Modern Environmental Science and Engineering (ISSN 2333-2581)
December 2020, Volume 6, No. 12, pp. 1333-1341
Doi: 10.15341/mese(2333-2581)/12.06.2020/007
Academic Star Publishing Company, 2020
www.academicstar.us

Evaluation of Phytoplanktonic Primary Productivity in Lagoon of Coyuca De Benítez, Guerrero, 2016-2017

Raúl Arcos Ramos, Eduardo Méndez Ramírez, and Kevin R. Arcos Hernández

Facultad de Estudios Superiores Zaragoza, Universidad Nacional Autónoma De México, Laboratorio de Contaminación Acuática, Mexico

Abstract: Primary productivity was evaluated to establish the trophic index of the lagoon, related to the quantification of chlorophyll, as well as fourteen physical and chemical parameters at five monitoring points at two depth levels from November 2016 to August 2017; the data were subjected to a statistical analysis using the Statgraphics Centurion XVI.I program. The results establish that the Laguna de Coyuca de Benítez (Guerrero) is an oligohaline system, stratified at the points of the Embarcadero, Río and Centro, it presents a high organic load, which significantly increases the availability of nutrients: ammonia (0.513 mg L^{-1}), phosphates (1.68 mg L^{-1}), nitrites (0.059 mg L^{-1}) and nitrates (1.81 mg L^{-1}), which together with the temperature (28.89°C) produce ideal conditions for proliferation planktonic and thus result in a high Productivity (35,993 mg C m^3), a level that classifies the lagoon as mesotrophic. The multivariate analysis established that the nutrients, temperature, transparency, depth, chlorophyll concentration and STD are the most important variables, since they describe the behavior of the system due to its direct relationship with organic matter, in addition to physical parameters and Productivity.

Key words: productivity, chlorophyll, mesotrophic

1. Introduction

The base of the trophic pyramid in aquatic ecosystems is given mainly by primary producers, who are determined in their development and proliferation by light, CO_2 as well as nutrients. These nutrients are inorganic salts and their main compounds are: Nitrogen sources, phosphorous sources and silica sources. In these aquatic systems, the primary producers par excellence are phytoplankton organisms, macrophytes and macroscopic algae, photosynthesis being their main production mechanism [1].

The present work focuses on a coastal lagoon. According to Lankford (1976) [2], referring expressly to basins in Mexico, "coastal lagoon is a depression in the coastal zone, below the level of upper middle high water (acronym MHHW in English), which it has a permanent or ephemeral connection with the sea, but protected from it by some type of bar". Taking into account the population growth and the tourist, commercial, agricultural and industrial activities in the municipality of Coyuca de Benítez, they generate large amounts of wastewater that affect the quality of the lagoon water [3].

The Coyuca de Benítez Lagoon It belongs to a coastal system comprising three bodies of water: Mitla Lagoon, Coyuca Lagoon and El Zarzal, it is located at the coordinates of 16°54' and 16°58' north latitude and The 99°57 'and 100°04' west longitude, is located in Pie de la Cuesta 10 km north of Acapulco, has an extension of 34 km^2 [4], an average length and width of 10.6 km and 2.78 km, respectively. Its average depth is 2.5 m [5].

2. Material and Methods

The methodology was divided into three phases:

Corresponding author: Raúl Arcos Ramos, Master, Geologist Engineer; research areas/interests: evaluation of water quality and evaluation of contaminated aquatic systems. E-mail: biolrar13@gmail.com.

field phase, laboratory phase and cabinet phase. The samplings were carried out monthly for 7 months from November 2016 to August 2017. For this, five points will be selected along the lagoon, which were determined by the high impact of anthropogenic activities.

The collection of water samples was carried out with the help of an outboard motor boat and a Garmin model Plus IV GPS receiver with WGS84 datum, the samples for laboratory analysis will be taken at five monitoring points: Embarcadero, Entrance of Embarcadero, Centro, Barra and Barra Entrance, since each of them have a direct impact with anthropogenic activities, the samples will be taken at surface level manually and bottom with a Van Dorn bottle, placing the samples in flasks of polyethylene with a capacity of 1 liter, the following parameters were determined in the field.

Quantification of chlorophyll-a based on the technique described in the Manual of Analytical Techniques for the Determination of Physicochemical Parameters and Marine Pollutants (Lorenzen method)

Performing first the filtration in low light conditions and in the shortest possible time after extraction to avoid photo-oxidation of chlorophyll. The filter containing the concentrated chlorophyll was placed in a test tube and 5 ml of 90% acetone were added, with the tissue macerator the fiberglass filter was disintegrated and an additional 5 ml of 90% acetone was added to complete 10 ml of extract, said tubes were kept in complete darkness for 24 hrs. at a temperature of 4°C to ensure the extraction of chlorophyll, the extract was subsequently centrifuged at 3000 rpm for 20 minutes to remove impurities. A blank reading was performed with 90% acetone. Finally, the samples were read at different wavelengths and the equations were performed to determine the concentration of chlorophyll a.

