Digital Journal of
El Hombre y su Ambiente Department
ISSN: 2007-5782

Vol. 2 (9): 20 - 30. July to December 2015.

# Primary production as indicator of water eutrophication in Xochimilco Lake channels (Mexico).

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## ABSTRACT

Eutrophication of an aquatic ecosystem is due to an increase in nitrogen and phosphorus load, producing an increase in primary biomass and a decrease in physical, chemical and biological system quality. Currently, one of the main problems in Xochimilco Lake is the poor water quality that feeds channels, runoff from surrounding agricultural area and water supply coming from domestic wastewater. In this study, the variation of primary production in different zones of channels in chinampera areas, aiming to use this parameter as indicatory of eutrophication grade. The highest concentrations of gross (GPP) and net (NPP) primary production were found in untreated water mouth coming from "Cerro de la Estrella" (134.20 $mgC.m^{-3}.h^{-1}$) and Cuemanco pier (1,124.38 $mgC\ m^{-3}\ h^{-1}$). In surface water it was obtained the highest values of R. Highest concentration chlorophyll *a, b, c1 and c2* were found in La Virgen lagoon. Physical-chemical parameters that had more influence in GPP and NPP were $N\text{-}NO_3^-$, and $P\text{-}PO_4^{2-}$. Obtained results allow to confirm that primary production and chlorophyll-a concentration are good indicators of eutrophication grade in this water body and channels in chinampera zone of Xochimilco who are in a homogeneous mesotrophic state.

**Key words**: Chemical characterization, chlorophyll, water column, trophic state

## RESUMEN

La eutrofización de un ecosistema acuático es producto del incremento en la carga de nitrógeno y fósforo, dando como consecuencia un aumento en la biomasa primaria y una disminución en la calidad física, química y biológica del sistema. En la actualidad, uno de los problemas centrales del lago de Xochimilco es la deficiente calidad del agua que alimenta los canales, las escorrentías de la zona agropecuaria aledaña y el aporte de agua proveniente de las descargas residuales domésticas. En el presente estudio se midió la variación de la producción primaria en diferentes zonas de los canales de la zona chinampera con el objetivo de utilizar este parámetro como indicador del grado de eutrofización. Las mayores concentraciones de producción primaria bruta (PPB) y neta (PPN) se encontraron en la desembocadura de las aguas semi tratadas provenientes del Cerro de la Estrella (134.20 $mgC.m^{-3}.h^{-1}$) y en el embarcadero de Cuemanco (1124.38 $mgC.m^{-3}.h^{-1}$). En el agua de superficie se obtuvieron los valores más altos de respiración. Las mayores concentraciones de clorofila *a, b, c1* y *c2* se presentaron en la Laguna de la Virgen. Los parámetros físico-químicos que tuvieron mayor influencia sobre PPB y PPN fueron el $N\text{-}NO_3^-$, el $P\text{-}PO_4^{2-}$ y la turbidez, mientras que la respiración se vio afectada por $P\text{-}PO_4^{2-}$. Los resultados obtenidos permiten afirmar que la producción primaria y la concentración de clorofila-a son buenos indicadores del grado de eutrofización en este cuerpo de agua y que los canales de la zona chinampera de Xochimilco se encuentran en estado mesotrófico homogéneo.

**Palabras clave:** Caracterización química, clorofilas, columna de agua, estado trófico.



Receive: September 30nd 2015 Accepted: November 15th 2015 Published: December 15th 2015

Digital Journal of
El Hombre y su Ambiente Department
ISSN: 2007-5782

Vol. 2 (9): 20 - 30. July to December 2015.

## INTRODUCTION

Primary producers are the main base of trophic networks (Roldan *et al.*, 2008), in water column this function is made by planktonic algae. Photoautrophic capacity is evaluated in many ways, but its direct estimation is obtained with primary production measurement. This is a reflection of photosynthetic process, so its measurement allows to have a clear idea in the phytoplankton community capacity to assimilate inorganic carbon and convert it in organic carbon (Pinilla 2009). Vertical distribution of phytoplankton productivity is mainly determined by luminous radiation intensity, nutrients availability, water clarity and water mixture (Esteves 1998).

