



# Analysis of the morphological and environmental changes at the confluence of the Daule and Babahoyo rivers in front of the city of Guayaquil.



## Distribución del fitoplancton en aguas marino-costeras en tres sectores de la península de Santa Elena

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**Abstract:** The composition, distribution, abundance and ecology of phytoplankton were studied during the wet season from December 2015 to May 2016 in six stations located in the coastal area of Ancon, Anconcito and Punta Carnero province of Santa Elena, where 36 samples were collected by surface trawls. Fifty-eight species were identified in the 6 stations, of which 31 species correspond to diatoms and 26 species belong to dinoflagellates, 1 species of silicoflagellates and tintinids as part of the accompanying fauna of the phytoplankton present in all stations. The total density of the first trophic link reported a total of 392652 cells/100m<sup>3</sup>, with the highest distribution in the Ancon sector in E2 with 107073 cells/100m<sup>3</sup>, followed by E3 located in the Anconcito sector with 84992 cells/100m<sup>3</sup>, while in the Punta Carnero sector the densities are low, reported in E6 with 43358 cells/100m<sup>3</sup>, considering that the phytoplankton presented a heterogeneous behavior between the three sectors during the sampling time. The distribution of diatom species reported its highest percentage in the species *Rhizosolenia imbricata* with 40.48% being present in the 6 months of sampling, but not in all stations, followed by the species *Rhizosolenia hebetata* with 16.84% being present only in December, followed by the species *Rhizosolenia hebetata* with 16.84% being present only in December, *Lectocylindrus danicus* reported 11.68% being absent in January and present in the other months, the species *Chaetoceros coarctatus*, *Climacodium frauenfeldianum* and *Cyclotella striata* registered percentages between 7.35%, 5.49% and 5.47% respectively. However the other species present in the study area registered their values below 5%, while in the dinoflagellate species reported their highest population abundance in percentage with the species *Ceratium furca* var. *furca* with 19.25%, followed by *Ceratium fusus* with 14. *Ceratium candelabrum*, *Ceratium macroceros*, *Pyrophacus steinii* and *Ceratium trichoceros* reported percentages between 9 and 5% respectively, the other species present in the study area registered their values below 5%.

**Keywords:** phytoplankton, variability, distribution, density, fitoplancton, variabilidad, distribución, densidad.

**Resumen:** Se estudió la composición, distribución, abundancia y ecología del fitoplancton durante la época húmeda desde

diciembre del 2015 a mayo del 2016 en seis estaciones ubicadas en la zona costera de Ancón, Anconcito y Punta Carnero provincia de Santa Elena, donde se recolectaron 36 muestras mediante arrastres superficiales. Se identificaron 58 especies en las 6 estaciones, de las cuales 31 especies corresponden a las diatomeas y 26 especies pertenecen a los dinoflagelados, 1 especie de silicoflagelados y los tintinidos como parte de la fauna acompañante del fitoplancton presente en todas las estaciones. La densidad total del primer eslabón trófico reportó un total 392652 cel/100m<sup>3</sup>, observándose su mayor distribución en el sector de Ancón en la E2 con 107073 cel/100m<sup>3</sup>, seguido de la E3 ubicada en el sector de Anconcito con 84992 cel/100m<sup>3</sup>, mientras que en el sector de Punta Carnero las densidades son bajas reportándose en la E6 con 43358 cel/100m<sup>3</sup>, considerándose que el fitoplancton presentó durante el tiempo de muestreo un comportamiento heterogéneo entre los tres sectores. La distribución de las especies de diatomeas reportaron su mayor porcentaje en la especie *Rhizosolenia imbricata* con el 40.48% estando presente en los 6 meses de muestreos, pero no en todas las estaciones, seguido de la especie *Rhizosolenia hebetata* con 16.84% estando presente solo en diciembre, *Lectocylindrus danicus* reportó un 11.68% estando ausente en enero y presente en los otros meses, las especies *Chaetoceros coarctatus*, *Climacodium frauenfeldianum* y *Cyclotella striata* registraron porcentajes entre 7.35%, 5.49% y 5.47% respectivamente. Sin embargo las otras especies presentes en el área de estudio registraron sus valores por debajo del 5%, mientras que en las especies de dinoflagelados reportaron su mayor abundancia poblacional en porcentaje con la especie *Ceratium furca* var. *furca* con el 19.25%, seguido de *Ceratium fusus* con 14.73% y *Ceratium tripos* estando presentes las tres especies en los seis meses de muestreo pero no en todas las estaciones, *Ceratium candelabrum*, *Ceratium macroceros*, *Pyrophacus steinii* y *Ceratium trichoceros* reportaron porcentajes entre 9 y 5% respectivamente, las demás de especies presentes en el área de estudio registraron sus valores por debajo del 5%.

## Introduction

Phytoplankton constitutes the first trophic level of the food chain, its structure is variable and regulated depending on the ecological habitat: thermal distribution, food availability and predation (Vera, 2007).

The surface layer is the most productive for phytoplankton, due to the requirement of sunlight. This condition also limits their abundance, due to the sun's rays, which penetrate the sea surface, whereas the microalgae increase in number, a greater portion of this radiation is absorbed (Loza et al., 2007).

Another fundamental factor of phytoplankton is temperature, where in equatorial waters, seawater is warm, which provides rapid growth of phytoplankton as opposed to cold waters (Basilio, 2014).

The organisms known as phytoplankton have cosmopolitan characteristics, morphologies and nutritional requirements that make them reproductively and growth-wise suitable for tropical waters (Jiménez, 1983).

Phytoplankton in oceanic areas of the equatorial central Pacific is influenced by constant processes of the equatorial upwelling, and on the coast by coastal

upwelling, which determines high nutrient contents in the surface layer (Jiménez, 2008).

Diatoms and dinoflagellates are two groups of great importance for phytoplankton, these are directly dependent on the availability of nutrients and environmental factors (Vera, 2014).

According to the dry and rainy seasons of the year, the density of dinoflagellate varies, being higher in the dry season and lower in the rainy season; its distribution reaches up to approximately 200 meters deep, originating the process of multiplication and photosynthesis transformation (Scarabino, 1994).

Research on phytoplankton in the eastern Pacific is numerous; studies have been carried out in Chile, Ecuador, Peru, Colombia and Panama, most of them within the framework of the Regional Study of the El Niño Phenomenon (ERFEN), where phytoplankton is the indicator of this phenomenon, which is associated with environmental factors such as temperature.

Marine ecosystems are complex, and present hierarchies in their structure according to the behavior of the environment, it is necessary to study small-scale variations since large-scale works ignore them, consider that the high frequency in plankton sampling, especially phytoplankton, tends to minimize the associated temporal error which is calculated at 35% in monthly sampling in variable ecosystems (Vera, 2014).

