EISSN 2602-473X

AQUATIC SCIENCES AND ENGINEERING

Aquat Sci Eng 2024; 39(1): 24-29 • DOI: https://doi.org/10.26650/ASE20241322577

Research Article

The Relationship of Bristle Worm, *Protodorvillea kefersteini* (McIntosh, 1869) (Eunicida, Dorvilleidae) Abundance with Environmental Variables in Çardak Lagoon (Turkish Straits) Exposed to domestic Discharge

Ertan Dağlı[1], A. Suat Ateş[2], Seçil Acar[2], Yeşim Büyükateş[2]

Cite this article as: Dagli, E., Ates, A.S., Acar, S., & Buyukates, Y. (2024). The relationship of bristle worm, *Protodorvillea kefersteini* (McIntosh, 1869) (Eunicida, Dorvilleidae) abundance with environmental variables in Çardak Lagoon (Turkish Straits) exposed to domestic discharge. *Aquatic Sciences and Engineering, 39(1)*, 24-29. DOI: https://doi.org/10.26650/ASE20241322577

ABSTRACT

This study presents the correlations between opportunistic polychatea, *Protodorvillea kefersteini* (McIntosh, 1869) abundance, and environmental variables in Çardak Lagoon. Samplings were carried out on the bottoms using a 30x30 cm quadrate seasonally between 1 and 1.8 m depths of seven sampling points in October 2018, February, April, and June 2019. A total of 1094 specimens belonging to *P. kefersteini* were collected. Environmental variables such as gravel content in sediment, pH, and salinity levels in the water had the highest correlations with the abundance through the sampling periods. Considering the sampling points, the highest correlation value was between water salinity and the abundance. Sediment gravel content, pH, salinity, temperature, anionic surfactant levels, and NO_2+NO_3 were major environmental variables affecting *P. kefersteini* abundance in the study area spatially and temporally.

Keywords: *Protodorvillea kefersteini*, abundance, environmental variables, Çardak Lagoon, Turkish Straits

ORCID IDs of the author:
E.D. 0000-0001-6579-505X;
A.S.A. 0000-0002-4682-1926;
S.A. 0000-0002-6426-8095;
Y.B. 0000-0002-4402-4587

[1]Ege University, Fisheries Faculty, İzmir, Turkiye

[2]Çanakkale Onsekiz Mart University Faculty of marine Sciences and Technology, Çanakkale, Turkiye

Submitted:
04.07.2023

Revision Requested:
18.09.2023

Last Revision Received:
18.09.2023

Accepted:
18.09.2023

Online Published:
17.11.2023

Correspondence:
A. Suat Ateş
E-mail:
asuatates@yahoo.com

INTRODUCTION

Anthropogenic environmental variables have negative effects on marine biodiversity, especially on some benthic communities dominant in polluted environments that are sensitive to disturbances (Santos *et al.* 2021). Sudden daily and seasonal fluctuations in the environmental variables in marine systems, mainly in lagoon areas, may change the abundance of benthic organisms (Koutsoubas *et al.* 2000). Water movement, dissolved oxygen concentration, salinity, sediment grain size, and organic matter content effectively affect the polychaeta abundance and distribution in marine environments (Guerra-Garcia & Garcia-Gomez 2004). Among these, organic matter accumulation in sediment with anthropogenic origin controls the macrofaunal communities (Magni *et al.* 2004). Sewage discharges are one of the most common anthropogenic disturbances on marine benthos. There is important information in the relevant literature on the temporal and spatial status of benthic assemblages, especially on conspicuous disturbances caused by organic enrichment in sediments (Del-Pilar-Ruso *et al.* 2009). Opportunistic macrozoobenthic species adapt easily to a new marine environment and can form dense populations in a short time (Carlton 1985).

Polychaetas with high sensitivity to changes on soft bottoms (Del-Pilar-Ruso *et al.* 2009) may be preferred for monitoring studies (Muxika *et al.* 2005). Some polychaetas are also highly tolerant to pollution and low oxygen stress caused by excessive accumulation of organic matter. Besides, they are important in detecting the effect of pollutants between water and sediment (Elias *et al.* 2003). Additionally, they can tolerate high organic matter content in marine soft bottoms (Fernández-Romero *et al.* 2019) and play an important role in the bioturbation of marine sediments (Hutchings 1998).

