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S.U. KARHAN, E. KALKAN, N. SIMBOURA, E. MUTLU, M. BEKOLET

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Research Article

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On the Occurrence and Established Populations of the Alien Polychaete *Polydora cornuta* Bosc, 1802 (Polychaeta: Spionidae) in the Sea of Marmara and the Bosphorus Strait (Turkey)

S. Ü. KARHAN[1], E. KALKAN[2], N. SIMBOURA[3], E. MUTLU[4] and M. BEKBÖLET[2]

[1] Division of Hydrobiology, Department of Biology, Faculty of Science, Istanbul University, TR-34118 Vezneciler, Istanbul, Turkey
[2] Department of Environmental Science, Institute of Environmental Sciences, Bogaziçi University, Hisar Campus,TR-34342 Bebek, Istanbul, Turkey
[3] Hellenic Centre for Marine Research, P.O. Box 712, Mavro Lithari, GR-19013 Anavissos, Hellas
[4] Institute of Marine Sciences and Technology (DEU-IMST), Dokuz Eylul University, TR-35340 Inciralti, Izmir, Turkey

e-mail: unsalkarhan@yahoo.com

Abstract

The present paper reports the first occurrence of Polydora cornuta in the Bosphorus Strait and its finding in a new locality in the Sea of Marmara, providing a link with its Aegean and Black Sea populations. The probable vector for the introduction of P. cornuta into the Sea of Marmara is shipping through the Dardanelles Strait. Both soft and hard-bottom populations were examined and the importance and prevalence of this species within the native macrozoobenthic communities were elucidated. Its abundance ranged between 40 and 3390 ind.m^{-2} (mean:1320 ±1199.45 SD) and its percent contribution to the total faunal populations ranged between 3.31 and 75.56 (mean:27.79 ±25.00 SD) in the Sea of Marmara soft-bottom community. During the sampling period, P. cornuta contributed little to the total faunal abundance of the hard-bottom communities in the Bosphorus Strait. Its mean abundance in the hard substrate ranged between 8.33 and 1000 ind.m^{-2} (mean:117.36 ±279.73 SD) and its percent contribution to the total faunal populations ranged between 0.02 and 21.86 (mean:2.07 ±6.25 SD).

The role of this invasive species in the soft-bottom macrobenthic community at an organically enriched site examined in the Sea of Marmara is highlighted, and a comparison with Aegean Sea populations of the species is also included.

Keywords: *Polydora cornuta;* Polychaeta; Alien species; Macrozoobenthic communities; Bosphorus Strait; Sea of Marmara.

Introduction

According to a recently updated annotated list of alien marine species in the Mediterranean Sea (ZENETOS *et al.,* 2005, 2008)) there are 37 polychaete species established or naturalized into the Mediterranean, another 29 referred to casual records, and another 19 with questionable or doubtful status. Among them, some have been described as invasive or locally invasive. The qualification as invasive is based on the proliferation, and/or geographical spread and/or impact of the species on native populations. According to STREFTARIS & ZENETOS (2006) the spionid *Polydora cornuta* Bosc, 1802 is considered one of the worst invasive alien polychaetes together with *Branchiomma luctuosum* (Grube, 1869), *Streblospio gynobranchiata* Rice & Levin, 1998, *Leonnates persicus* (Wesenberg-Lund, 1949) and *Pseudonereis anomala* Gravier, 1901.

Polydora cornuta was encountered for the first time in the Mediterranean in organically polluted sediments of Valencia Harbor (Spain) (TENA *et al.,* 1991). Fourteen years later, this species was reported in Alsancak Harbor in Izmir Bay (Aegean Sea, Turkey) based on the specimens collected between 1996–2004 (ÇINAR *et al.,* 2005). This was the first record for *P. cornuta* from the Aegean Sea and represented a significant range extension within the Mediterranean. However, a re-examination of the older material by ÇINAR *et al.* (2005) showed that the establishment of this species in Izmir Bay may be dated to 1986, if not earlier. Specimens collected along the Romanian coast from 1995 to 2000 represent the first record of this species in the Black Sea (SURUGIU, 2005). In addition, a recent report from Izmit Bay by DAGLI & ERGEN (in press) represented the first record of this species in the Sea of Marmara and constituted a large range extension from its previously known distribution in the Mediterranean and Black Sea.

As RADASHEVSKY (1999) pointed out, it is likely that *P. cornuta* has been transported to new areas via the ballast water of cargo ships. This species, which is widely distributed from the Atlantic (U.S.A., Mexico, Argentina and Europe) to the Pacific (Australia, China, Taiwan and Korea) (RADASHEVSKY & HSIEH, 2000), has also been introduced into the Mediterranean probably by shipping, as a dense population was found in and around a large commercial harbor in Izmir Bay, which hosts many inter-oceanic cargo ships (ÇINAR *et al.,* 2005).

