Centro de Investigaciones Marinas
Universidad de La Habana

Revista de Investigaciones Marinas

RESEARCH ARTICLE

Phytoplankton diversity in coral reefs of Guanahacabibes National Park, Cuba

Diversidad del fitoplancton en arrecifes de coral del Parque Nacional Guanahacabibes, Cuba

Claudia C. Tabio-García [1*]
Magaly E. Sánchez Lorenzo [2]
Dorka Cobián-Rojas [3]
Sandra L. Loza Álvarez [2]

[1] Centro de Investigaciones Marinas de la Universidad de La Habana (CIM-UH). Calle 16 No. 114. Playa. CP 11300. La Habana. Cuba.

[2] Instituto de Ciencias del Mar, Agencia de Medio Ambiente, Ministerio de Ciencia, Tecnología y Medio Ambiente. Calle Loma # 14 e/35 y 37, Nuevo Vedado, Plaza de la Revolución. La Habana. Cuba.

[3] Parque Nacional Guanahacabibes, Centro de Investigaciones y Servicios Ambientales, ECOVIDA Pinar del Río. Cuba.

Autor para la correspondencia:: claudiatabiogarcias@gmail.com

Editor: Sylvia Leal Lorenzo (CIM-UH)

Recibido:08.06.2025
Aceptado:27.11.2025

Abstract

Coral reefs are highly complex and biodiverse ecosystems that are fundamental to ecological balance and socioeconomic development. Assessing and monitoring the communities that comprise them is essential to preserving their stability and ensuring their long-term conservation. Guanahacabibes National Park is home to one of the best-preserved and most diverse reefs on the Cuban platform and in the Caribbean. Studies have been conducted on multiple species in the area, but there is a knowledge gap regarding phytoplankton. Changes in the composition of the phytoplankton community allow for the rapid detection of deteriorating environmental conditions in the ecosystem. This research aims to obtain an inventory of the diversity and composition of the phytoplankton community in the waters of the Guanahacabibes National Park reefs. In August 2022 and 2023, five reefs in the contemplative diving area were sampled. Seven phyla, seven classes, 27 orders, 31 families, and 32 genera were identified. Heterokontophyta had the greatest contribution to specific richness, with the highest number of organisms recorded in the Cabezo de Marcel and Acuario reefs. The genera *Navicula*, *Thalassiosira*, *Gymnodinium*, *Oxytoxum* and *Aphanocapsa* predominated, as did the species *Nitzschia longissima* and *Scrippsiella acuminata*. The waters of the reefs in the contemplative diving area of Guanahacabibes National Park present favorable environmental conditions, characterized by low phytoplankton richness and concentration. However, the presence of potentially harmful organisms highlights the importance of implementing continuous monitoring in this marine area.

Keywords: microalgae, cyanobacteria, oligotrophy, marine protected area (MPA), Guanahacabibes Peninsula.

Resumen

Los arrecifes coralinos son ecosistemas altamente complejos y biodiversos, fundamentales para el equilibrio ecológico y el desarrollo socioeconómico. La evaluación y seguimiento de las comunidades que los integran resulta esencial para preservar su estabilidad y asegurar su conservación a largo plazo. El Parque Nacional Guanahacabibes alberga uno de los arrecifes mejor conservados y más diversos de la plataforma cubana y el Caribe. En el área se han realizado estudios sobre múltiples especies, pero existe un vacío de conocimiento sobre el fitoplancton. Los cambios en la composición de la comunidad fitoplanctónica permiten detectar de manera rápida el deterioro de las condiciones ambientales del ecosistema. El objetivo de esta investigación fue obtener un inventario de la diversidad y composición de la comunidad fitoplanctónica en las aguas de los arrecifes del Parque Nacional Guanahacabibes. En agosto de 2022 y 2023 se muestrearon cinco arrecifes de la zona de buceo contemplativo. Se identificaron siete filos, siete clases, 27 órdenes, 31 familias y 32 géneros. Heterokontophyta tuvo la mayor contribución a la riqueza específica, con el mayor número de organismos registrados en los arrecifes Cabezo de Marcel y Acuario. Predominaron los géneros *Navicula, Thalassiosira, Gymnodinium, Oxytoxum* y *Aphanocapsa y las especies Nitzschia longissima* y *Scrippsiella acuminata*. Las aguas de los arrecifes en la zona de buceo contemplativo del Parque Nacional Guanahacabibes presentan condiciones ambientales favorables, caracterizadas por una baja riqueza y concentración de fitoplancton. No obstante, la presencia de organismos potencialmente dañinos resalta la importancia de implementar un monitoreo continuo en esta área marina.

Palabras clave: microalgas, cianobacterias, oligotrofia, área marina protegida (AMP), Península de Guanahacabibes.

Introduction

Coral reefs are highly complex and productive marine ecosystems (Roberts *et al*., 2002). Within these ecosystems, phytoplankton play a fundamental role by enabling energy input through photosynthetic processes and regulating gas exchange (Rodríguez-Gómez *et al*., 2015; Al-Yamani & Saburova, 2019; Yang *et al*., 2021). Additionally, they influence indispensable processes for ecosystem stability and regeneration, such as calcification and larval proliferation in different populations (D'Angelo & Wiedenmann, 2014).

The diversity and composition of the phytoplankton community can vary significantly due to environmental factors such as nutrient availability, water quality, hydrodynamics and the influence of adjacent ecosystems such as mangroves and seagrasses (Racault *et al*., 2015; Maldonado-Durán *et al*., 2021). These interactions affect not only productivity, but also the resilience of the reef to environmental disturbances.

Under normal conditions, the relationship between nutrient availability and the composition of the natural phytoplankton population shows a ratio of 106:16:1 (C:N:P) (Karl, 2002). This stoichiometric ratio varies according to the trophic state of the water body, as each species has specific nutritional requirements (Reimer & Rodríguez-Troncoso, 2014). Increased nutrient levels cause an exponential increase in the cell density of a species or a group of phytoplankton organisms (Morales *et al*., 2017), which can lead to harmful algal blooms (HABs).

Guanahacabibes National Park (GNP) is the core zone of the Guanahacabibes Peninsula Biosphere Reserve, which has one of the best preserved and most diverse coral reefs on the Cuban shelf and the Caribbean (Cobián-Rojas *et al*., 2023). It has been included in the Gulf of Mexico marine protected area network and the SPAW protocol area network (Perera-Valderrama *et al*., 2020) and declared a Site of Hope (Cobián-Rojas *et al*., 2023).

Research conducted in the GNP has provided valuable information on the state of coral communities, fish and the invasive lionfish species; as well as inventories of gorgonians, sponges, algae, corals, anemones, mollusks and crustaceans (Espinosa *et al*., 2007; González-Ferrer *et al*., 2007; Perera-Valderrama *et al*., 2013; Pina-Amargós *et al*., 2013; Cobián-Rojas *et al*., 2016, 2018; Márquez *et al*., 2018, 2024). These efforts have established critical baseline data, assessed conservation status, and supported effective management strategies for marine protected areas (MPAs) (Perera-Valderrama *et al*., 2020).

Restoration initiatives within the GNP have focused on increasing live coral cover by propagating *Acropora cervicornis* Lamarck, a key species for reef recovery. This project was led by the National Aquarium of Cuba (ANC) in collaboration with Guanahacabibes National Park, the National Center for Protected Areas (CNAP), and the María la Gorda International Diving Center (CIB) of Marinas Gaviota (Cobián-Rojas *et al*., 2022, 2023).

