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Article

Syntaxonomy of Charophyte Algal Communities in the Eastern Part of the Black Sea and Sea of Azov (Russia)

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Abstract: Within the eastern part of the Black Sea and Sea of Azov, the vegetation of charophytes was studied using the Brown-Blanquet approach. For the first time, five communities are described, including three associations and two subassociations from the alliance ***Charion canescentis*** Krausch 1964, the order ***Charetalia intermediae*** Sauer 1937, and the class ***Charetea intermediae*** F. Fukarek 1961. Diagnoses of the described syntaxa are given. A comparison with the Baltic and Mediterranean communities of charophytes is made. It is shown that all the Azov-Black Sea communities with the dominance of charophytes, in contrast to Western European ones, include *Lamprothamnium papulosum* with high constancy. At the same time, the communities of the southern seas of Russia are characterized by a lower occurrence and abundance of higher aquatic plants (except for *Nanozostera noltei*) and a slightly higher occurrence of red and green algae. An indirect ordination analysis showed the ecological isolation of the described phytocenoses and revealed two main factors influencing the floristic composition of communities – the granulometric composition of bottom sediments and water eutrophication.

Keywords: charophytes; phytocenosis; prodromus; Brown-Blanquet approach; indirect ordination analysis; Sea of Azov; Black Sea

1. Introduction

The vegetation of silty-sandy substrates of fresh and brackish waters with the dominance of charophytes is currently combined into one class – ***Charetea intermediae*** F. Fukarek 1961. The class includes submerged macroalgal stonewort swards growing in stagnant or slow flowing, fresh or brackish water, slightly acidic to alkaline, oligotrophic to mesotrophic, unpolluted, or very slightly polluted [1,2]. Communities colonize loose substrates, forming ephemeral or perennial often pioneer phytocenoses. The class includes two orders – ***Charetalia intermediae*** Sauer 1937 (submerged macroalgal stonewort swards in neutral to alkaline and lime-rich waters) and ***Nitelletalia*** W. Krause 1969 (submerged stonewort swards in acidic and lime-poor waters). Both orders combine 40 associations recognized by the majority of syntaxonomists [1,2]. Order ***Charetalia intermediae*** Sauer 1937 includes three alliances: ***Charion intermediae*** Sauer 1937 (perennial submerged macroalgal stonewort swards in neutral to alkaline waters), ***Charion vulgaris*** (W. Krause et Lang 1977) W. Krause 1981 (ephemeral macroalgal stonewort swards in neutral to alkaline waters) and ***Charion canescentis*** Krausch 1964 (submerged macroalgal stonewort swards in brackish waters) [2]. Thus, the alliance ***Charion canescentis*** Krausch 1964 combine all the diversity of charophytes communities in mineralized, brackish and sea waters with salinity from 0.5 to 18‰ [1].

Communities of the alliance ***Charion canescentis*** Krausch 1964 inhabit very characteristic biotopes: shallow areas of freshwater, brackish water bodies, or aquatories of variable salinity (ponds, lakes, lagoons, estuaries) subject to periodic or cyclic fluctuations in water level, flood waters, sometimes temporarily drying up. These communities, as a rule, are monodominant or usually contain a few species [1].

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In Russia, three associations of the alliance ***Charion canescentis*** Krausch 1964 were previously noted, and only in continental water bodies: ***Charetum canescentis*** Corill. 1957 [3,4], ***Charetum altaicae*** Kipriyanova 2005 [5] and ***Charetum conniventis*** Ionescu-Teculescl 1972 [6]. In marine habitats, the description of the syntaxa of this alliance using the Brown-Blanquet approach has not been previously carried out on the territory of Russia.

Charophyte communities are extremely sensitive to water pollution and eutrophication and show intense degradation around the world, including the Azov-Black Sea basin. For example, in the Tendrovskiy Bay of the Black Sea, the areas occupied by communities of charophytes decreased from 100 km^2 (in the 1960–1990th of the XX century) to 10–20 km^2 (by 2016) [7]. In Taman Bay and in the area of the Kerch Strait, the areas of charophyte communities do not exceed 50 km^2, and these water areas are now under a very intensive anthropogenic influence. It is believed that the reduction of the area of the natural range of charophytes is associated with its fragmentation as a result of human activities, recreation, eutrophication, technogenic pollution, as well as in connection with a decrease in river flow [8]. Some taxa of charophytes are used as bioindicators for assessing water quality [9,10].

The aim of this study is to create a syntaxonomic scheme of the alliance ***Charion canescentis*** Krausch 1964 (order ***Charetalia intermediae*** Sauer 1937, class ***Charetea intermediae*** F. Fukarek 1961) of the North Caucasian coast of the Black Sea and Sea of Azov using Braun-Blanquet approach for environment indication purposes.

2. Materials and Methods

The study is based on 87 geobotanical descriptions («relevés») of charophytes - dominated communities performed in the sublittoral zone of the North Caucasus shelf of the Black Sea (Sudzhuk Lagoon of the Novorossiysk Bay) and Taman Bay of the Sea of Azov (Figure 1) in 2009–2020. A map of the sampling sites was made with Google Maps [11]. Salinity was measured at each site using a calibrated hand-held refractometer with automatic temperature compensation (Euromex, Arnhem/NL). Communities were described on sites from 0.25 to 1.0 m^2 and a depth from 0 m to 2 m. The algae were determined mainly during the description of communities, and the refinement of the taxonomic identity of some species was carried out in the laboratory. Identification was based on typical morphological characters using identification keys [12,13]. Some species of *Ulva* could not be identified confidently and were marked as *Ulva* sp. Nomenclature is given according to AlgaeBase [14]. Saprobity of the species is given according to [10,15]. Lists of macroalgal species with an indication of their phytogeographic characteristics were used for phytogeographical analysis of the communities [15–17].

Classification of macroalgal communities followed the Braun-Blanquet approach [18,19]. Syntaxon names follow the International Code of Phytosociological Nomenclature [20]). Characteristic tables include 41 descriptions («relevés»). To assess the abundance of species, a modified Braun-Blanquet scale was used: r — rarely occurs; + — insignificant participation of the coenopopulation of the species in the phytocenosis; 1 — projective cover up to 5%; 2 — 6–15%; 3 — 16–25%; 4 — 26–50%; 5 — more than 51% [21]. The follow constancy scale was used: r — 0.1–5%; + — 6–10%; I — 11–20%; II — 21–40%; III — 41–60%; IV — 61–80%; V — 81–100% [19].

