Acta
oceanográfica del Pacífico
ISSN 1390-129X
eISSN 2806-5522

Phytoplankton in the Fauna Production Reserve Manglares El Salado, Guayaquil-Ecuador

Fitoplancton en la Reserva de Producción de Fauna Manglares El Salado, Guayaquil-Ecuador

Artículo

Acta Oceanográfica del Pacífico

María Elena Tapia
Master of Science in Management of bioaquatic resources and environment
Oceanographic and Antarctic Institute of the Navy.
Guayaquil, Ecuador
maria.tapia@inocar.mil.ec
ORCID: https://orcid.org/0000-0002-1988-5940

Luis Troccoli-Ghinaglia
PhD in Marine Ecology
Retired Professor, Universidad de Oriente, Venezuela.
Boca de Río, Margarita Island-Venezuela
luis.troccoli@gmail.com
ORCID: https://orcid.org/0000-0001-8684-6741

Richard Narea
Chemist
Oceanographic and Antarctic Institute of the Navy.
Guayaquil, Ecuador
richard.narea@inocar.mil.ec
ORCID: https://orcid.org/0000-0003-3516-3516-1384

Christian Naranjo
Master of Science in Management of bioaquatic resources and environment
Oceanographic and Antarctic Institute of the Navy
Guayaquil, Ecuador
christian.naranjo@inocar.mil.ec
ORCID: https://orcid.org/0000-0002-4283-2784283-2783

Acta Oceanográfica del Pacífico
DOI: https//doi.org/10.54140/raop.v3i2.67
Received November 11, 2022
Accepted December 08, 2022
Vol 5. No. 1. 2023
ISSN: 1390-129X
ISSN: 2806-5522
Pg. 84-100

Abstract

Phytoplankton is indicator of processes in aquatic environments. During may to november 2018 in the Salado de Guayaquil estuary, surface sampling of phytoplankton, chlorophyll *a*, temperature, salinity and surface pH measurements were carried out. Water samples were also collected for analysis of inorganic nutrients (phosphates and silicates). The biological and environmental variables were carried out during the two tidal states in four zones located within the Manglares de El Salado Faunal Production Reserve. The highest chlorophyll concentration was determined in the southwest zone (Puente Portete), in flow with a core of 18.7 mg/m^3 at surface level during september and characterized as the highest concentration in the entire study area. The composition of the phytoplankton community in net samples showed similarity between zones 2, 3 and 4 by means of the similarity index, while in zone 1 located to the north (Miraflores and Bellavista Stations) its composition was 73% different compared to the other three study zones. The environmental variables salinity, pH, nutrients and chlorophyll did not present significant differences according to the different zones, tidal states and months during the 2018 dry season, except for the temperature variable, which presented significant differences observed in zone 1 located to the north of the study

area due to the higher surface temperature recorded in may compared to the northwest, southwest and south zones. By means of a canonical correspondence analysis (CCA), orthogonal correspondence relationships of the dominant species in each sector and environmental variables were determined, strong correlations were presented between *Chorococcus limneticus* and temperature, favored by the high availability of phosphates and silicates during the dry season, november 2018 in the northern zone of the study area. So also other phytoplankton species showed a correspondence relationship with other environmental variables in other study areas of the El Salado faunal production reserve.

Key words: Phytoplankton, protected area, chlorophyll, abundance, species.

Resumen

Durante mayo a noviembre de 2018 en el estero Salado de Guayaquil, se efectuaron muestreos superficiales de fitoplancton, clorofila *a*, mediciones de temperatura, salinidad y pH superficial. Así también se recolectaron muestras de agua para los análisis de nutrientes inorgánicos (Fosfatos y Silicatos). Las variables biológicas y ambientales fueron realizadas durante los dos estados de mareas en cuatros zonas ubicadas dentro de la Reserva de producción Faunística Manglares de El Salado. Se determinó la mayor concentración de clorofila en la zona suroeste (Puente Portete), en flujo con un núcleo de 18.7 mg/m^3 a nivel superficial durante septiembre y caracterizando como la concentración más alta de toda el área de estudio. La composición de la comunidad de fitoplancton en muestras en redes presentó mediante el índice de similaridad similitud entre las zonas 2, 3 y 4, en tanto que en la zona 1 ubicadas al norte (Estaciones Miraflores y Bellavista) fue diferente en un 73 % su composición en comparación a las otras tres zonas de estudio. Las variables ambientales salinidad, pH, nutrientes y clorofila no presentaron diferencias significativas en función a las diferentes zonas, estados marea y meses durante la época seca de 2018, a excepción de la variable temperatura presentó diferencias significativas observadas en la zona 1 ubicada al norte del área de estudio debido a la mayor temperatura superficial registrado en mayo en comparación a las zonas noroeste, suroeste y sur. Mediante un análisis de correspondencia canónica (ACC), se determinaron relaciones de correspondencia ortogonal de las especies dominantes de cada sector y las variables ambientales, se presentaron fuertes correlaciones entre *Chorococcus limneticus* y la temperatura, favorecido por la alta disponibilidad de fosfatos y silicatos durante la época seca, noviembre de 2018 en la zona norte del área de estudio. Así también otras especies de fitoplancton mostraron una relación de correspondencia con otras variables ambientales en otras zonas de estudio de la reserva de producción faunística El Salado.

Palabras clave: Fitoplancton, área protegida, clorofila, abundancia, especies.

Introduction

The Gulf of Guayaquil is the largest and most productive estuary in the South Pacific, concentrating approximately 81% of Ecuador's mangrove system, and is home to the Salado estuary, catalogued as the El Salado Mangrove Fauna Production Reserve (RPFMS), part of Ecuador's National System of Protected Areas (SNAP) and located northwest of the Gulf of Guayaquil estuary and southwest of the main port.