Primary production was evaluated using the evolutionary method of in-situ light and dark bottle oxygen proposed by Gaarder and Gran in 1927.

By using bottles placed at the same depths where the chlorophyll a sampling was carried out, evaluating the amount of O_2 at the beginning of the incubation, the samples were later suspended on a rope, in order to maintain natural conditions, extracting in the period of established time and again analyzing the amount of O_2 with the HI9146 oximeter, to finally perform the corresponding equations.

Cabinet Work

The spatial and temporal behavior of all variables will be established through the Excel program. A multivariate statistical analysis will be carried out to establish their behavior of the means and medians using the Statgraphics Centurion 5.2, XVI statistical program.

3. Results and Discussion

The transparency showed a behavior by homogeneous monitoring point (P = 0.105659; P < 0.05 KW) (Fig. 1), having an average of 0.44 m which is outside the range established in CE-CCA-001/89 for the Protection of Aquatic Life (> 2.0 m) this due to the amount of organic matter, as well as suspended particles due to discharges from the main rivers that flow into this receiving body. The Bar is a point where the transparency is greater, but this is because the depth is minimal compared to the other points. On the other hand, its temporal behavior is heterogeneous (P = 0.0133985; P < 0.05 KW) (Fig. 2).

Dissolved Oxygen presented an average of 4.71 mg L^{-1} with a maximum concentration of 6.4 mg L^{-1} and a minimum of 2.53 mg L^{-1}, the average of Dissolved

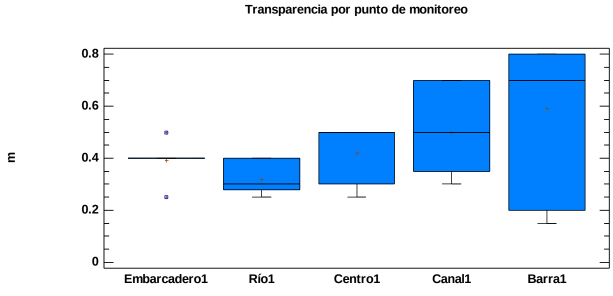

Fig. 1 Diagram of multiple boxes for the transparency of the Coyuca de Benítez Lagoon by monitoring point.

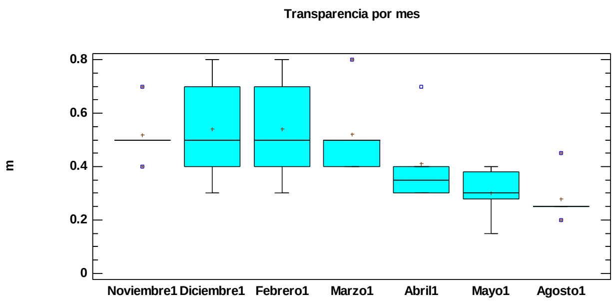

Fig. 2 Diagram of multiple boxes for the transparency of the Laguna de Coyuca de Benítez by time.

Oxygen is below the maximum permissible limits established in CE-CCA-001/89 (5.0 mg L^{-1}) for the protection of aquatic life (fresh water, -water, marine/ coastal areas), The lagoon presents significant differences between monitoring points ($P = 0.00000108181$; $P < 0.05$ KW), both on the surface and on the bottom ($P = 0.000445012$, $P = 0.0000761653$; $P < 0.05$ KW respectively), where the Center and the Channel stand out as the points with the least amount of Dissolved Oxygen, however it exceeds in the points of the Embarcadero, Río and in some cases in La Barra (Figs. 3 and 4).

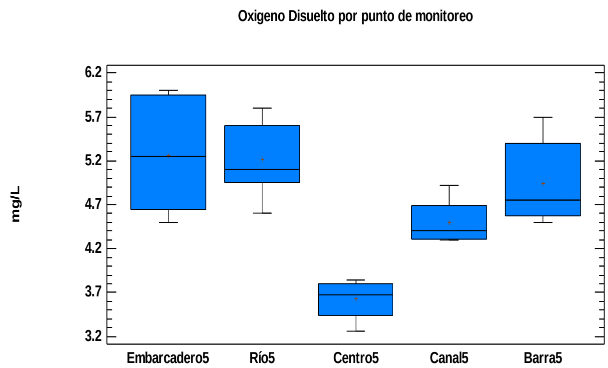

Fig. 3 Diagram of multiple boxes for the Dissolved Oxygen of the Coyuca de Benítez Lagoon per monitoring point.

