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TAXONOMIC DIVERSITY OF AMPHIPODA (CRUSTACEA) FROM THE BLACK SEA AND THE SEA OF AZOV

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In the Black Sea and the Sea of Azov, 140 Amphipoda species were registered belonging to 73 genera, 29 families, and 3 suborders. Taxonomic diversity of amphipods from these two seas was studied. For the investigation, average taxonomic distinctness Δ^+ and its variability Λ^+ were used, and cluster analysis and multidimensional scaling were applied. By Δ^+ index, the taxonomic structure of the Black Sea and the Sea of Azov Amphipoda is hierarchically aligned and close to a total taxonomic list of amphipods of these seas. By Λ^+ index, the taxonomic structure of Amphipoda both from the Sea of Azov and the Black Sea is close to the average expected level of structure variability of the phylogenetic tree. In the coastal areas of Turkey and Crimea, more Amphipoda species were recorded than in other regions. Out of the Black Sea regions studied by Δ^+ and Λ^+ indices and multidimensional scaling, two, *i. e.* northwestern coast and eastern coast (Caucasus), were selected as different ones. The first one is characterized by low taxonomic diversity due to a small number of genera and families against the backdrop of a significant number of species of the Ponto-Caspian fauna. It is associated with the presence of estuaries of large rivers and freshened lagoons. On the contrary, the Black Sea eastern coast is characterized by high taxonomic diversity against the backdrop of a small number of species. It is associated mostly with weak shelf manifestation and close slope of depth, with loose soils being poorly represented. Cluster analysis confirmed that these two Black Sea regions, *i. e.* northwestern coast and eastern coast, differ from other ones. Moreover, by cluster analysis, the similarity of Amphipoda taxonomic composition for the Black Sea northwestern coast and the Sea of Azov was revealed. Out of all the amphipods, Ponto-Caspian species stand out which inhabit predominantly estuaries of large rivers and freshened lagoons. Those are characterized by a taxonomic structure shifted in terms of taxonomic evenness towards impoverishment; it is due to a small number of genera and families against the backdrop of a significant number of species.

Keywords: Amphipoda, taxonomic diversity, Black Sea, Sea of Azov

In the ecosystems of sea and ocean coastal zones, Amphipoda play an important role. It is due to a large number of species (often with a high abundance), inhabitance in almost all the biotopes, and the fact that the amphipods are significantly involved in the food chains of marine fish and invertebrates (Greze, 1977). Amphipoda have been recorded in all coastal biotopes of the Black Sea and the Sea of Azov, where their density reaches tens of thousands of specimens *per* m^2 of conditional substrate surface (Greze, 1977). After long-term studies in all the areas of the Black Sea, as well as in the Sea of Azov, the lists of Amphipoda species, *i. e.* checklists, were published (Greze, 1977, 1985 ; Grintsov, 2011 ; Kiseleva, 1981 ; Kudrenko, 2017 ; Mordukhai-Boltovskoi et al., 1969 ; Nevrova, 2013 ; Kolyuchkina et al., 2019 ; Petrescu, 1998 ; Sezgin, 1998 ; Sezgin & Katağan, 2007 ; Uzunova, 2012).

As a result, using the information obtained, it became possible to analyze the taxonomic composition and structure of this group comparing the data by the Black Sea regions (western one – Bulgaria, Romania; southern – Turkey; eastern – Caucasus; northern – Crimea; and northwestern – Ukraine) and the Sea of Azov. This article is the first for that direction in the study of the amphipods for two seas. The research of the taxonomic composition of Amphipoda fauna is of great importance for ecological monitoring of the biodiversity state of coastal ecosystems.

The aim of the work was to study the fauna composition and compare the structure of Amphipoda taxocenes of the Black Sea and the Sea of Azov, as well as the Black Sea regions, by taxonomic diversity indices, multidimensional scaling (MDS), and cluster analysis.

MATERIAL AND METHODS

To compile a list of Amphipoda species of the Black Sea and the Sea of Azov, our own material was used, as well as the literature data (Greze, 1977, 1985 ; Grintsov, 2003a, b, 2009a, 2011 ; Kiseleva, 1981 ; Kudrenko, 2017 ; K"neva-Abadzhieva, 1968 ; Mordukhai-Boltovskoi et al., 1969 ; Nevrova, 2013, 2016 ; Gönlügür, 2006 ; Grintsov & Sezgin, 2011 ; Grintsov, 2009b, 2010, 2018 ; Kolyuchkina et al., 2019 ; Kudrenko, 2016 ; Özbek, 2011 ; Özbek & Özkan, 2011 ; Petrescu, 1998 ; Sezgin, 1998 ; Sezgin & Katağan, 2007 ; Sezgin et al., 2001 ; Uzunova, 2012). The taxonomic diversity of the amphipods was accessed by the statistical analysis algorithms of the PRIMER v5.2 package (Clarke & Gorley, 2001 ; Warwick & Clarke, 1998); the index of taxonomic distinctness Δ^+ (delta) and its variability Λ^+ (lambda); and the methods of cluster analysis and multidimensional scaling. The index of taxonomic distinctness and its variability was calculated for each Black Sea region as well. Moreover, the data were compared with material for the Sea of Azov. The following regions were compared: Turkey (southern region), Bulgaria (western), Romania (western), Caucasus (eastern), Ukraine (northwestern), Crimea (northern), and the Sea of Azov. For each of them, we took into account the lists of Amphipoda taxa compiled after long-term studies.

