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ИнБЮМ – IBSS

Морской биологический журнал
Marine Biological Journal
2023, vol. 8, no. 4, pp. 3–22
https://marine-biology.ru

SCIENTIFIC COMMUNICATIONS

UDC [595.142.241:551.462.32](262.5-16)

DISTRIBUTION OF POLYCHAETES OF THE FAMILY SPIONIDAE (ANNELIDA) ON THE SHELF OF THE NORTHWESTERN PART OF THE BLACK SEA

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Received by the Editor 09.03.2021; after reviewing 14.09.2021;
accepted for publication 04.08.2023; published online 01.12.2023.

The northwestern part of the Black Sea (NWBS) is a vast shallow water area, biocenoses of which are an important component of the Black Sea ecosystem. Since the benthos of this region has not been studied in recent decades, data on its current state are relevant. A significant contribution to the taxonomic composition of macrozoobenthos is made by polychaetes of the family Spionidae, which are represented by a large number of species and are characterized by high abundance rates. The aim of the research is to study the species composition, distribution, and quantitative representation of polychaetes of the family Spionidae in the NWBS at depths of more than 10–15 m. The material used was macrozoobenthos sampled from 160 stations (230 samples) during research cruises of the RV "Maria S. Merian" and the RV "Professor Vodyanitsky" in 2010–2017 at depths from 10 to 137 m. Bottom sediments were sampled with an Ocean-25 bottom grab (capture area of 0.25 m^2) and a box corer ($S = 0.1$ m^2). Bottom sediments were washed through sieves with the smallest mesh diameter of 1 mm. On the surveyed shelf area of the NWBS, 83 Polychaeta species were found, including 12 Spionidae species. Polychaetes were recorded at all the stations performed, while spionids were noted at 66% of their total number. At single stations, up to 6 Spionidae species were registered, but more often, there were 2–3 species. In total, 11 species were identified: *Aonides paucibranchiata* Southern, 1914, *Dipolydora quadrilobata* (Jacobi, 1883), *Microspio mecznikowiana* (Claparède, 1869), *Prionospio* cf. *cirrifera* Wirén, 1883, *Polydora cornuta* Bosc, 1802, *Pygospio elegans* Claparède, 1863, *Scolelepis tridentata* (Southern, 1914), *Scolelepis (Scolelepis) cantabra* (Rioja, 1918), *Spio decorata* Bobretzky, 1871, *Laonice* cf. *cirrata* (M. Sars, 1851), and *Marenzelleria neglecta* Sikorski & Bick, 2004. Non-identified specimens of the genus *Prionospio* were registered as well. Spionidae distribution in the water area of the NWBS is uneven, which is due to the response of certain species to various environmental factors. The maximum density of spionids was 2,984 ind.·m^{-2}, and the average density was (477 ± 126) ind.·m^{-2}. The highest density of Spionidae was observed in the depth range of 20–40 m. In terms of density, *P.* cf. *cirrifera*, *A. paucibranchiata*, and *D. quadrilobata* predominated. Out of identified species, three (*M. neglecta*, *P. cornuta*, and *D. quadrilobata*) are non-native for the Black Sea. In the taxonomic composition of Polychaeta of the NWBS, Spionidae accounted for 14%, while in the quantitative representation, their contribution reached 42% of the total density of polychaetes. This indicates a significant role of this family in the functioning of the benthic ecosystem of the NWBS.

Keywords: Polychaeta, Spionidae, *Dipolydora quadrilobata*, density, distribution, northwestern part of the Black Sea

In the second half of the XX century, 192 species were known in the Polychaeta fauna of the Black Sea [Mordukhai-Boltovskoi, 1972]; later, 195 species [Kiseleva, 2004]. In recent decades, the intensification of benthic research (especially in Turkish waters), the development of taxonomy, and the introduction of non-native species into the Black Sea resulted in a rapid increase in this number to 238 [Kurt-Şahin, Çinar, 2012] and then to 256 [Kurt Şahin et al., 2019]. Polychaetes were recorded at all depths inhabited by macrozoobenthos in the Black Sea – from 0 to 150 m. In terms of the species number, one of the most represented families in the Black Sea is Spionidae Grube, 1850: in 1972, 19 species were known (9.7% of the Polychaeta fauna); by the end of the XX century, 34 species (13.3%) [Kurt-Şahin, Çinar, 2012; Kurt Şahin et al., 2019; Mordukhai-Boltovskoi, 1972].

Spionidae is a family of small, predominantly detritivorous polychaetes that are found in a wide variety of biotopes from intertidal to deep-sea zone, but most of the species inhabit shallow waters. Spionids mainly inhabit soft bottoms, moving freely in sediments near the surface or living in temporary or permanent tubes. The density of such tube-dwelling polychaetes can reach thousands of individuals *per* m^2 [Blake, 1996; Radashevsky, 2012]. Some species of the genus *Polydora* Bosc, 1802 are borers in various substrates. Most spionids live in marine environments with oceanic salinity; at the same time, certain species exhibit low-salinity tolerance, and some representatives of the genera *Prionospio* Malmgren, 1867, *Pseudopolydora* Czerniavsky, 1881, and *Streblospio* Webster, 1879 are recorded only in estuaries or lakes [Blake, 1996; Radashevsky, 2012]. The larval development of spionids is varied – from pelagic and planktotrophic to almost entirely capsule-based and lecithotrophic [Blake, Arnofsky, 1999]. Larvae of shallow-water sublittoral species, especially those found in estuaries (often used as port areas), easily survive in ballast waters and are transported throughout the world [Radashevsky, 2012; Surugiu, 2012]. As a result, the proportion of spionids is significant in the number of non-native polychaetes in various areas of the World Ocean [Boltachova et al., 2015; Dağli et al., 2011; Radashevsky, Selifonova, 2013]. For the northern part of the Black Sea, 11 non-native Polychaeta species are known, and 5 out of them belong to the family Spionidae [Boltachova et al., 2021].

The northwestern part of the Black Sea (hereinafter NWBS) is its largest shallow bay, boarded by Romania, Ukraine, and Crimea. Its southern border has been drawn in different ways – along the line connecting Cape Kaliakra (Bulgaria) with Cape Tarkhankut on the Crimean coast [Biologiya, 1967], along the edge of the continental shelf or 100-m isobath [Samyshev, Zolotarev, 2018], and along the parallel 44°40′N [Severo-zapadnaya chast', 2006]. The bottom surface of the NWBS is flat, with a slight slope to the south; it is crossed by the trenches of the Odessa, Dnieper, and Karkinit basins, as well as by river paleochannels and sandbars. The predominant type of sediments in the NWBS are shell debris of varying degree of siltation, which occupy the central part of the area (depths of 10–30 m). In the north for the Odessa–Tendrovskaya depression and in the east for the Karkinit one, the characteristic type of sediments is fine aleurite silts. In the southern part of the area, at depths of 50–100 m, silts with a high content of pelite fraction are common [Samyshev, Zolotarev, 2018]. The NWBS is characterized by variations in water temperature and salinity over a wider range than that in other parts of the Black Sea. At a 20-m horizon, the minimum temperature is +4 °C in winter and +10 °C in summer. The water salinity at depths exceeding 10 m in the warm season varies from 16.6‰ in the west to 19.5‰ in the east. The oxygen content in autumn–winter is close to normal; in summer, its concentration can decrease, causing suffocation death [Biologiya, 1967; Samyshev, Zolotarev, 2018].

By the early 1960s, 63 species of polychaetes were known for the NWBS, *inter alia* 7 species of spionids [Biologiya, 1967]. Subsequently, numerous studies of shallow waters of the Romanian shelf, as well as estuaries and bays of the Odessa region and the western coast of Crimea, led to an increase in the faunal list of polychaetes to 132 species (out of them, 12 belonged to Spionidae) [Kiseleva, 2004; Marinov, 1977].

