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Reproductive dynamics of Diplostraca in the Black Sea: insights from Hamsilos Bay, Sinop, Türkiye

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Abstract: In the coastal marine ecosystem of the Black Sea, Diplostraca is the second most dominant mesozooplankton after Copepoda. Its parthenogenetic reproductive strategy enables significant population growth from spring (March) to fall (December), contributing substantially to mesozooplankton abundance. This study investigated the fecundity, embryonic development stages, and population structure of four of Diplostraca species in Hamsilos Bay: *Evadne spinifera*, *Pleopis polyphemoides*, *Penilia avirostris*, and *Pseudevadne tergestina*. Samples were taken every month from three stations between July 2015 and June 2016. Population analysis showed that parthenogenetic females were dominant, reaching up to 100% of the population. Gamogenetic females, females without embryos, and males constituted 23%, 33%, and 9% of the population, respectively. Embryonic development stages were species-specific: stage A embryos were predominant in *Ps. tergestina*, *Pl. polyphemoides*, and *E. spinifera*, whereas stage C embryos were most common in *Pe. avirostris*. The ultimate stage, stage D, was rare across all species. The number of embryos per parthenogenetic female varied from 1 to 5 in *E. spinifera*, 2–8 in *Pe. avirostris*, 1–8 in *Pl. polyphemoides*, and 1–6 in *Ps. tergestina*. Diplostraca primarily reproduced via parthenogenesis, enhancing their contribution to the mesozooplankton community in Hamsilos Bay. The number of embryos observed was lower compared to a similar study performed in the Marmara Sea, possibly due to distinct regional environmental differences such as nutrient availability and temperature. This study bridges a critical gap in understanding the reproductive dynamics of Diplostraca in semienclosed seas and factors affecting them, establishing a valuable reference for future research.

Key words: Diplostraca, reproductive biology, population structure, embryo number, embryo stage

1. Introduction

Diplostraca Gerstaecker, 1866, is a superorder of marine zooplankton. They are a vital component of the marine zooplankton community, playing a key role in the marine planktonic food web. Diplostraca are primary consumers of phytoplankton (He et al., 2023) and a major food source for zooplankton (Schroeder et al., 2022; Uye and Liang, 2022), fish larvae (Sabatés et al., 2015), and planktivorous fish (Lankov et al., 2010). Despite their global distribution in oceans, Diplostraca show relatively low species diversity in marine environments compared to freshwater environments, the latter including more than 620 species (Forró et al., 2008). To date, only eight Diplostraca species have been identified in marine habitats (Onbé, 1999).

The reproductive cycle of Diplostraca alternates between two stages: asexual reproduction (parthenogenesis) and sexual reproduction (gamogenesis) (Egloff et al., 1997). During the parthenogenetic stage, genetically identical embryos (Hebert and Ward, 1972) develop in the brooding chamber beneath the carapace of parthenogenetic females and are discharged into the sea as free-swimming adult individuals (Platt and Yamamura, 1986). When environmental conditions become unfavorable for population growth, Diplostraca transition to gamogenesis (Egloff et al., 1997). In this stage, males emerge, and gamogenetic females produce genetically diverse resting eggs that settle on the seabed (Onbé, 1985; Egloff et al., 1997).

Diplostraca species often achieve high population densities during certain times of the year, particularly from early summer to late fall. This rapid increase, driven by parthenogenetic reproduction, significantly enhances zooplankton abundance and species diversity in coastal marine ecosystems. However, their population density declines just as rapidly, eventually disappearing from the planktonic community (Kodama et al., 2021).

While the composition, seasonal abundance peaks, distribution, and environmental relationships of Diplostraca species in Turkish seas are well-documented (Buyukates and İnanmaz, 2007, 2009; Isinibilir, 2009; Gülşahin and Tarkan, 2012; Toklu Alıçlı et al., 2014; Terbiyik Kurt and Polat, 2014; Terbıyık Kurt and Polat,

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2017; Terbıyık Kurt et al., 2018; Üstün et al., 2016, 2018; Üstün, 2019; Killi, 2020; Yildiz, 2025), studies on their reproductive strategies and fecundity have been confined to the Sea of Marmara (Bedikoğlu et al., 2022). The growth and reproductive cycle of *Penilia avirostris* were previously investigated exclusively by Pavlova (1959) in Sevastopol Bay in the Black Sea. Although Pavlova's study (1959) provides an important foundation, it focused on a single species, and the considerable time elapsed since its publication underscores the need for updated and comprehensive data. To address this gap, the present study examines the sex ratios, embryo number, and embryonic development of *Evadne spinifera*, *Pleopis polyphemoides*, *Pe. avirostris*, and *Pseudevadne tergestina* in Hamsilos Bay in the Black Sea. By expanding on Pavlova's findings (1959), this study provides detailed and up-to-date insights into the reproductive dynamics of Diplostraca in the region. This study serves as a valuable foundation for future studies, as it is the first to explore Diplostraca reproductive biology in the Turkish waters of the Black Sea.

