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PRELIMINARY OBSERVATIONS OF COCCOLITHOPHORES IN ALFONSO BASIN, BAHIA DE LA PAZ, (GULF OF CALIFORNIA, MEXICO)

Observaciones preliminares de cocolitóforos en cuenca Alfonso, Bahía de La Paz, Golfo de California, México.

RESUMEN. El nanoplancton calcáreo, por su tamaño pequeño (micras) ha sido poco estudiado y se desconoce su diversidad en el Pacífico Mexicano, especialmente en el Golfo de California. Muestras de la columna de agua fueron recolectadas entre 0 y 75 m durante enero, mayo y agosto del 2008, a fin de conocer la variabilidad taxonómica de este grupo. En esta contribución inicial, presentamos el listado de los 27 taxones encontrados en la Cuenca Alfonso, Bahía de La Paz, así como una breve discusión sobre su diversidad. Durante el periodo estudiado las especies más frecuentes y abundantes fueron *Emiliania huxleyi* (Lohmann 1902) y *Gephyrocapsa oceanica* Kamptner 1943.

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Coccolithophores belong to the haptophyta phylum and prymnesiophyceae class. They are unicellular planktonic organisms with cell sizes between 5 to 20 µm, and at some point in their life cycle, they have two flagella. They have chlorophylls a, c1, c3, c2 as well as fucoxanthin, and present non-mineralized structures with organic flakes and mineralized forms with calcium carbonate plates (van den Hoek *et al*., 1995, Young *et al*., 1997). Coccolithophores are one of the major groups of primary producers that use carbon dioxide dissolved in the ocean to produce $CaCO_3$, and constitute a very conspicuous and diverse group of microalgae (Marsh, 2003). At Alfonso Basin, coccolith fluxes contributed up to 23 % of the C_{inorg} flux (Silverberg *et al*., 2007).

In the Pacific Ocean, Okada & Honjo (1973) reported more than 90 species from six areas with different oceanographic settings. In the north Pacific Central Gyre, Reid (1980) described 44 taxa of coccolithophores. In contrast, at the time-series station ALOHA in Hawaii, Cortés *et al*. (2001) reported 125 coccolithophores species in about three years of sampling. Hernández Becerril (2003) and Hernández-Becerril & Parra-Toriz (2015) reported 38 and 44 coccolith taxa from the Mexican Pacific. Meanwhile, Sidón-Ceseña *et al*. (2013) identified 61 coccolithophore taxa during a year sampling period at Alfonso Basin Gulf of California.

At Alfonso Basin *Gephyrocapsa oceanica* Kamptner 1943, *Emiliania huxleyi* (Lohmann 1902) and *Florisphaera profunda* Okada & Honjo, 1973 are the most abundant species in the water column from 0 to 75 m. *E. huxleyi* was the most abundant species in winter-spring (28%), alternating with *G. oceanica* in late autumn-winter (43%; Cortés *et al*., 2007). Coccolithophore studies from sediment trap samples in the same area showed a seasonal pattern with a minimum flux of 52.4 x10^8 coccolith /m^2/day in spring-autumn and maxima flux of 128.8 x10^8 coccolith /m^2/day in autumn-winter (Cortés *et al*., 2007, Silverberg *et al*., 2007; Rochín-Bagaña *et al*., 2013). This pattern reflects the strong seasonality of the sea surface temperature that ranges from 19.7 °C in February to 30 °C in August (Verdugo *et al*., 2014).

Here we present the coccolithophores composition identified in 16 samples from the water column in Alfonso Basin (24 ° 39 'N, 110 ° 36' W) collected in January, May, and August 2008. Seawater was collected with Niskin bottles at six water depths (0, 15, 30, 45, 60, 75 m; note that during August, only four depths were recovered), following the JGOFS protocol for hydrocasts (IOC, 1994) and modified for coastal regions. The water samples were filtered immediately according to the methodology of Bollmann *et al*. (2002). The samples were sputtered with gold and analyzed using a Hitachi S-2300 Scanning Electron Microscope in the Electron Microscopy Laboratory of the Autonomous University of Baja California Sur (Bollmann *et al*., 2002). Species identification was according to Young *et al.* (2017) and references therein. Species richness and the Berger – Parker Index "d" (dominance) were used as a simple measure of diversity (Magurran 1988). The inverse of the Berger – Parker Index was used to compare the grade of uniformity of the community of different samples (Magurran 1988). Sea Surface Temperature for the sampled period was taken from the 8-day composites of Modis Aqua (Silverberg *et al*., 2014).