Taxonomic confusion in the genus *Polydora* is a long-standing problem. This has been demonstrated and discussed in detail by RADASHEVSKY (2005). Adult individuals of *P. cornuta* have broadly similar morphology with those of *P. ciliata* (Johnston, 1838), *P. cirrosa* Rioja, 1943, *P. limicola* Annenkova, 1934 and *P. nuchalis* Woodwick, 1953. As RADASHEVSKY (2005) states, *P. cornuta* mainly differs from the others in having a slender subdistal longitudinal flange on falcate spines of chaetiger 5. In addition, it differs from *P. limicola* and *P. ciliata* in having an occipital antenna. *Polydora cornuta* is unique in the morphology of chaetiger 5 companion chaetae which closely adhere to convex side of spines. In other *Polydora* species, companion chaetae are positioned close to major falcate spines but not adhering to them. This apparent variability of the companion chaetae causes confusion among some authors. In addition, *P. cornuta* was erroneously considered to be a synonym of other species (e.g. RASMUSSEN, 1973), as some studies have showed considerable variation in some features such as the presence of eyes and occipital antenna, and the appearance of the companion chaetae (RADASHEVSKY, 2005). Moreover, a recent study showed that the populations of *P. cornuta* comprise a cryptic species complex composed of at least three separate species in North America (RICE *et al.,* 2008). Because of this confusion on the taxonomic status of *P. cornuta* and similar species and the difficulties in re-examination of old material, the exact dating of the first introduction of this species into the Mediterranean remains uncertain.

Pollution or physical disturbance can make an ecosystem more prone to invasion by alien species (GALIL, 2000). *P. cornuta,* along with a similar species *P. ciliata* and some other congenerics, is known to be one of the opportunistic species, and has been widely found in organically enriched and polluted environments (GRASSLE & GRASSLE, 1974; PEARSON & ROSENBERG, 1978). This species was found in polluted areas in all cases in the Mediterranean, the Sea of Marmara and the Black Sea (TENA *et al.,* 1991; SURUGIU, 2005; ÇINAR *et al.,* 2005, 2006, 2008; ERGEN *et al.,* 2006; DAGLI & ERGEN, in press). In addition, it seems to be a very invasive species, and there is evidence for it having caused changes in native species composition and abundance in hard- and soft-bottom benthic communities (ÇINAR *et al.,* 2005, 2006, 2008; ERGEN *et al.,* 2006).

The present paper reports on (1) the first occurrence of *P. cornuta* in the Bosphorus Strait, extending the distributional range of this species to the gateway between the Sea of Marmara and the Black Sea; (2) its finding in a new locality in the Sea of Marmara, providing a link with its Aegean and Black Sea populations. The importance and prevalence of this species within the native soft- and hard-bottom macrozoobenthic communities in the area are also elucidated.

Materials and Methods

Within the framework of the two thesis projects, benthic samples were collected to investigate the structure of soft- and hard-bottom macrozoobenthic communities in the Sea of Marmara and the Bosphorus Strait. In the Sea of Marmara stations, soft-bottom benthic samples were collected using a van Veen grab, with a sampling surface of 0.1 m^2. At Bosphorus stations, three replicates were taken at 0.5 m depth by scraping the hard substrate on a quadrate of 400 cm^2. Water salinity, dissolved oxygen and temperature were recorded at the same time as benthic samplings. The sieved (mesh size 0.5 mm) samples were fixed in 4% formalin in sea water in the field. Afterwards, the samples were re-sieved on 0.5 mm mesh sieve under fresh water and transferred to 70% ethanol in the laboratory. After sorting out the organisms from the samples, all specimens were identified to the lowest possible taxonomic level and counted for statistical analyses.

A constant soft-bottom population of *P. cornuta* was found in a sampling site (station MK) located in the Sea of Marmara at a depth of 8 m (Fig. 1). Sampling of macrozoobenthos at this site first occurred in September 2002 and with the exception of the first month of sampling, a population of this species was observed