This study area is subject to the interaction of tropical and subtropical marine waters, with nutrient-rich water masses flowing in from the Humboldt Current during the seasons, while tropical surface water currents are transported from the north. The direct interaction between oceanic and coastal water masses influences the distribution of dinoflagellates and diatoms (Vera, 2014).

In many cases, primary producers are explanatory of phenomena that occur at higher levels of the energy chain. The objective of this work is to obtain a baseline of phytoplankton species, determine their temporal distribution and abundance, depending on their variability of environmental factors.

In order to determine the distribution and abundance of diatoms and dinoflagellates, a phytoplankton collection schedule was carried out in the coastal marine sector of Ancon, Anconcito and Punta Carnero in the Province of Santa Elena, using horizontal trawling techniques, in order to contribute to the existing database.

## Materials and Methods

Horizontal sampling was carried out during December 2015 to May 2016, for the location of the sampling sites a GPS was used and these coordinates were transformed into UTM units. (Mujica, 2016) Table 1.

**Table 1**  
UTM coordinates of the stations

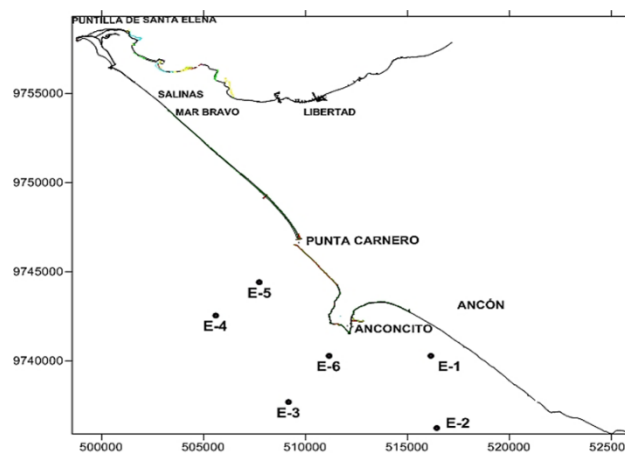
Estaciones	Este	Norte
Estación 1-Ancón	516139942	9740282796
Estación 2-Ancón	516430438	9736234827
Estación 3-Anconcito	509160013	9737694151
Estación 4-Punta Camero	505590067	9742543298
Estación 5-Punta Camero	507724268	9744413039
Estación 6-Anconcito	511149092	9740283234

The study conducted is comprised between sectors that carry out fishing and tourism activities, where anthropogenic activities also influence; it presents a tropical climate due to the interaction of tropical marine waters of the Bay of Panama and subtropical the Humboldt Current (Mujica, 2016) (Figure 1).

For the qualitative and quantitative analysis of phytoplankton, horizontal trawls were carried out at 6 stations during the morning hours,

A total of 36 samples were collected using a simple 50-micron conical net. The sampling time per station was 5 minutes at a speed of 2 knots. At each sampling station, temperature (SST) measurements were taken with a mercury thermometer with a range of 10 to 60°C, salinity (UPS) with a BIOMARINE refractometer model ABMTC with a range of 0 to 100 ups, depth was determined through the use of the secchi disk to record the visibility of the water, (Mujica, 2016).

All samples were fixed and preserved in situ, approximately 200 ml of sample were collected, standardized to 100 ml and placed 4 ml of 4% formaldehyde neutralized with borax (Tapia, 2013) Once homogenized the samples were analyzed using the plate counting method (Villon, 2012), where 3 drops of sample were placed on an object holder plate and superimposed with an object cover of 22 x 22mm, the totality of the species present on the plate was counted, this process was applied in each sample of the stations. A BOECO WF 10X18 microscope was used to identify the species and the data were used for the respective statistical analysis.



**Figure 1**

Location of the study area and sampling stations

### *Sample treatment*

The data obtained in the samples were expressed in cells/100m. using the following formulas:

a) The collected samples were standardized to a volume of 100 ml, allowing the cells to settle and eliminating the excess volume of water.

b) To measure the surface area of the net, the circle formula was used.

$$A = \pi (r^2)$$

Where:

r= Radius of the simple conical net mouth.

$$TT = 3.1416$$

c) To obtain the volume of filtered water, the surface area of the net mouth is taken into account by the distance of the drag (m) by filtration efficiency. To determine the filtration efficiency: The estimate mentioned by Pesantes (1979), obtained from the Manual Zooplankton Sampling (1968), was used, applying a filtration volume error of 0.9.

$$\eta = m^3 \times 9/10$$

d) The counted volume of the cover-plate was determined by semiquantitative analysis.

$$V = (22\text{mm})^2 \times 1\text{mm}$$

e) The semiquantitative method was used to estimate the number of cells per species in each sample for each season (Semina, 1978; Jiménez, 1975; and Pesantes, 1979).

$$\text{Cells}/m^3 \text{ or Species} / m^3 = [(n \times V) / v] / \eta.$$

Where:

**n** = **number** of cells per station

**V** = **total sample volume**

**v** = **volume/cover-object-quota**

**n** = **filtration efficiency**

Species were identified using taxonomic keys of Jiménez (1983), Pesantes (1983), Zambrano (1983), Balech (1988), Needham and Needham (1990), Tomas (1996).

To determine the community structure of phytoplankton in the investigated area, the diversity indexes (H) of Shannon-Weiner, equity (J') of Pielou (Moreno, 2001), which were calculated with Past software, were calculated.

The Shannon-Weiner index (1963) expresses the uniformity of importance values across all species in a sample.

$$H' = -\sum p_i \ln p_i$$

Where:  $p_i$  = The proportion of individuals found in  $i$  species.

Pielou's equitability or degree of uniformity in the distribution of abundances or frequencies, estimating the proportion of observed diversity in relation to the maximum expected diversity. Its value ranges from 0 to 1, so that 1 corresponds to situations where all species are equally abundant (Magurran, 1988).

$$J' = \frac{H'}{H'_{\max}}$$

Where:

$J'$  = Pielou's equity.

$H'$  = Shannon-Weiner diversity index.

$$H'_{\max} = \ln S$$

To establish affinity relationships between diatom and dinoflagellate sampling stations at the surface level, Cluster classification analysis with the Bray Curtis algorithm and unweighted mean affinity were used. (Legendre & Legendre, 1998). In addition, the relationship between the abiotic parameters and the abundance of the most frequent diatom and dinoflagellate species at surface level was determined using the ACC method, supported by Past software (ter Braak & Verdonschot, 1995). A confidence interval of 95% and a significance level of 5% were established for the statistical tests.

## Results

The maximum temperature values were recorded in December and January (27.3-27.5°C), and the minimum in April and May (26.1 -25.2°C); the highest salinity records were obtained in April and May (35.7- 35.8 ups), while the lowest in December (32.3 ups) (Figure 2), showing the highest visibility in the water column in May with 11 m and the lowest in March with 7 m.