2. Materials and methods

Sinop is situated on the Boztepe Peninsula on the northernmost coast of Anatolia, which extends into the Black Sea. This peninsula features two natural harbors oriented to the east and west, known as Büyük Liman (inner harbor) in the southeast and Akliman (outer harbor) in the northwest. Hamsilos Nature Park was designated a natural protected area in 2007[1] and is an ecologically significant region requiring conservation (Öztekin et al., 2024). Hamsilos Bay is located within the Akliman region of the park, and is therefore exposed to storms originating from the northwest (Uygun and Üstün, 2024).

Sampling was performed on a monthly basis at three stations between July 2015 and June 2016 in Hamsilos Bay. The geographical coordinates of the stations were as follows: station 1 (42°03′52″N, 35°03′14″E), station 2 (42°04′5″N, 35°02′59″E), and station 3 (42°04′12″N, 35°02′45″E). All stations were situated near the mouth of the bay, where it connects to the open sea at a depth of 30 m (Figure 1).

Surface seawater temperature and salinity were recorded in situ at each station using a 6600 MDS multiparameter device (YSI Inc., Yellow Springs, OH, USA) during sampling surveys. Chlorophyll-a concentrations (μg L^{-1}) of surface seawater were determined using the acetone extraction method described by Parsons et al. (1984). The average values of surface seawater chlorophyll-a, salinity, and temperature from the three stations were calculated and used in subsequent analyses.

Sampling was conducted through daytime vertical hauls from the seafloor to the surface using a plankton net (0.2 m^2 mouth area and 112 μm mesh size). The sample was promptly fixed in a solution of formaldehyde, seawater, and borax (4% v/v), for subsequent quantitative and qualitative analyses.

The abundance of Diplostraca species was calculated as previously described by Postel et al. (2000). Diplostraca species were identified and counted under a stereomicroscope in two 1 mL subsamples taken from each main sample with a Henson-Stempel pipette that had a known volume of either 75 mL or 100 mL. The mean values obtained from the replicates were extrapolated to estimate the total abundance per sample. Abundance values were averaged across the three stations and expressed as the mean ± standard deviation of individuals per cubic meter (ind. m^{-3}).

For each station, thirty individuals of each target species (*E. spinifera*, *Pe. avirostris*, *Ps. tergestina*, and *Pl. polyphemoides*) were randomly selected from the monthly samples. Sex and brood composition analyses were not conducted in months with low individual counts (<30 individuals per station), such as March and June 2016, due to insufficient sample size. The selected individuals were categorized based on their sex and whether they contained embryos or eggs in their brood pouches. For *E. spinifera*, *Pl. polyphemoides*, and *Ps. tergestina*, individuals were divided into four groups: female (F: female without embryos), parthenogenetic female (PF: female with embryos), gametogenetic female (GF: female with resting eggs) and male (M). For *Pe. avirostris*, an additional juvenile class (J: individuals not producing embryos, <500 μm) was included. All individuals were examined under a stereomicroscope, and the brood pouches of PF and GF individuals were carefully opened using a fine dissecting needle inserted through the anus.

The number of embryos in PF individuals was recorded, and their developmental stages were determined. Resting eggs (Re) extracted from GF individuals were also counted separately. Based on morphological characteristics, embryos from PF individuals were classified into four developmental stages: stage A (the first stage), stage B, stage C, and stage D (final stage) (Wong et al., 2004; Bedikoğlu et al., 2022).

Fecundity was defined in this study as the mean number of embryos per PF.

Spearman's rank correlation analysis was performed to assess the relationship between environmental variables (temperature, salinity, and chlorophyll-a) and the abundance of Diplostraca species. The analysis was conducted using R software version 4.2.3.[2]

[1]Republic of Türkiye Ministry of Agriculture and Forestry (2023). Sinop-Hamsilos Natural Park (in Turkish). Website https://bolge10.tarimorman.gov.tr/Menu/48/Sinop-Hamsilos-Tabiat-Parki [accessed 03 March 2023].

[2] R Core Team (2023). The R Project for Statistical Computing [online]. Website https://www.R-project.org [accessed 14 April 2025].

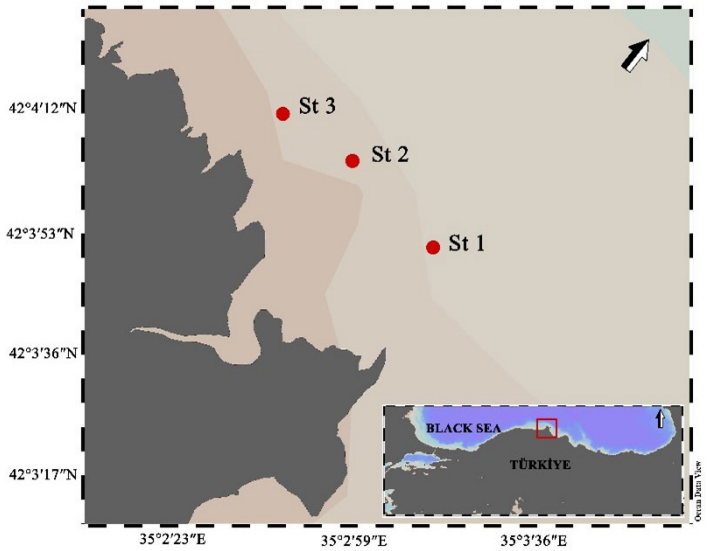

Figure 1. Map of the sampling area.