Despite the important knowledge acquired on the biodiversity of the GNP, there is no information on the phytoplankton community in the reef waters of the park. Given the relevance of phytoplankton in the productivity and functioning of this ecosystem, and its ability to predict the effects of pollution and climate change (Hayashida *et al*., 2020), it is essential to understand its composition. This research aims to obtain an inventory of the diversity and composition of the phytoplankton community in the reef waters of the Guanahacabibes National Park.

Materials and methods

Guanahacabibes National Park (GNP) is located in the western part of the Cuban archipelago and its marine area covers 15,950 ha extending from Cabo Corrientes to Cabo de San Antonio (Perera-Valderrama *et al*., 2013). Its coastal reefs span approximately 80 km, with the most visited ones situated in the contemplative diving zone of the park (Cobián-Rojas *et al*., 2023).

Three biotopes are identified in the region's reefs: rocky flat with gorgonians and corals (up to 2-4 m), headlands (5-8 m) and ridges (12-15 m), the latter showing the highest concentration of reef-forming organisms and fish (Valdivia *et al*., 2004). Within the study area, the Acuario (21°47'45.0"N, 84°30'52.7"W) and Cuevas de Pedro reefs (21°46'35.6"N, 84°31'13.3"W), located in the most protected area east of Corrientes Bay, exhibit the highest live coral cover and species richness. In contrast, Laberinto and Cabezo de Marcel provide refuge to diverse species due to their three-dimensionality (Perera-Valderrama *et al*., 2013; Cobián-Rojas *et al*., 2022).

In August 2022 and 2023, seawater samples were collected from five reefs in the GNP: Acuario, Cabezo de Marcel, Cuevas de Pedro, Laberinto and Yemaya (Fig. 1). These sites were selected because they represent key areas for contemplative diving and focal points for active intervention in *Acropora cervicornis* restoration projects (Cobián-Rojas *et al*., 2022). To determine the phytoplankton structure, one liter of seawater was collected from each reef site at its respective depths, ranging from 5 to 12 m. Samples were immediately fixed with acid lugol and preserved in darkness, according to the protocol of Miravet *et al*. (2009).

Organisms were identified and quantified using a biological microscope at 400X magnification. Phytoplankton diversity was characterized using reference literature (Licea *et al*., 1995; Moreno *et. al*., 1996; Throndsen, 1997; Tomas, 1997; Siqueiros, 2002; Sant'Anna *et. al*., 2005; Bonilla, 2009; Gómez, 2012a, b; Komárek *et al*., 2014; Morquecho-Escamilla *et al*., 2016; Reyes *et al*., 2023). Taxonomic categories were updated according to the website classification system: www.algaebase.org (Guiry & Guiry, 2025) and the World Register of Marine Species (WORMS Editorial Board, 2025). In addition, noxious and toxic species were identified, based on the work of Espinoza *et al*. (2013), Pinto-Torres *et al*. (2014) and Allen (2018).

Counts were performed using vertical transects within the counting chamber area (24 × 24 mm) until the minimum sample size (250 cells) was reached. Cell concentration was then calculated using the formula $\left(C=\frac{N}{Vb}\right)$ where N corresponds to the number of cells counted and Vb to the volume analysed (Miravet *et al*., 2009).

Species richness was calculated using an adaptation of the Gleason index (Frontier & Pichod-Viale, 1991), which has the following formula $\left(R_1=\frac{S-1}{\ln n}\right)$ where S

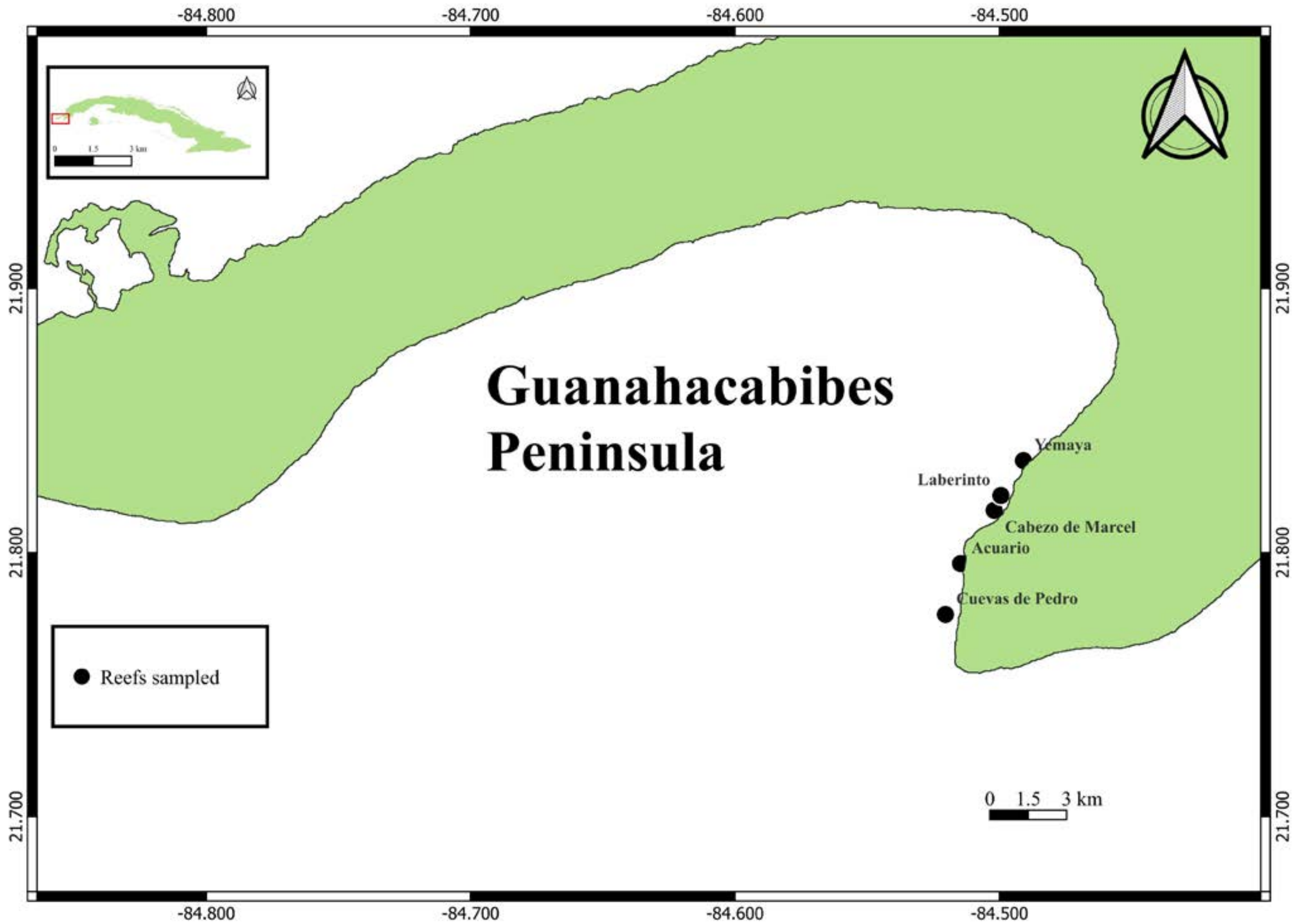

Fig. 1 Location of the coral reefs of Guanahacabibes National Park, Cuba.
Fig. 1 Localización de los arrecifes coralinos del Parque Nacional de Guanahacabibes.

represents the number of species or organisms and n represents the sampled area. In this research, the index was modified by replacing the sampled area with the number of sampling stations (García, 2014). The data obtained were processed with Microsoft Office Excel 2016 and RStudio version 4.3.1 (R Core Team, 2020) programs, using the "ggplot2" package for graphical visualization (Wickham, 2016).

