

Temporal and spatial changes of the family Temoridae (Copepoda, Calanoida) in northeastern Venezuela (Southeastern Caribbean Sea)

Cambios temporales y espaciales de la familia Temoridae (Copepoda, Calanoida) en el nororiente de Venezuela (Mar Caribe Suroriental)

Brightdoom Marquez-Rojas

D. in Sciences, mention in Ecology
Oceanographic Institute of Venezuela (IOV), Universidad de Oriente,
Núcleo Sucre. Cumaná - Venezuela
bmarquez2001@gmail.com
Orcid: 0000-0002-2703-8696

Huber Colina-Romero

B.Sc. in Biology
Department of Biology, School of Sciences, Universidad de Oriente, Sucre.
Cumaná - Venezuela
hubercolinar@gmail.com
Orcid: 0009-0005-6318-4438

Luis Troccoli

Ph.D. in Marine Sciences
Institute of Scientific Research, Faculty of Marine Sciences, Universidad de
Oriente, Núcleo Nueva Esparta.
Boca de Río - Venezuela
luis.troccoli@gmail.com
Orcid: 0000-0001-8684-6741

Artículo

Acta Oceanográfica del Pacífico

<https://creativecommons.org/licenses/by-nc-nd/4.0/>

Pacific Oceanographic Record
DOI: <https://doi.org/10.54140/raop.v6i1.73>
Received March 19, 2024
Accepted May 02, 2024
Vol 6. No. 2 2024
ISSN: 1390-129X
ISSN: 2806-5522
Pg. 18-37

Abstract

Temora is a representative genus of Calanoida copepods and is abundant in tropical pelagic ecosystems. The abundance of males, females, and sex ratio of the species of the Temoridae family and their relationship with environmental variables were studied in Mochima National Park between December 2015 and October 2016, in 3 external and 3 internal stations. Significant temporal differences in temperature, evidenced the period of coastal upwelling (December 2015, February and April 2016). *Temora turbinata* and *T. stylifera* were identified. *T. turbinata* was more abundant than *T. stylifera*. The density of *T. turbinata* did not vary temporally ($p > 0.05$); however, the highest values were recorded at the inner stations, while *T. stylifera* dominated at the outer stations. The abundance of adults (males and females) of *T. turbinata* during the upwelling period showed no correlation ($p > 0.05$) with any of the water physicochemical variables, while in the months of relaxation (June, August and October 2016) they were associated with dissolved oxygen. *T. turbinata*, showed a dominance of females; the first instars (CI - CV) were detected during the coastal upwelling

period, indicating that the species may be feeding on phytoplankton. *Temora* is proposed as an indicator species of the trophic web in eastern Venezuela.

Key words: *Temora turbinata*, *Temora stylifera*, Copepod, coastal upwelling, Mochima National Park

Resumen

Temora es un género representativo de los copépodos Calanoida y abunda en ecosistemas pelágicos tropicales. Se estudió la abundancia de machos, hembras, y la proporción de sexos de las especies de la familia Temoridae y su relación con las variables ambientales en el Parque Nacional Mochima entre diciembre 2015 a octubre 2016, en 3 estaciones externas y 3 internas. Las diferencias temporales significativas en temperatura, evidenciaron el período de surgencia costera (diciembre 2015, febrero y abril 2016). Se identificaron *Temora turbinata* y *T. stylifera*. *T. turbinata* fue más abundante que *T. stylifera*. La densidad de *T. turbinata* no varió temporalmente ($p > 0,05$); sin embargo, los mayores valores se registraron en las estaciones internas, mientras *T. stylifera* dominó en las estaciones externas. La abundancia de los adultos (machos y hembras) de *T. turbinata* durante el periodo de surgencia no mostró correlación ($p > 0,05$) con ninguna de las variables fisicoquímicas del agua, mientras que en los meses de relajación (junio, agosto y octubre 2016) se asociaron con el oxígeno disuelto. *T. turbinata*, mostró una dominancia de hembras; los primeros estadios (C1 – C5) se detectaron durante el período de surgencia costera, indicando que la especie puede estar alimentándose de fitoplancton. Se propone *Temora* como especie indicadora de la trama trófica en la zona oriental de Venezuela.

Palabras clave: *Temora turbinata*, *Temora stylifera*, Copépodo, surgencia costera, Parque Nacional Mochima

Introduction

Within the zooplankton community, copepods constitute the dominant functional group and are considered key members of aquatic and marine food webs due to their intermediate position, linking primary production with consumers at higher levels of the trophic cascade (Campos *et al.*, 2017). Copepods are the main food source for fish larvae and juveniles worldwide (Lahnsteiner *et al.*, 2009). They exhibit rapid response to changes in the physical and chemical properties of water thereby affecting their abundance and spatial distribution (Smitha *et al.*, 2013). In addition to physical factors, biological factors also play a role, such as the presence and abundance of

food, predators, life cycle of the organisms themselves, vertical migrations in the water column, among others (Campos-Hernández and Suárez-Morales, 1994) that influence fluctuations in the abundance and structure of zooplankton.

Within the subclass Copepoda, the order Calanoida dominates overwhelmingly in the pelagic domain (79.1 %), comprising approximately 44 families (Razouls *et al.*, 2024). The family Temoridae, is composed of 1 single marine genus *Temora* and 1 brackish genus: *Eurytemora* (Razouls *et al.*, 2024). The genus *Temora* is widely distributed in tropical, subtropical, temperate and sub-boreal waters, and they are the main members of the surface

region of the mesozooplankton community in oceanic waters, neritic zones and estuarine zones (Ara, 2002; Hwang *et al.*, 2004).

In studies of zooplankton in the Venezuelan coasts, the Caribbean Sea, the Gulf of Mexico, Florida and the Sargasso Sea, 3 species of the genus *Temora* (*Temora turbinata*, *T. stylifera* and *T. longicornis*) have been recorded (Márquez-Rojas and Zoppi, 2023; Razouls *et al.*, 2024). *Temora* Baird, 1850 is a common genus inhabiting the coastal marine area and often constitutes the dominant herbivorous group (Chang *et al.*, 2014). Among these, *T. turbinata* (Dana, 1849) is widely distributed in tropical, subtropical and the temperate waters of the Atlantic, Pacific and Indian Ocean, except in the eastern Pacific (Bradford-Grieve *et al.*, 1999). It is common on the surface of planktonic communities down to a depth of 200 m and is often highly abundant in coastal waters and around estuaries (Ara, 2002). The range covered by *T. turbinata* is wide, including Brazil (Ara, 2002; Rimoldi, 2008), India (Ali-Khan, 2006), Taiwan (Hwang *et al.*, 2004), New Zealand and Australia, including areas of the Great Barrier Reef (Bradford-Grieve *et al.*, 1999). In the western Pacific, Gulf of Mexico and Caribbean, it is usually the dominant member of mesozooplankton communities (Medellín-Mora and Navas, 2010; Morales-Ramírez, *et al.*, 2018). For its part, *Temora stylifera* is endemic to the Atlantic Ocean and adjacent regions, mainly between latitudes 40°N-35°S along the American coasts and 45°N-5°S in the eastern Atlantic and Mediterranean (Razouls *et al.*, 2024).

Copepods in general have been studied as indicators of water masses. Such is the case of *T. turbinata* associated with relaxation events and its presence is related to coastal and estuarine zones, while *T. stylifera* is associated with coastal upwelling events, associated with phytoplankton and microzooplankton, and can be detected in regions farther from the coast (Ara, 2002; Rimoldi, 2008).

There is a very interesting relationship between these two species; the first record of

T. turbinata was located on the coasts of Brazil in the 1980s (Araujo and Montú, 1993) in the Vasa-Barris estuary. Faunal studies prior to that date for the same region confirm the absence of this copepod, which is why it is considered an exotic invader (Lopes *et al.*, 1999). In the Cananéia-Iguape estuarine lagoon system (Sao Paulo, Brazil), *T. turbinata* replaced its congener *T. stylifera*, which was formerly one of the main copepod species (Ara, 2002; Rimoldi, 2008). *T. turbinata*, has become one of the most abundant species in estuaries and on the Brazilian continental shelf in recent years (Ara, 2002; David-Santos and Correa-Meuer, 2016). Villac *et al.* (2009) recorded the presence of *T. turbinata* in Sepetiba Bay, Rio de Janeiro, Brazil, and subsequently characterized it as an "established" and frequent species on Brazilian coasts, with no apparent ecological impacts.

