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Original paper

Distribution of Polychaetes of the Family Dorvilleidae (Annelida) on the Shelf of Crimea

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Abstract
In recent decades, the interest in polychaetes of the Dorvilleidae family, adapted to exist in marginal biotopes (cold methane seeps, hydrothermal vents, sulphide sediments) has increased. The work aims to analyze the ecological characteristics, distribution and quantitative representation of Dorvilleidae in the Black Sea. The study materials were samples of macrozoobenthos on the Black Sea shelf in 2010–2019, taken with an Okean-50 bottom grab (S = 0.25 m^2), and benthos samples, taken in the coastal areas of Crimea in 1997–2023 with a diving bottom grab (S = 0.04 m^2). Three species of the family Dorvilleidae were recorded in the northern Black Sea: *Dorvillea rubrovittata* (Grube, 1855), *Schistomeringos rudolphii* (Delle Chiaje, 1828), *Protodorvillea kefersteini* (McIntosh, 1869). Their bathymetric range was limited to the photic zone (up to 50 m). *D. rubrovittata* occurred mainly in the biotope of hard substrates fouling and formed relatively large aggregations (up to 438 ind.·m^{-2}) in underwater channels and caves. The species was first found by us in the northwestern part of the Black Sea. *S. rudolphii* was recorded in small quantities (2–300 ind.·m^{-2}) along the entire Crimean coast. This species was found mainly on shell substrates and among macrophytes. *P. kefersteini* was recorded in almost the entire northern part of the Black Sea (excluding the Caucasian coasts) on sandy-shell substrates with varying degrees of siltation. It is a mass species, and its density reached significant values in some areas. In Kruglaya Bay (Sevastopol area), a stable population of this species with the highest occurrence (up to 88 %) and density (up to 13,215 ind.·m^{-2}) was recorded for a long time. The supposed reason for this is the formation in Kruglaya Bay of large assemblages of bacteria and microalgae, which are a forage base for *P. kefersteini*.

Keywords: Polychaeta, Dorvilleidae, *Protodorvillea kefersteini,* Kruglaya Bay, Black Sea

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Распространение полихет семейства Dorvilleidae (Annelida) на шельфе Крыма

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Аннотация

В последние десятилетия возрос интерес к полихетам семейства Dorvilleidae, приспособленным к существованию в маргинальных биотопах – в холодных метановых сипах, гидротермальных источниках, сульфидных осадках. Целью настоящей работы являлся анализ экологических особенностей, распространения и количественной представленности Dorvilleidae в Черном море. Материалом для исследований послужили сборы макрозообентоса на Черноморском шельфе в 2010–2019 гг., выполненные с помощью дночерпателя «Океан-50» (S = 0.25 м^2), а также сборы бентоса в прибрежных районах Крыма в 1997–2023 гг. с использованием водолазного дночерпателя (S = 0.04 м^2). В северной части Черного моря зарегистрированы три представителя Dorvilleidae: *Dorvillea rubrovittata* (Grube, 1855), *Schistomeringos rudolphii* (Delle Chiaje,1828), *Protodorvillea kefersteini* (McIntosh, 1869). Батиметрический диапазон их обитания ограничивается фотической зоной (до 50 м). *D. rubrovittata* встречался преимущественно в биотопе обрастания твердых субстратов, относительно большие скопления (до 438 экз.·м$^{-2}$) образовывал в подводных канала и гротах. Видвпервые обнаружен нами в северо-западной части Черного моря. *S. rudolphii* зарегистрирован в небольших количествах (2–300 экз.·м$^{-2}$) вдоль всего побережья Крыма. Этот вид встречался преимущественно на ракушечных грунтах и среди макрофитов. *P. kefersteini* отмечен почти во всей северной части Черного моря (за исключением кавказских берегов) на песчано-ракушечных грунтах с разной степенью заиления. Это массовый вид, его плотность в отдельных районах достигала значительных величин. В бухте Круглой (район Севастополя) в течение длительного времени регистрировали устойчивую популяцию этого вида с наиболее высокими показателями встречаемости (до 88 %) и плотности (до 13 215 экз.·м$^{-2}$). Предполагаемая причина этого – образование в бухте Круглой больших скоплений бактерий и микроводорослей, которые являются кормовой базой для *P. kefersteini*.