In contaminated water bodies by nitrogen and phosphorus downloads, algal blooms increase and therefore planktonic primary production and turbidity of water column increase too; as a consequence of this, submerged vegetation disappears because photosynthetic process of planktonic algae in the surface does not supply oxygen into dipper zones in water column, except in spring an autumn when thermic stratification brakes in temperate zone lakes. When phytoplankton dies it reaches the bottom in form of detritus, causing organic matter rise as hypoxia, due to increased demand of dissolved oxygen (DO) that is consumed in breathing phase and organic matter oxidation by heterotrophic bacteria, limiting life of other organisms (Moreno et al. 2010).

Eutrophication of an aquatic ecosystem is due to an increase in nitrogen and phosphorus load, mainly in its affluent, causing an increase in primary biomass and a decrease in physical, chemical and biological quality system (Romero 2009). Massive algae and macrophytes proliferation can produce problems in use of this resources due to alteration in their organoleptic properties (smell and taste), ammonia accumulation in water column and resuspension in certain heavy metals as Fe and Mn that are found in sediment under anoxic conditions. Although eutrophication is a process that in a slow way can have a natural origin, today it is fundamentally of cultural nature and accelerated by continuous input of anthropogenic nutrients (Salas and Martino 2001).

Today one of the main problems of Xochimilco Lake, is the poor water quality that feeds channels of chinampera zone and part of common agricultural area. The main source of contamination, is input of semi purified water coming from domestic wastewater and some productive activities as livestock backyard and use of chemical fertilizers in agriculture (Alva-Martínez et al. 2005).

López et al. (2010) mentions that high grade of eutrophication in the zone is due to waters that feed Xochimilco Lake, are over enriched with nutrients as nitrogen, phosphorus and carbon that help algae growth. That is why, in this study it was measured primary production variance in different zones of Xochimilco Lake with the aim of using this parameter as existent eutrophication grade indicatory.

## MATERIAL AND METHODS

### *Sampling zone*

Xochimilco is located in Mexico City southeast between latitudes 19° 09’01” and 19°19’08”. It has a surface of 509 square kilometers (335 hectares), where 25 ha are chinampas and 140 kilometers of channels. Main currents that go through this zone are San Gregorio Atlapulco, San Lucas Xochimanca, Santiago Tepalcatlalpan and San Buenaventura, which most of them arise in Sierra Chichinautzin and discharge in Xochimilco channels (CONAGUA 2010). The weather is considered as templated, sub humid and rainy semi cold. (INEGI 2008).

This work was made in May 2013. Six sampling spots in the channel were chose: Cerro de la Estrella (station 1) located at 34°00´00´´ N, 68°54´22´´ W; Cuemanco pier (station 2), 34°00´00´´ N, 68°54´22.5´´ W; Tlilac lagoon (station 3), 19°31´22´´ N, 96°55´39.9´´ W; La



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ISSN: 2007-5782

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Virgen lagoon (station 4), 19.4°20´21.3´´ N 95°55.4´28.9´´ W; in front of the facilities of Centro de Investigaciones Biológicas y Acuicolas de Cuemanco (CIBAC) (station 5), 9°22´034´´ N 53°04´30.1´´ W and in front of Navy facilities (station 6), 19°28´029´´ N 53°07´21´´ W (Fig.1).

*Field work*

In each sampling station it was measured water temperature in surface and bottom using a bucket thermometer, salinity with a refractometer (Atago ATC-S/Mill-E), pH with a field potentiometer (Conductronic model pH10), profundity and turbidity with a Secchi disc (20 cm of diameter), dissolved oxygen concentration with the Winkler method (Barreiro and Signoret 1999), conductivity and OR using a multiparameter YSI 50.

Analysis of inorganic nutrient concentration (P-$PO_4^{2-}$, N-$NH_4^+$, N-$NO_2^-$, N-$NO_3^-$) was made from water samples (surface and bottom) of each sampling station, took with a Van Dorn bottle of one litter, for each determination 100 mL of water sample were filtrated through a Whatman GF/F membrane and a Millipore filtration system. Filtrated samples were stored in amber bottles of 125 mL at -20°C until their processing. For total phosphorus (TP) determination and total organic carbon (TOC), water samples were not filtrated.

Gross primary production (GPP) and net (NPP), were calculated with oxygen evaluation method in clear dark bottles incubated *in situ* during eight hours, in surface and bottom water.