In the present study, 27 coccolithophore taxa were identified as belonging to nine families and 16 genera (Young *et al*., 2003; Table 1). Some of the well-preserved coccolithophore specimens found during this study are illustrated in Fig. 1. In general, a similar number of coccolith taxa were identified during January and May 2008 (16 and 15 respectively), while in August, only eight coccolithophore taxa were found (Table 1). *E. huxleyi* and *G. oceanica* were the most abundant species during the sampling period (Fig. 2). However, *E. huxleyi* was the dominant species (>68 %) in the entire water column in January (SST 19°C,

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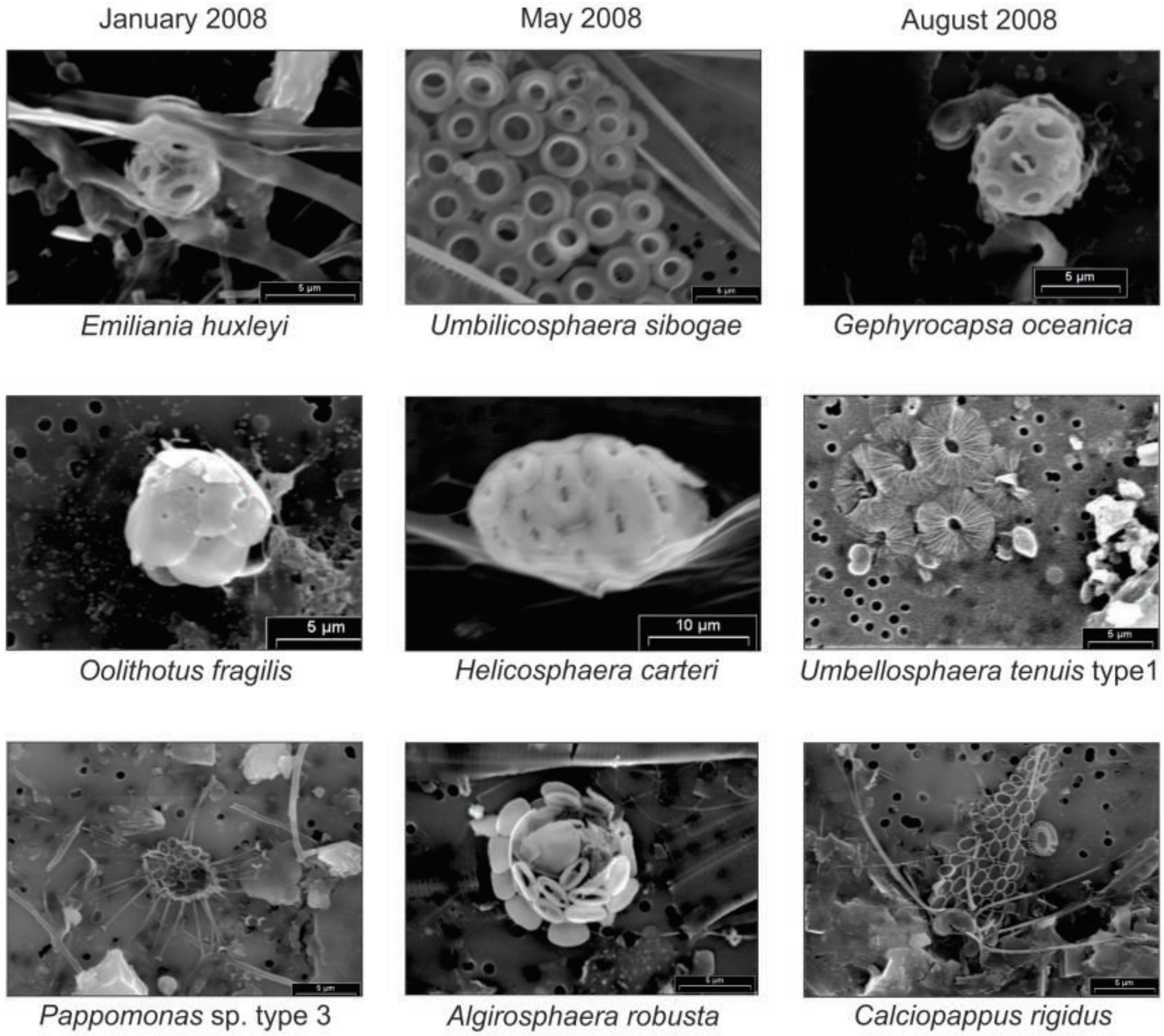