Effects of pollutants on polychaetes were previously studied by many researchers (Karakassis *et al.* 2000; Warwick 2001; Ergen *et al.* 2004; Como *et al.* 2007; Afli *et al.* 2008; Dauvin 2008; Zaaiba *et al.* 2009; Terlizzi *et al.* 2010; Zaâbi *et al.* 2010; Martins *et al.* 2013; Zaâbi-Sendi 2013; Cabral-Olivera *et al.* 2014; Hamdy *et al.* 2023). Those dorvilleid polychaetes are known as opportunistic communities in marine sediments enriched with organic matter (Alalykina & Polyakova 2022). Dorvilleid polychatea, *Protodorvillea kefersteini* which is an important biotope descriptive and pollution indicator (MES 2010), is one of the 14 known species of the genus, *Protodorvillea* (Worms 2023). *P. kefersteini* is a species that is 1-3 cm long, lives on mud, gravel, or sandy bottoms at depths of 10-30 m, and mostly uses empty tubes of serpulids under stones. *P. kefersteini* is distributed in the North Atlantic to the North Sea and English Channel, Mediterranean, and Black Sea (Tillin 2016). *P. kefersteini* is known from the Mediterranean (Núñez *et al.* 2013; Çınar *et al.* 2015; Mikac 2015) and the Black Sea (Kurt Şahin *et al.* 2017; Kopiy 2018). This study presents the relationships between *P. kefersteini* abundance and environmental variables measured in Çardak Lagoon affected by domestic discharges.

MATERIALS AND METHODS

The sampling area included the depths of 1 to 1.8 m of 7 different sampling points (GPS Coordinates: 40 ° 23'14 "K, 26 ° 43'30" D) chosen in Çardak Lagoon located in the northeast of Çanakkale Strait (Figure 1).

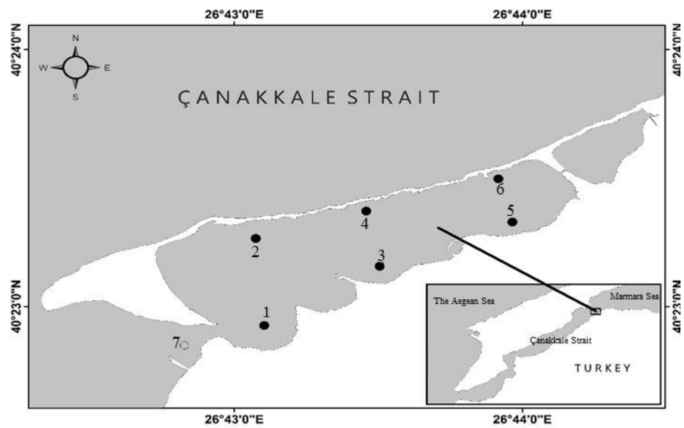

Figure 1. Map of the study area showing sampling points.

Benthos material including *Protodorvillea kefersteini* specimens was collected by a SCUBA diver with a 30x30 cm metal framed quadrat system in October 2018, February, April, and June 2019. Samples were fixed in 4% neutralized formaldehyde in 5 L plastic bottles. In the laboratory, the bottom samples were washed with the help of pressurized water and passed through a triple sieve system with apertures of 0.5, 1, and 2 mm. Faunal species remaining on the sieves were extracted at macro and micro levels and fixed in 70% ethanol in 50 cc glass tubes on a group basis. *P. kefersteini* specimens were identified on the trinocular stereomicroscope according to definitions based on previous studies, and all were counted. The definitions of Fauchald (1977) and Fauchald and Rouse (1997) were used for diagnosis.

The correlations between values of environmental variables and *P. kefersteini* abundance recorded for 7 different sampling stations in 4 seasons were calculated according to Pearson coefficient correlation (r) in the PAST program.

Water quality variables of lagoon water were measured in *situ* using a YSI 650 MDS. The number of nutrients (NO_2, NO_3, NH_4, PO_4-P, SiO2) and total suspended solids (TSS) in the lagoon water were measured based on the analysis method proposed by Strickland and Parsons (1972) at different wavelengths in the spectrophotometer. Analyses were made using the Jasco Brand UV spectrophotometer in the Laboratory of the Faculty of Marine Sciences and Technology. Analyses of % organic matter and % particle content in the sediment were performed in Çanakkale Onsekiz Mart University Central Laboratory. Particle size analyses in the sediment were done according to Allen (1997).

RESULTS

A total of 1094 specimens belonging to *P. kefersteini* were sampled in the study area (Figure 2).