Ordination analysis was performed using Canoco 4.5/CanoDraw 4.0 software [22]. The structure of the dataset was tested with detrended correspondence analysis (DCA), and the gradient length of the first DCA axis (1.000 SD units) indicated an application of linear ordination techniques. Principal components analysis (PCA), considering axes 1 and 2, was performed to detect the main environmental factors affecting the species composition of the sites in question, and to visualize any differences between them. Default options included: focus scaling on inter-sample distances, species scores divided by standard deviation, centering by samples and without transformation of the species data applied in PCA.

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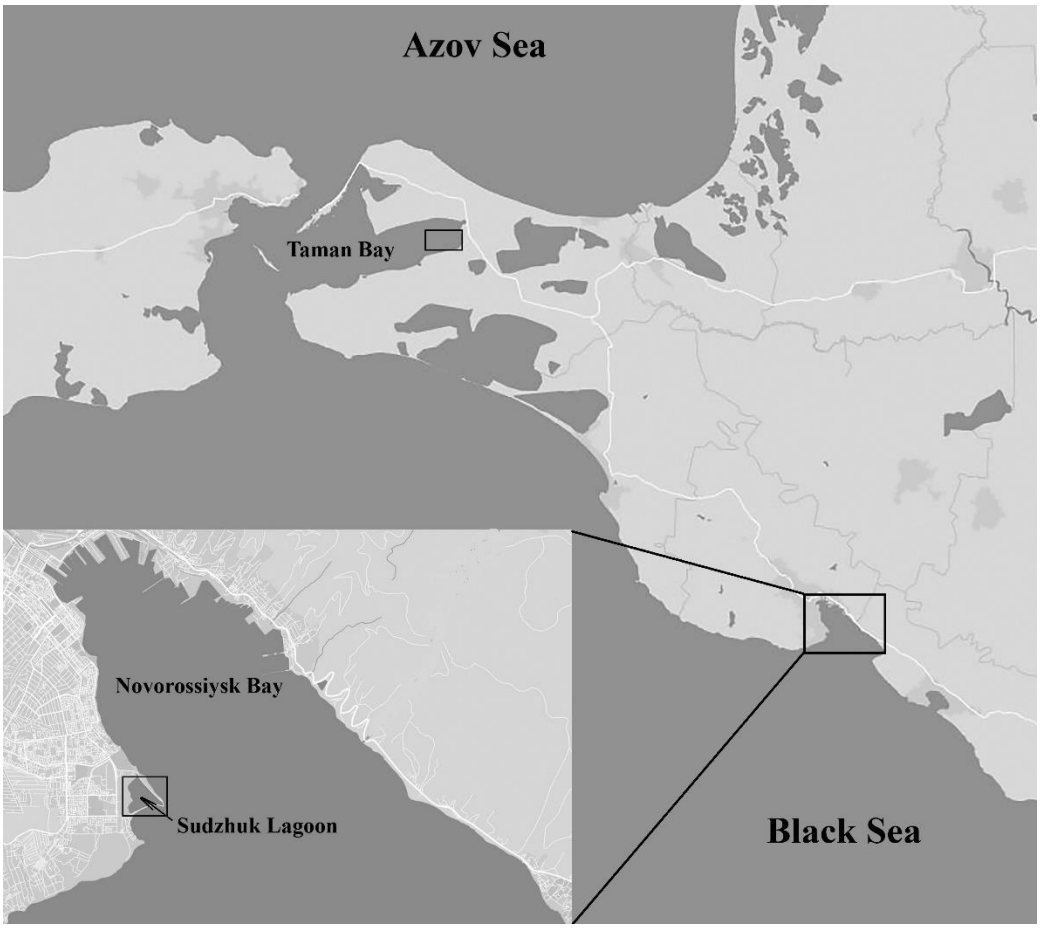

Figure 1. Map of sampling sites in the North Caucasian coast of the Black Sea and Sea of Azov.

3. Results

3.1. General taxonomic analysis

In the studied charophyte communities of the sublittoral zone of the Black Sea and Sea of Azov, 24 species of algae were identified, belonging to four phyla: Chlorophyta — 13 species; Rhodophyta — 8 species; Charophyta — 2 species; Ochrophyta, Phaeophyceae — 1 species. In addition, 3 species of higher aquatic plants (Magnoliophyta, Liliopsida) were identified (Tables A1–A3).

3.2. Description of new syntaxa

As a result of analysis of the collected material, we described five new communities, which combine oligosaprobic sublittoral charophyte vegetation of the Black Sea and Sea of Azov (Tables A1–A3).

The syntaxonomic synopsis of charophyte vegetation of the sandy-silty sublittoral of the Black Sea and Sea of Azov.

Cl.: ***Charetea intermediae*** F. Fukarek 1961
Ord.: Charetalia intermediae Sauer 1937
All.: ***Charion canescentis*** Krausch 1964
Ass.: ***Charae balticae–Lamprothamnietum papulosi*** Afanasyev & Abdullin ass. nova hoc loco
Ass.: ***Charae balticae–Nanozosteretum noltei*** Afanasyev & Abdullin ass. nova hoc loco
Subass.: ***Charae balticae–Nanozosteretum noltei*** subass. ***typicum*** Afanasyev & Abdullin subass. nov. hoc loco
Subass.: Charae balticae–Nanozosteretum noltei subass. cladophoretosum liniformisi Afanasyev & Abdullin subass. nov. hoc loco
Ass.: ***Lamprothamnio papulosi–Stuckenietum pectinatae*** Afanasyev & Abdullin ass. nova hoc loco
Subass.: ***Lamprothamnio papulosi–Stuckenietum pectinatae*** subass. ***typicum*** Afanasyev & Abdullin subass. nov. hoc loco

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Subass.: Lamprothamnio papulosi–Stuckenietum pectinatae subass. cladophoretosum albidae Afanasyev & Abdullin subass. nov. hoc loco

Association ***Charae balticae–Lamprothamnietum papulosi*** Afanasyev & Abdullin ass. nova hoc loco

Holotypus: Rel. 1 of Table A1 in this paper

Diagnostic species: *Chara baltica* (Hartm.) Bruz., *Lamprothamnium papulosum* (K.Wallroth) J.Groves

Description: The diagnostic and dominant species of the association are two species of charophytes, *Chara baltica* and *Lamprothamnium papulosum*, which usually form dense or rather dense thickets, in which other red and green algae with low abundance may also be present. Communities are photophilic, single-tiered, developing mainly in clear transparent waters, on sandy-shell substrates at a depth of 0.2–0.4 m in the Taman Bay. The salinity of sea water in the areas of growth of communities is 14–17‰. The number of species at the sample plot varies from 3 to 6; in total, 12 species of macrophytes were recorded in the communities. The total projective cover (TPC) of the community varies from 30 to 100%.