The role of estuaries in nutrient inputs to the coastal zone has been widely studied due to their importance in energy transfer and fish production (Alpine & Cloern, 1992). This nutrient load is mainly generated by the increase of human populations and their activities in the coastal zone, which when excessive can lead to eutrophication affecting the quality and use of the resources of these ecosystems (Nixon, 1995).

In Ecuador, 70% of inland water bodies flow into the coastal zone (Rendón *et al.,* 1983), especially the Gulf of Guayaquil, where most of the country's fishing and aquaculture activity is concentrated (San Martín, 2009). However, the load of nutrients from untreated wastewater from agriculture, livestock, domestic, industrial and aquaculture sources could have trophic characteristics that could affect water quality and the diversity of resources that develop there.

The importance of this reserve lies not only in the fact that it is a vital space for the native flora and fauna of the inner gulf, but also because of its great scenic, aesthetic and recreational value, especially since it is located within the largest and most populated city in the country.

The objective of this study was to determine the composition of phytoplankton species and their relationship with environmental parameters in the estuaries located in the Manglares El Salado Fauna Production Reserve in Guayaquil.

Materials and methods

The Salado estuary is located northwest of the estuary of the Gulf of Guayaquil and southwest of the city's port. It is composed of salt marsh areas, remnants of the tropical dry forest, mangrove forest, and the Plano Seco, Salado, and Mogollon estuaries (Carvajal *et al.*, 2005). It is divided by a natural barrier of islands and different channels that separate the Salado estuary from the Guayas River, which means that marine waters enter the Morro channel directly into the estuary, receiving freshwater from the river through the Cascajal channel and tidal currents.

It includes the different estuaries that make up the Manglares El Salado Fauna Production Reserve. Within this area, 7 stations were monitored, which were established in four zones and are shown in Table 1.

Table 1. Location of the study areas and stations located in the Fauna Production Reserve Manglares El Salado de Guayaquil, during the dry season of 2018.

Zone	Station	Location	Latitude	Longitude	Tide
North	1	Miraflores	620392	9760839	Flow - backflow
North	2	Bellavista	620914	9757914	Flow - backflow
Northwest	3	Puerto Hondo	609002	9757448	Flow - backflow
Southwest	4	Portete Bridge	618210	9757288	Flow - backflow
South	5	Estero Palanqueado	619817	9754106	Flow - backflow
South	6	Port Lisa	620684	9754123	Flow - backflow
South	7	Estero del Muerto	621030	9750885	Flow - backflow

Sampling in the Salado estuary was carried out aboard the hydrographic boat at the stations indicated in (Table 1), except for station 2 located in the northern zone, which was sampled by land and the positioning of the sampling stations was obtained using a GPS in order to collect water samples for physicochemical and biological variables.

The physicochemical variables were collected using a Van Dorn bottle and the water samples were analyzed following those described in the APHA (2005) protocols, standard method for the measurement of water and wastewater.

For the analysis of chlorophyll samples, 1 liter of water was collected and the Fluorometry method described in the Scor-Unesco Working Group 17 Manual (1966) was used.

For the collection of phytoplankton samples, surface hauls were made using a simple conical cylinder net with a 30 cm diameter net mouth, equipped with a flowmeter, with a mesh opening of 50 µ to collect phytoplankton samples during the two tidal stages. The samples were preserved with 4% formaldehyde solution previously neutralized with sodium tetraborate.

Results

North Zone of Estero Salado

The environmental variables showed during the dry season of 2018, in the Manglares del estero Salado reserve, that salinity has a pattern to increase its value during the dry season, from August to November, while temperature showed a significant difference, presenting its maximum of 29.9° C in May, decreasing its average from June to November 2018. The phosphate nutrient parameters presented its maximum average values of 20 *u*mol/L in June and September 2018, while silicates presented the maximum value of 350 *u*mol/L in August 2018. Chlorophyll *a* did not show significant differences during the study period, presenting the maximum

average values during the months of June and September, decreasing for the months of October and November 2018.

Hydrogen potential values were slightly alkaline over the study period. However the highest of salinity values were present for October and November 2018.

The environmental variables recorded at the stations located in the northern sector did not show significant differences, except for temperature, which showed significant differences during May compared to the following months of the study period (Figure 1).