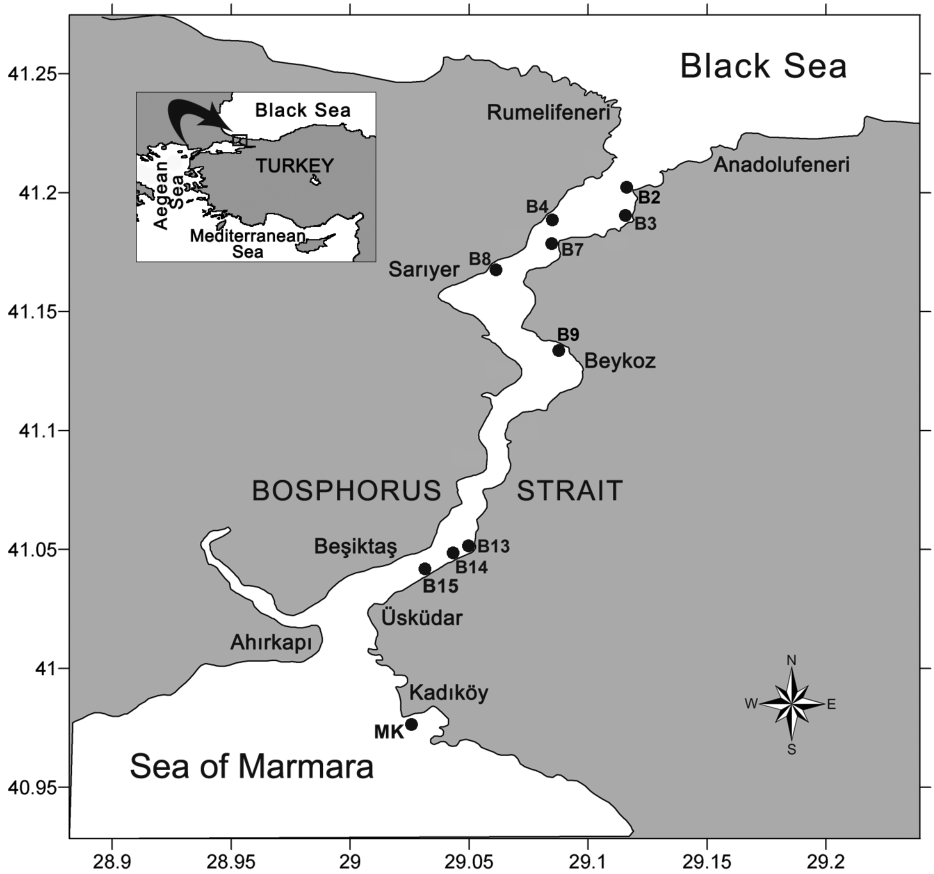

Fig. 1: Map showing the sampling sites of *Polydora cornuta.*

repeatedly every month between October 2002 and August 2003. This sampling site with organically enriched sediment was very close to the mouth of a heavily polluted stream (Kurbagali Dere) and the discharge point of a wastewater treatment plant. Shortly thereafter, specimens belonging to this spionid species were also obtained from nine sampling sites on different sampling occasions in shallow water (0.5 m depth) hard-bottom macrozoobenthic communities in the Bosphorus Strait from May 2004 to February 2005 (Fig. 1). Five of these sampling sites (stations B7, B8, B9, B13 and B14) were directly influenced by sewage discharge and were characterized as heavily polluted with poor ecological status (KALKAN *et al.,* 2007). The others (stations B2, B3, B4 and B15) were located far from any wastewater discharge points and were assessed as unpolluted or slightly polluted with good or moderate ecological status (KALKAN *et al.,* 2007). Details of the sampling sites are given in Table 1.

Some statistical methods were used to evaluate the biotic structure of the benthic communities in which the popu-

Table 1
Coordinates, depths, number of samplings and biotope characterizations of the sampling sites (N: total number of samplings, NP: number of samplings containing *Polydora cornuta*).

Station	Coordinates	Depth (m)	N	NP	Biotope
MK	40°58'36"N, 29°01'29"E	8	12	11	Silty black mud with detritus
B2	41°11'55"N, 29°07'05"E	0.5	4	1	Rocky, *Mytilus galloprovincialis* community
B3	41°10'50"N, 29°06'25"E	0.5	4	1	Rocky, *Cystoseira* spp. community
B4	41°11'08"N, 29°04'39"E	0.5	4	1	Rocky, *M. galloprovincialis* community
B7	41°10'22"N, 29°05'18"E	0.5	4	1	Rocky, *Cystoseira* spp. community
B8	41°10'09"N, 29°03'31"E	0.5	4	2	Rocky, *Bryopsis* spp. + *M. galloprovincialis* community
B9	41°08'13"N, 29°05'05"E	0.5	4	1	Rocky, *M. galloprovincialis* community
B13	41°03'01"N, 29°03'08"E	0.5	4	2	Rocky, *Bryopsis* spp. community
B14	41°02'37"N, 29°02'31"E	0.5	4	2	Rocky, *M. galloprovincialis* community
B15	41°02'19"N, 29°01'56"E	0.5	4	1	Rocky, *M. galloprovincialis* community

lations of *P. cornuta* were established. The numerical abundance on a scale of 1 m^2 and the percent contribution (proportional dominance) were estimated. Shannon-Wiener diversity index (*H'*) (SHANNON & WEAVER, 1963) and Pielou's evenness (J) (PIELOU, 1969) were also calculated. Non-parametric Spearman rank correlation coefficient was employed to determine the relationships between the number of *P. cornuta* individuals and environmental parameters (salinity, dissolved oxygen and temperature). Furthermore, partial correlation analysis was used for testing the relationships between density of the species and environmental parameters and uncovering hidden relationships, identifying intervening variables and detecting spurious relationships, because, in some cases, no linear relationship between the environmental parameters was revealed (SOKAL & ROHLF, 1969). Coefficients of variation (CV) were also calculated to compare percent variability of environmental parameters within the sampling sites.