Association ***Charae balticae–Nanozosteretum noltei*** Afanasyev & Abdullin ass. nov. hoc loco

Holotypus: Rel. 3 of Table A2 in this paper

Diagnostic species: Chara baltica, Lamprothamnium papulosum, Nanozostera noltei (Hornemann) Tomlinson & Posluszny, Pneophyllum fragile Kütz.

Description: The community habitat on sandy-shell substrates at a depth of 0.5–1.0 m at the distant part of the Taman Bay, in areas with fairly clean water with a salinity of 14–17‰. The communities are two-tiered, represented by thickets of *Nanozostera noltei* at the first tier, and *Chara baltica* and *Lamprothamnium papulosum* at the second tier. The PC of the first tier is 40–50%, the second – 70–90%. In total 15 species of macrophytes were identified in the communities of the association, most of them are highly constant species. The association has two subassociations.

Subassociation ***Charae balticae–Nanozosteretum noltei*** subass. ***typicum*** Afanasyev & Abdullin subass. nov. hoc loco

Holotypus: Rel. 3 of Table A2 in this paper

Diagnostic species: same as the association

Description: Communities usually grow on sandy substrates and are represented by dense thickets of *Nanozostera noltei*, *Chara baltica* and *Lamprothamnium papulosum*. The number of species at the sampling plots is within 6–7, in total 10 species were identified in the communities.

Subassociation ***Charae balticae–Nanozosteretum noltei*** subass. ***cladophoretosum liniformisi*** Afanasyev & Abdullin subass. nov. hoc loco

Holotypus: Rel. 6 of Table A2 in this paper

Diagnostic species: *Cladophora liniformis* Kütz.

Description: In contrast to typical communities, the cenoses of this subassociation habitat on the substrates with a large number of bivalve shells. The subassociation is characterized by greater floristic richness compared to typical communities of the association, due to a larger amount of shells overgrown with algae. The number of species on the sampling plots varies from 8 to 11; in total, 12 species were identified in the communities of the subassociation.

Association ***Lamprothamnio papulosi–Stuckenietum pectinatae*** Afanasyev & Abdullin ass. nova hoc loco

Holotypus: Rel. 3 of Table A3 in this paper

Diagnostic species: *Lamprothamnium papulosum*, *Stuckenia pectinata* (L.) Börner

Description: The diagnostic and dominant species of the association are the flowering plant *Stuckenia pectinata* and charophyte *Lamprothamnium papulosum*. The community is photophilic, develops mainly on silt, sometimes with some shells at a depth of 0.3 to 1.5 m in the Sudzhuk lagoon of the Novorossiysk Bay. The salinity of the lagoon is extremely unstable and varies in different parts of the lagoon and in different seasons from 5–7 to 15–18‰. Communities, as a rule, are quite dense, two-tiered, represented by thickets of *Stuckenia pectinata* in the first tier and *Lamprothamnium papulosum* in the second tier. PC of the first tier is 10–70%, the second – 25–90%. The total PC of the community varies from 65 to 100%, on average – about 90%. In total, 13 species of macrophytes were revealed in the communities.

There are two subassociations in the association.

Subassociation ***Lamprothamnio papulosi–Stuckenietum pectinatae*** subass. ***typicum*** Afanasyev & Abdullin subass. nov. hoc loco

Holotypus: Rel. 3 of Table A3 in this paper

Diagnostic species: same as the association

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Description: Communities grow at areas with extremely unstable salinity and include pure cenoses of two diagnostic species. Only on some sampling plots are other random species with low abundance and constancy found.

Subassociation Lamprothamnio papulosi–Stuckenietum pectinatae subass. cladophoretosum albidae Afanasyev & Abdullin subass. nov. hoc loco

Holotypus: Rel. 14 of Table A3 in this paper

Diagnostic species: *Cladophora albida* (Nees) Kutz.

Description: Unlike typical communities, the cenoses of this subassociation habitat at conditions of higher and more stable salinity, and also, possibly, increased water trophicity. The diagnostic species are covered with a large number of epiphytes, and associated algae species, mainly *Cladophora albida*. Subassociation is characterized by greater floristic richness compared to typical communities. The number of species on the sampling plots varies from 3 to 6; in total, 10 species of macrophytes were identified in the communities of the subassociation.

3.3. Ordination analysis

PCA (Figure 2) shows two principal groups of communities, which distinct separated of according to abiotic factors: 1) dominated with *Chara baltica* (A, B and C; semi-open habitats) and 2) prevailed with *Lamprothamnium papulosum* (D and E; enclosed lagoons). PCA analysis revealed two main complex factors influencing the floristic composition of these communities (Figure 2; eigenvalues: axis 1 – 0.462, axis 2 – 0.230). The first axis is interpreted as a decrease in the proportion of small-sized fractions of bottom sediments. The extreme position on the left on the first axis is occupied by groups D (***Lamprothamnio papulosi–Stuckenietum pectinatae***) and E (***Lamprothamnio papulosi–Stuckenietum pectinatae*** subass. ***cladophoretosum albidae***), which habitat exclusively on small-sized fractions of silty bottom sediments, whereas the extreme position on the right is occupied by groups A (***Charae balticae–Lamprothamnietum papulosi***), B (***Charae balticae–Pneophylletum fragile***), and C (***Charae balticae–Pneophylletum fragile*** subass. ***cladophoretosum liniformisi***), growing on silty-sandy, sandy and sandy-shell bottom sediments. The last community, which occupies the extreme right position on the axis, is characterized by rich floristic composition, due to the greater amount of shells overgrown with algae. The second axis is interpreted as the water eutrophication. The lower position on the second axis is occupied by groups B and C, which were not found under conditions of high water trophicity, while the uppermost position is occupied by group E, characterized by the presence of mesosaprobiont species. Other communities occupy an intermediate position.