Figure 2. General view of *Protodorvillea kefersteini* (Photographed by E. Dağlı).

Although it is known that *P. kefersteini* is tolerant to pollution, reference station (Stn. 7) with low sediment organic matter content and water chl.-*a* amount (OM%= 1.73% and chl.-*a*= 1.49 $\mu g\ L^{-1}$, respectively) was the most abundant in terms of specimen number (1001 out of a total of 1094 specimens) in the study area. Except for October 2018, *P. kefersteini* showed a regular distribution in terms of specimen number in other sampling periods (the lowest 34 individuals, di%= 3.10) (Table 1).

Considering the relationships between environmental variables and *P. kefersteini* abundance, the highest positive correlation ($r= 0.93$; $p <0.05$) was found between *P. kefersteini* abundance and

Table 1. Mean water quality, nutrient, chl-a, total suspended solids (TSS), chemical oxygen demand (COD), anionic surfactant (AS), and sediment variables values measured at sampling periods and points.

Sampling period	A	OM (%)	WOM (mg L^{-1})	T (°C)	S (‰)	O_2 (mg L^{-1})	ORP	pH	Chl.-a (µg L^{-1})	SiO_2
Autum 2018	34	6.42	11.02	14.76	20.77	8.07	80.41	8.14	3.79	0.34
Winter 2019	338	5.98	12.2	7.99	23.46	7.45	-83.37	8.15	1.19	0.39
Spring 2019	382	6.61	10.11	15.5	22.53	6.48	-90.98	8.31	1.83	0.17
Summer 2019	340	6.76	11.48	25.66	21.04	7.83	-100.52	8.29	5.31	0.83
Mean		6.44±0.15	11.2±0.38	15.98±3.15	21.95±0.55	7.46±0.30	-48.62±37.3	8.22±0.04	3.03±0.81	0.43±0.12
Sampling point										
Station 1	58	10.65	11.1	12.53	22.45	8.19	-27.63	7.89	3.63	0.36
Station 2	7	3.03	11.65	13.12	22.35	7.95	-31.6	8.32	2.64	0.56
Station 3	7	**15.52**	11.62	12.4	22.13	6.9	-31.23	8.14	3.38	0.29
Station 4	20	3.49	10.85	12.68	22.35	6.93	-30.16	8.27	2.96	0.57
Station 5	1	7.91	11.2	12.41	22.36	6.74	-35.23	8.22	2.59	0.55
Station 6	-	2.75	11.17	12.93	21.87	6.93	-35.1	8.27	4.47	0.18
Station 7 (ref.)	1001	1.73	10.85	13.1	22.66	7.7	-31.16	8.29	1.49	0.48
Mean		6.44±1.79	11.2±0.11	12.73±0.10	22.31±0.08	7.33±0.20	-31.73±0.94	8.2±0.05	3.02±0.32	0.42±0.05
Total number	**1094**									

Table 1. Continue.

Sampling period	TP	NO_2+NO_3 (mg L^{-1})	TN	TSS (mg L^{-1})	COD (mg L^{-1})	AD (mg L^{-1})	PO_4 (mg L^{-1})	Sand (%)	Gravel (%)	Mud (%)
Autum 2018	0.02	0.13	0.61	9.66	197.83	0.027	0.01	75.36	16.56	8.11
Winter 2019	0.02	0.09	0.23	35.28	178.71	0.029	0.01	69.29	19.9	10.74
Spring 2019	0.04	0.06	0.41	13.57	80.75	0.051	0.01	68.87	23.14	7.96
Summer 2019	0.09	0.03	0.21	6.64	74	0.032	0.02	72.91	21.1	5.95
Mean	0.04±0.01	0.08±0.02	0.37±0.08	16.29±5.62	132.82±27.95	0.03±0.0	0.01±0.0	71.61±1.34	20.18±1.19	8.19±0.85
Sampling point										
Station 1	0.048	0.083	0.48	11	127.87	0.045	0.03	61.8	24.1	14.16
Station 2	0.029	0.071	0.23	8.07	152.12	0.027	0.02	78.6	18.1	3.17
Station 3	0.026	0.071	0.42	22.15	126.66	0.032	0.02	55.2	31.6	13.24
Station 4	0.035	0.036	0.16	9.35	103.33	0.04	0.02	86.2	8.49	5.27
Station 5	0.051	0.089	0.49	19.07	201	0.034	0.01	57.6	25.6	**16.71**
Station 6	0.065	0.089	0.49	28.41	148.25	0.035	0.03	**92.8**	3.98	3.29
Station 7 (ref.)	0.053	0.094	0.26	15.98	163	0.032	0.01	69.1	**29.4**	1.49
Mean	0.04±0.004	0.07±0.006	0.36±0.04	16.29±2.60	146.03±10.95	0.035±0.002	0.02±0.002	71.61±5.10	20.18±3.68	8.19±2.19
Total number										