The readr package[3] was used for data import, and the Hmisc package[4] for correlation analysis.

3. Results

3.1. Environmental parameters, species composition, and seasonal occurrence of Diplostraca

Monthly variations in surface seawater temperature, salinity, chlorophyll-a concentrations, and Diplostraca abundance were observed in Hamsilos Bay. The minimum temperature, 8.5 ± 0.01 °C, was observed in February 2016, whereas the maximum temperature, 25.8 ± 0.18 °C, occurred in August 2015. Salinity fluctuated from 17.79 ± 0.08 in September 2015 to 18.96 ± 0.02 in May 2016. Chlorophyll-a concentration ranged from 0.14 ± 0.03 µg L^{-1} in June 2016 to 0.87 ± 0.03 µg L^{-1} in February 2016 (Figure 2).

The abundance of Diplostraca showed distinct seasonal trends, peaking in September 2015 with 1897.5 ± 200.53 ind. m^{-3} (Figure 2). Relatively high abundance values were also recorded in August 2015 (574.86 ± 220.87 ind. m^{-3}) and July 2015 (217.5 ± 21.03 ind. m^{-3}). Conversely, the lowest abundance values were recorded in March 2016 (0.28 ± 0.48 ind. m^{-3}) and June 2016 (3.72 ± 4.14 ind. m^{-3}).

The warm water species *Pe. avirostris*, *Ps. tergestina*, and *E. spinifera* first appeared in July 2015 (23.94 °C) and reached peak abundance in September 2015 (24 °C). These species were not observed in the samples after November (15.46 °C), October (19.58 °C), and September 2015, respectively. *Pl. polyphemoides* achieved maximum abundance in July 2015 under high-temperature conditions (23.94 °C), but it was not observed after November 2015. The species reemerged in March 2016 at lower temperatures (8.85 °C) (Figure 3).

The relationship between the abundances of Diplostraca species and environmental variables (temperature, salinity, and chlorophyll-a) is presented in Table 1. The abundance values of Diplostraca species showed a positive and statistically significant correlation with temperature ($p < 0.001$). This relationship was particularly strong for Diplostraca, *Pe. avirostris*, and *Ps. tergestina* ($r = 0.892$, $r = 0.832$, $r = 0.807$, respectively). In contrast, salinity showed a negative and statistically significant correlation for most species ($p < 0.001$), with Diplostraca ($r = -0.780$) and *Pe. avirostris* ($r = -0.767$) showing the strongest negative correlations. Correlations with chlorophyll-a were weaker; however, significant negative relationships were observed for some species, such as *E. spinifera* ($r = -0.508$, $p < 0.005$).

3.2. Population structure

PFs were the most abundant Diplostraca population in this study, comprising 74.4% to 100% of individuals. The population abundance increased rapidly from July 2015 to October 2015 due to parthenogenetic reproduction. GFs were observed more frequently than Ms, with the proportion of GF individuals varying by species. The proportion of GF individuals was 1.1% for *Pl. polyphemoides* and *Pe. avirostris* and 15.5% for *E. spinifera*. No GF individuals

[3] Wickham H, Hester J, Francois R, Bryan J, Bearrows S, Posit Software, PBC (2022). readr: Read Rectangular Text Data [online]. Website https://cran.r-project.org/package=readr [accessed 14 April 2025].

[4] Harrell FE Jr, Dupont C (2022). Hmisc: Harrell Miscellaneous [online]. Website https://cran.r-project.org/package=Hmisc [accessed 14 April 2025].

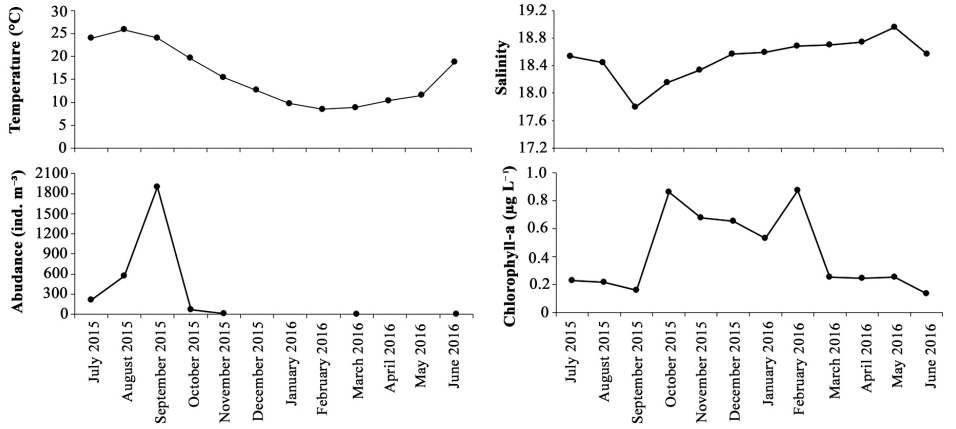

Figure 2. Monthly variation of mean surface seawater temperature (°C), salinity, chlorophyll-a (µg L^{-1}) values, and Diplostraca abundance (ind. m^{-3}) in Hamsilos Bay.