Serious disturbances in the Black Sea ecosystem in the 1970–1980s, related to anthropogenic eutrophication of the basin and its consequences (decrease in water transparency and formation of zones with near-bottom hypoxia), as well as siltation of the bottom substrate resulting from seafood fishing, were most disastrous for the NWBS. This led to a drop in species richness in benthic communities, sharp fluctuations in the density and biomass of benthos, a change in the role of some common species, the disappearance of certain species, and the appearance of new ones in the benthic fauna of the area [Losovskaya, 1977; Revkov et al., 2018; Severo-zapadnaya chast', 2006]. Specifically, in the 1980s compared to 1953–1960, in the areas between the Danube and Dnieper rivers, the number of polychaete species decreased from 29 to 17. However, in quantitative terms, mass development of some species was registered, including representatives of the genera *Spio*, *Prionospio*, and *Polydora*, identified as *Spio filicornis*, *Prionospio cirrifera*, and *Polydora limicola*, respectively [Losovskaya, 1991; Severo-zapadnaya chast', 2006]. De-eutrophication of the Black Sea basin since the mid-1990s [Zaika, 2011], the prohibition of bottom fishing for sprat and mussel dredging in the late 1980s in Ukraine, and subsequent stricter control over the use of bottom fishing gear gave rise to improved general indicators of zoobenthos representation [Revkov et al., 2018]. The benthic research in the last decade of the XX century and the first decades of the XXI century in the NWBS was mainly carried out in shallow bays, bights, and estuaries. The same applies to special studies of the polychaete fauna: those were mostly carried out in the Odessa region, Sevastopol bays, and shallow coastal areas of Romania [Boltachova, Lisitskaya, 2007; Boltachova et al., 2015; Bondarenko, 2009, 2017; Surugiu, 2005, 2012]. In the central region of the NWBS at depths of more than 10–15 m, benthic investigations were rare. Thus, in 2012, in the Zernov *Phyllophora* Field area (the central region of the NWBS), 14 species of polychaetes (*inter alia* 2 species of spionids) were noted in the composition of macrobenthos [Kovalishina, Kachalov, 2015]. In 2003, when studying meiobenthos along the western coast of the Black Sea (off the coast of Romania and Ukraine), 24 Polychaeta species were recorded (including 5 Spionidae species) [Vorobyova, Bondarenko, 2009]. In 2006–2007, a detailed investigation of the benthic fauna was carried out in a small area of the Romanian shelf, covering all depths inhabited by macrobenthos. It resulted in registration of 43 species of polychaetes (out of them, 10 spionids). Interestingly, mass development of a new species non-native for the Black Sea, *Dipolydora quadrilobata* (Jacobi, 1883), was observed [Begun et al., 2010; Surugiu, 2012].

Thus, we have to admit that the bottom fauna of the most extensive part of the Black Sea shelf, which is under ever-increasing anthropogenic load, has remained virtually out of the spotlight of researchers over the past 30 years. A significant part of macrobenthos, and often the predominant one in terms of density, are Polychaeta species, and out of them, in turn, Spionidae representatives usually dominate. The aim of our research is to study the species composition, distribution, and quantitative development of polychaetes of the family Spionidae in the northwestern part of the Black Sea at depths of more than 10–15 m.

MATERIAL AND METHODS

The material was macrobenthos sampled in the NWBS during the cruise no. 15/2 of the RV "Maria S. Merian" (May 2010) and cruises no. 64, 68, 70, 72, 84, 86, 90, and 96 of the RV "Professor Vodyanitsky" (July and November 2010, August 2011, May 2013, April, June, and October 2016, and July 2017). The stations were performed in the depth range of 10–137 m (Table 1). From the RV "Professor Vodyanitsky," bottom sediments were sampled with Ocean-25 bottom grabs (capture area of 0.25 m^2); from the RV "Maria S. Merian," using a box corer (capture area of 0.1 m^2). Bottom sediments were washed through sieves with the smallest diameter of 1 mm. The material was fixed with a 4% formaldehyde solution and further processed in a laboratory. In total, 230 samples from 160 stations were taken and processed. Golden Software Surfer 2011 was used to create species distribution maps.

Table 1. Coordinates of stations in the northwestern part of the Black Sea, performed in 2010–2017 on the RV "Maria S. Merian" (*) and "Professor Vodyanitsky," where Spionidae were found

Cruise no., date	Sta. no.	Coordinates		Depth, m	Cruise no., date	Sta. no.	Coordinates		Depth, m
		°N	°E				°N	°E	
15/2*, 05.2010	361	44.8123	31.9220	82	70, 07.2011	35	45.9822	33.2445	10
	362	44.8000	31.9167	83		36	45.8966	33.1836	11
	533	44.6427	33.0012	137		37	45.9187	33.2030	11
64, 07.2010	10	44.5637	33.3487	87		39	45.6855	32.7660	27
	14	44.9425	33.1562	93		43	45.0499	33.0611	87
	15	45.0163	33.2269	70	72, 05.2013	25	45.3927	30.9839	44
	16	45.0639	33.2757	30		27	45.5261	32.4353	29
	16a	45.0602	33.2408	46		28	45.5008	32.4574	30
68, 11.2010	1	45.2987	30.4802	39		29	45.5513	32.5885	25
	2	45.2991	30.7001	37		33	46.0380	31.5362	17
	3	45.2917	30.9250	41		34	45.5929	31.6435	41
	4	45.2986	31.3889	52		35	45.2912	32.6741	38
	5	45.2937	31.6469	48		42	45.2904	32.9596	19
	6	45.6448	31.7874	39		43	44.9267	33.1849	86
	7	45.6351	31.5076	43		46	45.1206	33.2371	12
	8	45.6365	31.2552	44		47	45.0747	33.2365	33
	9	45.6290	31.0414	36		48	45.0397	33.4934	18
	10	45.6356	30.8020	36	84, 04.2016	6	32.7348	45.3332	25
	11	45.6403	30.6059	27		7	33.1420	45.1580	22
	12	45.8440	30.7423	19		9	33.4366	44.9882	31
	13	45.8467	30.8700	23	86, 06.2016	1	33.1095	45.2032	18
	14	45.9829	30.8871	21		2	32.8980	45.2643	44
	15	46.0883	31.0988	34		4	32.7493	45.6053	22
	16	45.9818	31.0895	35		5	32.7767	45.6183	21
	17	45.8706	31.0942	35		6	32.7617	45.6407	22
	18	45.7575	31.1146	36		7	33.0298	45.7457	20
	19	45.5013	31.1370	46		8	33.0653	45.7542	15
	20	45.4717	31.3650	48		9	33.0360	45.7805	18
	21	45.7565	31.3578	41		10	33.0725	45.7917	14
	22	45.8446	31.3595	25		11	33.0402	45.8167	15
	23	45.9671	31.3588	22		12	32.5667	45.4955	23
	24	46.0685	31.3507	20		46	32.8333	44.8667	117
	25	46.0675	31.5848	20	90, 10.2016	5	45.0898	32.5528	81
	26	45.9552	31.5824	23		7	45.0375	32.2256	72
	27	45.8411	31.9533	26		8	45.1638	32.1172	57
	28	45.8470	31.5804	26		9	45.2914	32.0502	50
	29	45.7458	31.5857	33		12	44.9757	31.9271	59
	30	45.4820	31.5827	49	96, 07.2017	2	32.7175	45.6037	27
70, 07.2011	18	45.5061	31.4006	46		3	32.7698	45.5877	20
	19	45.5074	30.7159	38		4	32.7602	45.6324	20
	20	45.6205	30.6288	24		5	32.7684	45.6963	27
	21	45.6237	30.8368	35		6	32.9815	45.7229	20
	22	45.7381	30.9173	32		7	33.0648	45.7547	19
	23	45.6188	31.0552	35		8	32.9976	45.7855	19
	24	46.0582	31.2220	31		9	32.7175	45.7372	28
	25	46.4474	31.3842	15		14	33.3472	45.0042	30
	26	46.0482	31.5383	20		15	33.3581	44.8797	74
	27	46.6195	31.6360	45		41	32.2197	45.6271	34
	28	45.7008	31.9797	33		42	31.9658	45.5478	40
	30	45.8130	32.4892	31		44	31.6527	45.2310	59
	32	45.9190	33.0002	11		45	31.4489	45.1643	61
	33	45.9690	33.2062	11		48	32.5612	45.0892	79
	34	45.9224	33.2708	11					

RESULTS

Representatives of the family Spionidae were found in almost the entire surveyed shelf area – at 105 out of 160 stations performed (Fig. 1). In total, 20,263 Spionidae specimens were recorded, and 11 species were identified: *Aonides paucibranchiata* Southern, 1914, *Dipolydora quadrilobata* (Jacobi, 1883), *Microspio mecznikowiana* (Claparède, 1869), *Prionospio* cf. *cirrifera* Wirén, 1883, *Polydora cornuta* Bosc, 1802, *Pygospio elegans* Claparède, 1863, *Scolelepis tridentata* (Southern, 1914), *Scolelepis (Scolelepis) cantabra* (Rioja, 1918), *Laonice* cf. *cirrata* (M. Sars, 1851), *Marenzelleria neglecta* Sikorski & Bick, 2004, and *Spio decorata*[*] Bobretzky, 1871. *Prionospio* sp. (non-identified down to a species level) were registered as well.