Results

Seven phyla (Chlorophyta, Cyanobacteria, Cryptophyta, Haptophyta, Myzozoa, Heterokontophyta and Raphydophyta), seven classes, 27 orders, 31 families and 32 genera were identified. Of the 40 recognized taxa, only 14 could be identified to species level, as small organisms were predominant and difficult to recognize. Therefore, it was decided to group the classes Coccolithophyceae, Cryptophyceae and Raphydophyceae into microflagellates.

Heterokontophyta division made the greatest contribution to the number of taxa (51 %), followed by Myzozoa (28 %), Cyanobacteria and microflagellates, which contributed 8% each. Meanwhile, Chlorophyta and Haptophyta were only represented by one taxon. Table 1 exhibits the inventory of taxa found and their presence in each of the reefs evaluated.

In general, diatoms made the greatest contribution to the specific richness, and the greatest number of these organisms was detected in the Cabezo de Marcel and Acuario reefs. However, on the Cuevas de Pedro reef the contribution of diatoms (38 %) and dinoflagellates (31 %) was similar (Fig. 2). Among the diatoms, organisms of the class Bacillariophyceae were identified, belonging to 18 genera and eight species.

A comparative analysis of taxonomic composition between 2022 and 2023 revealed a greater number of organisms in the first monitoring. In 2022, the genera *Navicula*, *Thalassiosira*, *Gymnodinium*, *Oxytoxum* and *Aphanocapsa*, as well as the three classes of microflagellates were the most represented organisms within the community. However, in 2023 the greatest contribution to abundance was made by the genera *Navicula*, *Gymnodinium* and *Aphanocapsa*, the species *Nitzschia longissima* (Brébisson) Ralfs and *Scrippsiella acuminata* (Ehrenberg) Kretschmann, Elbrächter, Zinssmeister, S. Soehner, Kirsch, Kusber & Gottschling, as well as the three classes of the microflagellates.

With respect to phytoplankton species richness, it was found that the Acuario (R1= 16.15), Laberinto (R1= 14.29) and Cabezo de Marcel (R1= 12.43) reefs had the highest values, with respect to Cuevas de Pedro (R1= 7.46) and Yemaya (R1= 4.97), which were characterized by lower species richness (Fig. 3).

The phytoplankton community presented low concentrations ranging from 67 to 195 cells.ml^{-1}.

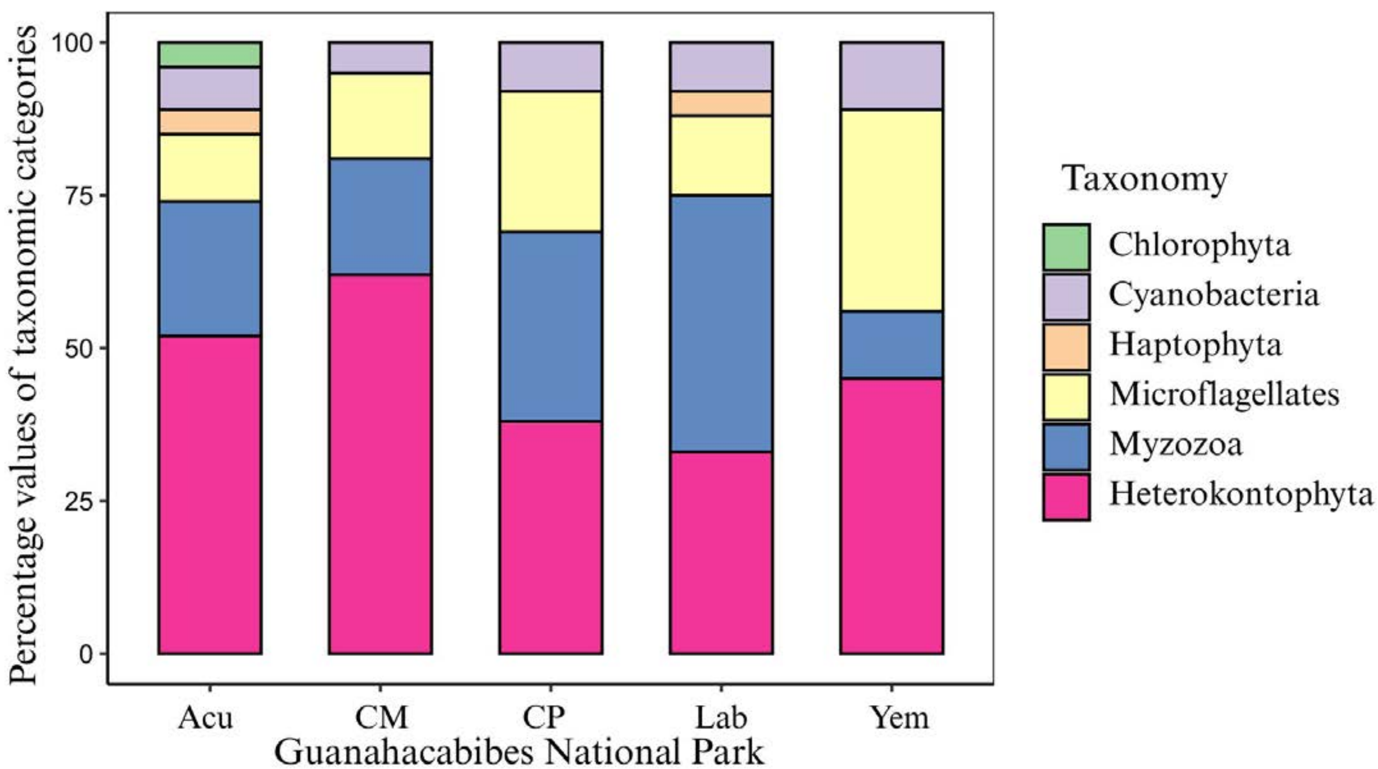

Fig. 2 Contribution of taxonomic categories to phytoplankton richness in the reef waters of the Guanacabibes National Park, Cuba. Reefs sampled: Laberinto (Lab), Cabezo de Marcel (CM), Acuario (Acu), Cuevas de Pedro (CP) and Yemaya (Yem).

Fig. 2 Contribución de las categorías taxonómicas a la riqueza del fitoplancton en las aguas de los arrecifes del Parque Nacional Protegido Guanacabibes. Arrecifes muestreados: Laberinto (Lab), Cabezo de Marcel (CM), Acuario (Acu), Cuevas de Pedro (CP) y Yemaya (Yem).

