CICIMAR OCEÁNIDES
ISSN 2448-9123
https://oceanides.ipn.mx
Centro Interdisciplinario de Ciencias Marinas
https://doi.org/10.37543/oceanides.v36i1-2.260

Vol.36 No. 1-2
Enero-Diciembre
2021

CHARACTERIZATION OF THE TROPHIC STATUS (SPRING-SUMMER) OF THE EL CONCHALITO ESTUARY, BCS, BASED ON THE CONCENTRATION OF CHLOROPHYLL *a*, PRIMARY PRODUCTIVITY AND PHOTOSYNTHETIC EFFICIENCY

Caracterización del estado trófico (Primavera-Verano) del Estero El Conchalito, con base en la concentración de clorofila *a*, productividad primaria y eficiencia fotosintética

RESUMEN. Los sistemas de manglar, tradicionalmente han sido reportados como áreas de alta productividad primaria, capaces de exportar biomasa hacia sistemas adyacentes favoreciendo a organismos de diferentes niveles tróficos. Su complejidad como sistemas altamente productivos estriba en gran parte en la coexistencia de productores primarios tanto foto como quimiosintéticos. El objetivo del presente estudio es determinar el estado trófico, la eficiencia fotosintética y productividad primaria de la comunidad fitoplanctónica presente en este manglar durante la temporada primavera verano del 2016. Se realizaron muestreos quincenales durante el periodo abril a julio en los cuales se tomaron muestras para determinación de concentración de clorofila a y estimación de la productividad primaria. De igual manera se registró la temperatura ambiental y la superficial del agua, además de considerar datos de niveles de mareas. La temperatura ambiente varió entre los 21.9 y 28.5 ° C, mientras que la temperatura superficial del agua presentó valores entre 21 y 24.5 °C. Los menores niveles de marea se registraron durante el primer y segundo muestreo (50 cm), mientras que los máximos durante la tercera y cuarta fecha (120 cm). Con relación a la concentración de clorofila a, su valor mínimo fue de 2.0 mg m^{-3}, mientras que el máximo de 4.6 mg m^{-3} (julio y marzo respectivamente). Durante Julio se registró el mínimo de productividad primaria (2.4 mg C m^{-3} h^{-1}), mientras que el máximo durante abril con 4.9 mg C m^{-3} h^{-1}. La eficiencia del proceso fotosintético presentó el mínimo durante mayo (0.79 y el máximo durante julio (1.20 mg C m^{-3} h^{-1}), coincidiendo con el mínimo de productividad primaria. De acuerdo al Índice Trófico de Carlson (> 30), el Estero El Conchalito se considera una zona de productividad media.

Verdugo-Díaz, Gerardo, Aída Martínez López & Francisco Javier Gómez-Ochoa. Instituto Politécnico Nacional, Centro Interdisciplinario de Ciencias Marinas, Departamento de Plancton y Ecología Marina, Apartado Postal 592, Av. Instituto Politécnico Nacional S/N Col. Playa Palo de Santa Rita, La Paz, Baja California Sur, 23096, México. email: gverdugo@ipn.mx

Verdugo-Díaz, G.,A. Martínez-López & F.J. Gómez-Ochoa. 2021. Characterization of the trophic status (Spring-Summer) of the El Conchalito estuary, BCS, based on the concentration of chlorophyll *a*, primary productivity and photosynthetic efficiency. ***CICIMAR Oceánides***, 36(1-2): 51-56.

Mangroves are one of the most important wetland systems because of the widely-recognized and essential ecological and economic role they play (Kuo *et al*., 2001) by functioning as areas of alimentation, refuge and breeding of numerous species of birds (Carmona & Carmona, 2000), fish (González-Acosta *et al*., 1999; González-Acosta *et al*., 2005), mollusks (Conabio, 2008), and crustaceans (Félix-Pico *et al.,* 2003), among others. The El Conchalito mangrove (Fig. 1) is a system formed basically by three species that, in order of importance, are *Avicennia germinans*, *Laguncularia facemosa* and *Rhizophora mangle*. This mangrove is located near Ensenada de La Paz (24º08′34”-24º07′40″ N and 110º21′04″-110º20′35″W) and covers an approximate surface area of 18.5 has. The principal rains occur in the summer with values close to 60 mm, while the mean annual precipitation is 184 mm. This system is subject to a desert climate with a mean annual temperature above 22°C. During the winter-spring, winds come from the northwest at speeds of 5-10 m s^{-1} but are weaker in the hot months (2-3 m s^{-1}) when they enter from the south. The objective of the present study was to evaluate the trophic condition of this estuary based on the variables of chlorophyll-*a* concentration, primary productivity and photosynthetic efficiency in a mangrove area that borders on a residential zone of the city La Paz, BCS. Nine, two-week sampling periods were performed between April and July 2016, which involved *in situ* recording of ambient temperature and the surface temperature of the water. Water samples were drawn at the estuary's mouth to determine chlorophyll-*a* concentrations (Strickland & Parsons, 1972) and estimate primary productivity employing the radioactive carbon assimilation technique (Steemann-Nielsen, 1952).