average % gravel content in sediment for the sampling periods. For sampling points, the highest correlation (r=0.64; p <0.05) was between abundance and salinity. There were positive correlations between *P. kefersteini* abundance and seawater pH, salinity, and anionic detergent amount (r= 0.67, 0.62, 0.58; p <0.05, respectively) in the sampling points. The weakest positive relationships were between the % of mud content in sediment and the amount of organic matter in water and sediment for the sampling points (r= 0.01, 0.02, 0.09; p <0.05, respectively) (Table 2).

Table 2. Correlations between total abundance and mean environmental variables for all sampling periods and sampling points (Pearson coefficient correlation, p <0.05).

	Sampling periods	Sampling points
EV	**A (ind. 0.09 m^{-2})**	**A (ind. 0.09 m^{-2})**
OM (%)	0.09	-0.39
WOM (mg L^{-1})	0.02	-0.50
Temperature (°C)	0.10	**0.50**
Salinity (‰)	**0.62**	**0.64**
O_2 (mg L^{-1})	-0.68	0.31
ORP	-0.99	0.14
pH	**0.67**	0.22
Chl.-α (µg L^{-1})	-0.31	-0.72
SiO_2	0.13	0.15
TP	0.43	0.28
NO_2+NO_3 (mg L^{-1})	-0.82	**0.39**
TN	-0.81	-0.31
TSS (mg L^{-1})	0.30	-0.05
COD (mg L^{-1})	-0.71	0.21
AD (mg L^{-1})	**0.58**	-0.18
PO_4 (mg L^{-1})	0.28	-0.52
Sand (%)	-0.84	-0.09
Gravel (%)	**0.93**	**0.39**
Mud (%)	0.01	-0.46

A: Abundance, EV: Environmental variable, OM: Organic matter in sediment, WOM: organic matter in water, ORP: Oxygen reduction potential, TP: total phosphate, TN: Total nitrogen, TSS: Total suspended solids, COD: Chemical oxygen demand, AD: Anionic detergent.

DISCUSSION

Effects of environmental variables such as temperature and salinity were previously studied at the population level in opportunistic polychaetas such as *Capitella* sp., *Ophryotrocha diadema*, and *Streblospio benedicti* in polluted areas (Simonini & Prevedelli, 2003). Based on the previous studies regarding *P. kefersteini* which is another opportunistic polychaeta, *P. kefersteini* is a recognizable species in areas affected by hypoxia (Leonhard 2006). Similarly, Warwick *et al.* (1986) stated that *P. kefersteini* is abundant in organic matter-rich habitats with sewage discharge. Hiscock *et al.* (2004) also indicated that *P. kefersteini* is an increasingly abundant species on sea bottoms where slight organic enrichment is observed. *P. kefersteini* abundance on the organic matter-rich bottoms of the Mediterranean and its relationship with other environmental variables were previously studied (Karakassis *et al.* 2000; Ergen *et al.* 2004; Como *et al.* 2007; Afli *et al.* 2008; Zaaiba *et al.* 2009; Terlizzi *et al.* 2010; Zaâbi *et al.* 2010; Martins *et al.* 2013; Zaâbi-Sendi 2013; Hamdy *et al.* 2023). Among these studies, Karakassis *et al.* (2000) found that *Protodorvillea kefersteini* and *Cirrophorus lyra* were dominant (more than 20% of the total abundance) on the bottoms of fish farms established at the Sounion coast (eastern Greece) at a depth of 13-20 m, with 80% silt and high carbon content.