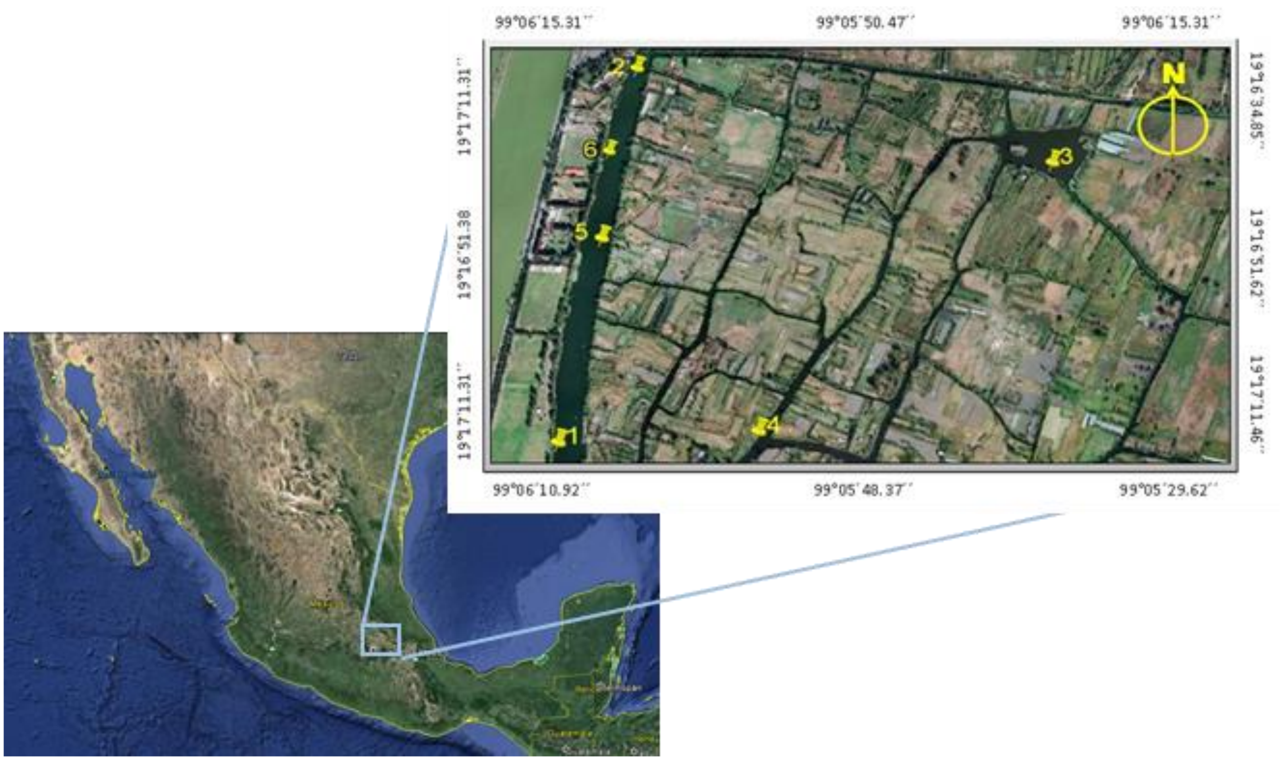


Figure 1. Map of study area, with stations.



Receive: September 30nd 2015 Accepted: November 15th 2015 Published: December 15th 2015

GPP, NPP and breathing (R) as carbon incorporation were calculated (Barreiro and Signoret 1999).

For the phytoplankton photosynthetic pigments determination, 300 mL of water were filtered through Whatman GF/F membranes by station and stratum, filters were maintained dry until their laboratory process. For photosynthetic pigment determination it was used the spectrophotometric method by Barreiro and Signoret (1999), which is based in equations proposed by Jeffrey and Humphrey (1975). For algae biomass estimation the obtained results of chlorophyll-a concentration (extracted with ethanol at 90%) were multiplied by 50 according to Montoya and Aguirre (2010).