Photosynthetic efficiency was evaluated by calculating the net assimilation rate (P^B=PP/Cl *a*), a widely recommended parameter for obtaining information on this aspect of efficiency per unit of chlorophyll (Gaxiola-Castro & Álvarez Borrego, 1986; Lara-Lara *et al*., 1993).

Carlson's index was utilized to classify the system according to its trophic condition since this scale is one of

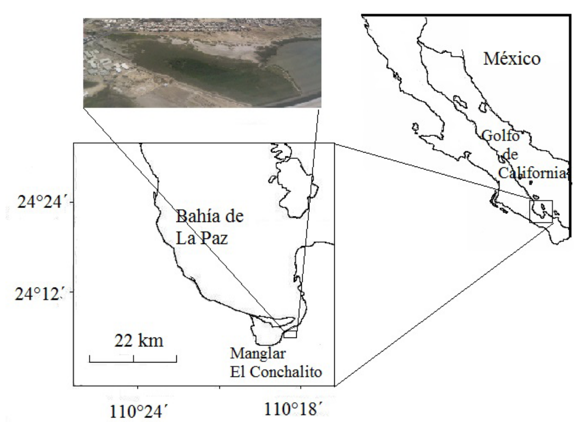

Figure 1. The study area, "El Conchalito" estuary.

Fecha de recepción: 05 de junio de 2020

Fecha de aceptación: 08 de diciembre de 2021

the most widely-recognized for use with studies in estuary systems and coastal lagoons (Carlson, 1977; Contreras-Espinosa *et al*., 1994).

Ambient temperature presented values between 21.9°C (May 21) and 28.5°C (July 16), clearly indicating the transition period between the cold and hot months that concurs with the seasonal pattern reported for this area by various authors (e.g. Robles Gil-Mestre, 1988). The surface temperature of the water presented similar behavior, though with relatively lower values: a minimum of 21°C and a maximum of 24.5°C (Fig. 2a), readings comparable to the annual averages of 24.7°C (Félix-Pico *et al.,* 2006) and 25.9°C (González-Acosta *et al*., 1999). Concerning the dynamics of the tides, observations showed that the maximum height was recorded during the two samples taken in May (1.2 m), followed by a reduction to a low of 0.7 m in July; however, the minimum value coincided in the first two samples (0.5 m). In this regard, Jiménez-Illescas *et al.* (1997) reported that the tide that affects the El Conchalito estuary is of the semidiurnal type, which presents a mean amplitude of 1.94 m and an average annual current of 21 cm s^{-1}, while Félix-Pico *et al*. (2006) reported a mean amplitude of 1.4 m. These physical conditions allow the exchange of water with the Laguna de La Paz. The chlorophyll-*a* concentration showed a tendency to decrease values between the first and final samples, so the maximum was recorded in March (4.6 mg m^{-3}) and the minimum in July (2.0 mg m^{-3}). Martínez-López *et al*. (2001) made similar observations, as they associated the decrease in chlorophyll with the increase in the temperature of the annual cycle. Likewise, but for the Bahía de La Paz, Verdugo-Díaz *et al*. (2014) reported surface values lower than 1 mg m^{-3} between 2005-2007, except for the value corresponding to December 2005, when a concentration above 6 mg m^{-3} was recorded, due to a punctual proliferation of phytoplankton. The maximum values for chlorophyll-*a* concentrations were observed during the lower tide. Under low tide conditions and the shallower depths this brings in the estuary, the tidal currents can remove sediments and resuspend cells of picophytoplankton that, in turn, can contribute to the increased concentration of chlorophyll and primary productivity. (Blanchard & Montagna, 1992; López-Fuerte & Siqueiros-Beltrones, 2006). From May onwards, both the height of the tide and the concentration of chlorophyll-*a* showed the same downwards pattern over time (Fig. 2b).

