Estimation of the phytoplankton biomass in Bahia Manzanillo, Colima (2016-2017)

Estimación de la biomasa fitoplanctónica en Bahía Manzanillo, Colima (2016-2017)

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Abstract

Phytoplankton biomass (Chl-*a*) was estimated in 7 stations of Manzanillo Bay, Colima on the surface and at the Secchi depth in the rainy and dry season (2016-2017). To evaluate the biomass, a Millipore equipment and fiberglass GF / F filters were used using the spectrophotometric technique (Lorenzen, 1967). The physicochemical parameters were estimated with a YSI 85 equipment and the nutrients using a San Plus II segmented flow autoanalyzer. The average depth of the Secchi disk ranged from 5.9 m at the Puerto station to 12.8m at the center (A1 and A2). The temperature ranged from 26.9 to 28.1 ° C, the salinity between 31.6 and 33 ups and the dissolved oxygen from 3.81 to 4.82 mg L-1. The nutrients presented high values in Puerto, A1 and Carrizales. The central part of the bay registered values greater than one mg of Chl-*a* and a maximum of 2.67 mg .m-3 in the Puerto station. In 2016, Chl-*a* decreased significantly because of a very intense Niño event, also showing high concentrations of phaeopigments, which reveal grazing conditions or degraded chlorophyll. Through an analysis of variance, it was determined that there is a significant difference between the chlorophyll-a values ($p \leq 0.05$).

Phytoplankton, Biomass, Manzanillo

Resumen

Se estimó la biomasa fitoplanctónica (Cl-*a*) en 7 estaciones de la Bahía de Manzanillo, Colima en superficie y a la profundidad Secchi en temporada de lluvia y estiaje (2016-2017). Para evaluar la biomasa se empleó un equipo Millipore y filtros GF/F de fibra de vidrio mediante la técnica espectrofotométrica (Lorenzen, 1967). Los parámetros físico-químicos se estimaron con un equipo YSI 85 y los nutrientes mediante un Autoanalizador de flujo segmentado San Plus II. La profundidad promedio del disco de Secchi fluctuó entre 5.9 m en la estación Puerto hasta 12.8m en el centro (A1 y A2). La temperatura varió de 26.9 a 28.1°C, la salinidad entre 31.6 y 33 ups y el oxígeno disuelto de 3.81 a 4.82 mg L^{-1}. Los nutrientes presentaron valores altos en Puerto, A1 y Carrizales. La parte central de la bahía registró valores mayores a un mg de Cl-*a* y un máximo de 2.67 mg $.m^{-3}$ en la estación Puerto. En 2016 la Cl-*a* bajó significativamente debido al efecto de un evento Niño muy intenso, apreciándose también altas concentraciones de feopigmentos, que revelan condiciones de pastoreo o clorofila degradada. Mediante un análisis de varianza, se determinó que existe diferencia significativa entre los valores de clorofila-*a* ($p \leq 0.05$).

Fitoplancton, Biomasa, Manzanillo

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Introduction

Biomass and phytoplankton productivity support the ocean's trophic webs and are the component of the pelagic ecosystem responsible for the transformation of carbon dioxide into organic carbon (Gaxiola-Castro *et al*., 2010). Therefore, it is essential to know the spatial and temporal variability of chlorophyll-a (Chl-*a*), an index of phytoplankton biomass and primary productivity to understand carbon cycles, changes in the populations of fishery resources, and the coupling of the physic-biogeochemical factors of the ocean.

Research on biomass variability and primary productivity in the Mexican seas is more abundant in the Pacific region of the California Peninsula and the Gulf of California (Lara-Lara *et al*., 1993), however, they are scarce and irregular in the coasts of Nayarit, Jalisco, and Colima (Otero-Dávalos, 1981, Zuria-Jordán, 1995, Blanco-Alonso and Madrid-Hernández, 2004).

The objective of the present study was to estimate the spatial-temporal variability of the phytoplankton biomass in the Bay of Manzanillo, Colima, in rainy and low-water conditions.

Materials and methods

Study area

Bahía Manzanillo, Colima is in the central Mexican Pacific, between 19º 05 ’and 19º 08’ north latitude and 104º 20 ’and 104º 25’ west longitude. This is the port of Manzanillo, one of the most important and with the largest maritime flow in Mexico (Figure 1).

Figure 1 Map of Manzanillo Bay, Colima
Source: *Taken from Google earth*

The beaches are semi-protected with a gentle slope and fine or coarse sand with alternating presence and at the ends of rocky massifs and fixed rocks of different sizes including boulders. The shallow subtidal (> 10 m) has rocky-sandy bottoms, fragments of dead coral and patches of live coral, mainly of the genus *Pocillopora* sp, which are better represented in the Carrizales area.