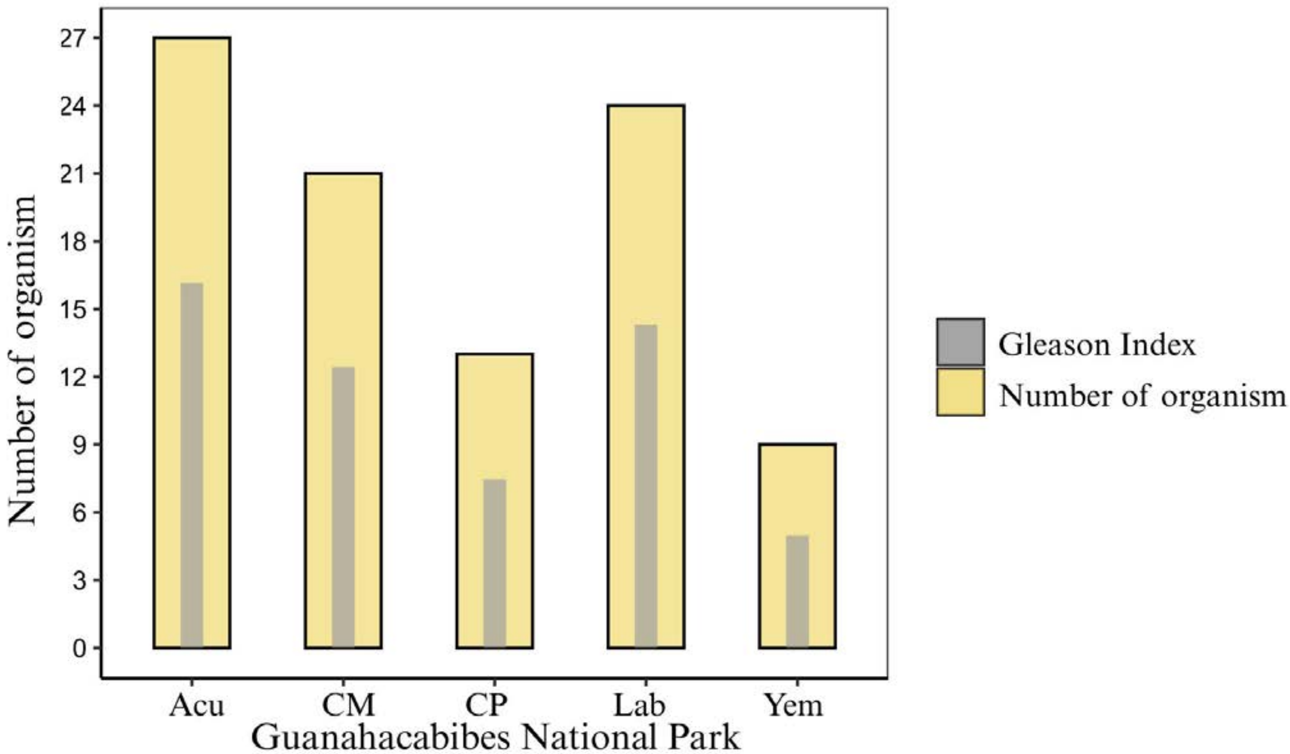

Fig. 3 Phytoplankton community richness in the reef waters of Guanahacabibes National Park, Cuba. Reefs sampled: Laberinto (Lab), Cabezo de Marcel (CM), Acuario (Acu), Cuevas de Pedro (CP) and Yemaya (Yem).

Fig. 3 Riqueza de la comunidad de fitoplancton en las aguas de los arrecifes del Parque Nacional Guanahacabibes. Arrecifes muestreados: Laberinto (Lab), Cabezo de Marcel (CM), Acuario (Acu), Cuevas de Pedro (CP) y Yemaya (Yem).

According to the Frontier index (1981), in 2023 the highest concentration values were detected in the waters of the Cabezo de Marcel (195 cells.ml^{-1}) and Laberinto (164 cells.ml^{-1}) reefs. When comparing the phytoplankton concentrations of Laberinto (100 cells.ml^{-1}) and Cabezo de Marcel (130 cells.ml^{-1}) in August 2022 with those obtained in 2023, it was observed that they were up to twice lower in the previous year.

In the samplings, opportunistic organisms capable of producing toxins and harmful algal blooms were found; the Laberinto reef stands out for having the highest number of opportunistic organisms. Among these opportunistic organisms, the cyanobacteria genera *Aphanocapsa* and *Phormidium* and the dinoflagellate species *Lepidodinium chlorophorum* (M. Elbrächter & E.Schnepf) Gert Hansen, Botes & Salas, *Ornithocercus steinii* Schütt, *Prorocentrum lima* (Ehrenberg) F.Stein, *Prorocentrum micans* Ehrenberg, *S. acuminata* and *Tripos furca* (Ehrenberg) F.Gómez; and diatoms *Leptocylindrus danicus* Cleve and *N. longissima*.

Discussion

In the reefs of Guanahacabibes National Park, the phytoplankton community is dominated mainly by organisms from the Heterokontophyta division, with a notable contribution from the Myzozoa division. The predominance of diatoms and dinoflagellates in the phytoplankton community reflects their rapid ability to adapt to different ecological niches. These microorganisms transform inorganic compounds into organic

Table 1. List of phytoplankton genera and species identified in the waters of the reefs of Guanahacabibes National Park, Cuba. Reefs sampled: Laberinto (Lab), Cabezo de Marcel (CM), Acuario (Acu), Cuevas de Pedro (CP) and Yemaya (Yem). Harmful Organisms: [1]Toxic Organisms, [2]Harmful Algal Bloom Forming Organisms (HABs).

Tabla 1. Listado de géneros y especies del fitoplancton identificados en las aguas de los arrecifes del Parque Nacional Guanahacabibes. Arrecifes muestreados: Laberinto (Lab), Cabezo de Marcel (CM), Acuario (Acu), Cuevas de Pedro (CP) y Yemaya (Yem). Organismos Nocivos: [1]Organismos Tóxicos, [2]Organismos formadores de florecimientos algales nocivos (FANs).

Phylum	Class	Order	Family	Genus and Species	Reefs					Years	
					Lab	CM	Acu	CP	Yem	2022	2023
Heterokontophyta											
	Bacillariophyceae Medlin & Kaczmarska, 2004										
		Achnanthales P.C.Silva, 1962									
			Achnanthaceae Kützing, 1844								
				Achnanthes sp. Bory, 1822			X			X	
			Cocconeidaceae Kützing, 1844								
				Cocconeis sp. Ehrenberg, 1836	X	X	X		X	X	X
		Bacillariales Hendey, 1937									
			Bacillariaceae Ehrenberg, 1831								
				Nitzschia longissima (Brébisson) Ralfs, 1861 (2)	X	X	X	X	X	X	X
		Biddulphiales Krieger, 1954									
			Biddulphiaceae Kützing, 1844								
				Biddulphia sp. S.F. Gray, 1821				X			X
		Climacospheniales Ehrenberg, 1841									
			Climacospheniaceae Ehrenberg, 1841								
				Climacosphenia moniligera Ehrenberg, 1843				X			X
		Fragilariales Silva, 1962									
			Fragilariaceae Greville, 1833								
				Synedra sp. Ehrenberg, 1830	X	X	X			X	X
		Hemiaulales Round & Crawford, 1990									
			Hemiaulaceae Heiberg, 1863								
				Hemiaulus sp. P.A.C. Heiberg, 1863			X				X
		Leptocylindrales Round & Crawford, 1990									
			Leptocylindraceae Lebour, 1930								
				Leptocylindrus danicus Cleve 1889 (2)			X				X
		Licmophorales Round, 1990									
			Licmophoraceae Kützing, 1844								
				Licmophora abbreviata C.Agardh 1831	X	X				X	
		Mastogloiales Round, F.E.; Crawford, R.M.; Mann, D.G. (1990)									

Phylum	Class	Order	Family	Genus and Species	Reefs					Years	
					Lab	CM	Acu	CP	Yem	2022	2023
			Mastogloiaceae Round, F.E.; Crawford, R.M.; Mann, D.G., 1990								
				Mastogloia asperuloides Hustedt, 1933			X				
				Mastogloia sp. G.H.K. Thwaites in W. Smith, 1856		X	X			X	X
		Melosirales Crawford, 1990									
			Melosiraceae Kützing, 1844								
				Melosira sp. C.A. Agardh, 1824			X			X	
		Naviculales Bessey, 1907									
			Naviculaceae Kützing, 1844								
				Navicula sp. J.B.M. Bory de Saint-Vincent, 1822	X	X	X	X	X	X	X
			Pleurosigmataceae Mereschkowsky, 1903								
				Pleurosigma sp. W. Smith, 1852		X	X			X	X
		Surirellales D.G.Mann, 1990									
			Entomoneidaceae Reimer, 1975								
				Entomoneis alata (Ehrenberg) Ehrenberg, 1845		X					X
		Thalassiophysales D.G.Mann, 1990									
			Catenulaceae Mereschkowsky, 1902								
				Amphora lineolata var. sinensis (Schmidt) Cleve, 1895	X	X	X		X	X	X
				Amphora sp. C.G. Ehrenberg ex F.T. Kützing, 1844		X					X
		Rhabdonematales Round & R.M.Crawford, 1990									
			Rhabdonemataceae Round & Crawford, 1990								
				Rhabdonema adriaticum Kützing 1844	X	X	X	X			X
		Rhizosoleniales Silva, 1962									
			Rhizosoleniaceae De Toni, 1890								
				Rhizosolenia sp. T. Brightwell, 1858		X					X
		Thalassiosirales Glezer & Makarova, 1986									
			Thalassiosiraceae Lebour, 1930								
				Thalassiosira sp. Cleve, 1873	X	X	X			X	
Myzozoa											
	Dinophyceae Fritsch, 1927										
		Dinophysales Lindemann, 1928									
			Dinophysaceae Bütschli, 1885								