Primary productivity showed a marked reduction over time, similar to what was observed regarding the variable described above (Fig. 3). This correlation (r= 0.81), however, may not be as consequential as has been reported previously (see, for example, Nixon, 1988) since it can be modulated by properties of the phytoplanktonic community, such as the degree of maturity/immaturity, adaptations and its physiological status, or even its size and the pigmentary print of its populations. In addition, this variability in the attributes of the community may also be modified by environmental conditioning factors that include photosynthetically-active radiation and nutrient concentrations. All these factors and their interaction modulate the pattern and variability of primary productivity (Behrenfeld & Falkowski, 1997, Claquin *et al*., 2010). Moreover, observations of estuaries have shown that primary productivity commonly registers behavior that is inverse to temperature (Boynton *et al.,* 1992).

The minimum productivity value was recorded in July with a reading of 2.4 mg C m^{-3} h^{-1}, while the maximum was found in the second sample in April (4.9 mg C m^{-3} h^{-1}). Concerning photosynthetic efficiency, expressed as the assimilation rate, the behavior recorded was distinct from primary productivity. It is possible to observe, especially in the second part of the curve, an inverse relationship between productivity and photosynthetic efficiency, a finding that may be associated with the nature of the radioactive carbon assimilation method, which estimates not only the primary productivity of the photosynthetic organisms but also that of non-photosynthetic primary producers (Holm-Hansen & Helbling, 1995). Minimum efficiency (0.79 mg C (mg Cl *a*)$^{-1}$ h^{-1}) was recorded in the first sample drawn in May, while the maximum appeared in the final sample of the study (1.20 mg C (mg Cl *a*)$^{-1}$ h^{-1}). There are no earlier reports on this variable in the study area, but Verdugo-Díaz *et al*. (2014) published values between 0.16 and 22.4 mg C (mg Cl *a*)$^{-1}$ h^{-1}) for Cuenca Alfonso in the northern area of Bahía de La Paz. It is important to point out that this high variability is associated mainly with the photophysiological adap-

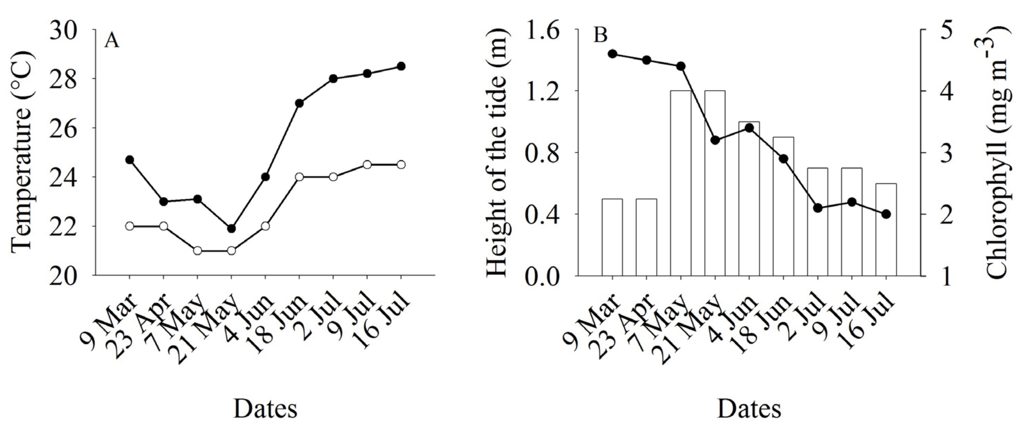

Figure 2. (a) Ambient (continuous line) and surface temperatures (broken line); and (b) height of the tide (empty bars) and chlorophyll-*a* concentration (continuous line) in "El Conchalito" estuary.