The region's climate is warm-sub-humid with rains in summer that corresponds to the Awo (e) subtype, according to the Köppen classification modified by García (2004). In the area, maximum temperatures of 39ºC and minimum temperatures of 16ºC are registered; and a humidity percentage higher than 75%. The annual rainfall in the Manzanillo region is **111** mm. The rains occur in the months of July to October in 93% and are mostly subject to cyclonic disturbances that almost always follow a path parallel to the coast (INEGI, 1980).

The prevailing winds come from the west and northwest, reaching an average annual speed of 4.38 m. s^{-1}. The marine currents present a direction towards the outside of the Santiago Bay through Punta Juluapan and then go to the Southeast, towards Punta Campos. There is an anticyclonic turn between Punta Santiago, Cerro del Vigía, near Punta Ojo de Agua and Punta Juluapan and convergence of currents at the center of Manzanillo Bay. The circulation is very homogeneous in the 5, 10, 15 and 20 m depth layers. Average speeds of ocean currents are of the order of 34 cm.s-1 (0.660 knots).

Field work

Four field trips were carried out, two in the dry season months and two in the warm humid season to estimate chlorophyll-*a* and its phaeopigments. Three sampling sites were in the central part (A1, A2 and A3) and the rest around the bay: Puerto, Punta Santiago, Juluapan and Carrizales (Figure 2).

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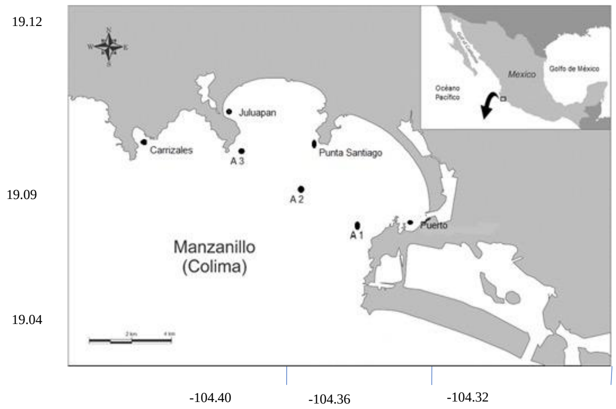

Figure 2 Location of sampling stations for phytoplankton in Manzanillo Bay, Colima

The depth of the sites varied between 8 m at the Puerto station and 70 m at the A1 station. The samples were obtained at the surface and at the Secchi depth using a 5-liter Niskin bottle. The physical-chemical variables (temperature, salinity, nutrients, and dissolved oxygen) were determined with a YSI-85 equipment, the turbidity was determined by means of the Secchi disk, and the direction and speed of the wind with an anemometer.

Chlorophyll-*a* and nutrient samples were kept in a cooler protected from light. One liter of water from each sample was filtered through a Millipore equipment using GF / F glass fiber filters of 25 mm diameter and 0.25 µm pore. Filters were kept frozen until analyzed. The chlorophyll-*a* was extracted with 90% acetone, after remaining 24 hours in the dark and refrigeration. The determinations were made with the spectrophotometric method described by Lorenzen (1967). Nutrients were determined with a San Plus II Segmented Flow Autoanalyzer.

The conditions that prevailed on the sampling days were contrasting, in January there was mild waves and weak winds and in June 2017 more intense waves with gusts of wind of more than 12 m.s-1 due to nearby tropical storms. Table 1 shows the spatial variation of the physical-chemical parameters and in figure 3 its seasonal variation. The depth of the Secchi disk fluctuated from 5.9 m at the Puerto station to 12.8 m in the center of the bay (A1, A2). The greater turbidity of the Puerto station is the result of greater contamination of organic matter in the site and in the most coastal stations due to the contribution of terrigenous materials and urban discharges. In addition, a higher demand for dissolved oxygen can be seen in these stations (Table 1).

The warmest temperatures were recorded in June, decreasing in January and February, with a difference between 3 to 4ºC (Figure 2b). In both months, homogeneous values of temperature and dissolved oxygen were observed in the water column by effective mixing in the bay.

The average salinity values varied according to the wet and dry season (Figure 2c).

