UNIVERSIDAD AUTÓNOMA METROPOLITANA
Casa abierta al tiempo
Unidad Iztapalapa

HIDROBIOLÓGICA
http:/hidrobiologica.izt.uam.mx
ISSN: 2448-7333

OPEN ACCESS
Research Article
April, 2020

Composition and abundance of macro zooplankton in the coastal waters off the El Mogote Sandbar

Composición y abundancia de macro zooplancton en aguas costeras de El Mogote

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Recibido: 08 de noviembre de 2018. *Aceptado:* 18 de febrero de 2020. *Publicado:* abril de 2020.

ABSTRACT

Background. Bahía de la Paz, Mexico have seasonal blooms of planktonic prey that support a range of marine species including whale sharks (*Rhincodon typus)*. **Goals**. This study includes the first sampling cycle that covers all climatic seasons, to know changes in the abundance and composition of zooplankton in the coastal waters off the El Mogote Sandbar, in Bahía de La Paz, BCS, Mexico. **Methods**. A total of 96 plankton samples were collected at predetermined field stations, spanning the entire length of the El Mogote from June 2016 to May 2017. **Results**. Total biomass was significantly different between seasons (Kruskal-Wallis chi-squared = 29.993, p = 0.000001385), with the lowest biomass recorded in spring (176.28 ml 100 m^{-3}, 10.1%); and highest observed for winter (703.04 ml 100 m^{-3}, 40.4%). Zooplankton composition was largely comprised of two main taxonomic groups: Copepoda (396,234 organisms100 m^{-3}, 43.1%) and Chaetognatha (196,986 organisms100 m^{-3}, 21.4%). The total number of individuals (sum of all taxonomic groups) per season showed significant differences (Kruskal-Wallis chi-squared = 29.78, p = 0.000001533) with the highest concentrations recorded in winter (292,429 organisms100 m^{-3}, 31.8%) and lowest in spring (162,995 organisms100 m^{-3}; 17.7%). **Conclusions**. This information provides the first work focused solely in the El Mogote area as a main foraging site for whale sharks, with clear changes in plankton communities with respect to shifting climatic seasons, and the importance of certain taxonomic groups to the diet of whale sharks.

Keywords: Bahía de La Paz, copepods, El Mogote, whalesharks, zooplankton

RESUMEN

Antecedentes. En la Bahía de la Paz, México se presentan proliferaciones de plancton estacionales que son presas potenciales de varias especies marinas incluyendo tiburón ballena (*Rhincodon typus*). **Objetivos**. En este estudio se presenta el primer ciclo de muestreo que cubre todas las temporadas climáticas, para conocer cambios en la abundancia y composición de zooplancton en aguas costeras de la barra de arena El Mogote en Bahía de La Paz, BCS, Mexico. **Metodología**. De junio 2016 a mayo 2017 se recolectaron 96 muestras de plancton en estaciones predeterminadas que cubren todo el largo de El Mogote. **Resultados.** La biomasa de zooplancton fue significativamente diferente entre temporadas (Kruskal-Wallis chi-cuadrada = 29.993, p = 0.000001385), la biomasa más baja se registró en primavera (176.28 ml 100 m^{-3}, 10.1%) y la más alta en invierno (703.04 ml 100 m^{-3}, 40.4%). El zooplancton estuvo compuesto principalmente por dos grupos taxonómicos: Copépodos (396,234 organismos100 m^{-3}, 43.1%) y Quetognatos (196,986 organismos100 m^{-3}, 21.4%). El número total de individuos (suma de todos los grupos taxonómicos) entre temporadas fue significativamente diferente (Kruskal-Wallis chi-cuadrada = 29.78, p = 0.000001533), las concentraciones más altas se registraron en invierno (292,429 organismos100 m^{-3}, 31.8%) y las más bajas en primavera (162,995 organismos100 m^{-3}; 17.7%). **Conclusiones**. Este es el primer trabajo enfocado exclusivamente al área de El Mogote como principal sitio de alimentación del tiburón ballena, con cambios estacionales claros en las comunidades de plancton y la importancia de ciertos grupos taxonómicos en la dieta del tiburón ballena.

Palabras clave: Bahía de la Paz, copépodos, El Mogote, tiburón ballena, zooplancton

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To quote as:
Whitehead D. A., U. Jakes-Cota, F. Galván-Magaña, F. Pancaldi & R. González-Armas. 2020. Composition and abundance of macro zooplankton in the coastal waters off the El Mogote Sandbar. *Hidrobiológica* 30 (1): 21-27.