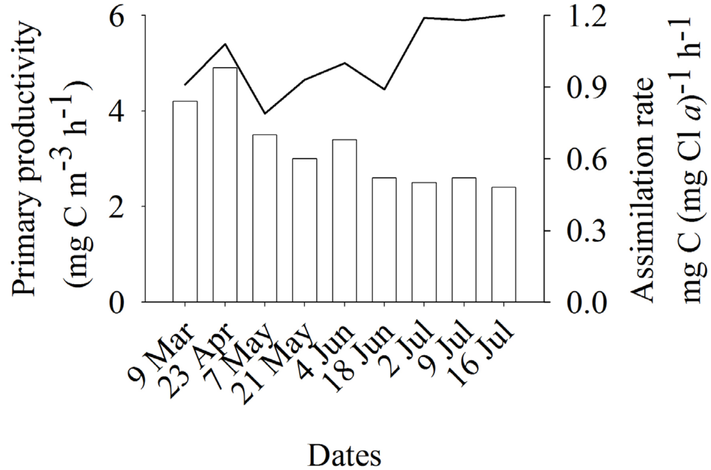

Figure 3. Primary productivity (empty bars) and assimilation rate (continuous line) during the sampling period "El Conchalito" estuary.

tations of the phytoplankton since those authors considered different levels of light inside the eutrophic zone.

The values for Carlson's trophic index (Fig. 4) show a slightly downward tendency over time, though those recorded were consistently above 30, the limit between oligotrophic and mesotrophic zones, which justifies considering the study zone as a mesotrophic estuary of medium productivity. However, it is important to keep in mind that this study was conducted only during spring/summer, so integrating similar values for chlorophyll-*a* concentrations and primary productivity would result in a classification as a eutrophic, or high productivity, zone (Martínez-López *et al*., 2001; Verdugo-Díaz *et al*., 2014). The choice of this particular index was based on reports in the literature that confer high resolution and an accurate representation of the trophic conditions of lagoon and estuary systems (Gómez-Ortega *et al*., 2014; Contreras Espinosa *et al*., 1994), in the present case, the latter variable was utilized because it is one of the most widely-accepted parameters for this type of environment since it responds directly to the variability of nutrients and phytoplanktonic biomass (Edmondson, 1980).

Despite this mangrove's reduced coverage, its importance is evident, especially when we consider the adjacent marsh area because, together, these zones are considered one of the regions of greatest productivity, capable of exporting organic material that positively influences neighboring systems (Costanza *et al*., 1997). In this regard, Félix-Pico *et al*. (2006) provide evidence of the high primary productivity of the "El Conchalito" estuary, as they observed values as high as 2.4 g dry weight m^{-2} d^{-1} of litterfall from the mangrove system. All the sampling for the present study was conducted before the tide began to ebb to quantify the potential primary productivity that could be exported to adjacent systems. Nevertheless, the values for primary productivity and photosynthetic efficiency suggest a relatively healthy environment, despite reports that this system –and some others around Ensenada de La Paz have been affected by urban development, above all due to the resulting fragmentation, reduction and loss of habitats (Carmona, 1995).

Classifying the "El Conchalito" estuary as a mesotrophic zone using Carlson's Index provides further evidence of the system's excellent health, for there is no scientific

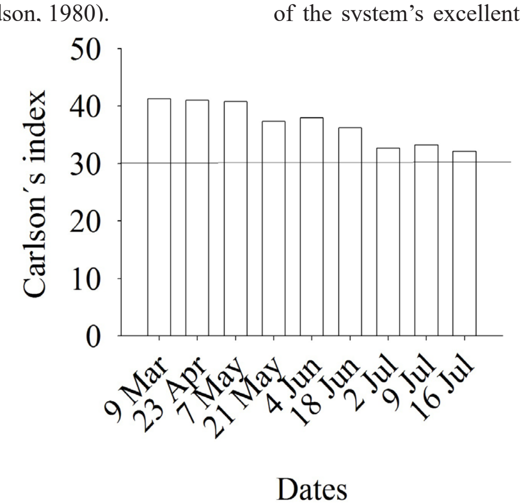

Figure 4. Carlson's trophic index (empty bars) limits between oligotrophic and eutrophic water

evidence of eutrophication due to anthropogenic activities, as has occurred in other coastal lagoons in Mexico (Gómez-Ortega *et al*., 2017; Martínez-López *et al*., 2017). It is important to mention that diverse lines of research involving various biotic resources, including birds (Carmona & Carmona, 2000), fish (González-Acosta *et al*., 1999; González-Acosta *et al*., 2005), and mollusks (Conabio, 2008), and crustaceans (Félix-Pico *et al*., 2003), allow us to infer that this is a zone with mid-to-high productive capacity that plays a significant role in maintaining regional –even continental– biodiversity, since it receives some migrant species, especially of birds.