To date, 140 Amphipoda species belonging to 73 genera, 29 families, and 3 suborders have been recorded in the Black Sea and the Sea of Azov (Table 1).

Table 1. Distribution of Amphipoda in the Black Sea regions (1–5) and in the Sea of Azov (6). Species names are aligned with http://www.marinespecies.org/ as of 20.03.2021

Amphipoda taxocene	Regions						
	1	2	3	4	5	6	
Ampeliscidae							
Ampelisca diadema (Costa, 1853)	+	+	+	+	+	+	Atl., Med.
Ampelisca pseudosarsi Bellan-Santini & Kaim-Malka, 1977	+						Med.
Ampelisca pseudospinimana Bellan-Santini & Kaim-Malka, 1977	+						Atl., Med.
Ampelisca spinipes Boeck, 1861	+						Atl., Med.
Ampithoidae							
Ampithoe ramondi Audouin, 1826	+	+	+	+	+	+	Atl., Med., Ind., Pac.
Biancolina algicola Della Valle, 1893	+	+	+				Atl., Med.
Cymadusa crassicornis (Costa, 1853)	+	+	+				Atl., Med.
Pleonexes gammaroides Spence Bate, 1856	+	+	+		+	+	Atl., Med.

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Amphipoda taxocene	Regions						
	1	2	3	4	5	6	
Aoridae							
Microdeutopus algicola Della Valle, 1893	+		+				Atl., Med.
Microdeutopus anomalus (Rathke, 1843)		+	+		+		Atl., Med.
Microdeutopus gryllotalpa Costa, 1853	+	+	+	+		+	Atl., Med.
Microdeutopus stationis Della Valle, 1893	+		+				Atl., Med.
Microdeutopus versiculatus (Spence Bate, 1857)	+	+	+		+	+	Atl., Med.
Atylidae							
Nototropis guttatus Costa, 1853	+	+	+	+	+	+	Atl., Med., Ind.
Nototropis massiliensis (Bellan-Santini, 1975)	+	+					Med.
Bathyporeiidae							
Bathyporeia guilliamsoniana (Spence Bate, 1857)	+	+	+	+	+	+	Atl., Med.
Behningiellidae							
Cardiophilus baeri G. O. Sars, 1896			+		+	+	PC
Calliopiidae							
Apherusa bispinosa (Spence Bate, 1857)	+	+	+	+	+	+	Atl., Med.
Apherusa chiereghinii Giordani-Soika, 1949	+	+					Med.
Caprellidae							
Caprella acanthifera Leach, 1814	+	+	+	+	+		Atl., Med.
Caprella danilevskii Czerniavski, 1868	+	+	+				Atl., Med., Ind., Pac.
Caprella equilibra Say, 1818	+						Atl., Med., Ind., Pac.
Caprella liparotensis Haller, 1879	+	+					Atl., Med.
Caprella mitis Mayer, 1890	+	+					Atl., Med.
Caprella rapax Mayer, 1890	+						Med.
Phtisica marina Slabber, 1769	+	+	+	+	+		Atl., Med., Ind., Pac.
Pseudoprotella phasma (Montagu, 1804)		+	+				Atl., Med.
Cheirocratidae							
Cheirocratus sundevallii (Rathke, 1843)		+	+				Atl., Med.
Cheluridae							
Chelura terebrans Philippi, 1839		+					Atl., Med., Ind., Pac.
Colomastigidae							
Colomastix pusilla Grube, 1861		+					Atl., Med., Ind., Pac.
Corophiidae							
Chelicorophium chelicorne (G. O. Sars, 1895)			+	+			PC
Chelicorophium curvispinum (G. O. Sars, 1895)	+		+	+		+	PC
Chelicorophium maeoticum (Sowinsky, 1898)	+	+	+			+	PC
Chelicorophium mucronatum (G. O. Sars, 1895)			+	+			PC
Chelicorophium nobile (G. O. Sars, 1895)			+	+			PC
Chelicorophium robustum (G. O. Sars, 1895)	+		+	+		+	PC
Chelicorophium sowinskyi (Martynov, 1924)			+	+			PC
Corophium orientale Schellenberg, 1928	+	+	+				Med.
Corophium volutator (Pallas, 1766)		+				+	Atl., Med.
Crassicorophium bonellii (H. Milne Edwards, 1830)			+	+			Atl.
Crassicorophium crassicorne (Bruzelius, 1859)		+	+	+		+	Atl., Med.
Leptocheirus pilosus Zaddach, 1844	+		+				Atl., Med.