DOI: 10.24275/uam/izt/dcbs/hidro/2020v30n1/Whitehead

INTRODUCTION

The Gulf of California is a highly productive area, characterized by having some of the highest surface nutrient concentrations of any ocean of the world (Santamaría-del-Ángel *et al.*,1994). Additionally, it experiences great changes in productivity both seasonally and spatially. During winter months, high biological productivity occurs, while in the summer months, there is very low productivity (Santamaría-del-Ángel *et al.,* 1994). These peaks in productivity are highly influenced by a number of hydrodynamic changes, caused in part by changes in local wind speed and its direction, and solar radiation, which is representative of a semi-arid dessert region with elevated rates of evaporation of its surface waters (Obeso-Nieblas *et al.,* 2007; Coria-Monter *et al.,* 2017). Furthermore, the Gulf of California is considered one of the most diverse seas of the world, inhabiting endemic and endangered or protected species, such as the whale shark (*Rhincodon typus* Smith, 1982).

In the Gulf of California, whale shark aggregations are known to occur in both Bahía de Los Ángeles and Bahía de la Paz (Eckert & Stewart, 2001; Ketchum *et al.,* 2013; Whitehead *et al.,* 2018, 2019) and seem to be related to high zooplankton abundance (Hacohen-Domené *et al.,* 2006; Nelson & Eckert, 2007). Initial work on prey preferences for the species have been investigated for Bahia de Los Ángeles (Nelson & Eckert, 2007; Lavaniegos *et al.,* 2012; Hernández-Nava & Álvarez-Borrego, 2013) and Bahía de La Paz (Clark & Nelson, 1997; Hacohen-Domené *et al.,* 2006; Ketchum *et al.*, 2013). Known prey items on which *R. typus* have been observed to forage on in the Gulf of California, include a number of copepod species, mainly *Acartia clausi*, *Acartia* spp. and members the Euphausiidae family, such as *Nictiphanex simplex* (Clark & Nelson, 1997; Hacohen-Domené *et al.,* 2006; Hernández-Nava & Álvarez-Borrego, 2013; Ketchum *et al.,* 2013).

Bahía de La Paz is the largest coastal water body in the Gulf of California with an approximate area of 2,635 km^2 and boasting both shallow and deep-water basins (Cruz-Orozco *et al.,*1996; Sánchez-Velasco *et al.,* 2006). Connectivity of the bay and its circulation is driven primarily by water exchange with the Gulf of California, which occurs by two passages, a northeasterly channel named Boca Grande and towards the southern part of the bay connectivity through the San Lorenzo Channel (Hernández-Trujillo *et al.,*1987; Monreal-Gómez *et al.,* 2001).

Ketchum *et al.* (2013), examined the foraging ecology of whale sharks in Bahía de La Paz and observed that plankton biomass varies seasonally, with the lowest in May and June and peaks of biomass occurring in November and February and all samples comprised of a mix of holoplankton and meroplankton taxonomic groups (Ketchum *et al.,* 2013). Earlier examinations of the composition of zooplankton present in Bahía de La Paz have shown that a number of species have a higher level of abundance during certain times of the year (Clark & Nelson, 1997; Hacohen-Domené *et al.,* 2006). Clark and Nelson (1997) witnessed a high density of copepods in the southern parts of the bay and reported that in this area composition seems to comprise mainly of *Acartia clausi* and *Acartia* sp. during the fall (Clark & Nelson, 1997; Hacohen-Domené *et al.,* 2006).

The area to the southern part of Bahía de La Paz, BCS, Mexico, encompasses a protruding sandbar attached at one end to the mainland and stretching out approximately 12 km parallel to the mouth of the bay, known as the El Mogote sandbar. The natural formation of this sandbar has created almost two separated bodies of water: the main bay itself and the inlet or lagoon known as the Ensenada de la Paz (León-de la Luz *et al.,* 2006). El Mogote covers an approximately 16 km^2 of surface vegetation comprised mainly of a sandy coastal environment with periodic patches of mangroves on its inlet side (León-de la Luz *et al.,* 2006). This region of Bahía de La Paz is thought to be influenced by its orientation to the mouth of the bay and changing environmental factors which occur throughout the year, such as seasonal changes in wind direction and magnitude and the circulation a central mesoscale cyclonic eddy, which is suspected to influence the horizontal distribution of all trophic groups of zooplankton in the bay (Durán-Campos *et al.,* 2015). This highly productive coastal zone experiences both primary and secondary productivity of planktonic species and is a known as the principle area for seasonally aggregating whale sharks (Ketchum *et al.,* 2013; Ramírez-Macías *et al.,* 2012; Whitehead *et al.,* 2019). Our study aimed to generate the first sampling annual cycle that covers all fours climatic seasons, to investigate changes in the overall abundance and composition of zooplankton members in the coastal waters off the El Mogote Sandbar, a foraging ground for juvenile whale sharks.