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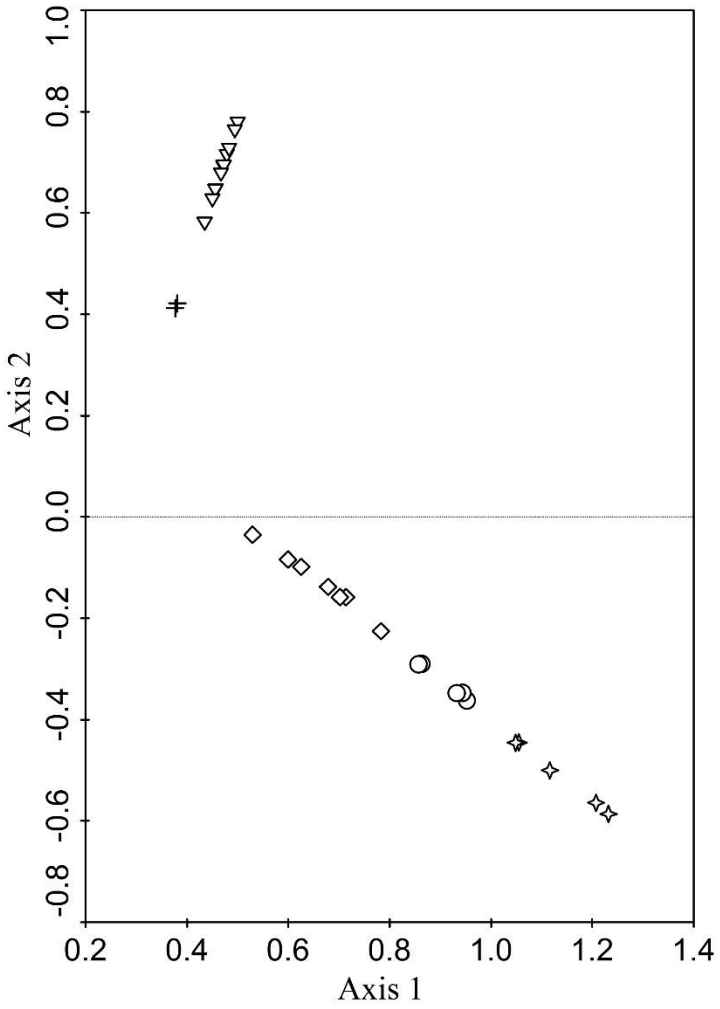

Figure 2. Principal components analysis (PCA) of charophyte algal communities in the eastern part of the Black Sea and Sea of Azov, with axis 1 and 2 represented. A (diamonds): ***Charae balticae–Lamprothamnietum papulosi***, B (circles): ***Charae balticae–Pneophylletum fragile***, C (stars): ***Charae balticae–Pneophylletum fragile*** subass. ***cladophoretosum liniformisi***, D (crosses): ***Lamprothamnium papulosi–Stuckenietum pectinatae***, E (triangles): ***Lamprothamnium papulosi–Stuckenietum pectinatae*** subass. ***cladophoretosum albidae***.

4. Discussion

Chara baltica (Hartman) Bruzelius was identified in the Black Sea and Sea of Azov only recently and was not previously mentioned for these areas [8]. Previously, all collections of charophytes from the northwestern part of the Black Sea, as well as the bays of the Azov Sea, were usually attributed to the species *C. papillosa* Kütz., known here under the epithets *C. aculeolata* Kütz. sensu Hollerb. et Krass. or *C. intermedia* A.Braun ex Lange, nom. illeg. [8].

An analysis of the syntaxonomic literature on the communities of charophytes shows that the following validly published syntaxa are closest to those described by us: the ass. ***Charetum balticae*** Kornas 1959 and the ass. ***Lamprothamnietum papulosi*** Corillion 1953 [1,23–27]. The first has been described in brackish lagoons and bays of the Baltic Sea [25,28], as well as on the western Mediterranean coast of Spain [29]) and France [1], the second – in estuaries and lagoons of European shores of the Mediterranean and the Atlantic Ocean [1,23,24]. These communities are distributed in fairly similar habitats: on silty and sandy-silty substrates, at depths of up to 1-2 m, in clean and transparent waters with a salinity of up to 18‰, in biotopes protected from the direct impact of waves.

The difference between the Azov-Black Sea communities described by us and close Mediterranean and Baltic associations shows at the Table 1. Firstly, all the Azov-Black Sea communities dominated by *Chara baltica*, in contrast to Western European ones, include *Lamprothamnium papulosum*, and with a high constancy. Secondly, the communities of the southern seas of Russia are characterized by a lower occurrence and abundance of higher aquatic plants (with the exception of *Nanozostera noltei*) and a slightly higher occurrence of red and green algae. Moreover, in some cases, the occurrence of green algae of the genus *Cladophora* is so high that we distinguish such communities as a particular

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subassociation ***Charae balticae–Nanozosteretum noltei*** subass. ***cladophoretosum liniformisi***. The main differences between the European association ***Lamprothamnietum papulosi*** and the association ***Lamprothamnio papulosi–Stuckenietum pectinatae*** are the high constancy and abundance of the flowering plant *Stuckenia pectinata* in the communities of the Sudzhuk Lagoon of the Novorossiysk Bay, as well as, in some areas, the relatively high participation of green and red algae, primarily *Cladophora albida*. At the same time, some species found in previously described European communities, including those indicated as diagnostic species, do not occur in the Azov and Black Seas or are rare. Among such taxa are *Althenia filiformis* Petit, *Ceramium tenuicorne* (Kütz.) Waern, species of the genus *Tolypella*, some species of the genus *Chara*, in particular, *C. galioides* De Candolle and *C. canescens* Loiseleur.

Table 1. Comparative characteristics of the charophyte communities in the Black Sea, Sea of Azov, Mediterranean, and Baltic Seas.