Ключевые слова: Polychaeta, Dorvilleidae, *Protodorvillea kefersteini,* бухта Круглая, Черное море

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Materials and methods

The macrozoobenthos samples from R/V *Professor Vodyanitsky* expeditions (cruises Nos. 64, 68, 70, 72, 75, 84, 86, 90, 96, 108) in 2010–2019 served as the present study material. The work was performed on the shelf of the northern part of the Black Sea from the coast of Romania to the Caucasian coast (Tuapse area) as well as in the Sea of Azov off the coast of Crimea. The stations were carried out in the depth range from 10 to 137 m. The salinity levels in the Black Sea ranged from 16.89 to 18.47‰ and in the Azov Sea, they fluctuated between 12.53 and 15.22‰ during the sampling. Collected from 291 stations, the materials obtained from the bottom grab samples were utilised. Bottom sediments were collected employing an Okean-50 bottom grab, with a capture area of 0.25 m^2. The collected sediments were then subjected to sieve washing, with the smallest mesh size employed being 1 mm.

Materials from benthic surveys carried out in the coastal areas of Crimea by the Benthos Ecology Department of IBSS from 1997 to 2023 were also utilised in the analysis. A series of studies were conducted in a number of locations throughout the region, including Karkinit Bay, Lake Donuzlav, the bays of Sevastopol, the Kara Dag water area and Feodosia Bay. In addition, a number of underwater caves of both natural and artificial origin in southeastern and southwestern Crimea were also investigated [16]. In 2005, year-round macrozoobenthos surveys were conducted at two stations (6–7.5 m depth) in the western part of Kruglaya Bay. Samples from loose substrates were taken with a diving bottom grab ($S = 0.04$ m^2), typically in two repetitions. Material was collected from hard surfaces using a frame ($S = 0.04$ m^2) with a silk bolting cloth bag sewn to it. A total of 440 stations, with a depth range of 0–25 m, were carried out. The collected material was then subjected to sieve washing, with the sieves having a mesh diameter of 0.5 mm. Following this, all specimens were fixed in 4% neutralised formalin. Taxonomic identification of polychaetes was facilitated by the utilisation of literature data [5)] [7].

Results and discussion

During the course of the study focused on cruise materials (on loose substrates at a depth of more than 10 m), dorvilleids were identified at 52 out of 291 stations in the Black Sea. Conversely, no dorvilleids were recorded in the Sea of Azov (21 stations). *P. kefersteini* was recorded at 30 stations, *S. rudolphii* – at 19 and *D. rubrovittata* – at three stations (Fig. 1). Thus, dorvilleids are relatively rare species on soft bottoms in the open sea, with only *P. kefersteini* demonstrating 10% occurrence, while *S. rudolphii* and *D. rubrovittata* have 6.5 and 1% occurrence, respectively. The maximum density of dorvilleids reached 704 $ind.\cdot m^{-2}$.

In the Crimean coastal area (1–22 m depth), dorvilleids were found in almost all areas on soft bottoms and in fouling (Fig. 1). Their density exhibited significant fluctuations within broad limits, consistently being higher in comparison to areas in the open sea. Representatives of this family were also found in underwater caves and channels.

[5)] Vinogradov, K.A. and Losovskaya, G.V., 1968. The Type of Segmeted Worms – Annelida. In: F. D. Mordukhay-Boltovskoy, ed., 1968. *Field Guide for the Black Sea and Sea of Azov Fauna*. Kiev: Naukova Dumka. Vol. 1: Free-Living Invertebrates, pp. 251–405 (in Russian).

(up to 125 ind.·m^{-2} at a depth of 2 m). In the underground Balaklava canal in the fouling of concrete walls at a depth of 2 m, the maximum values of this indicator were recorded – up to 438 ind.·m^{-2}. Conditions in the canal differ from other biotopes due to poor hydrodynamics and low light levels.

It is evident that *D. rubrovittata* is prevalent along the Black Sea coast of Crimea. The species has been recorded predominantly in the fouling biotope of hard substrates, with relatively large aggregations observed in areas of reduced hydrodynamics.

