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REVISION OF MACROPHYTOBENTHOS OF THE PROTECTED TERRITORIAL-AQUATIC COMPLEX OF THE BAKALSKAYA SPIT (THE BLACK SEA)

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The territorial-aquatic complex of the Bakalskaya Spit located in the northwestern Crimean Peninsula is a unique natural object, with a high variety of biota and landscapes. Despite the fact that it has the conservation status of a landscape park, its components undergo significant anthropogenic transformation. In this complex, structural and functional basis of the most coastal-marine and lagoonal biotopes is formed by microphytobenthos. However, the information on flora species composition and systematic structure was incomplete, and the latest changes in nomenclature and taxonomy adopted in phycology were not taken into account. In this regard, based on the data of our own research, we revised the macrophyte flora of marine and lagoonal water areas within the boundaries of the protected territorial-aquatic complex. As established, the flora includes 64 species: Chlorophyta, 23; Ochrophyta, 5; Rhodophyta, 31; and Tracheophyta, 5. The taxonomic structure includes 5 classes, 16 orders, 26 families, and 37 genera. According to the analysis of the ratio of ecological and floristic groups, 51.6 % are oligosaprobes. Short-vegetation species prevail (68.7 %). Among halobity groups, prevalence of marine and brackish-marine species was registered (in total, 90.7 %). A warm-water complex prevailed (45.3 %), but the contribution of cosmopolitan species characterized by eurybiontity was quite large (15.6 %). The rare fraction of the marine macrophyte flora includes 21 genera (32.8 %); habitats formed by macrophyte communities are listed in the EU Habitats Directive – Council Directive 92/43/EEC of 21 May, 1992 (codes 1110, 1150, and 1160). Considering high sozological significance of the territorial-aquatic complex analyzed, industrial sand mining must be stopped, since this is the main threat and a transforming factor. Moreover, the area of the complex has to be expanded, and the conservation status has to be risen (either as an independent object or as part of a large national park). It is also advisable to include the complex in the Emerald Network to provide additional opportunities for its protection and preservation. The presented results are the basis for additional hydrobotanical studies aimed at revealing the scale and vector of alterations in the composition and structure of macrophytobenthos and the entire ecosystem.

Keywords: Black Sea, Crimean Peninsula, Bakalskaya Spit, macrophytobenthos, species composition, revision

Due to specific physical and chemical properties of water in natural water bodies, dissolved substances and suspended matter are transferred to different distances altering hydrochemical parameters of the habitat of organisms and causing a direct physical transformation of the coastal zone.

In areas with accumulative shores, anthropogenic interference affects direction and thickness of loose sediment flows and rapidly changes configuration and size of coastal macroforms. Protected objects undergo transformation as well, though those seem to be located quite far from sources of negative effect. The same happened to the Bakalskaya Spit in the northwestern Crimean Peninsula. In recent years, due to sand mining at the Bakalskaya Bank, the situation has become so complicated that it even drew attention of representatives of the central media. For the scientific community, the Bakalskaya Spit – a unique natural phenomenon – is of great interest for a long time. So, it was reasonable and relevant to publish a special issue of the journal *Ecological Safety of Coastal and Shelf Zones of Sea* (2018, iss. 4), with the available data summarized and new material given by leading experts in various fields. Structural and functional basis of coastal-marine biotopes is formed by macrophytes; their thicket communities (first of all, seagrasses) slow down bottom and coastal abrasion, and this is extremely significant for the area. Importantly, the alterations affected the vegetation cover as well, but hydrobotanical information – neither compiled nor original – was not reflected in the special issue mentioned. Previously, NBG-NSC and IBSS staff carried out investigation on macrophytobenthos of the coastal-marine and lagoonal water areas of the protected territorial-aquatic complex of the Bakalskaya Spit (Evstigneeva & Tankovskaya, 2011 ; Sadogurskiy, 2010). Their results were not summarized, and data on the species composition were not published in full. At the same time, floristic lists are the basis of all further research for identification and preservation of biodiversity of the area and require regular revision (Yena, 2012). Taking into account the circumstances above and significant latest changes in nomenclature and taxonomy adopted in phycology, we aimed at summarizing the available data and revising the macrophyte flora of the coastal-marine and lagoonal water areas within the boundaries of the protected territorial-aquatic complex of the Bakalskaya Spit.

MATERIAL AND METHODS

Study area. A description of environmental conditions of the study area, along with data on localization of hydrobotanical sections and stations, is important for understanding composition and distribution of phytobiota, as well as for carrying out repeated investigations.