MATERIALS AND METHODS

Plankton trawls. A total of 96 zooplankton tows were routinely collected every two consecutive weeks from June 2016 through to May 2017 completing a full 12-month cycle of sampling in the coastal waters of the El Mogote sandbar. Plankton trawls were conducted at four predetermined sample stations, registered by GPS coordinates and encompassing the entire length of the el Mogote sandbar (Fig.1). All tows were performed in the surface waters using a 505 µm mesh plankton net with a 60 cm diameter mouth with a flowmeter and towed for five minutes behind the boat in a circular motion at approximately 1-1.5 knots h^{-1} for the capture of macro zooplankton. Upon the net being removed from the water, records of the flowmeter rotations were reported and collected prey items were washed down into the collecting container at the end, fixed with a 4 % formaldehyde solution buffered with borax, labeled for identification and stored in plastic screw top containers. The total volume of wet zooplankton was determined by using the displacement method (Beers, 1976) and the wet biomass was standardized using the standard biomass formula and the records collected from the flowmeter instrument to 100 m^3 (Smith & Richards, 1979). Total biomass was divided into four climatic seasons: 1) summer (June, July and August), 2) autumn (September, October, November), 3) winter (December, January, February) and 4) spring (March, April, May).

Counting of prey items. Enumeration of organisms was done by extracting a subsample using a Stempel pipette, then calculating the total faunal count for the whole sample. Zooplankton was grouped into eight taxonomic groups: Cladocera, Copepoda, Chaetognatha, Euphausiidae, Hydrozoa, Decapoda, Fish larvae and “Other”. After zooplankton was assembled into groups, individuals were counted and standardized to obtain the total number of individuals (No. 100 m^{-3}) for each sample and ultimately an overall total number of individuals of planktonic groups for each climatic season.

Statistical Analysis. Following the collection and organization, data was analyzed in the statistical program R (R-Core Team, 2018) using non-parametric statistics with a Kruskal-Wallis one-way analysis of variance test as a means to investigate any significant differences in the total biomass of zooplankton and the total number of individuals

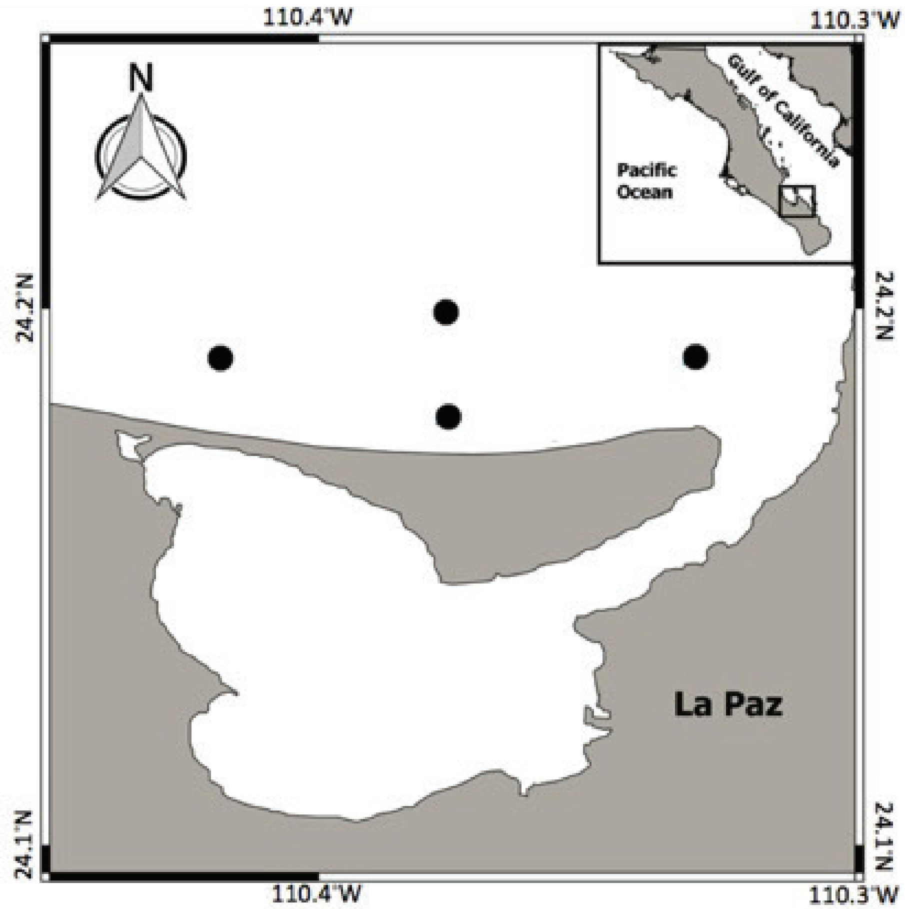


Figure1. Study area showing sample stations (black circles) along the El Mogote sandbar in Bahía de la Paz, BCS, Mexico.

between climatic seasons and between taxonomic groups. Following this, a post-hoc Dunn test was applied to further explore were the variance exists within the total biomass and composition of zooplankton in collected samples.