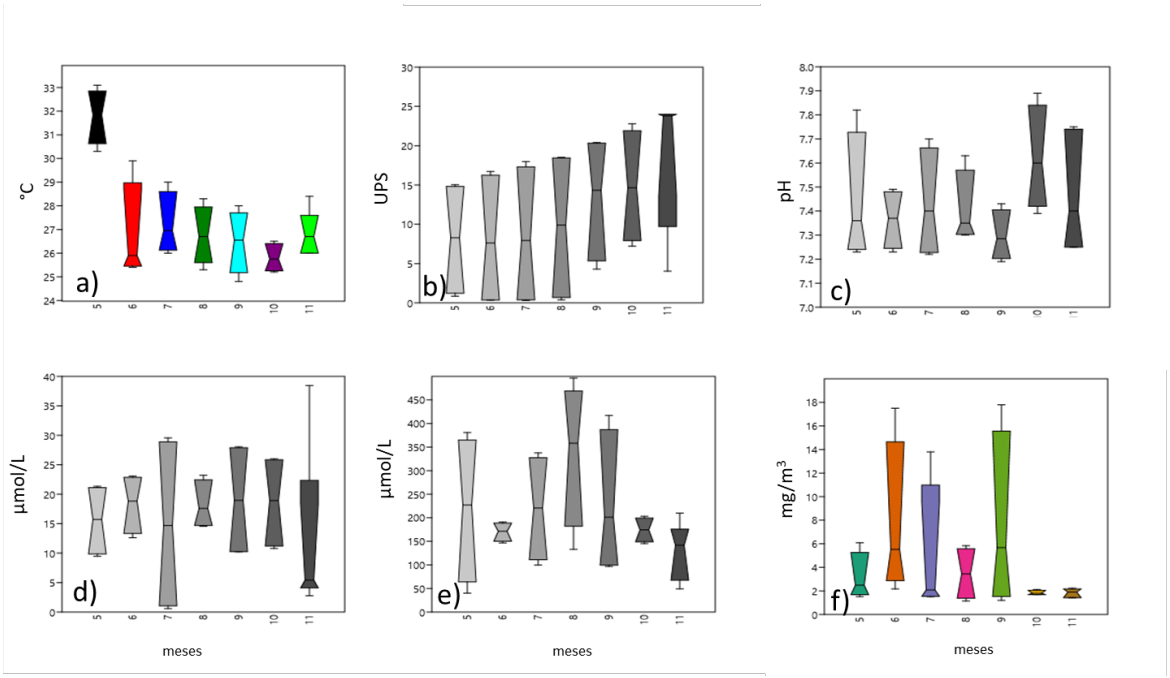

Figure 1. Monthly variation of environmental variables in the northern sector of the Salado estuary during May to November 2018. a) Temperature, b) Salinity, c) pH, d) Phosphates, e) Silicates, f) Chlorophyll *a.*

Canonical correspondence analysis showed that *Chorococcus limneticus* presented a strong relationship with surface temperature variables and presented its highest abundance due to the availability of phosphate and silicate nutrients observed in November 2018 and associated with optimal alkalinity values at stations located in the northern sector.

Regarding the temporal behavior of the species *Coscinodiscus sp.* presented its highest abundance in June 2018 in station 2 flow, in correlation with a hight concentration of chlorophyll *a*, associated with a high availability of inorganic nutrients such phosphates and silicates.(Figure. 2).

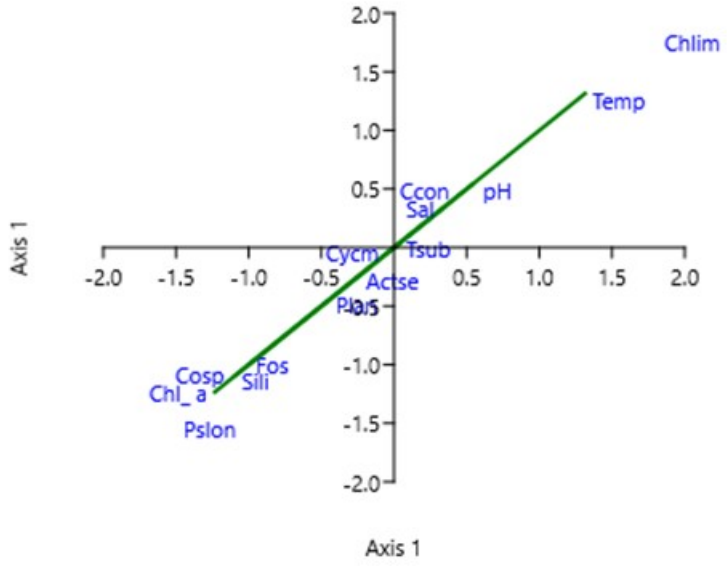

Figure 2 Orthogonal projection of the first two components of the ACC canonical correspondence analysis, in the northern sector during May-November 2018.

Northwest Zone of Estero Salado

Surface temperature, at station 3 located in Puerto Hondo showed a pattern similar to that observed in the northern sector and during May the highest temperature value was presented, while in June it decreased reaching average values of 25° in August and October 2018. Salinity showed a temporal distribution pattern and the lowest salinity value was recorded in May and gradually increased until reaching the maximum value of 27 ups in the months of October and November 2018 (Figure 3).

The phosphates and silicates variables did not present significant differences, determining the maximum value of phosphate in June and the lowest value was presented in November 2018. Silicates presented their maximum value in May and the lowest value in November 2018. The chlorophyll a variable presented the maximums in the months of June and July 2018 and did not present significant difference during the study period. A similar pattern presented the pH variable showed no significant differences and the maximum values of 7.7 pH were recorded in October 2018.

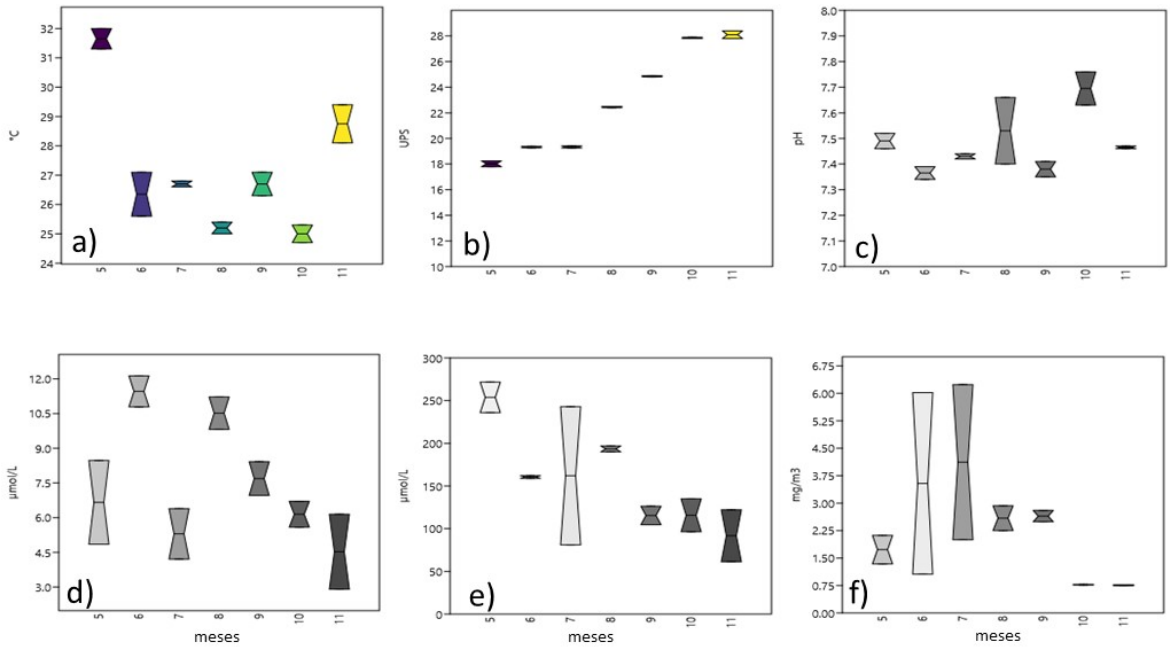

Figure 3. Monthly variation of environmental variables in the northwest sector of the Salado estuary during May to November 2018. a) Temperature, b) Salinity, c) pH, d) Phosphates, e) Silicates, f) Chlorophyll *a*.