Syntaxa	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Total number of species	**12**	**9**	**13**	**16**	**5**	**10**	**6**	**7**
Diagnostic species of the associations								
Chara baltica (Hartm.) Bruz.	V	V	V	V	.	.	.	I
Lamprothamnium papulosum (K.Wallroth) J.Groves	V	V	V	.	V	V	V	V
Nanozostera noltei (Hornemann) Tomlinson & Posluszny	.	V	V	V	.	.	I	.
Pneophyllum fragile Kütz.	.	V	V	.	.	.	.	.
Cladophora liniformis Kütz.	II	.	V	.	.	.	.	.
Stuckenia pectinata (L.) Börner	.	.	.	III	V	V	.	.
Cladophora albida (Nees) Kutz.	.	.	.	.	.	V	.	.
Tolypella salina Corillion	.	.	.	.	.	.	I	V
Other species								
Ruppia maritima L.	.	.	I	III	.	.	I	IV
Ulva sp.	III	V	V	.	.	.	.	.
Chondria capillaris (Hudson) M.J.Wynne	III	II	IV	.	.	.	.	.
Vertebrata reptabunda (Suhr) Díaz-Tapia & Maggs in Díaz-Tapia et al.	II	I	III	.	.	.	.	.
Chara galioides De Candolle	.	.	.	I	.	.	I	III
Stilophora tenella (Esper) P.C.Silva in P.C.Silva, Basson & Moe	I	.	IV	.	.	.	.	.
Chaetomorpha ligustica (Kütz.) Kütz.	+	.	III	.	.	.	.	.
Ceramium diaphanum (Lightfoot) Roth	I	.	II	.	.	.	.	.
Cladophora siwaschensis C.J.Meyer	I	.	II	.	.	.	.	.
Chondracanthus acicularis (Roth) Fredericq	+	I	.	.	.	.	.	.
Ulva maeotica (Proshkina-Lavrenko) P.Tsarenko in Burova et al.	+	I	.	.	.	.	.	.
Althenia filiformis Petit	.	.	.	.	.	.	I	III
Ceramium tenuicorne (Kützing) Waern	.	.	.	IV	.	.	.	.
Zannichellia palustris L.	.	.	.	IV	.	.	.	.
Chara aspera Willdenow	.	.	.	II	.	.	.	.
Cladophora glomerata var. *crassior* (C.Ag.) C.Hoek	.	.	.	II	.	.	.	.
Ectocarpus siliculosus (Dillwyn) Lyngb.	.	.	.	II	.	.	.	.
Tolypella nidifica (O.F.Müller) A.Braun	.	.	.	II	.	.	.	.

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Vertebrata fucoides (Hudson) Kuntze	.	.	.	II	.	.	.	.
Acrochaetium secundatum (Lyngb.) Näg. in Näg. & Cramer	.	.	.	.	.	II	.	.
Chaetomorpha tortuosa (Dillwyn) Kleen	.	.	.	.	.	II	.	.
Cladophora vadorum (Areschoug) Kütz.	.	.	.	.	.	II	.	.
Cladophora vagabunda complex	.	.	.	.	.	II	.	.
Ulva prolifera O.F.Müller	.	.	.	.	.	II	.	.
Tolypella hispanica Nordstedt ex T.F.Allen	.	.	.	.	.	.	.	II
Bolboschoenus maritimus (L.) Palla	.	.	.	I	.	.	.	.
Chara canescens Loiseleur	.	.	.	I	.	.	.	.
Myriophyllum spicatum L.	.	.	.	I	.	.	.	.
Schoenoplectus lacustris (L.) Palla	.	.	.	I	.	.	.	.
Stylonema alsidii (Zanardini) K.M.Drew	.	.	.	.	.	I	.	.
Chaetomorpha aerea (Dillwyn) Kütz.	.	.	.	.	+	.	.	.
Ulva kylinii (Bliding) H.S.Hayden, Blomster, Maggs, P.C.Silva, M.J.Stanhope & J.R.Waaland	.	.	.	.	+	.	.	.
Ulva rigida C.Ag.	.	.	.	.	+	.	.	.
Lophosiphonia obscura (C.Ag.) Falkenberg in F.Schmitz & Falkenberg	.	.	.	.	.	+	.	.

Notes. 1 – ass. Charae balticae–Lamprothamnietum papulosi; 2–3 – ass. Charae balticae–Nanozosteretum noltei (2 – subass. typicum; 3 – subass. cladophoretosum liniformisi); 4 – ass. Charetum balticae [1]; 5–6 – ass. Lamprothamnio papulosi–Stuckenietum pectinatae (5 – subass. typicum; 6 – subass. cladophoretosum albidae); 7–8 – ass. Lamprothamnietum papulosi (7 – subass. typicum; 8 – subass. tolypelletosum salinae; [1]). Diagnostic species of syntaxa are highlighted in gray.

In the Black Sea, communities of charophytes have been repeatedly described [15,30,31], using dominant approach. N.V. Morozova-Vodyanitskaya [30]) identified the community *Lamprothamnium papulosum* for shallow silty areas of bays and inlets of the Black Sea, including the Sudzhuk lagoon of the Novorossiysk. At the same time, unfortunately, she gave only a very brief and non-specific description, indicating only a few most characteristic species: *Stuckenia* sp., *Ruppia* sp., *Chondria capillaris* (Hudson) M.J.Wynne. From the standpoint of the dominant (physiognomic-ecological) approach and in a more precise manner the communities of charophytes were characterized by A.A. Kalugina-Gutnik [15]. She identified 3 communities of charophytes of silty and silty-sandy substrates: *Lamprothamnium papulosum* + *Chara vulgaris*, *Lamprothamnium papulosum* and *Chara papillosa* (original name – *Chara aculeolata*). The first was described in the Sudzhuk lagoon at a depth of 0.5–1.3 m, the second and the third are revealed in the northwestern part of the Black Sea. For the community *Lamprothamnium papulosum* + *Chara vulgaris*, A.A. Kalugina-Gutnik [15] listed 29 species of macroalgae and 2 species of flowering plants. It was reported that the core of the community was formed by the dominant *Lamprothamnium papulosum*, the subdominant *Chara vulgaris* L., and also *Chondria capillaris* (Hudson) M.J.Wynne, *Lophosiphonia obscura* (C.Ag.) Falkenberg, *Vertebrata reptabunda* (Suhr) Díaz-Tapia & Maggs, *Cladophora albida* (Nees) Kutz., *Cladophora sericea* (Hudson) Kütz., and *Rhizoclonium riparium* (Roth) Harvey. In the community *Lamprothamnium papulosum* she identified 33 species of macroalgae and 2 species of flowering plants. The core of the association was formed by the same dominant *L. papulosum* and subdominant *C. vulgaris* (but with a smaller PC), as well as *Chondria capillaris*, *Laurencia obtusa* (Hudson) J.V.Lamouroux, *Vertebrata subulifera* (C.Ag.) Kuntze, *Carradoriella denudata* (Dillwyn) Savoie & G.W.Saunders, *Dasya pedicellata* (C.Ag.) C.Ag., *Vertebrata reptabunda*, *Ceramium strictum* Roth, *Rhizoclonium riparium*, and *Ulothrix implexa* (Kütz.) Kütz. According to [15], the community *Chara papillosa* is very similar to the previous one, with the difference only in the composition of dominants and the addition of *Gongolaria barbata* f. *repens* (A.D.Zinova & Kalugina) Sadogurska. Thus, the above descriptions do not coincide with any syntaxa we have identified. It is noteworthy that even the descriptions made by us in the Sudzhuk lagoon differ significantly from the descriptions made in the same aquatory and on the same grid of stations by A.A. Kalugina-Gutnik [15]. It should be noted that the hydrological regime and phytocenoses of the Sudzhuk lagoon have undergone significant