In Venezuela, *T. turbinata* is one of the most abundant and frequent species on the continental shelf, associated with high temperature, during the relaxation season. However, it is important to highlight its abundance and frequency and in some cases as the dominant and constant species in studies on zooplankton in general in the northeastern part of the country, specifically in the Gulf of Cariaco (Márquez-Rojas *et al.*, 2020, 2023), Mochima Bay (Márquez-Rojas *et al.*, 2008; Márquez-Rojas and Zoppi de Roa, 2017) and Cariaco Basin (Márquez *et al.*, 2009). In that sense, it is important to mention that although *T. stylifera* is not so abundant and frequent it has been reported for the Cariaco Gulf and Mochima Bay (Márquez *et al.*, 2008; Márquez-Rojas and Zoppi de Roa, 2017, 2023). However, the highest dominance of *T. stylifera* in the surface stratum of the Cariaco basin was reported in the study by Márquez *et al.* (2009).

To date, there is little information on the composition of *T. turbinata* and *T. stylifera* populations, such as sex ratio and the proportion of copepods and adults in Mochima National Park (MNP). These species are important components of zooplankton.

Therefore, a thorough investigation of their biology and ecology is important and necessary. Therefore, in the present study, we measured the abundance of copepodites and male and female adults of *T. turbinata* and compared the spatiotemporal distribution patterns in the PNM to explain: (1) the seasonal composition of *T. turbinata* and *T. stylifera* populations in the zooplankton; (2) whether the geographic distribution of the two species is correlated with the location of the seasons; (3) the abundance and sexual

structure of *T. turbinata* is related to the two climatic epochs characteristic of the northeastern part of the country.

STUDY AREA

Mochima National Park (PNM), located in the northeastern region of Venezuela. Sampling stations were located in areas of the Las Caracas archipelago (external stations) and within Mochima Bay (internal stations; Figure 1).

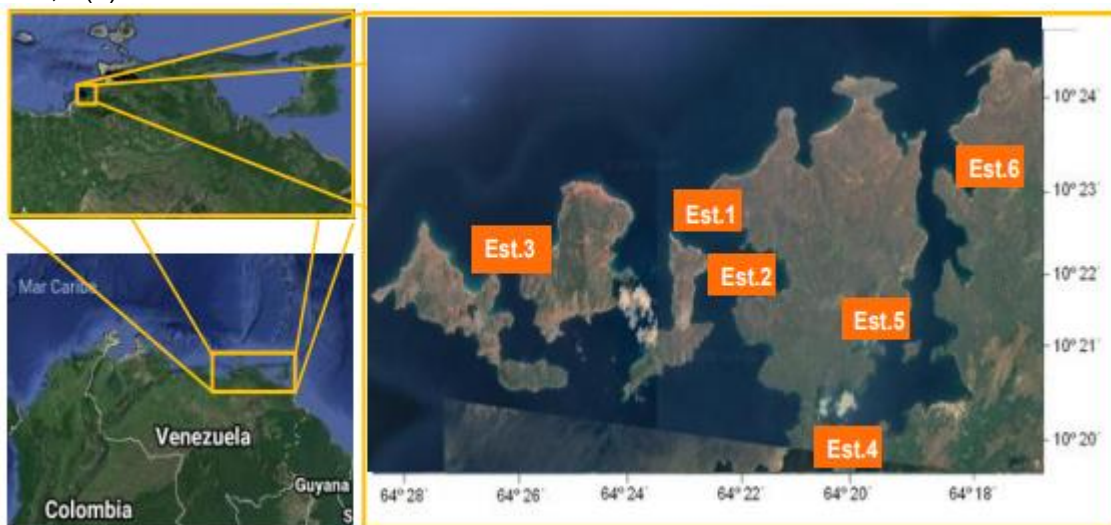


Figure 1. Geographical location of Sucre state, (B) Mochima Bay and Caracas Islands, of Mochima NP. Mochima and (C) study stations within Mochima Bay and Caracas Islands.

The external stations (stations: 1, 2, 3) comprise a system of islets located at the northern end of the MNP, considered oceanic stations, with sandy beaches with depth profiles > 20 m and limited by shallow coral reefs in the coastal part and octocorals formations in its deepest part (Fariña *et al.*, 2014). The internal stations are located within Mochima Bay, characterized by a smooth and regular topography with a maximum depth of 60 m; this bay is shallow and elongated, surrounded by mangroves (*Rhizophora mangle*) and with *Thalassia testudinum* meadows (Fariña *et al.*, 2014).

Methodology

Field Study

Samples were collected bimonthly for one year (December 2015 to October 2016) at 3 external stations (stations 1, 2 and 3) and 3 internal stations (stations 4, 5 and 6; Figure 1). Two simultaneous oblique drafts (above 10 m depth) were conducted at a speed of 1.5 knots, from a peñero-type boat for 10 min at 50 m distance from the shore using a bongo net (30 cm diameter, 300 μ m mesh size and 180 cm length). A digital flowmeter (General Oceanic) was used at the center of the net mouth to calculate the volume of filtered water. Zooplankton samples were immediately preserved in diluted 4% formaldehyde, prepared with filtered seawater and neutralized with sodium tetraborate for

subsequent identification and abundance counting in the laboratory. At each sampling and for each station, water surface temperature ($^{\circ}\text{C}$), salinity (ups) and dissolved oxygen ($\text{mg}\cdot\text{L}^{-1}$) were measured using a multiparameter probe (YSI 556).

Qualitative and quantitative analysis

Three samples per station were analyzed, which were concentrated (400 mL) and 3 subsamples of 10 mL were extracted with a Stempel pipette. They were then placed in a Bogorov chamber and subsequently analyzed under a Motic® SMZ-168 stereo microscope. From this sample we proceeded to quantify and identify the species of the Temoridae family, using a Motic® BA300 optical microscope, with the aid of 10x and 40x objective lenses. The taxonomic location of the species of the family Temoridae was done with the help of taxonomic references (Campos-Hernández and Suárez Morales, 1994; Bradford-Grieve *et al.*, 1999; Razouls *et al.*, 2024). Subsequently, the specimens were classified according to their stage of development in the different stages of copepodites, which range from stage I to V and are identified as CI, CII, CIII, CIV and CV, adult female (HA) and adult males (MA), using Carotenuto (1999) as the main guide. Abundance was expressed as individuals per cubic meter (ind. m^{-3}).

Statistical analysis

To establish possible temporal (months) and spatial (seasons) differences between the physical-chemical variables and the community indices, the Kruskal-Wallis (K-W) test was used, after checking for non-compliance with the assumptions of normality (Kolmogorov-Smirnov test) and homoscedasticity (Levene test) (Zar, 1999). In cases of significant differences, Dunn's a posteriori test was performed to evaluate the differences in each environmental parameter and the abundance of copepods and *T. turbinata*. Comparison between seasons (upwelling: December, February, April and relaxation: June, August, October) was performed with the non-parametric Mann-

Whitney test. Statistical tests, models, exploratory figures and other routines were developed using the Free Software R v 4.2.2, under the graphical interface R Studio (R CORE TEAN 2016). The results were plotted in box-plot diagrams to provide a better visual representation of the analyses.

Possible relationships between variables were determined with a Principal Component Analysis (PCA) from a multiple correlation matrix. A total of 90 samples were used to calculate similarities in a clustering analysis using Euclidean distance with the nearest neighbor strategy. Finally, to establish the relationship between physicochemical variables and the different sexual stages of *T. turbinata*, a multiple correlation analysis was performed using Spearman's rank correlation coefficient (Zar, 1999).

Results

Hydrographic conditions

Water surface temperature recorded values between 24.7 and 29 $^{\circ}\text{C}$ from December 2015 to April 2016 and between 27 and 30.2 $^{\circ}\text{C}$ from June to October 2016; significant temporal differences were found (K-W= 19.73, Dunn's Test: $p < 0.05$; Figure 2A); the lowest temperature (24.7 $^{\circ}\text{C}$) was recorded in February, while the warmest surface temperature (30.2 $^{\circ}\text{C}$) was detected in October. No significant differences were detected between the two periods studied (W= 1.167; $p > 0.05$; Figure 2B). In general, the inner stations were warmer than the outer stations, the minimum value recorded was 24.7 $^{\circ}\text{C}$ at station 6 in February 2016, while the highest average temperature ($> 27^{\circ}\text{C}$) was recorded in June. However, no significant differences were found between stations (K-W= 8.87; $p > 0.05$).

Salinity ranged from 34.2 recorded at station 4 in June 2016 to 39.98 at station 1 in February 2016; no significant differences were detected between months or stations (K-W= 10.51; K-W= 9.68; $p > 0.05$, respectively, (Figure 2C).

Significant differences were only detected between the two periods studied ($W=1.66$; $p<0.05$), registering the highest values in the upwelling period (Figure 2D).

