Artículo de investigación

Contribution to the knowledge of phytoplankton richness in Serranilla Key, Seaflower Biosphere Reserve, Caribbean Colombia

Contribución al conocimiento de la riqueza de fitoplancton en la isla Cayos de Serranilla, Reserva de Biósfera Seaflower, Caribe colombiano

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Abstract

The Archipelago of San Andres, Old Providence, and Sainte Catalina, declared Seaflower biosphere reserve in 2000, has a marine extension of about 300 000 km2 in the Caribbean Sea. In its northernmost part, there is SerraniIla Cay, an ancient atoll formed by small, emerged cays and a marine extension of about 1 200 km2, 400 km north of San Andres Island. Most of its marine extension includes deep water, but there is a shallow platform on the southwestern part of the bank. Due to its isolation and its distance to the closest inhabited islands of the Archipelago (San Andres and Old Providence islands, it is one of the least studied portions of the Reserve. In September 2017, the Colombian Commission for the ocean (CCO) organized a scientific expedition to SerraniIla, to start studying its biodiversity and ecological processes governing its ecosystems. Among the goals of the expedition, there was the characterization of the phytoplankton community in shallow water. Samples were taken with a phytoplankton net with a mesh size of 27 mum. The samples were taken vertically, from the bottom to the surface of the water at 13 sampling points. Water samples were preserved in transeau solution and observed at optical inverted microscope after sedimentation. A total of 28 genera of diatoms and 8 genera of dinoflagellates were identified. Among the species observed in most samples there are Bleakeleya notata, Nitzschia longissima, Striatella unipunctata, Podolampas palmiper and Tripos teres.

Keywords: *Phytoplankton; richness; diatoms; Serranilla Key; Seaflower Biosphere Reserve*

Resumen

El archipiélago de San Andrés, Providencia y Santa Catalina, declarado Reserva de Biósfera Seaflower en 2000, tiene una extensión marina de 300 000 km^2 en el mar Caribe. En su parte más septentrional se encuentra la isla Cayos de Serranilla, un antiguo atolón formado por pequeños cayos emergidos, con una extensión marina de aproximadamente 1 200 km^2, 400 km al norte de la isla de San Andrés. La mayor parte de esta extensión marina incluye agua profunda, pero hay una plataforma somera en la parte suroccidental del cayo. Debido a su aislamiento y a la distancia de las islas habitadas más cercanas (San Andrés y Providencia) es una de las regiones menos estudiadas de la Reserva. En septiembre 2017, la

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Comisión Colombiana del Océano (CCO) organizó una expedición científica a la isla Cayos de Serranilla, para empezar a estudiar su biodiversidad y los procesos ecológicos que gobiernan sus ecosistemas. Entre los objetivos de la Expedición estaba la caracterización de la comunidad fitoplanctónica en aguas someras. Se colectaron muestras de agua con una red de ojo de malla de 27 mm. La red fue lanzada verticalmente para colectar el agua desde el fondo hasta la superficie, en trece puntos de muestreo. Las muestras fueron preservadas en una solución Transeau; los organismos fueron identificados con un microscopio invertido después de sedimentación. Se identificaron un total de 28 géneros de diatomeas y 8 géneros de dinoflagelados. Entre los organismos observados se reportan *Bleakeleya notata, Nitzschia longissima, Striatella unipunctata, Podolampas palmiper* y *Tripos teres.*

Palabras clave: fitoplancton; riqueza; diatomeas; isla Cayos de Serranilla; Reserva de Biósfera *Seaflower*

Introduction

The Caribbean Sea is the largest adjacent sea of the Atlantic Ocean and is delimited by the coast of Central America to the West, the Northern coast of Colombia and Venezuela to the South, the Yucatan peninsula to the North and the Antillean arc to the North and the East and is divided in 9 ecoprovinces (Spalding *et al*., 2007). The Caribbean Sea is considered an oligotrophic basin with evidence of nitrogen limitation for planktonic systems (Margalef, 1969; Corredor, Howarth, Twilley & Morell, 1999).