Ammonia, nitrites, nitrates, orthophosphates, TP and TOC was made by spectrophotometric methods using specific kits of HACH® brand for continental waters. The N-$NH_4^+$ by salicita method 10031, HR (0.4 to 50.0 mg $L^{-1}$ $NH_3$-N); the N-$NO_2^-$ by ferrous sulfate method 863, HR (2 to 250 mg $L^{-1}$ $NO_2^-$); the N-$NO_3^-$ by cadmium reduction method 8039 HR (0.3 to 30 mg $L^{-1}$ $NO_3^-$- N); the P-$PO_4^{-2}$ by molybdovanadate method 8114 HR (0.3 to 45 mg $L^{-1}$ $PO_4^3$); and TOC by direct method 10173 MR (15 to 150 mg $L^{-1}$ C).

A correspondence multivariate analysis was made to evaluate the relation between PP and physical-chemical variables, also GPP, NPP, R and chlorophyll-a production in surface and bottom by a box and whisker diagram, using Statistica ® program (Statsoft, 1999) (Pielou, 1984).

## RESULTS

The average depth of the channels in the chinampas zone of Xochimilco lake, was of 90± 52.2 cm except station 1 that was 220 cm; in this station with Secchi disc, it was registered a clearness of 75 cm, different to other stations where it was around 45 cm and 30 cm. Average temperature in water column was of 22.3°C ± 1.03. Average pH was of 7.36 ± 1.28, the highest value was of 9.99 (in surface water) and lowest value was of 6.0 (in bottom water) in station 3. Average salinity was of 0.33± 0.025 UPS, conductivity was 0.70± 0.4 mS $m^{-1}$ and in general redox was electropositive (Table 1).

Highest concentration GPP were obtained in surface water, being twice as much as NPP in the mouth of semi treated waters in Cerro de la Estrella (134.20 mgC $m^{-3}$ $h^{-1}$) and Cuemanco pier (1124.38 mgC $m^{-3}$ $h^{-1}$), and this conduct is reverse in other stations. NPP values of bottom water in stations 4, 5 and 6 were higher than in surface waters and in stations 1, 2 and 3 the behavior was reversed (Table 2). Regarding to phytoplankton assembly, it was not observed a clear behavior pattern but in general, highest values were found in incubated bottles with surface water samples.

Photosynthetic pigments analysis showed that values of active chlorophyll-*a* and *b* were lower as it was expected in this type of ecosystems. Highest values of chlorophyll-*a*, were found in station 4 (La Virgen lagoon) in both strata (21.9 mg $m^3$ in surface and 23.7 mg $m^3$ in bottom) and lowest values in station 1 (Cerro de la Estrella) and 2 (Cuemanco pier), in surface (1.8 mg $m^3$ and 3.1 mg $m^3$ respectively) and bottom (1.0 mg.$m^{-3}$ and 1.3 mg $m^{-3}$ respectively) (Table 3). Highest values of chlorophyll-b were presented in surface water of Cuemanco pier (1.1 mg $m^3$), in Tlilac lagoon (1.1 mg $m^3$), and La Virgen lagoon (1.5 mg $m^3$).

Lowest concentrations of chlorophyll *c1* was found in station 4 located in La Virgen lagoon in the surface (2.1 mg $m^3$) and bottom (2.4 mg $m^3$) and in surface water of station 2 Cuemanco pier (1.2 mg $m^3$).



Receive: September 30nd 2015 Accepted: November 15th 2015 Published: December 15th 2015

Digital Journal of
El Hombre y su Ambiente Department
ISSN: 2007-5782

Vol. 2 (9): 20 - 30. July to December 2015.

**Table 1. Environmental variables of the study sites. 1) Cerro de la Estrella, 2) Cuemanco´s pier, 3) Tlilac lagoon, 4) La Virgen lagoon, 5) Front to CIBAC, 6) Front navy installations. S) Surface, B) Bottom.**

| Station | Geographic location | Environmental temperature | Depth cm | Transparency cm |
|---|---|---|---|---|
| 1 | N. 34°00´00´´<br>E. 68° 54´22´´ | 22° | 220 | 75 |
| 2 | N. 34°00´00´´<br>E. 68°54´22.5´´ | 23 | 80 | 45 |
| 3 | N. 18°31´2´´<br>E. 0.96°55´33.9´´ | 20 | 80 | 32.5 |
| 4 | N. 19.4°0´21.3´<br>O.0.95°55.4´28.9´´ | 24 | 100 | 35 |
| 5 | N. 19° 22´0.34´´<br>O. 53° 0.4´30.1´´ | 21.5 | 100 | 30 |
| 6 | **N** 19° 28´0.29´´<br>O 53° 07´21´´ | 22 | 80 | 35 |

