastal and oceanic sites indicating differences in the water column environment. Fifteen phytoplankton species were potentially harmful algal bloom-forming suggesting the necessity of a monitoring program in waters off Havana City since its large vulnerability to HABs.

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