Schistomeringos rudolphii

S. rudolphii is widespread in the Atlantic Ocean (European and American coasts), the Mediterranean Sea and is also indicated for parts of the Pacific and Indian Oceans [1, 7, 9, 17]. There are isolated records of this species in the Black Sea. The species has been recorded in the Bosporus outlet area of the Black Sea [2)], the coasts of Turkey and Bulgaria [8–10, 13]. There are also two indications of *S. rudolphii* for the Caucasus coasts [11, 15]. In Crimea, the species was found only in Sevastopol Bay on sandy-shell substrates among Zostera roots [6), 7)]. The next occurrence of *S. rudolphi* was also recorded near Sevastopol at the end of the 20th century [23]. The first records of this species in the northwestern Black Sea date back to the end of the 20th and beginning of the 21st century, when it was found [4)] in the shallow waters of Yagorlyk, Tendra and Karkinit Bays [12].

In our materials, *S. rudolphii* was recorded in open sea areas on soft bottoms along the entire Crimean coast (Fig. 1). The species was found at depths of 10–45 m, with one occurrence at a depth of 88 m. The maximum density values were recorded in the Karkinit Bay (240 ind.·m^{-2}) and the Kerch pre-strait area (210 ind.·m^{-2}) at depths of 20 and 34 m, respectively.

In coastal samples, *S. rudolphii* was found at a depth of 2–22 m at some stations on the eastern and southern coasts of Crimea (Feodosia Bay, Kara Dag area, Laspi Bay), in many bays of southwestern Crimea and also in Lake Donuzlav. The density of these polychaetes was relatively low, but sometimes it reached 300 ind.·m^{-2} (Laspi Bay, 13 m depth) [24]. The species was discovered to inhabit a variety of substrates, yet it was most frequently observed in association with shell substrates and among macrophytes (Fig. 3).

It has been observed that *S. rudolphii* is present in Donuzlav and Kruglaya Bay, where it has been recorded inhabiting areas of algae fam. Characeae and sea grasses *Potamogeton* and *Zostera*, growing on silty substrates at a depth of 2–7 m. The species has also been found in small numbers (8–50 ind.·m^{-2}) in the fouling of the walls of caves and underground Balaklava canal.

Protodorvillea kefersteini

P. kefersteini is an Atlantic-Mediterranean species indicated for the North American and European coasts, widely distributed in the seas of the Mediterranean basin [1, 9, 17]. The distribution of *P. kefersteini* has been documented in nearly all areas of the Black Sea [7–10, 13]. However, it did not occur in the NWBS until

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[7)] Pereyaslavtseva, S.M., 1891. [Additions to the Black Sea Fauna]. In: Kharkov University, 1891. *Trudy Obshchestva Ispytateley Prirody at the Kharkov University*. Vol. 25, pp. 235–274 (in Russian).

F i g . 3 . Occurrence of *Schistomeringos rudolphii* on different sediments

almost the beginning of the 21st century [20]. The first detection of this species refers to the pseudomeiobenthos of Yagorlyk Bay [12]. In subsequent years, *P. kefersteini* was identified in the shallow waters of Tendra and Karkinit Bays. No records of the species have been found in other NWBS areas [4)] [25]. It is likely that the species inhabits the shores of the Caucasus, its occurrence is known off the coast of the Taman Peninsula [26]. *P. kefersteini* has been documented as a species that is abundant in certain Crimean coastal areas, as well as in the coastal waters of Bulgaria [6, 7].

In open sea areas, we encountered *P. kefersteini* (Fig. 2, *b*) in almost the entire northern part of the Black Sea, with the exception of the Caucasian coasts (Fig. 1). The species was recorded at depths of 12–45 m, with a single occurrence off the Southern Coast of Crimea at a depth of 94 m. *P. kefersteini* was predominantly found on sandy-shell substrates, with occasional instances of silty substrates. Its density was found to vary from 4 to 464 ind.·m^{-2}.

The species was recorded in the majority of the coastal shallow water areas of Crimea that were the subject of the study, with the areas in question being located along the eastern and southern coasts (Kerch pre-strait area, Feodosia Bay, Kara Dag water area, Laspi Bay), off southwestern Crimea as well as in Karkinit Bay and Lake Donuzlav. *P. kefersteini* was recorded at a depth of 1–17 m on sandy-shell substrates with different degrees of siltation. Its density varied within large limits and in some areas reached such significant values as 1200 ind.·m^{-2} (Laspi Bay, 13 m depth, sandy-shell substrate) and 4975 ind.·m^{-2} (Kara Dag water area, Experimental mussel farm area, 7 m depth, silty sand).