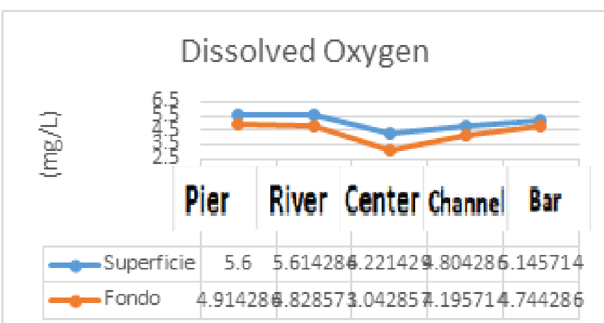

Fig. 4 Linear graph of Dissolved Oxygen behavior by monitoring point.

Carbon dioxide changes the differences between the monitoring points ($P = 0.00000108181$; $P < 0.05$ KW), with an average of 0.508 mg CO_2 L^{-1}, with a maximum level of 1.83 mg CO_2 L^{-1} and with points where it is absent (Fig. 5), it is within the maximum permissible limits established in CE-CCA-001/89 (25 mg CO_2 L^{-1}) for the Protection of Aquatic Life; La Barra station was the one with the highest concentration of CO_2, due to the contribution of organic matter from commercial areas, homes, as well as mangroves, since they can constitute inorganic "carbon deposits" and organic waste, whichever whether they are permanently retained in the sediments and by movement in the system there is sediment removal [6].

The BOD_5 presented an average of 45.43 mg L^{-1} with a maximum concentration of 60.98 mg L^{-1} and a minimum of 28.91 mg L^{-1}, which are within the maximum allowable limits established in NOM-001-SEMARNAT-1996 for use in agricultural irrigation or for recreation (75 mg L^{-1}), however if it is exceeded for the protection of aquatic life (30 mg L^{-1}), the lagoon presents significant differences between the points monitoring ($P = 0.000413736$; $P < 0.05$ KW) with the center and the channel being the points that showed the lowest concentration of BOD_5 (Fig. 6), due to the depth of the sites, since they have a greater dilution capacity than by the depth level, the bottom is not in all cases the biochemical degradation of organic matter is carried out by aerobic biological processes mainly by bacteria (fecal origin) and protozoa, in addition to the concentration of organic matter from discharges contributed by the club activities pogénicas that are made along the lagoon as well as the discharges from the mountains [7].

The NH_4 presented a heterogeneous behavior ($P = 0.0321484$; $P < 0.05$ KW), presenting high values at the point of the River and Barra (Fig. 7), being these points the ones that receive wastewater discharges which contain organic matter, cleaning products, as well as fertilizer infiltration by the growing area. Its average was 0.513 mg L^{-1}, which tells us that the Lagoon contains well-oxygenated waters (< 1 mg / l), however, higher values have been recorded in previous studies, such as De la Lanza, 2004, who recorded an annual measurement of 0.1246 mg L^{-1} of ammonia in the Coyuca de Benítez Lagoon.

Nitrates presented an average of 1.81 mg L^{-1}, which is outside the maximum permissible limits in the Ecological Criteria for Water Quality for the protection of marine aquatic life, which is 0.04 mg L^{-1}; However, this is within the limits for drinking water supply and

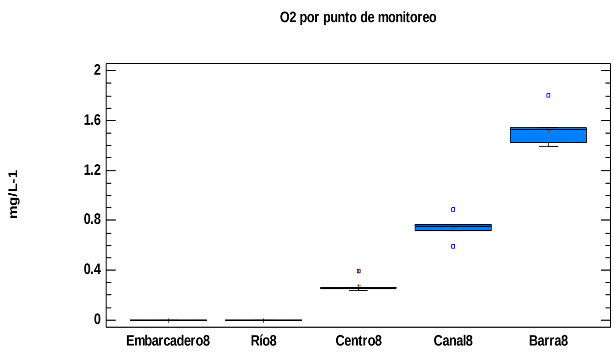

Fig. 5 Diagram of multiple boxes for CO_2 from the Coyuca de Benítez Lagoon by monitoring point.

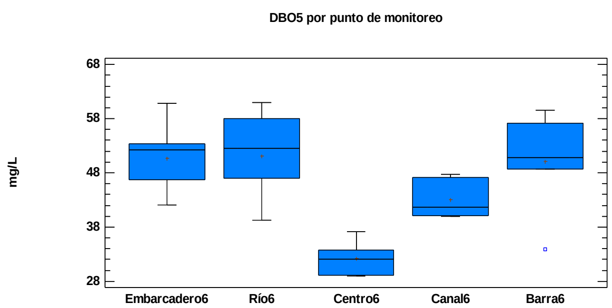

Fig. 6 Diagram of multiple boxes for BOD_5 of the Coyuca de Benítez Lagoon by monitoring point.

