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ARTICLE

Microphytoplanktonic assemblage in a region with upwelling events on the north coast of Bahia, Brazil

Asociaciones microfitoplanctónicas en una región con eventos de surgencia en la costa norte de Bahía, Brasil

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Resumen.- El objetivo del presente estudio fue caracterizar los cambios estacionales en la composición y abundancia del microfitoplancton en la plataforma continental de Bahía, una región con presencia de eventos de surgencia. Se realizaron muestreos semestrales durante los veranos e inviernos de 2017 a 2021 en nueve puntos. El microfitoplancton se muestreó utilizando una red cónica de plancton en arrastres horizontales debajo de la superficie, utilizando un medidor de corriente acoplado a la red, para medir el volumen total de agua filtrada. La temperatura y la salinidad fueron medidas *in situ*, presentando valores típicos de aguas tropicales. Además, las concentraciones de nutrientes inorgánicos disueltos corroboraron el patrón oligotrófico marino tropical. Se identificaron un total de 144 taxones en la región, siendo los phyla Heterokontophyta y Dinoflagellata los más representativos, como se registra típicamente en las regiones costeras tropicales. La densidad varió de $6{,}08 \times 10^4$ a $3{,}38 \times 10^8$ células L^{-1}, con valores promedio más altos en verano. Aunque las cianobacterias representaron solo el 3,2% de la riqueza de especies en la región, debido a las floraciones de verano de *Trichodesmium erythraeum* (2018, 2019 y 2021), fue el grupo más abundante a lo largo del estudio. Se observó que los eventos de surgencia no parecen establecer condiciones favorables para cambios estacionales marcados en la composición y abundancia del microfitoplancton. Las floraciones de *Trichodesmium erythraeum* están estrechamente relacionadas con la fisiología y la capacidad ecológica de esta especie. Con excepción de los períodos de floración, el área de estudio presentó patrones de alta riqueza y diversidad de especies a lo largo de la serie temporal analizada.

Palabras clave: Microalgas marinas, floraciones de verano, región costera tropical

Abstract.- This study aimed to characterize seasonal changes in microphytoplankton composition and abundance on Bahia continental shelf, a region with upwelling events. Semi-annual sampling was conducted during summer and winter from 2017 to 2021 at nine points. Microphytoplankton was sampled using a conical plankton net through horizontal subsurface drags, using a flowmeter coupled to the net, to measure the total volume of filtered water. Temperature and salinity were measured *in situ*, presenting typical values of tropical waters. In addition, dissolved inorganic nutrient concentration corroborated a tropical marine oligotrophic pattern. A total of 144 taxa were identified in the region, with the phyla Heterokontophyta and Dinoflagellata being the most representative, as is typically recorded in tropical coastal regions. The density ranged from 6.08×10^4 to 3.38×10^8 cells L^{-1}, with higher average values in summer. Although cyanobacteria accounted for only 3.2% of species richness in the region, due to summer blooms of *Trichodesmium erythraeum* (2018, 2019, and 2021), it was the most abundant group throughout the study. It was observed that upwelling events do not seem to establish favorable conditions for marked seasonal changes in microphytoplankton composition and abundance. *Trichodesmium erythraeum* blooms are closely related to physiology and ecological capacity of this species. Except for bloom periods, the study area presented a high species richness and diversity throughout the analyzed time series.

Key words: Marine microalgae, summer blooms, tropical coastal region

INTRODUCTION

Temporal variations in the composition and structure of phytoplankton communities in tropical coastal regions are often modulated by the rainfall regime and fluvial nutrient inputs (Thompson *et al*. 2015). Particularly in upwelling areas, the rise of nutrient-rich cold water (Kämpf & Chapman 2016) is another important factor in phytoplankton dynamics, often driving significant increases in local primary productivity (Moser *et al*. 2014).

Similar to what occurs in areas of known upwelling events on the Brazilian Eastern Margin, in the narrowest region of the Brazilian continental shelf off Bahia northern coast (South Atlantic), wind-driven upwelling events have been characterized (Santos *et al*. 2014) predominantly during spring and summer (Aguiar *et al*. 2018), lasting from 3 to 21 days with negative temperature anomalies (< 2.8 °C) and thermal stratification in the water column (for a more detailed understanding of the regional oceanographic processes, see Thévenin *et al*. 2019). The continental influence in this coastal region comes from small fluvial inputs of Jacuípe and Joannes rivers (Paredes 1992, Santos *et al*. 2014), and is of secondary importance on the shelf (Cirano & Lessa 2007, Santana *et al*. 2018).

Phytoplankton represent the first link in the marine trophic web (Reynolds 2006). Their high biological dynamics (short life cycle, rapid responses to abiotic changes) make them reliable bioindicators of environmental variability and the ecological dynamics of coastal ecosystems (*e.g.,* Eskinazi-Leça *et al*. 2004, Sagert *et al*. 2008, Conceição *et al*. 2021, Otsuka *et al*. 2022). Bahia, which corresponds to the most extensive stretch of the Brazilian coast, includes two of the largest bays in the country (Todos os Santos and Camamu Bay); however, outside these two estuarine systems, important knowledge gaps regarding marine microalgae diversity persist. In this study, the composition and abundance of microphytoplankton was analyzed to characterize seasonal changes in assemblage patterns on Bahia continental shelf, a region with upwelling events.