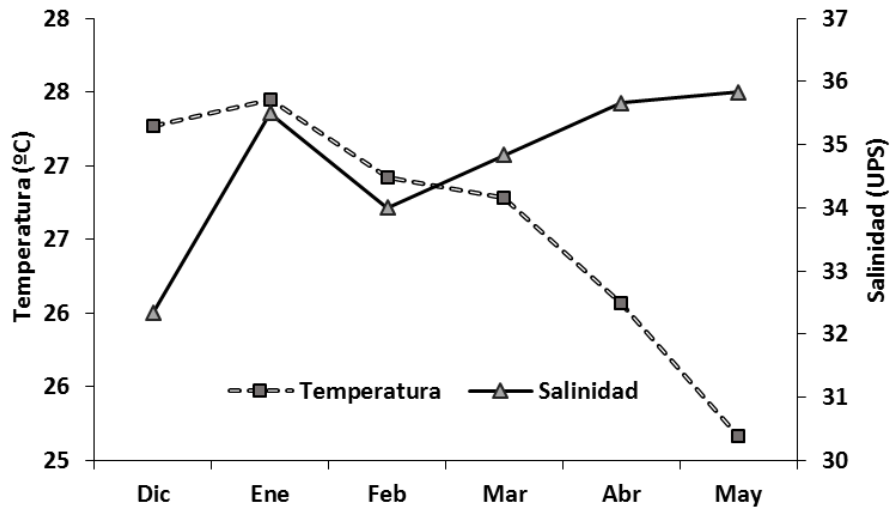


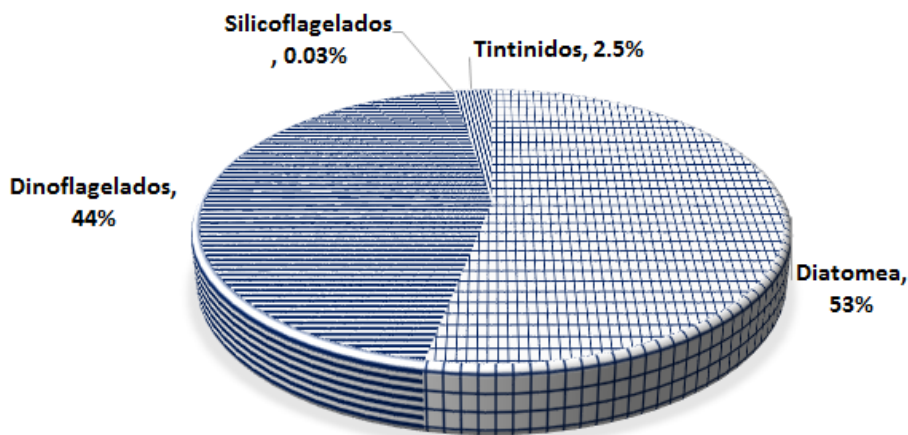
Figure 2.

Variation of sea surface temperature and salinity, average of the 6 stations in the coastal zone of Ancon, Anconcito and Punta Carnero during December 2015 to May 2016.

### *Phytoplankton composition and abundance*

Of the total samples collected in the 6 stations, 58 species were identified, of which 31 correspond to diatoms and 26 to dinoflagellates, 1 species of silicoflagellates, as part of the accompanying fauna the tintinnids, which were present in almost all stations.

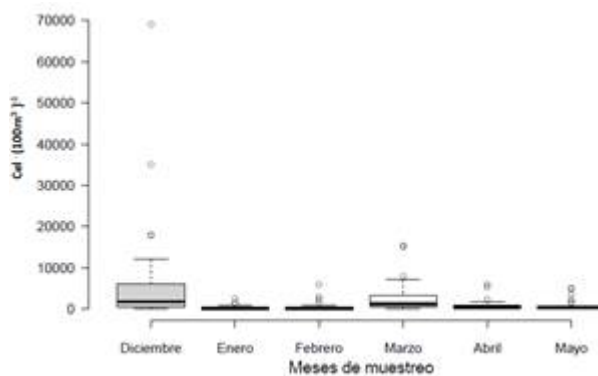
Phytoplankton at the group level resulted in Diatoms with 208468 cells/100m. . Being the most abundant, followed by Dinoflagellates with 174320 cel/100m. , decreasing considerably in density in tintinnids with 9750 cel/100m. , and silicoflagellates with 114 cel/100m. (Figure 3).



**Figure 3**  
Abundance of the main phytoplankton groups.

*Phytoplankton abundance by season*

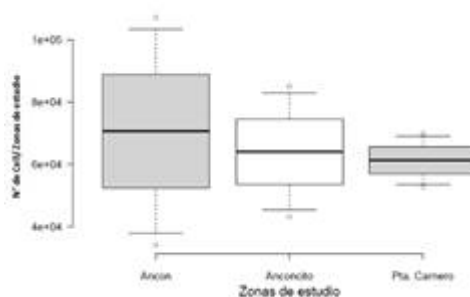
The total abundance of phytoplankton was 392652 cells/m<sup>3</sup>, where the highest density was in the Ancon sector in E2 with 107073 cells/m<sup>3</sup>, followed by E3 located in the Anconcito sector with 84992 cells/m<sup>3</sup>, while in the Punta Carnero sector the densities are low, being reported in E6 with 43358 cells/m<sup>3</sup>, considering that the phytoplankton presented during the sampling time a heterogeneous behavior among the three sectors corresponding to the province of Santa Elena (Figure 4).



**Figure 4**  
Variation in phytoplankton abundance by study area.

*Monthly phytoplankton abundance*

Sampling conducted in the study area recorded the highest abundance in December 2015 with 218158 cell/m<sup>3</sup>, and the lowest density in the month of January 2016 with 11628 cell/m<sup>3</sup>, while in the months of February, March, April and May a heterogeneous behavior of the species was recorded (Figure 5)



**Figure 5.**  
figure 5

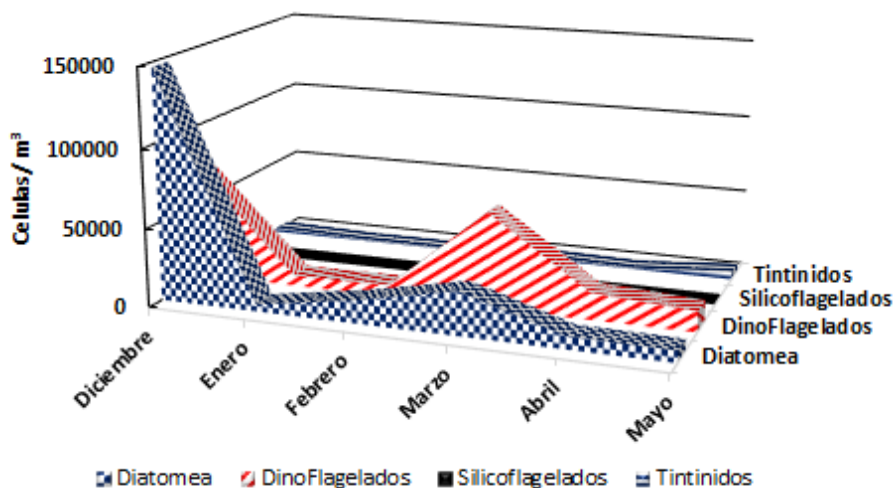
### *Distribution of phytoplankton groups*

The abundance of diatoms is evidenced in the months of December and March. However, the dinoflagellates demonstrating higher densities in March while in December there were higher densities, but this did not exceed the diatom values. It is also observed low densities of diatoms and dinoflagellates in January. Tintinids were present during the test time, but not in all seasons, registering their greatest abundance in May. However, silicoflagellates evidenced in December and February, state absent in the other months (Figure 6).