Similarly, Ergen *et al.* (2004) found dense populations of *P. kefersteini* (3060 ind. m^{-2}) on the polluted or semi-polluted bottoms of cage farms in the eastern Aegean Sea. In addition, regarding organic matter content in sediment, Como *et al.* (2007) found that *P. kefersteini* dominated the inlet area of Oristano Bay (Sardinia, Italy) with high organic matter content (mean value of 25% of the total sediment dry weight). Terlizzi *et al.* (2010) also observed *P. kefersteini* in abundance on mud-character bottoms rich with organic matter where fish cages are located, approximately 100 to 500 m offshore of Corsica Island (France, Mediterranean). On the contrary, Hamdy *et al.* (2023) recorded *P. kefersteini* only on the bottoms with low organic matter content (max. 1.25%) off the coast of Alexandria (Egypt, Mediterranean). Considering the sediment type depending on the sediment grain size, Zaaiba *et al.* (2009) found *P. kefersteini* to be the most dominant (1900 ind. m^{-2}) at Cap Bon Peninsula coasts (northern Tunisia) in the bottoms where the sediment-gravel ratio varies between 0.2 and 60.6%. *P. kefersteini* is known as of the few polychaeta species that preferred the bottoms with a coarser particle in the Bizerte Lagoon (southern Tunisia) (Afli *et al.* 2008). The Bizerte Lagoon example presented for *P. kefersteini* specimens was observed in this study. We found the highest number of individuals on the bottoms where the average sand+gravel content was the highest and mud content was the lowest. Similarly, Zaâbi-Sendi (2013) stated that *P. kefersteini* was well represented in coarse sand bottoms where the coarse fraction between 500 and 630 µm dominates the Tunisia coasts. Further, *P. kefersteini*, characteristic of the fine and coarse sandy bottoms of Cap Bon Peninsula coasts, was abundant in all seasons with an average abundance of 66 ± 32.73 (ind. m^{-2}) (Zaâbi *et al.* 2010).

Considering the northeastern Atlantic specimens of *P. kefersteini*, the species was defined as a characteristic species for Portugal coast bottoms with a mean depth of 50 m, 68.8% sand, 27.2% gravel, and 1% mean organic matter content (Martins *et al.* 2013). Lourido *et al.* (2008) also found *P. kefersteini* in abundance on the bottoms of the Ria de Aldan coasts (northwest Spain) with an average content of 1.46% organic matter, 19.57% gravel, and 78.06% sand. On the other hand, although *P. kefersteini* prefers shallow waters as its habitat, it was also recorded at depths between 984 and 1113 m in Capbreton Canyon (Biscay Bay, NE Atlantic) (Aguirrezabalaga & Ceberio 2003). Furthermore, *P. kefersteini* was dominant in surface waters with an average redox potential (ORP) value of +61 ± 177 mV on the western Scottish coast (Pearson & Stanley 1979). In this study, no significant relationship was found between ORP and *P. kefersteini* abundance.

Considering only *P. kefersteini* abundance, Kopiy (2018) observed *P. kefersteini* on Sevastopol coasts (Crimea, Black Sea) throughout the year. Besides, there are many studies regarding polychaeta assemblages including *P. kefersteini* in Turkish Seas. Among these, Çınar *et al.* (2011) found *P. kefersteini* was most abundant (2900 ind. m^{-2}) at 17 m depth of Erdek coasts (the southern Marmara Sea). Then, Kurt Şahin *et al.* (2017) recorded *P. kefersteini* (8675 ind. m^{-2}) during spring in fine particle sand bottoms at 3 m depths of the Sinop Peninsula (southern Black Sea) being the most abundant species.

Apart from all these studies, a study examining polychaeta communities and their relationship with environmental variables was conducted by Can Yılmaz (2009) in Homa Lagoon (Turkish Aegean Sea). Can Yılmaz (2009) has found negative correlations between polychaeta abundance and sediment surface temperature in winter, and pH and abundance in spring (p= -0.730; p= -0.782; p<0.05, respectively) in Homa Lagoon. Can Yılmaz (2009) has also stated that the environmental variable that shows a positive correlation with polychaeta abundance (p= 0.697; p<0.05) in Homa Lagoon was % sand content in the sediment for the summer period. In this study, on the contrary, while % sand content of bottoms in the study area was negatively correlated with abundance temporally and spatially, seawater salinity moderately affected *P. kefersteini* abundance both temporally and spatially. In addition, very weak positive and negative correlations were recorded between *P. kefersteini* abundance and % sediment organic matter content in this study. This may be because the abundance of *P. kefersteini* was greatest at the reference point outside the lagoon area with very low organic matter bottoms.