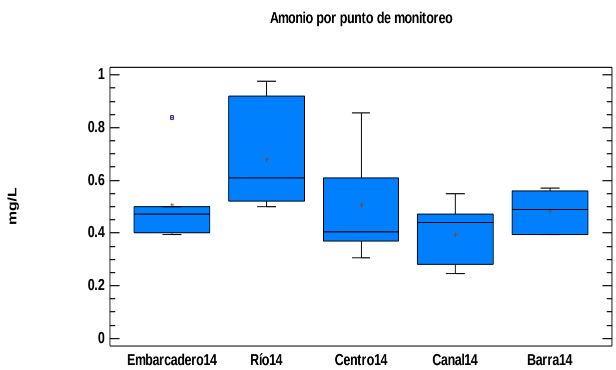

Fig. 7 Multiple box diagram for the conductivity of the Coyuca de Benítez Lagoon by monitoring point.

livestock use (5.0 and 90 mg L^{-1} respectively). Its surface and bottom behavior was homogeneous (P = 0.0628631, 0.0910213; P < 0.05 KW respectively), as well as parallel between the two depth levels (Fig. 8), however it can be seen that the Center point had the highest level low, this due to the depth of this point which has a greater dilution capacity, on the contrary the point of the Embarcadero, Río and la Barra were the points with a higher level.

Nitrites presented an average of 0.059 mg L^{-1}, this value is outside the maximum limits established by the Ecological Water Quality Criteria for the protection of aquatic life (0.002 mg L^{-1}), however it is within the maximum limits for drinking water supply and livestock use (0.05-10 mg L^{-1} respectively). Its behavior by monitoring point on the surface and bottom was homogeneous since it did not present significant differences between the medians (P = 0.60296, 0.0562319; P < 0.05 KW respectively), where again the point of the River and Embarcadero are the points where the levels were recorded higher (Fig. 9), the presence of nitrites is indicative of recent fecal contamination, points where precisely we find the greatest amount of it due to the shops around them, as well as the discharge of the Conchero River which contains a high number of domestic downloads, in the same way the Bar point presents higher levels in the upper quartile than in the other two points, since at this point there is also a large number of domestic downloads.

The average of the phosphates was 1.68 mg L^{-1}, presenting a homogeneous behavior between the monitoring points on the surface and bottom (P = 0.250735, 0.149135; P < 0.05 KW respectively), where comparing the medians, the points are from the Embarcadero, Río and Barra with the highest values (Fig. 10), which receive the contributions of organic and inorganic compounds from the Meander channel, from human activities that take place in the upper part of the municipality of Coyuca de Benítez and Surrounding communities, producing the enrichment

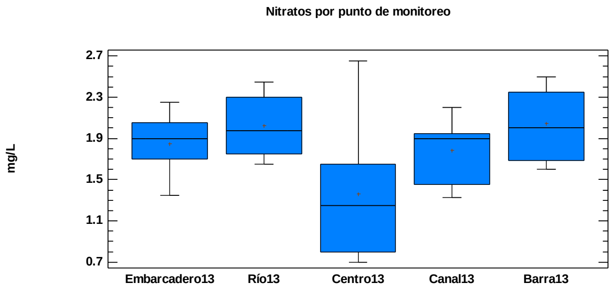

Fig. 8 Diagram of multiple boxes for Nitrates from the Coyuca de Benítez Lagoon by monitoring point.

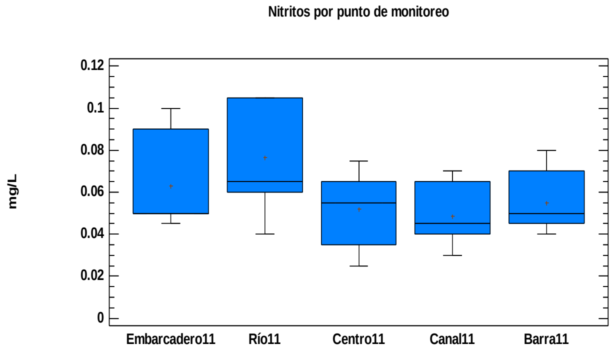

Fig. 9 Diagram of multiple boxes for Nitrites from the Coyuca de Benítez Lagoon by monitoring point.