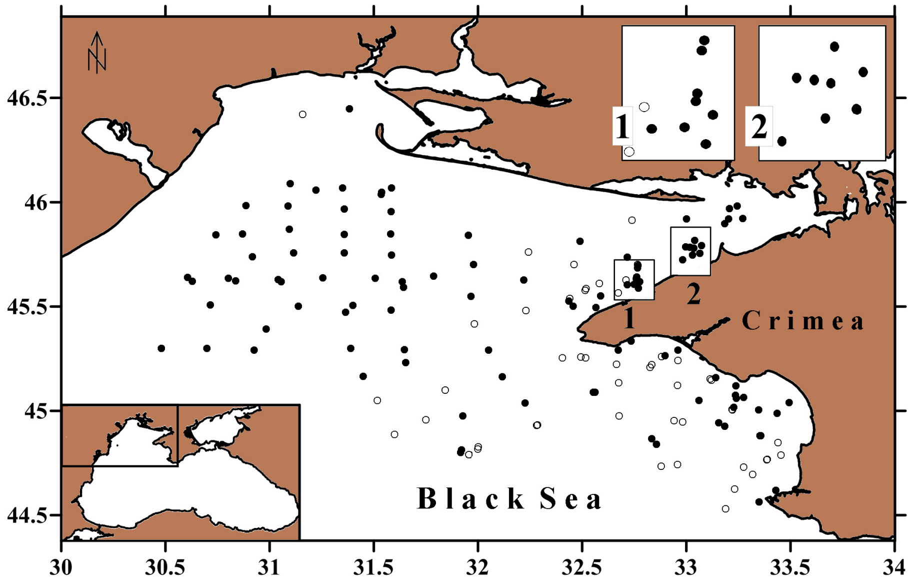

Fig. 1. Spionidae distribution on the shelf of the northwestern part of the Black Sea in 2010–2017: ○, benthic stations; ●, stations where Spionidae representatives were found

Spionidae were noted at all surveyed depths – down to 137 m. As known, in the Black Sea, the maximum depths suitable for macrozoobenthos habitat are limited by isobaths of 150–170 m; in the NWBS, 110–125 m [Kiseleva, 1981, 2004]. Thus, representatives of this family inhabit the entire depth range of the NWBS. Spionids were recorded on various sediments, but preferred coarse sand with shell debris; there, their average density was 729 ind.·m^{-2}, while on finer silted sand, the value was 399 ind.·m^{-2}. On aleurite and pelite silts, spionids were less common, and their density was minimum, 33 ind.·m^{-2}. At individual stations, Spionidae density reached 2,984 ind.·m^{-2}, and the average value was (477 ± 126) ind.·m^{-2}. Especially high density of spionids was registered in the west of the central region of the NWBS and in some coastal areas of the Karkinitsky and Kalamitsky bays (Fig. 2).

***Aonides paucibranchiata* Southern, 1914.** The material was 619 ind. The RV "Professor Vodyanitsky": cruise no. 64, sta. 14; cruise no. 68, sta. 2–4, 7–10, 12, 14, 19, 24, 25, 28, 30; cruise no. 70, sta. 19–22, 26, 43; cruise no. 72, sta. 25, 47; cruise no. 84, sta. 6, 7; cruise no. 86, sta. 5, 12, 46; cruise no. 90, sta. 8, 12; cruise no. 96, sta. 14, 44, 45. The RV "Maria S. Merian": cruise no. 15/2, sta. 361, 362.

[*] A thorough examination of polychaetes of the genus *Spio*, previously attributed by us, as well as by most other researchers, to the species *S. filicornis* (Müller, 1776), led to the conclusion that this is *S. decorata* Bobretzky, 1871 [Boltachova, Lisitskaya, 2019]. The opinion that the Black Sea is inhabited by the latter species is currently shared by a number of authors [V. Radashevsky, oral report; Surugiu, 2005].

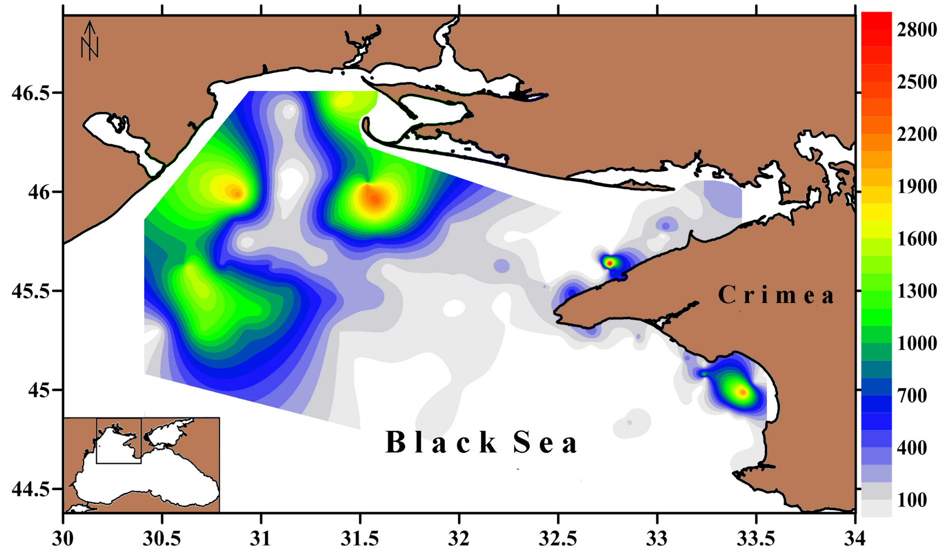

Fig. 2. Spionidae density on the shelf of the northwestern part of the Black Sea in 2010–2017

Amphi-Atlantic species. It is distributed in the White and North seas, off the Atlantic coast of Europe, in the Mediterranean Sea, and in the Gulf of Mexico [Dauvin et al., 2003; Fauchald et al., 2009; Fauvel, 1927]. In the Black Sea, it is recorded everywhere – off the coasts of Bulgaria, Romania, and Turkey [Marinov, 1977; Kurt-Şahin, Çinar, 2012; Surugiu, 2005], in the NWBS [Biologiya, 1967], and off the Crimean and Caucasian coasts [Kiseleva, 2004; Vinogradov, Losovskaya, 1968].

We found this species at 35 stations in a wide depth range (19–117 m) on sand, shell debris, and their mixture, sometimes slightly silted (Fig. 3). A higher frequency of occurrence was revealed at depths of 20–60 and 80–100 m. The density varied in the range of 2–260 ind.·m^{-2}, with the average value of (44 ± 20) ind.·m^{-2}. The maximum density for *A. paucibranchiata* was registered in the western region of the NWBS – 260 and 192 ind.·m^{-2} (cruise no. 70, sta. 21, depth of 35 m; cruise no. 72, sta. 25, depth of 44 m). The species had relatively low density and frequency of occurrence at the lowest (less than 20 m) and greatest (more than 100 m) depths.

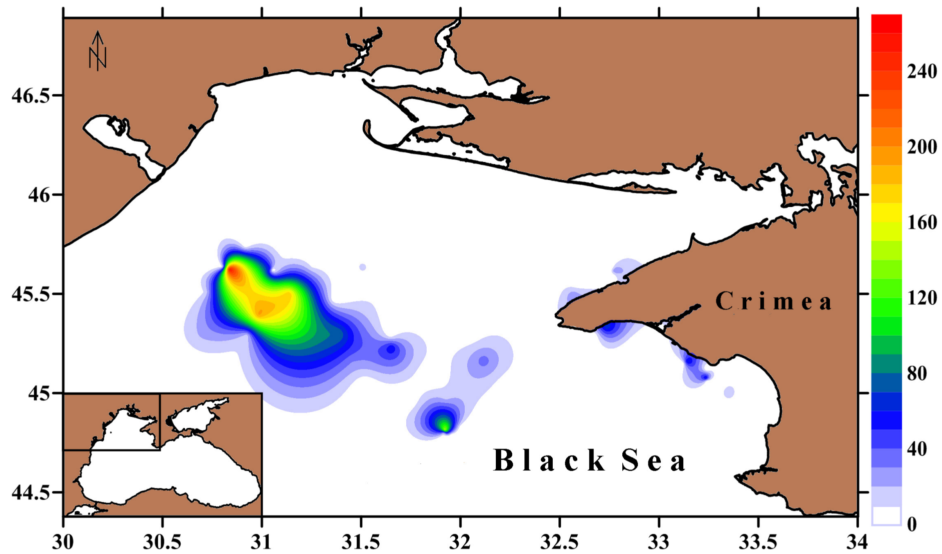

Fig. 3. *Aonides paucibranchiata* distribution on the shelf of the northwestern part of the Black Sea in 2010–2017

There are contradictory data on *A. paucibranchiata* confinement to various depths and sediments. According to K. Vinogradov, this species is found primarily on coarse sand with shell debris at depths of 10–22 m [Vinogradov, Losovskaya, 1968]. At the same time, its large accumulations were revealed by M. Băcescu off the Romanian coast on silty sediments at depths of 110 and 124 m, where its density reached 1,000 and 3,000 ind.·m^{-2}, respectively [Kiseleva, 2004]. Our data confirm the wide ecological range of *A. paucibranchiata* distribution in the Black Sea.