Results and Discussion

Environmental Parameters

The annual variation in water temperature at station MK ranged from 7.1°C in March 2003 to 22°C in September 2002 and was highly variable (CV%=40.18) throughout the year. Dissolved oxygen varied between 5.35 mg/L in August 2003 and 10.65 mg/L in March 2003 (CV%=20.04), and salinity ranged from 20.6 psu in September 2002 to 28 psu in February 2003 and the least dispersion of probability was observed in salinity measurements among months (CV%=9.23) (Fig. 2).

The pattern of the temporal fluctuation of dissolved oxygen and temperature appeared to be similar in all stations in which *P. cornuta* was found in the Bosphorus Strait. The water temperature showed a regular annual cycle, ranging between 6°C in February (station B13) and 22°C in August (station B3), resulting in that temporal variation being characterized with CV%=35.80. Dissolved oxygen values fluctuated between 6.62 mg/L in August

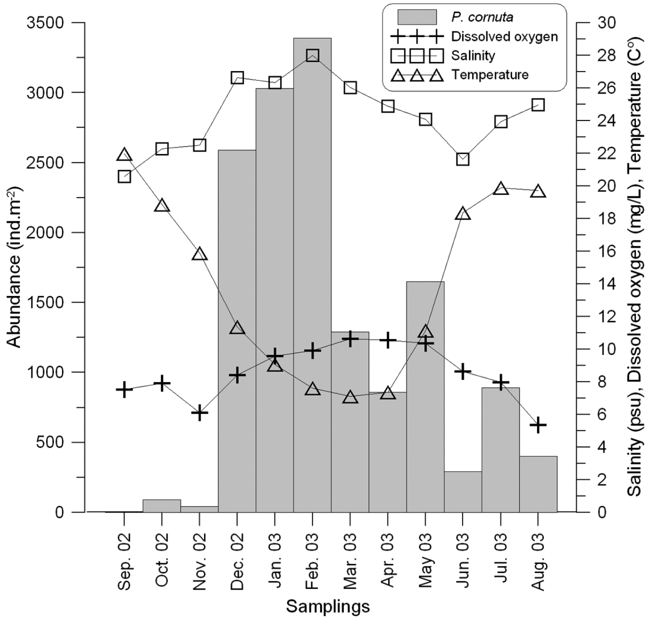

Fig. 2: Temporal changes in environmental variables and the abundance of *Polydora cornuta* in the Sea of Marmara.

(station B3) and 8.9 mg/L in November (station B9) (CV%=10.70), and salinity ranged between 11 psu in February (station B8) and 18.4 psu in May (station B2) (CV%=12.36) (Fig. 3).

Overall, fluctuation of individual environmental parameters (temperature and dissolved oxygen) presented higher variation in the Sea of Marmara than the Bosphorus Strait. Temporal variability was not considerably different for individual parameters between the Sea of Marmara and the Bosphorus Strait. Only dissolved oxygen was temporally more fluctuating in the Sea of Marmara as compared with the Bosphorus Strait, where fluctuations were less pronounced.

Soft-bottom Sea of Marmara Population

Polydora cornuta was found in all samplings after September 2002 at station MK. Its abundance ranged between 40 and 3390 ind.m^{-2} (mean: 1320 ±1199.45 SD) and its percent contribution to the total faunal populations ranged between 3.31 and 75.56 (mean:27.79 ±25.00 SD) after the first sampling (Figs 2, 4; Table 2). Similarly, this worm was reported as one of the dominant and most frequent species in the area near Alsancak Harbor (Izmir Bay) in 2004 (ÇINAR *et al.,* 2006). Together with the other alien polychaetes, *Streblospio gynobranchiata* and *Pseudopolydora paucibranchiata* Okuda, 1937, it was reported to constitute more than 90% of the faunal populations in the majority of samples collected in Alsancak Harbor, which is located at the most polluted part of the Izmir Bay (ÇINAR *et al.,* 2006; DAGLI & ÇINAR, 2008).

Abundances of *P. cornuta* increased with increasing water salinity and dissolved oxygen but decreased with

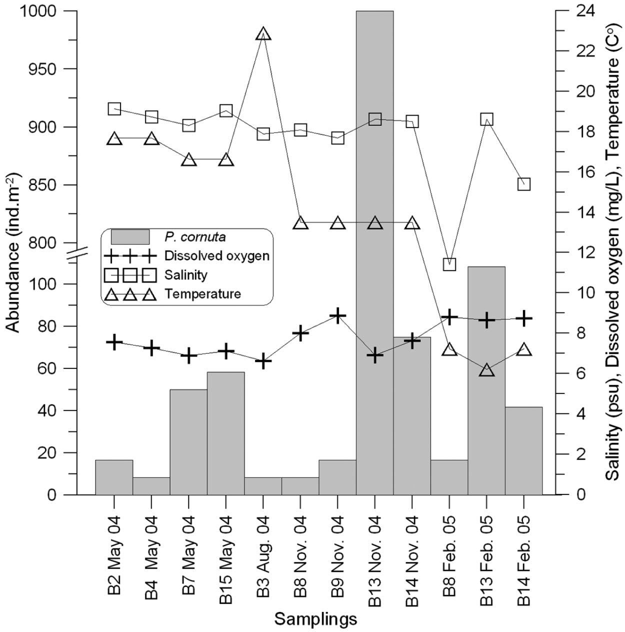

Fig. 3: Spatial and temporal changes in environmental variables and the abundance of *Polydora cornuta* in the Bosphorus Strait.