MATERIALS AND METHODS

STUDY AREA

The north coast of Bahia is located in the narrowest (approximately 8 km) region of the Eastern Brazilian shelf (8-15°S) with a depth of 70-80 m (Knoppers *et al*. 2002, Dominguez *et al*. 2013) in a highly favorable upwelling area owing to the seasonality of the wind field (Thévenin *et al*. 2019). This area is dominated by tropical water (TW), which is typically oligotrophic, with a temperature above 20 °C and salinity above 36 (Rezende *et al*. 2011). Small fluvial inputs (average annual flows ~10 m^3s^{-1}) from the Jacuípe and Joannes rivers are the main sources of nutrients of continental origin (Paredes 1992, Santos *et al*. 2014), with low influence on the shelf (Cirano & Lessa 2007, Santana *et al*. 2018). The region has a warm and wet climate with greater rainfall between March and July, a dry period between August and February (Pereira & Lessa 2009) and an average annual rainfall of 2,100 mm (Cirano & Lessa 2007, Hatje & Andrade 2009).

SAMPLING

Seasonal sampling (January-summer and July-winter) was conducted between 2017 and 2021 at nine fixed collection stations (St1-St9; Fig. 1) using a conical plankton net (50 µm mesh opening) through subsurface horizontal drags of 10 min each, at a speed of 2 knots, using a flowmeter coupled to the plankton net to measure the total volume of filtered water. Concentrated samples (n= 90; 1 L each) were fixed with formaldehyde (4%).

At each collection station, environmental variables (temperature, salinity, pH, dissolved oxygen, and turbidity) were measured using a multiparameter probe (Hanna HI-9829). Seawater samples for analysis of dissolved inorganic nutrients (nitrate, ammonia, total phosphorus) and chlorophyll *a* were collected using a Van Dorn bottle (2 L). Nutrient concentrations were analyzed using spectrophotometric method (Grasshoff *et al*. 1983; spectrophotometer: Biospectro Mod. SP-220) and chlorophyll *a* was analyzed according to trichromatic method (Jeffrey & Humphrey 1975).

MICROSCOPY ANALYSIS

In the laboratory, the samples were analyzed under a light microscope (Olympus® CX31), at 200x or 400x magnification. Microphytoplankton were identified based on specialized literature (*e.g.*, Cupp 1943, Cleve-Euler 1955, Wood 1968, Balech 1988, Hernández-Becerril 1996, Tomas 1997, Tiffany & Hernández-Becerril 2005, Throndsen *et al*. 2007), following the taxonomic classification system of Guiry & Guiry (2024). Microphytoplankton quantitative analysis was conducted in sedimentation chambers (2 mL) according to Utermöhl method (Utermöhl 1958). Cell counting was performed under an inverted microscope (Motic® AE 2000) over half of the bottom area of the chamber, without a defined cell number.

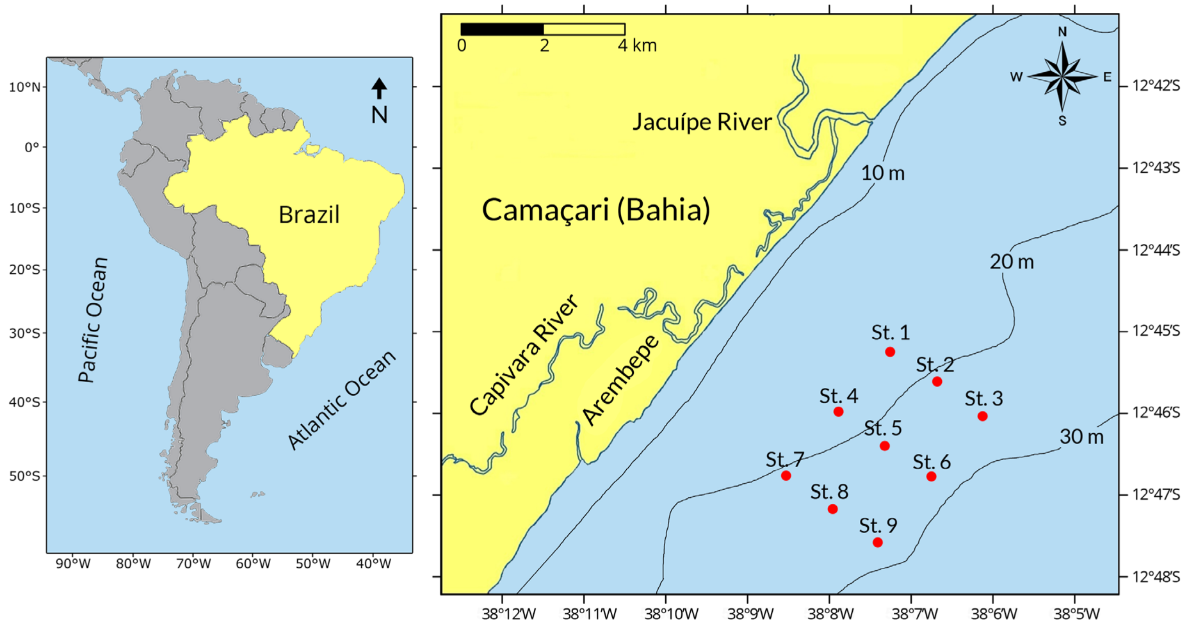


Figure 1. Study area with the location of sampling stations (St1-St9) on the north coast of Bahia (Brazil) / Área de estudio con la ubicación de las estaciones de muestreo (St1-St9) en la costa norte de Bahía (Brasil)

Data analysis

Density (cells L^{-1}), species richness, Shannon-Wiener diversity (Shannon & Weaver 1963), and Pielou equitability indices were calculated from the phytoplankton quantitative analysis. Significant differences ($P < 0.05$) in the environmental variables and microphytoplankton were analyzed using Mann-Whitney test after checking for data normality and homoscedasticity using Shapiro-Wilk and Levene tests, respectively, in BIOESTAT version 5.3 (Ayres *et al*. 2007). Summer and winter data were compared to verify samples and species grouping as a function of seasonality. A cluster two-way dendrogram was used based on the Euclidean distance and Ward method with a relative abundance (%) data matrix of the species present than in at least 3% of the samples. PAST statistical package (Hammer *et al*. 2001) was used to perform the analysis.