The accumulative Bakalskaya Spit is located in the northwestern Crimean Peninsula, in the Karkinitsky Bay of the Black Sea. It is formed by narrow western and wide eastern branches, with the lagoonal Bakalskoye Lake (Bakal) enclosed between them (Fig. 1). During our observations, its length from the base to the distal end (Peschany Cape) was about 8 km, but the macroform has an underwater continuation – in the form of a bank of the same name (Goryachkin & Kosyan, 2018 ; Zenkovich, 1960). The seabed is deep. The western branch of the spit and the seabed are composed of unsorted sediments with no signs of siltation (Zenkovich, 1960). An intense alongshore current and sediment flow (directed from the Tarkhankut Peninsula to the northeast) split near the Bakalskaya Spit. Previously, one branch leaving to the north formed a bank, and the second bending around Peschany Cape again deviated to the bedrock bank and increased both the spit tip and the wide eastern branch. At the same time, its steep underwater slope gradually flattened and silted up with depth and in the direction of the bedrock bank. In the study area, there are no natural solid soils. During the observation period, temperature of seawater surface layer reached +23…+25 °C, and mineralization reached 17.2 $g \cdot L^{-1}$ (Sadogurskiy, 2010); to date, the latter has slightly increased due to cessation of water discharge from rice fields (Goryachkin & Kosyan, 2018). On the eastern branch of the spit, in depressions between coastal ridges, swampy areas and small shallow isolated water bodies are localized. During the observation period, those had a depth

up to 0.5 m, temperature +30…+34 °C, and mineralization 31–58 g·L^{-1}. Both branches adjoin an intensively abraded cliff (0.5–3 m *per* year) which is composed of clays and forms southern and eastern shores of the Bakalskoye Lake.

During the observation period, the lake, with a silty lakebed (silty-shelly near the sand embankment), had a depth 0.6–0.8 m, temperature +28…+34 °C, and mineralization 100 g·L^{-1} (salt deposits were observed), although the values of the latter vary widely over the years (Kurnakov et al., 1936 ; Shadrin et al., 2004). On the distal, extended spit part, a complex network of semi-isolated lagoonal water bodies was recorded, with a shell-sandy bottom (silty sometimes), depths up to 0.5 m, temperature +26…+29 °C, and mineralization 18–22 g·L^{-1} (Sadogurskiy, 2010).