The basin is influenced by the discharge of the Orinoco and Amazon rivers, in the Eastern Caribbean, and the Magdalena River in the Southern portion (Sheng & Tang, 2003). Furthermore, local upwelling along the coast of Venezuela and Colombia contribute seasonally to nutrient input to coastal environments (Rodríguez & Cróquer, 2008; Eidens, Bayraktarov, Pizarro, Wilke & Wild, 2012). Through river plumes and run-off, sediments and nutrients have historically entered the Caribbean basin, but increasing loads since the early 1980's continue to impact coastal ecosystems (Restrepo, Zapata, Díaz, Garzón-Ferreira & García, 2006). Industrialization, intensive farming and deforestation have led to an increase in nutrient inputs (Heileman, 2007), that reach the coastal ecosystems. Therefore, portions of the basin are experiencing eutrophication, especially those close to coastline. Far from the coast and industrial discharges, the water is still considered oligotrophic.

The Caribbean Sea harbors about 15 of the 425 atolls worldwide (Díaz, Sánchez, Zea & Garzón-Ferreira, 1996). Most of them are relatively close to the coast (p.e. Los Roques, in Venezuela, about 130 km from mainland; Glover´s Reef in Belize, about 45 km from the coast). The Archipelago of San Andres, Old Providence and Sainte Catalina includes some oceanic atolls, which are far from the three inhabited islands of the Archipelago and isolated from the continental coast. Among these atolls, in the northernmost portion of the Archipelago lies Serranilla Key, which is approximately 325 km NE of Old Providence and 280 km SW of Jamaica. This atoll, along with Nuevo and Alicia shoals, also part of the Archipelago, are the most isolated atolls in the Caribbean Sea. In this area, neither the plumes of the Orinoco, Amazon and Magdalena rivers show impact on the water, nor industrial, agricultural discharge or close-by human settlements directly influence its nutrient concentration (Beier, Bernal, Ruiz-Ochoa & Barton, 2017).

Due to the distance from Colombian continental coast, and also from the inhabited islands of the Archipelago, Serranilla has received very little attention from a scientific point of view and is one of the least known area of the Caribbean Sea. In 2009 CORALINA organized an expedition to Serranilla, Alicia and Nuevo shoals to determine the genetic variability of the gastropod *Lobatus gigas* L. 1758, an important commercial species. In 2010, CORALINA and the local Government organized another expedition to the same area to characterize for the first time the benthic assemblages (coral and macroalgal cover, presence of coral diseases) and the fish community (Abril-Howard, Orozco-Toro, Bolaños-Cubillos & Bent-Hooker, 2012; Bolaños-Cubillos, Abril-Howard, Bent-Hooker, Caldas & Acero, *2015*). In 2011, INVEMAR organized an expedition to the same locations to characterize the marine habitats (Vega-Sequeda, Díaz-Sánchez, Gómez-Campo, López-Londoño, Díaz-Ruíz & Gómez-López, 2015), including the planktonic community (Gutiérrez-Salcedo, Cabarcas-Mier & Suárez-Mozo, 2015). In

2017, the Ocean Colombian Commission, with the collaboration of Dimar, Colciencias, the Colombian Navy and the CIOH, organized the Scientific Expedition *Seaflower* 2017 to Serranilla, to study different aspects of the marine habitats of the atoll, such as the fish assemblages associated to coral reef, macroalgal richness in benthic environments and estimation of ecosystem services of the coral reef of Serranilla.

One of the main biological components of the pelagic medium is plankton, which is formed by autotrophic (phytoplankton) and heterotrophic (zooplankton) organisms. Plankton is important because it regulates energy flows along food webs in pelagic environment and coastal ecosystems as well (Gutierrez-Salcedo *et al.* 2015).

During the 2017 Scientific Expedition Seaflower some phytoplanktonic net samples were collected to contribute to the knowledge of this group in this remote area of the Caribbean Sea.

Materials and methods

Serranilla is an ancient atoll located at 15°47′-52′N and 79°45′-80°03′W (Fig. 1). It is part of the Joint Regime Area Jamaica-Colombia, created through the Sanin-Robertson treaty in 1993; in 2000, the entire Archipelago was declared Biosphere Reserve by UNESCO, and Serranilla was included in the Reserve. It is 40 km long and 32 km wide and includes an area of approximately 1100 km^2. It is characterized by carbonate platform, which lies almost entirely in deep waters. Small islands emerge from the water, with Beacon Key being the largest one. Here there is a lighthouse and a permanent post of the Colombian Army to ensure territorial sovereignty. The coral reef is about 23 km long and is fractioned by small channels, which may experience turbulence and strong currents (Abril-Howard *et al.,* 2012).