Redundancy analysis (RDA) was performed to determine existing relationships between community structure (density, diversity, equitability, richness), environmental variables (*i.e*., rainfall, temperature, salinity, pH, dissolved oxygen, turbidity), and chlorophyll *a*. A forward selection procedure sequentially tested the statistical significance of the environmental variables that most strongly contributed to the canonical model through 499 Monte Carlo permutations. Nutrients were excluded from the analysis because they were below the detection level of the method (< 0.2 mg L^{-1}).

A Monte Carlo permutation test was conducted to assess the statistical significance of abiotic parameters and canonical axes contribution to the model (Ter Braak 1986). These analyses were conducted using the statistical package CANOCO version 4.5 (Leps & Smilauer 2003). To normalize the data, log transformation was used for environmental variables and square root transformation for species data (Cassie 1962).

Results

Environmental variables and chlorophyll *a*

Considering the precipitation accumulated in the 30 days prior to each collection period, no significant seasonal difference was observed (Test U, $P = 0.117$), although more rainfall was recorded in the winter campaigns (86.04 ± 33.01 mm), compared to summer (51.12 ± 42.38 mm), as expected for the region. The exception was 2020 summer (111 mm), when it rained above the average for the analyzed time series (68.6 ± 40.26 mm).

Seawater surface temperature presented an average of 27.33 (± 0.59) °C in summer and 25.61 (± 0.39) °C in winter. Seawater surface salinity presented an average of 36.44 (± 0.64) in summer and 35.33 (± 2.53) in winter. The Mann-Whitney test showed that temperature significantly differed between summer and winter, whereas salinity did not present significant seasonal differences (Table 1). Thermohaline structure from all sampling stations (summer and winter) across the five years showed the presence of tropical water (TW) and coastal water (CW) masses. TW mass is characterized by temperatures > 20 °C and salinities > 36.5. CW mass is characterized by salinities < 36.0, only to be found in summer of 2017 and winter of 2021 (Fig. 2).

Table 1. Environmental variables, microphytoplankton community structure and *P*-value (Mann-Whitney test) comparing summer and winter samplings, along Bahia northern coast (Brazil) during 2017-2021 time series / Comparación de variables ambientales, estructura de la comunidad de microfitoplancton y valor *P* (pruebas de Mann-Whitney) en los muestreos de verano e invierno, a lo largo de la costa norte de Bahía (Brasil) durante la serie temporal de 2017-2021)

	Summer					Winter					*P*-value (Summer x Winter)
	2017	2018	2019	2020	2021	2017	2018	2019	2020	2021	
Temperature (°C)	26.9-28.0	26.5-27.6	27.4-28.6	27.3-27.7	26.8-27.9	24.86-25.42	25.7-26.2	25.5-26.3	25.9-26.2	25.0-25.8	0.009
Salinity	35.2-35.3	37.0-37.1	36.5-36.6	36.5-36.7	36.5-36.6	36.9-37.4	35.9-36.2	36.1-36.4	36.3-36.4	30.4-30.9	0.251
Oxygen (mg L^{-1})	5.8-6.8	6.6-6.7	6.5-6.7	6.6-6.8	6.6-6.7	6.8 6.9	5.5-6.8	6.6-6.7	6.7-6.9	6.7-7.3	0.144
pH	8.0-8.2	7.9-8.0	7.8-8.1	7.7-8.1	7.8-8.1	8.2-8.5	7.8-8.1	7.8-8.1	8.1-8.3	8.1	0.144
Turbidity (NTU)	0-0.6	0	0-0.18	0	0	0-1.2	0	0	0	0-0.29	0.676
Ammonia (mg L^{-1})	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	1
Nitrate (mg L^{-1})	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	1
Phosphorus (mg L^{-1})	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	1
Chlorophyll-*a* (µg L^{-1})	0.4-0.8	1.8-2.0	1.0-2.3	1.3-2.3	0.4-1.4	0.2-1.2	0.2-1.2	0.2-1.4	0.2-1.2	0.2-1.4	0.251
Precipitation (mm)	20.01	29.55	24.84	111.04	80.19	85.32	54.54	125.33	86.21	88.83	0.117
Species richness	13-22	13-22	13-22	22-32	13-31	22-50	26-45	17-24	17-44	13-22	0.047
Shannon-Wiener index	2.44-3.35	1.81-2.89	1.61-2.69	2.92-3.63	1.10-3.36	2.71-3.81	4.05-5.05	1.93-2.49	3.55-4.65	1.81-2.89	0.076
Pielou uniformity index	0.67-0.79	0.49-0.70	0.48-0.69	0.65-0.75	0.27-0.91	0.52-0.73	0.83-0.92	0.64-0.81	0.81-0.93	0.49-0.70	0.037
Density (cells L^{-1})	1.36×10^3- 1.59×10^4	5.39×10^5- 4.13×10^7	8.69×10^5- 4.13×10^7	2.02×10^3- 1.59×10^4	2.02×10^3- 4.13×10^7	1.15×10^3- 5.33×10^4	1.47×10^3- 8.52×10^4	2.02×10^3- 6.38×10^4	2.02×10^3- 8.69×10^4	2.02×10^3- 8.75×10^4	0.602

Turbidity average values were low, ranging between 0.06 (± 0.08) and 1.2 (± 0.17) NTU in the summer and winter, respectively. Dissolved inorganic nutrients had concentrations lower than the method detection level (< 0.2 mg L^{-1}). pH was always alkaline, with averages ranging from 8.04 (± 0.08) (summer) to 8.19 (± 0.18) (winter). Dissolved oxygen was high, with average values of 6.56 (± 0.30) mg L^{-1} (summer) and 6.79 (± 0.12) mg L^{-1} (winter). Chlorophyll *a* biomass ranged from 1.2 (± 0.74) µg L^{-1} in winter, generally increasing in summer (2.3 ± 0.49 µg L^{-1}) owing to higher cell density. These variables did not show significant differences between seasonal samplings over the five-year time series (Table 1).