Dipolydora quadrilobata **(Jacobi, 1883).** The material was 2,560 ind. The RV "Professor Vodyanitsky": cruise no. 64, sta. 10, 14, 15; cruise no. 68, sta. 1–4, 9–13, 16–20, 22–24, 28–30; cruise no. 70, sta. 18–24, 43; cruise no. 72, sta. 33, 34, 43; cruise 90, sta. 5. The RV "Maria S. Merian": cruise no. 15/2, sta. 362.

Arctic-boreal species. It is known for the Atlantic coast of Europe and North America [Blake, 1969; Dauvin et al., 2003; Fauvel, 1927], the Okhotsk Sea, the Sea of Japan, and the Bering Sea [Radashevsky, 1993; Ushakov, 1955], the Pacific coast of North America [Blake, 1996], and the Adriatic Sea [Castelli et al., 1995]. This species is a recent invader into the Black Sea [Todorova, Panayotova, 2006, cited from: Surugiu, 2012].

We found *D. quadrilobata* at 36 stations in a wide depth range (17–93 m) on sandy and shell debris sediments of varying degree of siltation. The species was most often registered in the central region of the NWBS; its maximum density was also recorded there (cruise no. 70, sta. 2, depth of 37 m) (Fig. 4). *D. quadrilobata* frequency of occurrence was higher at depths of 20–40 and 80–100 m (Fig. 5). However, high density was noted in the range of 20–60 m, while at depths exceeding 80 m, the value was low. In general, the density varied from 4 to 1,184 ind.·m^{-2}, and the average was (177 ± 99) ind.·m^{-2}.

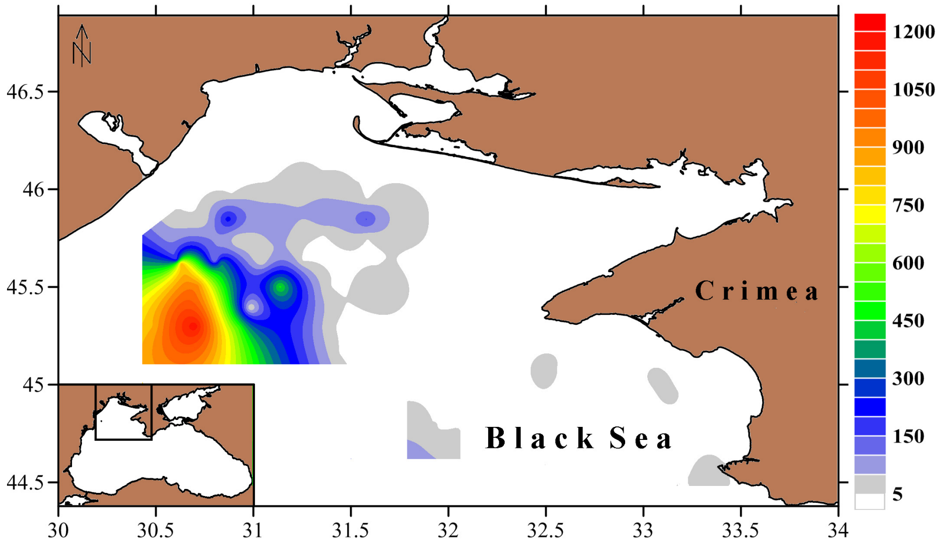

Fig. 4. *Dipolydora quadrilobata* distribution on the shelf of the northwestern part of the Black Sea in 2010–2017

Despite the fact that *D. quadrilobata* was recorded on various sediments, its distribution was uneven. Specifically, on silty sediments, the minimum density was registered, on average 14 ind.·m^{-2}. On silted shell debris, the value was an order of magnitude higher, 142 ind.·m^{-2}. On sandy and shell debris, the average density of this species was 277 ind.·m^{-2}.

The high (50%) frequency of occurrence of *D. quadrilobata* at great depths is of interest. Studies of this species off the Atlantic coast of North America showed the existence of two ecological forms that differ in the type of larval development [Blake, 1969]. Those were characterized by different temperature optimums for larval growth – +6…+10 and +10…+15 °C [Blake, 1969]. In the Black Sea, at a depth of more than 50–55 m, water temperature is constant, about +8 °C, while at lower depths, 30–40 m, it rises to +11…+13 °C [Ivanov, Belokopytov, 2011]. These temperatures correspond to the optimal ones for the indicated ecological forms of *D. quadrilobata*. In the very surface layer, the water can warm up to +28…+29 °C, which may explain the absence of this species at depths less than 20 m. It can be assumed that the Black Sea is inhabited by both ecological forms of *D. quadrilobata*, the taxonomic status of which requires further research.

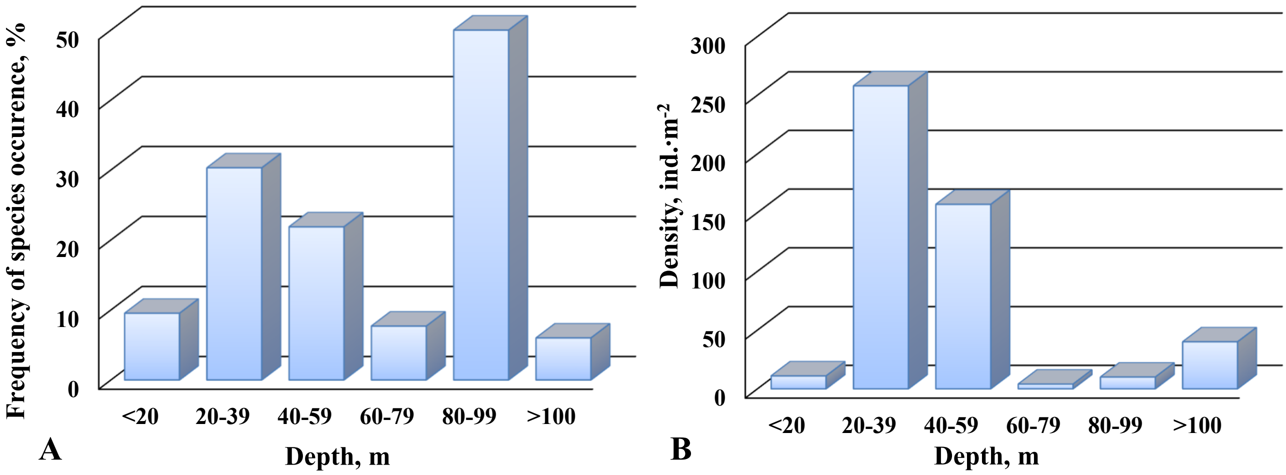

Fig. 5. *Dipolydora quadrilobata* frequency of occurrence (A) and density (B) on the shelf of the north-western part of the Black Sea in 2010–2017

***Laonice* cf. *cirrata* (M. Sars, 1851).** The material was 2 ind. The RV "Professor Vodyanitsky": cruise no. 96, sta. 2, 5.

The species is distributed in the Arctic seas, the northern Pacific Ocean, the Atlantic, and the Mediterranean and Marmara seas [Blake, 1996; Fauvel, 1927; Rullier, 1963; Sikorski, 2003; Zhirkov, 2001; Çinar et al., 2014]. In the Black Sea, single finds are known for the Karadag water area [Vinogradov, 1949], the Bosphorus outlet area, and the coast of Bulgaria [Kurt-Şahin, Çinar, 2012; Rullier, 1963].

We noted *L.* cf. *cirrata* off the coast of Crimea in the Karkinitsky Bay (Fig. 6) at a depth of 27 m on silted shell debris.

***Marenzelleria neglecta* Sikorski & Bick, 2004.** The material was 1 ind. The RV "Professor Vodyanitsky": cruise no. 84, sta. 6.