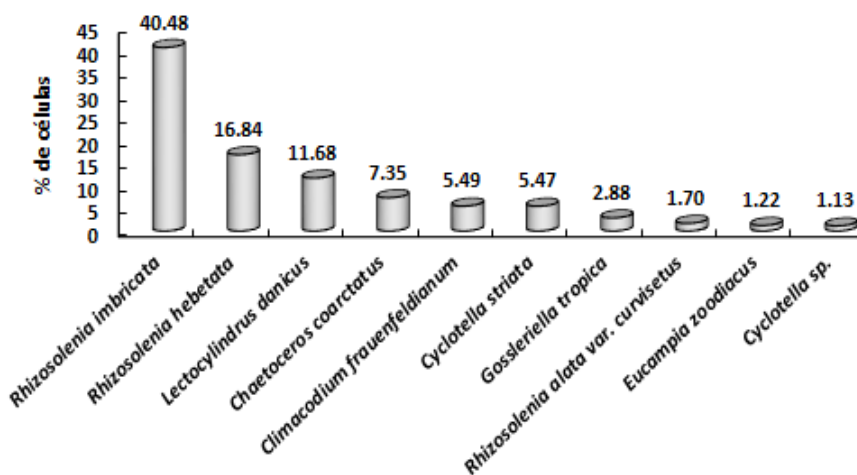
### *Distribution of diatom species*

Diatoms reported their highest percentage in the species *Rhizosolenia imbricata* with 40.48% being present in the 6 months of sampling, but not in all seasons, followed by the species *Rhizosolenia hebetata* with 16.84% being present only in December and absent in the other months,

*Lectocylindrus danicus* reported 11.68% being absent in January, the species *Chaetoceros coarctatus*, *Climacodium frauenfeldianum* and *Cyclotella striata* registered percentages between 7.35%, 5.49% and 5.47% respectively, however the other species present in the study area registered their values below 5% (Figure 7)



**Figure 6**  
Phytoplankton distribution during December 2015 to May 2016



**Figure 7.**  
Relative abundance of the most representative diatom species

#### *Dinoflagellate species distribution*

Dinoflagellates reported their highest population abundance with *Ceratium furca* var. *furca* with 19.25%, followed by *Ceratium fusus* with 14. *Ceratium candelabrum*, *Ceratium macroceros*, *Pyrophacus steinii* and *Ceratium trichoceros* showed percentages between 9 and 5% respectively, the other species present in the study area registered their values below 5% (Figure 8).

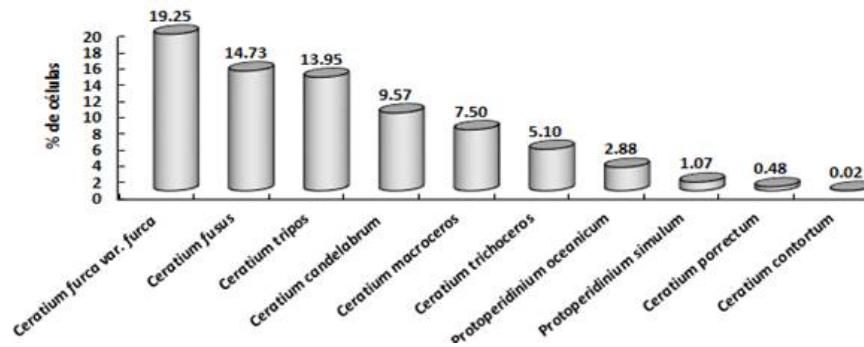


Figure 8

Relative abundance of dinoflagellate species in the study area.

Table 2

Density (cells/m<sup>3</sup>), relative abundance (%), ecological affinity and habitat of diatom species collected at surface level.