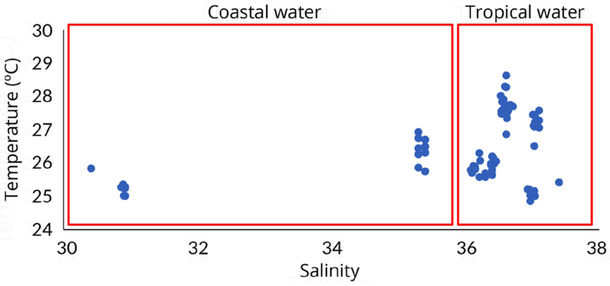


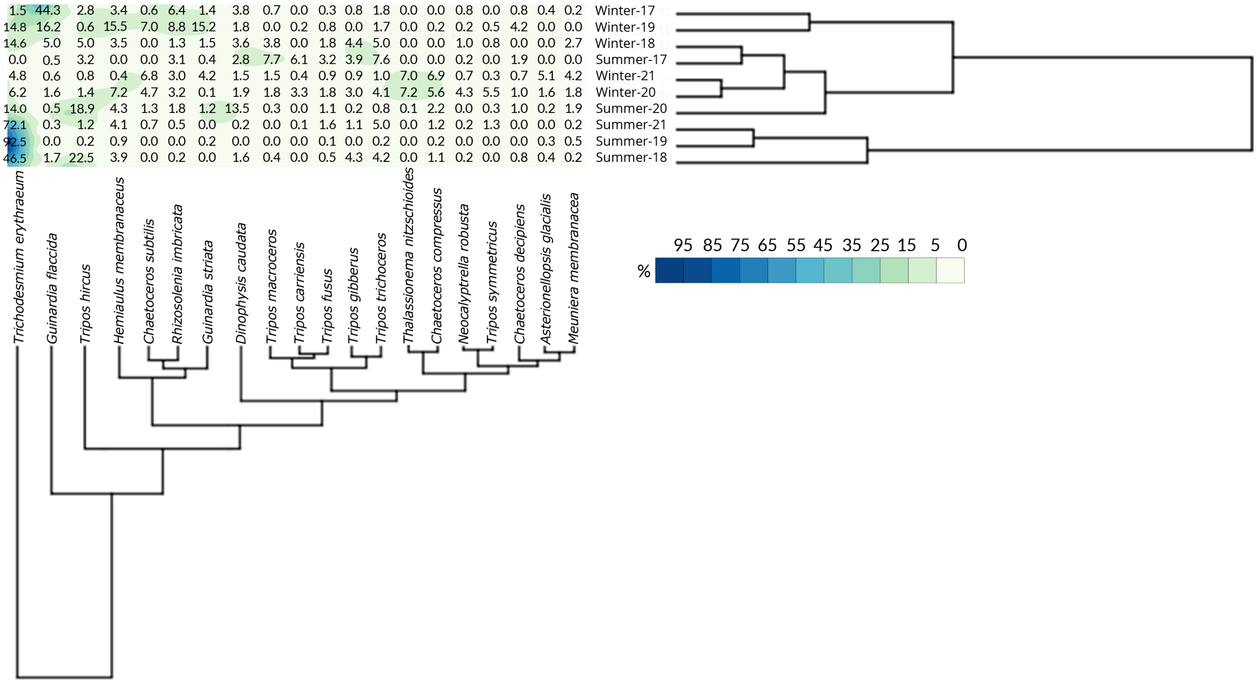
Figure 2. Temperature-salinity plot along the north coast of Bahia (Brazil) during 2017-2021 time series / Diagrama de temperatura-salinidad a lo largo de la costa norte de Bahía (Brasil) durante la serie temporal de 2017-2021

MICROPHYTOPLANKTON ASSEMBLAGE

The 5-year-long series analysis of microphytoplankton showed a small seasonal change in composition, with an increase in cell density during summer. A total of 151 taxa were identified (Table S1), with Heterokontophyta (S= 76 taxa) and Dinoflagellata (S= 69 taxa) being the most representative phyla. One species of Haptophyta (*Gephyrocapsa huxleyi*) was recorded, as well as five species of cyanobacteria: *Johannesbaptistia* sp., *Lyngbya* sp., and *Nostoc* sp., as well as *Trichodesmium erythraeum* and *T. thiebautii* that were present throughout the study period.

Trichodesmium erythraeum blooms and species richness were the major factors that separated phytoplankton assemblages into two main groups in the cluster analysis dendrogram (Fig. 3). The "summer group" consisted of summer samples (2018, 2019, and 2021), with greater similarity determined by *T. erythraeum* blooms and the low species richness. The second group consisted of all winter samples in addition to those from summer 2017 and 2020, owing to the greater species richness and diversity during these periods without blooms. *Trichodesmium erythraeum* blooms were recorded in 2018, 2019 and 2021 summer, presenting average densities of 1.84 × 10^7 (± 3.30 × 10^6) cells L^{-1}, 4.15 × 10^7 (± 1.40 × 10^7) cells L^{-1}, and 2.70 × 10^6 (± 1.20 × 10^6) cells L^{-1}, respectively. During these periods, Cyanobacteria were dominant in the study area, causing a marked change in water color. Although *T. thiebautii* was present throughout the study period, it occurred at low densities during winter samplings, increasing in a non-significant manner during summer samplings.