Our study did not agree with the results regarding the correlation between *P. kefersteini* abundance and % sediment organic matter content presented by Warwick *et al*. (1986), Ergen *et al*. (2004), and Como *et al*. (2007). On the contrary, findings by Hiscock *et al*. (2004), Lourido *et al*. (2008), Martins *et al*. (2013), and Hamdy *et al*. (2023) were supported in the present study. Moreover, based on our results, we may point out that excessive accumulation of organic matter in the sediment may not be a major environmental variable that positively affects *P. kefersteini* abundance since the abundance was the greatest in the sediment with the lowest % organic matter content in the study area.

CONCLUSION

Sediment gravel content is one of the most important environmental variables that positively correlated with *P. kefersteini* abundance temporally. According to the results of this study and other studies performed on the Mediterranean and eastern Atlantic coasts, we may state that salinity, temperature, sediment particle size, and % sediment organic matter content had the most effect on *P. kefersteini* abundance. Although *P. kefersteini* is known as a pollution indicator species, we think that it cannot be concluded that the sediment of an area is polluted based only on *P.kefersteini* abundance.

Conflict of Interests: The authors declare that they have no financial interests or personal relationships that could affect this work, hence no conflict of interest.

Financial disclosure: This study is within the scope of the COST Action Project supported by TUBITAK coded 117Y510.

REFERENCES

Afli, A., Ayari, R., Zaabi, S. 2008. Ecological quality of some Tunisian coast and lagoon locations. by using benthic community parameters and biotic indices. Estuarine, Coastal and Shelf Sciences, 80, 269–280.

Aguirrezabalaga, F. & Ceberio, A. (2003). Dorvilleidae (Polychaeta) from the Capbreton Canyon (Bay of Biscay, NE Atlantic) with the description of *Pettiboneia sanmartini* sp. nov. *Cahiers de Biologie Marine*, 44 (1), 41-48.

Alalykina, I.L. & Polyakova, N.E. (2022). New species of Ophryotrocha (Annelida: Dorvilleidae) associated with deep-sea reducing habitats in the Bering Sea, Northwest Pacific. *Deep-Sea Research Part II*, 206, 105217. https://doi.org/10.1016/j.dsr2.2022.105217.

Allen, J.R.L. (1997). Subfossil mammalian tracks (Flandrian) in the Severn Estuary. S.W. Britain: *mechanics of formation, preservation and distribution, Philosophical Transactions of the Royal Society, London B. 352, 481–518.*

Cabral-Olivera, J., Mendes, S., Maranhão, P. & Pardal, M.A. (2014). Effects of sewage pollution on the structure of rocky shore macroinvertebrate assemblages. *Hydrobiologia*, 726, 271-283. http://doi.org/10.1007/s10750-013-1773-5.

Can Yılmaz, E. (2009). The polychaeta of the Homa lagoon (Izmir Bay). Dokuz Eylül University, Institute of Natural and Applied Sciences, PhD. Thesis, 60 pp.

Carlton, J.T. (1985). Transoceanic and interoceanic dispersal of coastal marine organisms: the biology of ballast water. Oceanography and Marine Biology Annual Review 23: 313-371.

Como, S., Magni, P., Casu, D., Floris, A., Giordani, G., Natale, S., Fenzi, G.A., Signa, G., & De Falco, G. (2007). Sediment characteristics and macrofauna distribution along a human-modified inlet in the Gulf of Oristano (Sardinia, Italy). *Marine Pollution Bulletin*, 54, 733–744.

Çınar, M.E., Dağlı, E. & Açık, Ş. (2011). Annelids (Polychaeta and Oligochaeta) from the Sea of Marmara, with descriptions of five new species. *Journal of Natural History*, 45 (33-34), 2105-2143. http://doi.org/10.1080/00222933.2011.582966.

Çınar, M.E., Dağlı, E., Çağlar, S. & Albayrak, S. (2015). Polychaetes from the northern part of the Sea of Marmara with the description of a new species of *Polydora* (Annelida:Polychaeta: Spionidae). *Mediterranean Marine Science*, 16, 524–532. http://doi.org/10.12681/mms.1226.

Dauvin, J.C. (2008). Effects of heavy metal contamination on the macrobenthic fauna in estuaries: the case of the Seine estuary. *Marine Pollution Bulletin*, 57 (1–5), 22-40. http://doi.org/ 10.1016/j.marpolbul.2007.10.016.