Station	Secchi (m)	Temperature (°C)	Salinity (ups)	Oxygen (mgL^{-1})
A1	12.7	27.6	32.7	4.69
A2	12.8	28.1	32.9	4.82
A3	10.7	28.1	32.9	4.70
Carrizales	10.1	28.1	32.7	4.55
Juluapan	6.8	27.8	33.0	4.39
Santiago	9.3	27.4	32.2	4.55
Puerto	5.9	26.9	31.6	3.81

Table 1 Spatial variation of average values of physical-chemical factors in Manzanillo Bay, Colima (2016-2017)

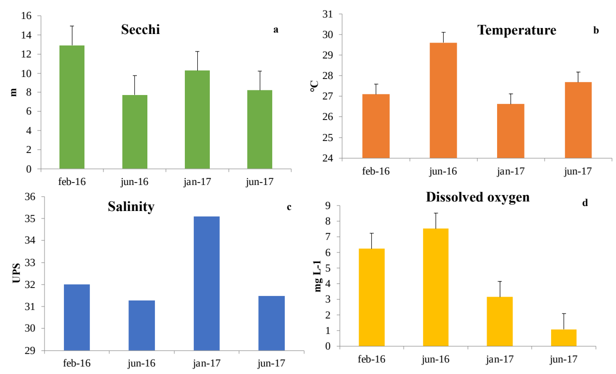

Figure 3 Temporal variation of average values of physical-chemical factors in the Bay of Manzanillo, Colima (2016-2017)

The nutrients presented higher values at the bottom of the stations, being particularly higher at the Puerto, A1 and Carrizales stations. Table 2 shows the average values for each month and the minimum and maximum value in parentheses.

Month	NO_3+NO_2	NH_4 (µM)	PO_4	SiO_2
Feb 16	**7.83** (2.3-18.3)	**1.37** (0.9-1.8)	**0.30** (0.1 -0.7)	**103.29** (38.4-152)
Jun 16	**6.68** (3.9-14.6)	**0.22** (0.19-0.3)	**0.76** (0.3-2.5)	**12.48** (2.9-30.5)
Jan 17	**3.34** (2.6-4.0)	**0.28** (0.20-0.4)	**0.9** (0.78-0.8)	**7.47** (6.5-8.5)
Jun 17	**5.30** (4.6-5.9)	**0.11** (0.08-0.13)	**0.71** (0.6-0.83)	**9.34** (8.6-9.9)

Table 2 Temporal variation of nutrients in Bahía Manzanillo, Colima. Average and minimum and maximum values in parentheses (µM)

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The concentration of nutrients was like those reported by other authors in studies of the Mexican Pacific, where the trend is that they increase with depth, generally at the level of the nutritional content, from there, they can be maintained or decreased, depending on the characteristics. dynamics of local deep circulation (Lara-Lara and Bazán Guzmán, 2005).

The average values of nitrates and nitrites were slightly higher, with respect to those reported for the Mexican Pacific by De la Lanza-Espino (2001), which describes a higher content of nitrites (3.6 µM) and values less than 0.1 ml L^{-1} oxygen in the anoxic layer, and increased nitrates and dissolved oxygen below it.

The phosphate values were lower than those reported for the Mexican Pacific by Vázquez *et al*. (1998). In their study they mention that orthophosphates vary between 0.1 and 1.5 µM at the surface level and increase to 3.0 µM at depths below the thermocline. It is the nutrient that is assimilated in the least amount as shown by the atomic proportion in organic matter (C106N16P1) and when decomposed, the proportion is preserved (Redfield *et al*., 1963).

The values of the silicates in this work presented values like those reported for the Gulf of Tehuantepec (Vázquez *et al*., 1998), where surface variations of 1.0 to 174 µM have been found in autumn-winter and from 0.3 to 207 µM in summer, attributable to river contributions. Diatoms especially assimilate silicates, so their optimal growth is regional.

Photosynthetic pigments

Spatial variation

Values greater than one milligram of chlorophyll-*a* were recorded in the central part of the bay, unlike the rest of the stations, except for the Puerto station, which had a value of 2.67 mg.m^{-3} in February (Figure 4).