Microphytoplankton Shannon-Wiener Index (H') varied between 2.52 (± 0.78) bits ind^{-1} (summer) and 3.81 (± 1.02) bits ind^{-1} (winter). Pielou uniformity index (J') presented an average of 0.59 (± 0.16) in summer and 0.80 (± 0.10) in winter. Species richness presented an average of 46 (± 6) in summer and 63 (± 12) in winter, indicating summer taxa dominance. Mann-Whitney test (Table 1) showed that diversity (H'), equitability (J'), and richness significantly differed between summer and winter (U test, $P < 0.05$). Phytoplankton density was greater in summer; however, these variations had no significant difference (U test= 0.602) between seasons (Table 1).



	Trichodesmium erythraeum	*Guinardia flaccida*	*Tripos hircus*	*Hemiaulus membranaceus*	*Chaetoceros subtilis*	*Rhizosolenia imbricata*	*Guinardia striata*	*Dinophysis caudata*	*Tripos macroceros*	*Tripos carriensis*	*Tripos fusus*	*Tripos gibberus*	*Tripos trichoceros*	*Thalassionema nitzschioides*	*Chaetoceros compressus*	*Neocalyptrella robusta*	*Tripos symmetricus*	*Chaetoceros decipiens*	*Asterionellopsis glacialis*	*Meuniera membranacea*
Winter-17	1.5	44.3	2.8	3.4	0.6	6.4	1.4	3.8	0.7	0.0	0.3	0.8	1.8	0.0	0.0	0.8	0.0	0.8	0.4	0.2
Winter-19	14.8	16.2	0.6	15.5	7.0	8.8	15.2	1.8	0.0	0.2	0.8	0.0	1.7	0.0	0.2	0.2	0.5	4.2	0.0	0.0
Winter-18	14.6	5.0	5.0	3.5	0.0	1.3	1.5	3.6	3.8	0.0	1.8	4.4	5.0	0.0	0.0	1.0	0.8	0.0	0.0	2.7
Summer-17	0.0	0.5	3.2	0.0	0.0	3.1	0.4	2.8	7.7	6.1	3.2	3.9	7.6	0.0	0.0	0.2	0.0	1.9	0.0	0.0
Winter-21	4.8	0.6	0.8	0.4	6.8	3.0	4.2	1.5	1.5	0.4	0.9	0.9	1.0	7.0	6.9	0.7	0.3	0.7	5.1	4.2
Winter-20	6.2	1.6	1.4	7.2	4.7	3.2	0.1	1.9	1.8	3.3	1.8	3.0	4.1	7.2	5.6	4.3	5.5	1.0	1.6	1.8
Summer-20	14.0	0.5	18.9	4.3	1.3	1.8	1.2	13.5	0.3	0.0	1.1	0.2	0.8	0.1	2.2	0.0	0.3	1.0	0.2	1.9
Summer-21	72.1	0.3	1.2	4.1	0.7	0.5	0.0	0.2	0.0	0.1	1.6	1.1	5.0	0.0	1.2	0.2	1.3	0.0	0.0	0.2
Summer-19	92.5	0.0	0.2	0.9	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.3	0.5
Summer-18	46.5	1.7	22.5	3.9	0.0	0.2	0.0	1.6	0.4	0.0	0.5	4.3	4.2	0.0	1.1	0.2	0.0	0.8	0.4	0.2

Figure 3. Cluster analysis with the 20 most abundant phytoplankton species along the north coast of Bahia (Brazil) during 2017-2021 time series / Análisis de conglomerados con las 20 especies de fitoplancton más abundantes a lo largo de la costa norte de Bahía (Brasil) durante la serie temporal de 2017-2021

CORRELATIONS BETWEEN MICROPHYTOPLANKTON AND ENVIRONMENTAL VARIABLES

Redundancy analysis based on the set of six environmental variables (temperature, salinity, pH, dissolved oxygen, turbidity, rainfall), chlorophyll *a*, and microphytoplankton structure presented an order with eigenvalues ranging from 0.69 (RDA 1) to 0.01 (RDA 4). The first two axes explained 99% of the accumulated percentage of the species–environment correlation.

Samples were ordered according to the seasonal patterns (Fig. 4), evidencing an environmental gradient with higher temperature, salinity, turbidity, and chlorophyll *a* in summer (right side), correlated with higher cellular density of microphytoplankton, especially considering the blooms recorded during 2018, 2019, and 2021. In winter (left side), there was a correlation between higher rainfall volumes, pH, and dissolved oxygen, with greater richness, diversity, and equitability of the microphytoplankton assemblage.

DISCUSSION

The northern coast of Bahia has a historical rainfall pattern consisting of higher rainfall between March and July (winter) and a dry period between August and February (summer) (Pereira & Lessa 2009), with a linear trend of annual reduction in rainfall volume (-10 mm year^{-1}) (Lessa *et al*. 2018). During the 5-year time series of the present study, a typical pattern of higher rainfall in winter was observed, corroborating the historical series; however, a stochastic event of high rainfall was recorded on summer 2020 (January). These summer rains are frequently recorded on the northeast coast, often causing changes in coastal waters or even occurring as an extreme event, resulting in major socio-economic impacts such as the one from November 2021. These events generally result from the effects of El Niño or La Niña (Marengo *et al*. 2018), and may be intensified in the context of ongoing climate change.