Dissolved oxygen fluctuated with a minimum value of 5.4 mg.L^{-1} at station 5 in June 2016

and a maximum of 8.4 mg.L^{-1} at stations 2 and 3 in February 2016. No significant temporal or spatial differences were found ($K-W =10.37$; $K-W =9.82$; $p>0.05$, respectively; (Figure 2E). Nor did the periods show significant differences ($W=1.0$; $p>0.05$, Figure 2F).

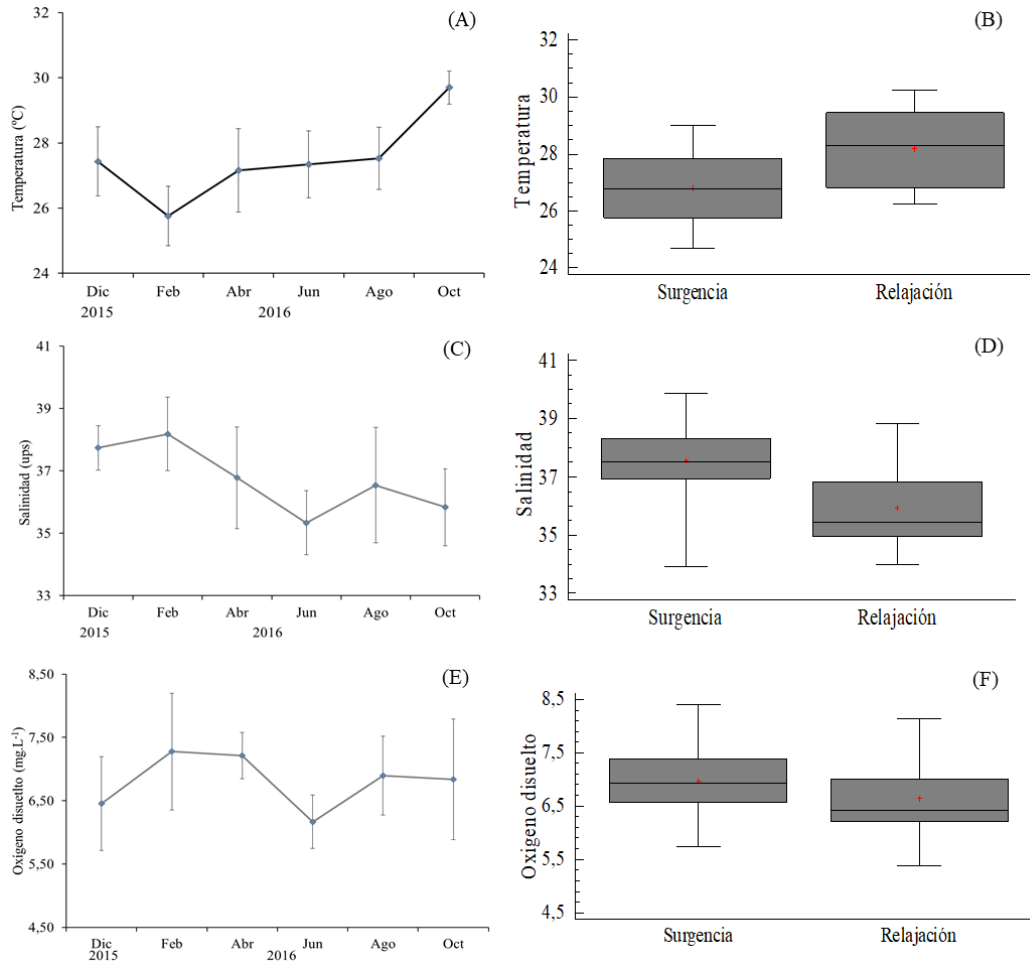


Figure 2. Temporal variation of water surface temperature (A), salinity (C) and dissolved oxygen (E). Box-and-whisker plots of temperature (B), salinity (D) and dissolved oxygen (F) for the periods studied, in Mochima NP, Sucre state, Venezuela. Mochima, Sucre State, Venezuela.

Copepod density ratio

In general, the zooplanktonic composition was dominated by copepods; they were abundant

in June, August and October 2016, reaching a density of 760 ind.m^{-3} , 730 ind.m^{-3} and 459 ind.m^{-3}

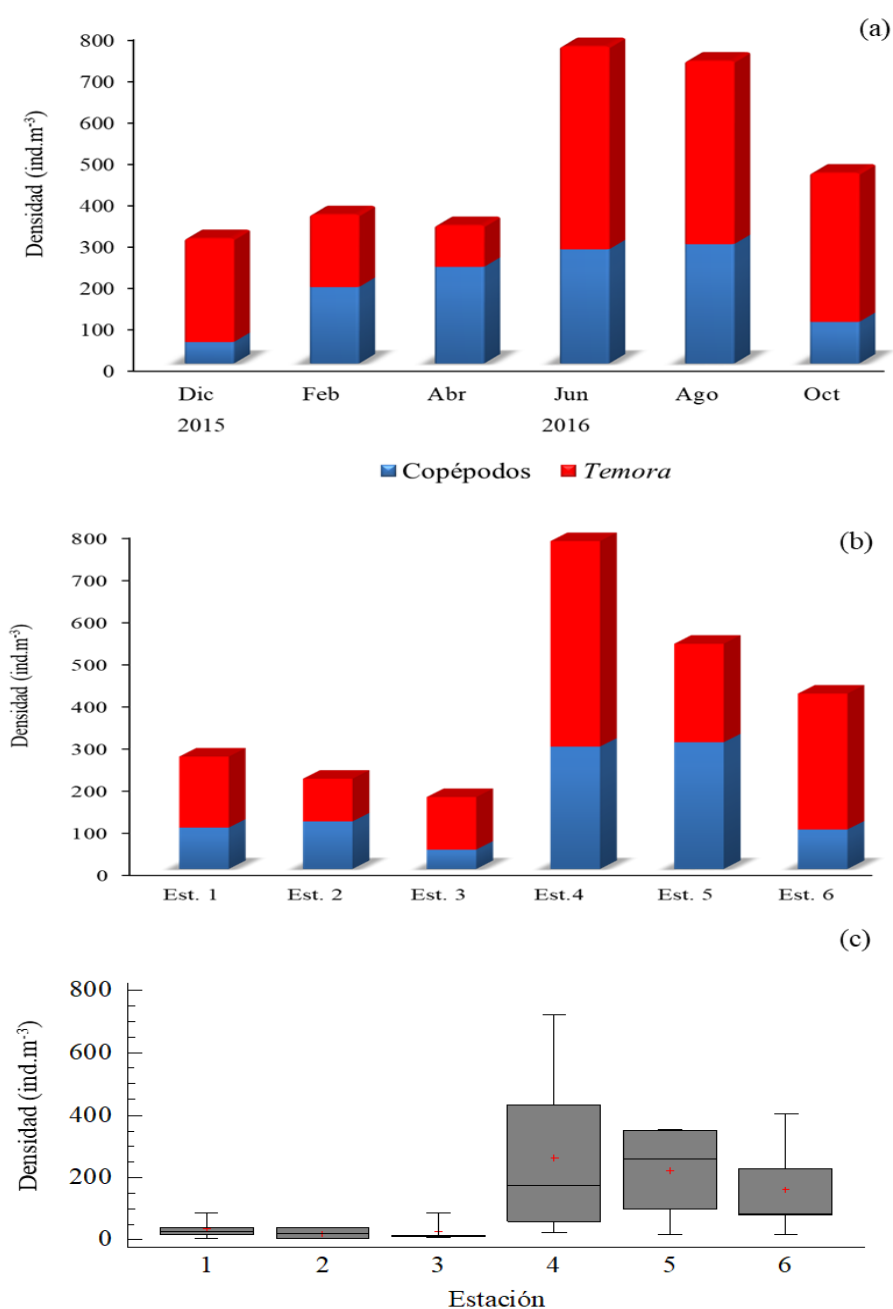


Figure 3.- Temporal (A), spatial (B, C) variation of copepod density and *Temora* species (ind.m⁻³) in Mochima NP, Sucre state, Venezuela . Mochima, Sucre state, Venezuela.