RESULTS

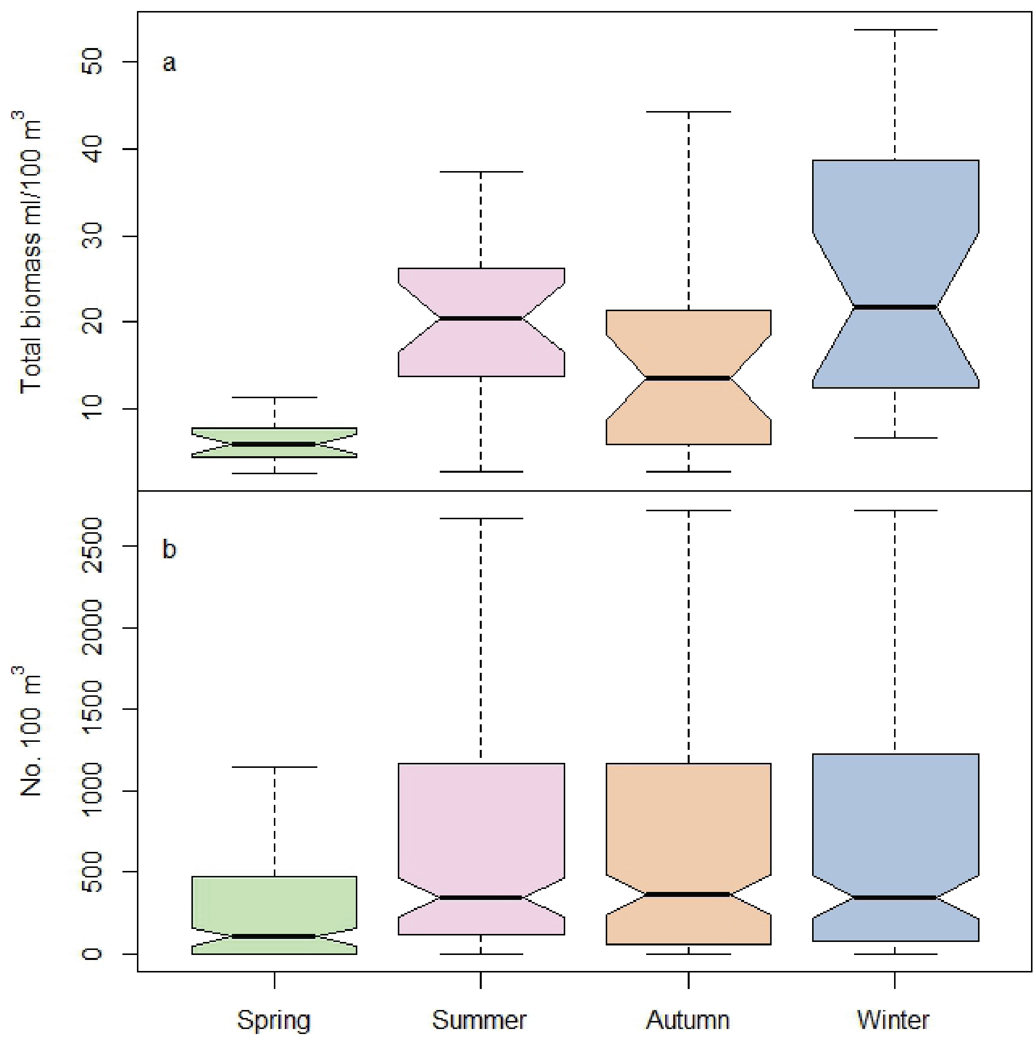
Zooplankton Biomass. A seasonal shift in the overall biomass of zooplankton was observed during the study period with the lowest zooplankton biomass recorded in spring (176.28 ml 100 m^{-3}, 10.1%), while the highest values were observed for winter (703.04 ml 100 m^{-3}, 40.4%), followed by summer (493.92 ml 100 m^{-3}, 28.4%) and autumn (366.57 ml 100 m^{-3}, 21.1%) (Fig. 2a). A Kruskal-Wallis one-way analysis of variance test did show a statistically significant difference in total biomass between seasons (Kruskal-Wallis chi-squared = 29.993, p =0.000001385). A Post Hoc Dunn-Test revealed significant differences between almost all seasons, except for summer compared to autumn and winter (Table 1).