Del-Pilar-Ruso, Y., De-La-Ossa-Carretero, J.A., Loya-Fernandez, A., Ferrero-Vicente, L. M., Giménez-Casalduero, F. & Sánchez-Lizaso, J.L. (2009). Assessment of soft-bottom Polychaeta assemblage affected by a spatial confluence of impacts: Sewage and brine discharges. *Marine Pollution Bulletin*, 58 (5), 776-782. http://doi.org/10.1016/j.marpolbul.2009.03.002.

Elias, R., Rivero, M.S. & Vallarino, E.A. (2003). Sewage impact on the composition and distribution of Polychaeta associated to intertidal mussel beds of the Mar del Plata rocky shore, Argentina. *Iheringia, Sér. Zool.*, Porto Alegre, 93 (3), 309-318.

Ergen, Z., Çınar M.E. & Dağlı E. (2004). Effects of fish farming in the distribution of polychaetes in the Aegean Sea, *Rapport de la Commission International Exploration de la Mer Mediterranée*, 37, 350.

Fauchald, K. & Rouse, G. (1997). Polychaeta systematics: Past and present. Zoologica Scripta, 26 (2), 71-138.

Fauchald, K. (1977). The Polychaete Worms. Definitions and Keys to the Orders. Families and Genera. Natural History Museum of Los Angeles County Allan Hancock Found. Science Series, Los Angeles, 28, 1-188.

Fernández-Romero, A., Moreira, J. & Guerra-García, J. M. (2019). Marinas: An overlooked habitat for exploring the relation among polychaete assemblages and environmental factors. *Marine Pollution Bulletin*, 138, 584-597. https://doi.org/10.1016/j.marpolbul.2018.11.064.

Guerra-Garcia, J.M. & Garcia-Gomez, J.C. (2004). Polychaete assemblages and sediment pollution in a harbour with two opposing entrances. *Helgoland Marine Research*, 58, 183–191.

Hamdy, R., Elebiary, N., Abdel Naby, F., Borghese, J., Dorgham, M., Hamdan, A. & Musco, L. (2023). Hard-bottom polychaetes exposed to multiple human pressure along the Mediterranean coast of Egypt. Water, 15, 997. https://doi.org/10.3390/w15050997.

Hiscock, K., Southward, A., Tittley, I. & Hawkins, S. (2004). Effects of changing temperature on benthic marine life in Britain and Ireland. Aquatic Conservation: *Marine and Freshwater Ecosystems*, 14 (4), 333-362.

Hutchings, P. (1998). Biodiversity and functioning of polychaetes in benthic sediments. *Biodiversity and Conservation*, 7, 1133-1145.

Karakassis, I., Tsapakis, M., Hatziyanni, E., Papadopoulou, K.-N., & Plaiti, W. (2000). Impact of cage farming of fish on the seabed in three Mediterranean coastal areas. *ICES Journal of Marine Science*, 57 (5), 1462–1471. https://doi.org/10.1006/jmsc.2000.0925.

Kopiy, V. (2018). Some aspects of the biology and the present state of the population of *Protodorvillea kefersteini* (Polychaeta: Dorvilleidae) in the coastal zone of the Crimea (The Black Sea). Diversity in Coastal Marine Sciences, Edited by C. Finkl and C. Makowski, Coastal Research Library book series, Springer Publ., 23, 405–412.

Koutsoubas D., Dounas, C., Arvanitidis C., Kornilios S., Petihakis G., Triantafyllou G. & Eleftheriou, A. (2000). Macrobenthic community structure and disturbance assessment in Gialova Lagoon, Ionian Sea. *ICES Journal of Marine Science*, 57, 1472–1480.

Kurt Şahin, G., Dağlı, E. & Sezgin, M. (2017). Spatial and temporal variations of soft bottom polychaetes of Sinop Peninsula (southern Black Sea) with new records. *Turkish Journal of Zoology*, 41, 89-101, http:// doi:10.3906/zoo-1510-15.

Leonhard, S.B. (2006). Horns Rev offshore wind farm. Environmental impact assessment of sea bottom and marine biology. Technical Report, 54 Environmental Sciences; 17 Wind Energy; Seabed; Environmental Impact Statements; Wind Turbines; Offshore Sıtes, 43 pp.

Lourido, A. Cacabelos, E. & Troncoso, J.S. (2008). Patterns of distribution of the polychaete fauna in subtidal soft sediments of the Rı´a de Alda´n (north-western Spain). *Journal of the Marine Biological Association of the United Kingdom*, 88 (2), 263–275. http:// doi.org/10.1017/S0025315408000696.