P. kefersteini was recorded in all bays and gulfs under study off the coast of southwestern Crimea, and during the summer surveys its occurrence and average density varied considerably in different areas (Table).

In the abovementioned areas, the occurrence of *P. kefersteini* did not generally exceed 50% and in Kazachya Bay, it was 50% with relatively low average density 62 ind.·m^{-2}. An exception was observed in Kruglaya Bay, where the occurrence was 88% and the average density was 2514 ind.·m^{-2}. Herewith, the maximum density of the species (13,215 ind.·m^{-2}) was recorded in summer 2004 (4 m depth, coarse sand). Work carried out in the bay in 1990 also recorded relatively high levels

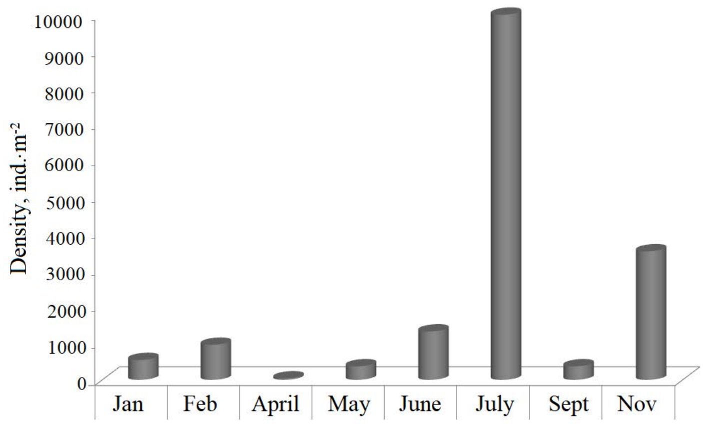
Quantitative parameters of *P. kefersteini* distribution at coastal areas of southwestern Crimea

Study area	Occurrence, %	Mean density, ind.·м$^{-2}$
Balaklava Bay	18	10
Sevastopol Bay	6	4
Kruglaya Bay	**88**	**2514**
Streletskaya Bay	9	233
Kazachya Bay	50	62
Cape Fiolent	33	217
Coast near the village of Lyubimovka	10	76
Donuzlav Lake	24	9

of *P. kefersteini*, with its occurrence of 40% and average density of 280 ind.·m^{-2} [27]. According to our data obtained in 2013 in Kruglaya Bay, the maximum density of the species in May was 11,288 ind.·m^{-2}, and in November, it reached 13,375 ind.·m^{-2} (5–6 m depth at sampling stations, coarse sand), with the average density being 2893 ind.·m^{-2}.

Thus, in Kruglaya Bay, the population of *P. kefersteini* has been recorded for many years and it has always been characterised by high density. It is hypothesised that the high abundance of this species during summer surveys is due to recruitment of juveniles. It is further assumed that the Black Sea is the breeding ground for *P. kefersteini* during the summer season as mature individuals were found in June [7]. Seasonal surveys carried out in 2005 in Kruglaya Bay showed that the species is present in the benthos throughout the year in significant numbers, reaching a maximum in July (Fig. 4).

It is evident that high density values of this species are also present in other Black Sea areas. In the Taman Peninsula, the average density of *P. kefersteini* was recorded as 320 ind.·m^{-2} [26], near Kara Dag – 445 ind.·m^{-2}, with its maximum of 2000 ind.·m^{-2} [7]. Along the Bulgarian coast, *P. kefersteini* is categorised as a mass



F i g . 4 . Seasonal dynamics of *P. kefersteini* density in Kruglaya Bay(2005)

species, exhibiting an average density of 556 ind.·m^{-2} in specific biocenoses, with its maximum of 6200 ind.·m^{-2} [6].

Consequently, the population of *P. kefersteini* in Kruglaya Bay exhibited remarkably elevated quantitative indices over an extended period when compared to all other areas under study. This prompts the question of the underlying causes of this phenomenon. The following hypothesis is proposed.

P. kefersteini belongs to small species of the family Dorvilleidae, which are characterised by feeding on microalgae and bacterial film, which is possible due to the peculiarities of their mouth apparatus structure [4]. It can be assumed that the forage supply of this species is extremely high in Kruglaya Bay.