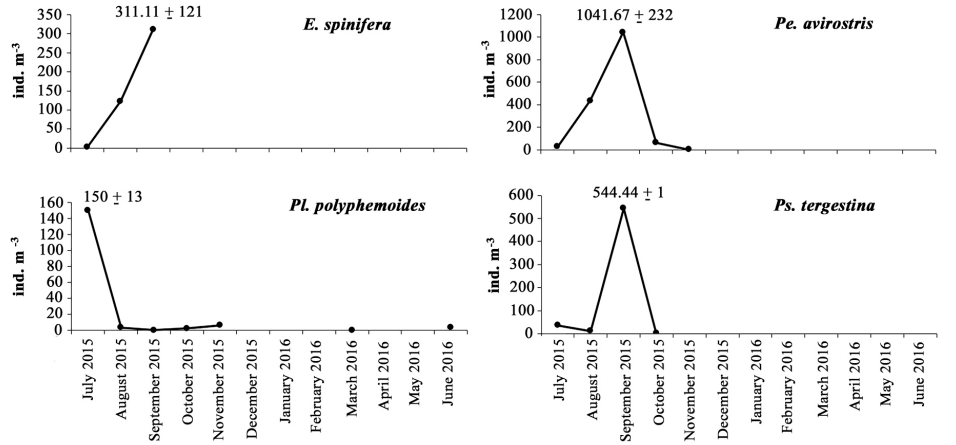

Figure 3. Monthly variations in the mean abundance of four Diplostraca species in Hamsilos Bay.

were detected in the *Ps. tergestina* population. In this study, the proportion of Ms in the population was around 3%, with no *Pl. polyphemoides* and *Pe. avirostris* males found. The proportion of F in the Diplostraca population ranged from 3.1% to 22.2%. Juvenile individuals were identified only in the *Pe. avirostris* species, ranging from 2.2% to 7.8%. This suggests that the *Pe. avirostris* population has an active reproductive cycle (Figure 4).

All species were present at all stations. Except for *Pl. polyphemoides* in August 2015 (30 individuals from only one station), all species—including *Pl. polyphemoides* in July 2015—were present at all three stations, with 30 individuals examined per station. PFs were notably more numerous during the summer months across all species. GFs, although observed in lower numbers, showed a notable increase in *E. spinifera* in September 2015. Additionally, only one resting egg was observed per GF individual across all species (Table 2).

A higher abundance of embryos at the initial developmental stage (stage A) was detected in *E. spinifera* (46% to 48%), *Ps. tergestina* (38% to 51%), and *Pl. polyphemoides* (40% to 43%). On the other hand, stage C was most frequently noted in *Pe. avirostris* (48% to 68%). Stage D, the last phase of embryonic development, was the least common stage observed among all species (1% to 5%). In every species analyzed, the mean number of embryos in stage A was higher compared to the other embryonic stages (Figure 5).

3.3. Reproductive strategies

The embryo number of PFs varied across the four Diplostraca species studied: *Pe. avirostris* carried between two and eight embryos, *E. spinifera* between one and five, *Ps. tergestina* between one and six, and *Pl. polyphemoides* between one and eight. The highest mean embryo number (5.77 ± 0.80 embryos PF^{-1}) was observed in *Pe. avirostris*

Table 1. Spearman correlation coefficients between environmental variables and the abundance of Diplostraca species.

Taxa	Temperature	Salinity	Chlorophyll-a
Diplostraca	0.892***	–0.780***	–0.364*
E. spinifera	0.705***	–0.460*	–0.508**
Pe. avirostris	0.832***	–0.767***	–0.177
Pe. polyphemoides	0.655***	–0.485*	–0.198
Ps. tergestina	0.807***	–0.644***	–0.292

Significance levels: * $p < 0.05$, ** $p < 0.005$, *** $p < 0.001$.

Table 2. Numbers of PF, GF, and Re for each species based on the combined data of individuals collected from three stations each month (30 individuals per station for each species).