Phylum	Class	Order	Family	Genus and Species	Reefs					Years	
					Lab	CM	Acu	CP	Yem	2022	2023
				Ornithocercus steinii Schütt, 1900 [2]	X					X	
		Gymnodiniales Lemmermann, 1910									
			Gymnodiniaceae Lankester, 1885								
				Gymnodinium sp. F.Stein, 1878	X	X	X	X		X	X
				Lepidodinium chlorophorum (M.Elbrächter & E.Schnepf) Gert Hansen, Botes & *Salas, 2007* [1,2]	X		X			X	
			Gyrodiniaceae Moestrup & Calado, 2018								
				Gyrodinium sp. Kofoid & Swezy, 1921	X			X			X
		Gonyaulacales Taylor, 1980									
			Ceratiaceae Kofoid, 1907								
				Tripos furca (Ehrenberg) F.Gómez, 2013 [1,2]			X			X	
		Peridiniales Haeckel, 189									
			Oxytoxaceae Lindemann, 1928								
				Oxytoxum sp. Stein, 1883	X	X	X			X	X
			Protoperidiniaceae J.P. Bujak & E.H. Davies, 1983								
				Protoperidinium sp. Bergh, 1881	X					X	
		Prorocentrales Lemmermann, 1910									
			Prorocentraceae Stein, 1883								
				Prorocentrum lima (Ehrenberg) F.Stein 1878 [1]	X		X			X	X
				Prorocentrum micans Ehrenberg 1834 [1]	X					X	
				Prorocentrum sp. Ehrenberg, 1834	X	X		X		X	X
		Thoracosphaerales Tangen in Tangen, Brand, Blackwelder & Guillard, 1982									
			Thoracosphaeraceae Tangen in Tangen, Brand, Blackwelder & Guillard, 1982								
				Scrippsiella acuminata (Ehrenberg) Kretschmann, Elbrächter, Zinssmeister, S.Soehner, Kirsch, Kusber & Gottschling, 2015 [1, 2]	X	X	X	X	X	X	X
Chlorophyta											
	Trebouxiophyceae Friedl 1995										
		Chlorellales H.C.Bold & M.J.Wynne 1978									
			Chlorellaceae Brunnthaler, 1913								
				Chlorella sp. M.Beijerinck, 1890			X			X	

Phylum	Class	Order	Family	Genus and Species	Reefs					Years	
					Lab	CM	Acu	CP	Yem	2022	2023
Haptophyta											
	Coccolithophyceae Rothmaler, 1951										
		Coccolithales Schwarz, 1932									
			Coccolithaceae Poche, 1913								
				Coccolithus sp. E.H.L.Schwarz, 1894	X		X			X	X
Cyanobacteria											
	Cyanophyceae Schaffner, 1909										
		Chroococcales R. von Wettstein von Westerheim, 2002									
			Microcystaceae Elenkin, 1933								
				Aphanocapsa sp. C.Nägeli, 1849 (1)	X	X	X		X	X	X
		Oscillatoriales Cavalier-Smith, 2002									
			Oscillatoriaceae Engler, 1898								
				Phormidium sp. Kützing ex Gomont, 1892 (1)	X						X
		Spirulinales J.Komárek, J.Kastovsky, J.Mares & J.R.Johansen, 2014									
			Spirulinaceae (Gomont) L.Hoffmann, J.Komárek & J.Ka in J.Komárek et al., 2014								
				Spirulina sp. Turpin ex Gomont, 1892			X	X		X	X

ones, providing essential nutrients for the rest of the organisms in the marine food chain (Hevia-Orube, 2017). Therefore, they play crucial roles in the health and stability of ecosystems.

A high frequency of benthic diatoms was identified in the samples analyzed. Among the species present, *Climacosphenia moniligera* Ehrenberg, *Entomoneis alata* (Ehrenberg) Ehrenberg, *Leptocylindrus danicus* Cleve and *Nitzschia longissima* (Brébisson) Ralfs stand out. Specimens of the genera *Achnanthes*, *Amphora*, *Biddulphia*, *Cocconeis*, *Hemiaulu*s, *Mastogloia*, *Melosira*, *Navicula*, *Pleurosigma*, *Rhizosoleni*a, *Synedra*, and *Thalassiosira* were also recorded.

Benthic diatoms have a remarkable ability to rapidly colonize both living and dead substrates. In association with cyanobacteria, they contribute to the formation of mucilaginous mats that promote nitrogen fixation in coral reefs (Charpy *et al*., 2012), stabilize sediments, and prevent erosion (Launeau *et al*., 2018).

The results obtained on the structure of the phytoplankton community are consistent with those reported by Loza *et al*. (2007) regarding the variation of phytoplankton in the waters of the Cuban shelf. In the GNP, the presence of cyanobacteria was detected, organisms that have the ability to synthesize chemical compounds that allow them to defend themselves from herbivory (Pick, 2016).

In the waters of the GNP reefs, cyanobacteria were sparsely represented, with only three taxa (*Aphanocapsa* sp., *Phormidium* sp., and *Spirulina* sp.) and a contribution to phytoplankton richness of 8%. From this, it can be inferred that cyanobacteria proliferation and colonization of the coral skeleton is not expected to occur in the reefs of GNP following a bleaching event (Prato, 2013) that could prevent larval recruitment (Salomón *et al*., 2020).

The low species richness values recorded in the waters of the GNP may be closely associated with the intense herbivory pressure characteristic of these reefs. Sustained grazing exerts a direct influence on the phytoplankton community, modulating its structure and composition (Jales *et al*., 2021). This scenario could explain the identification of a reduced number of taxa compared to what might have been quantified in the waters adjacent to the beaches of Guanahacabibes. Contributing to this pattern is the limited availability of nutrients, typical of crystal-clear tropical waters, where the natural hydraulic network is restricted and terrestrial inputs to the sea are scarce. These conditions reinforce the interpretation of a reduced phytoplankton diversity (Iturralde-Vinent, 2004).

On the other hand, the samples revealed a predominance of small-sized organisms, typical of environments with low nutrient concentrations. This pattern is consistent with the observations of Van Duyl *et al*. (2002), who describe a decrease in the cell size of organisms from the coast to the reefs, due to a decrease in the availability of nutrients from one ecosystem to another.

When analyzing the results obtained in this research together with those reported by Pérez-Castresana *et al*. (2014), Ferreira *et al*. (2015) and Maldonado-Durán *et al*. (2021) for the waters of other protected areas in the region, it is observed that the ecosystems share similar oligotrophic characteristics and biodiversity patterns, despite differences in their hydrographic conditions, anthropogenic impact and seasonal dynamics.

Pérez-Castresana *et al*. (2014) suggest that oligotrophic waters restrict phytoplankton density, although they reported differences in densities according to the location and hydrographic conditions of the reefs of Los Roque Archipelago National Park. In contrast, this research did not reveal significant spatial variations in phytoplankton density within the Guanahacabibes National Park (GNP), which could be attributed to the homogeneity of environmental conditions in the contemplative diving zone.