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Amphipoda taxocene	Regions						
	1	2	3	4	5	6	
Medicorophium runcicorne (Della Valle, 1893)	+	+	+		+		Med.
Monocorophium acherusicum (Costa, 1853)	+	+	+				Atl., Med., Ind., Pac.
Monocorophium insidiosum (Crawford, 1937)		+	+				Atl., Med., Pac.
Dexaminidae							
Dexamine spiniventris (Costa, 1853)	+						Atl., Med., Ind.
Dexamine spinosa (Montagu, 1813)	+	+	+	+	+	+	Atl., Med.
Dexamine thea Boeck, 1861		+					Atl., Med.
Tritaeta gibbosa (Spence Bate, 1862)	+	+					Atl., Med.
Gammarellidae							
Gammarellus angulosus (Rathke, 1843)			+				Atl., Med.
Gammarellus carinatus (Rathke, 1837)		+			+		BS
Gammaridae							
Amathillina cristata (G. O. Sars, 1894)	+		+	+		+	PC
Chaetogammarus placidus (G. O. Sars, 1896)				+			PC
Chaetogammarus olivii (H. Milne Edwards, 1830)	+	+	+	+			Atl., Med.
Dikerogammarus villosus (Sowinskyi, 1894)		+		+		+	PC
Dikerogammarus haemobaphes (Eichwald, 1841)	+					+	PC
Dikerogammarus gruberi Mateus & Mateus, 1990	+			+			PC
Dikerogammarus istanbulensis Özbek, 2011	+						PC
Echinogammarus foxi (Schellenberg, 1928)	+	+	+				Med.
Echinogammarus ischnus (Stebbing, 1899)		+		+		+	Atl.
Echinogammarus karadagiensis Grintsov, 2009		+					BS
Echinogammarus warpachowskyi (G. O. Sars, 1894)				+			PC
Gammarus aeqiucauda (Martynov, 1931)	+	+		+		+	Med.
Gammarus crinicornis Stock, 1966	+	+	+				Atl., Med.
Gammarus insensibilis Stock, 1966	+	+	+	+			Atl., Med.
Gammarus subtypicus Stock, 1966	+	+	+	+			Med.
Gmelina costata G. O. Sars, 1894				+		+	PC
Gmelinopsis tuberculata G. O. Sars, 1896				+		+	PC
Kuzmelina kusnezowi (Sowinskyi, 1894)				+		+	PC
Shablogammarus subnudus (G. O. Sars, 1896)				+			PC
Yogmelina pusilla (G. O. Sars, 1896)				+		+	PC
Hyalidae							
Apohyale crassipes (Heller, 1866)	+	+	+				Atl., Med.
Apohyale perieri (Lucas, 1849)	+	+	+	+			Atl., Med., Pac.
Apohyale prevostii (H. Milne Edwards, 1830)		+				+	Atl., Med.
Hyale pontica Rathke, 1836	+	+	+	+		+	Atl., Med.
Parhyale aquilina (Costa, 1857)	+						Med., Pac.
Parhyale taurica Grintsov, 2009		+					BS
Protohyale (Boreohyale) camptonyx (Heller, 1866)	+						Atl., Med.
Protohyale (Protohyale) schmidti (Heller, 1866)	+	+					Atl., Med.
Iphigenellidae							
Iphigenella acanthopoda G. O. Sars, 1896				+			PC
Iphigenella andrussowi G. O. Sars, 1894				+		+	PC