Figure 1. Best preserved coccolithophore species present in the water column at Alfonso Basin, Bay of La Paz, Baja California Sur, in January 2008 (*Emiliania huxleyi* (60 m), *Oolithotus fragilis* (75 m), *Pappomonas* sp. type 3 (75 m), May 2008 (*Umbilicosphaera sibogae* (30 m), *Helicosphaera carteri* (30 m), *Algirosphaera robusta* (45 m) and August 2008 (*Gephyrocapsa oceanica* (0 m), *Umbellosphaera tenuis* type 1 (0 m), *Calciopappus rigidus* (30 m).

cold conditions), while *G. oceanica* dominated (69%) in August (SST 30°C, warm conditions; Fig. 2). *Calciopappus rigidus* (Murray et Blackman) Loeblich Jr. et Tappan, 1978 and *E. oceanica* were both the most abundant species at 30m in August, although the first one was present only in 3 of the 16 samples. During May, *E. huxleyi* was the most abundant species in the most in-depth samples, and *G. oceanica* tends to dominate the shallow samples (Fig. 2).

Additionally, some coccolithophore species were present only during a specific time of the year (Table 1). For example, *Oolithotus fragilis* (Lohmann 1912) Martini & Müller, 1972, *Syracosphera didyma* Kleijne & Cros 2009, and *Anthosphaera* spp were found only during January, whereas *G. ericsonii* and *Umbellosphaera tenuis* Kleijne, 1993 were found in August, corresponding to warm conditions. *Ophiaster hydroideus* (Lohmann 1903) Lohmann, 1913 and *Umbillicosphaera sibogae* (Weber-Van Bosse) Gaarder, 1970 were present in January-May or May-August. This pattern could be explained by the transition from cold to warm conditions during May.

The results presented here are similar to those reported by Cortés *et al*. (2007), who indicated that the dominance of *E. huxleyi* and. *G. oceanica* alternate between winter-spring (Cold) and late summer-early autumn (warm). However, the coccolithophore species *Scyphosphaera apsteinii* and *Reticulofenestra sessilis* in association with the *Thalassiosira* diatom species were not found in this study although these species have been reported from nearby Bahía de La Paz, West coast of Baja California (Gárate-Lizárraga, 2012; López-Fuerte *et al*., 2015). The reason for this is unknown but may be related to different oceano-

Table 1. Coccolithophore taxa found during the sampling period in Alfonso Basin. * indicates the presence of the taxa per month.