The centric diatom *Cyclotella menenghiana* showed a degree of correlation with surface temperature, because its abundance increased as temperatures between 25° and 26.5° C increased. The species *Chaetoceros subtilis* showed a strong relationship with salinity, the highest abundance of this species was presented with values of 24.8 ups. In this zone, the species *Pleurosigma angulatum showed a* strong relationship with the variables Silicates and Chlorophyll a (Figure 4).

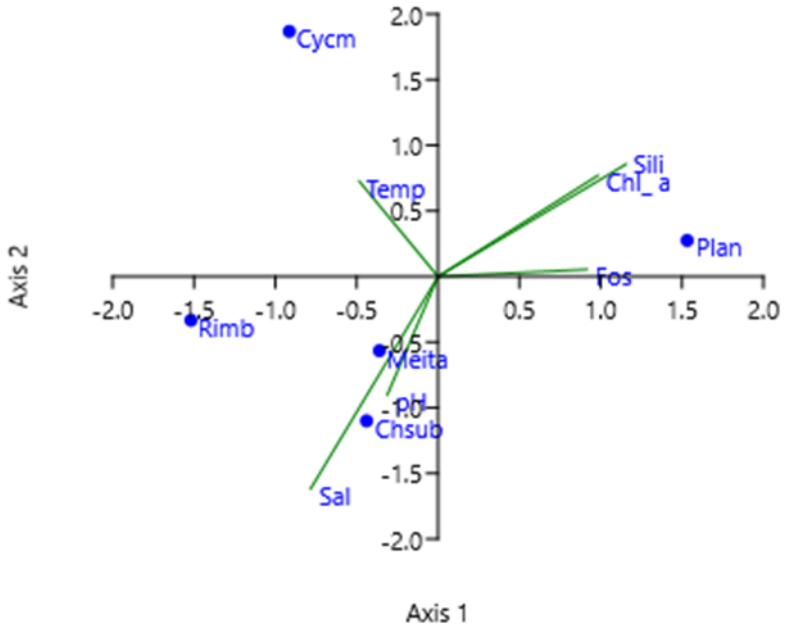

Figure 4. Orthogonal projection of the first two components of the ACC canonical correspondence analysis, in the northwest zone during May-November 2018.

Southwest Zone of Estero Salado

The environmental variables recorded during the study period did not show significant differences except for temperature, which showed its highest value in May 2018 and its tendency to decrease in the following months of the dry season. Salinity showed an inverse pattern to temperature, registering the lowest value in May and increasing in the following months of the dry season (Figure 5).

The highest chlorophyll a averages were related to high nutrient availability, with averages 8 and 145 umol/L of phosphates and silicates respectively, and pH presented average values of 7.5 observed in September 2018.

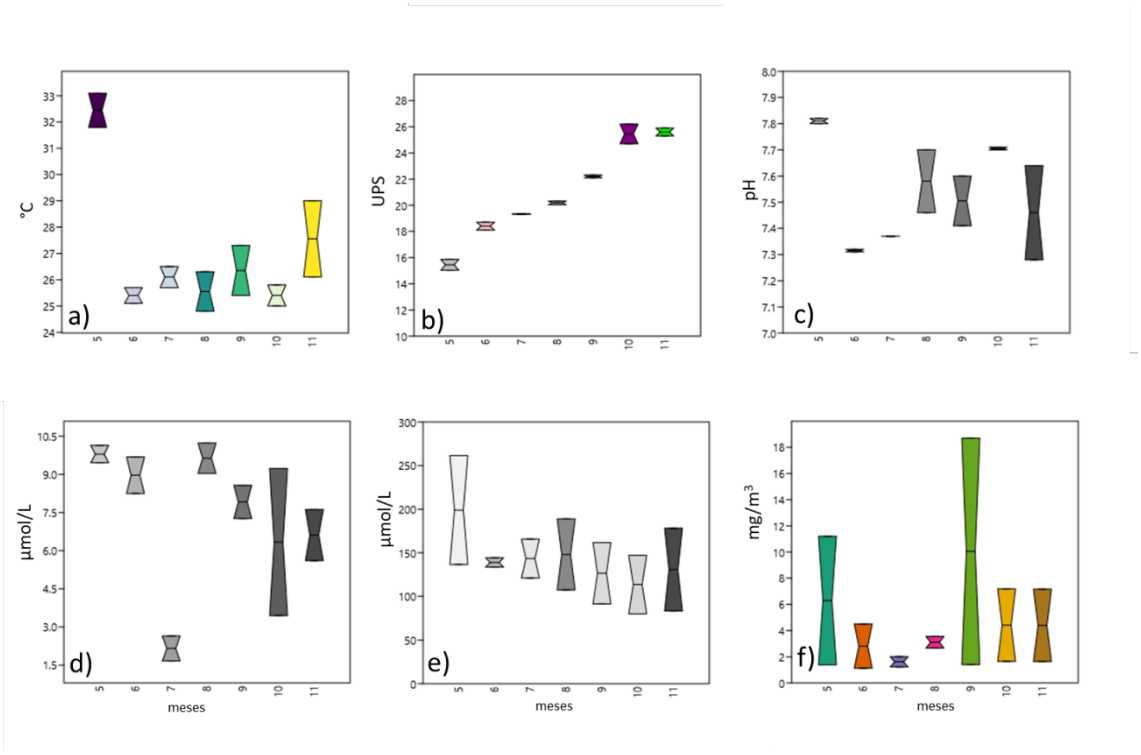

Figure 5. Monthly variation of environmental variables in the southwestern sector of the Salado estuary during May to November 2018. a) Temperature, b) Salinity, c) pH, d) Phosphates, e) Silicates, f) Chlorophyll *a*.