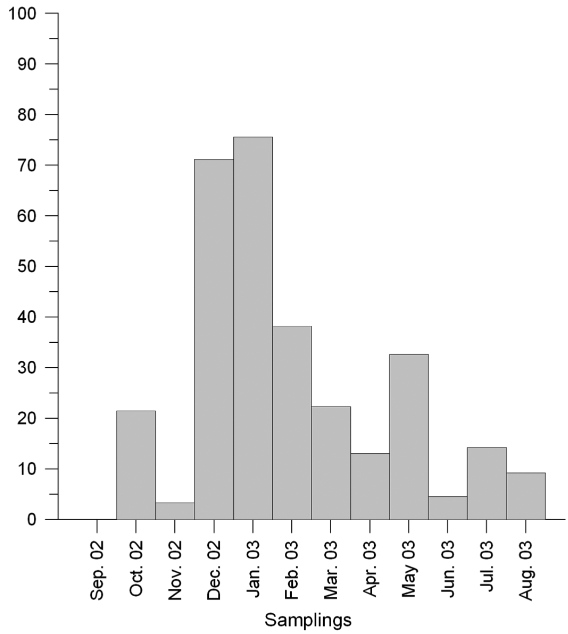

Fig. 4: Percent contribution of *Polydora cornuta* to the total faunal abundance during the study period in the Sea of Marmara.

increasing water temperature, as proved by significant correlations among those parameters (Spearman r=0.62, 0.88, and -0.63 respectively). In addition, water salinity was found to play a crucial role in determining changes in the species abundance as showed by the partial correlation analysis ($r=0.75$, $p=0.01$). Before the present study, no correlation was reported between the number of individuals of *P. cornuta* and any of these environmental variables in any area inhabited by this worm in the Mediterranean or Black Sea. Nevertheless, abundance of this worm was reported to be negatively correlated with pH and positively correlated with the silicate concentration in Izmir Bay by ÇINAR *et al.* (2006).

Before the population of *Polydora cornuta* was encountered, there was a very poor soft-bottom macrofaunal community represented by only three peracarid crustacean species at the sampling site. It was rapidly transformed to a community dominated by opportunistic species with high abundance. In this recovery process, the initial colonizers were three opportunistic polychaetes, *Capitella capitata* (Fabricius, 1780), *Neanthes succinea* (Frey & Leuckart, 1847) and *P. cornuta.* They are all considered deposit-feeders (FAUCHALD & JUMARS, 1979) and highly pollution tolerant (see e.g. PEARSON & ROSENBERG, 1978). The first species to appear in large numbers was *C. capitata* and it was the dominant species in most of the samplings. *Polydora cornuta* was the secondary dominant species to attain a large population and sometimes outnumbered *C. capitata* during the sampling period (Table 2).

The macrofaunal community hosting the *P. cornuta* population was largely dominated by polychaetes and although the succession continued, the initial very degraded community still corresponded to a poor condition with very low diversity (range: 0.278-1.991, mean:1.194 ±0.43 SD) and a low number of species (range: 3-22, mean:8.42 ±5.93 SD) over the sampling period (Table 2).

Most general models of community structure are based on the concept that biological communities do not form a series of distinct groups of assemblages along an environmental gradient, but show a corresponding gradient in community composition. According to the classical model of PEARSON & ROSENBERG (1978) showing the variation of community parameters along a gradient of increasing stress after a defaunation event, a suite of first order or primary opportunistic r-selected species settle on the bottom, recruiting from larvae originating from neighboring communities (mostly polychaete species), and this is gradually followed by secondary opportunists leading towards 'climax' communities which are in equilibrium with the physical/chemical conditions of the habitat. This suite (or stages of succession) is defined by ELLIS (2003) as 'sustaining ecological succession' and implies that the succession will continue until a climax community has been attained. In this sense, *P. cornuta* together with *C. capitata* and *N. succinea* are likely to constitute one of the major elements of the suite of primary opportunists sustaining themselves throughout the year in the present study. These primary opportunists are initiating the succession that may be followed by further stages, always in equilibrium with the environmental conditions.