Surface ocean currents around Serranilla are dominated by the Caribbean current. During dry season (December-April), the current flows towards west, while in the wet season (August-November) its direction is more variable. The months May to July are a transition season between dry and wet, with occasional rainfall. The temperature is relatively uniform along the whole year, with a mean annual temperature of the air being 26.7ºC. Winds blow mainly in an E-NE direction with mean monthly speeds ranging 3.2-6.2 m/s (Zambrano & Andrade, 2011).

Sampling was carried out between September 7-14, 2017, at 13 sites (Table 1) with a 27 mm mesh size planktonic net in a vertical profile.

Table 1. Sampling station with coordinates and maximum depth.

Sampling site	Coordinates		Date	Maximum depth (m)
1	N 15°48′12.0″	W 79°50′13.8″	07/IX/17	11
2	N 15°48′12.0″	W 79°50′34.7″	07/IX/17	5
3	N 15°49′27.0″	W 79°51′05.6″	08/IX/17	9
4	N 15°49′21.6″	W 79°50′53.0″	08/IX/17	4
5	N 15°49′54.8″	W 79°52′27.9″	09/IX/17	10
6	N 15°49′03.2″	W 79°52′42.4″	09/IX/17	3
7	N 15°48′02.7″	W 79°51′05.0″	10/IX/17	9
8	N 15°55′57.6″	W 79°49′16.4″	11/IX/17	3
9	N 15°53′02.5″	W 79°47′13.7″	11/IX/17	12
10	N 15°48′32.8″	W 79°50′27.8″	12/IX/17	8
11	N15°48′09.3″	W 79°50′55.5″	12/IX/17	10
12	N15°48′09.4″	W 79°50′25.6″	13/IX/17	7
13	N15°52′25.0″	W 79°46′12.2″	14/IX/17	8

Water samples were preserved in opaque plastic bottles and ethanol and formaldhehide solution were added to a final concentration equivalent to Transeau solution (6:3:1 seawater, etanol and formaldehide concentration respectively). In the laboratory, the water samples were analyzed with Utermöhl method (Edler & Elbrächter, 2010): the sample was homogenized, and 25 ml were sedimented for 24 hours and subsequently observed at an inverted light microscope with contrasting phase, Advanced Optical XD-202, with a camera Micrometrics S18.CU. The magnification used were 20x and 40x.

The algae in the samples were identified to the lowest possible taxonomic level using specific literature (Cleve, 1878; Wood, 1968; Balech, 1988; Tomas, 1997; Okolodkov, 2010). Information on nomenclature and taxonomy classification was obtained from AlgaeBase (Guiry & Guiry 2024).