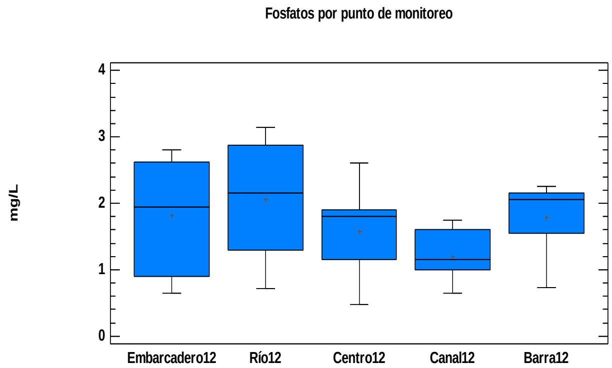

Fig. 10 Diagram of multiple boxes for Phosphates of the Coyuca de Benítez Lagoon by monitoring point.

of the waters, whose origin is largely due to urban runoff, poor agricultural and livestock activities, among others.

The registered values exceed the maximum allowable for the Ecological Criteria of Water Quality for the Protection of Aquatic Life in marine or coastal waters and freshwater (0.002 and 0.25 mg L^{-1} respectively).

Chlorophyll presented an average concentration of 19.61 µg/L, with a heterogeneous behavior on the surface and on the bottom ($P = 0.0000038259$, 0.00000423187; $P < 0.05$ KW respectively) with a significantly high level at the points of Embarcadero, Río, Centro and Barra (Fig. 11), points at which the values are directly influenced by human activities, mixing periods, depth, temperature, incidence of light and stratification in the distribution of phytoplankton. The tourist activities are found in greater quantity in the points of the Embarcadero, Río and la Barra, activities that directly affect the parameters such as: Temperature, transparency, dissolved oxygen, pH, TDS, BOD_5 as well as the nutrients which are directly related to the proliferation of phytoplankton, making them increase or decrease significantly according to the period (vacation, or low season) in which the Lagoon is found; The discharge of wastewater of domestic origin as well as inorganic matter from these activities alter the concentration of suspended particles, affecting the incidence of light, reducing the euphotic zone, thus altering photosynthetic activity, however, in turn, these discharges favor the distribution of nutrients necessary for the metabolism of phytoplankton.

There was a clear difference between the surface and the bottom of the lagoon (Figs. 12 and 13), presenting a higher concentration of chlorophyll on the surface than at the bottom, this due to the amount of light that falls on the body of water, Although chlorophyll a concentrations could be found at the monitoring point "Centro", this due to the currents present in the lagoon, which cause the mixing of the water column thus dragging certain amounts of phytoplankton, without However, this point was the one with the lowest concentration due to the low incidence of light as well as the lack of nutrients compared to the other monitoring points.

Chlorophyll a is equally useful to establish the Laguna trophic index, it was calculated following the proposal by Carlson (1977) [8], in which based on the concentration of chlorophyll a, it is converted to a decimal numerical scale, which is compared in the scale of the trophic state values in the bodies of water

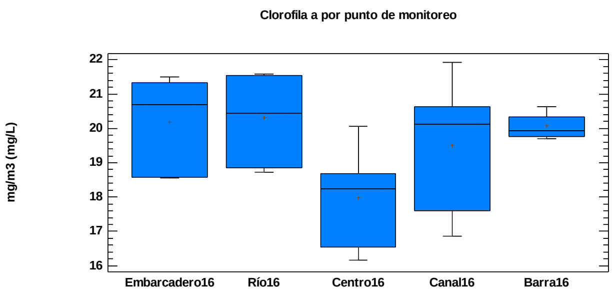

Fig. 11 Multiple box diagram for Chlorophyll of the Coyuca de Benítez Lagoon by monitoring point.

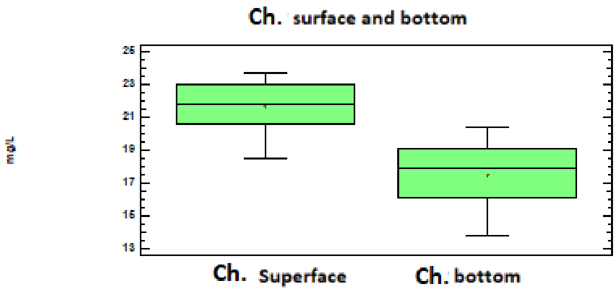

Fig. 12 Multiple box diagram for Chlorophyll of the Coyuca de Benítez Lagoon. Surface and Bottom.

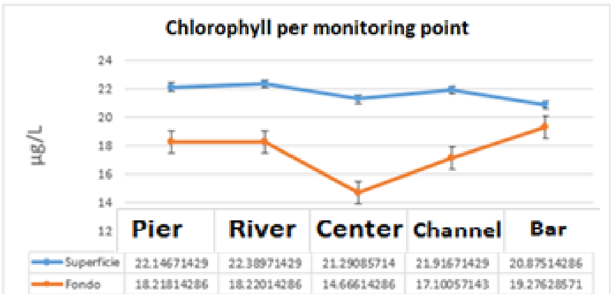

Fig. 13 Linear behavior graph for Chlorophyll of the Coyuca de Benítez Lagoon by monitoring point.