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transformations over the past 50 years, caused, among other things, by human activities, which are described in a fairly large number of works [32–35].

Charophyte communities are characterized by the formation of ecotone phytocenoses with other hydrophytes, and charophytes are included in such cenoses as components of the lower tier. The upper tier is most often represented by species of Potamogetonaceae. It is considered that such stratification is an overlay of separate groups of associations or fragments of associations belonging to separate phytosociological units (Felzines, Lambert, 2012). It should be noted that some authors describe such communities as distinct associations or subassociations. For example, the ass. ***Cladophoro fractae–Stuckenietum chakassiensis*** Kipriyanova 2017 has been described [36]. Other researchers believe that it would be preferable to designate such communities only in the rank of variants [1]. All three revealed associations are such ecotone syntaxa. Thus, the ass. ***Charae balticae–Lamprothamnietum papulosi*** is the ecotone community between the ass. ***Charetum balticae*** Kornas 1959 and the ass. ***Lamprothamnietum papulosi*** Corillion 1953, the ass. ***Charae balticae–Nanozosteretum noltei*** – between the ass. ***Charae balticae–Lamprothamnietum papulosi*** and ***Nanozosterion noltii*** Den Hartog ex Mucina 2016, ***Lamprothamnio papulosi–Stuckenietum pectinatae*** – between the ass. ***Lamprothamnietum papulosi*** Corillion 1953 and ***Potamogetonetum pectinati*** Carstensen ex Hilbig 1971.

Charophytes communities described by us are dominated by annual cosmopolitan and subcosmopolitan species, especially in communities dominated by ***Lamprothamnium papulosum***. Communities dominated by ***Chara baltica*** are somewhat more diverse in terms of phytogeographic composition, in addition to cosmopolitans and subcosmopolitans, there are several species of Indo-Atlantic and boreal-Atlantic origin, as well as two endemics.

Thus, in the studied areas of the Black Sea and Sea of Azov, the oligosaprobiotic vegetation of sandy and silty-sandy substrates with the dominance of charophytes belongs to the one class ***Charetea intermediae*** F. Fukarek 1961, one order ***Charetalia intermediae*** Sauer 1937, one alliance ***Charion canescentis*** Krausch 1964 and is represented by five communities united in three associations and two subassociations. In the lagoons, bays and estuaries of the Mediterranean, such vegetation is represented by seven described communities of the same alliance, united in six associations; of the Baltic Sea – in three associations [1]. In the eastern regions of the Black Sea and Sea of Azov, there are probably no communities with the dominance of *Tolypella hispanica* Nordstedt ex T.F.Allen (ass. ***Tolypelletum hispanicae*** Corillion 1957), *Chara galioides* De Candolle (ass. ***Charetum galioidis*** Corillion 1957), *Chara connivens* Salzmann ex A.Braun (ass. ***Charetum conniventis*** Ionescu-Teculescu 1972), *Chara canescens* Loiseleur (ass. ***Charetum canescentis*** Corillion 1957) (all of them occur in the brackish waters of the Mediterranean), as well as *Chara horrida* Wahlstedt (ass. ***Charetum horrido-balticae*** F. Fukarek 1961) and *Tolypella nidifica* (O.F.Müller) A.Braun (ass. ***Tolypelletum nidificae*** Kornâs 1959) (which are typical for the brackish waters of the Baltic). Thus, the vegetation of charophytes of geologically young seas – the Black, Azov, and Baltic seas – is poor compared to the Mediterranean Sea.

5. Conclusions

In general, significant differences in the floristic composition between the communities of charophytes described by us and their Mediterranean and Baltic counterparts make it possible to distinguish the Azov-Black Sea communities as independent new syntaxa. The diversity of the vegetation of charophytes in the studied areas of the Black Sea and Sea of Azov is poor and presented only by three associations and two subassociations. Because the charophyte communities are extremely sensitive to water pollution and eutrophication the revealed syntaxa can be indicators of water quality dynamic and therefore can be used in monitoring of the coast water quality in the Black Sea and Sea of Azov.

Author Contributions: Conceptualization, methodology, data analysis, visualization, writing—original draft preparation, supervision, project administration, D.F.A. and S.R.A.; sampling, D.F.A. and N.S.B.; writing—review and editing, D.F.A., S.R.A. and S.B. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Association ***Charae balticae–Lamprothamnietum papulosi*** Afanasyev & Abdullin ass. nova hoc loco.

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No. of relevé	1*	2	3	4	5	6	7	8	Constancy
Depth (m)	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.2	
Macroalgae cover (%)	100	100	90	70	55	40	20	20	
No. of species	5	4	3	6	5	4	4	4	
Diagnostic species of the ass. ***Charae balticae–Lamprothamnietum papulosi***									
Chara baltica (Hartman) Bruzelius	5	5	5	4	4	3	2	2	V^{2-5}
Lamprothamnium papulosum (K.Wallroth) J.Groves	2	2	1	2	1	2	1	+	V^{+-2}
Other species									
Chondria capillaris (Hudson) M.J.Wynne	1	.	.	+	.	+	+	.	III^{+-1}
Vertebrata reptabunda (Suhr) Díaz-Tapia & Maggs	.	+	.	+	+	.	.	+	III^{+}
Ulva sp.	.	.	.	.	+	+	+	+	III^{+}
Cladophora siwaschensis K.I.Meyer	+	.	.	.	+	.	.	.	II
Stilophora tenella (Esper) P.C.Silva	.	+	.	+	.	.	.	.	II
Cladophora liniformis Kütz.	.	.	+	+	.	.	.	.	II

Notes. * – holotypus.