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Amphipoda taxocene	Regions						
	1	2	3	4	5	6	
Iphigenella shablensis Carausu, 1943				+			PC
Ischyroceridae							
Centraloecetes dellavallei (Stebbing, 1899)	+	+	+		+		Atl., Ind., Med.
Ericthonius difformis H. Milne Edwards, 1830	+	+	+	+	+	+	Atl., Med.
Ericthonius punctatus (Spence Bate, 1857)	+		+				Atl., Ind., Med.
Ericthonius rubricornis (Stimpson, 1853)			+				Atl., Med., Pac.
Jassa marmorata Holmes, 1905	+	+					Atl., Ind., Pac., Med.
Jassa ocia (Spence Bate, 1862)	+	+	+	+		+	Atl., Med.
Jassa pusilla (G. O. Sars, 1894)		+	+				Atl., Med.
Kuriidae							
Micropythia carinata (Spence Bate, 1862)	+		+				Atl.
Leucothoidae							
Leucothoe spinicarpa (Abildgaard, 1789)	+						Atl., Ind., Pac., Med.
Lysianassidae							
Nannonyx propinquus Chevreux, 1911	+						Atl.
Nannonyx reductus Greze, 1975		+					BS
Megaluropiidae							
Megaluropus agilis Hoek, 1889		+	+		+		Atl., Ind., Med.
Megaluropus massiliensis Ledoyer, 1976		+	+				Med.
Melitidae							
Melita palmata (Montagu, 1804)	+	+	+	+		+	Atl., Pac., Med.
Microprotopidae							
Microprotopus longimanus Chevreux, 1887		+	+	+	+	+	Atl.
Microprotopus maculatus Norman, 1867		+	+			+	Atl., Med.
Oedicerotidae							
Deflexilodes gibbosus (Chevreux, 1888)	+	+	+		+		Atl., Med.
Deflexilodes griseus (Della Valle, 1893)	+						Atl., Med.
Perioculodes longimanus (Spence Bate & Westwood, 1868)	+	+	+	+	+	+	Atl., Ind., Pac., Med.
Synchelidium maculatum Stebbing, 1906	+	+		+	+		Atl., Med.
Phoxocephalidae							
Harpinia crenulata (Boeck, 1871)	+						Atl., Med.
Harpinia dellavallei Chevreux, 1910	+						Atl., Med.
Photidae							
Megamphopus cornutus Norman, 1869		+	+		+		Atl., Med.
Photis longicaudata (Spence Bate & Westwood, 1862)	+						Atl., Pac., Med.
Pontogammaridae							
Compactogammarus compactus (G. O. Sars, 1895)				+			PC
Euxinia sarsi (Sowinsky, 1898)				+		+	PC
Euxinia weidemanni (G. O. Sars, 1896)				+		+	PC
Niphargogammarus intermedius (Carausu, 1943)				+		+	PC
Niphargoides corpulentus G. O. Sars, 1895				+			PC
Obesogammarus crassus (G. O. Sars, 1894)				+		+	PC
Obesogammarus obesus (G. O. Sars, 1894)				+		+	PC
Pandorites podoceroides G. O. Sars, 1895						+	PC

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Amphipoda taxocene	Regions						
	1	2	3	4	5	6	
Paraniphargoides motasi (Carausu, 1943)				+			PC
Pontogammarus abbreviatus (G. O. Sars, 1894)				+			PC
Pontogammarus aestuarius (Derzhavin, 1924)	+						PC
Pontogammarus maeoticus (Sovinskij, 1894)	+		+	+		+	PC
Pontogammarus robustoides (G. O. Sars, 1894)	+			+		+	PC
Stenogammarus compressus (G. O. Sars, 1894)				+			PC
Stenogammarus deminutus (Stebbing, 1906)				+		+	PC
Stenogammarus kereuschi Derzhavin & Pjatakova, 1962				+			PC
Stenogammarus (Stenogammarus) macrurus (G. O. Sars, 1894)				+		+	PC
Stenogammarus similis (G. O. Sars, 1894)				+		+	PC
Turcogammarus aralensis (Uljanin, 1875)						+	PC
Turcogammarus turcarum (Stock, 1974)	+			+			PC
Uroniphargoides spinicaudatus (Carausu, 1943)				+			PC
Stenothoidae							
Stenothoe marina (Spence Bate, 1856)	+		+			+	Atl., Med.
Stenothoe monoculoides (Montagu, 1813)	+	+	+	+	+		Atl., Med.
Talitridae							
Britorchestia brito (Stebbing, 1891)			+				Atl., Med.
Cryptorchestia cavimana (Heller, 1865)	+		+	+			Atl., Med.
Deshayesorchestia deshayesii (Audouin, 1826)	+	+	+				Atl., Med.
Orchestia bottae H. Milne Edwards, 1840		+		+		+	Atl.
Orchestia gammarellus (Pallas, 1766)	+	+	+				Atl., Med.
Orchestia mediterranea Costa, 1853	+	+	+				Atl., Med.
Orchestia montagui Audouin, 1826	+	+		+			Atl., Ind., Med.
Platorchestia platensis (Krøyer, 1845)	+	+					Atl., Ind., Pac., Med.
Speziorchestia stephenseni Cecchini, 1928	+						Med.
Talitrus saltator (Montagu, 1808)	+						Atl., Med.
Tryphosidae							
Orchomene humilis (Costa, 1853)	+	+	+		+		Atl., Med.

Note: 1 denotes Turkey, southern region; 2, Crimea, northern region; 3, Bulgaria, Romania, western region; 4, Ukraine, northwestern region; 5, Caucasus, eastern region; 6, the Sea of Azov. Atl. denotes the Atlantic Ocean; Ind., the Indian Ocean; PC, Ponto-Caspian fauna; Med., the Mediterranean Sea; Pac., the Pacific Ocean; BS, the Black Sea (endemic species).

The distribution of the number of Amphipoda species in the regions of the Black Sea and the Sea of Azov is shown in Fig. 1.