Diatoms					Dinoflagellados				
Especie	cel/m <sup>3</sup>	%	Afinidad ecológica	Hábitat	Especie	cel/m <sup>3</sup>	%	Afinidad ecológica	Hábitat
<i>Acartonema elongatum</i> (Peridini, 1934)	122	0.07	Tropical - Templada	n-o	<i>Amphitetrasella bifurcata</i> (Schubert, 1900)	4408	2.53	Tropical - Templada	n
<i>Biddulphia uncinata</i> (Bretagne, 1858)	722	0.35	Cenopelágica	n-o	<i>Ceratium condelabrum</i> (Stein, 1883)	16682	9.57	Tropical - Subtropical	n
<i>Biddulphia uncinata</i> (Bretagne, 1858)	134	0.05	Cenopelágica	n-o	<i>Ceratium contortum</i> (Cleve, 1906)	38	0.02	Tropical - Subtropical	n
<i>Chaetoceros affinis</i> (Lauder, 1894)	920	0.46	Cenopelágica	n-o	<i>Ceratium furca</i> var. <i>furca</i> (Claparede y Lachmann, 1859)	33554	19.25	Tropical - Subtropical	n
<i>Chaetoceros carotensis</i> (Lauder, 1894)	1074	0.51	Cenopelágica	n-o	<i>Ceratium fuscus</i> (Dujardin, 1841)	23671	14.73	Tropical - Subtropical	n
<i>Chaetoceros debilis</i> (Ehrenberg, 1842)	228	0.11	Cenopelágica	n-o	<i>Ceratium macroceros</i> (Vanhöffen, 1897)	13072	7.50	Tropical - Subtropical	n
<i>Chaetoceros filiformis</i> (Grunow, 1862)	1428	0.68	Cenopelágica	n-o	<i>Ceratium porrectum</i> (Karsten, 1907)	836	0.48	Tropical - Subtropical	n
<i>Chaetoceros muelleri</i> (Ehrenberg, 1842)	194	0.09	Tropical - Subtropical	n	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Cocconeis peruvianus</i> (Ehrenberg, 1844)	1282	0.62	Tropical - Subtropical	n	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Cyclotella choctawhatcheeana</i> (Grunow, 1862)	276	0.13	Tropical - Subtropical	n	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Cyclotella choctawhatcheeana</i> (Grunow, 1862)	1040	0.47	Tropical - Subtropical	n	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Denticula striatella</i> (Carter, 1885)	122	0.07	Tropical - Templada	n-o	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Dicella choctawhatcheeana</i> (Grunow, 1862)	186	0.08	Tropical - Templada	n-o	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Dicella choctawhatcheeana</i> (Grunow, 1862)	254	0.12	Cenopelágica	n-o	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Gomphonema affine</i> (Stein, 1883)	884	0.43	Cenopelágica	n-o	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Heterocapsa tripos</i> (Grunow, 1862)	198	0.09	Cenopelágica	n-o	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Leptocylindrus curvatus</i> (Grunow, 1862)	808	0.39	Tropical - Templada	n-o	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Leptocylindrus curvatus</i> (Grunow, 1862)	2428	1.18	Cenopelágica	n-o	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Leptocylindrus curvatus</i> (Grunow, 1862)	204	0.09	Tropical - Templada	n-o	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Leptocylindrus curvatus</i> (Grunow, 1862)	74	0.03	Tropical - Templada	n-o	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Leptocylindrus curvatus</i> (Grunow, 1862)	106	0.05	Cenopelágica	n-o	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Leptocylindrus curvatus</i> (Grunow, 1862)	374	0.17	Tropical	n	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Leptocylindrus curvatus</i> (Grunow, 1862)	262	0.12	Tropical	n	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Leptocylindrus curvatus</i> (Grunow, 1862)	808	0.43	Cenopelágica	n-o	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Leptocylindrus curvatus</i> (Grunow, 1862)	34	0.01	Tropical	n	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Leptocylindrus curvatus</i> (Grunow, 1862)	198	0.09	Tropical - Templada	n-o	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Leptocylindrus curvatus</i> (Grunow, 1862)	722	0.35	Tropical - Templada	n-o	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Leptocylindrus curvatus</i> (Grunow, 1862)	114	0.05	Tropical - Templada	n-o	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Leptocylindrus curvatus</i> (Grunow, 1862)	198	0.09	Tropical - Templada	n-o	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n
<i>Leptocylindrus curvatus</i> (Grunow, 1862)	74	0.03	Tropical - Templada	n-o	<i>Ceratium tripos</i> (Keifeld, 1907)	3914	2.25	Tropical - Subtropical	n

Simbología: %= abundancia relativa, Hábitat: n=nerítica, o=oceánica, n-o= nerítica y oceánica

Temporal variability of the Ecological Indices: Shannon-Weaver, Simpson and Pielou in the diatom and dinoflagellate community.

Diatoms: surface layer (0 m)

During the wet season, the maximum value of diversity was observed in February with H': 1.96 bits/ind, and an evenness of 0.75 bits/ind, in contrast to the minimum value of diversity observed in March with H': 0.14 bits/ind, and evenness of 0.06 bits/ind found during the months of study, evidencing the presence of *Rhizosolenia imbricata*, thus changing seasonally, with the highest diversities observed in the stations (E1 and E3) influenced by the nutrient input from the Anconcito fishing zone (Figure 9A).

Dinoflagellates: surface layer (0 m)

At the surface level, diversity was higher than in the water column, registering the maximum value  $H'$ : 2.29 bits/ind in December and evenness of 0.86 bits/ind, while the minimum diversity value was reported in April with  $H'$ : 0.32 bits/ind, evenness of 0.14 bits/ind, showing high Shannon values in the stations (E1 and E3) and *Ceratium furca* var *furca* as the dominant species, gradually decreasing between stations 4,5,6 and 2. (Figure 9B).

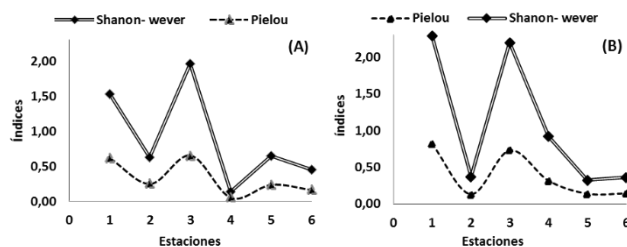


Figure 9.

Distribution of ecological indices in the Ancon, Anconcito and Punta Carnero Coastal Marine Zone from December 2015 to May 2016 A) Diatoms surface layer; B) Dinoflagellates surface layer.

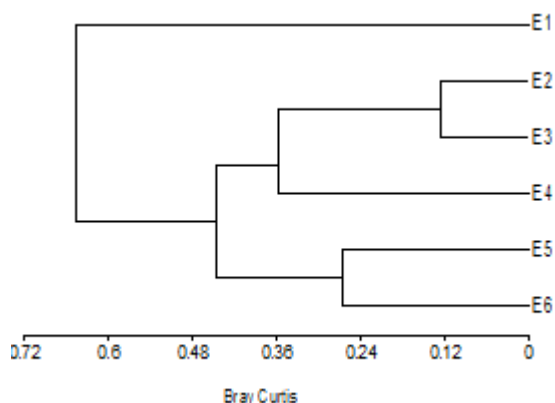
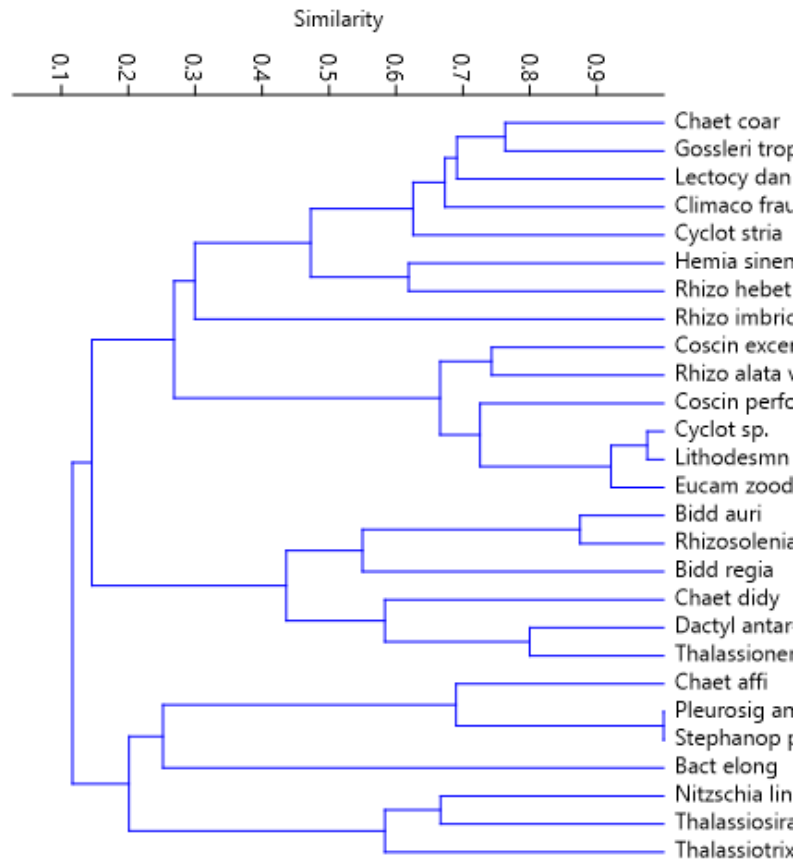