The species *Coscinodiscus concinnus* showed a degree of correspondence with the temperature and phosphate variables, i.e., its abundance increased when the temperature increased and an optimum phosphate concentration was present. On the other hand, the species *Coscinodiscus excentricus* decreased in abundance when average values were below 25°C (Figure 6).

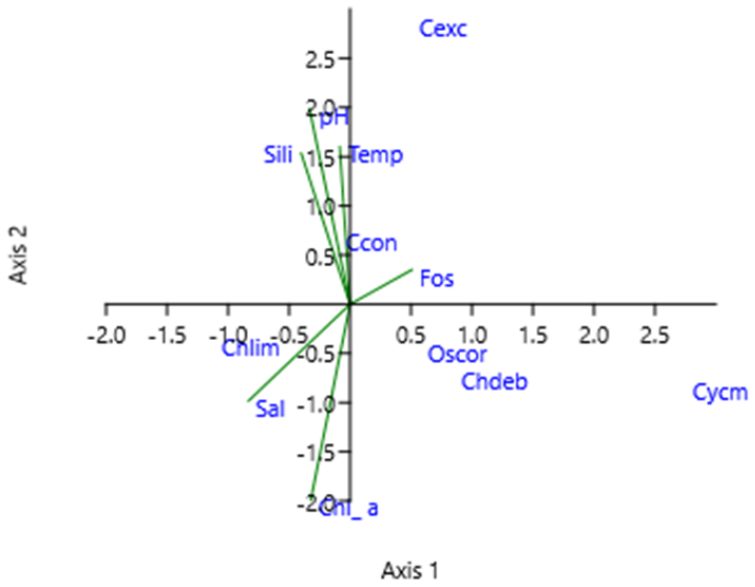

Figure 6. Orthogonal projection of the first two components of the ACC canonical correspondence analysis, in the southwest zone during May-November 2018.

South Zone of Estero Salado

In the stations sampled in the southern zone, there were no significant differences in the variation of the monthly average of the environmental variables. Sea surface temperature presented its maximum value in May and its tendency to decrease in the following months. While salinity its average are low in May and from July it presented a tendency to rise as the months of the dry season pass, reaching its maximum value of 26 ups in October 2018. In this sector the maximum silicate values were associated with the highest values of chlorophyll *a* in May and characterized with a slightly alkaline pH with average value 7.44. Another maximum value occurred in June 2022, however, silicate averages were lower than that observed in May (Figure. 7).

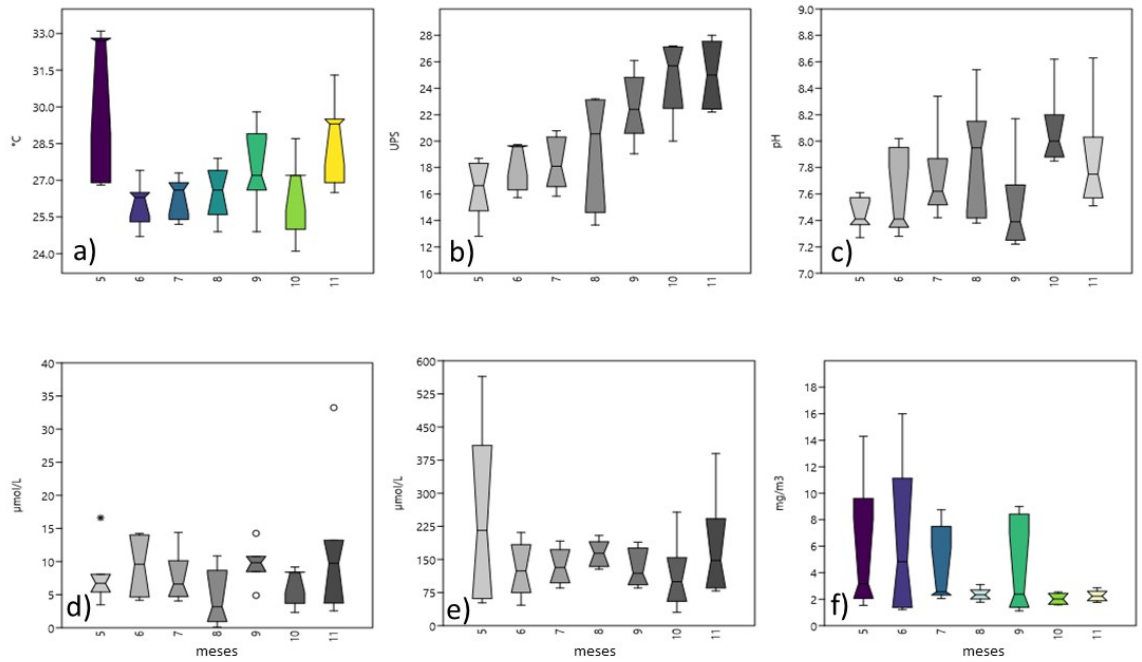

Figure 7. Monthly variation of environmental variables in the southern sector of the Salado estuary during May to November 2018. a) Temperature, b) Salinity, c) pH, d) Phosphates, e) Silicates, f) Chlorophyll *a*.

The diatom *Chaetoceros subtilis* had a moderate relationship with chlorophyll with average values between 1.9 and 2.5 mg/m^3 with excellent availability in silicate and phosphate concentrations.

The species *Euglena sp.* showed a strong correlation with temperature and salinity, mainly with average values of 26°C and 18 ups respectively, in the stations located in the southern zone during the dry season (Figure 8).