Collection date	Species	PF	GF	Re
July 2015	***E. spinifera***	-	-	-
	Pe. avirostris	75	-	-
	Pl. polyphemoides	89	1	1
	Ps. tergestina	90	-	-
August 2015	***E. spinifera***	90	-	-
	Pe. avirostris	79	-	-
	Pl. polyphemoides	30	-	-
	Ps. tergestina	90	-	-
September 2015	***E. spinifera***	73	14	14
	Pe. avirostris	79	-	-
	Pl. polyphemoides	-	-	-
	Ps. tergestina	79	-	-
October 2015	***E. spinifera***	-	-	-
	Pe. avirostris	67	1	1
	Pl. polyphemoides	-	-	-
	Ps. tergestina	-	-	-

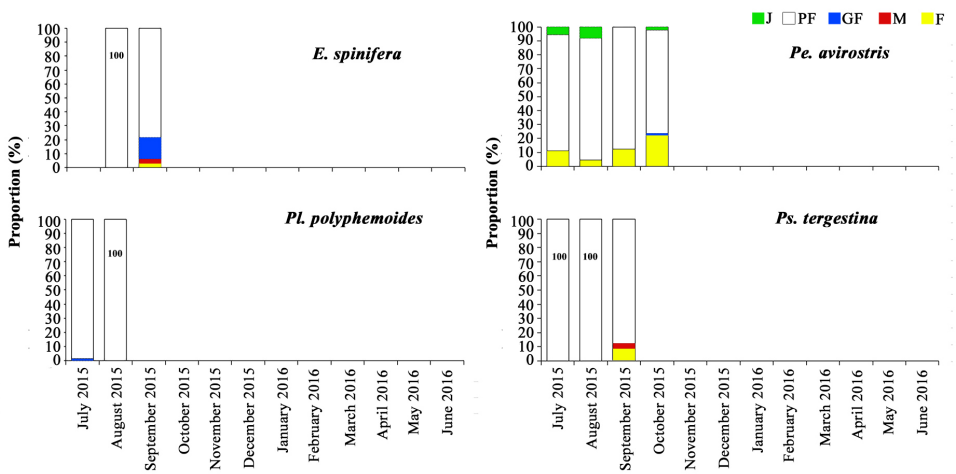

Figure 4. Monthly variation in the population stage composition of four Diplostraca species in Hamsilos Bay, based on combined data from three stations.

in July 2015, under higher chlorophyll-a concentrations (0.86 μg L^{-1}) and elevated temperatures (25.8 °C). High reproductive success was recorded for *Pe. avirostris* in July, September, and October 2015, whereas *Pl. polyphemoides* showed high reproductive success in August 2015 (Table 3).

4. Discussion

4.1. Seasonal occurrence of Diplostraca

Diplostraca plays a crucial role in the mesozooplankton community of coastal marine ecosystems, particularly during warm seasons (Du et al., 2022). Their reproductive strategies are key to population dynamics, as larval fish depend on zooplankton such as copepods and diplostraceans for feeding (Sabatés et al., 2015). Studies suggest that larval fish may preferentially target diplostraceans over copepods, with those primarily feeding on diplostraceans showing higher survival rates compared to individuals consuming other zooplankton (Mayer and Wahl, 1997; Graeb et al., 2004). Through parthenogenetic reproduction, Diplostraca species can rapidly achieve high population densities, providing a vital food source for fish larvae, especially during critical developmental stages. This may increase survival rates and enhance recruitment success in the early ontogenetic stages of fish (Uygun and Hoşsucu, 2024). Thus, fluctuations in Diplostraca

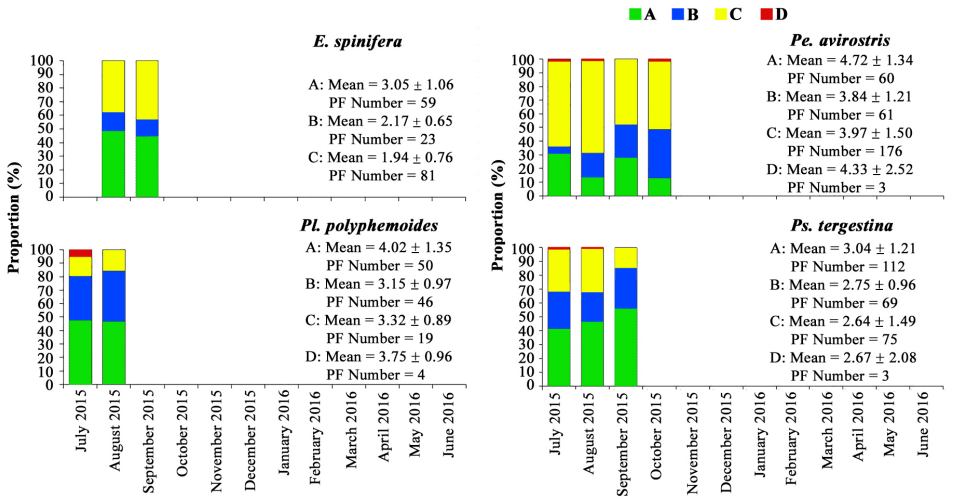

Figure 5. Monthly variation of embryo stages of PFs of four Diplostraca species in Hamsilos Bay, based on the combined data from three stations.

Table 3. Fecundity of PFs of four Diplostraca species in Hamsilos Bay.