Zooplanktonic groups. Overall composition was largely comprised of three main taxonomic groups: Copepoda presented the highest concentrations of individuals (396,234 No. 100m^{-3}) accounting for 43.1% of the overall composition, followed by Chaetognatha (196,986 No. 100m^{-3}) 21.4% of the composition and Decapoda (116,513 No. 100m^{-3}) 12.6% of the composition, with the remaining five groups showing the lowest concentrations of individuals: Hydrozoa (50,475 No. 100m^{-3}) 5.4%, Cladocera (47,986 No. 100m^{-3}) 5.2%, Fish Larvae (40,906 No. 100m^{-3}) 4.4%, Other (36,625 No. 100m^{-3}) 3.9% and Euphausiida (33,967 No. 100m^{-3}) 3.7%. The total number of individuals (sum of the eight taxonomic groups) per season also showed significant differences (Kruskal-Wallis chi-squared = 29.78, p =0.000001533). The highest concentration of individuals was recorded in winter (292,429 No. 100 m^{-3}) accounting for 31.8% of the total amount of all individuals, followed by summer (243,489 No. 100 m^{-3}) 26.4% of individuals, autumn (220,779 No. 100 m^{-3}) 24% of individuals and spring (162,995 No. 100 m^{-3}) 17.7% of individuals (Fig. 2b). Results from the Post Hoc Dunn-Test explained that the difference in the number of individuals between seasons occurred in spring when compared to the other seasons (Table 2). In spring, the total number of individuals between taxonomic groups was significantly different (Kruskal-Wallis chi-squared = 84.615, p =1.571e^{-15}), with dominant taxonomic group being Copepoda (106,059 No. 100 m^{-3}, 65%), followed by Chaetognatha (25,282 No. 100 m^{-3}, 15.5%) and Fish Larvae (12,617 No. 100 m^{-3}, 7.7%) (Fig. 3).

Table 1. Post Hoc Dunn-Test results of the comparison of total zooplankton biomass between seasons presenting z-values in the lower section & *p*-values in upper section in the El Mogote in Bahía de La Paz, BCS, Mexico.

	Spring	Summer	Autumn	Winter
Spring		0.0000	0.0186	0.0000
Summer	-4.300605		0.0892	0.2309
Autumn	-2.601088	1.699516		0.0223
Winter	-5.036371	-0.735766	-2.435282	

In summer, the total number of individuals between taxonomic groups was also significantly different (Kruskal-Wallis chi-squared = 53.603, $p = 2.818e^{-09}$). Copepoda (73,307 No. 100 m^{-3}, 30.1%) remained as the dominant taxonomic group followed by Decapoda (49,347 No. 100 m^{-3}, 20.2%), Chaetognatha (42,475 No. 100 m^{-3}, 17.4%) and Cladocera (37,940 No. 100 m^{-3}, 15.6%) (Fig. 3). In autumn, the total number of individuals between taxonomic groups was also significantly different (Kruskal-Wallis chi-squared = 72.406, $p = 3.02e^{-13}$) revealing Chaetognatha (75,420 No. 100 m^{-3}, 34.1%) to be the dominant taxonomic group followed by Copepoda (60,745 No. 100 m^{-3}, 27.5%) and Decapoda (27,605 No. 100 m^{-3}, 12.5%) (Fig. 3). Finally in winter, the total number of individuals between taxonomic groups was again significantly different (Kruskal-Wallis chi-squared = 84.615, $p = 1.571e^{-15}$) with the dominant taxonomic group being Copepoda (156,122 No. 100 m^{-3}, 53.3%) followed by Chaetognata (53,807 No. 100 m^{-3}, 18.4%) and Decapoda (30,335 No. 100 m^{-3}, 10.3%) (Fig. 3).



Figures 2a-b. a) Seasonal averages of total zooplankton biomass in the waters off the El Mogote in Bahía de la Paz, BCS, Mexico; b) Seasonal average of the total number of individuals (sum of the eight taxonomic groups) in the waters off the El Mogote in Bahía de la Paz, BCS, Mexico.

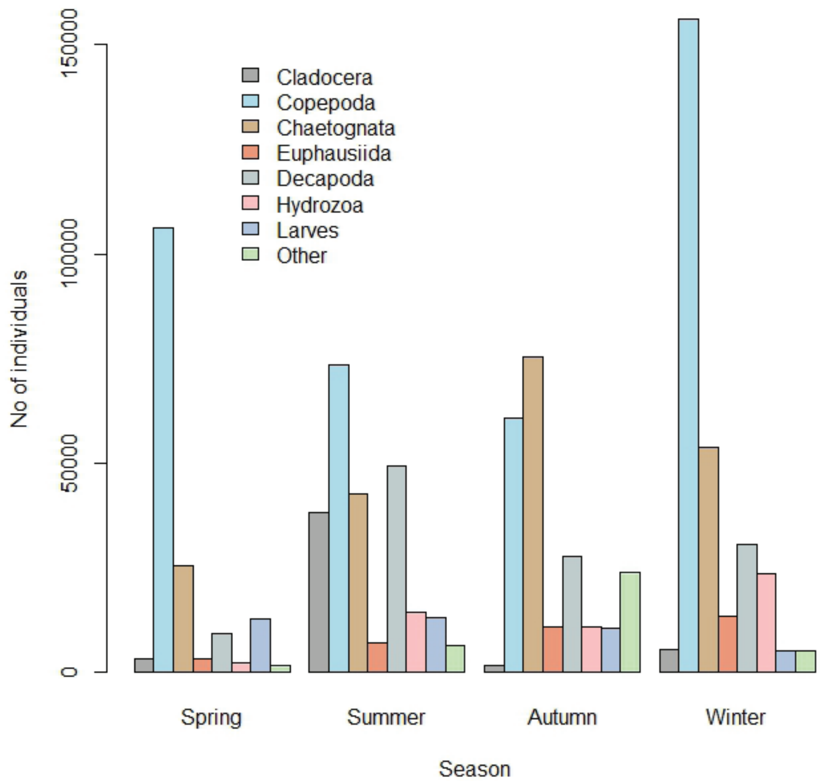


Figure 3. Number of individuals per taxonomic group per season in the waters off the El Mogote sandbar in Bahía de La Paz, BCS, Mexico.