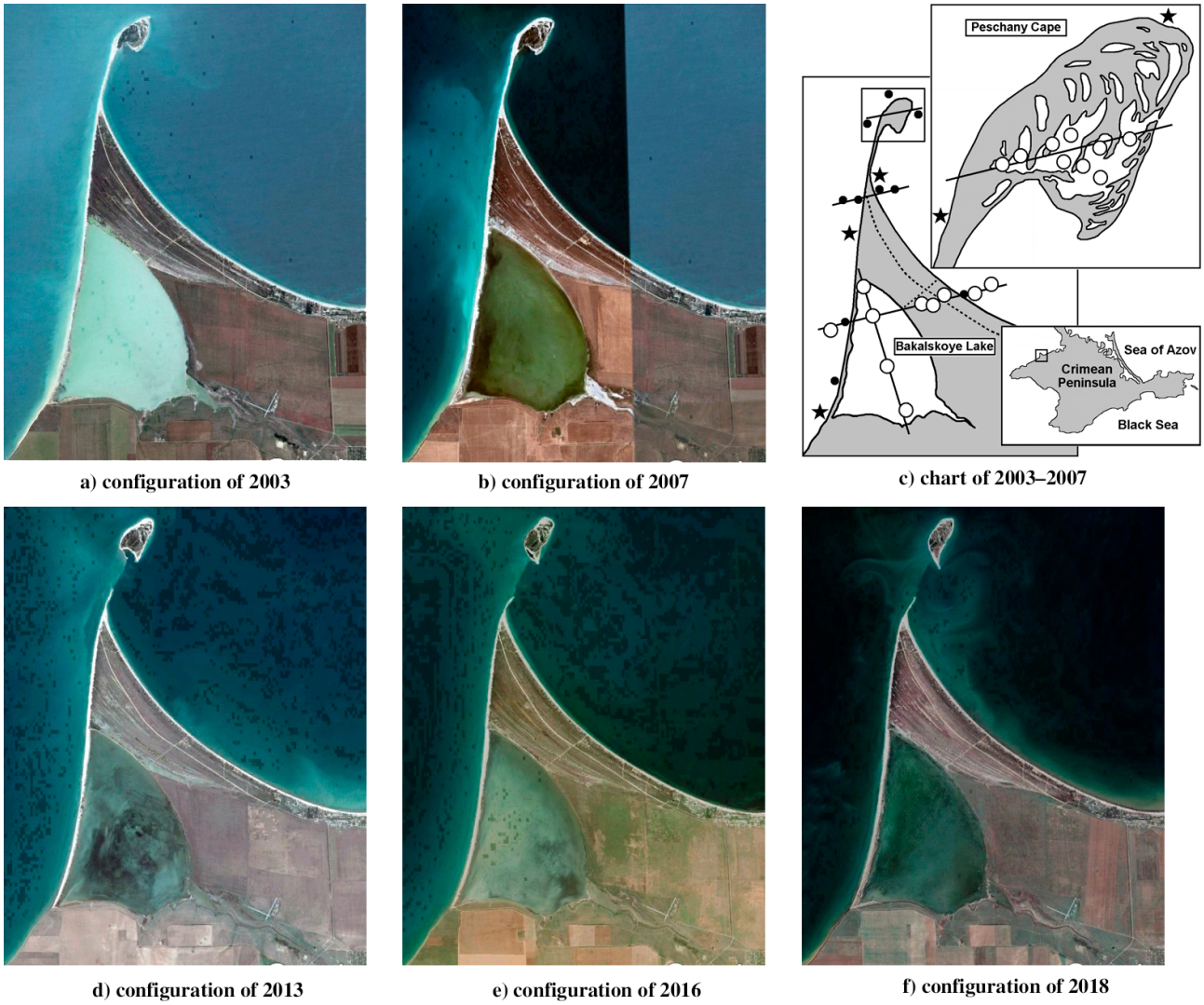

Fig. 1. Dynamics of the Bakalskaya Spit configuration in 2003–2018 (a, b, and d–f) according to https://earth.google.com/web/ and a map of sampling points location in 2003–2007 (c) in accordance with (Evstigneeva & Tankovskaya, 2011 ; Sadogurskiy, 2010). On the map: ○ denotes stations where bottom vegetation was recorded and sampling was carried out in 2003; ● denotes stations where bottom vegetation was not registered in 2003; ★ denotes stations where bottom vegetation was recorded and sampling was carried out in 2007

The macroform was relatively stable (see Fig. 1a, b) during the observation period. However, against the backdrop of sea level rise and alongshore sediment flow weakening, researchers have already recorded an acceleration of abrasion, with the distal spit part tending to shift and separate (Klyukin, 2005). Sand mining which became industrial in 2015 exacerbated the sediment deficit and catastrophically accelerated the process (see Fig. 1d–f). To date, a 1-km wide channel separates the newly formed Peschany Island from the spit body which has decreased down to 5.7 km; this resulted in a complete change in litho- and hydrodynamic conditions in the area, and its consequences have not been studied (Goryachkin & Kosyan, 2018).

Back in 1972, coastal waters near the Bakalskaya Spit, with an area of 410 hectares, received the status of a natural monument (coastal aquatic complex). In 2000, with adding 300 hectares of the spit itself and 810 hectares of the lake (in total, 1,520 hectares), the object was turned into a territorial-aquatic one. Its status was changed, and it is known as the regional landscape park "Bakalskaya Spit" (since 2018, in fact, it is in the status of a landscape and recreational park). The territorial-aquatic complex is part of both IBA (Important Bird and Biodiversity Area) by BirdLife International and Ramsar wetlands of international importance "Karkinitsky and Dzharylgachsky bays" (Ramsar List, 2020).

Material was sampled in summer according to the generally accepted hydrobotanical method (Kalugina, 1969). In 2003, dives were carried out with surface-supplied equipment at 19 stations in marine and lagoonal areas (*inter alia* the Bakalskoye Lake), and 95 hydrobotanical samples were taken. In 2007, 25 samples were taken manually at 5 stations (see Fig. 1c). A visual survey (with no sampling) of the seabed was carried out down to a depth of 12 m. Thus, stations and visual surveys span all the benthal zones and most of a depth spectrum where macroscopic vegetation cover is recorded in the study area.

The object of the study is benthic macrophytes. Their nomenclature for the divisions Chlorophyta, Ochrophyta, Rhodophyta, and Tracheophyta is given according to AlgaeBase (2020); the names of taxa authors are abbreviated as standard, in accordance with IPNI recommendations (The International Plant Names Index, 2020). When needed, we added nomenclatural combinations from biological keys used as basic guidelines for identification of macroalgae (Zinova, 1967 ; Opredelitel' vysshikh rastenii Ukrainy, 1987). The vegetation period duration and phytogeographic characteristics of algae are given according to A. Kalugina-Gutnik (1975), and saprobiological and halobic characteristics are presented in accordance with A. Kalugina-Gutnik and T. Eremenko (unpublished data) – with clarifications concerning seagrasses (Sadogurskiy, 2013 ; Sadogurskiy & Belich, 2003). Given the small size of the Black Sea, as well as interconnection and interdependence of some of its coastal areas, identification of a rare fraction was carried out taking into account all published national and international phytosozological lists on macrophytobiota.

RESULTS AND DISCUSSION

Within the boundaries of the protected territorial-aquatic complex of the Bakalskaya Spit, macroscopic benthic vegetation with a biomass 0.1–2.7 kg·m^{-2} developed on soft soils during the observation period. In the sea, the most mobile sandy and shell-sandy sediments (especially near convex sections of the coast along the western branch and on the steepest underwater slopes of the eastern branch) had no permanent vegetation cover. From a depth 4–5 m, a community of unattached form of *Phyllophora crispa* (Hudson) P. S. Dixon, 1964 was recorded there. With a local decrease in hydrodynamics, small accumulations are found much closer to the coast as well (up to the pseudolittoral zone).