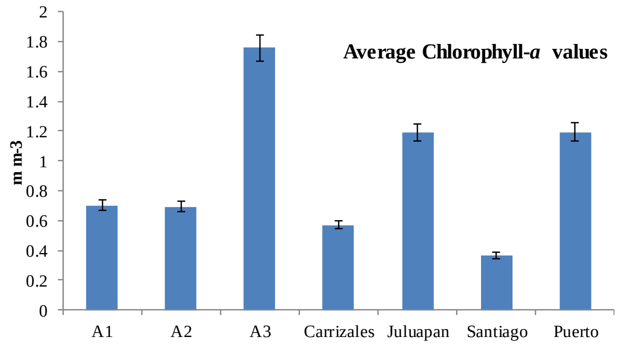

Figure 4 Average values of chlorophyll-a in the sampling stations

In 2017 the values were high in most of the stations, mainly in the center of the bay (A2, A3), with a gradual decrease towards the most coastal stations in a clockwise direction, this due to the geomorphology of the bay and to the anticyclonic turn between Punta Santiago, Cerro del Vigía, near Punta Ojo de Agua and Punta Juluapan with convergence of currents to the center of Manzanillo Bay, with the exception of the Puerto station that is outside this influence and the values tend to increase (Figure 5).

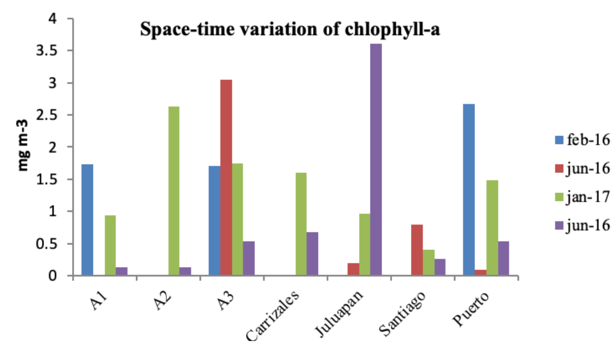

Figure 5 Space-time variation of Chlorophyll-*a*, in Manzanillo Bay, Colima

Temporal variation

A marked seasonal difference in chlorophyll-a values was observed in the study area. The dry months (January, February) presented higher values and decreased in the rainy season (June), mainly associated with consumption by grazing (Figure 6a).

According to an analysis of variance (ANOVA), it was possible to determine that there is a significant difference between the chlorophyll-*a* values ($p \leq 0.05$).

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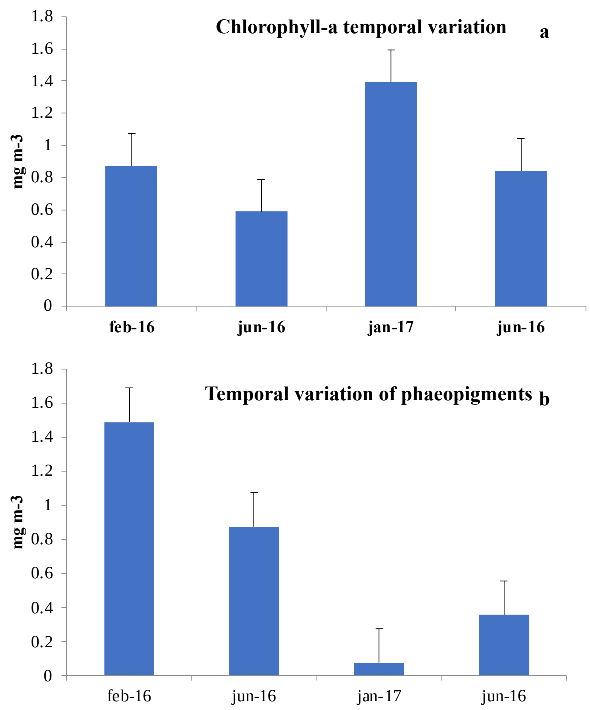

Figure 6 a) Average values of chlorophyll-*a* and b) of phaeopigments in the sampling months

The low values of Chl-*a* in 2016 resulted from a Niño event (2015-2016) that occurred with great magnitude and intensity in the Pacific Ocean. Gómez-Ocampo *et al*. (2017b) reported a decrease in chlorophyll-*a* recorded through satellite images and modeled primary production for the southern part of the California Current, during El Niño from 2015–2016. This phenomenon caused a significant decrease in phytoplankton productivity, economic losses due to collapse in fisheries and droughts in the continental part of several countries (De la Cruz-Orozco *et al*., 2017).

According to these conditions, the high values of phaeopigments registered in 2016 (Figure 6b) reveal conditions of chlorophyll-a degraded by decomposition of phytoplankters (Barreiro and Signoret, 1999). On the other hand, the phaeopigment values registered in 2017 were low or undetectable by the technique in several stations, mainly for the month of January, which suggests a recovery of phytoplankton communities due to the seasonal pattern indicated in several studies.

In winter there is a decomposition-remineralization, with an increase in the nutrients for the next cycle, as observed in the present study (January, February) to be available in the spring bloom, where the nutrient content decreases due to biological assimilation.