Taxon	January	May	August
Order ISOCHRYSIDALES Young & Bown 1997			
NOËLAERHABDACEAE			
Emiliania Hay et Mohler in Hay et al. 1967			
Emiliania huxleyi (Lohmann 1902) Hay et Mohler in Hay et al., 1967	*	*	*
Gephyrocapsa Kamptner 1943			
Gephyrocapsa ericsonii McIntyre & Bé, 1967			*
Gephyrocapsa oceanica Kamptner 1943	*	*	*
Order COCCOSPHAERALES Haeckel 1894 emend Young & Bown 1997			
CALCIDISCACEAE Young & Bown 1997			
Calcidiscus Kamptner 1950			
Calcidiscus leptoporus (Murray et Blackman) Loeblich Jr. et Tappan, 1978		*	*
Oolithotus Reinhart in Cohen & Reinhart 1968			
Oolithotus fragilis (Lohmann 1912) Martini & Müller, 1972	*		
Umbilicosphaera Lohmann 1902			
Umbilicosphaera sibogae (Weber-Van Bosse) Gaarder, 1970		*	*
Order ZYGODISCALES Young & Bown 1997			
HELICOSPHAERACEAE Black			
Helicosphaera Kamptner 1954			
Helicosphaera carteri (Wallich 1877) Kamptner 1954		*	
Order SYRACOSPHAERALES Hay 1977 emend.			
SYRACOSPHAERACEAE (Lohmann 1902) Lemmermann 1903			
Calciopappus Gaarder et Ramsfjell emend. Manton & Oates, 1983			
Calciopappus rigidus Heimdal, in Heimdal & Gaarder 1981	*		
Coronosphaera Gaarder in Gaarder & Heimdal, 1977			
Coronosphaera sp.		*	
Syracosphaera Lohmann 1902			
Syracosphaera didyma Kleijne & Cros 2009	*		
Syracosphaera orbiculus Okada & McIntyre 1977		*	
Syracosphaera pirus Halldal & Markali 1955.		*	
Syracosphaera Gaarder, in Gaarder & Hasle 1971 ex Jordan, 1994	*	*	
Syracosphaera pulchra Lohmann, 1902 HOL oblonga type, sensu Young et al., 2003	*		
Ophiaster Gran, 1912			
Ophiaster hydroideus (Lohmann 1903) Lohmann, 1913	*	*	
RHABDOSPHAERACEAE Haeckel, 1894			
Algirosphaera Schlauder, emend. R. E. Norris, 1984			
Algirosphaera robusta (Lohmann 1902) Norris, 1984	*	*	*
INCERTAE SEDIS			
PAPPOSPHAERACEAE Jordan & Young 1990			
Papposphaera Tangen, 1972			
Papposphaera lepida Tangen, 1972	*	*	

Table 1. Continued.

Taxon	January	May	August
Papposphaera type 2 Cros & Fortuño 2002	*		
Papposphaera type 3 Cros & Fortuño 2002		*	
Pappomonas Manton et Oates 1975			
Pappomonas sp. type 3 Cros & Fortuño 2002	*		
Pappomonas sp. type 4 Cros & Fortuño 2002	*		
Pappomonas sp. type 5 Cros & Fortuño 2002	*		
Pappomonas sp.		*	
UMBELLOSPHAERACEAE Young & Kleine			
Umbellosphaera Paasche in Markali & Paasche 1955			
*Umbellosphaer*a *tenuis type I sensu* Kleijne 1993			*
NANOLITOS INCERTAE SEDIS			
Florisphaera Okada & Honjo, 1973			
Florisphaera profunda Okada & Honjo, 1973		*	*
Florisphaera profunda var *rhinocera* Quinn, Cortés & Bollman, 2005.		*	
CALIPTROSPHAERACEAE Boudreaux, J.E. & Hay, W.W., (1969)			
Anthosphaera Kamptner, 1937			
Anthosphaera sp.	*		
Total Nr. Species	15	16	8

graphic conditions or the use of different methods. Bollmann *et al*. (2002) reported that large but rare coccolithophore species (such as *Scyphosphaera apsteinii*) are more frequently found using the Uthermohl settling technique (light microscope) compared to Scanning Electron Microscopes techniques. With the first technique, a larger volume of water is analyzed, and therefore, the probability is higher to detect rare species. However, small species are often overlooked because of the lower magnification of the light microscope. Ongoing research will reveal whether the observed seasonal variation of species abundance is a reoccurring pattern or whether it changes over several years.