Inactive silty soils in the bay, near the eastern branch, were covered with *Zostera marina* Linnaeus, 1753 communities, but with increasing depth and decreasing light intensity, seagrasses contributed less to the composition of the vegetation cover, and the unattached *Ph. crispa* contributed more. In inland hyperhaline water bodies of the eastern branch of the spit and in the Bakalskoye Lake, communities of *Cladophora siwaschensis* K. I. Meyer, 1922 and *Ruppia maritima* Linnaeus, 1753 prevailed. In the pseudolittoral and the shallowest areas of the sublittoral of water bodies in the distal spit part, semi-isolated from the sea by accumulative macroforms, *Ulva maeotica* (Proshkina-Lavrenko) P. M. Tsarenko, 2011 communities prevailed. With growing connection with the sea, increasing depth, and decreasing amplitude and duration of surge oscillations (with water redistribution through the channel system), the pseudolittoral was less and less pronounced in these lagoons, while in the sublittoral, various macroalgal communities were replaced by thickets of *Zannichellia palustris* subsp. *major* (Hartm.) Van Ooststroom & Reichgelt and *Zostera noltei* Hornemann, 1832. In total, 13 communities were registered within the boundaries of the object; out of them, 10 were attributed to inland water bodies, including 6 to the distal spit part. There, on a small area in the system of lagoons, due to their different isolation from the sea, a spatial complex gradient of the environment was formed; along it, mineralization, temperature, water level, and granulometric composition of the substrate changed concomitantly. Importantly, in the marine area, a small fragment of an anthropogenic solid substrate covered with macrophytes was examined in 2007. Among other things, this contributed to expansion of the species list given below but did not significantly affect either general characteristics of the flora or vegetation of the studied object.

When specifying the conservation status of taxa in the species list, the following designations are used: ◆ – European Red List of Vascular Plants (Bilz et al., 2011); ● – Convention on the Conservation of European Wildlife and Natural Habitats (Appendix I) (1979); ○ – Convention for the Protection of the Mediterranean Sea Against Pollution – Barcelona Convention, 1976 (Proposal for a Council Decision, 2009); ✱ – Red Data Book of Ukraine (2009); ✚ – Red Book of the Russian Federation (2008); □ – Red Data Book of the Republic of Bulgaria (2015); ★ – Black Sea Red Data Book (1999); ✪ – Black Sea Red Data List (1997); ▲ – Red Book of the Republic of Crimea (2015); ❖ – Red Data Book of Priazovsky Region (2012). The following abbreviations are used: LP, lagoonal pseudolittoral; LS, lagoonal sublittoral; MP, marine pseudolittoral; and MS, marine sublittoral.

CHLOROPHYTA Rchb.

Ulvophyceae Mattox et K. D. Stewart

Bryopsidales J. H. Schaffn.

Bryopsidaceae Bory

Bryopsis J. V. Lamour.

***Bryopsis hypnoides* J. V. Lamour.** □: MS (Sadogurskiy, 2010).

Cladophorales Haeckel

Cladophoraceae Wille

Chaetomorpha Kütz.

***Chaetomorpha aërea* (Dillwyn) Kütz.** [*Chaetomorpha chlorotica* (Mont.) Kütz.; *Chaetomorpha crassa* (C. Agardh) Kütz.]: LS (Sadogurskiy, 2010).

***Chaetomorpha gracilis* Kütz.**: LS (Sadogurskiy, 2010).

***Chaetomorpha linum* (O. F. Müll.) Kütz.**: LS, MS (Sadogurskiy, 2010).

Cladophora Kütz.

***Cladophora albida* (Nees) Kütz.** [*Cladophora albida* (Huds.) Kütz.]: LS, MP, MS (Evstigneeva & Tankovskaya, 2011 ; Sadogurskiy, 2010).

***Cladophora laetevirens* (Dillwyn) Kütz.**: LS, MP (Evstigneeva & Tankovskaya, 2011 ; Sadogurskiy, 2010).

***Cladophora liniformis* Kütz.**: MP (Evstigneeva & Tankovskaya, 2011).

***Cladophora sericea* (Huds.) Kütz.**: LS, MS (Sadogurskiy, 2010).

***Cladophora siwaschensis* K. I. Mey. ▲**: LP, LS predominantly in the Bakalskoye Lake (Sadogurskiy, 2010). Note: the author of this nomenclature combination incorrectly indicated C. J. Meyer (AlgaeBase, 2020), while the standard abbreviation for K. I. Meyer (1881–1965) is K. I. Mey. (The International Plant Names Index, 2020).

***Cladophora vadorum* (Aresch.) Kütz. ✱**: MP (Evstigneeva & Tankovskaya, 2011).

Rhizoclonium Kütz.

***Rhizoclonium riparium* (Roth) Harv.** [*Rhizoclonium implexum* (Dillwyn) Kütz.]: LS (Sadogurskiy, 2010).

Ulotrichales Borzi

Ulotrichaceae Kütz.

Ulothrix Kütz.

***Ulothrix flacca* (Dillwyn) Thur.**: LP, LS (Sadogurskiy, 2010).

Ulvales F. F. Blackman et Tansley

Phaeophilaceae D. F. Chappell, C. J. O'Kelly, L. W. Wilcox et G. L. Floyd

Phaeophila Hauck

***Phaeophila dendroides* (P. Crouan et H. Crouan) Batters**: LS (Sadogurskiy, 2010).

Ulvaceae J. V. Lamour. ex Dumort.

Ulva L.

***Ulva clathrata* (Roth) C. Agardh** [*Enteromorpha clathrata* (Roth) Grev.]: LS (Sadogurskiy, 2010).

***Ulva intestinalis* L.** [*Enteromorpha intestinalis* (L.) Link, nom. illeg.?]: LP, LS, MP, MS (Evstigneeva & Tankovskaya, 2011 ; Sadogurskiy, 2010).