Sporadic species: Rel. 1: *Ceramium diaphanum* (Lightfoot) Roth +.

Sampling data: Rel. 1 – Russia, Krasnodar Territory, settlement Sennoy, Azov Sea, 15.07.2020, 45°28.075′ N, 36°97.742′ E. Rel. 2 – Russia, Krasnodar Territory, settlement Sennoy, Azov Sea, 15.07.2020, 45°28.103′ N, 36°97.890′ E. Rel. 3 – Russia, Krasnodar Territory, settlement Sennoy, Azov Sea, 15.07.2020, 45°28.134′ N, 36°97.898′ E. Rel. 4 – Russia, Krasnodar Territory, settlement Sennoy, Azov Sea, 15.07.2020, 45°28.187′ N, 36°97.999′ E. Rel. 5 – Russia, Krasnodar Territory, settlement Sennoy, Azov Sea, 16.07.2020, 45°28.186′ N, 36°97.855′ E. Rel. 6 – Russia, Krasnodar Territory, settlement Sennoy, Azov Sea, 16.07.2020, 45°28.271′ N, 36°98.151′ E. Rel. 7 – Russia, Krasnodar Territory, settlement Sennoy, Azov Sea, 16.07.2020, 45°28.294′ N, 36°98.275′ E. Rel. 8 – Russia, Krasnodar Territory, settlement Sennoy, Azov Sea, 15.07.2020, 45°28.250′ N, 36°97.929′ E.

Author of relevés: Rel. 1–8 – Afanasyev D.F.

Plot size (m^2): Rel. 1–8 – 0.1225.

Substrate: Rel. 1–8 – sand and shell.

Table A2. Association ***Charae balticae–Nanozosteretum noltei*** Afanasyev & Abdullin ass. nova hoc loco.

No. of relevé	1	2	3*	4	5	6*	7	8	9	10	C1	C2
Depth (m)	0.5	0.5	0.5	0.6	0.7	0.5	0.5	0.5	0.5	0.5		
Macrophytes cover (%)	100	100	75	70	55	100	90	95	80	50		
No. of species	6	7	7	6	7	11	8	11	9	8		
Number of relevés											5	5
Diagnostic species of the ass. ***Charae balticae–Nanozosteretum noltei***												
Chara baltica (Hartman) Bruzelius	5	5	4	3	3	5	5	4	4	3	V^{3-5}	V^{3-5}
Lamprothamnium papulosum (K.Wallroth) J.Groves	2	1	1	2	1	2	1	2	1	1	V^{1-2}	V^{1-2}
Pneophyllum fragile Kütz.	+	+	+	+	+	+	+	+	+	+	V^{+}	V^{+}
Diagnostic species of the ass. ***Charae balticae–Nanozosteretum noltei***, the ass. ***Nanozosteretum noltii*** Harmsen 1936,												

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the all. ***Nanozosterion noltii*** Den Hartog ex Mucina 2016, the ord. ***Zosteretalia*** Beguinot ex Pignatti 1953 and the cl. ***Zosteretea*** Pignatti 1953												
Nanozostera noltei (Hornemann) Tomlinson & Posluszny	2	2	2	3	3	2	1	3	3	2	V^{1-3}	V^{2-3}
Diagnostic species of the subass. ***cladophoretosum liniformisi***												
Cladophora liniformis Kütz.	.	.	.	.	.	+	+	+	+	+	.	V^{+}
Other species												
Ulva sp.	+	1	+	+	+	+	+	+	+	+	V^{+-1}	V^{+}
Chondria capillaris (Hudson) M.J.Wynne	.	+	.	+	.	1	.	+	+	+	II	IV^{+-1}
Vertebrata reptabunda (Suhr) Díaz-Tapia & Maggs	.	.	+	.	.	+	+	+	.	.	I	III^{+}
Cladophora siwaschensis K.I.Meyer	+	.	+	.	.	.	.	.	.	.	II	.
Chondracanthus acicularis (Roth) Fredericq	.	+	.	.	+	.	.	.	.	.	II	.
Stilophora tenella (Esper) P.C.Silva	.	.	.	.	.	+	+	+	+	.	.	IV^{+}
Chaetomorpha ligustica (Kütz.) Kütz.	.	.	.	.	.	+	.	.	+	+	.	III^{+}
Ceramium diaphanum (Lightfoot) Roth	.	.	.	.	.	+	.	+	.	.	.	II

Notes. C1 – constancy of species in the subass. ***typicum***. C2 – constancy of species in the subass. ***cladophoretosum liniformisi***. * – holotypus. Relevés 1–5 – subass. ***typicum***. Relevés 6–10 – subass. ***cladophoretosum liniformisi***.

Sporadic species: Rel. 5: *Ulva maeotica* (Proshkina-Lavrenko) P.M.Tsarenko +. Rel. 8: *Ruppia maritima* L. 1.

Sampling data: Rel. 1 – Russia, Krasnodar Territory, settlement Sennoy, Azov Sea, 18.07.2020, 45°28.257′ N, 36°97.832′ E. Rel. 2 – Russia, Krasnodar Territory, settlement Sennoy, Azov Sea, 18.07.2020, 45°28.245′ N, 36°97.762′ E. Rel. 3 – Russia, Krasnodar Territory, settlement Sennoy, Azov Sea, 18.07.2020, 45°28.221′ N, 36°97.720′ E. Rel. 4 – Russia, Krasnodar Territory, settlement Sennoy, Azov Sea, 18.07.2020, 45°28.213′ N, 36°97.663′ E. Rel. 5 – Russia, Krasnodar Territory, settlement Sennoy, Azov Sea, 18.07.2020, 45°28.197′ N, 36°97.625′ E. Rel. 6 – Russia, Krasnodar Territory, settlement Sennoy, Azov Sea, 18.07.2020, 45°28.229′ N, 36°97.592′ E. Rel. 7 – Russia, Krasnodar Territory, settlement Sennoy, Azov Sea, 21.07.2020, 45°28.375′ N, 36°97.983′ E. Rel. 8 – Russia, Krasnodar Territory, settlement Sennoy, Azov Sea, 18.07.2020, 45°28.238′ N, 36°97.713′ E. Rel. 9 – Russia, Krasnodar Territory, settlement Sennoy, Azov Sea, 18.07.2020, 45°28.267′ N, 36°97.815′ E. Rel. 10 – Russia, Krasnodar Territory, settlement Sennoy, Azov Sea, 21.07.2020, 45°28.439′ N, 36°98.217′ E.