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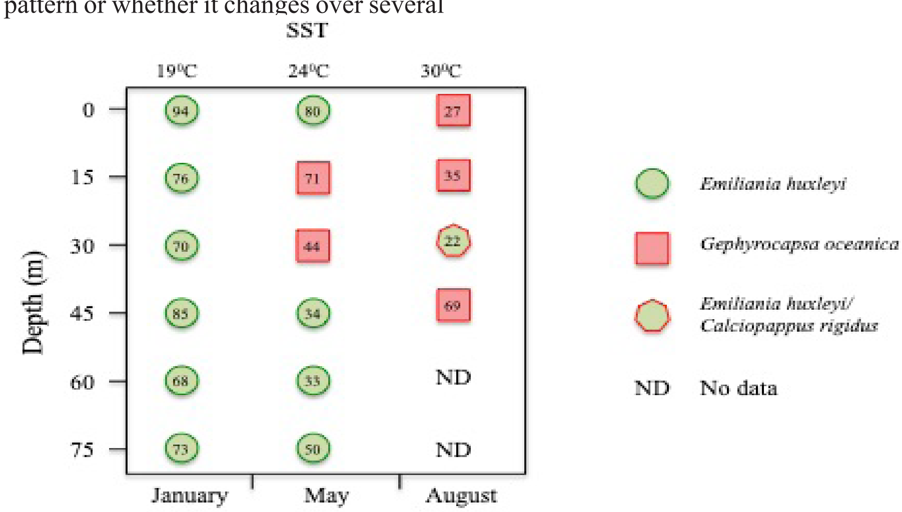

Figure 2. Vertical distribution of the grade of uniformity (1/Berger-Parker index) in the community. The most abundant species at each sampling depth are also shown.

Tabla 2. Coccolithophore Species Richness during January, May, and August 2008. ND = No data.

Depth (m)	January		May		August	
	Nr. Ind	SR	Nr. Ind	SR	Nr. Ind	SR
0	101	4	10	2	22	7
15	29	4	7	2	17	5
30	77	8	16	5	65	13
45	40	6	58	11	13	3
60	38	3	15	7	ND	ND
75	22	4	26	6	ND	ND

REFERENCES

Bollmann, J., M.Y. Cortés, A.T. Haidar, B. Brabec, A. Close, R. Hofmann, S. Palma, L. Tupas, & H.R. Thierstein. 2002. Techniques for quantitative analyses of calcareous marine phytoplankton. *Mar Micropaleontol*, 44: 163-185. https://doi.org/10.1016/S0377-8398(01)00040-8.

Cortés, M.Y., J. Bollmann & H.R. Thierstein. 2001. Coccolithophore ecology at the HOT station HOT, Hawaii. *Deep-Sea Res PT II*, 48: 1957-1981. https://doi.org/10.1016/S0967-0645(00)00165-X.

Cortés, M.Y., Bollmann, J., Cervantes-Duarte, R., Silverberg, N., 2004. Living coccolithophores at the marginal Basin Alfonso at Bay of La Paz, Gulf of California. *J Nannoplank Res.*, 26 (2), 22. https://ui.adsabs.harvard.edu/abs/2007AGUSMOS32A..05C

Cortés, M. Y., F. J. Urcádiz-Cázares, N. Silverberg, F. Aguirre-Bahena & J Bollmann. 2007. *Coccolithophore Dynamics in Alfonso Basin: Seasonal Variation and Species Composition*. A conference presented at the meeting 2007 of the *American Geophysical Union*, Spring Meeting 2007. Abstract id. # 2007AGUSMOS32A..05C.

Gárate-Lizárraga, I. 2012. Proliferation of *Amphidinium carterae* (Gymnodiniales: Gymnodiniaceae) in Bahía de La Paz, Gulf of California. *CICIMAR Oceánides*, 27(2): 37-49.

Hernández-Becerril, D.U. 2014. Biodiversidad de algas planctónicas marinas (Cyanobacteria, Prasinophyceae, Euglenophyta, Chrysophyceae, Dictyochophyceae, Eustigmatophyceae, Parmophyceae, Raphidophyceae, Bacillariophyta, Cryptophyta, Haptophyta, Dinoflagellata) en México. Revista Mexicana de biodiversidad. 86: 44-53. https://doi.org/10.7550/rmb.32037.

Hernández-Becerril, D.U. & D. Parra-Toriz. 2015. Catálogo de especies de fitoplancton marino del Pacífico Mexicano. Universidad Nacional Autónoma de México. Instituto de Ciencias del Mar y Limnología. Informe final SNIB- CONABIO, proyecto No. KT006. México D. F.