It is necessary to carry out studies of the various biological resources of this system in order to develop the capacity to prevent, or remedy, anthropogenic affectations caused by the growth of urban sprawl (González-Acosta, *et al*., 2005),

We thank the Instituto Politécnico Nacional and the Secretaría de Investigación y Posgrado for the funding provided for the research project SIP 20161404 "Efectos del clima y la eutrofización en la productividad primaria y tasas de fijación biológica de nitrógeno" and SIP 20210185 "Indicadores de variabilidad climática y cambio ambiental (microplásticos)", directed by Aida Martínez López. We also thank COFAA-IPN and EDI for their support through Fellowships granted to GVD, AML, authors of this publication.

REFERENCES

Behrenfed, M. J. & P. G. Falkowski. 1997. A consumer's guide to phytoplankton primary productivity models. *Limnology and Oceanography,* 42(7): 1479-1491. https://https://doi.org/10.4319/lo.1997.42.7.1479

Blanchard, G. F. & P. A. Montagna. 1992. Photosynthetic response of natural assemblages of marine benthic microalgae to short- and long-term variations of incident irradiance in Baffin Bay, Texas. *Journal of Phycology,* 28: 7-14. https://https://doi.org/10.1111/j.0022-3646.1992.00007.x

Boynton, W. R., W. M. Kemp & C.W. Keefe. 1982. A comparative analysis of nutrients and other factors influencing estuarine phytoplankton production. *In*: Kennedy, V. S. (Ed.) Estuarine comparisons. Academic Press, New York, p. 69-9.

Carlson, R. E. 1977. A trophic state index for lakes. *Limnology and Oceanography*, *22*: 361-369. https://doi.org/10.4319/lo.1977.22.2.0361

Carmona-Piña, R. 1995. Distribución temporal de aves acuáticas en la playa "El Conchalito", Ensenada de La Paz, B.C.S. CICIMAR *Investigaciones Marinas,* 10 (l-2): 1-21.

Carmona-Piña, R. & C. Carmona, 2000. Abundancia y riqueza específica de aves playeras en la Playa El Conchalito, Baja California Sur, durante 1993 y 1995. *Hidrobiológica*, 10(1): 69-73.

Claquin, P., S. N. Longphuirt, P. Fouillarum, P. Huonnic, O. Ragueneau, C. Klein & A. Leynaert. 2010. Effects of simulated benthic fluxes on phytoplankton dynamic and photosynthetic parameters in a mesocosm experiment (Bay of Brest, France). *Estuarine Coastal Shelf Scence*, 86: 93-101.

Costanza, R., R. D. Arge, R. De Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. O´Neill, J. Paruelo, R. G. Raskin, P. Sutton & M. Van Den Belt. 1997. The value of the world's ecosystem services and natural capital. *Nature*, (387): 253-260. https://https://doi.org/10.1038/387253a0

CONABIO, 2008. Manglares de México. 38 p

Contreras–Espinosa, F., O. Castañeda-López & A. García-Nagaya. 1994. La clorofila *a* como base para un índice trófico en lagunas costeras mexicanas. Anales del Instituto de Ciencias del Mar y Limnología, 21 (1-2): 55-66.

Contreras-Espinosa, F., O. Castañeda-López, R. Torres-Alvarado & F. Gutiérrez. 1996. Nutrientes en 39 lagunas costeras mexicanas. *Revista de Bioloogía Tropical*, 44(2): 417-425.

Edmondson, W. T. 1980. Secchi disk and chlorophyll. *Limnology and Oceanography,* 25 (2): 378-379.

Félix-Pico, F. E., O. E. Holguín-Quiñones, A. Hernández-Herrera, & F. Flores-Verdugo. 2006.

Producción primaria de los mangles del Estero El Conchalito en Bahía de La Paz (Baja California Sur, México). *Ciencias Marinas*, 32(1A): 53-63.

Félix-Pico, F.E., O. E. Holguín- Quiñones, E. Campos & J. Salgado-Barragán. 2003. Cangrejos (decapoda brachyura) de los sistemas lagunares con mangle en la costa oriental de Baja California Sur. In: Contribuciones al estudio de los crustáceos del Pacífico Este. Michael E. Hendrickx (Ed). Instituto de Ciencias del Mar y Limnología, 383 pp.