The largest number of species is characteristic of two regions: the southern area of the Black Sea (Turkey) and the Crimean coast (see Fig. 1). The number of species in other regions is significantly lower. The coast of Turkey is characterized by a variety of biotopes contributing to survival of a larger number of Amphipoda species than in other Black Sea regions. Moreover, this region is primarily invaded by organisms from the Mediterranean Sea. Specifically, several species have been registered off the coast of Turkey alone (see Table 1). In Crimea, all the variants of substrates are represented: from the vast shelf in the west, with clearly defined biotopes of loose soils, to the rocky coastline from the southwest to the southeast, with abundant biotopes of solid substrates, which allows a larger number of species to inhabit the coastal zone.

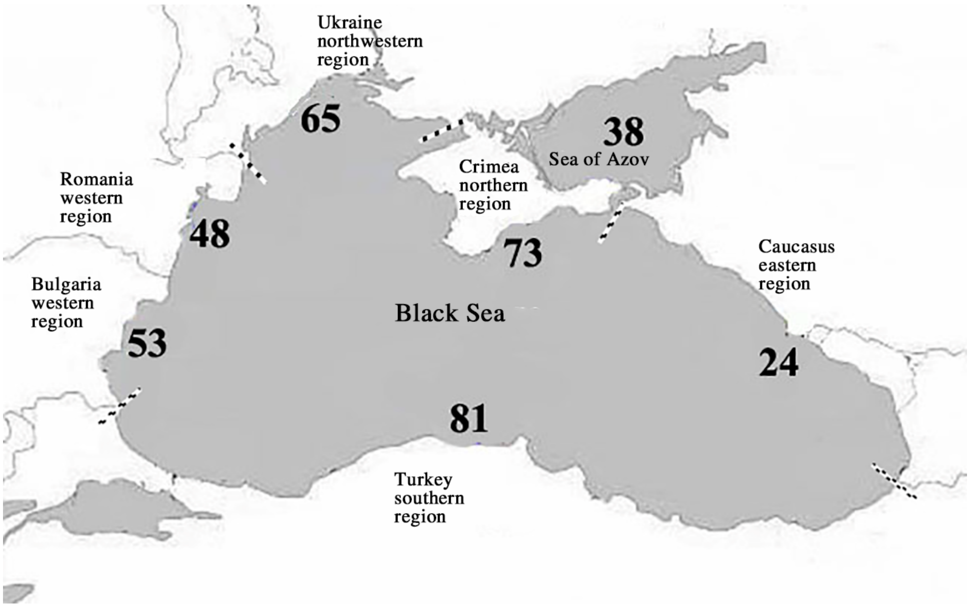

Fig. 1. Number of Amphipoda species recorded in the coastal areas of the Black Sea and the Sea of Azov (the boundaries of the regions are indicated by dotted lines)

Analysis according to (Uzunova, 2012) of the average taxonomic distinctness Δ^+ (delta) and the index of variability Λ^+ (lambda) for the amphipods of the Black Sea and the Sea of Azov revealed the following peculiarities. By Δ^+ values, all Amphipoda of both seas are located almost on the line of the average expected value (a dotted line in Fig. 2) for the total list of the amphipods for the Black Sea and the Sea of Azov (Fig. 2). This characterizes these taxonomic structures as hierarchically aligned and close in vertical architectonics to structure of all Amphipoda of the Sea of Azov and the Black Sea.

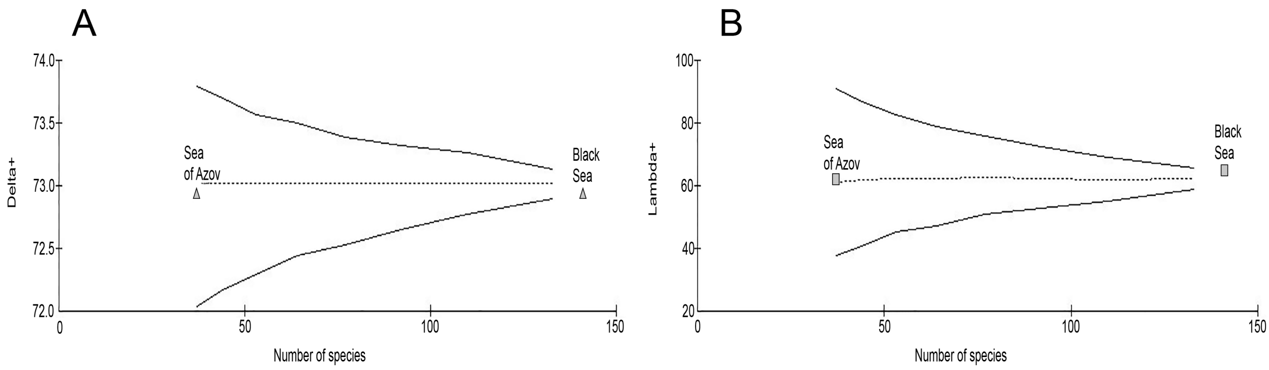

Fig. 2. Average taxonomic distinctness Δ^+ (A) and its variability Λ^+ (B) for Amphipoda taxocene from the Black Sea and the Sea of Azov (based on total species list for both seas)

By Λ^+ values (Fig. 2B), the taxocene of all the amphipods of both seas is close to the average expected structure of a taxonomic tree of the entire Sea of Azov – Black Sea region (Fig. 3).