Along the northeast coast of Brazil, sea surface water is predominantly warm and saline depending on radiation and evaporation intensity (Silveira *et al*. 2000). Temperatures were always above 25 °C and salinity was approximately 36, varying very subtly throughout the year as a consequence of the strong presence of tropical water on the continental shelf and the inexpressive fluvial input (Santana *et al*. 2018), even in the rainy season.

Similarly, the typical oligotrophic pattern of these waters with nutrient concentrations almost constantly below method detection limit was recorded, evidencing that fluvial inputs do not condition an increase in nutrients in the system, as observed in the internal areas of Todos os Santos Bay during rainy season (*e.g*., Affe *et al*. 2021, Conceição *et al*. 2021). Although this is an upwelling area with wind-forced resuspension processes which are more intense in summer (Santos *et al*. 2014, Aguiar *et al*. 2018, Thévenin *et al*. 2019), cannot ascertain whether this mechanism increases the support capacity of the system, because of the constantly low concentrations of nutrients recorded throughout the study.

Microphytoplankton temporal analysis on northern Bahia continental shelf revealed a tropical species composition and structural pattern, with greater richness of diatoms and dinoflagellates. The former, in general, are predominant in coastal and estuarine systems (*e.g.*, Eskinazi-Leça *et al*. 2004, Procopiak *et al*. 2006, Silva *et al*. 2009, Rochelle-Newall *et al*. 2011, Carvalho *et al*. 2016, Affe *et al*. 2018, 2019, 2021; Santos *et al*. 2020, Conceição *et al*. 2021), presenting less diversity in relation to dinoflagellates in oceanic areas microphytoplankton (Koening & Macêdo 1999, Fernandes & Brandini 2004). Among these, the genus *Tripos*, which is considered an indicator of the Brazilian Current (Balech 1988), had the highest species richness in the study area, as

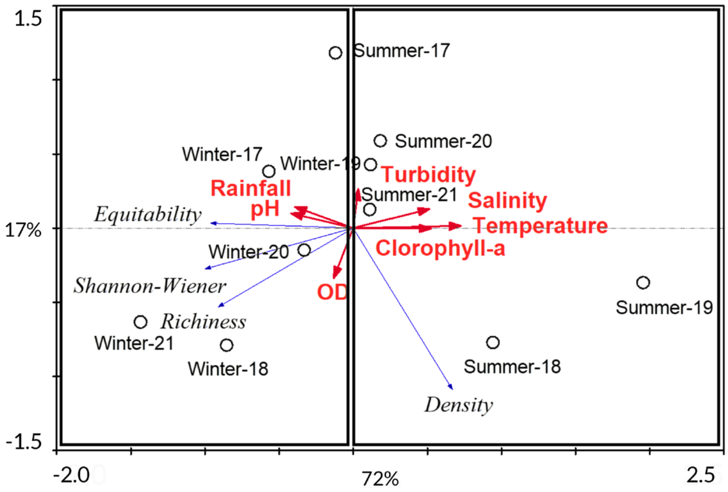


Figure 4. Redundance Analysis (RDA) ordination plot of the community structure score index and correlation vectors of environmentals variables, along the north coast of Bahia (Brazil) during 2017-2021 time series / Diagrama de ordenación del Análisis de Redundancia (RDA) del índice de puntaje de estructura comunitaria y vectores de correlación de variables ambientales, a lo largo de la costa norte de Bahía (Brasil) durante la serie temporal de 2017-2021

observed in previous studies conducted in the Pernambuco continental shelf region (Koening & Macêdo 1999, Koening & Lira 2005).

The identification of *Trichodesmium erythraeum* and *T. thiebautii* as typical species in the study area also corresponds to an expected pattern, considering that these filamentous cyanobacteria have a cosmopolitan distribution in oligotrophic marine environments of tropical and subtropical regions (Karl *et al*. 1992, Capone *et al*. 1997, Queiroz *et al*. 2004, Detoni *et al*. 2016, Detoni & Ciotti 2020), with a relatively common occurrence along the Brazilian northeast coast (*e.g.*, Naithirithi *et al*. 2005, Koening *et al*. 2009, Monteiro *et al*. 2010, 2012; Affe *et al*. 2018, 2019; Santos *et al*. 2020), where *T. erythraeum* blooms have already been recorded, especially in summer (Koening *et al*. 2009, Proença *et al*. 2009, Affe *et al*. 2016).

Studies suggest that *Trichodesmium* distribution along the Brazilian coast is also a result of the transport of this organism by the Brazilian Current (*e.g.*, Brandini 1988, Gianesella-Galvão *et al*. 1995, Siqueira *et al*. 2006). Generally, cell density increases during periods of light winds with warm and calm waters after the occurrence of rain (Letelier & Karl 1996, Capone *et al*. 1997, Hood *et al*. 2001, Hegde *et al*. 2008, Affe *et al*. 2016), and especially under conditions of low availability of dissolved nitrogen (Sañudo-Wilhelmy *et al*. 2001, Bif & Yunes 2017). Suggesting therefore that oligotrophic conditions and water temperature in the study area is favorable for *T. erythraeum* summer blooms and *T. thiebautii* high densities, considering that these diazotrophic cyanobacteria present an ecological advantage over other phytoplanktonic species, that are unable to fix atmospheric nitrogen for use in their metabolic activities (Carpenter & Price 1976). These blooms represent an important increase in local primary productivity, accounting for a large part of the nitrogen input in various oligotrophic regions (Capone *et al*. 1997, 2005; Carvalho *et al*. 2008, Agawin *et al*. 2013). These cyanobacteria also have the capacity to store phosphorus, and, in general, their cellular abundance and biomass do not depend on this nutrient dissolved concentration (Moutin *et al*. 2005, Spungin *et al*. 2014, Bif & Yunes 2017).