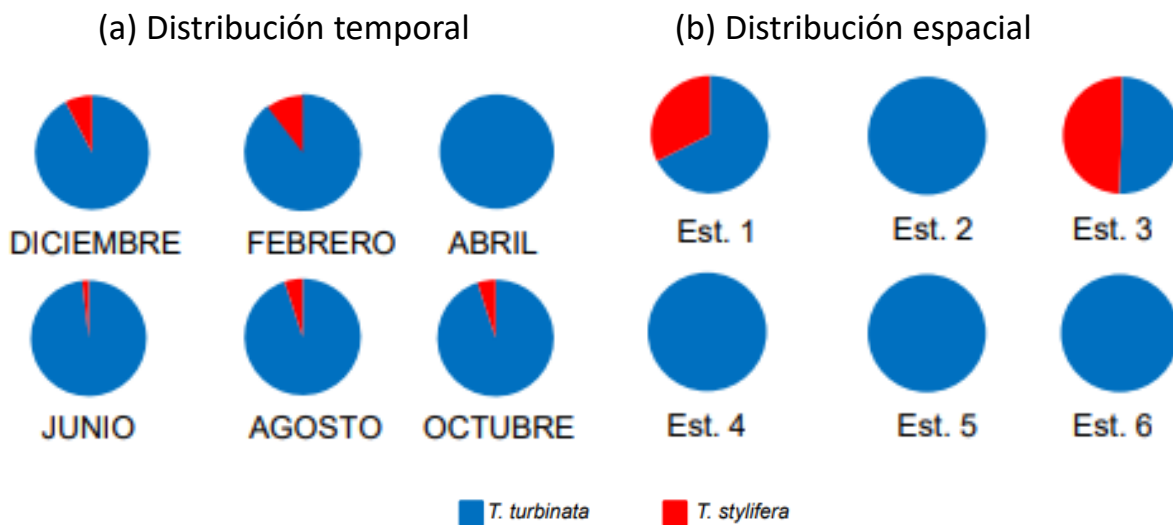
respectively (Figure 3a). Within the class Copepoda, the genus *Temora* was the most abundant; it excelled between 60 - 70% in relative abundance in June, August and October 2016, with 489 ind.m⁻³, 442 ind.m⁻³

and 350 ind.m⁻³, respectively (Figure 3a). No significant temporal differences were found for the genus *Temora* (K-W=7.83; $p > 0.05$). With respect to the stations, significant differences were found (K-W = 16.47, Dunn's test: $p < 0.05$, Figure 3b,c), the highest density of these

crustaceans was recorded in the inner stations, detecting the highest values in Est. 4 (488 ind.m⁻³), Est. 5 (234 ind.m⁻³) and Est. 6 (322 ind.m⁻³; Figure 3b,c). Between the periods studied, no significant differences were found ($W = 0.38, p > 0.05$).

Species of the genus *Temora*

The species identified were *Temora turbinata* and *Temora stylifera*. *T. turbinata* dominated during the entire sampling period, with high percent abundances (> 70%) in all months. However, *T. stylifera* was also detected during almost all survey months, but with relatively low percentage abundances (6 - 13%), except in April when it was not detected (Figure 4a).



Percentage distribution of temporal (a) and spatial (b) variation of *T. turbinata* and *T. stylifera* in Mochima National Park between December 2015 and October 2016.

Temora turbinata was always more abundant at the inner stations (Est. 4,5,6), corroborated by statistical test ($W = 0.66, p < 0.05$, Figure 4b), while *T. stylifera* was more abundant at the outer stations (Est. 1 and 3; Figure 4b).

Spatiotemporal distribution of the age structure of *Temora turbinata*

During the study period, a dominance of adults over copepodites was observed. Copepodites were abundant in December 2015, also being collected in February and April 2016 in smaller proportions. Adults dominated from June 2016 onwards, coinciding with the relaxation season (Figure 5). In December 2015, the abundance of CI-CIII copepodites was 39 and 43 ind.m⁻³ at stations 4 and 5, respectively, while for CIV-CV stages it was 34 ind.m⁻³ at station 4; for

this month, females were more abundant than males, their highest densities were obtained at stations 4 and 5 (90 and 170 ind.m⁻³, respectively). From February onwards, the density of copepodites decreased. However, CI-CIII and CIV-CV copepodites were counted, both stages with 13 ind.m⁻³. Males and females maintained the same trend as the previous month. In April, CI-CIII and CIV-CV copepodites were reported at station 1, with 30 and 14 ind.m⁻³, respectively, while in the rest of the stations only CI-CIII stages were identified with values between 14 - 17 ind.m⁻³; females were more abundant than males. However, densities were relatively low (20 - 70 ind.m⁻³; Figure 5c). From June onwards, only adults were counted; in this month, the highest densities of the entire study were counted, mainly in the inner stations with the dominance of females (200 - 500 ind.m⁻³). In August and

October, only adults were quantified in all stations, although with the highest densities in the inner stations, with values between 30 - 110 ind.m⁻³ and 10 - 200 ind.m⁻³ for females and 13 - 44 ind.m⁻³ and 5 - 70 ind.m⁻³ for males, respectively (Figure 5e,f).

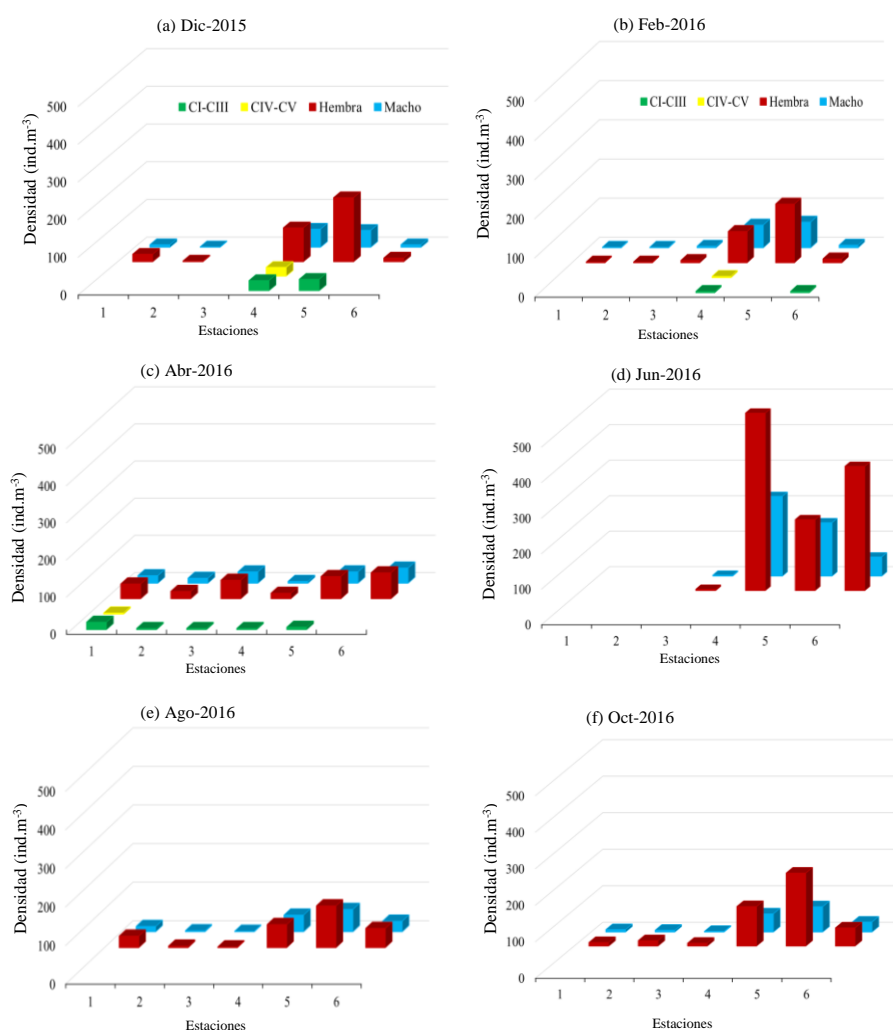


Figure 4. Temporal and spatial variation in the density of the sex ratio of *T. turbinata* in Mochima National Park.

The results of the cluster analysis are mainly divided into two groups (Figure 6). The first group (group A) with a short separation distance (100) between them, contains the samples from the external stations. The second cluster (cluster B) is further divided

into two groups, a small group formed by stations 5 and 6 at a distance of 300 and this in turn joined to station 4; this second group corresponds to the internal stations (Figure 6). The results of the dendrogram showed that

there were clear differences between the populations of *T. turbinata* between stations.