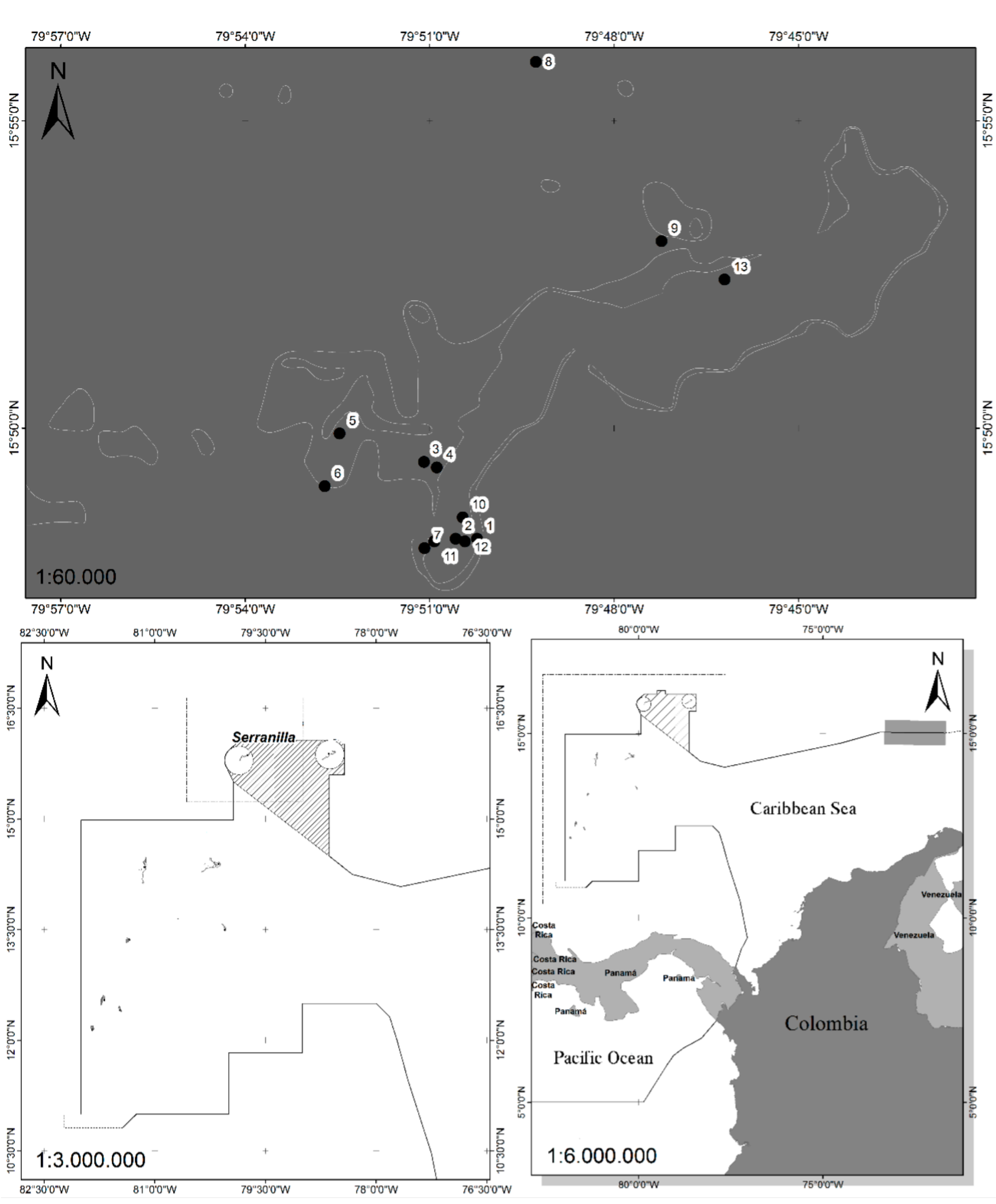

Figure 1. Location of Serranilla Cay in the Caribbean Sea and sample site location.

Results

Twenty-eight genera and twenty-two species of diatoms were identified, as well as eight genera and fifteen species of dinoflagellates (Table 2).

Table 2. species list and station where they were observed.

Taxa	Sample site												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Bacillariophyceae													
Amphiprora sp.										X			
Amphora sp.								x					
Asterolampra marylandica Ehrenberg 1844						X		X					
Bacillaria paxillifera (O. F. Müller) T. Marsson 1901										x			
Bacteriastrum sp.									X				X
Bleakeleya notata (Grunow) Round 1990		X	X	X	X			X	X		x		
Chaetoceros atlanticus Cleve 1873			X	X								X	X
Chaetoceros curvisetus Cleve 1889													X
Chaetoceros pendulus Karsten 1905										X			
Climacosphenia moniligera Ehrenberg 1843										x			
*Cylindrotheca closterium (*Ehr.) Reimann & J.C. Lewin 1964									X		X		X
Eucampia zodiacus f. *cylindricornis* Syvertsen 1983										x			
Grammatophora serpentina Ehrenberg 1844		X							X				
Guinardia striata (Stolterfoth) Hasle 1996			x		x								
Hemiaulus hauckii Grunow ex Van Heurck 1882					X			X					
Isthmia enervis Ehrenberg 1838	x						x			x			
Licmophora sp.	X	X	X	X	X	X	X	X	X	X	X	X	
Mastogloia rostrata (Wallich) Hustedt 1933									x				
Navicula sp.										X			
Nitzschia longissima (Brébisson ex Kützing) Grunow 1862	X	X	X	X	X	X			X	X	X		
Nitzschia sigma (Kützing) W.Smith 1853		X											
Indeterminate pennate diatoms	X	X	X	X	X	X	X	X		X	X	X	X
Pleurosigma sp.		X						X					
Proboscia alata (Brightwell) Sundström 1986	X		x					x	x				
Pseudo-nitzschia delicatissima complex			X	X									
Rhabdonema adriaticum Kützing 1844					x								
Rhizosolenia sp.			X			X			X				