Except for *Trichodesmium erythraeum* bloom periods, high species diversity was observed even with a constant low nutrient availability in the system. In this regard, summer blooms are important as a potential nutrient source for the area at the time of its senescence, owing to the action of the microbial loop (Alonso-Sáez *et al*. 2008, Bif & Yunes 2017), in addition to physical processes that prevent competitive exclusion (Hutchinson 1961). It is suggested that the action of the winds, which promote upwelling events in the area (Santos *et al*. 2014, Thévenin *et al*. 2019), certainly interferes with the community dynamics, given that turbulence favored nutrient absorption by phytoplankton (Barton *et al*. 2014), allowing the maintenance of the high species richness and diversity patterns observed throughout the temporal series analyzed in this study.

In conclusion, this study examined microphytoplanktonic assemblage composition and abundance seasonal patterns, recording summer blooms, that contributed to reducing phytoplankton dynamics knowledge gap on Bahia continental shelf. Typical abiotic conditions of areas under the influence of the Brazilian Current (*i.e.*, oligotrophic waters with tropical values in temperature and salinity) were recorded. Even though it is a region with a recently described upwelling system, this environmental forcing does not seem to establish favorable conditions for large seasonal changes, although it can interfere with microphytoplanktonic assemblage dynamics owing to turbulence. *Trichodesmium erythraeum* blooms are closely related to the physiology and ecological capacity of this species. Future studies should include analyses of nano- and picoplanktonic fractions, which have not been studied so far, to expand our knowledge regarding the entire phytoplankton community structure in the area, as well as the effects of upwelling events on these organisms.

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Supplementary material

Table S1. List of phytoplankton species identified, along the time series (2017 - 2021) on the north coast of Bahia, Brazil /. Lista de especies de fitoplancton identificadas, a lo largo de la serie temporal (2017 - 2021) en la costa norte de Bahía, Brasil

Phyllum	Family	Species
Heterokontophyta	Asterionellopsidaceae	*Asterionellopsis glacialis* (Castracane) Round
	Asterolampraceae	*Asteromphalus* sp.
	Bacillariaceae	*Bacillaria paxillifera* (O.F.Müller) T.Marsson
		Fragilariopsis sp.
		Nitzschia sp.
		Pseudo-nitzschia sp.
	Bellerocheaceae	*Bellerochea horological*is Sotsch
		Bellerochea malleus (Brightwell) Van Heurck
	Biddulphiaceae	*Biddulphia* sp.
	Catenulaceae	*Amphora* sp.
	Chaetocerotaceae	*Bacteriastrum delicatulum* Cleve
		Bacteriastrum hyalinum Lauder
		Chaetoceros aequatorialis Cleve
		Chaetoceros affinis Lauder
		Chaetoceros atlanticus Cleve
		Chaetoceros coarctatus Lauder
		Chaetoceros compressus Lauder
		Chaetoceros contortus F.Schütt
		Chaetoceros curvisetus Cleve
		Chaetoceros danicus Cleve
		Chaetoceros decipiens Cleve
		Chaetoceros eibenii Grunow
		Chaetoceros mitra (Bailey) Cleve
		Chaetoceros peruvianus Brightwell
		Chaetoceros subtilis Cleve
	Chrysanthemodiscaceae	*Chrysanthemodiscus floriatus* A.Mann
	Coscinodiscaceae	*Coscinodiscus centralis* Ehrenberg
		Coscinodiscus sp.
		Coscinodiscus wailesii Gran & Angst
		Palmerina hardmaniana (Greville) G.R.Hasle
	Dictyochophyceae	*Dictyocha fibula*
	Diploneidaceae	*Diploneis* sp.
	Entomoneidaceae	*Entomoneis alata* (Ehrenberg) Ehrenberg
	Grammatophoraceae	*Grammatophora marina* (Lyngbye) Kützing
	Hemidiscaceae	*Actinocyclus* sp.
	Hemiaulaceae	*Cerataulina pelagica* (Cleve) Hendey
		Hemiaulus membranaceus Cleve
		Neomoelleria cornuta (Cleve) S.Blanco & C.E.Wetzel
	Isthmiaceae	*Isthmia enervis* Ehrenberg
	Koernerellacae	*Bleakeleya notata* (Grunow) Round
	Leptocylindraceae	*Leptocylindrus danicus* Cleve
		Leptocylindrus minimus Gran
	Licmophoraceae	*Podocystis adriatica* (Kützing) Ralfs
		Podocystis sp.
	Lithodesmiaceae	*Helicotheca tamesis* (Shrubsole) M.Ricard
	Mastogloiaceae	*Mastogloia* sp.
	Melosiraceae	*Melosira inflexa* (Roth) Guiry
	Naviculaceae	*Gyrosigma balticum* (Ehrenberg) Rabenhorst
		Gyrosigma sp.
		Gyrosigma littorale (W.Smith) J.W.Griffith & Henfrey
		Haslea wawrikae (Husedt) Simonsen
		Navicula sp.
		Trachyneis aspera (Ehrenberg) Cleve
	Odontellaceae	*Odontella* sp.
		Odontella aurita (Lyngbye) C.Agardh
	Paraliaceae	*Paralia sulcata* (Ehrenberg) Cleve
	Parodontellaceae	*Trieres mobiliensis* (Bailey) Ashworth & E.C.Theriot
	Plagiotropidaceae	*Meuniera membranacea* (Cleve) P.C.Silva
	Pleurosigmataceae	*Pleurosigma angulatum* (J.T.Quekett) W.Smith
	Probosciaceae	*Proboscia alata* (Brightwell) Sundström
	Rhaphoneidaceae	*Adoneis* sp.
	Rhizosoleniaceae	*Guinardia flaccida* (Castracane) H.Peragallo
		Guinardia striata (Stolterfoth) Hasle
		Neocalyptrella robusta (G.Norman ex Ralfs) Hernández-Becerril & Meave
		Pseudosolenia calcar-avis (Schultze) B.G.Sundström
		Rhizosolenia curvata Zacharias
		Rhizosolenia decipiens B.G.Sundström
		Rhizosolenia imbricata Brightwell
		Sundstroemia setigera (Brightwell) Medlin
	Stephanodiscaceae	*Cyclotella* sp.
	Surirellaceae	*Campylodiscus fastuosus* Ehrenberg
		Surirella sp.
	Thalassionemataceae	*Thalassionema frauenfeldii* (Grunow) Tempère & Peragallo
		Thalassionema nitzschioides (Grunow) Mereschkowsky
	Triceratiaceae	*Triceratium favus* Ehrenberg
		Triceratium favus f. *quadratum (*Grunow) Hustedt