(Table 1), making the corresponding equation the maximum values obtained from the Trophic State Index (IET or TSI) for the Coyuca de Benítez Lagoon were 60.49 and the minimum 58.93, these values were relatively constant both by monitoring point and by time with an average of 59.77, which in comparison with the table of values of the trophic state, it is determined that the Lagoon presents a Mesotrophic degree with a very clear tendency towards Eutrophy, being within the limits of TSI in the mesotrophic state, which can lead to an alteration of biota as well as biological biodiversity, causing a proliferation of algae, cyanobacteria and too much macrophytes causing the increase of turbidity of the water directly affecting the

Table 1 Scale of values of the trophic state in bodies of water Modified from Carlson (1997; 1980).

Eutrophic state	TSI	Chlor a (mg/m^3)
Oligotrophic (TSI < 30)	0	0.04
	10	0.12
	20	0.34
	30	0.94
Mesotrophic (30 < TSI < 60)	40	2.6
	50	6.4
	60	20
Eutrophic (60 < TSI < 90)	70	56
	80	154
	90	427
Hyperotrophic (90 < TSI < 100)	100	1183

submerged aquatic vegetation is affected losing food, habitats and dissolved oxygen.

The calculated net productivity had an average of 35,993 mg C m^3, presenting a homogeneous behavior in surface and bottom throughout the Lagoon (P = 0.132445, 0.214126; P < 0.05 KW respectively) (Fig. 14), where the River, Embarcadero and La Barra show a high value compared to the point of the Center and the Canal, points where the discharges are greater (Fig. 15) with La Barra and the River being the main contribution points for the Lagoon, from which a large number come of organic and inorganic matter from nearby and high communities of localities such as: Aserraderos de Salinas, Bajos del Ejido, Brasilia, El Bordonal, El Conchero, El Embarcadero, El Ranchito, Kilometro 17, El Baradero, La Gloria, Luces en el mar, Macahuite y San Nicolás de las Playas, in addition to being points of great impact as most anthropogenic activities are carried out around them, ranging from tourism, recreation, fishing, livestock and agriculture. Productivity at the center point was lower, because at that point the depth is greater compared to the other points, having a greater dilution capacity for organic matter in addition to the significant difference in the incidence of light in the background. The highest level of NP registered was 62.5 mg C m^3 (Embarcadero and River on the Surface) and the lowest was 4.68 mg C m^3 (Center in Background). With a marked difference, the

PN was greater on the surface than on the bottom (Fig. 16), again due to the amount of incident light in the deepest part of each point, both due to the depth levels and the amount of particulate matter throughout of the water column.

3.1 Principal Component Analysis (PCA)

The Principal Component Analysis was used to determine which were the parameters that most influenced the behavior of the system, 16 variables were used, obtaining 4 main components, of which component one obtained Percentage of Variance: 29,808%, component two 28,135%, the three 9,204 & and the four 7,225%, with a 74,371% accumulated

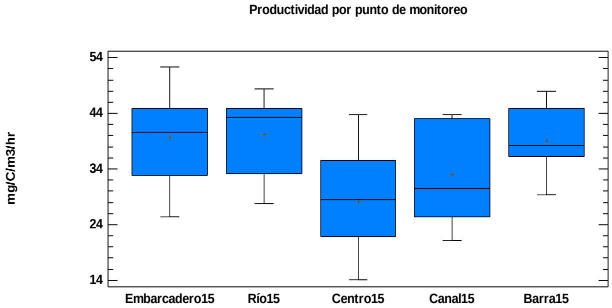

Fig. 14 Diagram of multiple boxes for the PN of the Coyuca de Benítez Lagoon by monitoring point.

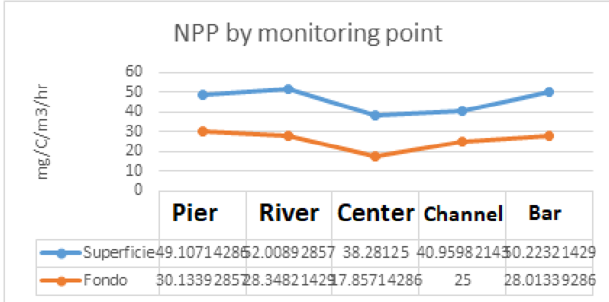

Fig. 15 Linear behavior graph for the Coyuca de Benítez Lagoon NP by monitoring point.