| Station | Stratum | Temperature °C | pH | Salinity SPU | Conductivity mS $cm^{-1}$ | Eh mV |
|---|---|---|---|---|---|---|
| 1 | **S** | 21.2° | 7.02 | 0.31 | 0.645 | 646.7 |
| | **B** | 21.25° | 6.97 | 0.32 | 0.649 | -51 |
| 2 | **S** | 22.11 | 7.99 | 0.33 | 0.671 | 571 |
| | **B** | 21.32 | 7.38 | 0.33 | 0.684 | 639 |
| 3 | **S** | 21.1 | 9.99 | 0.37 | 0.7599 | 14.5 |
| | **B** | 20.92 | 8.4 | 0.36 | 0.739 | -188.5 |
| 4 | **S** | 23.55 | 8.47 | 0.34 | 0.703 | 313 |
| | **B** | 21.75 | 7.23 | 0.34 | 0.707 | 372 |
| 5 | **S** | 23.01 | 7.7 | 0.33 | 0.745 | 285 |
| | **B** | 22.45 | 5.97 | 0.33 | 0.728 | 296 |
| 6 | **S** | 23.77 | 5.64 | 0.31 | 0.677 | 31.4 |
| | **B** | 23.17 | 5.63 | 0.27 | 0.678 | 27.4 |

Multivaried analysis of correspondence (r=≤7) of physicochemical parameters and of GPP, NPP and R for surface and bottom water, showed that parameters that have a higher influence on GPP and NPP were turbidity and N-$NO_3^-$ and P-$PO_4^{2-}$, concentration in both stratums (Table 4), and in a lower grade but not less important, TP, TOC and temperature. Breathing showed a high correlation with P-$PO_4^{2-}$ (r=0.98), and in a lower grade with TOC (r=0.72) and Eh (r=0.71), in bottom water (Table 5).

It was observed differences between GPP, NPP and R between surface and bottom water, sometimes higher than 100%. Only in



Receive: September 30nd 2015 Accepted: November 15th 2015 Published: December 15th 2015

Digital Journal of
El Hombre y su Ambiente Department
ISSN: 2007-5782

Vol. 2 (9): 20 - 30. July to December 2015.

**Table 2. Variety of the primary gross production (Gp), net production (Np) and of the respiration (R), in the different stations and biotypes of study: surface water (s) and bottom water (b): Expressed in mgC m$^{-3}$ h$^{-1}$.**

| Station number | Station name | Stratum | GPP | NPP | R | Primary biomass (mgCl-a.m$^{-3}$) |
|---|---|---|---|---|---|---|
| 1 | Cerro de la Estrella | S | 134.20 | 60.68 | 88.21 | 90 |
| | | B | 90.05 | 57.14 | 39.49 | 50 |
| 2 | Cuemanco Pier | S | 124.38 | 73.78 | 60.72 | 155 |
| | | B | 95.54 | 35.03 | 72.61 | 65 |
| 3 | Tlilac lagoon | S | 239.74 | 199.04 | 48.83 | 500 |
| | | B | 172.50 | 176.04 | 4.24 | 295 |
| 4 | La Virgen lagoon | S | 126.50 | 130.04 | 4.24 | 1095 |
| | | B | 171.62 | 152.16 | 23.35 | 1185 |
| 5 | Front CIBAC | S | 168.08 | 196.39 | 33.97 | 215 |
| | | B | 220.27 | 206.12 | 16.98 | 360 |
| 6 | Front navy installations | S | 68.11 | 62.81 | 6.36 | 200 |
| | | B | 127.39 | 106.15 | 25.47 | 355 |