Taxa	Sample site												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Striatella sp.												x	
Striatella unipunctata (Lyngbye) C.Agardh 1832		X		X	X	X		X	X		X	X	X
Synedra sp.		X											
Thalassionema nitzschioides (Grunow) Mereschkowsky 1902	X	X	X	X			X		X				
Thalassiophysa hyalina (Greville) Paddock & P.A.Sims 1981			X	X	X				X	X		X	
Toxarium undulatum Bailey 1854				X	X			X	X		X		
Dinophyceae													
Ceratocorys horrida Stein 1883						x		x					
Acanthodinium caryophyllum Kofoid 1907						X							
Indeterminate thecate dinoflagellates					x			X	X	X			X
Ornithocercus steinii Schütt 1900							X						
Phalacroma rotundatum (Claparéde & Lachmann) Kofoid & J. R. Michener 1911												X	
Podolampas palmipes F. Stein 1883	X			X			X		X	X			X
Podolampas spinifer Okamura 1912					x								
Prorocentrum micans Ehrenberg 1834									X				
Protoperidinium cf. *pellucidum* Bergh 1882				x									
Tripos cf. *minutus* (Jörgensen) F. Gómez 2013	X												
Tripos gracilis (Pavillard) F. Gómez 2013											x		
Tripos macroceros (Ehrenberg) Hallegraeff & Huisman 2020	X	X	X										
Tripos muelleri Bory 1826	X					x			x				
Tripos pentagonus (Gourret) F. Gómez 2021													X
Tripos setaceus (Jørgensen) F. Gómez 2013						X							
Tripos sp.	X				X	X	X	X	X		X	X	
Tripos teres (Kofoid) F. Gómez 2013	X	X		X		X		X		X	X	X	

For diatoms, the most common observed species were *Nitzschia longissima,* present at nine of the thirteen sites, and *Thalassionema nitzschioides*, found at six sites. The least common species were *Chaetoceros curvisetus*, *Chaetoceros pendulus* and *Eucampia zodiacus* f. *cylindricornis.* Furthermore, we observed some benthic species: *Striatella unipunctata*, *Grammatophora serpentina, Bacillaria paxillifera*, *Climacosphenia moniligera*, *Mastogloia rostrata*, *Nitzschia sigma*, *Rhabdonema adriaticum*, *Amphora* sp., *Amphiprora* sp., *Licmophora* sp. and *Synedra* sp. For dinoflagellates, the most common species were *Tripos teres* (eight sites) and *Podolampas palmipes* (six sites).

Centric diatoms are 24%, pennate diatoms are 42% (66% of the total diatoms) and dinoflagellates represent 34% of the listed species.

Among potential toxicogenic species, we found the diatom *Pseudo-nitzschia delicatissima*, which produces domoic acid (causing amnesic shellfish poisoning) and *Phalacroma rotundatum* (okadaic acid and/or dinophysistoxin-2 and/or pectenotoxin-2), although there is controversy about its toxigenic nature (Zingone & Larsen, 2011).

Eleven of the twenty-two species of diatoms encountered, are new records for Serranilla (Table 2); *Mastogloia rostrata* is a new record for the country (Fig. 2), and *Grammatophora serpentina* for the Caribbean Sea (Fig. 2). Thirteen of the fifteen species of dinoflagellates are new records for Serranilla; *Tripos minutus* and *Podolampas spinifer* are new records for the country (Fig. 2), while *Phalacroma rotundatum* is a new record for the Caribbean but has been previously reported for the Gulf of Mexico. Furthermore, *Cladopyxis caryophyllum* (Fig. 2) is reported for the first time in the Caribbean Sea.