By the index of the average taxonomic distinctness Δ^+, two regions fall outside the 95 % probability funnel: the Black Sea northwestern coast and the eastern coast (Caucasus). Each region is characterized by its own specificity, and this imprints on Amphipoda taxonomy. In the Black Sea northwestern coast, due to the presence of estuaries of large rivers (Danube and Dnieper) and freshened lagoons, the salinity is lower. As a result, out of all the Black Sea regions, the greatest diversity of the Ponto-Caspian fauna was recorded in the northwestern one. However, the Ponto-Caspian fauna is characterized by a low diversity of genera and especially families. Several genera are represented by a significant number of species. Specifically, the greatest diversity is noted at the level of *Chelicorophium*, *Pontogammarus*, and *Stenogammarus*. All this resulted in a shift of the dot of the Black Sea northwestern coast to the area of Δ^+ graph (Fig. 3A) below the 95 % probability funnel.

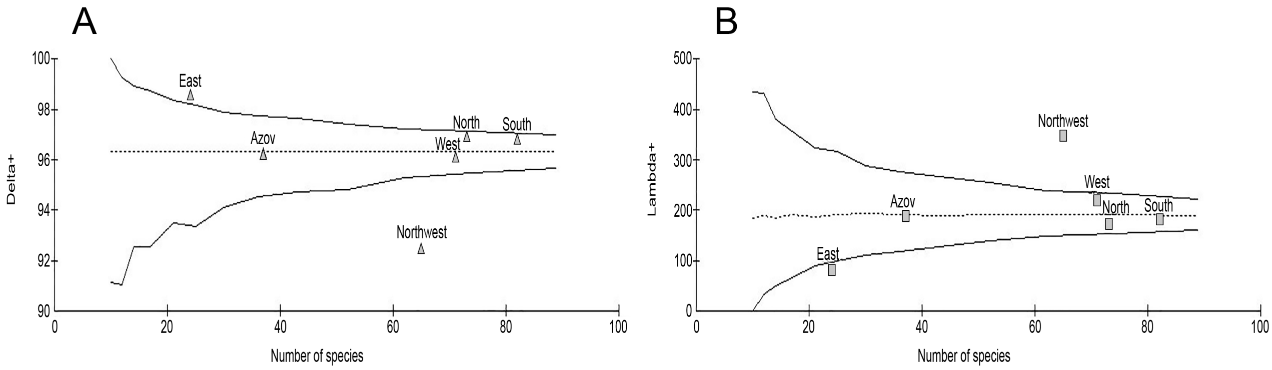

Fig. 3. Average taxonomic distinctness Δ^+ (A) and its variability Λ^+ (B) for Amphipoda taxocene from the regions of the Black Sea and the Sea of Azov. Azov denotes the Sea of Azov; East, Black Sea eastern coast (Caucasus); West, Black Sea western coast (Bulgaria, Romania); Northwest, Black Sea northwestern coast (Ukraine); North, Black Sea northern coast (Crimea); South, Black Sea southern coast (Turkey)

The Black Sea eastern coast (Caucasus) is characterized by a close slope of depth and weak shelf manifestation. Among biotopes of the coastal area, rock formations, boulders, and stones prevail, while loose soils are poorly represented. This led to an impoverishment of Amphipoda fauna as a whole. In contrast to Amphipoda fauna of the Black Sea northwestern coast, the fauna of the eastern coast is represented by a relatively large number of genera and families against the backdrop of a small number of species, and the greatest diversity is recorded precisely at the level of families. All this contributed to a shift of the dot of the Black Sea eastern coast to the area of Δ^+ graph (Fig. 3A) above the 95 % probability funnel.

Other Black Sea regions, as well as the Sea of Azov, fall within the 95 % probability funnel. It allows applying the results obtained to these regions.

By Λ^+ values (Fig. 3B), two regions fall outside the 95 % probability funnel as well: the Black Sea northwestern and eastern coasts. The reasons are pointed out above, when analyzing the index of average taxonomic distinctness Δ^+.

The results of multidimensional scaling (MDS ordination, Fig. 4A) revealed certain differences in the position of the Black Sea regions and the Sea of Azov.

According to the cluster analysis data, two regions are located most closely: Crimea and western region (Bulgaria, Romania). At a zero level of the stress function, the coincidence was recorded of the similarity of the species composition in nature and the similarity of the species composition on the graph. The differences revealed between the regions are confirmed by the data of the cluster analysis carried out based on the Bray–Curtis similarity in the "presence/absence" mode (Fig. 4B).