**Table 3. Variation in the concentration of chlorophyll a, b, c1 expressed in g m$^3$ for each sample station: surface (S) and bottom (B) water.**

| Station number | Station name | Biotope | Chlorophyll-*a* | Chlorophyll-*b* | Chlorophyll-*c1* |
|---|---|---|---|---|---|
| 1 | Cerro de la Estrella | S | 1.8 | 0.6 | 0.9 |
| | | B | 1.0 | 0.2 | 0.3 |
| 2 | Embarcadero Cuemanco | S | 3.1 | 1.1 | 1.2 |
| | | B | 1.3 | 0.9 | 0.1 |
| 3 | Laguna Tlilac | S | 10.0 | 1.1 | 1.0 |
| | | B | 5.9 | 0.9 | 0.6 |
| 4 | Laguna La Virgen | S | 21.9 | 1.5 | 2.1 |
| | | B | 23.7 | 1.7 | 2.4 |
| 5 | Frente al CIBAC | S | 4.3 | 0.6 | 0.5 |
| | | B | 7.2 | 0.7 | 0.6 |
| 6 | Frente a las instalaciones de la Marina | S | 4.0 | 0.4 | 0.3 |
| | | B | 7.1 | 0.7 | 0.5 |



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**Table 4. Variation of nutrients in the different sampling stations and studied biotopes: surface water (S) and bottom water (B); total phosphorus (TP), total organic carbon (TOC).**

| Station number | Station name | Biotope | $N\text{-}NO_3^-$ (mg $L^{-1}$) | $N\text{-}NO_2^-$ (mg $L^{-1}$) | $N\text{-}NH_4^+$ (mg $L^{-1}$) | $P\text{-}PO_4^{2-}$ (mg $L^{-1}$) | PT (mg $L^{-1}$) | COT (mg $L^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| **1** | Cerro de la Estrella | S | 7.4 | 0.33 | 0.44 | 9.1 | 8.8 | 214 |
| | | F | 6 | 0.37 | 0.62 | 8.2 | 8.7 | 256 |
| **2** | Cuemanco Pier | S | 3.2 | 0.7 | 0.97 | 8.1 | 3 | 63 |
| | | F | 3.6 | 0.21 | 0.92 | 8.7 | 10.4 | 213 |
| **3** | Tlilac lagoon | S | 1.4 | 2.12 | 0.42 | 5.2 | 14.8 | 26 |
| | | F | 1.1 | 1.4 | 0.43 | 6.4 | 20.6 | 19 |
| **4** | La Virgen lagoon | S | 1.6 | 0.9 | 0.65 | 7 | 34 | 32 |
| | | F | 1.8 | 0.6 | 0.57 | 8.1 | 33 | 26 |
| **5** | Front CIBAC | S | 2.2 | 0.74 | 0.42 | 9.8 | 5.2 | 22 |
| | | F | 2.5 | 0.88 | 0.5 | 10 | 5.3 | 7 |
| **6** | Front navy installations | S | 1.6 | 0.83 | 0.3 | 8.2 | 5.4 | 18 |
| | | F | 1.5 | 0.72 | 0.37 | 7.7 | 5.9 | 23 |

**Table 5. Canonical correlation of physic-chemical parameters obtained during sampling vs gross production, net production and respiration to surface (S) and bottom (B) water.**

| | Gross production | | Net production | | Respiration | |
|---|---|---|---|---|---|---|
| | **S** | **B** | **S** | **B** | **S** | **B** |
| $N\text{-}NO_3$ **(mg $L^{-1}$)** | 0.7 | 0.79 | 0.72 | 0.81 | 0.52 | 0.51 |
| $N\text{-}NO_3$ **(mg $L^{-1}$)** | 0.35 | 0.41 | 0.43 | 0.39 | 0.32 | 0.32 |
| $N\text{-}NH_4$ **(mg $L^{-1}$)** | 0.53 | 0.31 | 0.65 | 0.27 | 0.64 | 0.56 |
| $P\text{-}PO_4^{2-}$ **(mg $L^{-1}$)** | 0.81 | 0.93 | 0.86 | 0.89 | 0.67 | 0.98 |
| Total phosphorus **(mg $L^{-1}$)** | 0.76 | 0.76 | 0.69 | 0.69 | 0.65 | 0.61 |
| COT **(mg $L^{-1}$)** | 0.69 | 0.74 | 0.62 | 0.69 | 0.59 | 0.72 |
| Salinity (USP) | 0.21 | 0.02 | 0.11 | 0.13 | 0.09 | 0.03 |
| pH | 0.33 | 0.43 | 0.28 | 0.31 | 0.16 | 0.54 |
| Conductivity (mS $m^{-1}$) | 0.42 | 0.57 | 0.33 | 0.44 | 0.31 | 0.51 |
| Eh (mV) | 0.08 | 0.59 | 0.12 | 0.67 | 0.14 | 0.71 |
| Temperature (°C) | 0.67 | 0.71 | 0.69 | 0.65 | 0.21 | 0.67 |
| Turbidity (cm) | 0.74 | 0.89 | 0.79 | 0.91 | 0.11 | 0.52 |