The phytoplankton community pattern dominated by diatoms and presence of cyanobacteria described by Pérez-Castresana *et al*. (2014), supports the idea that healthy coral reefs usually maintain communities with low density and high specific diversity.

The low phytoplankton concentration values detected may be associated with the occurrence of constant grazing of the benthic community and herbivorous organisms. Ferreira *et al*. (2015) observed that grazing exerts an efficient trophodynamic control on microalgal biomass, particularly in those inhabited by soft corals.

Phytoplankton is consumed directly by meiofaunal organisms, mollusks and herbivorous fish, and indirectly by higher organisms. Herbivores being able to consume between 60% and 100% of the algal biomass and determine whether the ecosystem is dominated by corals or algae (Prato, 2013).

The results obtained in this research show good environmental conditions in the reefs of the GNP, according to the response of phytoplankton diversity and concentration. However, it is important to be aware of the presence of potentially harmful organisms capable of producing toxins or harmful algal blooms (HABs).

In the dinoflagellate group, the highest number of harmful organisms was identified. The species *L. chlorophorum, O. steinii, P. lima, P. micans* and *S. acuminata* are associated with episodes of hypoxia that cause fish mortality (Illoul *et al*., 2008; Espinoza *et al*., 2013; Nunes *et al*., 2022). Similarly, the non-toxic species *T. furca* known to cause fish gill damage and hypoxia events resulting in the death of lobsters, shrimp and fish was detected (Marshall, 2016). Although this species has been recognized for years as part of the phytoplankton community of the Cuban shelf, it has not been recorded so far as causing blooms in Cuban waters (Loza & Lugioyo, 2009; Moreira *et al*., 2016).

Various species belonging to the genera *Aphanocapsa* sp., *Gymnodinium* sp., *Gyrodinium* sp., *Oxytoxum* sp., *Phormidium* sp., and *Protoperidinium* sp. have been identified as toxin producers and responsible for blooms that have caused the mortality of bivalves and fish (Pérez-Olmedo, 2017; Allen, 2018). The occurrence of these harmful algal blooms is favored by temperature increases above 25 °C (Salomón *et al*., 2020) and eutrophication (Quiblier *et al*., 2013), causing serious impacts on marine ecosystems.

Although no algal blooms have been recorded to date in Guanahacabibes National Park, continuous monitoring of the phytoplankton community is essential. Changes in the availability of essential nutrients and the progressive increase in temperatures, exacerbated annually by climate change, create conditions conducive to the occurrence of these phenomena. Monitoring and studying them are crucial for preserving ecological balance and protecting marine biodiversity.

Conclusions

The characterization of the phytoplankton community in the reefs of Guanahacabibes National Park is a strategic tool in the face of increasing climate vulnerability. Incorporating phytoplankton as a biological indicator in monitoring programs would enable faster detection of changes in water quality and ecosystem functioning. Such research not only enriches scientific knowledge but also supports the design of public policies that foster the sustainability and resilience of coral ecosystems.

Acknowledgments

We are grateful for helpful comments and criticisms from referees who improved the manuscript. We thank the Caribbean Biodiversity Fund (CBF) and The Ocean Foundation for funding the project "Community-based coastal remediation in the two largest nations of the insular Caribbean: Cuba and the Dominican Republic". We thank Agencia de Medio Ambiente (AMA), the team of the National Aquarium of Cuba (ANC), the National Center for Protected Areas (CNAP), the María la Gorda International Diving Center of Marinas Gaviota, the coastal community La Bajada and the Center for Marine Research of the University of Havana (CIM-UH). We thank Ramón Damián Morejón Arrojo, BSc., Pedro P. Chevalier Monteagudo, PhD., Silvia Patricia González Díaz, PhD., Eudalys Ortiz Guilarte, PhD. and Gladys Margarita Lugioyo Gallardo, PhD. for their collaboration in carrying out this work. We thank the research team of the Institute of Marine Sciences (ICiMAR) for the opportunity to use their facilities and equipment for sample processing. We thank Leina Zuñiga Fundora, BSc. e Ileana Morales, BSc.

Disclosures

Funding

This study received funding from the Caribbean Biodiversity Fund (CBF) and The Ocean Foundation.

Conflict of interest

The authors have no financial or non-financial conflicts of interest to declare that are relevant to the content of the manuscript.

Ethical considerations

No animals were used in the conduct of this study.

Sampling permits and other permits

No permits were required to conduct this research.

Author contributions

The authors made the following contributions to the manuscript: Conceptualization, CCTG; Software, CCTG; Research, CCTG, MESL and SLLA; Data curation, CCTG; Draft preparation, CCTG and SLLA; Writing-Review and editing, CCTG, DCR, and SLLA; Supervision, DCR and SLLA; Fund acquisition, DCR.

References

Allen, J. (2018). *Chapter I. HABSOS Initiative: Training Programs for the Identification of Harmful Algae.* Guide to the Identification of Harmful Microalgae in the Gulf of Mexico, 1.

Al-Yamani, F., Saburova, M.A. (2019). *Marine phytoplankton of Kuwait's waters. Volume II Diatoms. Cyanobacteria, Dinoflagellates, Flagellates.* Kuwait Institute for Scientific Research, Kuwait.

Bonilla, S. (Ed). (2009). *Cianobacterias planctónicas del Uruguay. Manual para la identificación y medidas de gestión*. Uruguay: Programa Hidrológico Internacional.

Charpy, L., Casareto, B., Langlade, M., Suzuki, Y. (2012). Cyanobacteria in Coral Reef Ecosystems: A Review. *J. Mar. Biol*. (1), 1-9.

Cobián-Rojas, D., Chevalier Monteagudo, P.P., Schmitter Soto, J.J., Corrada Wong, R.I., Salvat Torres, H., Cabrera Sansón, E., García Rodríguez, A., Fernández Osorio, A., Espinosa Pantojam L., Cabrera Guerra, D., Pantoja Echevarría, L.M., Caballero Aragón, H., Perera Valderrama, S. (2016). Density, size, biomass, and diet of lionfish in Guanahacabibes National Park, western Cuba. *Aquat. Biol., 24*(3), 219-226.

Cobián-Rojas, D., Schmitter Soto, J.J., Alfonso Aguilar, A., Aguilar Betancourt, C., Ruiz Zarate, M., González Sansón, G., Chevalier Monteagudo, P.P., García Rodríguez, A., Herrera Pavón, R., Perera Valderrama, S., Caballero Aragón, H., de la Guardia Llansó, E. (2018). Diversidad de las comunidades de peces en dos áreas marinas protegidas del Caribe y su relación con el pez león. *Rev. Biol. Trop. 66*(1), 189-203.

Cobián-Rojas, D., Márquez Llauger, L., Chevalier Monteagudo, P.P., Perera Valderrama, S., González Méndez, J., Caballero Aragón, H., Navarro Martínez, Z. M. (2022). Investigación, monitoreo y manejo para la conservación y uso sostenible de los arrecifes coralinos en el Parque Nacional Guanahacabibes. *Ana. Acad. Cienc. Cub., 12*(2), e1051 Disponible en: http://www. revistaccuba.cu/index.php/revacc/article/view/1051

Cobián-Rojas, D., Perera-Valderrama, S., Chevalier-Monteagudo, P.P., Schmitter-Soto, J.J., Corrada Wong, R.I., de la Guardia Llansó, E., Caballero-Aragón, H. (2023). Guanahacabibes National Park: Research, Monitoring, and Management for the Conservation of Coral Reefs. In V.N. Zlatarski, J.K. Reed, S.A. Pomponi, S. Brooke, S. Farrington (eds) *Coral Reefs of Cuba. Coral Reefs of the World*, vol *18. Springer*, Cham. https://doi.org/10.1007/978-3-031-36719-9_18

D'Angelo, C., Wiedenmann, J. (2014). Impacts of nutrient enrichment on coral reefs: new perspectives and implications for coastal management and reef survival. Current Opinion in *Environmental Sustainability*, *7*, 82-93. Doi: https://doi.org/10.1016/j.cosust.2013.11.029.