According to the cluster analysis data, at the level of the Bray–Curtis similarity value of 45 %, three clusters are distinguished. Cluster I covers the region of Caucasus – the area with a relatively small number of species, but with a high taxonomic diversity (Fig. 4B). The reasons are given above, in the analysis of the index of average taxonomic distinctness Δ^+. Cluster II unites three Black Sea regions: southern one (Turkey), western one (Bulgaria, Romania), and Crimea. This cluster can be characterized as covering the largest part of the Black Sea water area and having great taxonomic diversity and a relatively large number of species. Cluster III covers the freshened shallow Black Sea area (northwestern) and the Sea of Azov (more freshened basin than the Black Sea). This cluster has low taxonomic diversity against the backdrop of the highest species diversity of Ponto-Caspian Amphipoda.

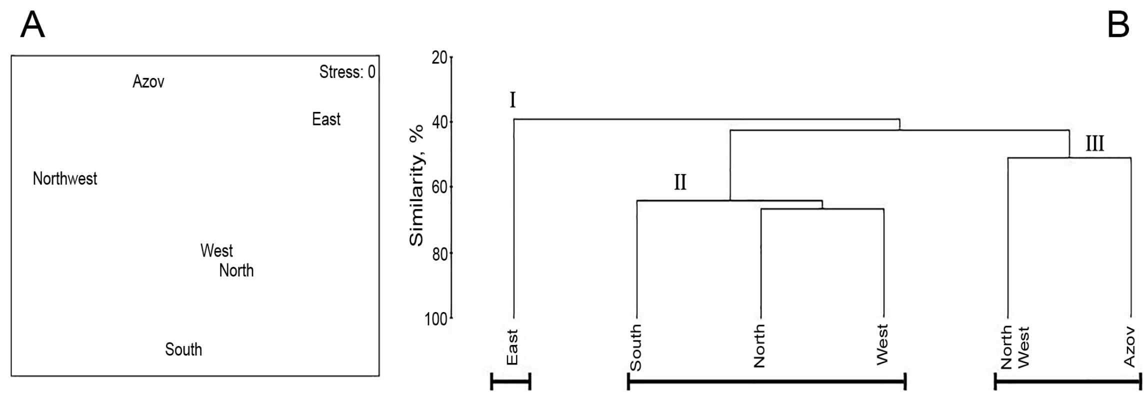

Fig. 4. MDS ordination plot (A) and dendrogram of similarity (B) for the regions of the Black Sea and the Sea of Azov (Bray–Curtis index, presence/absence, stress 0). The designations are the same as in Fig. 3

The Ponto-Caspian fauna of amphipods of the Black Sea and the Sea of Azov differs from other zoogeographic groups of Amphipoda in terms of distribution and ratio of the number of families, genera, and species. Specifically, Ponto-Caspian species inhabit predominantly estuaries of large rivers and freshened lagoons and are characterized by few families and genera against the backdrop of a large number of species. Due to these peculiarities, the Ponto-Caspian fauna can be analyzed separately from other zoogeographic groups of Amphipoda: Atlantic, Mediterranean–Atlantic, Black Sea endemics, worldwide spread, and Mediterranean–Black Sea [the zoogeographic groups are named according to (Greze, 1977)] (Fig. 5).

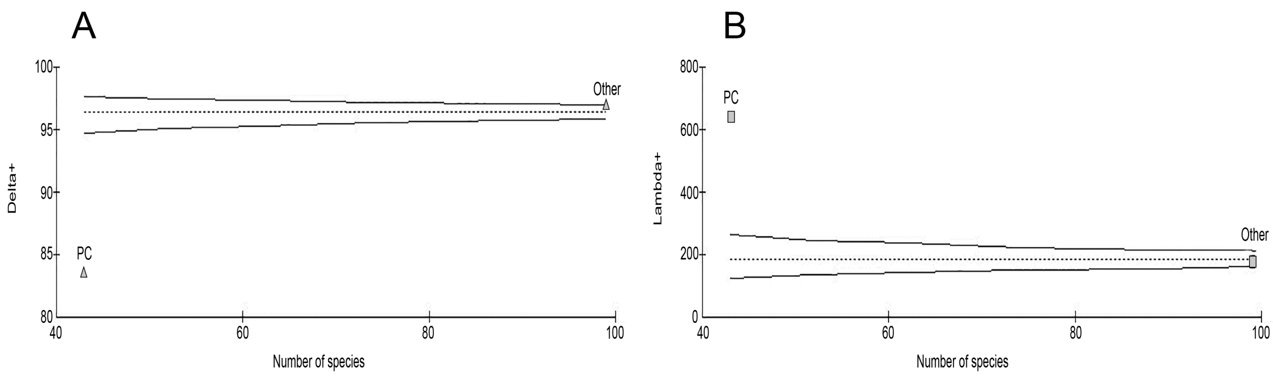

Fig. 5. Average taxonomic distinctness Δ^+ (A) and its variability Λ^+ (B) for Ponto-Caspian Amphipoda and Amphipoda of other zoogeographic groups of the Black Sea and the Sea of Azov (PC and other, respectively)