Gaxiola-Castro, G. & S. Álvarez-Borrego. 1986. Photosynthesis-irradiance relationship for winter phytoplankton in Pacific waters off Mexico. Oceanologica Acta, 9(4): 497-501.

Gómez-Ortega, R., C. Tovilla, E. Barba, O. Castañeda, F. J. Valle, E. I. Romero & E. Ramos. 2014. Trophic levels of ecological importance and relationship with some physical and chemical parameters in the estuarine lagoon system Chantuto-Panzacola, Chiapas, Mexico. *Revista Cubana de Investigaciones Pesqueras*, 31(2): 47-57.

González-Acosta, A. F., G. De la Cruz-Agüero, J. De la Cruz-Agüero & G. Ruiz-Campos. 1999. Ictiofauna asociada al manglar del estero El Cochalito, Ensenada de La Paz, B.C.S., México. CICIMAR *Oceánides*, 14(2): 121-131.

González-Acosta, A. F., G. De la Cruz-Agüero, J. De la Cruz-Agüero & G. Ruiz-Campos. 2005. Patrones estacionales en la estructura de los peces del manglar El Conchalito, Bahía de La Paz, Baja California Sur, México. *Hidrobiológica*, 15(2): 205-214.

Holm-Hansen O. & E. W. Helbling. 1995. Técnicas para la medición de la productividad primaria en el fitoplancton. In: Alveal, K., M. E. Ferrario, E. C. Oliveira & E. Sar (Eds.)Manual de métodos ficológicos. Universidad de Concepción, Concepción, Chile, 329- 350.

Jiménez-Illescas A, A. F. González-Acosta, M. Obeso-Nieblas, G. de la CruzAgüero & J. de la Cruz-Agüero. 1997. Comportamiento de la marea, corrientes, temperatura y salinidad, en la boca del Estero El Conchalito, La Paz, B.C.S. In: Resúmenes de GEOS, Boletín Informativo de la UGM, Epoca II, Reunión anual de la Unión Geofísica Mexicana, 1997, 17: 22.

Kuo, S. R., H. J. Lin & K. T. Shao. 2001. Seasonal changes in abundance and composition of the fish assemblage in Chiku lagoon, Southwestern Taiwan. *Bulletin of Marine Science,* 68(1): 85-99.

Lara-Lara J. R., R. Millán-Núñez, J. L. Lara-Osorio & C. Bazán-Guzmán. 1993. Producción y biomasa del fitoplancton por clases de tamaño, en la parte central del Golfo de California durante primavera de 1985. *Ciencias Marinas*, 19(2): 197-154.

López-Fuerte, F. O. & D. A. Siqueiros-Beltrones. 2006. Distribución y estructura de comunidades de diatomeas en sedimentos de un sistema de manglar. *Hidrobiológica*, 16(1) 23-33.

Martínez-López, A., R. Cervantes-Duarte, A. Reyes-Salinas & J. E. Valdez-Holguín. 2001. Cambio estacional de clorofila a en la Bahía de la Paz, B.C.S., México. *Hidrobiológica, 11*(1): 45-52.

Martínez-López, A., C. Hakspiel-Segura, D. C. Escobedo-Urias & B. González-Acosta. 2017. Influence of agriculture and aquaculture activities on the response of autotrophic picoplankton in Laguna Macapule, Gulf of California (Mexico). *Ecological Processes*, 6(6): 1-11.

Nixon, W. S. 1988. Physical energy inputs and the comparative ecology of lake and marine ecosystems. *Limnology and Oceanography*, 33: 1005-1025.

Robles Gil-Mestre, S. 1998. El clima de la ciudad de La Paz. Tesis de Maestría. UNAM. 233 pp.

Steeman-Nielsen, E. 1952. The use of radioactive carbon (14C) for measuring organic production in the sea. *J Conseil, Perm International pour l´Exploration de la Mer,* 18: 117-140. https://doi.org/10.1093/icesjms/18.2.117

Strickland J. & T. Parsons. 1972. *A Practical Handbook of Seawater Analysis. Fisheries Research Board of Canada,* 67(2): 311.

Verdugo-Díaz, G., A. Martínez-López, M. M. Villegas-Aguilera & G. Gaxiola-Castro. 2014. Producción primaria y eficiencia fotosintética en Cuenca Alfonso, Bahía de La Paz, Golfo de California, México. *Revistade Biología. Marina y Oceanología*, 49(3): 527–536. https://doi.org/10.4067/S0718-19572014000300009