Espinosa, J., Ortea, J., Femández-Garcés, R., Moro, L. (2007). Additions to the marine molluscan fauna of Guanahacabibes Peninsule, with description of new species. *Avicennia, 19*, 63-88.

Espinoza Navarrete, J.J., Mendoza Torres, A.J, Rivera Torres, W.E., Parada Herrera, N.P., Alvarado Callejas, Y., Flores Vanegas, M.I., Campos Durán, L., Cabezas Peña, S I. (2013). *Atlas de Fitoplancton Marino.* 1ed. Ciudad Universitaria, San Salvador: LABTOX-UES. Facultad de Ciencias Naturales y Matemáticas.

Ferreira, L.C., Cunha, M.G.G.S., de Aquino, E.P., Borges, G.C.P., Feitosa, F.D.N., Leca, E.E., de Lima, J.C. (2015). Temporal and spatial variation of phytoplankton in a tropical reef area of Brazil. *Tropical Ecology, 56*(3), 367-382.

Frontier, S. (1981). Recuentos y Análisis de los datos. Tratamiento de los datos. 169-188. En: Atlas del zooplancton del Atlántico Sudoccidental y método de trabajo con zooplancton marino. D. Boltovskoy. (Ed.) Rep. Argentina.

Frontier, S., D. Pichod-Viale. (1991). *Ecosystémes: structure, fonctionnement, evolution*. Collection d'ecologie (21), Masson, Paris.

García Nieto, M.H. (2014). *Aportaciones sobre las distribuciones del bastón roto y de pielou* (Doctoral dissertation, Universidad de Salamanca).

Gómez, F. (2012a). A checklist and classification of living dinoflagellates (Dinoflagellata, Alveolata). *Cicimar Oceánides*, *27*(1), 65-140. Doi: http://doi:10.37543/oceanides

Gómez, F. (2012b). A quantitative review of the lifestyle, habitat and trophic diversity of dinoflagellates (Dinoflagellata, Alveolata). *Syst. Biodivers.*, *10*(3), 267-275. http://dx.doi.org/10.1080/14772000.2012.721021

González-Ferrer, S., Caballero, H., Alcolado, P.M., Jiménez, A., Martín, F., Cobián, D. (2007). Diversidad de corales pétreos en once sitios de buceo recreativo de "María la Gorda", Cuba. *Rev. Invest. Mar., 28*(2), 21-30.

Guiry, M.D., Guiry, G.M. (2025). *AlgaeBase.* World-wide electronic publication, National University of Ireland, Galway.Available online at http://www.algaebase.org

Hayashida, H., Matear, R.J., Strutton, P.G. (2020). Background nutrient concentration determines phytoplankton bloom response to marine heatwaves. *Glob. Change Biol., 26*(9), 4800-4811.

Hevia-Orube, J. (2017). *Molecular, morphological and physiological analyses of Mediophyceae diatoms in Bilbao Estuary.* (Doctoral dissertation, Universidad del País Vasco).

Illoul, H., Maso, M., Fortuno, J.M., Cros, L., Morales-Blake, A., Seridji, R. (2008). Potentially harmful microalgae in coastal waters of the Algiers area (Southern Mediterranea Sea). *Cryptogam., Algol.*, *29*(3), 261-278

Iturralde-Vinent, M. (2004). *Tipos de rocas de Cuba*. Recuperado en enero 12, 2009.

Jales, M.C., Feitosa, F.A., Koening, M.L., Montes, M.D.J.F., Pedrosa, V.B. (2021). Influence of abiotic factors on phytoplankton diversity and distribution in an atoll environment. *Acta Bot. Brasil*., *35*, 503-516. doi: 10.1590/0102-33062020abb0269

Karl, D. M. (2002). Nutrient dynamics in the deep blue sea. *Trends Microbiol.*, *10*(9), 410-418.

Komárek, J., Kaštovský, J., Mareš, J., Johansen J.R. (2014). Taxonomic classification of cyanoprokaryotes 2014 using a polyphasic approach. *Preslia, 86* (4): 295-335.

Launeau, P., Méléder, V., Verpoorter, C., Barillé, L., Kazemipour-Ricci, F., Giraud, M., Jesus, B., Le Menn, E. (2018). Microphytobenthos biomass and diversity mapping at different spatial scales with a hyperspectral optical model. *Remote Sens., 10*(5), 716.

Licea Duran, S., Moreno, J.L., Santoyo, H., Figueroa, G. (1995). *Dinoflagelados del Golfo de California*. Universidad Autónoma de Baja California. Secretaría de Educación Pública, México, DF.

Loza Álvarez, S., Lugioyo Gallardo, G.M. (2009). Diversidad del microfitoplancton en las aguas oceánicas alrededor de Cuba. *Rev. Cienc. Mar. Cost., 1*, 29-47.

Loza, S., Lugioyo, M., Martínez, M., Miravet, M.E., Montalvo, J., Sánchez, M. (2007). Evaluación de la calidad de las aguas del Golfo de Batabanó a partir de indicadores biológicos y químicos. *Rev. Invest. Mar., 28*(2), 111-120.

Maldonado-Durán, J., Hernández, M.I.C., Jerez-Guerrero, M., Valcarcel-Castellanos, C. (2021). Fitoplancton del Parque Nacional Natural Corales del Rosario y de San Bernardo durante los periodos de precipitación del 2016 a 2019. *Intropica*, 204-213.

Márquez, L., Cobián, D., Camejo, J.A., Linares, J. L., Borrego, O., Sosa, A., Varela, R. (2018). *Plan de Manejo del Parque Nacional Guanahacabibes, periodo 2019-2023*. Centro de Investigaciones y Servicios Ambientales ECOVIDA, CITMA, Pinar del Río, Cuba.

Márquez, L.; Cobián-Rojas, D.; Camejo, J.A.; Linares, J.L.; Borrego, O.; Sosa, A.; Varela, R. (2024). *Plan de Manejo del Parque Nacional Guanahacabibes, Periodo 2024-2028*. Centro de Investigaciones y Servicios Ambientales, ECOVIDA, CITMA: Pinar del Río, Cuba, 2023.

Marshall, M.W. (2016). A first study of the diversity of the Tripos genus in the marine waters of Belize and the Gulf of Honduras. *Harmful Algae News, 53*, 12-13

Miravet, M.E.; Lugioyo, M.; Loza, S.; Enríquez, D.; Delgado, Y.; Carmenate, M., Pérez, D. (2009). *Procedimientos para el monitoreo de la calidad ambiental en la zona marino costera a partir de microorganismos*. Ediciones Centenario, Santo Domingo, Rep. Dominicana.

Morales, E.A., Rivera, S.F., Vildozo, L.H., Pol, A. (2017). Harmful algal bloom (HAB) produced by cyanobacteria in Alalay Shallow Lake, Cochabamba, Bolivia. *Acta Nova*, *8*, 50-75.

Moreira, A. R., Comas, A., Valle, A., Seisdedo, M., Fernandes, L.F. (2016). Bloom of Vulcanodinium rugosum linked to skin lesions in Cienfuegos Bay, Cuba. *Harmful Algae News, 55,* 10-11.