By the index of average taxonomic distinctness Δ^+ (Fig. 5A), the Ponto-Caspian fauna falls outside the 95 % probability funnel. This fauna, as mentioned above, is characterized by low diversity due to a small number of genera and especially families. Three genera (*Chelicorophium*, *Pontogammarus*, and *Stenogammarus*) are represented by a significant number of species, *i. e.* the greatest diversity is recorded at the level of genera. This characterizes the taxonomic structure of the Ponto-Caspian amphipods as shifted in terms of taxonomic evenness towards impoverishment; this affects the position of the dot of the Ponto-Caspian fauna on the graph (Fig. 5A). The values for other Amphipoda perfectly match the average expected taxonomic evenness and fall within the 95 % probability funnel.

By Λ^+ values (Fig. 5B), the Ponto-Caspian fauna of amphipods is distinguished as well. Due to the above-mentioned peculiarity in taxonomy, the position of the dot for this group on the graph corresponds to a low variability in the taxonomic composition. Other amphipods fall within the 95 % probability funnel and almost on the line of the average expected value for the Black Sea and the Sea of Azov.

Conclusions:

1. In the Black Sea and the Sea of Azov, 140 Amphipoda species have been registered belonging to 73 genera, 29 families, and 3 suborders.
2. The taxonomic structure of Amphipoda fauna of the Black Sea and Amphipoda fauna of the Sea of Azov is hierarchically aligned by the ratio of taxa and close to a total taxonomic list of amphipods of these two seas.
3. Taking into account the results of the multivariate statistical analysis, two regions were selected as different ones: northwestern coast (characterized by low taxonomic diversity due to a small number of genera and families against the backdrop of a significant number of species) and eastern coast (characterized by the highest taxonomic diversity against the backdrop of a relatively small number of species).
4. The cluster analysis revealed the similarity of Amphipoda taxonomic composition in the freshened water areas: the Black Sea northwestern coast and the Sea of Azov. Ponto-Caspian species inhabiting predominantly estuaries of large rivers and freshened lagoons are characterized by a taxonomic structure shifted in terms of taxonomic evenness towards impoverishment. This is due to a small number of genera and families against the backdrop of a significant number of species.

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ТАКСОНОМИЧЕСКОЕ РАЗНООБРАЗИЕ AMPHIPODA (CRUSTACEA) ЧЁРНОГО И АЗОВСКОГО МОРЕЙ

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На основе собственных и литературных данных установлено, что в настоящее время в Чёрном и Азовском морях зарегистрировано 140 видов амфипод, относящихся к 73 родам, 29 семействам и 3 подотрядам. Таксономическое разнообразие амфипод исследовано с использованием индекса таксономической отличительности Δ^+ (дельта) и его вариабельности Λ^+ (лямбда), а также с применением кластерного анализа и многомерного шкалирования. По индексу Δ^+ отмечено, что таксономическая структура амфипод Чёрного моря и Азовского моря иерархически выровнена и близка к общему списку амфипод этих морей. По индексу Λ^+ таксономическая структура амфипод как Азовского, так и Чёрного моря близка к среднеожидаемому уровню вариабельности структуры таксономического древа. В районе Турции и Крыма зарегистрировано больше видов амфипод, чем в других регионах. Из проанализированных районов Чёрного моря по Δ^+, Λ^+ и методу многомерного шкалирования выделено два отличающихся региона — северо-западная часть и восточное прибрежье (Кавказ). Первый характеризуется слабым таксономическим разнообразием вследствие малого числа родов и семейств на фоне значительного числа видов понто-каспийской фауны. Причиной этого является наличие эстуариев крупных рек и распреснённых лиманов. Восточное прибрежье, напротив, характеризуется большим таксономическим разнообразием на фоне относительно малого числа видов. Одна из причин — слабая выраженность шельфа и близкий свал глубины, что сопровождается малой представленностью рыхлых грунтов. Кластерный анализ подтвердил отличия северо-западной части Чёрного моря и восточного прибрежья (Кавказ) от других регионов. Кроме того, по методу кластерного анализа выявлено сходство таксономического состава Amphipoda северо-запада Чёрного моря с таковым Азовского моря. Из всех амфипод выделены понто-каспийские виды, обитающие почти исключительно в эстуариях крупных рек и в распреснённых лиманах. Они, вследствие малого числа родов и семейств на фоне значительного числа видов, характеризуются таксономической структурой, сдвинутой по отношению к таксономической выровненности в сторону обеднения.

Ключевые слова: Amphipoda, таксономическое разнообразие, Чёрное море, Азовское море