***Ulva linza* L.** [*Enteromorpha linza* (L.) J. Agardh; *Enteromorpha ahlneriana* Bliding, nom. illeg.]: MP (Evstigneeva & Tankovskaya, 2011).

***Ulva maeotica* (Proshk.-Lavr.) P. M. Tsarenko** [*Enteromorpha maeotica* Proshk.-Lavr.]. ✱▲: LP, MP (Evstigneeva & Tankovskaya, 2011 ; Sadogurskiy, 2010).

***Ulva prolifera* O. F. Müll.** [*Enteromorpha prolifera* (O. F. Müll.) J. Agardh]: LS (Sadogurskiy, 2010).

Ulvellaceae Schmidle

Epicladia Reinke

***Epicladia perforans* (Huber) R. Nielsen** [*Entocladia perforans* (Huber) Levring]: MP (Evstigneeva & Tankovskaya, 2011).

Ulvella P. Crouan et H. Crouan

***Ulvella lens* P. Crouan et H. Crouan**: LS (Sadogurskiy, 2010).

***Ulvella leptochaete* (Huber) R. Nielsen, C. J. O'Kelly et B. Wysor** [*Ectochaete leptochaete* (Huber) Wille]: LS, MS (Sadogurskiy, 2010).

***Ulvella scutata* (Reinke) R. Nielsen, C. J. O'Kelly et B. Wysor** [*Pringsheimiella scutata* (Reinke) Marchew.]: LS, MS (Sadogurskiy, 2010).

***Ulvella viridis* (Reinke) R. Nielsen, C. J. O'Kelly et B. Wysor** [*Entocladia viridis* Reinke]. ✪: LS, MS (Sadogurskiy, 2010).

OCHROPHYTA Caval.-Sm.

Phaeophyceae Kjellm.

Ectocarpales Bessey

Acinetosporaceae G. Hamel ex J. Feldmann

Feldmannia Hamel

***Feldmannia lebelii* (Aresch. ex P. Crouan et H. Crouan) Hamel**: MP (Evstigneeva & Tankovskaya, 2011).

Chordariaceae Grev.

Stilophora J. Agardh

***Stilophora tenella* (Esper) P. C. Silva** [*Stilophora rhizodes* (Ehrh.) J. Agardh, nom. illeg.?]. ✱✚▲: MS (Sadogurskiy, 2010).

Fucales Bory

Sargassaceae Kütz.

Treptacantha Kütz.

***Treptacantha barbata* (Stackh.) S. Orellana et M. Sansón** [*Cystoseira barbata* (Stackh.) C. Agardh; *Cystoseira barbata* (Gooden. et Woodw.) C. Agardh, nom. illeg.]. ★✪○▲: MP (Evstigneeva & Tankovskaya, 2011). Note: is not a typical inhabitant of the Bakalskaya Spit; was recorded in small quantity on a solid substrate of anthropogenic origin.

Sphacelariales Mig.

Cladostephaceae Oltm.

Cladostephus C. Agardh

***Cladostephus spongiosum* f. *verticillatum* (Lightf.) Prud'homme** [*Cladostephus verticillatus* (Lightf.) C. Agardh, nom. illeg.]. ✱: MP (Evstigneeva & Tankovskaya, 2011).

Sphacelariaceae Decne.

Sphacelaria Lyngb.

***Sphacelaria cirrosa* (Roth) C. Agardh**: MS (Sadogurskiy, 2010).

RHODOPHYTA Wettst.

Florideophyceae Cronquist

Acrochaetiales Feldmann

Acrochaetiaceae Fritsch ex W. R. Taylor

Acrochaetium Nägeli

***Acrochaetium parvulum* (Kylin) Hoyt** [*Kylinia parvula* (Kylin) Kylin]: MS (Sadogurskiy, 2010).

***Acrochaetium secundatum* (Lyngb.) Nägeli** [*Kylinia virgatula* (Harv.) Papenf.; *Kylinia secundata* (Lyngb.) Papenf.]: MP (Evstigneeva & Tankovskaya, 2011).

Colaconematales J. T. Harper et G. W. Saunders

Colaconemataceae J. T. Harper et G. W. Saunders

Colaconema Batters

***Colaconema savianum* (Menegh.) R. Nielsen** [*Acrochaetium savianum* (Menegh.) Nägeli]: MS (Sadogurskiy, 2010).

Corallinales P. C. Silva et H. W. Johans.

Corallinaceae J. V. Lamour.

Hydrolithon (Foslie) Foslie

***Hydrolithon farinosum* (J. V. Lamour.) Penrose et Y. M. Chamb.** [*Melobesia farinosa* J. V. Lamour.]: MP (Evstigneeva & Tankovskaya, 2011).

Pneophyllum Kütz.

***Pneophyllum confervicola* (Kütz.) Y. M. Chamb.** [*Melobesia minutula* Foslie]: LS, MS (Sadogurskiy, 2010).

***Pneophyllum fragile* Kütz.** [*Melobesia lejolisii* Rosan.]: LS, MS (Sadogurskiy, 2010).

Gigartinales F. Schmitz

Phyllophoraceae Willk.