Moreno, J. L., Licea, S., Santoyo, H. (1996). *Diatomeas del golfo de California*. Universidad Autónoma de Baja California Sur.

Morquecho-Escamilla, L., Reyes-Salinas, A., Okolodkov, Y.B. (2016*). Illustrated Taxonomic Guide of the Marine Dinoflagellate Collection (CODIMAR) Guía Taxonómica Ilustrada de la Colección de Dinoflagelados Marinos (CODIMAR).* Mexico: Centro de Investigaciones Biológicas del Noreste.

Nunes, C. C.D.S., Silva, D. M. L.D., Affe, H. M.D.J., Nunes, J.M.D.C. (2022). Occurrence and distribution of Scrippsiella cf. acuminata (Dinophyta, Thoracospharaceae) in a tropical estuarine gradient. *Rodriguésia*, 73, e02162020.

Perera-Valderrama, S., Alcolado, P.M., Aragón, H.C., de la Guardia Llansó, E., Rojas, D.C. (2013). Condición de los arrecifes coralinos del Parque Nacional Guanahacabibes, Cuba. *Rev. Cienc. Mar. Cost. 5*, 69-86.

Perera-Valderrama, S., Hernández-Ávila, A., Ferro-Azcona, H., Cobián-Rojas, D., González-Méndez, J., Caballero-Aragón, H., Lara, A. (2020). Increasing marine ecosystems conservation linking marine protected areas and integrated coastal management in southern Cuba. *Ocean Coast. Manage*., 196, 105300.

Pérez-Castresana, G., Villamizar, E., Varela, R., Fuentes, Y. (2014). Descripción preliminar del fitoplancton en seis arrecifes coralinos del parque nacional archipiélago de los roques. *Acta Biol. Venez., 34*(2), 293-309.

Pérez-Olmedo, L. (2017). *Composición y abundancia de especies tóxicas y nocivas de dinoflagelados causantes de mareas rojas en la zona costera de Tuxpan, Veracruz*. (Master of Science), Universidad Veracruzana, Tuxpan, Veracruz.

Pick, F. R. (2016). Blooming algae: a Canadian perspective on the rise of toxic cyanobacteria. Can. *J. Fish. Aquat. Sci*, *73*(7), 1149-1158. Doi: 10.1139/ cjfas-2015-0470.

Pina-Amargós, F., Cobián Rojas, D., Martínez, J. (2013). *Protocolo para el monitoreo de la ictiofauna en arrecifes coralinos.* Proyecto GEF/PNUD Aplicación de un enfoque regional al manejo de las áreas marinos-costeras protegidas en la Región de los Archipiélagos del Sur de Cuba. La Habana. Cuba.

Pinto-Torre, M, Frangópulos Riera M, Pizarro Nova G., Alarcón C., Pacheco H. (2014). *Catálogo fotográfico de microalgas productoras de florecimientos algales nocivas.* Centro de Estudios del Cuaternario Fuego Patagonia y Antártica.

Prato Calderrama, J. (2013). *Afloramientos de cianobacterias marinas bentónicas en San Andrés, Providencia y las Islas del Rosario (Caribe colombiano): Caracterización y evaluación de su posible papel ecológico.* (Doctoral dissertation). Universidad Nacional de Colombia.

Quiblier, C., Wood, S., Echenique-Subiabre, I., Heath, M., Villeneuve, A., Jean-François, H. (2013). A review of current knowledge on toxic benthic freshwater cyanobacteria–ecology, toxin production and risk management. *Water Res.*, *47*(15), 5464-5479. Doi: 10.1016/j.watres.2013.06.042.

R Core Team (2020) A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, http://www.R-project.org/

Racault, M. F., Raitsos, D. E., Berumen, M. L., Brewin, R.J., Platt, T., Sathyendranath, S., Hoteit, I. (2015). Phytoplankton phenology indices in coral reef ecosystems: Application to ocean-color observations in the Red Sea. *Remote Sens. Environ*., *160*, 222-234.

Reimer, J., Rodríguez-Troncoso, A. P. (2014). Introducción a la química marina: importancia de los principales nutrientes inorgánicos en el océano. *Invest. Cost.*, 9.

Reyes Motavita, M.C., Díaz Barrios, M.C., Hernández Castillo, B.E. (2023). *Microalgas y cianobacterias. Fichas de morfoespecies. Biodiversidad acuática del Sitio Demostrativo de Ecohidrología PHI- UNESCO, DRMI-Sitio Ramsar Complejo Cenagoso Zapatosa, 2.* Fundación Natura, Ideam.

Roberts, C. M., Mcclean, C., Veron, J., Hawkins, J., Allen, G., McAllister, D., Mittermeier, C., Schueler, F., Spalding, M., Wells, F., Vynne, C., Werner, T. (2002). Marine biodiversity hotspots and conservation priorities for tropical reefs. *Science, 295*(5558), 1280-1284.

Rodríguez-Gómez, C.F., Aké Castillo, J.A., Campos Bautista, G., Okolodkov, Y.B. (2015). A review of the study of phytoplankton in the National Park Sistema Arrecifal Veracruzano. *Revista Digital E-BIOS*. *2*(8)

Salomón, S., Rivera-Rondón, C. A., Zapata, Á. M. (2020). Floraciones de cianobacterias en Colombia: estado del conocimiento y necesidades de investigación ante el cambio global. *Rev. Acad. Colomb. Cienc. Exactas Fis. Naturales, 44*(171), 376-391. doi: https://doi.org/10.18257/raccefyn.1050

Sant'Anna, C., Azevedo, M.T., Agujaro, L., Carvalho, M. C., Souza, R. C. (2005). *Manual ilustrado para identificación y conteo de cianobacterias planctónicas de aguas continentales brasileiras*. SP, Brasil: Interciencia.

Siqueiros, B. D. (2002). *Diatomeas bentónicas de la península de Baja California; Diversidad y Potencial Ecológico*. Comité Editorial IPN – CICIMAR. La Paz, B. C. S. México.

Throndsen, J. (1997). The Planktonic marine flagellates. En Tomas, C., Editor. *Identifying marine phytoplankton*. Elsevier. San Diego, California.

Tomas, C.R., ed. (1997). *Identifying Marine Diatoms and Dinoflagellates.* Academic Press, New York.

Valdivia, A., Guardia, E.D. L., Armenteros, M., González, P., Suárez, A. M., Aguilar, C., González Sansón, G. (2004). Inventario de los componentes más comunes de la flora y la fauna de algunos arrecifes coralinos de la Península de Guanahacabibes, Pinar del Río, Cuba. *Rev. Invest. Mar., 25*(2), 113-121.

Van Duyl, F., Gast, G., Steinhoff, W., Kloff, S., Veldhuis, M., Bak, R. (2002). Factors influencing the short-term variation in phytoplankton composition and biomass in coral reef waters. *Coral Reefs, 21*, 293-306.

Wickham H (2016) ggplot2: *Elegant graphics for data analysis*. https://ggplot2.tidyverse.org

World Register of Marine Species (WoRMS) Editorial Board (2025). *World Register of Marine Species*. Available from https://www.marinespecies.org at VLIZ. Accessed 2024-10-24. doi:10.14284/170

Yang, J.R., Yu, X., Chen, H., Kuo, Y.M., Yang, J. (2021). Structural and functional variations of phytoplankton communities in the face of multiple disturbances. *J. Environ. Sci., 100*, 287-297.

Como citar este artículo

Tabio-García, C.C., Sánchez Lorenzo, M.E., Cobián-Rojas, D., Loza Álvarez, S.L. (2024). Phytoplankton diversity in coral reefs of Guanahacabibes National Park, Cuba. *Rev. Invest. Mar.*, *44*(2), e-11279.