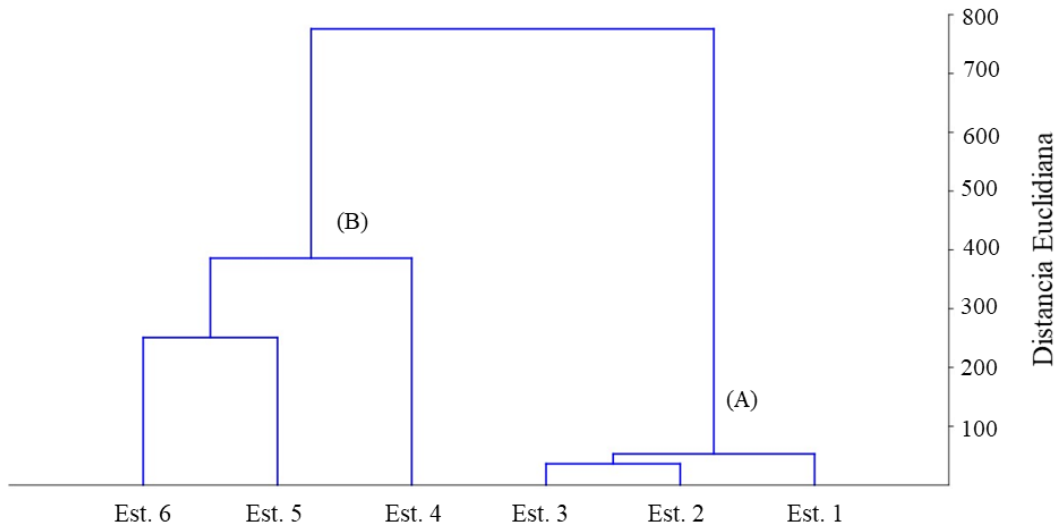


Figure 5 Station classification analysis of different samples of *Temora turbinata* using Euclidean distances and nearest neighbor clustering strategy in Mochima National Park.

The abundance of all adults as well as males and females of *T. turbinata* during the upwelling period were not significantly correlated with any of the water physico-chemical variables ($p > 0.05$; Table 1), while copepodites were significantly negatively correlated with salinity ($r = -0.588$, $p < 0.05$). In contrast to the relaxation period, which the abundance of all adults as well as males and females of *T. turbinata* were negatively correlated with dissolved oxygen ($r = -0.535$; p

< 0.05). It is worth noting that during upwelling, there was significantly positive correlation between abundance of all adults and abundance of males, females and copepodites ($r = 0.976$, 0.998 and 0.579 $p < 0.001$, respectively), while at relaxation they were also significantly correlated with males and females ($r = 0.968$, $r = 0.999$ $p < 0.001$, respectively) (Table 1).

Table 1. Results of Spearman correlation analysis by rank of all adult abundance (individuals m⁻³), male abundance, female abundance and copepodite abundance of *Temora turbinata*. Value represents correlation (r), value in parentheses represents p and absence of copepodites in relaxation (--), * significant differences, ** highly significant differences.

		Abundance all adults	Abundance Males	Abundance Females	Abundance Copepoditos
SURGENCY	Salinity	-0,204 (0,414)	-0,245 (0,326)	-0,211 (0,399)	-0,588 (<0,05)*
	Temperature	0,436 (0,081)	0,322 (0,198)	0,442 (0,077)	0,389 (0,119)
	Oxygen	-0,349 (0,162)	-0,360 (0,149)	-0,368 (0,141)	-0,199 (0,426)
	Abundance all adults		0,976 (<0,001)**	0,998 (<0,001)**	0,579 (<0,001)**
	Abundance Males			0,967 (<0,001)**	0,544 (<0,001)**
	Abundance Females				0,590 (<0,001)**
RELAXATION	Salinity	-0,446 (0,084)	-0,502 (0,052)	-0,435 (0,092)	--
	Temperature	0,318 (0,217)	0,318 (0,217)	0,329 (0,203)	--
	Oxygen	-0,535 (<0,001)**	-0,535 (<0,001)**	-0,534 (<0,001)**	--
	Abundance all adults		0,968 (<0,001)**	0,999 (<0,001)**	--
	Abundance Males			0,967 (<0,001)**	--

Discussion

The abundance of copepods varied significantly between the two periods studied, registering the highest values during relaxation. These results are not related to the characteristic behavior of the northeastern zone of Venezuela, subject to an active upwelling center, as described by several authors (Rueda-Roa *et al.*, 2018) with the rise of subsurface water masses, with high nutrient concentration and lower temperature, which is also manifested in an increase of planktonic communities and/or the primary productivity regime in the surface layers (Rivas-Rojas *et al.*, 2007). In the present study, the low density of copepods during the upwelling showed an antagonistic effect, possibly due to the

intensity and fluctuations of the upwelling during the sampling days, as well as the cascade effect of the predator-prey relationships that result in the drastic decrease of zooplankton (Carpenter *et al.*, 2001), which later during the relaxation, zooplankton have a rebound in abundance. This behavior would be a product of the response of the communities to hydrographic changes, which in the tropical zone are generally non-linear and present a consistent dome-shaped relationship called "optimal environmental window" that was introduced by Cury and Roy (1989) and described extensively by Botsford *et al.* (2003, 2006). The dome-shaped relationship between physical conditions and

biological productivity reflects a trade-off between two processes, both related to upwelling: (i) nutrient supply, which is controlled by wind forcing and near-surface stratification and (ii) plankton loss due to offshore advection associated with upwelling (Botsford *et al.*, 2003, 2006; Romero *et al.*, 2020). This same pattern was found in the research of Márquez-Rojas *et al.* (2016) in the study of mesozooplankton in the Gulf of Cariaco, Venezuela.

Regarding spatial differences, the abundance of copepods and *Temora* specimens were more abundant in the inner stations and this was clearly observed in the dendrogram. This greater increase could be related to the influence of rainfall runoff, which is a seasonal phenomenon, so it should be considered that rainfall is also an important source of allochthonous nutrients in coastal environments that favor phytoplankton productivity (Ferraz-Reyes and Fernandez, 1990). In this sense, Mochima Bay is a semi-enclosed system in which the effects of rainfall, during the relaxation period, are increased by having a relatively long hydraulic residence time. Therefore, exogenous nutrient inputs can have a fertilization effect either immediately or after a period of time (Jordan *et al.*, 1991). The latter was confirmed by the higher density records of copepods during the relaxation period and especially in the inner stations in the present investigation. These results coincide with Márquez-Rojas *et al.* (2008) who reported the highest zooplankton density values in the inner stations of Mochima Bay, between 10 and 15 m depth. Likewise, these results coincide with other Caribbean areas, such as those of Carrillo-Baltodano and Morales-Ramírez (2016) and Morales-Ramírez *et al.* (2018) who found higher zooplankton concentrations at nearshore stations with respect to offshore stations in the Mexican Caribbean Sea and on the reef of Cahuita National Park, Caribbean coast of Costa Rica, respectively.

Temora turbinata was the most abundant and dominant species during the sampling period, with a marked spatial difference, dominating in the inner stations. This confirms its abundance in coastal waters, as reported by Ara (2002) and Rimoldi (2008). It is also important to note, that the highest densities of this species were found in relaxation, so it could be considered an indicator species for warm waters, as mentioned by Hwang *et al.* (2006) and Dur *et al.* (2007) in northwestern Taiwan, who found that *T. turbinata* was more abundant in waters with temperature >28 °C. However, relaxation correlation analysis showed no correlations with temperature, but only with dissolved oxygen. Similar results agree with Yan-Guo *et al.* (2021) in northeastern Taiwan, who found the records of maximum abundance of *T. turbinata* in summer, attributing it to possible temperature effects. In that sense, *T. turbinata* is a warm-water epipelagic neritic species (Razouls *et al.*, 2024). It can tolerate wide ranges of temperature (5 to 35 °C) and salinity (20 to 45 ppt), although the ideal temperature and salinity for cultivation were 25-28 °C and 30-35 ppt, respectively (Yan-Guo *et al.* 2021). This species is widely distributed in tropical, subtropical and temperate waters of the Atlantic, Pacific and Indian Oceans, except in the eastern Pacific (Bradford-Grieve *et al.*, 1999; Razouls *et al.*, 2024), and is often a native and predominant species in tropical mesozooplankton communities in coastal and oceanic environments of the Gulf of Mexico and the Caribbean Sea (Campos-Hernández & Suárez-Morales, 1994; Bradford-Grieve *et al.*, 1999). The aforementioned coincides with the antecedents on the dominant copepod fauna in the Cariaco basin and gulf (Márquez-Rojas *et al.*, 2020, Márquez-Rojas and Zoppi de Roa, 2023), Mochima Bay (Márquez *et al.*, 2008; Márquez-Rojas and Zoppi de Roa, 2017), as well as from the Caribbean Sea and southeastern Caribbean (Márquez-Rojas and Zoppi de Roa, 2023), where they mention *T. turbinata* as one of the most abundant and frequent species in the northeastern part of the country. Yan-Guo *et al.* (2021) in northeastern

Taiwan confirmed that it is highly adaptable and could survive in diverse environments. Therefore, it represents the dominant and representative copepod species of mesozooplankton in Taiwan's coastal waters; it was likewise the most abundant species in the Oman Sea, Indian Ocean, showing no clear seasonality, attributable to its wide feeding variety, from smaller heterotrophic nanoflagellates (i.e., microbial loop) when diatoms are scarce to withstanding periods of limited phytoplankton abundance (AlBusaidi and Claereboudt, 2023).