DISCUSSION

Understanding the productivity of a specific habitat, mainly at the base of the food web, may help to provide important information on the foraging behaviors of marine organisms that depend on it. A seasonal shift in the total biomass of zooplankton prey items was observed in our data, revealing that the largest accumulation of zooplankton biomass in the coastal waters of the El Mogote occurs in the winter months and lowest concentrations in the months around spring. An early study by Jiménez-Pérez & Lara-Lara (1988) examined zooplankton biomass and copepod community structure in the Gulf of California and in their observations showed that this region seems to present two unique community assemblages that may be related to different environmental factors caused by the shifting of climatic seasons that drive productivity in the entire region. Aggregations of whale sharks within the El Mogote area seem to be seasonal and have been documented to occur with a maximum peak during the winter months (Ramírez-Macías *et al.,* 2012; Whitehead *et al.,* 2019). Ketchum *et al.* (2013) mentioned the segregation and foraging of whale shark in the southern Gulf of California, also reported seasonal correlation of juvenile whale sharks with zooplankton biomass in the coastal waters off the El Mogote. Whale shark aggregations and its correlation with changes in the abundance of available food sources has also been observed in other regions of the Gulf of California, such as Bahía de Los Angeles in the autumn months (Nelson & Eckert, 2007) and in the Gulf of Mexico in the summer (Hoffmayer *et al.,* 2007; Motta *et al.,* 2010). The size of the annual aggregation of juvenile whale sharks in Bahía de La Paz is suspected to be around 70 individuals (Whitehead *et al.*, 2019), but this number seems to vary among seasons and may be influenced by the presence of importance sources of macro zooplankton. An earlier study by Ketchum (2003), proposed that the populations of whale sharks in Bahía de La Paz may be highly influenced by seasonal and inter-annual changes and anomalies of oceanographic patterns in the Gulf of California, such as El Niño years and annual hurricanes in the region. Seasonal changes in this region such as wind direction and magnitude may alter the natural circulation of the mesoscale cyclonic eddy in coastal waters, which is suspected to influence the entire horizontal distribution of macro groups of zooplankton as previously reported (Durán-Campos *et al.,* 2015).

Table 2. Post Hoc Dunn-Test results of the comparison of the total number of individuals between seasons presenting z-values in the lower section & p-values in upper section in the El Mogote in Bahía de La Paz, BCS, Mexico.

	Spring	Summer	Autumn	Winter
Spring		0.0000	0.0001	0.0000
Summer	-4.7535		0.6417	0.4019
Autumn	-3.9606	0.7929		0.5861
Winter	-4.5050	0.2484	-0.5444	

Zooplankton composition in our study showed an overall dominance to the Copepoda. Absolute values of these individuals did show a significant difference throughout climatic seasons with a peak in the number of individuals recorded in the winter months and the peak of the seasonal aggregation of whale sharks (Whitehead *et al.,* 2019). Similar work on zooplankton and the foraging ecology of whale sharks in Bahía de La Paz have documented high concentrations of copepods during the autumn and winter months (Palomares-García, 1996; Hacohen-Domené *et al.,* 2006; Ketchum *et al.,* 2013). Observations of juvenile whale sharks foraging on dense patches of zooplankton comprising of more than 90% Copepoda species in the southern regions of the bay near San Juan de la Costa (Clark & Nelson, 1997), and concentrations of up to 80% Copepoda species in the waters in front of the El Mogote (Hacohen-Domené *et al.,*2006) similar to our results. Likewise, in Bahía de Los Angeles a study focused on analyzing the composition of zooplankton, also reported a dominance of copepods, mainly in areas where whale sharks were sighted (Hernández-Nava & Álvarez-Borrego, 2013). Daily or monthly changes in prey items within Bahía de La Paz and around the coastal waters of the El Mogote is highly influenced by its connectivity with water from the Gulf itself, which has been shown to be the main driving factor motivating water exchange (Monreal-Gómez *et al.,* 2001).