Figure 10

Dendrogram based on BrayCurtis similarity between diatom sampling stations

In the coastal zone (E1, E5, E6), four groupings of diatom species are observed, where there are differences in the distribution of diatom abundances, it is worth mentioning that the species that had the highest degree of similarity were: *Cyclote* sp, *Lithodesmiun undulatum*, *Eucampia zodiacus*, *Biddulphia aurita*, *Rizosolenia hebetata*, *Dactilum antarcticum*, *thalasionema nitzschiode* *Peurosigma angulatum* and *Stephanopixis palmeriana* (Figure 11).

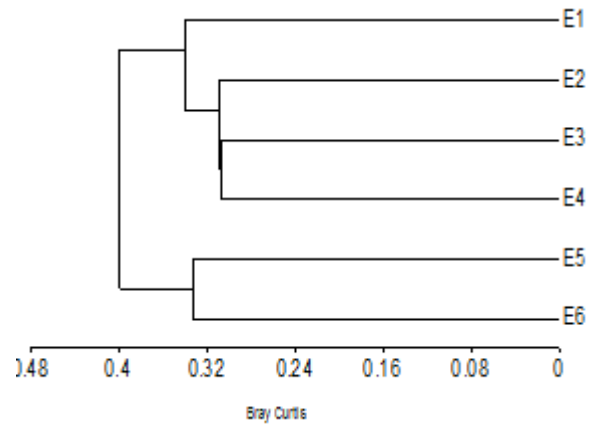


**Figure 11**

Distribution of diatom species abundance among stations in the coastal zone (E2, E3, E4).

**Dinoflagellates at surface level (0 m)**

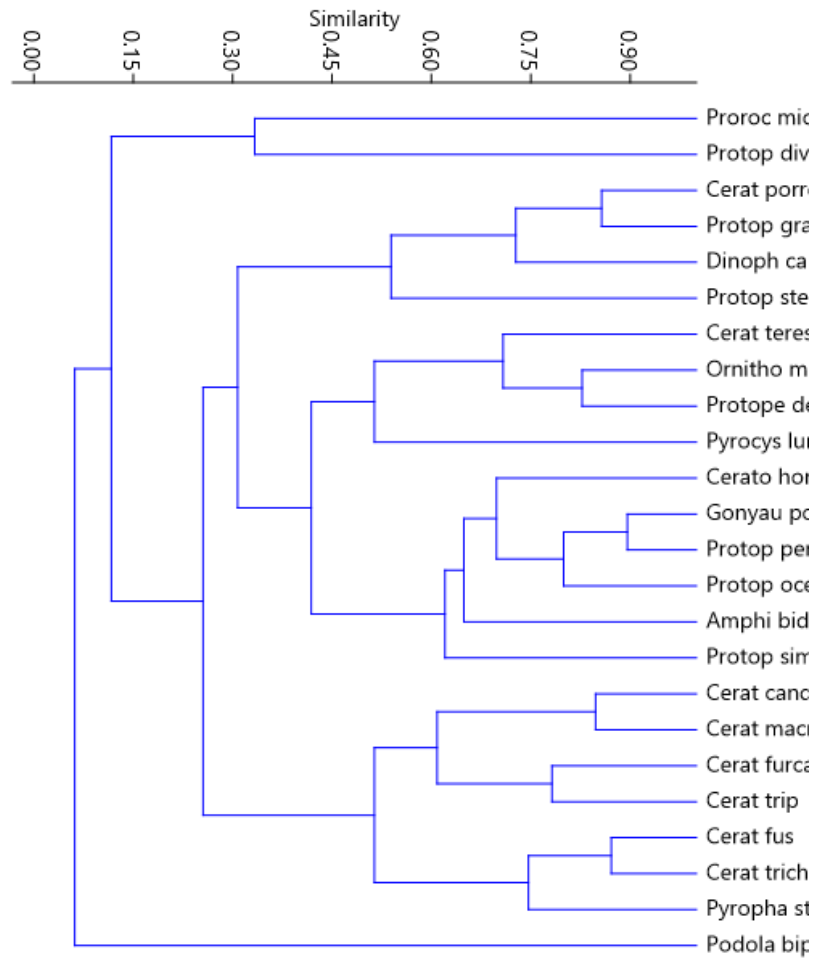
The conglomerate presents that the stations E3, E4 (moderate abundance) has the species *Ceratium fusus* and *Ceratium tripos* as the most related due to a homogeneous density in all the months of sampling, from this group comes a branch that integrates *Ceratium furca var. furca*, an abundant species for the following regions E2 and E1, and presenting a difference due to its low densities in stations E5, E6, formed by *Ceratium candelabrum*, *Ceratium macroceros*, *Pyrophacu*, *steiniy Ceratium trichoceros* is determined by its eventual presence, (Figure 13),



**Figure 13**

Dendrogram based on BrayCurtis similarity between dinoflagellate sampling stations

At the species level in the coastal stations (E1, E5, E6), there are five superficial groupings within the conglomerate that show the greatest degree of similarity in distribution of the dinoflagellates associated with the time of study. It is worth mentioning that the distribution of the species shows a moderate to strong similarity, except for *Polampas bipes*, a species found in low density in E1 and absent in E5 and E6 (Figure 14).