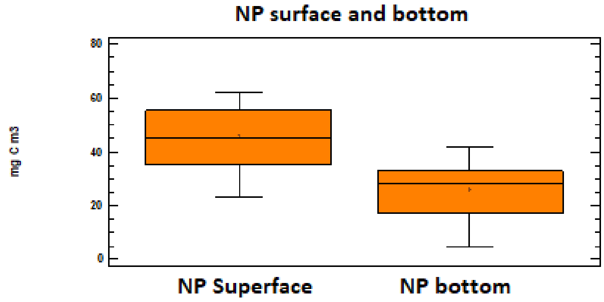

Fig. 16 Diagram of multiple boxes for the NP of the Coyuca de Benítez Lagoon. Surface and Bottom.

percentage, as observed in Table 2. The analysis indicates that with these components, the behavior of more than half of the variables can be explained evaluated.

Table 2 Component weight table.

	Component	Component	Component	Component
	1	2	3	4
Temperature	0.167755	0.135233	0.361357	0.44262
Transparency	-0.236582	-0.176887	-0.170996	0.372705
Depth	-0.193707	0.343497	0.150711	-0.0465458
pH	0.245208	0.328967	-0.234809	-0.0762969
DO	0.338723	-0.216263	0.056799	-0.0189788
BOD_5	0.327065	-0.268547	-0.00328301	-0.0905455
CDO	0.37376	-0.0464061	-0.0510063	-0.0878614
CO_2	-0.234907	-0.370447	0.198168	0.0852356
Conductivity	0.184937	0.397782	-0.140057	-0.0309746
TDS	0.162074	0.402942	-0.163318	0.064111
Nitrites	0.331926	0.0101935	0.410072	0.159493
Phosphates	0.2232	-0.0538479	0.324107	-0.454193
Nitrates	0.175385	-0.259582	-0.28714	0.0846244
Ammonium	0.183685	0.0801945	0.00866956	0.618903
Chlorophyll	0.296209	-0.18805	0.0696285	0.0674244
Productivty	0.170156	-0.182123	-0.557098	0.0458265

For the determination of the most relevant variables, the table of weights of main components is taken into account (Table 2), in which the variables and contribution loads by which component one is represented are COD (0.37376), OD (0.338723), Nitrites (0.331926), BOD_5 (0.327065); which indicate that there is a high level of productivity, in relation to the amount of organic matter rich in nutrients and from which a high amount of dissolved oxygen is produced due to the significant requirement of oxygen used for the degradation of organic matter. In component two the main variables are TDS (0.402942); which has direct influence with transparency, conductivity (0.397782), as well as the distribution of heat (Temperature), CO_2 (-0.370447), Depth (0.343497) on which the distribution and availability of nutrients and dissolved gases, mainly oxygen, depends. Refuted in components three and four, where the most relevant variables are nutrients and physical parameters, which have the greatest influence and correlation on Primary Production in the system by favoring or not the proliferation of phytoplanktonic organisms.

3.2 Cluster Analysis

For this analysis, 16 variables were used: physical, chemical and biological parameters, which include Chlorophyll and Primary Productivity. All evaluated at the five monitoring points along the lagoon, with the values of these parameters clusters were formed between the sampling sites, this from the greatest number of similarities between the behavior of the parameters.

The relationship between them is shown in Fig. 17, which establishes which monitored sites have similar behavior, giving them a relationship value which, being closest to zero, means more variables with similar behavior. The first conglomerate is formed by: Center and Canal, since their distance that marks their relationship is less than five, which indicates that these sites have the most similar behavior, this because both sites are located in the central area of the Laguna and

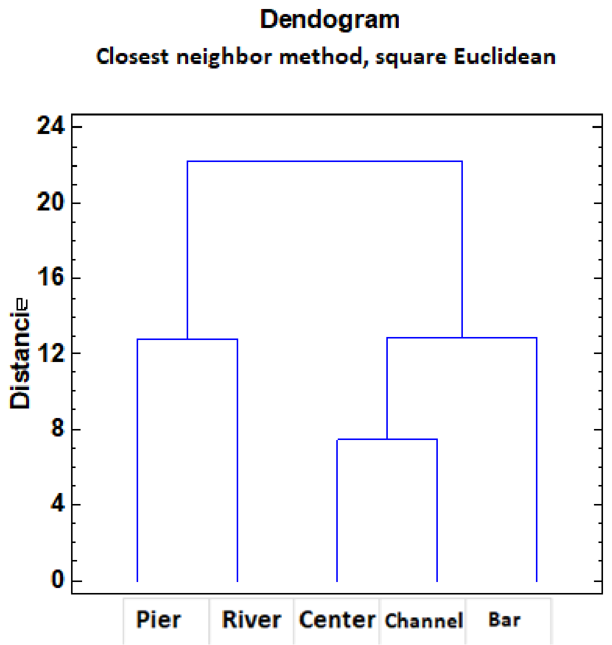

Fig. 17 Cluster analysis.

have a greater depth compared to the others, in addition to receiving almost the same number of discharges as the other points that have a greater impact. Followed by this, the second conglomerate is formed by the previous one but also includes the point of the bar, this due to the fact that the number of downloads received comes mostly from said point, thus relating it to the central part that derives from the meandering channel. The third conglomerate is formed by the pier and the River, points that present a greater relationship in most parameters due to their proximity to the perimeter of the Lagoon, presenting a lesser relationship with its central behavior, these points being the that present a greater quantity of discharges of organic and inorganic matter due to anthropogenic activities, accompanied by the Barra point, making them the most affected and in turn the most contaminated.