Historical reports from aggregations in the upper gulf (Hernández-Nava & Álvarez-Borrego, 2013; Nelson & Eckert, 2007) and Bahía de La Paz (Hacohen-Domené *et al.,* 2006; Ketchum *et al.,*2013) together with our current report strongly support the perception that the presence of whale sharks is highly related to the number of Copepoda species available and that these planktonic organisms play an important role in the dietary preference of whale sharks in the entire Gulf of California. The presence of juvenile whale sharks coupled with the occurrence of an abundant food supply off the coastal waters of the El Mogote sandbar provides a much needed refuge for the development and fast growth of juvenile sharks (Wintner, 2000; Ketchum *et al.,*2013; Whitehead *et al.,* 2019). Now as whale shark related tourism is on the increase in this specific area, it is vital that continued work to monitor and provide good management of this ever growing industry alongside scientific research may help to understand the influences seasonal climatic changes have on the availability of food and its visiting sharks. In conclusion, this paper provides the first complete annual zooplankton sampling focused exclusively in the coastal water of the El Mogote area, and exposing that there is a clear fluctuation in zooplankton biomass and communities with respect to shifting environmental conditions and a solid baseline of information for this important aggregation area.

ACKNOWLEDGEMENTS

Fieldwork was supported by Instituto Politecnico Nacional, Centro Interdisciplinario de Ciencias Marinas (CICIMAR), project´s SIP-20161235 and SIP-20170585 under the national permit for investigation by Secretaria de Medio Ambiente y Recursos Naturales (SEMARNAT). Thanks to CONACYT for study fellowships. FGM, RGA and UJC thanks to Instituto Politecnico Nacional for fellowships (COFAA, EDI). We also thank Dr. Hacohen for her comments and suggestions and all the volunteer participants during sampling trips for their help and effort with collections.

REFERENCES

Beers, J. R. 1976. Volumetric methods. *In:* Steedman, H. F. (ed.). Zooplankton Fixation and Preservation. *Monographs on Oceanographic Methods*, *Paris, Unesco 4: 54-60.*

Clark, E. & D. R. Nelson. 1997. Young whale sharks, *Rhincodon typus*, feeding on a copepod bloom near La Paz, México. *Environmental Biology of Fishes* 50: 63-73. DOI:10.1023/A:1007312310127

Coria-Monter, E., M. A. Monreal-Gómez, D. A. Salas de León, E. Durán-Campos & M. Merino-Ibarra. 2017. Wind driven nutrient and subsurface chlorophyll-*a* enhancement in the Bay of La Paz, Gulf of California. *Estuarine, Coastal and Shelf Science* 196: 290-300. DOI:10.1016/j.ecss.2017.07.010

Cruz-Orozco, R. C., C. Martínez-Noriega & A. Mendoza-Maravillas. 1996. Batimetría y sedimentos de la Bahía de La Paz, B.C.S. *Oceánides* 11 (1): 21-27.

Durán-Campos, L., D. A. Salas-de-León, M. A. Monreal-Gómez, J. Aldeco-Ramírez & E. Coria-Monter. 2015. Differential zooplankton aggregation due to relative vorticity in a semi-enclosed bay. *Estuarine*, *Coastal* and *Shelf Science* 164: 10-18. DOI:10.1016/j.ecss.2015.06.030

Eckert, S. A. & B. S. Steward. 2001. Telemetry and satellite tracking of whale shark *Rhincodon typus*, in the Sea of Cortez and the North Pacific Ocean. *Environmental Biology of fishes* 60: 299-308. DOI: 10.1023/A:1007674716437

Hacohen-Domené A., F. Galván-Magaña & J. Ketchum. 2006. Abundance of whale shark (*Rhincodon typus*) preferred prey species in the southern Gulf of California, Mexico. *Cybium* 30 (4): 99-102.

Hernández-Nava M. F. & S. Álvarez-Borrego. 2013. Zooplankton in a whale shark (*Rhincodon typus*) feeding area of Bahía de los Ángeles (Gulf of California). *Hidrobiológica* 23 (2): 198-208 Available on line at: http://www.scielo.org.mx/pdf/hbio/v23n2/v23n2a8.pdf

Hernández-Trujillo, S., A. Esquivel-Herrera & R. Saldierna-Martínez. 1987. Biomasa zooplanctónica en la costa oeste de Baja California Sur (1982-1985). *In:* Ramirez- Rodriguez, E. M. (ed.). *Memorias del Simposio en Investigaciones Biológicas, Oceanográficas y Pesqueras en México*, CICIMAR-IPN. La Paz, B.C.S, México, pp. 161-170.

Hoffmayer E. R., J. S. Franks, W.B. Driggers, K.J. Oswald & J. M. Quattro. 2007. Observations of a feeding aggregation of whale sharks, *Rhincodon typus*, in the north central Gulf of Mexico. *Gulf and Caribbean Research* 19: 69-74. DOI:10.18785/gcr.1902.08

Jiménez-Pérez, L. C. & J. R. Lara-Lara. 1988. Zooplankton biomass and copepod community structure in the Gulf of California during the 1982-1983 El Niño event. *California Current and fisheries Report* 12: 122-128.