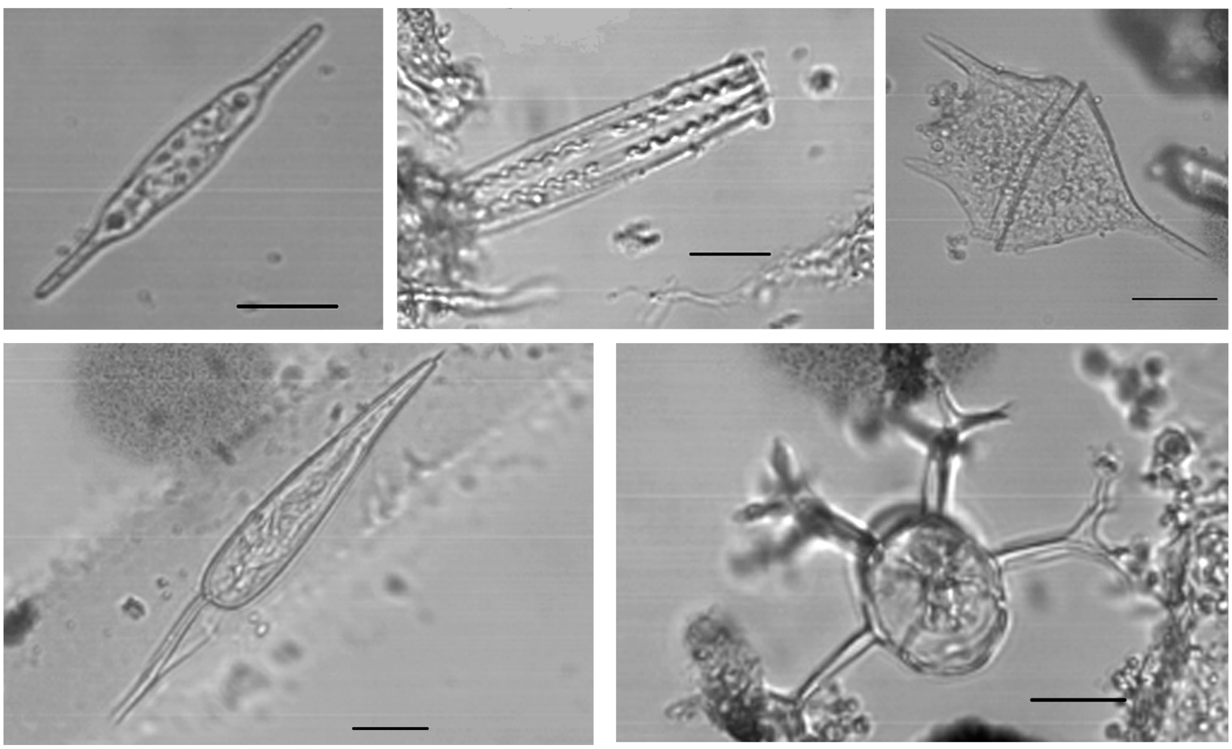

Figure 2. Top left. *Mastogloia rostrata*. Top center. *Grammatophora serpentine*. Top right. *Tripos minutus*. Bottom left. *Podolampas spinifer*. Bottom right. *Cladopyxis caryophyllum*. Scale bars : 20 mm.

Discussion

In Colombia, there are not many published studies on marine phytoplankton diversity (Vidal & Carbonell, 1977; Carbonell, 1979a; 1979b; 1982; Vidal, 1981; Fernández & García, 1998; De la Hoz Aristizábal, 2004; Ramírez-Barón, Franco-Herrera, García-Hoyos & López, 2010). Lozano-Duque, Vidal & Navas (2010, 2011) published a checklist of diatoms (312 species) and dinoflagellates (169 species) for the Colombian Caribbean; for the Archipelago, they report 48 taxa of diatoms and 49 species of dinoflagellates.

The present study accounts with 36 genera and 37 species of phytoplankton, all of them either diatoms or dinoflagellates. These values are typical of oligotrophic seas and are close to what has been reported for Old Providence islands, where Campos-González (2007) found 46 genera at 39 stations. Along the continental coast of Colombia, near Santa Marta, 47-51 genera of phytoplanktonic species were observed, according to seasonality (Ramírez-Barón *et al.*, 2010).

At Los Roques, Venezuela, which is an atoll lying about 130 km from the main coast, Cavada-