The species is listed for the Atlantic coast of North America, the Canadian Arctic, and the North and Baltic seas [Sikorski, Bick, 2004]. *M. neglecta* is a non-native species widely distributed in the Baltic Sea; in 2014, it was revealed in the Sea of Azov, where it seemed to arrive with the ballast waters of ships passing the Volga-Baltic and Volga-Don channels on their way from the North Atlantic and the Baltic Sea [Syomin et al., 2016]. The species is spreading rapidly in the Sea of Azov and has already been registered in the Kerch Strait and off the coast of the Taman Peninsula [Syomin et al., 2017].

We recorded *M. neglecta* near the Tarkhankut Peninsula (western coast of Crimea) at a depth of 25 m on sand with shell debris (Fig. 6). This find is the first for the NWBS. Considering the rapid distribution of this species, in the coming years, we can expect its naturalization throughout the Sea of Azov–Black Sea basin.

***Microspio mecznikowiana* (Claparède, 1869).** The material was 15 ind. The RV "Professor Vodyanitsky": cruise no. 68, sta. 1, 11; cruise no. 70, sta. 33; cruise no. 96, sta. 41 (Fig. 6).

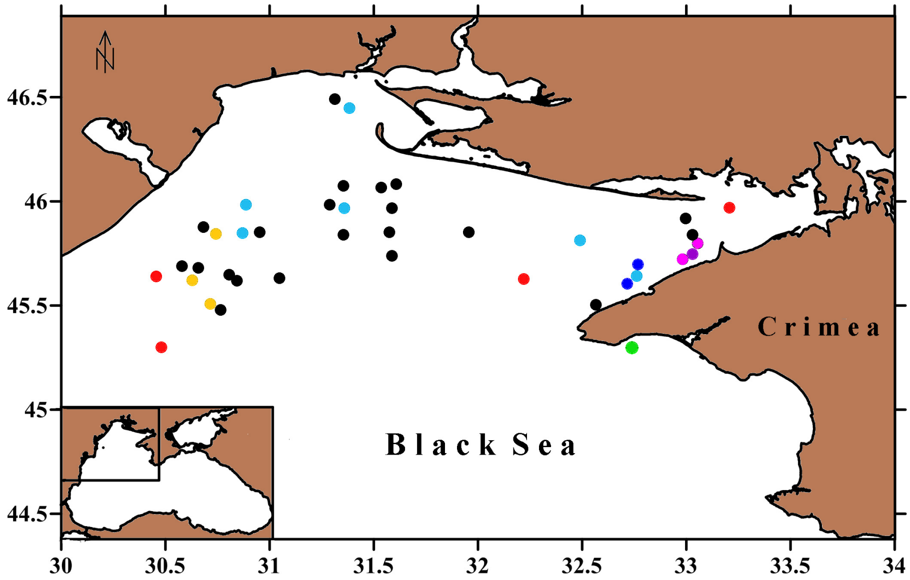

Fig. 6. Finds on the shelf of the northwestern part of the Black Sea in 2010–2017: ●, *Polydora cornuta*; ●, *Laonice* cf. *cirrata*; ●, *Microspio mecznikowiana*; ●, *Marenzelleria neglecta*; ●, *Scolelepis tridentata*; ●, *Pygospio elegans*; ●, *Scolelepis (Scolelepis) cantabra*; ●, *Spio decorata*

The species is noted off the Atlantic coast of Europe, in the Mediterranean, Red, Marmara, and Black seas, and in the Sea of Azov [Dauvin et al., 2003; Kiseleva, 2004; Çinar et al., 2014]. In the Black Sea, it is recorded in different areas at depths of 0–49 m [Kiseleva, 1981, 2004; Marinov, 1977; Samyshev, Zolotarev, 2018; Vinogradov, 1949; Vinogradov, Losovskaya, 1968].

We found *M. mecznikowiana* at depths of 11–39 m on silted shell debris; its density did not exceed 20 ind.·m^{-2} (Fig. 6). Since this species prefers shallow-water areas [Vinogradov, 1949], it was extremely rarely identified in cruise material.

Polydora cornuta **Bosc, 1802.** The material was 30 ind. The RV "Professor Vodyanitsky": cruise no. 68, sta. 13, 14, 23; cruise no. 70, sta. 25, 30; cruise no. 86, sta. 6.

Widespread species, cosmopolitan. It is especially abundant in estuaries and seaports, in eutrophicated water areas [Blake, 1996; Radashevsky, Selifonova, 2013]. It is one of the first invaders to spread massively in the Black Sea [Boltachova, Lisitskaya, 2007; Losovskaya, Nesterova, 1964; Boltachova et al., 2021; Radashevsky, Selifonova, 2013; Surugiu, 2012].

In our samples, *P. cornuta* was found singly at depths of 15–31 m on silted shell debris and sand mixed with silt. Its density did not exceed 30 ind.·m^{-2}. This can be explained by the fact that our studies were carried out mainly at depths exceeding 20 m in open waters, remote from bays, estuaries, and ports (see Fig. 6). Meanwhile, as known, in shallow bays, at depths of 0–33 m, *P. cornuta* is a widespread species; off the Romanian coast, in the Gulf of Mangalia, its density reached 150 thousand ind.·m^{-2} [Surugiu, 2012].

***Prionospio* cf. *cirrifera* Wiren, 1883.** The material was 15,611 ind. The RV "Professor Vodyanitsky": cruise no. 64, sta. 14, 15, 16, 16a; cruise no. 68, sta. 1–30; cruise no. 70, sta. 18–21, 23–28, 32–37, 39, 43; cruise no. 72, sta. 25–29, 33–35, 42, 46–48; cruise no. 84, sta. 6, 7, 9; cruise no. 86, sta. 1, 2, 4–8, 10–12; cruise no. 90, sta. 7, 9, 12; cruise no. 96, sta. 3, 4, 6–9, 14, 15, 41, 42, 44, 48. The RV "Maria S. Merian": cruise no. 15/2, sta. 533.

For a long time, the species was considered as widespread and cosmopolitan. It was first described from the Arctic Ocean; it is known for the North Atlantic [Dauvin et al., 2003; Zhirkov, 2001], the coasts of Asia and South Africa [Day, 1967; Shen et al., 2010], and the Mediterranean Sea [Castelli et al., 1995;

Çinar, Ergen, 1999]. Some researchers consider the species to be cold-water and question the fact of its habitat in the Mediterranean basin [Faulwetter et al., 2017; Maciolek, 1985; Mackie, 1984]. In the Black Sea, *P.* cf. *cirrifera* is noted everywhere – off the coasts of Bulgaria, Romania, and Turkey [Kurt-Şahin, Çinar, 2012; Marinov, 1977; Surugiu, 2005; Çinar et al., 2014], as well as off the Crimean and Caucasian coasts [Biologiya, 1967; Kiseleva, 1981, 2004; Vinogradov, Losovskaya, 1968].

We found this species at 92 stations over the entire range of depths studied (10–137 m) on a variety of sediments (shell debris, sand, their mixture, silted sand or shell debris, and silt). *P.* cf. *cirrifera* was especially widespread in the central region of the NWBS and in the Karkinitsky and Kalamitsky bays (Fig. 7).

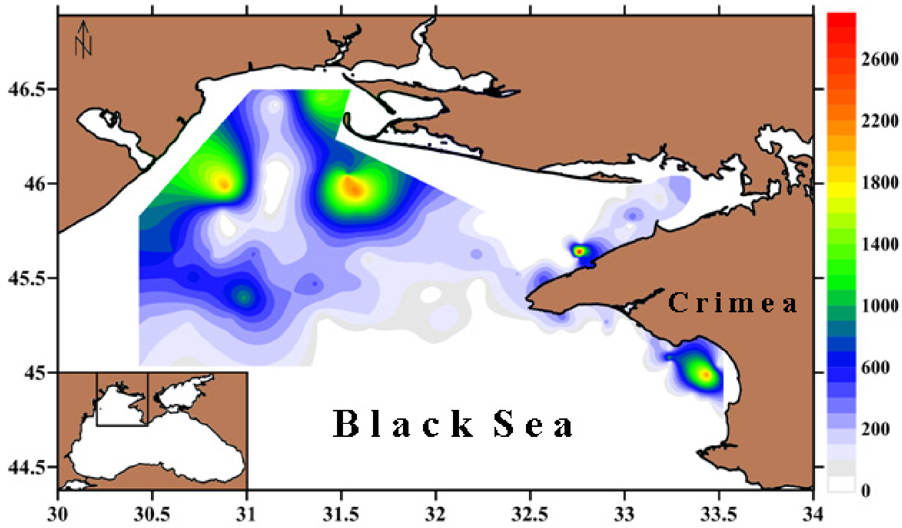

Fig. 7. *Prionospio* cf. *cirrifera* distribution on the shelf of the northwestern part of the Black Sea in 2010–2017

Analysis of *P.* cf. *cirrifera* bathymetric distribution showed as follows. Despite the fact that the species occurs at all depths studied, its frequency of occurrence drops with increasing depth. The frequency of occurrence exceeding 50% (indicator of the fact that the species was one of the leading in communities) was registered at depths of down to 60 m (Fig. 8).