4. Conclusions

The Coyuca de Benítez Lagoon is an oligohaline system, stratified at the Embarcadero, Río and Centro points, presenting a slight alkalinity with a tendency to be slightly acidic at points near the Barra where the Lagoon comes into contact with the sea.

The physical and chemical variables are outside the maximum permissible limits established according to the Ecological Criteria for Water Quality (CE-CCA-001/89): Transparency, STD, Nitrates, Nitrites and Phosphates.

The behavior of the physical and chemical parameters of the system on a temporary average is relatively similar, however, it varies significantly in some months, due to the seasons that lead to meteorological phenomena that directly alter the behavior of the body of water.

A high organic load was found in the lagoon, which significantly increases the availability of nutrients: ammonium, nitrites, nitrates and phosphates, which are the basis of the high plankton proliferation.

Anthropogenic activities are the main sources of organic matter, since the points at which nutrients, as well as some physical and chemical parameters, are higher at points where they develop on a larger scale, the points are: Embarcadero, Rio and Barra.

In the evaluation of nutrients, comparing nitrites and nitrates in the table established by Esteves (1998), the lagoon is determined as "mesotrophic".

The system has not significantly changed its nutritional behavior, however, increasing the concentration of organic matter may accelerate its eutrophication process.

The concentration of Chlorophyll a is at a high level at points of greatest contribution of organic matter, which have a high concentration of nutrients, favoring its proliferation; these points have significant anthropogenic activity.

The chlorophyll a concentration determines the Coyuca de Benítez Lagoon as "mesotrophic" when compared in the Table of trophic state proposed by Carlson (1997) [8].

Primary Productivity, as well as the concentration of Chlorophyll a, is higher at points of higher contribution of organic matter, which present a high concentration of nutrients, affected by anthropogenic activity.

The Primary Productivity determines the Coyuca de Benítez Lagoon as "mesotrophic" when compared in the Table of trophic state proposed by Boulion and Hakanson (2003).

Taking into account the above, the Coyuca de Benítez Lagoon is established as "mesotrophic" with a slight tendency to "eutrophy" due to the fact that in the parameters evaluated, despite not exceeding the levels of this trophic degree, all are found at the limit, which may exceed it with the continuous organic contribution due to the increasing anthropogenic activity.

References

[1] F. Contreras, L. Castañeda and N. García, La clorofila a como base para un índice trófico en las Lagunas Costeras Mexicanas, Análisis del instituto del mar y limnología, UNAM, 1993.

[2] R. R. Lankford, Coastal lagoons of Mexico: their origin and classification, in: M. Wiley (Ed.), *Estuarine Processes*, Vol. II, Academic Press, New York, N.Y., 1976, pp. 182-215.

[3] R. M. Torres, Evaluación de la contaminación por detergentes en el río Coyuca de Benítez, Edo de Guerrero. Tesis de Ing. Química Industrial, Esc. Sup. De Ing. Química e Industrias Extractivas, IPN, 1980.

[4] A. Yáñez-Arancibia, Patrones ecológicos y variaciones cíclicas de la estructura trófica de las comunidades nectónicas en las lagunas costeras del Pacífico mexicano, *Anales del Centro de Ciencias del Mar y Limnología* 5 (1978), UNAM, México.

[5] S. C. Álvarez and A. Torres, Composición y abundancia del zooplancton de la Laguna de Coyuca, Guerrero, México, *Hidrobiología* 23 (2013) (2) 241-249.

[6] M. Mendoza, A. Martínez, M. Espinoza, O. Peralta and T. Castro, Caracterización de dos Lagunas Costeras del Pacífico Tropical Mexicano en la relación con el contenido de carbono y la captura y emisión de CH y CO_2, *Revista de Comunicación Ambiental* 29 (2013) (2) 145-154.

[7] G. R. Aguirre, Caracterización óptica de la laguna costera de Coyuca de Benítez, *Investigaciones Geográficas: Boletín del Instituto de Geografía* 46 (2001) 78- 97.

[8] R. E. Carlson, A trophic state index for lakes, *Limnol. Oceanogr* 22 (1977) 361-369.