Table 2
Percent contribution of *Polydora cornuta* to the total faunal and polychaete abundance with some biotic properties of the macrofaunal community over the sampling period of station MK in the Sea of Marmara (*H'*: Shannon-Wiener diversity index; J: Pielou's evenness; values in parenthesis indicate the number of species found in each taxonomic group).

	SAMPLINGS											
	Sept. 2002	**Oct. 2002**	**Nov. 2002**	**Dec. 2002**	**Jan. 2003**	**Feb. 2003**	**Mar. 2003**	**Apr. 2003**	**May 2003**	**Jun. 2003**	**Jul. 2003**	**Aug. 2003**
% of total faunal populations	0	21.43	3.31	71.15	75.56	38.26	22.28	13.09	32.61	4.57	14.24	9.24
% of total polychaete populations	0	21.43	3.33	73.79	76.32	38.35	22.28	13.52	35.18	4.57	15.11	9.39
Total number of species	3	3	3	10	7	6	4	10	17	6	22	10
Total density (ind.m^{-2})	50	420	1210	3640	4010	8860	5790	6570	5060	6340	6250	4330
Polychaetes (%)	0	100 (3)	99.17 (2)	96.43 (6)	99.00 (3)	99.77 (5)	100 (4)	96.80 (4)	92.69 (7)	100 (6)	94.24 (6)	98.38 (5)
Crustaceans (%)	100 (2)	0	0.83 (1)	3.30 (3)	1.00 (4)	0.23 (1)	0	1.67 (3)	5.14 (5)	0	3.2 (8)	0.23 (1)
Molluscs (%)	0	0	0	0.27 (1)	0	0	0	1.52 (3)	1.98 (4)	0	2.56 (8)	1.38 (4)
Phoronids (%)	0	0	0	0	0	0	0	0	0.20 (1)	0	0	0
Dominant species	*P.m., J.m.*	*C.c.*	*C.c.*	*P.c.*	*P.c.*	*C.c.*	*C.c.*	*C.c.*	*C.c.*	*C.c.*	*C.c.*	*C.c.*
H'	1.522	1.009	0.278	1.436	1.031	1.377	1.407	1.264	1.991	0.898	1.274	0.842
J	0.96	0.636	0.175	0.432	0.367	0.533	0.704	0.381	0.487	0.347	0.286	0.254

P.m.: *Phtisica marina* Slabber, 1769, J.*m.*: *Jassa marmorata* Holmes, 1903, *C.c.*: *Capitella capitata* (Fabricius, 1780), *P.c.*: *Polydora cornuta* Bosc, 1802

Hard-Bottom Bosphorus Strait Population

Polydora cornuta was found at 9 out of the 15 sampling sites and at 20% of the samplings carried out on the shallow hard-bottoms of the Bosphorus Strait (Table 1). The only spionid found co-existing with this alien species was *Prionospio multibranchiata* (Berkeley & Berkeley, 1927), which was recorded for the first time in this area. In addition, three nereidids [*Hediste diversicolor* (O.F. Müller, 1776), *Platynereis dumerilii* (Audouin & Milne-Edwards, 1833) and *Perinereis cultrifera* (Grube, 1840)], a capitellid [*C. capitata*] and a syllid [*Salvatoria alvaradoi* (San Martín, 1984)], which is being recorded for the first time on the coasts of Turkey, co-existed with *P. cornuta* at these sampling sites.

During the sampling period, *P. cornuta* contributed little to the total faunal abundance, contrary to its large contribution to the soft-bottom community in the Sea of Marmara. It attained its maximum density in November 2004 at station B13. Its mean abundance ranged between 8.33 and 1000 ind.m^{-2} (mean: 117.36 ±279.73 SD) and its percent contribution to the total faunal populations ranged between 0.02 and 21.86 (mean: 2.07 ±6.25 SD) (Figs 3, 5; Table 3). Similarly, according to ÇINAR *et al.* (2008) *P. cornuta* was not among the highly dominant species (only 0.19% of overall abundance) in hard-bottom mussel beds of the area in or around Alsancak Harbor (Izmir Bay), contrary to the previously studied soft-bottoms (ÇINAR *et al.,* 2006). The maximum density of this worm was recorded in fall 2004 and was 1600 ind.m^{-2} in hard-bottoms examined in Izmir Bay (ÇINAR *et al.,* 2008).

Abundance values of *P. cornuta* were not significantly correlated with water temperature, salinity and dissolved oxygen at $p<0.05$ (Spearman rank correlation and partial correlation). The Strait's hard-bottom communities, mainly dominated by peracarid crustaceans, showed better condition with higher levels of diversity (range:1.325-3.686, mean:2.77 ±0.58 SD) and number of species (range:13-38, mean:26.42 ±8.13 SD) than the soft-bottom community in which the population of this alien spionid was found in the Sea of Marmara (Table 3).