Blanco, Zubillaga & Bastidas (2016) observed that 62% of the phytoplanktonic species were diatoms, followed by dinoflagellates (25.4%) and cyanobacteria (8%). In our study no cyanobacteria were found, but the percentage of diatoms was very close to the above-mentioned study, and so was the dinoflagellate portion. Gutiérrez-Salcedo *et al*. (2015) reported 138 species of phytoplankton for the entire Joint Regime Area, which covers SerraniIla, Alicia and Bajo Nuevo shoals. For SerraniIla, they reported 121 species, which is a much higher number of what was found in the present paper and for what has been reported for the Archipelago by Lozano-Duque *et al*. (2010; 2011). The main reason for the discrepancy between the above-mentioned study and the present one, is the methodology used: Gutiérrez-Salcedo *et al*. (2015) used a 20 µm mesh size, lowered at a depth of 50 m and trawled it horizontally for 10 minutes. Our net had a slightly bigger mesh size (27 µm) which was lowered vertically to the bottom (3-12 m depth) and then recovered. No sample concentration was obtained by lowering vertically the net. However, the species that have been reported both by Gutiérrez-Salcedo *et al.* (2015) and this study, are very few: *Chaetoceros curvisetum*, *Hemiaulus hauckii* and *Thalassionema nitzschioides* for the diatoms; *Ceratocorys horrida* and *Ornithocercus* steinii for the dinoflagellates. Some diatoms identified only to genus in both studies are also in common: *Amphora*, *Bacteriastrum*, *Navicula*, *Pleurosigma* and *Rhizosolenia*. All the other species identified in the present study increment the diversity of phytoplankton in Serranilla. In oceanic waters, phytoplanktonic organisms tend to reduce their size: at Los Roques, Venezuela, most species of diatoms identified (62% of all counted diatoms) were small (6-10 and 16-20 mm), as well as the majority of dinoflagellates (48% of total were 16-20 µm in size) (Cavada-Blanco *et al*., 2016). The lowest number of taxa identified here may be due to the mesh size, which did not capture small organisms. There is evidence that phytoplankton response to climate change include a shift to smaller sizes (Taylor *et al*., 2012), and this factor should be taken in account for further studies. However, the lack of oceanographic information in the study area does not allow relating the biological community to its environment and thus compare it to other studies.

Gutierrez-Salcedo *et al*. (2015) observed a great relative abundance of the genera *Chaetoceros*, *Bacteriastrum*, *Pseudonitzschia*, and *Leptocylindrus*. With the exception of the latter, these genera were also found in the present study. The authors suggested that the water mass around SerraniIla may present coastal conditions since these genera are more typical of coastal systems and could have been brought by the current from the Magdalena River or the Panama-Colombia Gyre (Gutiérrez-Salcedo *et al*., 2015). However, the water plume of Magdalena River has not been proved to reach latitude 15 degrees (Cañón-Páez & Santamaría del Ángel, 2003), where Serranilla is located, while a more recent study showed a marked influence of river discharge in the Colombian basin south of latitude 12 degrees, and little or no effect northern than that (Beier *et al*., 2017). It is clear that oceanographic studies in the area are needed, to better understand phytoplankton composition and dynamics in Serranilla Kay.

In the samples a toxic diatom was observed, *Pseudo-nitzschia delicatissima,* a domoic acid producer, which may cause the amnesic shellfish poisoning. A species of *Prorocentrum* was also identified, *P. micans*. Many taxa of the genus are involved in ciguatera and paralytic shellfish poisoning and have been observed at other sites in the Archipelago (Rodríguez, Mancera-Pineda & Gavio, 2010). According to Pottier, Vernoux & Lewis (2001) ciguatera is endemic to the Caribbean Sea, with Florida being its northern limit and Martinique its southern one. However, outbreaks of ciguatera have been observed further south, especially in the last decade (Celis & Mancera-Pineda, 2015), including San Andres Island. Even though the toxicity of *P. micans* is doubtful, Gutiérrez-Salcedo *et al.* (2015) found other species of the genus in the area which might be toxic; Moreover, *Prorocentrum gracile* and *P. micans*, observed in the region, have been involved in red tides phenomena in many areas around the world (Alvial & García, 1986; Fukuyo, Sako, Matsuoka, Imai, Takamashi & Watanabe, 2003).

Non-photosynthetic dinoflagellates, such as *Phalacroma rotundatum* (found in the present study), have also been associated to diarrheic shellfish poisoning (Caroppo, Congestri & Bruno, 1999), and considered to synthetize domoic acid and its derivatives. However, new evidence suggests that *P. rotundatum* does not produce toxins *de novo* but acts as a vector from its toxic preys to shellfish (González-Gil, Pizarro, Paz, Velo-Suárez & Reguera, 2011). Since Serranilla Cay is used as a fishing area, both legally and illegally (Abril-Howard *et al.,* 2012), further monitoring on toxic or potentially toxic species should be carried out in order to avoid intoxication outbreaks.

The present paper is far from presenting an exhaustive list of phytoplanktonic species in SerraniIla. Due to the distance from any human settlement, the area is almost unknown from a scientific point of view. Only very recently (the past 7 years), Colombian Institutions have started to invest resources to study this region of the Biosphere Reserve. Further studies are needed to understand dynamics undergoing in the most isolated atoll of the Caribbean Sea.

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Authors` contribution

ER identified the algae, took the pictures, and wrote the manuscript. BG collected the samples, wrote and revised the manuscript. TR helped with identification, revised the manuscript

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