Temora turbinata, despite being an exotic species for the coasts of Brazil, has often exceeded the biomass and abundance values of the native species *T. stylifera* (Ara, 2002; Rimoldi, 2008). However, Rimoldi (2008) in his study along the Southeast Brazilian continental shelf (PCSE), found discrepancy with this study, reporting temporal differences, with the highest abundance values of *T. turbinata* in summer for the southern hemisphere (January), alluding that the high concentrations are related to the influence of availability (high concentrations of chlorophyll a) and food quality.

On the other hand, *Temora stylifera*, despite being less abundant than *T. turbinata*, was always represented in almost all months of the study, with higher abundances in the outer seasons. This corroborates the preference of this species for oceanic waters, frequent in regions farther from the coast, as confirmed by Ara (2002) and Rimoldi (2008). *T. stylifera* is considered an oceanic species, typical of the surface waters of the Caribbean Sea and has been recorded in the equatorial tropics, in regions adjacent to the northwestern Atlantic, in the western Caribbean, the Florida Current, the Guyana Current and in the Gulf of Mexico (Campos-Hernández and Suárez-Morales, 1994; Razouls *et al.*, 2024). Therefore, the presence of this species in the study area and in the external stations may possibly indicate the entrance of the Caribbean Equatorial

Current, due to its association with oceanic waters coming from the system of this current, which has high salinity and temperature higher than 20 °C, as mentioned by Marsh *et al.* (2021).

On the validity of the results, *T. turbinata* was much more abundant than *T. stylifera*. Similar results were reported by David-Santos and Correa-Meuer (2016) in Sepetiba Bay, Brazil, noting that the density of the invasive species *T. turbinata* was higher than that of the native species *T. stylifera* throughout the sampling period, considering the second species as accidental. This accidental presence of the native species was also observed in the work of Villac *et al.* (2009), where *T. stylifera* was displaced by the invasive species *T. turbinata*, with great representativeness within the group of copepods. Some other studies carried out in estuarine complexes in Brazil also recorded a predominance of the invasive species, even reporting it as one of the most important species (Ara, 2002). This high abundance and dominance of *T. turbinata* may be due to its feeding habit, as it is omnivorous (Chang *et al.*, 2014; Razoul *et al.*, 2024).

The coexistence of both species in the study area may be due to the synchronization of life cycles, since the type of diet changes according to the stages of development, as mentioned by Ianora *et al.* (1998), noting that these species occupy different niches at the same time (Tseng *et al.*, 2020). On the other hand, overlap in resource utilization does not necessarily lead to competition (Lakkis, 1994); the intensity of competition between species is not always directly related to the degree of niche overlap. In addition, some horizontal segregation was observed in the present study in both study periods, with the species *T. turbinata* more abundant in the coastal stations and *T. stylifera* in the more oceanic stations.

As is well known, copepod populations in the field are dominated by juvenile stages, usually

the abundance of copepodites usually exceeds that of adults (McKinnon and Duggan, 2014). For example, copepodites represent between 27 - 41% of the total zooplankton abundance in the southeastern Baltic Sea (Polunia *et al.*, 2019), while in the coastal waters of Taiwan the percentage of copepodites was between 27 - 60% (Yan-Guo *et al.*, 2021). In this research the percentage of copepodites is much lower (< 10%) than reported in other areas. The percentage of copepodites may be closely related to differences in the strategies and life expectancy of different species.

Studies on reproductive cycles in planktonic copepods are fundamental for understanding the mechanisms that regulate population densities in the sea (Lanora *et al.*, 1989). It is known that *T. stylifera* has 4 to 6 generations per year (Carotenuto, 1999) and *T. longicornis* has 2 to 6 generations; therefore, they are species that have a low number of generations per year. Meanwhile, for *T. turbinata*, Ara (2002) showed 6 generations during one year. Because *T. turbinata* has a short life cycle (Rimoldi, 2008) and, as indicated above, a high number of generations per year, it has a reproductive advantage over other species, becoming abundant and even dominant over the group of planktonic copepods. Although the life cycle of this species was not studied in the present research, this condition could favor the greater abundance of this species in this study.

The age structure of the population of *T. turbinata* showed a dominance of adults over copepodites. The copepodites CI - CIII, CIV - V of *T. turbinata* were counted in the first months of the study, coinciding with the period of coastal upwelling. Ferraz-Reyes and Fernandez (1990) state that this phenomenon brings a high concentration of nutrients to the surface, giving rise to a high production of phytoplankton. Although this study did not analyze phytoplankton abundance and composition, it is well documented for the

northeastern part of the country that during the coastal upwelling season there is a greater abundance of phytoplankton (Ferraz-Reyes and Fernández, 1990; Rivas-Rojas *et al.*, 2007), so the predominance of the first juvenile stages or copepodites of *T. turbinata* were possibly counted during the first months of the study. This hypothesis was confirmed by Rimoldi (2008) in his study along the Southeastern Continental Shelf of Brazil (PCSE), who found higher abundance of juveniles in summer for the southern hemisphere (January), coinciding with high values of chlorophyll *a* and phytoplankton. On the other hand, Lopez (1997) found a significant correlation of *T. turbinata* with total chlorophyll *a* through the quantification of pigments in the digestive tract. Similarly, Paffenhöfer (1998) in the northeastern shelf of Florida (USA) during a coastal upwelling event with high concentration of particulate matter, was positively associated with the abundance of *T. turbinata*.

For the genus *Temora*, the characteristics that make the greatest difference between the copepodite stages are the number of thoracic segments and free urosomal segments, as well as the number of swimming legs (Carotenuto, 1999); this same author also indicates that the complete development of this genus takes 19 days from the first naupliar stage to the adult stage. The early stages of copepodites of both species *T. stylifera* and *T. turbinata* show pointed posterolateral corners of the cephalosome, finally the late stages of copepodites and adults of *T. turbinata* have a more rounded posteroventral corner of the last thoracic segment than in *T. stylifera* (Carotenuto, 1999; Razoul *et al.*, 2024). Based on the above assumptions, in the present investigation, neither early stages nor copepodites of *T. stylifera* were identified, with copepodites of *T. turbinata* always dominating in all seasons and months analyzed. This could be due to several reasons; the first, based on what Rimoldi (2008) concluded in his work along the PCSE, Brazil, where there is no

synchrony in the reproductive cycle of both species; secondly, the low abundance of *T. stylifera* adults in the area and finally, the fact that the females of *T. turbinata* do not have an ovigerous sac, i.e. their eggs are released directly into the water (Kiørboe, 2006). This characteristic is a reproductive advantage, since the eggs that are retained in the egg sac are subject to die if the female dies, while the eggs released into the water are independent and can be dispersed to areas with advantageous characteristics for their development (Orsi *et al.*, 1983).

The sex ratio of *T. turbinata* and *T. stylifera* in this work was dominated by females throughout the study. These results agree with Yan-Guo *et al.* (2021) in the coastal waters of Taiwan, indicating that the sex ratio of *T. turbinata* was female-biased; however, Rimoldi (2008) for *T. turbinata* in the PCSE, Brazil, found higher numbers of females in summer for the southern hemisphere (January) and males in winter (August), while for *T. stylifera* the male/female ratio was quite close to 1 in both summer and winter. The latter can be explained by the fact that this species needs constant fertilization, since there is no seminal receptacle. With a higher proportion of male individuals, the chance of encountering females increases, increasing the probability of more than one fertilization per female. It is documented that the material deposited in spermatophores is used throughout the reproductive period (Kiørboe, 2006). Thus, *T. stylifera*, according to Ianora *et al.* (1989) requires mating before each litter. Gusmão and McKinnon (2009) mention that there are differences in the sex ratio between species and seasonally within the same species. Likewise, Moore and Sanders (1983) indicate that differences in sex ratio cannot be explained simply as a response to variations in temperature and food availability, but to a set of factors, from genetic characteristics to

behaviors in response to environmental variations, mainly in the most juvenile stages. All of the above represents an adaptive advantage for *T. turbinata*, contributing to a greater establishment in the study area. On the other hand, Gusmão and McKinnon (2009) and Hirst *et al.* (2010) suggest that male-female ratio biases in pelagic copepods are mainly caused by differential mortality due to predation of the sexes in the adult stage, also lack of food can cause sex ratios biased towards females, especially by harmful blooms of dinoflagellates (Carotenuto *et al.*, 2011) and cyanobacteria (Engström-Öst *et al.*, 2015). Therefore, further research should be conducted to clearly understand the interaction of sex ratio with population dynamics.