The Sea of Marmara population of *P. cornuta* shares some similarities with soft-bottom populations in Izmir Bay (Aegean Sea). In both cases, this species was found in heavily polluted habitats at a similar depth. The macrofaunal communities studied were mainly colonized by polychaetes and were characterized by low diversity, low number of species and high abundance in both the Sea of Marmara and most sampling sites in Izmir Bay (ÇINAR *et al.,* 2005, 2006; ERGEN *et al.,* 2006). In addition, the two opportunistic polychaetes, *Capitella capitata* and *Neanthes succinea,* were always found co-existing with *P. cornuta* in Izmir Bay, as in the Sea of Marmara soft-bottom community. It is worth mentioning that the polychaete species co-existing with *P. cornuta* presented a higher diversity in Izmir Bay (ÇINAR *et al.,* 2006) than those in the Sea of Marmara. On the other hand, hard-bottom communities hosting *P. cornuta* in the Bosphorus Strait were dominated by peracarid crustaceans instead of polychaetes, which are unlikely to be found in the hard-bottom mussel beds examined in Izmir Bay. In terms of diversity and number of species, communities in Izmir Bay were substantially richer than those of the Bosphorus Strait (ÇINAR *et al.,* 2008).

Table 3
Percent contribution of *Polydora cornuta* to the total faunal and polychaete abundance with some biotic properties of the macrofaunal community over the sampling period of the sampling sites in the Bosphorus Strait (*H'*: Shannon-Wiener diversity index; J: Pielou's evenness; values in parenthesis indicate the number of species found in each taxonomic group).

	SAMPLINGS											
	B2 May 2004	**B3 Aug. 2004**	**B4 May 2004**	**B7 May 2004**	**B8 Nov. 2004**	**B8 Feb. 2005**	**B9 Nov. 2004**	**B13 Nov. 2004**	**B13 Feb. 2005**	**B14 Nov. 2004**	**B14 Feb. 2005**	**B15 May 2004**
% of total faunal populations	0.06	0.03	0.02	0.44	0.02	0.04	0.25	21.86	1.54	0.23	0.19	0.15
% of total polychaete populations	0.21	0.18	0.10	3.39	2.78	4.88	1.06	60.61	5.58	5.06	1.42	3.06
Total number of species	34	34	29	26	13	16	38	21	24	24	21	37
Total density (ind.m^{-2})	30116.67	25008.33	54400.00	11383.33	37708.33	41283.33	6733.33	4575.00	7050.00	32175.00	21733.33	37933.33
Crustaceans (%)	0.06 (1)	0	0.02 (1)	0	0	0	0.62 (1)	0	0	0	0	0.24 (1)
Turbellarians (%)	0	0.8 (1)	0.06 (1)	0	0	6.82 (1)	4.95 (2)	0	13.83 (1)	0	0	1.14 (3)
Nemerteans (%)	0.22 (2)	0.40 (1)	0	0	0	0.04 (1)	1.61 (2)	0	0	0.28 (2)	0	1.16 (1)
Polychaetes (%)	26.67 (8)	18.26 (8)	15.63 (10)	12.96 (8)	0.80 (5)	0.83 (5)	23.27 (10)	36.07 (6)	27.54 (7)	4.61 (6)	13.46 (5)	5.03 (10)
Oligochaetes (%)	0.47 (1)	0	15.87 (2)	5.27 (1)	1.44 (1)	27.19 (1)	2.85 (2)	0	49.05 (2)	0.16 (1)	0.35 (1)	1.38 (1)
Pycnogonids (%)	0.28 (1)	0	0	0	0	0	0	0	0	0	0	0.04 (1)
Crustaceans (%)	38.13 (15)	38.69 (17)	18.34 (13)	48.17 (14)	74.10 (5)	27.11 (6)	26.73 (15)	37.34 (12)	8.51 (12)	72.16 (12)	70.40 (13)	53.32 (13)
Molluscs (%)	34.17 (6)	41.89 (7)	50.09 (2)	33.60 (3)	23.67 (2)	38.01 (2)	39.98 (6)	26.59 (3)	1.06 (2)	22.79 (3)	15.80 (2)	37.68 (7)
Dominant species	*H.p.*	*M.l.*	*M.l.*	*M.g.*	*E.o.*	*M.g*	*M.g.*	*M.g.*	*E.b.*	*E.o.*	*E.o.*	*J.m.*
H'	3.150	3.258	2.920	3.081	1.325	2.390	3.686	3.042	2.675	2.523	2.623	2.606
J	0.619	0.640	0.601	0.655	0.358	0.597	0.702	0.693	0.583	0.550	0.597	0.500

H.p.: *Hyale perieri* (Lucas, 1849), *M.l.*: *Mytilaster lineatus* (Gmelin, 1791), *M.g.*: *Mytilus galloprovincialis* Lamarck, 1819, *E.o.*: *Echinogammarus olivii* (Milne-Edwards, 1830), *E.b.*: *Enchytraeus buchholzi* Vejdovsky, 1879, *J.m.*: *Jassa marmorata* Holmes, 1903