Magni, P., Micheletti, S., Casu, D., Floris, A., de Falco, G. & Castelli, A. (2004). Macrofaunal community structure and distribution in a muddy coastal lagoon. *Chemistry and Ecology*, 20 (1), 397–S409.

Martins, R., Sampaio, L., Rodrigues, A.M. & Quintino, V. (2013). Soft-bottom Portuguese continental shelf polychaetes: Diversity and distribution. *Journal of Marine Systems*, 123–124, 41-54. https://doi.org/10.1016/j.jmarsys.2013.04.008.

MES (2010). Marine Macrofauna Genus Trait Handbook. Marine Ecological Surveys Limited. http://www.genustraithandbook.org.uk/

Mikac, B. (2015). A sea of worms: Polychaete checklist of the AdriaticSea. *Zootaxa* 3943, 001–172. http://doi.org/10.11646/zootaxa.3943.1.1.

Muxika, I., Borja, Á. & Bonne, W. (2005). The suitability of the marine biotic index (AMBI) to new impact sources along European coasts. *Ecological Indicators*, 5 (1), 19-31.

Núñez, J., Maggio, Y. & Riera, R. (2013). Dorvilleidos (Polychaeta,Dorvilleidae) recolectados durante el proyecto“Faunalbérica”y catálogo de las especies íbero-baleares. *Graellsia*, 69, 275–282. http://doi.org/10.3989/graellsia.2013.v69.i2.

Pearson, T.H., & Stanley, S.O. (1979). Comparative measurement of the redox potential of marine sediments as a rapid means of assessing the effect of organic pollution. *Marine Biology*, 53, 371-379.

Santos, M.E.M., Silva, C.C. & de Azevedo-Cutrim, A.C.G. (2021). Spatial-temporal distribution of polychaeta in urbanized sandy beaches of northeastern Brazil: Tools for environmental assessment. *Oecologia Australis*, 25 (4), 834–845. https://doi.org/10.4257/oeco.2021.2504.04.

Simonini, R. & Prevedelli, D. (2003). Effects of temperature on two Mediterranean population of *Dinophilus gyrociliatus* (Polychaeta: Dinophilidae) II. Effects on demographic parameters. *Journal of Experimental Marine Biology and Ecology*, 291, 95–110.

Strickland, J.D.H. & Parsons, T.R. (1972). A Practical Handbook of Seawater Analysis. Fisheries Research Board of Canada. Ottawa, 167, 310 p.

Terlizzi, A., De Falco, G., Felline, S., Fiorentino, D., Gambi, M.C. & Cancemi, G. (2010). Effects of marine cage aquaculture on macrofauna assemblages associated with *Posidonia oceanica* meadows. *Italian Journal of Zoology*, 77, 362-371.

Tillin, H.M. (2016). *Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. https://dx.doi.org/10.17031/marlinhab.1115.1.

Warwick, R.M., Collins, N.R., Gee, J.M. & Geaorge, C.L. (1986). Species size distributions of benthic and pelagic Metazoa: evidence for interaction? *Marine Ecology Progress Series*, 34, 63-68.

Warwick, R.M. (2001). Evidence for the effects of metal contamination on the intertidal macrobenthic assemblages of the Fal Estuary. *Marine Pollution Bulletin*, 42 (2), 145-148.

WORMS, 2023. World Register of Marine Species. Accessed by http:// https://www.marinespecies.org.

Zaâbi, S., Gillet, P., Afli, A. & Boumaiza, M. (2009). Biodiversity of polychaetous annelids from the peninsula of Cap Bon, northeast coast of Tunisia. *Zoosymposia*, 2, 587–600.

Zaâbi, S., Gillet, P., Afli, A., & Boumaiza, M. (2010). Structure and diversity of polychaetous annelids population along the eastern coast of the Cap Bon Peninsula (north-east coast of Tunisia, western Mediterranean). *Marine Biodiversity Records*, page 1 of 11, 3, e100. http:// doi.org/10.1017/S1755267210000850.

Zaabi-Sendi, S. (2013). Etude faunistique et ecologique des annelides polychetes de la cote nord-est de la Tunisie (Peninsule du Cap Bon, Mediterranee Ouest). These de Doctorat, Université de Carthage, Faculté des Sciences de Bizerte, 494 pp.