Conclusions

The hydrographic environment in our study area was characterized by the phenomenon of coastal upwelling during the first months of the research with influence towards the inner stations of Mochima Bay and later the relaxation period. *T. turbinata* was more abundant and dominant than its congener *T. stylifera*; the highest densities of *T. turbinata* were recorded in the inner stations, unlike *T. stylifera* which were found in the outer stations. The abundance of adults (males and females) of *T. turbinata* during the upwelling period showed no correlation with any of the physicochemical variables of the water, while in relaxation they were associated with dissolved oxygen. The age structure of the *T. turbinata* population showed a dominance of adults, with a predominance of females; the first stages were counted in the first months of the study, coinciding with the period of coastal upwelling, indicating that the species may possibly be feeding on phytoplankton and microzooplankton. The population dynamics of these species are still poorly studied in the area, so more detailed studies are needed in

the future. In addition, information on food availability, mortality and a good spatiotemporal sampling frequency will be needed to comprehensively understand the population dynamics of one of the most abundant species of mesozooplankton such as *T. turbinata* in eastern Venezuela.

References

- AlBusaidi, S. & Claereboudt, M. 2023. Seasonal variations of surface mesozooplankton community structure in the Sea of Oman and the Arabian Sea. *Journal of Agricultural and Marine Sciences*, 28(1), 30-46.
- Ali-Khan, J. 2006. Adults and copepodite stages of *Temora turbinata* (Copepoda: Calanoida) from the Indian Ocean. *Pakistan Journal of Zoology*, 38(3), 201-205.
- Ara, K. 2002. Temporal variability and production of *Temora turbinata* (Copepoda, Calanoida) in the Cananea Lagoon estuarine system. *Scientia Marina*, 66(4), 399-406.
- Araujo, H. & Montú, M. 1993. Novo regitro de *Temora turbinata* Dana (1894) (Copepoda, Crustacea) para águas Atlânticas. *Naupilus*, 1, 89-90.
- Botsford, L.W., Lawrence, C. A., Dever, E. P., Hastings, A. & Largier, J. 2003. Wind strength and biological productivity in upwelling systems: an idealized study. *Fisheries Oceanography* 12(4-5):245 - 25. DOI: <https://doi.org/10.1046/j.1365-2419.2003.00265.x>
- Botsford, L.W., Lawrence, C.A., Dever, E.P., Hastings, A. & Largier, J. 2006. Effects of variable winds on biological productivity on continental shelves in coastal upwelling systems. *Deep Sea Research Part II: Topical Studies in Oceanography*, 53(25-26): 3116-3140. DOI: <https://doi.org/10.1016/j.dsr2.2006.07.011>.
- Bradford-Grieve, J. M., Markoseva, E. L., Rocha, C. E. & Abichi, B. 1999. Copepoda. In D. Boltovskoy (Ed), *South Atlantic Zooplankton* (pp. 869-1098). Leiden. The Netherlands, Backhuys Publishers.
- Chang, K.-H., Doi, H., Nishibe, Y., Nam, G.-S., & Nakano, S.-I. 2014. Feeding behavior of the copepod *Temora turbinata*: clearance rate and prey preference on the diatom and microbial food web components in coastal area. *Journal of Ecology and Environment. The Ecological Society of Korea*, 37(4), 225-229. DOI: <https://doi.org/10.5141/ecoenv.2014.027>.
- Campos, C.C., Garcia, T.M., Neumann-Leitao, S. & Soares, M.O. 2017. Ecological indicators and functional groups of copepod assemblages. *Ecological Indicators*. 83: 416-426. DOI: <https://doi.org/10.1016/j.ecolind.2017.08.018>.
- Campos-Hernández, A. & E. Suárez-Morales 1994. *Pelagic copepods of the Gulf of Mexico and Caribbean Sea. Biology and Systematics*. Quintana Roo Research Center. (CIQROII CONACYT). Mexico.
- Carotenuto, Y. 1999. Morphological analysis of larval stages of *Temora stylifera* (Copepoda, Calanoida) from the Mediterranean Sea. *Journal Plankton Research*, 21, 1613-1632.
- Carotenuto, Y., Ianora, A. & Miralto, A. 2011. Maternal and neonate diatom diets impair development and sex differentiation in the copepod *Temora stylifera*. *Journal of Experimental Marine Biology and Ecology*, 396(2), 99-107. DOI: <https://doi.org/10.1016/j.jembe.2010.10.012>.
- Carpenter, S., Cole, J., Hodgson, J., Kitchell, J., Pace, M. & Bade, D. 2001. Trophic cascades, nutrients, and lake

- productivity: whole-lake experiments. *Ecological Monographs*, 71(2), 163-186.
- Carrillo-Baltodano, A. M., & Morales-Ramírez, A. 2016. Changes in abundance and community composition of coral reef zooplankton after 25 years in a Caribbean reef. *Journal of Tropical Biology*, 64(3), 1029-1040. DOI: <https://doi.org/10.15517/rbt.v64i3.21449>
- Cury, P. & Roy, C. 1989. Optimal environmental window and pelagic fish recruitment success in upwelling areas. *Canadian Journal of Fisheries and Aquatic Sciences*, 46(4), 670-680.
- David-Santos, E. & Correa-Meuer, B. 2016. Densidade dos copépodes *Temora stylifera* (Dana, 1849) e *Temora turbinata* (Dana, 1849) na Baía de Sepetiba, Rio de Janeiro, Brazil. *Revista de Estudos Brasileiros*, 2, 27-35.
- Dur, G., Hwang, J.S., Souissi, S., Tseng, L.C., Wu, C.H., Hsiao, S.H. & Chen, Q.C. 2007. An overview of the influence of hydrodynamics on the spatial and temporal patterns of calanoid copepod communities around Taiwan. *Journal Plankton Research*, 29(1), i97-i116. DOI: <https://doi.org/10.1093/plankt/fbl070>.
- Engström-Öst, J., Brutemark, A., Vehmaa, A., Mothwani, N.H. & Katajisto, T. 2015. Consequences of a cyanobacteria bloom for copepod reproduction, mortality and sex ratio. *Journal Plankton Research*, 37(2), 388-398. DOI: <https://doi.org/10.1093/plankt/fbv004>
- Fariña, A., Méndez, E., Rabascal C., Márquez, A., Rojas, M., Peñuela, J., Rondón, J. & Flores, E. 2014. Monthly and intraday changes of the ichthyofauna associated with a sandy beach in east caracas island, Mochima National Park, Venezuela. *Boletín Instituto Oceanográfico de Venezuela*, 53(2), 171-183.
- Ferraz-Reyes, E. & Fernández, E. 1990. Annual cycle of planktonic heterotrophic bacteria and phytoplankton in the Gulf of Cariaco, Venezuela. *Boletín Instituto Oceanográfico de Venezuela*, 29(1&2), 43-56.
- Gusmão, L.F. & McKinnon, A.D. 2009. Sex ratios, intersexuality and sex change in copepods. *Journal Plankton Research*, 31(9), 1101-1117. DOI: <https://doi.org/10.1093/plankt/fbp059>
- Hirst, A.G., Bonnet, D., Conway, D.V. & Kiørboe, T. 2010. Does predation control adult sex ratios and longevities in marine pelagic copepods? *Limnology and Oceanography*, 55(5), 2193-2206. DOI: <https://doi.org/10.4319/lo.2010.55.5.2193>
- Hwang, J., Tu, Y., Tseng, L., Fang, L., Souissi, S., Fang, T., Lo, W., Twan, W., Hsiao, S., Wu, S., Peng, S., Wei, T. & Chen, Q. 2004. Taxonomic composition and seasonal distribution of copepods assemblage from waters adjacent to nuclear power plant I and II in northern Taiwan. *The Journal of Marine Science and Technology*, 12(5), 380-391.
- Hwang, J. S., Souissi, S., Tseng, L.C., Seuront, L., Schmitt, F., Fang, L.S., Peng, S.-H., Hsiao, S. H., ... & Wong, K. 2006. A 5-year study of the influence of the northeast and southwest monsoons on copepod assemblages in the boundary coastal waters between the East China Sea and the Taiwan Strait. *Journal of Plankton Research*, 28(10), 943-958.
- Ianora, A., Scotto-di-Carlo, B. & Mascellaro, P. 1989. Reproductive biology of the planktonic copepod *Temora stylifera*. *Marine Biology* 101,187-194.