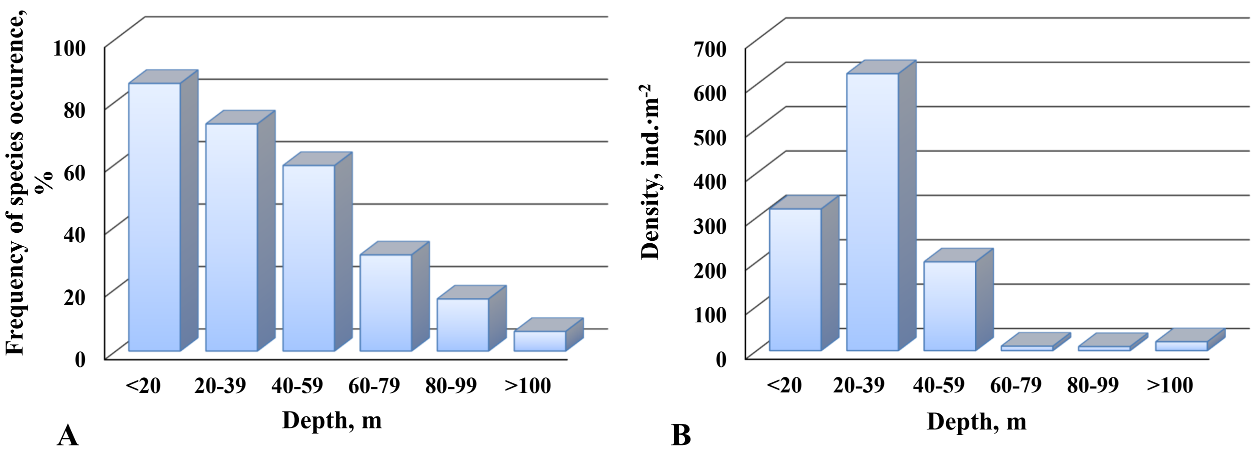

Fig. 8. *Prionospio* cf. *cirrifera* frequency of occurrence (A) and density (B) on the shelf of the northwestern part of the Black Sea in 2010–2017

Average density of this species at the site was (419 ± 126) ind.·m^{-2}. The maximum density of *P.* cf. *cirrifera* was recorded in the Karkinitsky Bay, in the area of the Small *Phyllophora* Field – 2,984 ind.·m^{-2} (cruise no. 96, sta. 4, depth of 20 m). The species was most abundant in shallow waters; at depths of more than 60 m, its density was extremely low. This depth distribution is likely to result from the fact that these polychaetes prefer denser sediments, which lie at lower depths. When comparing the density of *P.* cf. *cirrifera* on various sediments, the values turned out to be maximum on shell debris with an admixture of silt [(653 ± 213) ind.·m^{-2}] and minimum on purely silty sediments [(104 ± 61) ind.·m^{-2}]. The confinement of this species to silted sands is also revealed for the eastern Mediterranean basin [Dağli et al., 2011]. The values obtained during our research on the maximum density of *P.* cf. *cirrifera* exceed those known for the Black Sea. Specifically, off the Crimean coast on sandy sediments, *P.* cf. *cirrifera* density was 396 ind.·m^{-2}, while in the NWBS off the coast of Bulgaria on shell debris–sandy sediments, the value was 267 ind.·m^{-2} [Kiseleva, 2004; Marinov, 1977].

Pygospio elegans **Claparède, 1863.** The material was 15 ind. The RV "Professor Vodyanitsky": cruise no. 68, sta. 12; cruise no. 70, sta. 19, 20. Depths were 19–24 m; sediments were sand with shell debris.

The species is distributed very widely – the Arctic seas, the Baltic Sea, the Atlantic coast of Europe and North America [Dauvin et al., 2003; Radashevsky et al., 2016; Zhirkov, 2001], the Pacific coast of Asia and North America [Blake, 1996; Ushakov, 1955], the Mediterranean, Marmara, and Black seas, and the Sea of Azov [Kiseleva, 2004; Rullier, 1963]. Genetic studies confirmed that *P. elegans* is an amphiboreal species [Radashevsky et al., 2016].

We found it in the central region of the NWBS at depths of 19–38 m on sand and silted shell debris; the density did not exceed 52 ind.·m^{-2} (Fig. 6). In the Black Sea, *P. elegans* is known to inhabit sandy-silty sediments at depths of 0–100 m [Kiseleva, 1981]. It does not form large aggregations. The species tolerates a wide range of salinity and is more often registered in desalinated zones [Vinogradov, Losovskaya, 1968].

Scolelepis (Scolelepis) cantabra **(Rioja, 1918).** The material was 1 ind. The RV "Professor Vodyanitsky": cruise no. 86, sta. 7.

It is distributed in the Atlantic off the coast of Portugal, France, and Ireland [Dauvin et al., 2003; Kiseleva, 2004; Rioja, 1918], as well as in the Mediterranean Sea. In the Black Sea, it is a rare species recorded only off the western coast of Crimea and off the coast of Romania [Boltachova et al., 2022; Marinov, 1977; Mokievsky, 1949].

We found *S. cantabra* at a depth of 16 m on silted sand in the southern area of the Karkinitsky Bay, west of the Bakal Spit (Fig. 6). In the Black Sea, the species is typical for sandy shallow waters. According to O. Mokievsky [1949], it was widespread in the pseudolitoral zone of the western coast of Crimea, where its density reached 325 ind.·m^{-2}.

Scolelepis tridentata **(Southern, 1914).** The material was 5 ind. The RV "Professor Vodyanitsky": cruise no. 86, sta. 9; cruise no. 96, sta. 6.

The species is distributed off the coast of Ireland, in the northern Atlantic Ocean, and in the Mediterranean Sea [Dauvin et al., 2003; Faulwetter et al., 2017; Southern, 1914; Çinar et al., 2014]. In the Black Sea and the Sea of Azov, it is recorded for almost all areas at depths of down to 27 m, but its occurrence and density are low [Kiseleva, 2004; Kurt-Şahin, Çinar, 2012; Marinov, 1977; Vorobyova, Bondarenko, 2009].

We noted *S. tridentata* at a depth of 18–20 m, on silted sand with shell debris in the southern Karkinitsky Bay, in the area of the Small *Phyllophora* Field (Fig. 6).

Spio decorata **Bobretzky, 1871.** The material was 1,404 ind. The RV "Professor Vodyanitsky": cruise no. 68, sta. 9, 11–14, 22–29; cruise no. 70, sta. 19–21, 25, 26, 32; cruise no. 86, sta. 10, 12.

The species is distributed along the Atlantic coast of Europe [Bick et al., 2010; Dauvin, 1989; Dauvin et al., 2003], in the Mediterranean Sea [Faulwetter et al., 2017; Giordanella, 1969; Simboura, Nicolaidou, 2001], and in the Black Sea – off the Caucasian coast [Chernyavskii, 1880], in Turkey [Kurt Şahin et al., 2017; Çinar, Gönlügür-Demirci, 2005] and Romania [Surugiu, 2005]. Assuming that for a long time researchers of the Black Sea mistakenly attributed *Spio decorata* to *Spio filicornis* [Boltachova, Lisitskaya, 2019], *S. decorata* should be considered as widespread along all the shores of the Black Sea and in the Sea of Azov [Kiseleva, 2004; Marinov, 1977; Vinogradov, Losovskaya, 1968].

We registered the species at 21 stations at depths from 11 to 38 m on sandy-shell debris sediments (Fig. 6). The highest frequency of occurrence of *S. decorata* was recorded at a depth of 20–30 m (Fig. 10). Its density ranged within 2–556 ind.·m^{-2}, averaging (136 ± 72) ind.·m^{-2}. The species is especially widespread in the central region of the NWBS, in the Zernov *Phyllophora* Field area; there, its maximum density was registered (cruise no. 68, sta. 12, depth of 19 m). The maximum density, in contrast to the frequency of occurrence, was noted in the range of 10–20 m; the value decreased with increasing depth (Fig. 9).