		Number of embryos PF^{-1}					Temperature	Salinity	Chlorophyll-a
Species	**Number of embryos**	**July 2015**	**August 2015**	**September 2015**	**October 2015**	**Overall Mean ± SD**			
E. spinifera	1–5		2.38 ± 1.06	2.37 ± 0.95		2.37 ± 1.01	24 (September)–25.8 (August)	17.8 (September)–18.4 (August)	0.16 (September)–0.22 (August)
Pe. avirostris	2–8	5.77 ± 0.80	2.41 ± 0.59	4.04 ± 0.82	4.28 ± 1.00	4.1 ± 1.45	19.6 (October)–25.8 (August)	17.8 (September)–18.5 (July)	0.16 (September)–0.86 (October)
Pl. polyphemoides	1–7	3.27 ± 1.00	4.43 ± 1.30			3.56 ± 1.19	23.9 (July)–25.8 (August)	18.4 (August)–18.5 (July)	0.22 (August)–0.23 (July)
Ps. tergestina	1–7	3.70 ± 1.20	2.52 ± 1.11	2.23 ± 0.91		2.84 ± 1.26	23.9 (July)–25.8 (August)	17.8 (September)–18.5 (July)	0.16 (September)–0.23 (July)

abundance, driven by seasonal and environmental factors, can significantly impact the growth of fish larvae and recruitment success within the Black Sea ecosystem. Investigating these dynamics is necessary for predicting the function of mesozooplankton communities in coastal food webs and evaluating overall ecosystem productivity.

Environmental factors, particularly temperature, significantly affect the seasonal distribution and abundance of Diplostraca (Pavlova, 1959; Marazzo and Valentin, 2003a; Yildiz, 2025). Diplostraca species emerge in early spring, with maximum abundance observed in summer and autumn months. They become scarce or absent in winter (Isinibilir, 2009; Terbiyik Kurt and Polat, 2014), with their resting eggs remaining on the seabed (Ramírez and Pérez Seijas, 1985). The abundance of Diplostraca species increased throughout the summer and autumn periods in this research. This seasonal distribution aligns with the ecological characteristics of the species and supports findings from similar studies conducted in the Black Sea (Lebedeva et al., 2015; Üstün et al., 2016, 2018; Bişinicu et al., 2023; Yildiz, 2025).

4.2. Population structure

Gametogenetic reproduction, one of the two reproductive strategies of Diplostraca, is essential for ensuring the continuity of their lineage. Within the population structures of these species, GF and M represent individuals using this reproductive strategy. In general, gametogenetic individuals constitute only a small proportion of the population in coastal marine regions (Hairston and Cáceres, 1996; Miyashita et al., 2010). However, there are exceptions, as observed in this study for *E. spinifera*. For instance, gamogenetic individuals of *Ps. tergestina* make up 13.6% of the population in the Atlantic Ocean (Oghenekaro and Chigbu, 2019), and between 3% and 7% in the Gulf of Mexico (Cházaro-Olvera et al., 2024). In some cases, this proportion exceeds 70% in the South Atlantic Ocean (Marazzo and Valentin, 2004a). The proportion ranges from 20% to 50% in the South Atlantic Ocean for *Pl. polyphemoides* (Marazzo and Valentin, 2003b). Marazzo and Valentin (2003a) suggested that high population densities could increase the probability of encounters between female and male specimens, thus enhancing the proportion of gametogenetic individuals. In our study, the high proportion of gamogenetic individuals observed in *E. spinifera* suggests that this species may use an alternative reproductive strategy in response to environmental conditions. Furthermore, the preference for gametogenetic reproduction may serve as a strategy to enhance genetic diversity and increase the adaptive capacity of the species.

Although the mechanisms underlying the transition from parthenogenetic to gamogenetic reproduction in marine Diplostraca remain unclear (Marazzo and Valentin, 2003a), GF and M individuals in marine Diplostraca species typically appear during periods of high population density and reach their maximum abundance just before the population disappears from the plankton (Egloff et al., 1997). GF and M individuals were observed in *E. spinifera*, *Pl. polyphemoides*, and *Ps. tergestina* during the months when their abundance peaked (September 2015 and July 2015) in the present study. However, GF *Pe. avirostris* individuals were detected in October 2015, after the peak abundance in September. A similar trend has been documented for *Pe. avirostris* in prior investigations from the Western Mediterranean Sea (Atienza et al., 2008), the Sea of Marmara (Bedikoğlu et al., 2022), the Gulf of Mexico (Cházaro-Olvera et al., 2024), and the South Atlantic Ocean (Marazzo and Valentin, 2003a, 2004b). Gametogenetic individuals are less frequently observed due to insufficient sampling frequency and the analysis of only subsamples, making their detection more challenging. According to Egloff et al. (1997), different Diplostraca species may exhibit varying responses to the same environmental cues within the same time and region, with gametogenetic reproduction occurring in some species but not in others under similar conditions.