In summer it increases by decomposition of dead organic matter and in autumn there is again an assimilation process.

The winds ranged from 0 to 8.7 km. h^{-1} with a predominantly west direction, favoring the mixing of the water column. The depth of the euphotic zone and the mixed layer are of relevant importance for phytoplankton, which receives light energy to carry out its most important physiological functions: photosynthesis and growth.

On the other hand, in regions where the nutrition and thermocline are present near the surface layer, the enrichment of the euphotic zone is favored by the mixture that is generated with a minimum wind effort, increasing the production of these areas (Estrada and Blasco, 1985). In regions such as the tropical eastern Pacific, where the thermocline is very shallow, the euphotic zone can be enriched in nutrients with relatively low winds, increasing phytoplankton productivity (Lara-Lara and Bazán-Guzmán, 2005; López-Sandoval *et al*., 2009).

A trend of increasing Chl-*a* concentrations with depth was observed in several stations during the sampling months. In the stations located in the central part of the bay, subsurface concentrations were recorded between 10 and 15 m, as has been reported in other studies (Lara-Lara and Bazán-Guzmán, 2005). This increase is associated with the quantity and quality of light, which is optimal for photosynthesis, as well as an increase in the concentration of nutrients at these depth levels.

Table 3 compares the results obtained from phytoplankton biomass (Chl-*a*) with studies carried out in the waters of the Mexican Pacific.

Study area	Chlorophyll*a* (mg m-3)	Authors
Chamela Bay, Jal.	0.0 – 16.0	Blanco-Alonso y Madrid-Hernández, 2004
Gulf of Tehuantepec, Oax.	0.04 -11.1	Robles Jarero y Lara- Lara, 1993
Mexican tropical pacific	0.09 – 3.78	Lara-Lara y Bazán Guzmán, 2005
Cabo Corrientes, Jal.	0.8 – 11.3	López-Sandoval *et al*., 2009
Manzanillo Bay, Col.	1.1 -20.8	Sosa-Avalos *et al*., 2015
Manzanillo Bay, Col.	0.0 – 2.73	Present study

Table 3 Chlorophyll-*a* values in some places in the Mexican Pacific

Chlorophyll-a has been related to the estimation of primary production. Raymont (1980) proposes equivalences of chlorophyll-*a* and Carbon in phytoplankton as follows: 1 µg of chlorophyll-*a* = 13.6 to 17. 3 µg C, 1 mm3 of algal volume at 0.01 - 0.125 mg C and 1 µg of chlorophyll-*a* 34.8 µg of dry weight of organic matter. However, this estimate is approximate, since the content of this pigment in phytoplankton varies widely depending on the species, their nutritional and physiological status, the degree of illumination and type of light, among other factors.

Therefore, maximums can be registered below the surface (20 m in coastal areas, 50 to 200 m in oceanic areas), depending on the solar position and experience planktonic increases or sinks within the euphotic zone, depending on the time of day. There is also a temporal variation depending not only on the nictemeral (daily) cycles of the organisms, but also seasonal, as happens more clearly in temperate zones. Therefore, the chlorophyll-*a* content varies widely, depending on the region.

It is important to continue systematic studies of the primary producers of the coast throughout the Mexican tropical Pacific, since the dynamics that together they contribute to the coastal system and the role they play with the flow of carbon is unknown.

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Conclusions

In the present study, the chlorophyll-a values were low, especially in 2016, due to the presence of the El Niño phenomenon (2015-2016) on the eastern coast of the Pacific Ocean, which caused a decrease in phytoplankton productivity and economic damage in several countries, however, the registered values are found in the intervals reported for the Mexican Pacific.

Significant differences ($p \leq 0.05$) were observed in the temporal variation in the Chl-*a* values. In the dry months (January and February) they were higher and decreased in the wet season (June), mainly due to grazing activity. In 2017 the values increased up to an order of magnitude and the phaeopigments were low or undetectable in several sampling stations, particularly in January, being clear evidence that the phytoplankton community was in a process of recovery and growth, which is manifested in flowering. of spring.

According to the geomorphology and local circulation of the study area, a trend was observed in the variation of chlorophyll-*a* and phaeopigments, with increases in the center of the bay (station A2, A3), to gradually decrease towards the most coastal stations and increase again at the Puerto station.

The maximum values of Chl-*a* were recorded at the subsurface level, occurring between 10 and 15 m in the central stations that are deeper, the foregoing agrees with several authors, who mention that adequate light and concentration of nutrients to carry out photosynthesis optimally.

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