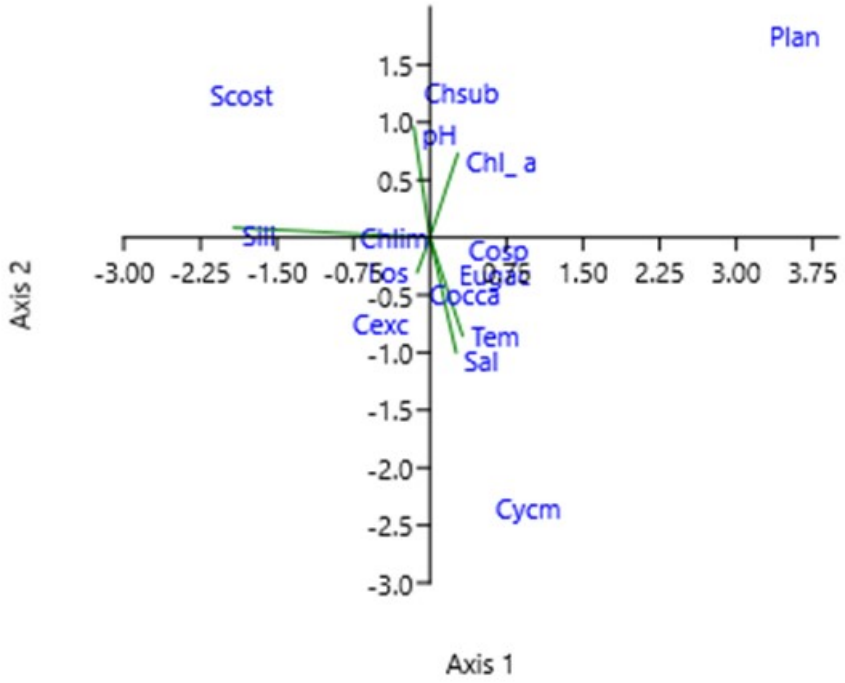

Figure 8. Orthogonal projection of the first two components of the ACC canonical correspondence analysis, in the southern zone during May-November 2018.

The distribution of phytoplankton species, using the Bray Curtis similarity index in each of the study zones, showed a strong similarity in the stations located in the south, southwest and northwest zone during study period represented in the (Figure 9) which is represented by the cardinal numbers from 67 to 98 with 0.9, representing 90% similar composition during the dry season of 2018. However, in station 1 corresponding to May 2018, during flow represents 0.33, which are similar to stations 1 and 2 located in the northern zone.

The first cluster corresponding to cardinal numbers 1 to 10 presented a species composition that represents a low similarity of 0.33 compared to the other study zones, i.e. there is a 77% difference in phytoplankton composition and richness compared to zones 2, 3 and 4 during the study period (Figure 9).

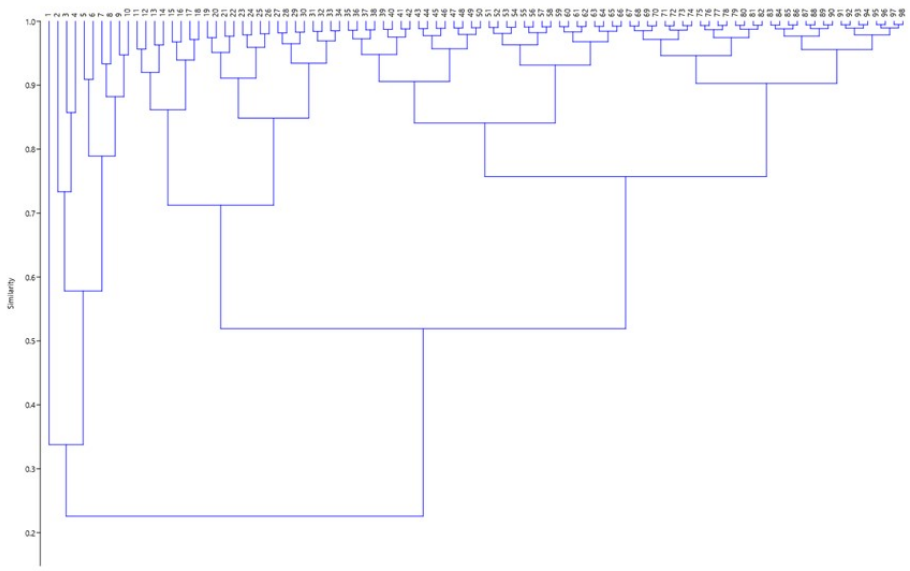

Figure 9. Bray-Curtis similarity index applied to phytoplankton species in the four zones located in the Salado estuary during the 2018 dry season.

Discussión

The expansion of the city of Guayaquil may cause detriment to the surrounding natural ecosystems due to the growth of parishes and the settlement of companies and factories of different commercial nature located in areas surrounding the Manglares El Salado Wildlife Production Reserve.

For this reason, the study was developed to establish the composition of phytoplankton and its relationship with the environmental variables present in the reserve located in the inner zone of the estuary, consisting of several estuaries, canals and mangrove forests that are located west of the city of Guayaquil, and includes the estuaries located within the city, the Miraflores, Bellavista and Kennedy neighborhoods.

Cullen, Reid & Stewart, (1982) consider chlorophyll *a as an* indicator of phytoplankton biomass, used to define potentially productive zones, although not all cases show a high correlation between chlorophyll *a* and the number of phytoplankton cells. However, sometimes when there is a high concentration of chlorophyll a as observed in the interior of the branches located in the Salado estuary can be attributed in some cases to a high concentration of chlorophyll a and availability of inorganic nutrients, a pattern that was recorded at the station located at the Portete bridge during the dry season of 2018.

Primary production in the oceans varies in response to environmental stressors and other factors such as seasonality. Seasonal variation in temperature, solar radiation availability and nutrients are key factors in ocean primary productivity (Henson *et al.,* 2013) and therefore temperature, salinity and inorganic nutrients can also be considered to influence the presence or dominance of phytoplankton species recorded in the Salado estuary and its channels located towards the urban area of Guayaquil.