Kruglaya Bay is located within the Sevastopol municipal boundaries and experiences a high recreational load. During the summer and autumn period, elevated concentrations of organic nitrogen and phosphorus, in addition to nitrates, have been recorded in the sea water. This observation is corroborated by long-term data [28]. Studies have shown that the ammonium nitrogen content in bottom sediments of Kruglaya Bay is about 10 times higher than in the sediments of the open sea [27]. It can be hypothesised that the elevated level of organic pollution in Kruglaya Bay contributes to the augmentation of the polychaete forage base and is a contributing factor to the mass development of *P. kefersteini* in this water area.

It should also be noted that the bays of Sevastopol are characterised by the presence of jet gas emissions (cold gas seeps) caused by methane flow from the deep sediment layers into the surface substrate horizons. Seeps in this area were registered at shallow depths (from 11–12 m) [29]. The presence of methanotrophic microorganisms forming bacterial mats has been demonstrated in the area surrounding jet gas outlets [30]. Evidence has been found which suggests the presence of jet gas emissions in the Kruglaya Bay area [31]. In other regions of the world ocean, research conducted on methane seeps ecosystems has revealed the prevalence of dorvilleids within these environments. These organisms are particularly abundant in the bacterial mats that proliferate around the seeps, with their abundance reaching up to 92% of the total macrofauna [3, 32]. There is evidence to suggest that certain members of the family Dorvilleidae consume chemosynthetic bacteria as part of their diet [4]. It has been hypothesised that the dorvilleids assemblages observed in proximity to methane seeps can be attributable to the forage specialisation of these polychaetes on specific prokaryotes [2, 3]. Assuming the presence of bacterial mats in Kruglaya Bay, formed around jet gas emissions, and their role as a forage source for *P. kefersteini*, it can be deduced that the development of a stable population of the species within this water area is a consequence.

Conclusion

Three species of the family Dorvilleidae were recorded in the northern Black Sea during the study: *Dorvillea rubrovittata* (Grube, 1855), *Schistomeringos rudolphii* (Delle Chiaje, 1828), *Protodorvillea kefersteini* (McIntosh, 1869). All of the above species are considered to be fairly widespread; however, their bathymetric range is limited to the photic zone (up to 50 m). This can be related to their feeding habits, which are specialised on micro- and macrophytes. The data obtained suggest that the distribution of dorvilleids in the Azov-Black Sea basin is also influenced by water salinity. It can be hypothesised that the salinity of 17–18‰, which is typical of the Black Sea, is a limiting factor for dorvilleids. To date, no species of dorvilleids has been found in the Sea of Azov, despite the recent increase in its salinity (up to 15‰) and pontization of the fauna. This can be indicative of the rarity of dorvilleids in the NWBS where coastal areas can be subject to desalination processes.

D. rubrovittata is a common species on the Black Sea coasts of Crimea. It occurs mainly in the biotope of hard substrates fouling and forms relatively large aggregations in areas with poor hydrodynamics and low light levels (underwater channels and caves), where its density reached 438 ind.$\cdot$m^{-2}. The species was first found by us in the northwestern part of the Black Sea.

S. rudolphii was previously considered rare in the Black Sea, with only isolated occurrences documented. In the present study, the species was recorded in low numbers (2–300 ind.$\cdot$m^{-2}) on soft bottoms along the entire Crimean coast. The species was most frequently found on shell substrates and among macrophytes. In Lake Donuzlav, *S. rudolphii* was observed to be widespread in areas of algae fam. Characeae and sea grasses *Potamogeton* and *Zostera*.

P. kefersteini was recorded in almost the entire northern part of the Black Sea (excluding the Caucasian coasts) on sandy-shell substrates with varying degrees of siltation. It is a mass species and its density reached significant values in some areas. In Kruglaya Bay (Sevastopol area), a stable population of this species with the highest occurrence (up to 88 %) and density (up to 13,215 ind.$\cdot$m^{-2}) was recorded for a long time. The features of Kruglaya Bay are as follows: firstly, there is an increased level of organic pollution, and secondly, there is the presence of jet gas emissions around which bacterial mats can form. It is hypothesised that this leads to the formation of large assemblages of bacteria and microalgae which are a forage base for *P. kefersteini*.

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Elena V. Lisitskaya – analysis of the distribution of representatives of the family Dorvilleidae in fouling, manuscript editing

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