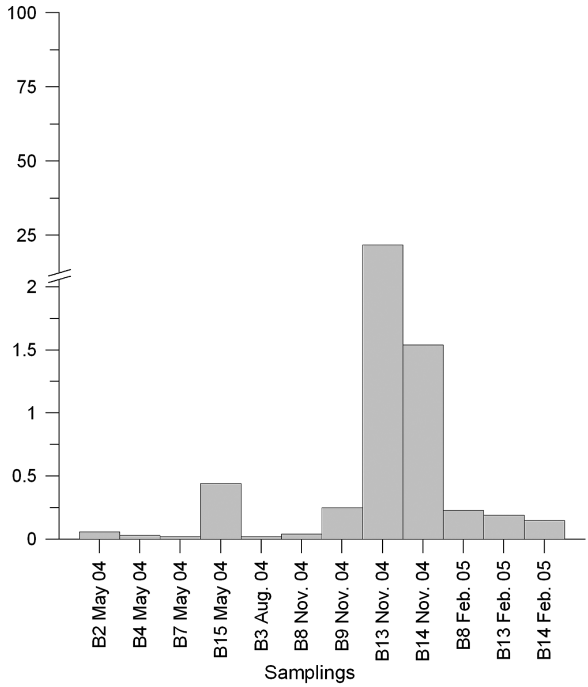

Fig. 5: Percent contribution of *Polydora cornuta* to the total faunal abundance during the study period in the Bosphorus Strait.

In the Sea of Marmara the highest density values of *P. cornuta* were recorded in the winter months of the present study (Table 2). In 2002, the maximum density of this species was observed also in winter (1940 ind.m^{-2}) in Izmir Bay (ERGEN *et al.,* 2006). However, in 2003 maximum density was observed in summer (3170 ind.m^{-2}) (ÇINAR *et al.,* 2005), and one year later the density of this species attained its maximum level in spring (ÇINAR *et al.,* 2006). In addition, because of limited sampling number and frequency and short sampling period, hard-bottom data do not allow making any interpretations on the seasonality of this species either in Izmir Bay or in the Bosphorus Strait. Therefore, it is not possible to arrive at a conclusion about distinct seasonal abundance pattern for *P. cornuta* in these regions. Unfortunately, TENA *et al.* (1991) and SURUGIU (2005) gave no data concerning the density or abundance patterns of *P. cornuta.* Hence, it is not possible to compare the populations of the study area with those of Valencia Harbor (Western Mediterranean) or the Romanian coast of the Black Sea. Changes in the abundance pattern of this species may have occurred asynchronously at different locations with variable ecological conditions. Longer-term studies at different sites are necessary to understand the environmental variables affecting the abundance and seasonality of this alien species.

The Turkish Straits System, consisting of the Bosphorus and Dardanelles Straits and the Sea of Marmara, is the only connection between the Black Sea and the Mediterranean. The system hosts a unique ecosystem formed by its peculiar biological, physiographical and hydrological characteristics (e.g. ÜNLÜATA *et al.,* 1990; BEŞIKTEPE *et al.,* 1994; ÖZSOY *et al.,* 1996; ÖZTÜRK & ÖZTÜRK, 1996). It constitutes a transition zone between the Black Sea and the Mediterranean, and plays significant roles in the biology of these basins. It acts as a biological barrier limiting the distribution of certain species of both Mediterranean and Black Sea origin. On the other hand, by means of its two-layered current regime, many species are able to penetrate the Black Sea from the Aegean Sea through the Sea of Marmara and vice versa, thus the system serves as a biological corridor. It is also an acclimatization zone where some Mediterranean species can slowly adapt to conditions more similar to those in the Black Sea, or Black Sea species to conditions of the Aegean Sea (ÖZTÜRK & ÖZTÜRK, 1996; ÖZTÜRK, 2002). In this instance, it is likely that the Turkish Strait System is the route of introduction for *P. cornuta* into the Black Sea. The system is one of the busiest waterways in the world with approximately 50,000 vessels per year (ÖZTÜRK *et al.,* 2001). Therefore, it is suggested that the most likely vector for the introduction of this alien species into the Sea of Marmara is shipping through the Dardanelles Strait. This species may undergo a process of acclimatization in the Sea of Marmara before its introduction into the Black Sea through the Bosphorus Strait. In other words, the Sea of Marmara population of *P. cornuta* may be the source population for the introduction of this species into the Black Sea. However, it is also possible that the dispersal of this species in this area may be the result of multiple introduction events. Consequently, the origin of the species' Black Sea population may be an independent introduction process by ships from outside or inside the Mediterranean. This ambiguity can be resolved by investigating the spatial and temporal dynamics of the invasion of this species in the Mediterranean using molecular genetic methods.

In conclusion, additional records and further spatio-temporal studies are needed to understand the current status of *P. cornuta* in the Mediterranean. In addition, long-term monitoring studies will enable us to have better knowledge of its impact on native benthic communities.

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