Author of relevés: Rel. 1–10 – Afanasyev D.F.

Plot size (m^2): Rel. 1–8 – 0.1225.

Substrate: Rel. 1–8 – sand and shell.

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Table A3. Association *Lamprothamnio papulosi–Stuckenietum pectinatae* Afanasyev & Abdullin ass. nova hoc loco.

No. of relevé	1	2	3*	4	5	6	7	8	9	10	11	12	13	14*	15	16	17	18	19	20	21	C1	C2
Depth (m)	1.4	1.2	0.8	0.6	1.0	0.3	1.2	0.6	0.3	0.3	0.3	1.1	0.8	1.0	0.4	0.4	1.1	0.3	1.5	1.5	0.3		
Macrophytes cover (%)	100	100	100	100	100	65	100	100	85	70	70	100	100	100	100	100	100	100	75	80	75		
No. of species	2	2	2	3	3	2	2	2	3	2	5	5	6	6	5	3	6	6	4	4	4		
Number of relevés																						10	11
Diagnostic species of the ass. ***Lamprothamnio papulosi–Stuckenietum pectinatae***																							
Lamprothamnium papulosum (K.Wallroth) J.Groves	5	5	5	5	4	5	5	5	3	3	5	5	5	5	5	5	5	4	4	3	3	V$^{3-5}$	V$^{3-5}$
Diagnostic species of the ass. ***Lamprothamnio papulosi–Stuckenietum pectinatae*** and the ass. ***Potamogetonetum pectinati*** Carstensen ex Hilbig 1971																							
Stuckenia pectinata (L.) Börner	5	5	5	4	4	4	3	2	1	1	5	5	4	4	4	4	1	3	1	3	3	V$^{1-5}$	V$^{1-5}$
Diagnostic species of the subass. ***cladophoretosum albidae***																							
Cladophora albida (Nees) Kutz.	.	.	.	.	.	.	.	.	.	.	2	1	1	1	1	1	1	2	1	2	1	.	V$^{1-2}$

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Other species																									
Cladophora vadorum (J.E.Areschoug) Kütz.	.	.	.	.	.	.	.	.	.	.	2	.	1	1	.	.	.	.	1	.	.	.	II
Ulva prolifera O.F.Müller	.	.	.	.	.	.	.	.	.	.	1	.	1	1	1	.	.	.	.	.	.	.	II
Acrochaetium secundatum (Lyngb.) Näg.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	1	.	1	.	.	II
Chaetomorpha tortuosa (Dillwyn) Kleen	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	1	.	II
Cladophora vagabunda complex	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	2	.	.	.	.	II
Stylonema alsidii (Zanardini) K.M.Drew	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	I

Notes. C1 – constancy of species in subass. ***typicum***. C2 – constancy of species in subass. ***cladophoretosum albidae***. * – holotypus. Relevés 1–10 – subass. ***typicum***. Relevés 11–21 – subass. ***cladophoretosum albidae***.

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Sporadic species: Rel. 4: *Chaetomorpha aerea* (Dillwyn) Kütz. +. Rel. 5: *Ulva kylinii* (Bliding) H.S.Hayden, Blomster, Maggs, P.C.Silva, Stanhope & Waaland 1. Rel. 9: *Ulva rigida* C.Ag. 1. Rel. 17: *Lophosiphonia obscura* (C.Ag.) Falkenberg 1.

Sampling data: Rel. 1 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 10.07.2010, 44°68.098′ N, 37°80.117′ E. Rel. 2 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 10.07.2010, 44°68.134′ N, 37°80.122′ E. Rel. 3 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 10.07.2010, 44°68.170′ N, 37°80.040′ E. Rel. 4 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 16.07.2009, 44°68.216′ N, 37°80.002′ E. Rel. 5 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 16.07.2009, 44°68.210′ N, 37°80.143′ E. Rel. 6 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 16.07.2009, 44°68.299′ N, 37°79.951′ E. Rel. 7 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 16.07.2009, 44°68.190′ N, 37°80.180′ E. Rel. 8 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 11.07.2010, 44°68.265′ N, 37°80.129′ E. Rel. 9 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 17.07.2009, 44°68.285′ N, 37°79.890′ E. Rel. 10 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 17.07.2009, 44°68.289′ N, 37°79.874′ E. Rel. 11 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 10.07.2010, 44°68.009′ N, 37°80.617′ E. Rel. 12 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 11.07.2010, 44°68.030′ N, 37°80.359′ E. Rel. 13 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 11.07.2010, 44°68.007′ N, 37°80.461′ E. Rel. 14 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 10.07.2010, 44°67.972′ N, 37°80.400′ E. Rel. 15 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 11.07.2010, 44°67.895′ N, 37°80.395′ E. Rel. 16 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 17.07.2009, 44°67.892′ N, 37°80.515′ E. Rel. 17 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 17.07.2009, 44°67.967′ N, 37°80.318′ E. Rel. 18 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 11.07.2010, 44°67.913′ N, 37°80.763′ E. Rel. 19 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 17.07.2009, 44°68.031′ N, 37°80.347′ E. Rel. 20 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 11.07.2010, 44°68.037′ N, 37°80.350′ E. Rel. 21 – Russia, Krasnodar Territory, Sudzhuk Lagoon of the Novorossiysk Bay, Black Sea, 11.07.2010, 44°67.992′ N, 37°80.686′ E.

Author of relevés: Rel. 1–21 – Berezenko N.S.

Plot size (m²): Rel. 1–21 – 0.25.

Substrate: Rel. 1–9, 11–18 – silt. Rel. 11, 19–21 – shell rock and silt

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