- Jordan, T., Correll, D., Miklas, J. & Weller, D. 1991. Long-term trends in estuarine nutrients and chlorophyll, and short-term effects on variations in watershed discharge. *Marine Ecology Progress Series*, 75, 121-32.
- Kjørboe, T. 2006. Sex, sex-ratio, and the dynamics of pelagic copepod population. *Oceanologia*, 148: 40-50.
- Lahnsteiner, F., Kletzl, M. & Weismann, T. 2009. The risk of parasite transfer to juvenile fishes by live copepod food with the example *Triaenophorus crassus* and *Triaenophorus nodulosus*. *Aquaculture*, 295(1-2), 120-125. DOI: <https://doi.org/10.1016/j.aquaculture.2009.06.038>.
- Lakkis, S. 1994. Coexistence and competition within *Acartia* (Copepoda, Calanoida) congeners from Lebanese coastal water: Niche overlap measurements. *Hydrobiologia*, 292/293, 481-490.
- Lopes, R. 1997. *Special distribution, temporal variation and feeding activity of zooplankton in the estuarine complex of Paraguaná. Curitiba (Ph.D. thesis)*. Science Program, Zoology. Biological Sciences Sector. Federal University of Paraná, Brazil.
- Lopes, R., Brandini, F. & Gaeta, S. 1999. Distributions patterns of epipelagic copepods off Rio de Janeiro (SE Brazil) in summer 1991-1992 and winter 1992. *Hydrobiologia*, 411, 161-174. DOI: <https://doi.org/10.1023/A:1003859107041>
- Márquez-Rojas, B., Troccoli, L., Marcano, L., Morales, J., Allen, T., Marín, B. & Díaz-Ramos, J. 2008. Biomass, Density and Composition of Mochima Bay, Venezuela. *Gayana*, 72(1), 52-67. DOI: <https://doi.org/10.4067/S0717-65382008000100008>
- Márquez-Rojas, B., Díaz-Ramos, J. R., Troccoli, L., Marín, B. & Varela, R. 2009. Zooplankton density, biomass and composition, in the surface stratum of the Cariaco basin, Venezuela. *Journal of Marine Biology and Oceanography*, 44 (3), 737-749. DOI: <https://doi.org/10.4067/S0718-19572009000300019>
- Márquez-Rojas, B., Benítez-Brito, M. & Troccoli, L. 2016. Hydrography and structural changes of mesozooplankton in the Gulf of Cariaco in two contrasting periods. *Revista Biodiversidad Neotropical* 6(2), 135-46. DOI: <https://doi.org/10.18636/bioneotropical.v6i2.346>
- Márquez-Rojas, B. & Zoppi de Roa, E. 2017. Zooplankton of Mochima Bay: Retrospective and Prospective. *Saber, Universidad de Oriente, Venezuela*, 29, 59-71.
- Márquez-Rojas, B., Zoppi De Roa, E. & Zegarra-Narro, J. 2020. An Updated Checklist of Copepod Species (Arthropoda: Crustacea) from the Gulf of Cariaco, Venezuela. *Pan-American Journal of Aquatic Sciences*, 15(3), 143-150.
- Márquez-Rojas, B. & Zoppi de Roa, E. 2023. Planktonic copepods from the northeastern Caribbean and Venezuelan Atlantic. *Boletín de Investigaciones Marinas y Costeras*, 52(2), 9-40. DOI: <https://doi.org/10.25268/bimc.invemar.2023.52.2.1187>
- Marsh, R., Addo, K. A., Jayson-Quashigah, P. N., Oxenford, H. A., Maxam, A., Anderson, R. & Tompkins, E. L. 2021. Seasonal predictions of holopelagic Sargassum across the tropical Atlantic accounting for uncertainty in drivers and processes: the SARTRAC ensemble forecast system. *Frontiers in Marine Science*, 8, 722524. DOI: <https://doi.org/10.3389/fmars.2021.722524>

- <https://doi.org/10.3389/fmars.2021.72524>
- McKinnon, A.D. & Duggan, S. 2014. Community ecology of pelagic copepods in tropical waters. In Laurent Seuront (Ed.), *Copepods: Diversity, Habitat and Behavior* (pp. 25-49). Nova Science Publishers: New York, USA.
- Medellín-Mora, J. & Navas, G. 2010. Taxonomic listing of copepods (Arthropoda: Crustacea) from the Colombian Caribbean Sea. *Boletín de Investigaciones Marinas y Costeras*, 39 (2), 265-306. DOI: <https://doi.org/10.25268/bimc.invenmar.2010.39.2.151>
- Moore, E. & Sander, F. 1983. Physioecologic of tropical marine copepods. II Sex ratios. *Crustaceana*, 44,113-122.
- Morales-Ramírez, A., Corrales-Ugalde, M., Esquivel-Garrote, O., Carrillo-Baltodano, A., Rodríguez-Sáenz, K. & Sheridan, C. 2018. Marine zooplankton studies in Costa Rica: a review and future perspectives. *Journal Tropical Biology* 66(Suppl. 1): S24-S41. DOI: <https://doi.org/10.15517/rbt.v66i1.33258>
- Orsi, J., Bowman, T., Marelli, T. & Hutchinson, A. 1983. Recent introduction of planktonic calanoid copepod *Sinocalanus doerrii* from mainland China to the Sacramento-San Joaquin Estuary of California. *Journal Plankton Research*, 5 (3), 357-375.
- Paffenhöfer, G. 1998. Feeding rates and behavior of zooplankton. *Bulletin of Marine Science*, 43 (3), 430-445.
- Polunia, J.J., Lange, E.K. & Krechik, V. A. 2019. Structure and Distribution of Autumn Zooplankton in the Southeastern Baltic Sea in 2015. *Oceanology*, 59, 66-74. DOI: <http://dx.doi.org/10.1134/S0001437019010181>
- Razouls, C., de Bovée, F., Kouwenberg, J. & Desreumaux, N. 2024. *Diversity and Geographic Distribution of Marine Planktonic Copepods*. *Marine Planktonic Copepods*. Retrieved from: <<http://copepodes.obsbanyuls.fr/en>>
- Rimoldi, D. 2008. *Estudo comparativo dos Copépodes Temora stylifera e T. turbinata na plataforma continental sudeste do Brasil na verao e inverno de 2002* (Master's Thesis). Oceanographic Institute of the University of Sao Paulo. Sao Paulo, Brazil.
- Rivas-Rojas, T., Díaz-Ramos, J., Troccoli-Ghinaglia, L., Charzeddine-Charzeddine, L., Subero-Pino, S. & Márquez, A. 2007. Daily variation of some physical-chemical variables and phytoplankton biomass in a tropical beach, Cumaná, Sucre state, Venezuela. *Boletín Instituto Oceanográfico de Venezuela*, 46 (1), 13-21.
- Romero, O. E., Baumann, K.-H., Zonneveld, K. A., Donner, B., Hefter, J., Hamady, B., Pospelova, V. & Fischer, G. 2020. Flux variability of phyto- and zooplankton communities in the Mauritanian coastal upwelling between 2003 and 2008, *Biogeosciences*, 17, 187-214, DOI: <https://doi.org/10.5194/bg-17-187-2020>
- Rueda-Roa, D., Ezer, T. & Müller-Karger, F. 2018. Description and mechanisms of the mid-year upwelling in the southern Caribbean Sea from remote sensing and local data. *Journal of Marine Science and Engineering*, 6(2), 36. <https://doi.org/10.3390/jmse6020036>
- Smitha, P., Shivashankar, A. & Venkataramana, G. 2013. Zooplankton diversity of Chikkadevarayana canal in relation to physico-chemical characteristics. *Journal of Environmental Biology*, 34, 819-24.

- Tseng, L. C., Wang, Y. G., Lian, G. S. & Hwang, J. S. 2020. A multi-year investigation of the Temoridae (Copepoda, Calanoida) assemblage succession within the interplay waters of the northern South China Sea. *Crustaceana*, 93(3-5), 519-540. DOI: <http://dx.doi.org/10.1163/15685403-00004009>
- Villac, M., Lopes-Rivera, I., Rodrigo, T., Bassanello, R., Cunha, D., Martinelli-Filho, J.E. & Santos, D. 2009. Informe sobre as espécies exóticas invasoras invasoras marinhas no Brasil / Ministério do Meio Ambiente; Rubens M. Lopes/IO-USP. [et al.], Editor. - Brasília: MMA/SBF. (Série Biodiversidade, 33), 440.
- Yan-Guo, W., Li-Chun, T., Bing-Peng, X., Rou-Xin, S., Xiao-Yin, C., Chun-Guang, W. & Jiang-Shiou, H. 2021. Seasonal Population Structure of the Copepod *Temora turbinata* (Dana, 1849) in the Kuroshio Current Edge, Southeastern East China Sea. *Applied Sciences* 11(16), 7545. DOI: <https://doi.org/10.3390/app11167545>.
- Zar, J. 1999. *Biostatistical Analysis*. Prentice Hall, Upper Saddle River, New Jersey, USA.