Intergovernmental Oceanography Commission. 1994. Protocols for the Joint Global Ocean Flux Study (JGOFS) Core Measurements, *IOC Manuals and Guides 29*, UNESCO, Paris.

López-Fuerte, F.O., I. Gárate-Lizárraga, D.A. Siqueiros-Beltrones & R. Yabur. 2015. First record and geographic range extension of the coccolithophore *Scyphosphaera apsteinii* Lohman, 1902 (Haptophyta: Pontosphaeraceae) from the Pacific coast of Mexico. *Check List* 11(5): 1-3. https://doi.org/10.15560/11.5.1754

Magurran, A. E. 1988. *Ecological diversity and its measurements*. Cambridge University Press, Cambridge, 175 pp.

Marsh, M.E. 2003. Regulation of $CaCO_3$ formation in coccolithophores. *Comp Biochem Phys B*, 136: 743–754. https://doi.org/10.1016/S1096-4959(03)00180-5.

Okada, H. & S. Honjo. 1973. The distribution of oceanic coccolithophorids in the Pacific. *Deep-Sea Res,* 20: 55-374. https://doi.org/10.1016/0011-7471(73)90059-4.

Reid, F.M.H. 1980. Coccolithophorids from the North Pacific central gyre with notes on their vertical and seasonal distribution. *Micropaleontology*, 26: 151-176. https://doi.org/10.2307/1485436

Rochín-Bañaga, H., M.Y. Cortés, F. Aguirre Bahena, N. Silverberg & J. Bollmann. 2013. Aporte de carbonato de calcio en Cuenca Alfonso mediante el flujo de nanoplancton calcáreo. *Resumen del XIII Congreso de la Asociación de Investigadores del Mar de Cortés y VII Simposium Internacional sobre el Mar de Cortés* (8 - 12 de Abril, 2013, Ensenada, Baja California, México). p. 162-163.

Sidón-Ceceña K., M.Y. Cortés, F. Aguirre-Bahena, N. Silverberg & J. Bollmann. 2013. Coccolithophore assemblage composition and cell densities at Alfonso Basin, Gulf of California. *J Nannoplank Res.*, Special Issue, 33: 111.

Silverberg, N., F. Aguirre-Bahena, M.Y. Cortés-Martínez & F. Urcádiz-Cázares. 2007. Flujos verticales de carbono orgánico e inorgánico particulado en Cuenca Alfonso, Bahía de La Paz, y comparación con otros ambientes en el norte de México. *In*: B. Hernández de la Torre, G. Gaxiola Castro (Eds.), *Carbono en Ecosistemas Acuáticos de México*, INE, México (2007), pp. 414–425.

Silverberg, N., F. Aguirre-Bahena & A. Mucci. 2014. Time-series measurements of settling particulate matter in Alfonso Basin, La Paz Bay, southwestern Gulf of California. *Cont Shelf Res.,* 84: 169-187. https://doi.org/10.1016/j.csr.2014.05.005.

van den Hoek, C., D.G. Mann & H.M. Jahns. 1995. *Algae. An introduction to phycology*. Cambridge University Press, Cambridge, England. 623 p.

Verdugo-Díaz, G. Martínez-López, A. Villegas-Aguilera, M.G., and Gaxiola-Castro G. 2014. Producción primaria y eficiencia fotosintética en Cuenca Alfonso, Bahía de La Paz, Golfo de California, México. *Rev Biol Mar Oceanog*. 49(3): 527-536.

Young, J.R., J.A. Bergen, P.R. Bown, J.A. Burnett, A. Fiorentino, R.W. Jordan, A. Kleijne, B.E. van Niel, A.J.T. Romein & K. von Salis. 1997. Guidelines for coccolith and calcareous nannofossil terminology. *Paleontology*, 40(4): 875-912.

Young, J.R., P.R. Bown & J.A. Lees. 2017. Nannotax3 website. International Nannoplankton Association. Accessed 21 Apr. 2017. URL: http://www.mikrotax.org/Nannotax3.

Young, J. R., M. Geisen, L. Cros, A. Kleijne, I. Probert y J. B. Ostergaard. 2003. A guide to extant coccolithophore taxonomy. *J Nannoplank Res.*, Special Issue 1: 1-132.