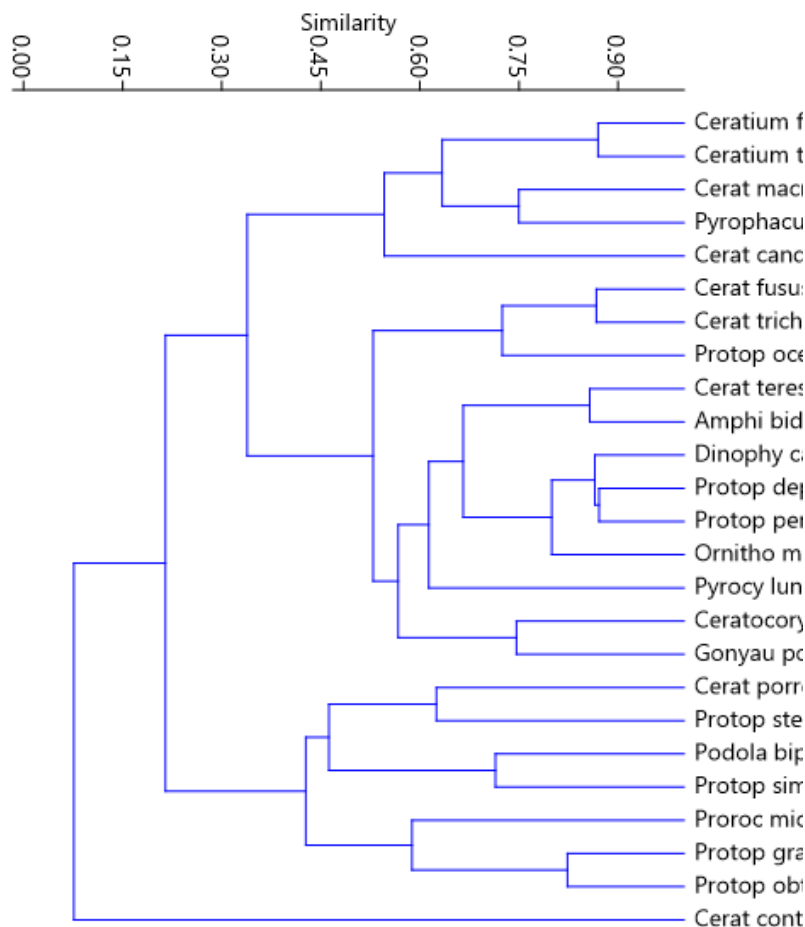


**Figure 14.**

Clustering analysis for dinoflagellate species observed based on the Bray Curtis similarity index.

According to the analysis of similarity in the stations (E2, E3, E4), there are five groups within the cluster, showing moderate to strong differences in the behavior of the dinoflagellate species associated with the hydrological conditions of the study area.

Group 1, formed by five species, showed moderate similarity in species distribution, group 2 presented a mixture of species of greater constancy and abundance over time, group 3 recorded species with low to moderate similarity over time in the study area, group 4 recorded a mixture of species with different distributions, while the fifth group represented by *Ceratiun contorta* presented a low population of cells (Figure 15).

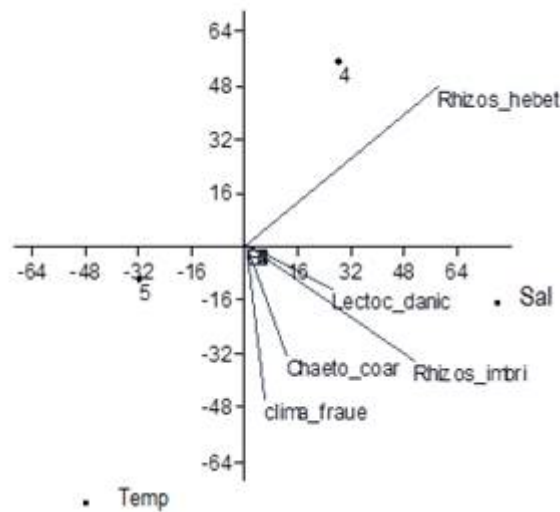


**Figure 15.**  
Clustering analysis for dinoflagellate species observed based on the Bray Curtis similarity index at stations E2, E3 and E4.

*Canonical correspondence analysis*

**Diatoms**

In the group of diatoms, the months of December and May present a correlation of 0.99, with values of 0.71 and 0.74 in the following months of January, February and March. Figure 12 shows a direct relationship between the parameters of the species *Rhizosolenia hebetata* of cosmopolitan neritic characteristic with the temperature and surface salinity of the sea, as well as with *Lectocylindrus danicus*, while with the species *Rhizosolenia imbricata* there is an inversely proportional relationship and a slightly weaker relationship with the species *Chaetoceros coarctatus* and *Climacodium frauenfeldianum* (Figure 16).

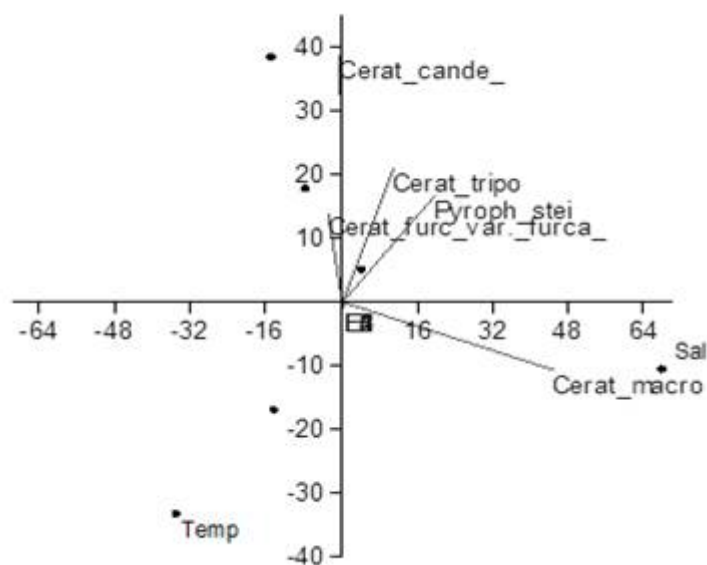


**Figure 16**

Canonical correspondence analysis between Rhizo\_hebet Lectoc\_danic Chaeto\_coar Clima\_fraue frequent species and environmental variables

### Dinoflagellates

In the group of dinoflagellates for the months of December and January there is a correlation of 0.26, increasing progressively until the months of February and March, reaching a maximum value of 0.85 and decreasing in the following months, obtaining a value of 0.04 in the month of May, being the maximum value in that month. In the dinoflagellate species, the relationship between the parameters temperature-surface salinity between the species *Ceratium candelabrum* and *Ceratium tripos* stands out, as well as with *Protoperidinium steinii* and *Ceratium furca* var. *furca* in a weaker proportion and presenting a relationship inversely proportional to the parameters is the species *Ceratium macrocero* (Figure 17).



**Figure 17**

Canonical correspondence analysis between *Cerata\_tripos*, *Pyrochloa\_etei*, *Cerata\_furca\_var\_furca*, and *Cerata\_macro*, frequent species and environmental variables.

## Discussion

The diversity and abundance of phytoplankton (diatoms and dinoflagellates) present in the coastal waters of Ancon, Anconcito and Punta Carnero are mentioned in the study.

The environmental conditions of temperature, salinities reported by Vera (2014) and Tapia (2013) were similar this study, these factors influence the abundance and diversity of phytoplankton; during the study conducted by Tapia in 2009 the average salinity and temperature was 32.9 UPS and 24.1°C.

Monitoring conducted superficially in coastal waters of the study area presented high densities of dinoflagellates associated for warm waters and abiotic fluctuations of the marine environment, causing changes in the abundance of phytoplankton, (Vera, 2007; 2014), the identified species of phytoplankton in the sampling areas coincide with the records of Tapia (2013), Vera (2014), Pozo (2014), Salinas (2014), Prado and Cajas (2010).