Table S1 continued / Continuación Tabla S1

Phyllum	Family	Species
Cyanobacteria	Cyanothrichaceae	*Johannesbaptistia* sp.
	Microcoleaceae	*Lyngbya* sp.
		Trichodesmium erythraeum Ehrenberg ex Gomont
		Trichodesmium thiebautii Gomont
	Nostocaceae	*Nostoc* sp.
Haptophyta	Noelaerhabdaceae	*Gephyrocapsa huxleyi* (Lohmann) P.Reinhardt
Dinoflagellata	Amphisoleniaceae	*Amphisolenia bidentata* B.Schröder
		Amphisolenia globifera F.Stein
	Ceratiaceae	*Tripos arietinus* (Cleve) F.Gómez
		Tripos candelabrum (Ehrenberg) F.Gómez
		Tripos carriensis (Gourret) Hallegraeff & Huisman
		Tripos furca (Ehrenberg) F.Gómez
		Tripos fusus (Ehrenberg) F.Gómez
		Tripos gibberus (Gourret) F.Gómez
		Tripos gracilis (Pavillard) F.Gómez
		Tripos gravidus (Gourret) F.Gómez
		Tripos hircus (Schröder) F.Gómez
		Tripos inflatus (Kofoid) F.Gómez
		Tripos lineatus (Ehrenberg) F.Gómez
		Tripos longipes (Bailey) F.Gómez
		Tripos macroceros (Ehrenberg) Hallegraeff & Huisman
		Tripos massiliensis (Gourret) F.Gómez
		Tripos muelleri Bory
		Tripos pentagonus (Gourret) F.Gómez
		Tripos platycornis (Daday) F.Gómez
		Tripos pulchellus (Schröder) F.Gómez
		Tripos ranipes (Cleve) F.Gómez
		Tripos setaceus (Jørgesen) F.Gómez
		Tripos symmetricus (Pavillard) F.Gómez
		Tripos teres (Kofoid) F.Gómez
		Tripos trichoceros (Ehrenberg) Gómez
	Dinophysaceae	*Dinophysis caudata* Kent
		Dinophysis cf. *schuettii* G.Murray & Whitting
		Dinophysis sp.
		Histioneis depressa J.Schiller
		Ornithocercus magnificus F.Stein
		Ornithocercus sp.
	Gonyaulacaceae	*Gonyaulax* sp.
		Gonyaulax spinifera (Claparède & Lachmann) Diesing
	Gymnodiniaceae	*Gymnodinium* sp.
	Gyrodiniaceae	*Gyrodinium* sp.
	Lingulodiniaceae	*Sourniaea diacantha* (Meunier) H.Gu., K.N.Mertens, Zhun Li & H.H.Shin
	Oxyphysaceae	*Phalacroma favus* Kofoid & J.R.Michener
		Phalacroma cf. *mitra* F.Schütt
		Phalacroma sp.
	Podolampadaceae	*Podolampas palmipes* F.Stein
	Polykrikaceae	*Polykrikos* sp.
	Prorocentraceae	*Prorocentrum compressum* (Bailey) T.H.Abé ex J.D.Dodge
		Prorocentrum emarginatum Y.Fukuyo
		Prorocentrum gracile F.Schütt
		Prorocentrum micans Ehrenberg
		Prorocentrum sp.
	Protoceratiaceae	*Ceratocorys armata* (Schütt) Kofoid
		Ceratocorys horrida Stein
		Ceratocorys sp.
		Protoceratium sp.
	Protoperidiniaceae	*Protoperidinium conicum* (Gran) Balech
		Protoperidinium divergens (Ehrenberg) Balech
		Protoperidinium brevipes (Paulsen) Balech
		Protoperidinium claudicans (Paulsen) Balech
		Protoperidinium crassipes (Kofoid) Balech
		Protoperidinium depressum (Bailey) Balech
		Protoperidinium oceanicum (Vanhöffen) Balech
		Protoperidinium pellucidum Bergh
		Protoperidinium pentagonum (Gran) Balech
		Protoperidinium sp.
		Protoperidinium steinii (Jørgensen) Balech
	Pyrocystaceae	*Alexandrium* sp.
		Gambierdiscus sp.
		Ostreopsis sp.
		Pyrocystis lunula (F.Schütt) F. Schütt
		Pyrophacus horologium F.Stein
		Pyrophacus sp.
	Thoracosphaeraceae	*Scrippsiella acuminata* (Ehrenberg) Kretschmann, Elbrächter, Zinssmeister, S.Soehner, Kirsch, Kusber & Gottschling 2015
		Scrippsiella sp.