Phyllophora Grev.

***Phyllophora crispa* (Huds.) P. S. Dixon** [*Phyllophora nervosa* (DC.) Grev.]. ✚★✪▲: MP, MS (Evstigneeva & Tankovskaya, 2011 ; Sadogurskiy, 2010).

Hapalidiales W. A. Nelson, J. E. Sutherland, T. J. Farr et H. S. Yoon

Hapalidiaceae J. E. Gray

Phymatolithon Foslie

***Phymatolithon lenormandii* (Aresch.) W. H. Adey** [*Lithothamnion lenormandii* (Aresch.) Foslie]: LS, MS (Sadogurskiy, 2010).

Peyssonneliales D. M. Krayesky, S. Fredericq et J. N. Norris

Peyssonneliaceae Denizot

Peyssonnelia Decn.

***Peyssonnelia dubyi* P. Crouan et H. Crouan**: MS (Sadogurskiy, 2010).

Ceramiales Nägeli

Callithamniaceae Kütz.

Callithamnion Lyngb.

***Callithamnion granulatum* (Ducluz.) C. Agardh.** ✱: LS (Sadogurskiy, 2010).

Ceramiaceae Dumort.

Ceramium Roth

***Ceramium arborescens* J. Agardh**: LS, MS (Sadogurskiy, 2010). Note: earlier, *C. arborescens* was considered a synonym for *C. rubrum* and, accordingly, was not indicated for water areas within the boundaries of the protected object; however, there was a corresponding remark on its registration (Sadogurskiy, 2010).

***Ceramium deslongchampsii* Chauv. ex Duby**: MP (Evstigneeva & Tankovskaya, 2011).

***Ceramium diaphanum* (Lightf.) Roth** [*Ceramium tenuissimum* (Lyngb.) J. Agardh]: LS, MP, MS (Evstigneeva & Tankovskaya, 2011 ; Sadogurskiy, 2010).

***Ceramium siliquosum* var. *elegans* (Roth) G. Furnari** [*Ceramium diaphanum* var. *elegans* (Roth) Roth; *Ceramium elegans* Ducl.]: LS, MS (Sadogurskiy, 2010).

***Ceramium virgatum* Roth** [*Ceramium pedicellatum* (Duby) J. Agardh, nom. illeg.; *Ceramium rubrum* (Huds.) C. Agardh, nom. illeg.]: LS, MP, MS (Evstigneeva & Tankovskaya, 2011 ; Sadogurskiy, 2010).

Dasyaceae Kütz.

Dasya C. Agardh

***Dasya apiculata* (C. Agardh) J. Agardh** [*Dasyopsis apiculata* (C. Agardh) Zinova; *Eupogodon apiculatus* (C. Agardh) P. C. Silva]. ✱▲: MS (Sadogurskiy, 2010).

***Dasya baillouviana* (S. G. Gmel.) Mont.** [*Dasya pedicellata* (C. Agardh) C. Agardh]. ✪: LS, MP, MS (Evstigneeva & Tankovskaya, 2011 ; Sadogurskiy, 2010).

Rhodomelaceae Horan.

Chondria C. Agardh

***Chondria capillaris* (Huds.) M. J. Wynne** [*Chondria tenuissima* (Gooden. et Woodw.) C. Agardh]: LS, MP, MS (Evstigneeva & Tankovskaya, 2011 ; Sadogurskiy, 2010).

***Chondria dasyphylla* (Woodw.) C. Agardh**: MP (Evstigneeva & Tankovskaya, 2011).

Laurencia J. V. Lamour.

***Laurencia coronopus* J. Agardh.** ✱▲: MP, MS (Evstigneeva & Tankovskaya, 2011 ; Sadogurskiy, 2010).

***Laurencia obtusa* (Huds.) J. V. Lamour.** ✪: MP, MS (Evstigneeva & Tankovskaya, 2011 ; Sadogurskiy, 2010).

Lophosiphonia Falkenb.

***Lophosiphonia obscura* (C. Agardh) Falkenb.**: LS (Sadogurskiy, 2010).

Osmundea Stackh., nom. rejic.

***Osmundea hybrida* (DC.) K. W. Nam** [*Laurencia hybrida* (DC.) Lenorm., nom. illeg.?]. ✱▲: LS (Sadogurskiy, 2010).

Palisada K. W. Nam

***Palisada thuyoides* (Kütz.) Cassano, Sentíes, Gil-Rodríguez et M. T. Fujii** [*Laurencia paniculata* J. Agardh]: LS (Sadogurskiy, 2010).

Polysiphonia Grev.

***Polysiphonia denudata* (Dillwyn) Grev. ex Harv.** [*Polysiphonia denudata* (Dillwyn) Kütz., nom. illeg.?]: LS, MS (Sadogurskiy, 2010).

***Polysiphonia elongata* (Huds.) Spreng.** [*Polysiphonia elongata* (Huds.) Harv., nom. illeg.?]: MS (Sadogurskiy, 2010).