During the 2018 dry season of the variables analyzed, the temperature recorded in the northern zone presented significant differences, during May and was decreasing the value as the months of the dry season passed, while salinity showed an inverse pattern to temperature.

In the inner estuary of the Gulf of Guayaquil, Jiménez (1998) reported *Skeletonema costatum* as a small diatom that forms chains and plays an important role in the estuarine food chain; Prado-España, M. *et al.* (2017) mentioned that the species *Nitzschia longissima, Chaetoceros decipiens*, and *Skeletonema costatum were* positively correlated with temperature and inversely with phosphates and nitrates. In the present study carried out in the Salado estuary, it was found that the species *Coscinodiscus concinnus* presented a positive correspondence with the variables temperature and phosphates, inversely with chlorophyll observed in the area located to the southwest.

Thus, there are other environmental variables that are influencing the maximum chlorophyll a values reported at the Puente Portete station located in the southwest zone.

In the stations located in the southern zone, the species *Euglena sp.* showed a strong correlation with temperature and salinity, mainly with average values of 26°C and 18 ups respectively. The presence of Euglena spp. characterizes a zone with the beginning of environmental problems, added to the high concentrations of nutrients, which can generate a threat for the development of a eutrophication process mainly in sites where the tidal states do not contribute to improve oxygenation and a replacement in the water column of the physicochemical conditions.

Previous studies, among them Solórzano (1989), indicated that the waters of the Salado estuary were eutrophicated by that date. When the inner estuary is subjected to high turbulence, therefore, species are limited in light intensity and adapted to low concentrations of dissolved oxygen, so that *Paralia sulcata, Skeletomena costatum* and *T. nitzschioides*, have been recorded as indicators of eutrophic waters (Huisman *et al*., 2004; Garmendia *et al.,* 2013), it is suggested to develop a temporal follow-up through future outings to establish and confirm that the aforementioned species could be considered as a type of eutrophic waters in the inner zone of the Salado estuary.

Chlorophyll a concentrations compared to previous studies, it was found that during March of 2002 productive waters in the Estero Salado with 1.32 mg/m^3 and in the area located in the area of the bridges of the city of Guayaquil values of 3.74 mg/m^3 (Gualancañay, Tapia & Naranjo, 2003-2004) considered normal for that time and year of study. Comparing with 2018, about two decades later, it is currently reported that in the south zone (Estero Palanqueado, Puerto Lisa and Estero El Muerto), southwest zone (Puente Portete Station) high values of chlorophyll a and being much higher during the process in flow tide when the tide advances towards the north zone (in front of Bellavista), This allows us to hypothesize that there are many inputs from urban settlements product of the contribution of wastewater and domestic water near the banks of the Salado estuary. That are contributing to a high concentration of micronutrients, which in the future will cause eutrophication processes in some of the stations and areas mentioned above and that are in the important estuarine ecosystem of the El Salado Faunal Production Reserve.

The highest chlorophyll concentrations were observed during reflux at the surface level located in Zone 1 with a very productive core of 12.1 mg/m^3 during May E-20 (Estero Salado Tranche A), while the lowest chlorophyll concentration was in Zone 4 (Puerto Hondo), with 0.78 mg/m^3 during the months of October and November 2018. The highest chlorophyll concentration was recorded in the bottom stratum located in Zone 1 at E-5 (17th Street Bridge), during September of 2018 with 12.5 mg/m^3.

Conclusions

During the study period a total of 73 phytoplankton species were identified characterizing a similar composition in the southern and southwestern zones based on the Bray-Curtis Similarity Index. The dominant species *Cyclotella menenghiniana, Chaetoceros decipiens, Ch. subtile, Nitzschia longissima, Pleurosigma angulatum* and *Chrococcus limneticus* in August 2018 and in lower cell density were recorded *Melosira italica* and *Euglena acus*, typical species of the estuarine environment.

The Miraflores and Bellavista stations located in the northern zone share 33% similarity compared to the stations located in the three zones under study, according to the Bray Curtis Index.

The areas and stations sampled presented higher chlorophyll concentrations were the southern (Estero Palanqueado, Puerto Lisa and Estero El Muerto), southwestern (Puente Portete) and northern (in front of Bellavista) areas, which suggests that anthropogenic processes and added to environmental factors are causing high chlorophyll *a* concentrations, showing a strong canonical correspondence observed between phytoplankton species and environmental variables in each of the study areas during the dry season of 2018. It is suggested that the Environmental Directorate of the Municipality of Guayaquil continue with permanent controls of the companies located on the banks of the Salado Estuary, which discharge their effluents and solid waste in violation of environmental regulations, in order to protect and prevent the deterioration of this important ecosystem of the internal estuary of the Estero El Salado Fauna Production Reserve.

Recognition

The authors express their gratitude to Mr. CPNV-EM Carlos Zapata, Director of the Oceanographic and Antarctic Institute of the Navy, and to TNNV-SU José Alcívar, Director of Oceanography and Marine Meteorology, for providing all the facilities for the publication of this research.

References

APHA. 2005. Standard Methods for the Examination of Water and Wastewater. 21st, American Public Health Association/American Water Works Association/Water Environment Federation, Washington DC.

Alpine, A. & J.E. Cloern. 1992. Trophic interactions and direct physical effects control phytoplankton biomass and production in an estuary. Limnol.Oceanogr., 375: 946-955.

Carvajal, R. I., Saavedra, M. & Alava, J. 2005. Population ecology, distribution and habitat study of Crocodylus acutus (Cuvier, 1807) in the "Reserva de producción de fauna manglares El Salado" of the estuary of the Gulf of Guayaquil, Ecuador. Journal of Marine Biology and Oceanography 40:141-150. ¬ Organic Code of Territorial Organization, Autonomy.