Receive: September 30nd 2015 Accepted: November 15th 2015 Published: December 15th 2015

Cuemanco pier bottom water and in Cerro de la Estrella surface water, it was observed predominance of breathing on GPP. Phytoplankton biomass variation was high (422%) with a high average value (380.42 mgC Cl-*a*.m$^{-3}$), with a minimum value of 50 mgC Cl-*a*.m$^{-3}$ corresponding to bottom water of Cerro de la Estrella station and a maximum value of 1185 50 mgC Cl-*a*.m$^{-3}$ of bottom water in La Virgen lagoon (Table 3).

## DISCUSSION

In physicochemical variables analysis results, it is not observed significant difference between surface and bottom waters, due to low deepness that exists in channels, as indicated by Olivia et al. (2008) who mentions that a characteristic of shallow lakes is that water column frequently mixed by wind, fisheries and ecotourism, so Xochimilco channels can be typically considered polymathic, because of the wind action that cause mix in water column, altering its stability and preventing nutrient limitation, which can favor microalgae growth with low sedimentation rate and high growth rates.

Although pH is a limiting factor in this type of ecosystem, there was not a correlation with NPP, because in hard waters as Xochimilco, carbonates presence make an absorber effect, allowing that hydrogen ions concentration stay relatively stable as suggested by Quiroz-Flores et al. (2008).

Because primary production of an aquatic ecosystem depends on phtosyntetic organisms, it is indispensable that this parameter is considered for its sustainable potential evaluation. Obtained net primary production results were similar to reported values in some Colombian lagoons and Brazilian lowland lakes (Montoya and Aguirre 2010), these authors also reported a significant relation between NPP and GPP with water level, Secchi transparency and water temperature, which matches with obtained data in multivariate correspondence analysis made in this investigation (Table 5). Relatively low nitrogen values (2.83±1.98 mg L$^{-1}$ N-$NO_3^-$ and 0.55±0.21 mg L$^{-1}$ N-$H_4^+$) and high TP values (12.93±10.76 mg L$^{-1}$) (Table 4), suggest that PP in this one is limited by nitrogen. Photosynthetic activity in low as indicated by chlorophyll values that were <23 mg m$^{-3}$. Results of canonical correlation tests confirmed that PP and R are limited by N-$NH_4^+$, N-$NO_3^-$, and P-$PO_4^{2-}$ and this activities in bottom water can be limited by Eh and suspended organic matter, as reported by González et al. (2004).

From analyzed inorganic nutrients, orthophosphate showed a high significant correlation with net and gross primary production, in both surface (r=0.81 and 0.93) and bottom (r=0.93 and 0.89) water, as breathing in bottom water (r=0.89); this last activity was clearly related with Eh (r=0.72) and bottom water temperature (r=0.71).

Gonzales et al. (2004), reported that temperature and inorganic nutrient combination generate a high biomass that leads to a high primary production and therefore obtain high breathing rates because an increase in temperature elevates the organism’s metabolic rate. Observed correlation between turbidity, NPP and GPP may be because turbidity limits primary production due to poor light environment. On the other side, expressed biomass in chlorophyll concentration is a simple and useful estimator of phytoplankton density and has been highly used in models as the most relevant parameter to predict the density of algae in lakes. Sometimes, trophic response in lakes is not the expected by diverse causes, as in biological costs that can modify nutrient content


Receive: September 30nd 2015 Accepted: November 15th 2015 Published: December 15th 2015

Digital Journal of
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and therefore trophic response (Salas, 2001). With respect to obtained Cl-a data (0.007±0.008 μg $L^{-1}$), it can be consider that in this time of the year the channels trophic state was mesotrophic, according with limit values of Organización, Cooperación y Desarrollo Económico de las Aguas Interiores (OECD) (Ledezma et al. 2013).