Ketchum, J. T. 2003. Distribución espacio-temporal y ecología alimentaria del Tiburón ballena (*Rhincodon typus*) en la Bahía de la Paz y zonas adyacentes en el Suroeste del Golfo de California. Tesis de Maestría en Ciencias Marinas, Centro Interdisciplinario de Ciencias Marinas-IPN, La Paz, BCS, México. 91p

Ketchum, J. T., F. Galván-Magaña & P. Klimley. 2013. Segregation and foraging ecology of whale sharks, *Rhincodon typus*, in the southwestern Gulf of California. *Environmental Biology of Fishes* 96 (3): 779-755. DOI: 10.1007/s10641-012-0071-9

Lavaniegos, B. E., G. Heckel & P. Ladrón de Guevara. 2012. Seasonal variability of copepods and cladocerans in Bahía de Los Ángeles (Gulf of California) and importance of *Acartia clausi* as food for whale sharks. *Ciencias Marinas* 38 (1A): 11-30. DOI:10.7773/cm.v38i1A.1880

León-de la Luz, J., B. E. López-Romero & G. De la Cruz. 2006. Estructura y composición de la barra arenosa El Mogote, Baja california Sur, México. *Boletín de la Sociedad Botánica de México* 79: 21-32. DOI:10.17129/botsci.1730

Monreal-Gómez M. A., A. Molina-Cruz & D. Salas-de-León. 2001. Water masses and cyclonic circulation in Bay of La Paz, Gulf of California, during June 1998. *Journal of Marine Systems* 30: 305-315. DOI:10.1016/S0924-7963(02)00075-1

Motta, P. J., M. Maslanka, R. E. Hueter, R. L. Davis, R. de la Parra, S. L. Mulvany, M. L. Habegger, J. A. Strother, K. R. Mara, J. M. Gardiner, J. P. Tyminski & J. D. Zeigler. 2010. Feeding anatomy, filter-feeding rate, and diet of whale sharks *Rhincodon typus* during surface ram filter feeding off the Yucatán Península, Mexico. *Zoology* 113: 199-212. DOI:10.1016/j.zool.2009.12.001

Nelson, J. D. & S. A. Eckert. 2007. Foraging ecology of whale sharks (*Rhincodon typus*) within Bahía de Los Ángeles, Baja California Norte, Mexico. *Fisheries Research* 84: 47-64. DOI:10.1016/j.fishres.2006.11.013

Obeso-Nieblas, M., B. Shirasago-German, J. H. Gavino-Rodríguez, H. Obeso-Huerta, E. L. Pérez-Lezama & A. R. Jiménez-Illescas. 2007. Hydrography at the North Mouth of La Paz Bay, Baja California Sur, Mexico. *Ciencias Marinas* 33(3): 81-291. DOI:10.7773/cm.v33i3.1170

Palomares-García, J. R. 1996. Estructura espacial y variación estacional de los copépodos en la Ensenada de La Paz. *Oceánides* 11: 29-43.

Ramírez-Macías, D., A. Vázquez-Hakin & R. Vázquez-Juárez. 2012. Whale shark *Rhincodon typus* populations along the west coast of the Gulf of California and implications for management. *Endangered Species Research* 18: 115-128. DOI:10.3354/esr00437

R-Core Team. 2018. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. Available online at: http://www.r-project.org/

Sánchez-Velasco, L., E. Beier, C. Avalos-García & M. F. Lavin. 2006. Larval fish assemblages and geostrophic circulation in Bahía de La Paz and the surrounding southwestern region of the Gulf of California. *Journal of Plankton Research* 28 (11): 1-18. DOI:10.1093/plankt/fbl040

Santamaría-del-Ángel, E., S. Álvarez-Borrego & F. E. Muller-Karger. 1994. Gulf of California biogeographic regions based on coastal zone color scanner imagery. *Journal of Geophysical Research* 99 (C4): 7411-7421. DOI:10.1029/93JC02154

Smith, P. E. & S. L. Richards. 1979. *Standard techniques for pelagic fish eggs and larval surveys*. FAO, Rome. 100 p.

Whitehead, D. A., E. Becerril-García, D. Petatán-Ramírez, A. Vázquez-Haikan, R. González-Armas & F. Galván-Magaña. 2018. Whale shark *Rhincodon typus* strandings in the Gulf of California, Mexico. *Journal of fish biology* 94(1): 65-167. DOI:10.1111/jfb.13845

Whitehead, D. A., D. Petatán-Ramírez, D. Olivier, R. González-Armas, F. Pancaldi & F. Galván-Magaña. 2019. Seasonal trends in whale shark *Rhincodon typus* sightings in an established tourism site in the Gulf of California, Mexico. *Journal of Fish Biology* 95 (3): 982-984. DOI:10.1111/jfb.14106

Wintner, S. P. 2000. Preliminary study of vertebral growth rings in the whale shark, *Rhincodon typus*, from the east coast of South Africa. *Environmental Biology of Fishes* 59: 441-451. DOI:10.1023/A:1026564707027