***Polysiphonia opaca* (C. Agardh) Moris et De Not.** [*Polysiphonia opaca* (C. Agardh) Zanardini, nom. illeg.?]: LS, MP, MS (Evstigneeva & Tankovskaya, 2011 ; Sadogurskiy, 2010).

Vertebrata Gray

***Vertebrata fucoides* (Huds.) Kuntze** [*Polysiphonia fucoides* (Huds.) Grev.; *Polysiphonia nigrescens* (Dillwyn) Grev., nom. illeg.?]: LS, MP, MS (Evstigneeva & Tankovskaya, 2011 ; Sadogurskiy, 2010).

***Vertebrata subulifera* (C. Agardh) Kuntze** [*Polysiphonia subulifera* (C. Agardh) Harv.]: MP, MS (Evstigneeva & Tankovskaya, 2011 ; Sadogurskiy, 2010).

Wrangeliaceae J. Agardh

Spermothamnion Aresch.

***Spermothamnion strictum* (C. Agardh) Ardiss.** ✪: MP (Evstigneeva & Tankovskaya, 2011).

Stylonematophyceae H. S. Yoon, K. M. Müller, R. G. Sheath, F. D. Ott et D. Bhattacharya

Stylonematales K. M. Drew

Stylonemataceae K. M. Drew

Chroodactylon Hansg.

***Chroodactylon ornatum* (C. Agardh) Basson** [*Asterocytis ramosa* (Thwaites) Gobi ex F. Schmitz]. ✱: LP, LS, MS (Sadogurskiy, 2010).

TRACHEOPHYTA Sinnott ex Cavalier-Smith.

Monocots

Alismatales R. Br. ex Bercht. et J. Presl

Ruppiaceae Horan., nom. cons.

Ruppia L.

***Ruppia maritima* L.** ◆▲❖: LS, *inter alia* in the Bakalskoye Lake (Sadogurskiy, 2010).

Potamogetonaceae Bercht. et J. Presl

Stuckenia Börner

***Stuckenia pectinata* (L.) Börner** [*Potamogeton pectinatus* L.]: LS (Sadogurskiy, 2010).

Zannichellia L.

***Zannichellia palustris* subsp. *major* (Hartm.) Ooststr. et Reichg.** [*Z. major* Boenn.]. ▲❖: LS (Sadogurskiy, 2010).

Zosteraceae Dumort., nom. cons.

Zostera L.

***Zostera marina* L.** ●★✪▲❖: MS (Evstigneeva & Tankovskaya, 2011 ; Sadogurskiy, 2010).

***Zostera noltei* Hornem.** [*Z. minor* (Cavol.) Nolte ex Rchb.; *Z. nana* Roth., nom. illeg.]. ★✪▲❖: LS, MS (Evstigneeva & Tankovskaya, 2011 ; Sadogurskiy, 2010).

Thus, the macroflora of marine and lagoonal water areas within the boundaries of the territorial-aquatic complex of the Bakalskaya Spit includes 64 species (hereinafter, intraspecific taxa are taken into account as well): Chlorophyta, 23 (35.94 %); Ochrophyta, 5 (7.81 %); Rhodophyta, 31 (48.44 %); and Tracheophyta, 5 (7.81 %). The smallest number of species was recorded for inland water bodies with the highest mineralization and water temperature; the minimum number (*Cladophora siwaschensis* and *Ruppia maritima* alone) was registered in the Bakalskoye Lake and in shallow water bodies between relatively young swells of the eastern branch of the spit. In the water bodies of the older part of this branch (closer to the lake), with greater depth and lower temperature and mineralization, the species composition was more diverse (6 species). In the lagoons of the distal spit part – with a rise in the sea effect and a decline in temperature and mineralization – the number of species from the western, most isolated water basin to the eastern increased 14 to 34. In total, in the network of semi-isolated lagoonal water bodies, the level of species diversity of macrophytes was lower (37 species) but comparable with that in adjacent marine areas (45 species).

In coastal-marine biotopes, macroalgae develop mainly epiphytically. The richest species composition of epiphytes (and some endophytes) was noted for *Phyllophora crispa* thalli; together with animal population, the total weight of fouling could exceed the weight of the phorophyte. In this regard, the role of mollusc shells and seagrass shoots is lower here. In lagoons, on the contrary, this is the main substrate for macroalgae development. *Cladophora siwaschensis* should be mentioned as well: in the central Bakalskoye Lake, it forms free-floating accumulations which along the periphery are attached to bottom sediments of self-depositing salt.

The taxonomic structure of the macrophyte flora includes 4 divisions, 5 classes, 16 orders, 26 families, and 37 genera (Table 1). If compared with similar structures of Crimean territorial-aquatic nature reserves (being a fairly large object, the landscape park approaches them in terms of its area), then, quite expectedly, the greatest similarity can be traced to indicators established for the Lebyazhye Islands (Sadogurskiy et al., 2019). Interestingly, it can be traced despite the difference in the total number of species (which is due to a lesser degree of study as well) and the absence of charophytes. This is explained not so much by geographical proximity, but by an almost identical set of coastal-marine biotopes, including a series of lagoons isolated from the sea to varying degrees.