In Diplostraca species, individuals in the last stage (stage D) of embryonic development have pigmented eyes (Platt and Yamamura, 1986) and are more easily detected by planktivorous fish and other predators, such as chaetognaths (Mullin and Onbé, 1992; Wong et al., 2008). Therefore, PFs carrying developed embryos are generally found in the water column at night to avoid intense predation pressure (Mullin and Onbé, 1992). This study was carried on during the daytime, which might explain the low number of stage D embryos observed.

4.3. Reproductive strategies

Few studies have characterized the reproductive biology of Diplostraca species, including *E. spinifera*, *Pl. polyphemoides*, *Pe. avirostris*, and *Ps. tergestina*. The limited detailed research on these species has been conducted in five regions: the South Atlantic Ocean, the Western Mediterranean Sea, the China Sea, the Gulf of Mexico, the Inland Sea of Japan, and the Sea of Marmara.

The varying embryo numbers for *Pe. avirostris* in Hamsilos Bay is generally consistent with the values reported for the Inland Sea of Japan (Mullin and Onbe, 1992), the Catalan Sea (Atienza et al., 2008), and Gulf of Mexico (Cházaro-Olvera et al., 2024). However, the values noted in the present study were lower than those documented for the Gulf of Mexico (Della Croce and Angelino, 1987), the Southern China Sea (Tang et al., 1995), the coastal region of Brazil (Marazzo and Valentin, 2003a, 2004b; Miyashita et al., 2010), and the Sea of Marmara (Bedikoğlu et al., 2022). The embryonic fecundity observed in this study is similar to the values documented for the coastal regions of the Inland Sea of Japan (Mullin and Onbe, 1992), the Southern China Sea (Tang et al., 1995), the coastal region of Brazil (Marazzo and Valentin, 2004b; Miyashita et al., 2010), and the Gulf of Mexico (Cházaro-Olvera et al., 2024) (Tables 3 and 4).

Table 4. Fecundity of PFs of four Diplostraca species from different environments.

Species	Number embryos	Number of embryos PF^{-1}	Study area	References	Temperature	Salinity
Pe. avirostris	1–11		Black Sea	Pavlova (1959)		
	1–10		Gulf of Mexico	Della Croce and Angelino (1987)	27.0–30.9	34.7–38.0
	1–8	3.25	Inland Sea of Japan	Mullin and Onbé (1992)	24–26	
	1–14	4.4	South China Sea	Tang et al. (1995)	16–32	7.3–37.2
	3–9		Brazil – South Atlantic Ocean	Marazzo and Valentin (2003a)	20.5–27.5	23–26
	1–11	4.35	Brazil – South Atlantic Ocean	Marazzo and Valentin (2004b)	21.2–28.5	24.6–35.6
	1–8	3.21 ± 0.09 in 2003 4.23 ± 0.99 in 2004	Spain – Northwest Mediterranean	Atienza et al. (2008)	16–27	
	1–12	3.6 ± 1.5	Brazil – South Atlantic Ocean	Miyashita et al. (2010)	14.8–28.2	31.1–36
	1–11		Sea of Marmara	Bedikoğlu et al. (2022)	11.5–24.7	21.8–28.8
	2–7	3.7 ± 0.26	Gulf of Mexico	Cházaro-Olvera et al. (2024)	26.5–29.3	33.4–35.9
Ps. tergestina	3–12	7.76	Chesapeake Bay, USA	Bryan (1979)	25.2–29.6	14.4–31.2
	1–8		Gulf of Mexico	Della Croce and Angelino (1987)	16.4–30.9	29.92–38.03
	1–7	3.3	Inland Sea of Japan	Mullin and Onbé (1992)	24–26	
	2–6	3.3	Gulf of Mexico	Mullin and Onbé (1992)	27–28	
	1–14	4.6	South China Sea	Tang et al. (1995)	16–32	7.3–37.2
	2–8	4.3 ± 0.16	Gulf of Mexico	Cházaro-Olvera et al. (2024)	26.5–29.3	33.4–35.9
	4–8	6.36 ± 0.77	Brazil – South Atlantic Ocean	Marazzo and Valentin (2004a)	21–27	
	1–14	6.49	Brazil – South Atlantic Ocean	Marazzo and Valentin (2004b)	21.2–28.5	24.7–35.6
	1–10	3.7 ± 1.5	Brazil – South Atlantic Ocean	Miyashita et al. (2011)	14.8–28.2	31.1–35.7
	1–19	6.57 ± 0.15	Atlantic Ocean	Oghenekaro and Chigbu (2019)	20.6–23.7	30–35.5
	1–9		Sea of Marmara	Bedikoğlu et al. (2022)	10.4–24.2	21.9–27.3
Pl. polyphemoides	5–8	6.71 ± 0.78	Brazil – South Atlantic Ocean	Marazzo and Valentin (2003b)	21–28	23–35
	1–10	3.6 ± 0.3	Baltıc Sea	Põllupüü et al. (2010)	5–25	1–6
	1–6	2.9 ± 1.5	Brazil – South Atlantic Ocean	Miyashita et al. (2011)	15.3–25	33.7–35.7
	1–13		Sea of Marmara	Bedikoğlu et al. (2022)	6.9–24.5	21.8–28.5
E. spinifera	1–10	5 ± 1.5	Brazil – South Atlantic Ocean	Miyashita et al. (2011)	14.8–27.2	31.1–35.6
	4–6	4.3 ± 0.33	Atlantic Ocean	Oghenekaro and Chigbu (2019)		