Cullen, Reid & Stewart. 1982. Phytoplankton in the surface and chlorophyll maximum of southern. California in august, 1978. Res. 4:665-694.

Cupp, E., 1943. Marine plankton diatoms of west coast. Bulletin Scripps Institution of Oceanography of the University of California. Eds H. Sverdrup, R. Fleming, L. Miller, 5(1): 1-238.

Dziengo-Czaja, M., Koss, J. & Matuszak, A. 2008. Teratological forms of diatoms (Bacillariophyceae) as indicators of water pollution in the western part of

Puck Bay (Southern Baltic Sea). *Oceanological and Hydrobiological Studies*, *37*, 119-132.

ECOLAP and MAE. 2007. Heritage Guide of Natural Protected Areas of Ecuador. ECOFUND, FAN, Darwin Net, IGM. Quito, Ecuador.

Garmendia, M., A. Borja, J. Franco and M. Revilla. 2013. Phytoplankton composition indicators for the assessment of eutrophication in marine waters: present state and challenges within the European directives. Mar. Pollut. Bull., 661: 7-16.

Gualancañay, E, M. Tapia & C. Naranjo. 2003-2004. Composition and seasonal variation of Phytoplankton, Zooplankton and Microbenthos in the inner estuary of the Gulf of Guayaquil. Acta Oceanográfica del Pacífico (INOCAR), Ecuador, 12 (1): 103-128.

Henson, S., Cole, H., Beaulieu, C., Yool, A., 2013. The impact of global warning on seasonlity of ocean primary production. Biogeosciences 10. 4357-4369.

Huisman, J., J. Sharples, J. Stroom, P. Visser, W. Kardinaal and J. Verspagen. 2004. Changes in turbulent mixing shift competition for light between phytoplankton species. Ecology, 85: 2960-2970.

Jiménez R., 1983. Diatoms and dinoflagellates from the Gulf of Guayaquil. Acta Oceanográfica del Pacífico. INOCAR. Vol. 2(2): 193-282.

Lawrence. Keith. 1996. Compilation of EPA'S. Sampling and Analysis Methods. Second Edition. Lewis Publishers.

Moreno, J., S. Licea & H. Santoyo. 1996. Diatoms of the Gulf of California. Autonomous University of Baja California Sur: 1-280.

Nixon, S.W. 1995. Coastal eutrophication: a definition, social causes, and future concerns. Ophelia 41: 199-220.

Pesantes, F. 1983. Dinoflagellates of the phytoplankton of the Gulf of Guayaquil. Acta Oceanográfica del Pacífico, INOCAR. Vol. 1(1): 91-208.

Prado, M., L, Troccoli, & J, Cajas. 2017. Analysis of the trophic state and microphytoplankton of the coastal zone of Guayas province, Ecuador. Boletín de Investigaciones Marinas y Costeras, Colombia, 46 (2): 91-114.

Rendón, M., N. de Padilla & E. Pérez. 1983. Preliminary study of the rivers of the littoral region of Ecuador. Rev. Sci. Limnol. INP. Ecuador, 21:179-222.

Rodríguez, A. 2003. Estudio de Impacto Ambiental que la Ciudad de Guayaquil ocasiona a la cabecera Norte del Estero Salado. University of Guayaquil. Graduate Thesis.

Romero, J. 1996. Physicochemical and Bacteriological Factors of Aquatic Ecosystems. https://www.cortolima.gov.co/sites/default/files/images/stories/centro_documentos/pom_coello/diagnostico/l211.pdf. Retrieved February 23, 2019.

San Martín, V. 2009. Gulf of Guayaquil. Chapter 3. Study area. Escuela Superior Politécnica del Litoral ESPOL. DSpace en ESPOL. https://www.dspace.espol.edu.ec/bitstream/123456789/5234/3/8719.pdf. 01/10/2016.

SCOR UNESCO Working group 17, 1966. Determination of photosynthetic pigment in the sea water. Monographs on oceanographic methodology 1, UNESCO: 8-9.

Semina G., 1967. Phytoplankton: In the Biology of the Pacific Ocean: party I, Plankton. Bogorov V. 7: 27-85.

Shannon, C. & W. Weaver. 1964. The Mathematical Theory of Communication. University Illinois Press, Urbana: 117.

Solórzano L., 1989. Status of coastal water quality in Ecuador. A sustainable shimp mariculture for Ecuador. Technical reprt. Series YR-E-6. International Coastal Resources Management Project: 163-177.

Strickland, J., and T, Parson. 1972. A practical Handbook of Sea Water Analysis.

Tapia, M., 2002. Study of the phytoplankton communities in the Daule, Guayas and Estero Salado rivers. Acta Oceanográfica, Vol. 11. (1): 35-47.

Tapia, M., 2013. Phytoplankton composition and distribution during the Seismic Survey off the Ecuadorian coast, December 2008. Acta Oceanográfica, Vol. 18. (1): 75-89.

Tapia M., & C. Naranjo. 2014. Phytoplankton in the outer Gulf of Guayaquil during January 2014. Acta Oceanográfica del Pacífico, Vol. 21(1):49-60.

Tsirtsis, G. & M. Karydis. 1998. Evaluation of phytoplankton community indices for detecting eutrophic trends in the marine environment. Environ. Monit. Assess, 50: 255-269.

Tomas, C. 1997. Identifying marine diatoms and dinoflagellates. Academic Press, New York: 265.

Twilley, R. R., W. Cárdenas, V. H. Rivera-Monroy, J. Espinoza, R. Suescum, M. M. Armijos y L. Solórzano. 2001. The Gulf of Guayaquil and the Guayas River estuary, Ecuador. Pp. 245-263. In: Coastal Marine Ecosystems of Latin America. Springer Berlin Heidelberg.

Zambrano, I, 1983. Pesantes, F. 1983. Tintinnids of the Gulf of Guayaquil. Acta Oceanográfica del Pacífico, INOCAR. Vol. 1(1): 251-317.