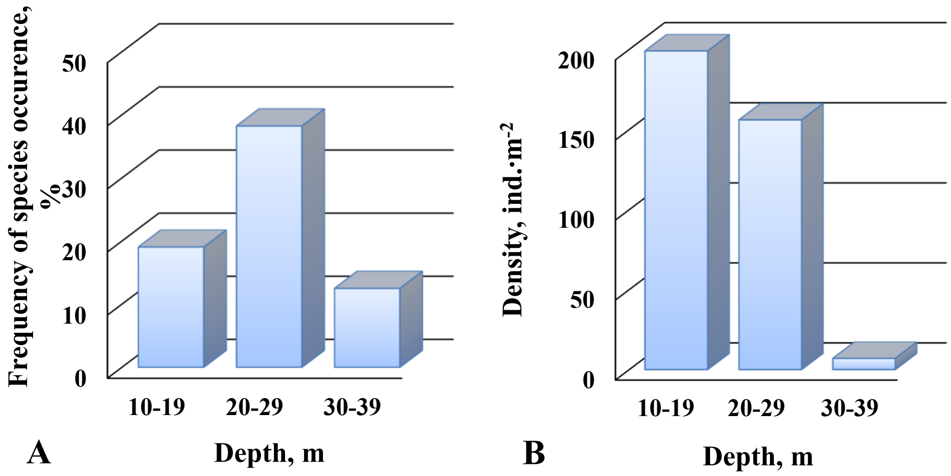

Fig. 9. *Spio decorata* frequency of occurrence (A) and density (B) on the shelf of the northwestern part of the Black Sea in 2010–2017

It is known that *S. decorata* (listed as *S. filicornis*) is common in the Black Sea at depths of down to 30 m at a salinity of 10.5–18.08‰ [Kiseleva, 2004; Vinogradov, Losovskaya, 1968]. Considering that *S. decorata* reproduction occurs at water temperatures above +8 °C, it can be assumed that the lower limit of the species distribution is determined by the position of the thermocline [Boltachova, Lisitskaya, 2019]. In the shallow NWBS, the boundary of the upper layer, heated in the summer season to +28…+29 °C, lies at a depth of about 30 m; deeper, there is a quasi-homogeneous layer with water temperature of about +8 °C [Ivanov, Belokopytov, 2011].

DISCUSSION

In recent years, numerous studies have been carried out in the field of the taxonomy of the family Spionidae. New species have been identified, some of the previously described ones have been redescribed, and ranges have been clarified. Specifically, the redescription of *Spio filicornis* Müller, 1776 [Bick et al., 2010], as noted above, led to the revision of the Black Sea specimens of the genus *Spio* and to the conclusion that this is *S. decorata* Bobretzky, 1871 [Boltachova, Lisitskaya, 2019].

The features of the systematic status of the Black Sea spionids *Prionospio* cf. *cirrifera* and *Laonice* cf. *cirrata* also raise questions. Both species were previously considered as widespread, but some researchers, as mentioned earlier, are of the opinion that these are cold-water species and doubt the fact of their occurrence in the Mediterranean Sea [Maciolek, 1985; Mackie, 1984; Sikorski, 2003]. To date, *P. cirrifera* and *L. cirrata* from the seas of the Mediterranean basin have uncertain systematic status (questionable) [Faulwetter et al., 2017]. Finds of *L. cirrata* in the Mediterranean may be finds of another species – *Laonice bahusiensis* Söderström, 1920 [Sikorski, 2003]. The distribution of the first one is limited to subpolar territories, but *L. bahusiensis*, a very similar species, has a more southern distribution and is also present in the Central and Eastern Mediterranean [Sikorski, 2003; Çinar et al., 2014]. The specimens of this genus we found were not well preserved, so we tentatively assigned them to *L.* cf. *cirrata*.

Some authors believe that *P. cirrifera* is a species from the seas of the Arctic Ocean and is unlikely to occur south of Portugal [Maciolek, 1985]. A. Mackie [1984] assumed that the Mediterranean specimens belong to other, endemic species. From the Mediterranean specimens of *Prionospio*, a new species was isolated – *Prionospio maciolekae* Dağlı & Çınar, 2011. Other *P. cirrifera* specimens, from Italy, were revised by Dağlı and Çınar [2011] and classified as a non-native species *Prionospio pulchra* Imajima, 1990. However, *P. cirrifera* retains the status of the widespread *Prionospio* species in the region [Çinar et al., 2014]. Recently, several species of the genus *Prionospio* (the group *Minuspio*) have been recorded off the Turkish coast of the Black Sea [Kurt Şahin et al., 2017; Çinar et al., 2014]. However, *P. cirrifera* is still considered as one of the most abundant Spionidae representatives in the Black Sea [Kiseleva, 2004; Kurt-Şahin, Çinar, 2012; Surugiu, 2005]. Recent studies of *Prionospio* specimens sampled off the Caucasian coast led the authors to conclude the presence of two species – *P. pulchra* and *Prionospio* cf. *multibranchiata* Berkeley, 1927 [Syomin, Simakova, 2020]. In our material, there was a small number of *Prionospio* sp. (non-identified down to a species level). Those, according to morphological characteristics, were rather close to *P. maciolekae*, but it was impossible to accurately identify them. Most of *Prionospio* (the group *Minuspio*) could not be assigned to these three species (*P. pulchra*, *P. multibranchiata*, and *P. maciolekae*), and we, in anticipation of further studies, more detailed, *inter alia* genetic ones, left the name *P.* cf. *cirrifera* for them.

In the Black Sea macrozoobenthos, the group of polychaetes, as a rule, is the most abundant among all the taxa – both in the number of species and in quantitative terms, *i. e.*, in the number of specimens. On the surveyed area of the NWBS shelf, we noted 83 Polychaeta species, and out of them, 12 species were Spionidae, which accounted for 14% of the taxonomic composition of this group. Polychaetes were registered at all performed stations, spionids – at 66% of their total number. At most stations, 2–3 species were recorded, and at single stations, up to 6 Spionidae species were found. The density of polychaetes at stations ranged from 66 to 17,708 ind.·m^{-2}, averaging 1,127 ind.·m^{-2}. At the same time, the density of spionids varied from 4 to 2,984 ind.·m^{-2}, and the average value was (477 ± 126) ind.·m^{-2}. Thus, while spionids accounted only for 14% of the taxonomic composition of polychaetes in the NWBS, their contribution in quantitative representation reached 42%, which may indicate a significant role of polychaetes of this family in the functioning of the benthic ecosystem of the NWBS.

The distribution of spionids in the NWBS is uneven, which is due to the response of individual species to various environmental factors. In the Black Sea, such important factors for the life of hydrobionts, as water temperature, in coastal areas water salinity as well, and the composition of sediments, vary naturally with changes in depth. Consequently, it is of some interest to fix the bathymetric boundaries of species habitat, although it is not always clear, which environmental factor limits the depth distribution of a certain species. In the NWBS, spionids were recorded at depths of 10–137 m. Depths of 11–40 m, which warm up well in the warm season, limited the distribution of the Atlantic–Mediterranean species *M. mecznikowiana*, *S. decorata*, *S. tridentata*, and *S. cantabra*, as well as amphiboreal *P. elegans*, inhabiting warm waters of temperate latitudes. In the widest range of depths in the NWBS, the species of Arctic-boreal origin were found – *D. quadrilobata* (17–93 m) and *A. paucibranchiata* (19–117 m).

The highest density of spionids was noted in the range of 20–40 m – (721 ± 206) ind.·m^{-2} (Fig. 10). At depths exceeding 60 m, spionids were not abundant – from (15 ± 10) ind.·m^{-2} at 60–80 m to (44 ± 38) ind.·m^{-2} at 80–100 m. The proportion of thermophilic species (*S. decorata*, *M. mecznikowiana*, *S. tridentata*, and *S. cantabra*) in the total density of spionids accounted for 33% at a depth of 10–20 m and 12% at 21–40 m. The maximum density of Spionidae was determined by a small number of species. The density of cold-water *A. paucibranchiata* at a depth of down to 60 m did not exceed 15%, but deeper than 60 m, it ranged from 30 to 60% of the total density.