The embryo number range for *Ps. tergestina* was similar to that observed in the Inland Sea of Japan (Mullin and Onbé, 1992) and the Gulf of Mexico (Della Croce and Angelino, 1987; Cházaro-Olvera et al., 2024). However, embryo numbers reported for Chesapeake Bay (Bryan, 1979), the Southern China Sea (Tang et al., 1995), the coastal region of Brazil (Marazzo and Valentin, 2004a, 2004b; Miyashita et al., 2011), the Atlantic Ocean (Oghenekaro and Chigbu, 2019), and the Sea of Marmara (Bedikoğlu et al., 2022) were found to be quite high and varied widely. The embryonic fecundity for *Ps. tergestina* in the present study is significantly lower than those reported for the Chesapeake Bay (Bryan, 1979), the Inland Sea of Japan (Mullin and Onbé, 1992), the Gulf of Mexico (Della Croce and Angelino, 1987; Mullin and Onbé, 1992; Cházaro-Olvera et al., 2024), the coastal region of Brazil (Marazzo and Valentin, 2004a, 2004b; Miyashita et al., 2011), and the Atlantic Ocean (Oghenekaro and Chigbu, 2019) (Tables 3 and 4).

The embryo number range and the mean number of embryos for *Pl. polyphemoides* observed in the current study were similar to those reported from the coastal region of Brazil (Miyashita et al., 2011), but lower than the higher embryo numbers reported in the Sea of Marmara and the Baltic Sea (Põllupüü et al., 2010; Bedikoğlu et al., 2022) (Tables 3 and 4). Compared to the Sea of Marmara and the Baltic Sea, the lower number of embryos observed in this study may be associated with the relatively higher seawater temperature. In the Sea of Marmara, the highest embryo number for this species was recorded at 10.7 °C (Bedikoğlu et al., 2022), while studies in the Baltic Sea reported a negative correlation between parthenogenetic fecundity and seawater temperature (Põllupüü et al., 2010). In both regions, higher embryo production by PFs was observed at lower temperatures.

Similarly, the embryo number range and the mean number of embryos of *E. spinifera* determined in this study were notably lower than those reported the South Atlantic Ocean (Miyashita et al., 2011) and the Atlantic Ocean (Oghenekaro and Chigbu, 2019) (Tables 3 and 4). In the South Atlantic Ocean, a negative correlation between seawater temperature and embryo number was identified. Moreover, in the Atlantic Ocean, *E. spinifera* was observed only in July 2012, coinciding with a peak in chlorophyll-a concentration (5.8 μg L^{-1}), suggesting that food availability may play a critical role in reproductive output. Accordingly, the relatively high seawater temperatures and low chlorophyll-a concentrations recorded in Hamsilos Bay during the present study may have contributed to the lower embryo numbers observed.

Fecundity values reported from various marine regions such as the South Atlantic Ocean, the Gulf of Mexico, the Sea of Marmara, and the Black Sea (this study) vary (Tables 3 and 4). These differences suggest geographical variation in reproductive capacity that may be influenced by regional environmental and biological factors. Changes in environmental conditions and population density are known to affect the reproductive dynamics of Diplostraca species (Egloff et al., 1997; Cházaro-Olvera et al., 2024). Such variation in reproductive capacity and embryo numbers may be associated with differences in nutrient levels, salinity, temperature, regional ecological conditions, methodological approaches, and population genetics.

5. Conclusion

The Diplostraca species in Hamsilos Bay successfully reproduce during the short warm period in summer and early autumn, making significant contributions to the mesozooplankton community. Our findings showed that these species predominantly reproduce through parthenogenesis during their presence in the water column. Embryo numbers were lower compared to similar species in the Sea of Marmara, which may be attributed to environmental and genetic factors. The study area is free from pollution and maintains its natural structure, further enhancing the reliability of the surveyed data. Achieving a more comprehensive understanding of the predation pressures, ecological roles, and population dynamics of Diplostraca in the Black Sea calls for long-term studies with frequent and regular sampling are recommended. As a pioneering investigation into the reproductive strategies of Diplostraca species inhabiting the Turkish waters of the Black Sea, this research serves as an important reference for understanding the reproductive patterns of species in the region.

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Abundance data, along with temperature, salinity, and chlorophyll-a measurements from station 2 were obtained from Üstün (2019). In this study, the data from station 2 were combined with data from two additional stations and are presented as averages. This study was delivered as an oral presentation at the VI. International Agricultural, Biological and Life Science Conference held in Edirne, Türkiye, September 18–20, 2024.

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Conflict of interest

The author declares no conflict of interest.

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