Founded chlorophyll-a concentrations can be caused, as reported by Baley in 1995, that in dry season there is a higher mineralization of organic nutrients, giving as consequence a low presence of chlorophylls and therefore a low primary production rate.

Through a box and whisker diagram (Fig.2), it was able to prove that due to low profundity in water column there is no significant difference between GPP, NPP and primary biomass in surface and bottom water. In general, there was a dominance of cyanobacteria and chlorophylls in the channels, nevertheless in station 4, La Virgen lagoon, it was detected dinoflagellate presence. Results match with observed blooms of cyanobacteria in this ecosystem by other authors and can become potentially toxic, as genus *Microcystis* (Pineda-Mendoza et al. 2011, Oliva-Martínez et al. 2014).

## CONCLUSIONS

According to obtained results it can be said that primary production and chlorophyll-*a* concentration are good indicators of eutrophication grade in this ecosystem.

Despite with what was reported by other authors (Rocha-Ramírez et al. 2014), that in same time of the year sampling, the Xochimilco chinampera zone channels were found in an homogeneous mesotrophic state due to its low profundity.

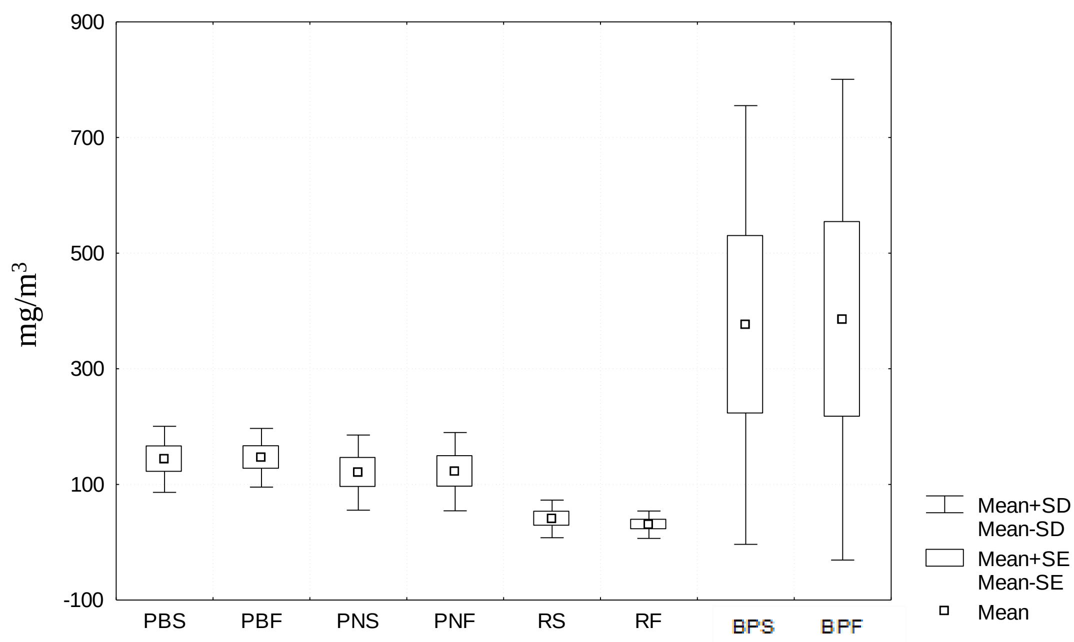


**Fig. 2. Graph of primary production, disaggregated by stratum.**



Receive: September 30nd 2015 Accepted: November 15th 2015 Published: December 15th 2015

## ACKNOWLEDGMENTS

To the biology department that allow us through the modular investigation, to obtain all necessary resources to make this work.

To PhD. María Jesús Ferrara Guerrero and PhD. José Roberto Ángeles Vázquez, Biogeochemical Cycles career module professors teachers for their support and counseling and to Biogeochemical Cycles 13P modular group for their support in field and laboratory work.

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Receive: September 30nd 2015 Accepted: November 15th 2015 Published: December 15th 2015

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Receive: September 30nd 2015 Accepted: November 15th 2015 Published: December 15th 2015