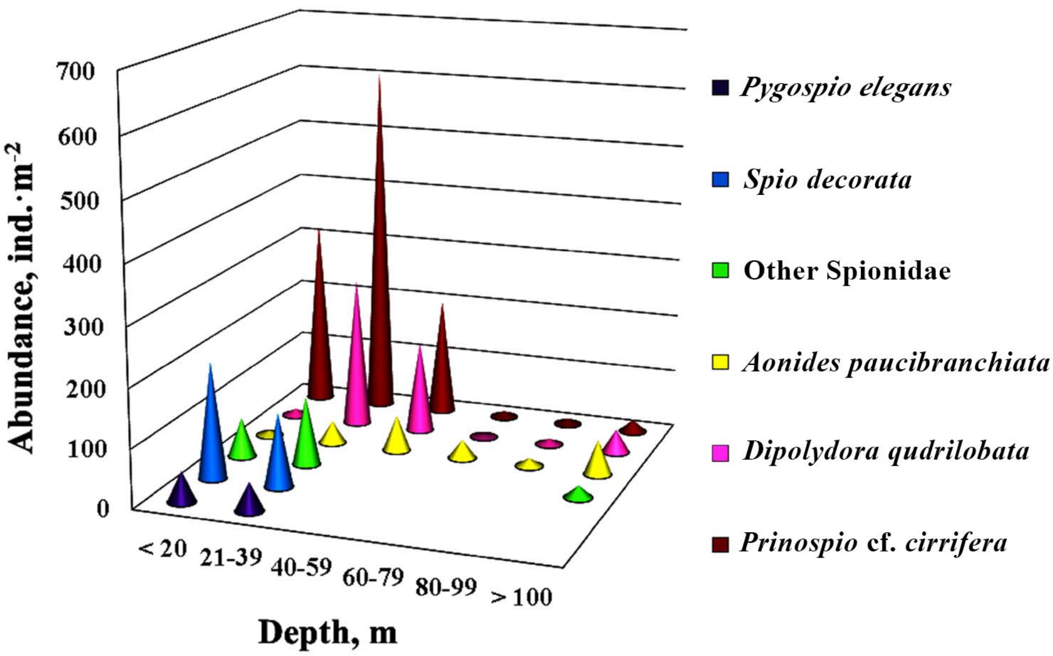

Fig. 10. Density of common Spionidae species at different depths on the shelf of the northwestern part of the Black Sea in 2010–2017

The density of the most abundant species, *P.* cf. *cirrifera*, at depths of down to 60 m accounted for about 50%, while deeper, it accounted for 15–30% of the total density of spionids. The density of another common species, *D. quadrilobata*, was maximum at a depth of 20–60 m [(232 ± 127) ind.·m^{-2}], but its frequency of occurrence was relatively high both at 20–39 m [30%] and 80–99 m [50%]. Such a wide bathymetric distribution of *P.* cf. *cirrifera*, as well as the previously discussed complexities of *P.* cf. *cirrifera* systematic status and the features of *D. quadrilobata* reproductive biology, allow suggesting that the NWBS is inhabited by several species of the genera *Prionospio* and *Dipolydora*.

Conclusion:

1. In 2010–2017, during the research, 12 Polychaeta species belonging to the family Spionidae were recorded on the shelf of the northwestern part of the Black Sea. In total, 11 species were identified: *Aonides paucibranchiata*, *Dipolydora quadrilobata*, *Microspio mecznikowiana*, *Prionospio* cf. *cirrifera*, *Polydora cornuta*, *Pygospio elegans*, *Scolelepis tridentata*, *Scolelepis (Scolelepis) cantabra*, *Spio decorata*, *Laonice* cf. *cirrata*, and *Marenzelleria neglecta*. *Prionospio* sp. were registered as well.

2. Spionids were found at depths from 10 to 137 m, on different bottom sediments, and in various communities. The highest values of their density and frequency of occurrence were noted in the depth range of 20–40 m. The maximum density of Spionidae reached 2,984 ind.·m^{-2}, the average value was (477 ± 126) ind.·m^{-2}. *P.* cf. *cirrifera*, *A. paucibranchiata*, and *D. quadrilobata* dominated in terms of density.
3. Out of the species we recorded, three are non-native. Thus, *P. cornuta* is a species known since the middle of the XX century and now widely distributed throughout the Black Sea. *D. quadrilobata* is a species introduced in the early XXI century and rapidly distributing from the coast of Romania in the eastern direction. *M. neglecta* is a species registered in the Black Sea in 2017 and not yet widespread.
4. In the taxonomic composition of polychaetes of the northwestern part of the Black Sea, Spionidae accounted for only 14%, while in quantitative representation, their contribution reached 42% of the total density of Polychaeta. It indicates a significant role of this family in the functioning of the benthic ecosystem of the surveyed area.

This work was carried out within the framework of IBSS state research assignment "Regularities of formation and anthropogenic transformation of biodiversity and biological resources of the Sea of Azov–Black Sea basin and other areas of the World Ocean" (No. 121030100028-0) and "Investigation of mechanisms of controlling production processes in biotechnological complexes with the aim of developing scientific foundations for production of biologically active substances and technical products of marine genesis" (No. 121030300149-0).

Acknowledgment. We would like to thank the participants of the research cruises – N. Sergeeva, N. Revkov, V. Timofeev, I. Bondarev, V. Kopiy, Kh. Kharkevich, A. Nadolny, and M. Makarov – for their assistance in sampling, as well as L. Lukyanova, V. Kopytova, I. Anninskaya, and G. Dobrotina for their participation in the analysis of the material. We express our gratitude to highly respected reviewers for their detailed analysis of our work and valuable advice on improving the final version of the article.

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РАСПРОСТРАНЕНИЕ ПОЛИХЕТ СЕМЕЙСТВА SPIONIDAE (ANNELIDA) НА ШЕЛЬФЕ СЕВЕРО-ЗАПАДНОЙ ЧАСТИ ЧЁРНОГО МОРЯ

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Северо-западная часть Чёрного моря (СЗЧМ) — обширная мелководная акватория, биоценозы которой являются важной частью экосистемы Чёрного моря. Поскольку в последние десятилетия бентос этого региона практически не был исследован, сведения о его современном состоянии актуальны. Существенный вклад в таксономический состав макрозообентоса вносят полихеты семейства Spionidae, которые представлены большим количеством видов и характеризуются высокими показателями численности. Цель исследования — изучить видовой состав, распределение и количественное развитие полихет семейства Spionidae в СЗЧМ на глубинах более 10–15 м. Материалом послужили пробы макрозообентоса, собранные с 160 станций (230 проб) в рейсах НИС Maria S. Merian и «Профессор Водяницкий» в 2010–2017 гг. на глубинах от 10 до 137 м. Отбор донных осадков осуществляли с помощью дночерпателей «Океан-25» (площадь захвата 0,25 м^2) и box corer (S = 0,1 м^2). Грунт промывали через сита с наименьшим диаметром 1 мм. На обследованной части шельфа СЗЧМ обнаружено 83 вида Polychaeta, в том числе 12 Spionidae. Полихеты отмечены на всех выполненных станциях, спиониды — на 66 % их общего количества. На отдельных станциях зарегистрировано до 6 видов спионид, но чаще встречалось 2–3 вида. Идентифицировано 11 видов: *Aonides paucibranchiata* Southern, 1914, *Dipolydora quadrilobata* (Jacobi, 1883), *Microspio mecznikowiana* (Claparède, 1869), *Prionospio* cf. *cirrifera* Wirén, 1883, *Polydora cornuta* Bosc, 1802, *Pygospio elegans* Claparède, 1863, *Scolelepis tridentata* (Southern, 1914), *Scolelepis (Scolelepis) cantabra* (Rioja, 1918), *Spio decorata* Bobretzky, 1871, *Laonice* cf. *cirrata* (M. Sars, 1851) и *Marenzelleria neglecta* Sikorski & Bick, 2004. Зарегистрированы не идентифицированные до вида экземпляры *Prionospio* sp. Распределение спионид в акватории СЗЧМ неравномерно, что обусловлено реакцией отдельных видов на различные экологические факторы. Максимальная плотность Spionidae достигала 2984 экз.·м$^{-2}$, средняя составляла (477 ± 126) экз.·м$^{-2}$. Наиболее высокую плотность спионид наблюдали в диапазоне глубин 20–40 м. По плотности доминировали *P.* cf. *cirrifera*, *A. paucibranchiata* и *D. quadrilobata*. Из идентифицированных видов три (*M. neglecta*, *P. cornuta* и *D. quadrilobata*) являются вселенцами в Чёрное море. В таксономическом составе полихет СЗЧМ Spionidae занимали 14 %, тогда как в количественном развитии их вклад достигал 42 % суммарной плотности Polychaeta, что свидетельствует о существенной роли этого семейства в функционировании донной экосистемы СЗЧМ.

Ключевые слова: Polychaeta, Spionidae, *Dipolydora quadrilobata*, плотность, распределение, северо-западная часть Чёрного моря