Vera (2014) in his study of dinoflagellates, during the months of October 2011 to March 2012, reporting a maximum of 29.5°C in March and a minimum of 21.5 °C in October. The maximum and minimum temperature in this study were 27.5°C 25.2°C and the maximum and minimum salinity 35.8 ups and 32.3 ups, obtaining 24 surface samples of phytoplankton in this area (10 miles), identified 27 species of dinoflagellates, and the dominant ones are *Ceratium furca* var. *furca*, *Dinophysis caudata*, *Ceratium tripos*. *Protoperidinium depressum* and *Ceratium macroceros*. Salinas (2014) in his study of dinoflagellates during November 2013 to March 2014 in Anconcito determined that the genus *Ceratium* is the most predominant; Prado and Cajas (2010) in a study conducted in the area of Puerto Lopez consider the genera *Ceratium* and *Protoperidinium*

more representative. The INP considers *Ceratium furca*, *C. fusus*, *C. massiliense*, and *C. massiliense* typical of the Equatorial zone.

*Protoperidinium brochi*. In this study the most representative were *Ceratium furca* var. *furca*, *Ceratium fusus* and *Ceratium tripos*, therefore this genus is the most representative of this area.

Of 58 species identified in the 36 samples, in the group of diatoms *Rhizosolenia Imbricata* was the predominant and heterogeneous species in the 6 stations, similar to what was reported by Basilio (2014), in the Bay of Santa Elena where he mentions that the diatom species with the highest density are *Rhizosolenia alata*, *Rhizosolenia imbricata* and *Coscinodiscus excentricus*, and that their concentration is due to the fact that they are cosmopolitan species and tolerate sudden changes that can occur in the marine environment, however Pozo (2014) reported *Cerataulina compacta* and *Bellerochea malleus* as the most abundant species in November 2013 to March 2014 in Anconcito. However, the genus *Rhizosolenia* was also present. The Instituto Nacional de Pesca mentions that the diatom species that occur consistently over time and are considered typical of the equatorial front zone are: *Rhizosolenia styliformis*, *Proboscia alata*, *Itletonema costatum*, *Chaetoceros curvisetus*, *Thalassionema nitzschioides*, *Bacteriastrum delicatulum*, *lacosdecipiens*, *Planlctoniella sol*.

Tapia (2009), in Santa Elena Bay in May 2006, reported ranges between 0.52 to 0.94 bits/ind, classifying it as an area of low phytoplankton diversity. In ebb phase, Pozo (2014) considers the Anconcito area as an area of high biological diversity being his results 2.72 bits/ind, associated to the contributions of the Anconcito Fishing Port.

While in the present study, the fluctuation of diversity between diatoms and dinoflagellates was determined, with  $H'$  values from 1.96 bits/ind in February to 0.14 bits/ind in March for diatoms, associated with the temperature and salinity of the moment, while dinoflagellates registered higher values for December with  $H'$  of 2.29 bits/ind and low values in April of 0.32 bits/ind.

## Conclusions

The most abundant phytoplankton group was diatoms, recorded in all stations, followed by dinoflagellates, silicoflagellates and tintinids.

- In December there was a higher presence of phytoplankton 218158 cells/m<sup>3</sup>.
- The Dinoflagellate species with the highest population density was *Ceratium furca* var *furca* which was present during the sampling time, but not in all seasons.
- The Diatom species with the highest population abundance was *Rhizosolenia Imbricata*, with a heterogeneous distribution in each season.
- There was a low diversity of diatom and dinoflagellate species in January in the areas surveyed.

## References

- Basilio, V. (2014). *Distribution and Abundance of Phytoplankton (Diatoms and Dinoflagellates) in Santa Elena Bay (Salinas-Ecuador) from July-December 2013*". (Undergraduate thesis). Santa Elena Peninsula State University. Santa Elena. Ecuador.

- Balech, E. (1988). *The dinoflagellates of the southwestern Atlantic*. Madrid. Ministerio de Agricultura y Alimentación - Secretaría General Técnica.
- INP (2000). *Scientific Bulletin. Phytoplankton and microzooplankton variability off the Ecuadorian coast during 1995-1999*. Retrieved June 20
- Magurran, A. E. 1988. *Ecological diversity and its measurement*. Princeton University Press, New Jersey, 179 pp.
- Moreno, C.E. 2001. *Methods for measuring biodiversity*. M & T- Manuales y Tesis SEA, vol. I. Zaragoza, 84 pp.
- Mujica M, (2016). *Distribution and ecology of jellyfish and siphonophores in the coastal marine area of Ancon, Anconcito and Punta Carnero*. (Undergraduate thesis) Universidad Península de Santa Elena, Ecuador.
- Needham, J. & P. Needham. (1990). *Guide to the study of freshwater living things*. Barcelona. Reverte. S.A.
- Pesantes, F. (1983). *Dinoflagellates of the phytoplankton of the Gulf of Guayaquil*. *Acta Oceanográfica del Pacífico (INOCAR)*, Ecuador, 2(2): 283-399.
- Pielou, E. C., 1975. *Ecological diversity*. John Wiley & Sons, Inc., New York, 165pp.
- Pozo, K. (2014). *Distribution and abundance of diatoms and their relationship with environmental parameters in the bay of Anconcito province of Santa Elena-Ecuador, November 2013- March 2014*. (Undergraduate thesis). Santa Elena Peninsula State University. Santa Elena. Ecuador
- Shannon, C. E. & W. Wiener. 1949. *The mathematical theory of communication*. University of Illinois Press, Urbana 117p
- Tapia, M. (2013). *Phytoplankton Composition and Distribution During the Seismic Survey on the Ecuadorian Coast, December 2008*. *Acta Oceanográfica Del Pacífico*. Ecuador.
- Tomas, C. (1996). *Identifying Marine Phytoplankton*. Academic Press. Accessed December 20, 2015. Online: [https://books.google.es/books?id=8WLABHmo-K8C&printsec=frontcover&dq=Identifying+Marine+Phytoplankton.+Academic+Press.&hl=en&sa=X&ved=0ahUKEwi\\_3oDa3pzUAhUG4SYKHa41ANAQ6AEII TAA#v=onepage&q=Identifying%20Marine%20Phytoplankton.%20Academic%20Press.&f=false](https://books.google.es/books?id=8WLABHmo-K8C&printsec=frontcover&dq=Identifying+Marine+Phytoplankton.+Academic+Press.&hl=en&sa=X&ved=0ahUKEwi_3oDa3pzUAhUG4SYKHa41ANAQ6AEII TAA#v=onepage&q=Identifying%20Marine%20Phytoplankton.%20Academic%20Press.&f=false).
- Vera, E. (2014). *Incidence of nutrients and SST on dinoflagellate proliferation in two marine-coastal sectors of Santa Elena province*. (Master's thesis). University of Guayaquil.