Table 1. Taxonomic structure of the macrophyte flora in the coastal-marine and lagoonal water areas of the territorial-aquatic complex of the Bakalskaya Spit

Division	Taxa number by divisions, units / %				
	Classes	Orders	Families	Genera	Species
Chlorophyta	1 / 20.0	4 / 25.0	6 / 23.1	9 / 24.3	23 / 35.9
Ochrophyta	1 / 20.0	3 / 18.8	5 / 19.2	5 / 13.5	5 / 7.8
Rhodophyta	2 / 40.0	8 / 50.0	12 / 46.2	19 / 51.4	31 / 48.4
Tracheophyta	1 / 20.0	1 / 6.3	3 / 11.5	4 / 10.8	5 / 7.8
In total	**5 / 100.0**	**16 / 100.0**	**26 / 100.0**	**37 / 100.0**	**64 / 100.0**

Analysis of the ecological and floristic groups shows that oligosaprobes make up more than half of the species list (Fig. 2).

By the vegetation period duration, short-vegetative (annual and summer seasonal) species prevail. Out of halobity groups, prevalence of marine and brackish-marine species is registered. Among phytogeographic groups united in two complexes, the warm-water one prevails. At the same time,

the contribution of cosmopolitan species characterized by eurybiontity was quite large there, the same as near the Lebyazhye Islands. In terms of a set of ecological and floristic characteristics, the flora of the studied object is also very similar to that of the Lebyazhye Islands (Sadogurskiy et al., 2019). Of the obvious differences, we should note the absence of winter seasonal species (which are not uncommon even in summer) and freshwater ones. The latter, together with the absence of charophytes, is due to the following fact: during the observation periods, there were no desalinated coastal-marine and lagoonal water areas on the spit (importantly, to date, those are no longer present near the Lebyazhye Islands as well).

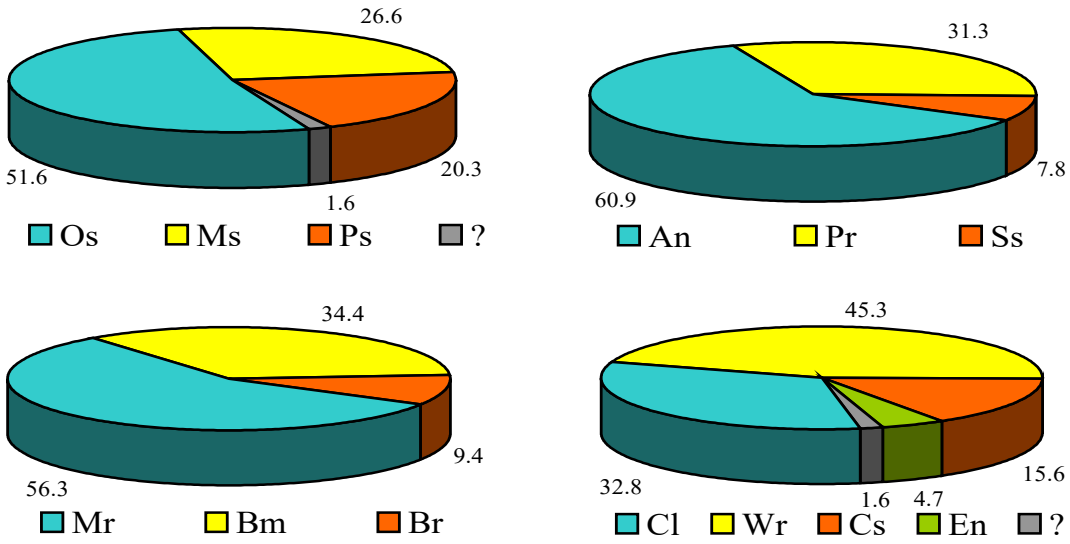

Fig. 2. Ecological and floristic characteristics of the macrophyte flora in the coastal-marine and lagoonal water areas of the territorial-aquatic complex of the Bakalskaya Spit (ratios of groups are shown in %). Saprobiological groups: Os, oligosaprobes; Ms, mesosaprobes; and Ps, polysaprobes. Groups in terms of vegetation period duration: An, annual; Pr, perennial, and Ss, summer seasonal. Halobity: Mr, marine; Bm, brackish-marine; and Br, brackish. Phytogeographic groups: Cl, cold-water; Wr, warm-water; Cs, cosmopolitans; and En, endemics. ? denotes lack of data

The rare fraction of the macrophyte flora in the territorial-aquatic complex of the Bakalskaya Spit includes 21 species (32.81 %). Within its boundaries, there are coastal-marine biotopes which are subject to special protection in accordance with the EU Habitats Directive – Council Directive 92/43/EEC of 21 May, 1992 (biotope codes: 1110, sandbanks which are slightly covered by sea water all the time; 1150, coastal lagoons; and 1160, large shallow inlets and bays) (Interpretation Manual of European Union Habitats, 2007).

Considering high regional and international conservation status of the spot and significant diversity and rarity of its phytobiota, ten years ago we already recommended to include it in the national natural park as an integral territorial-aquatic core, along with the “Lebyazhye Islands” reserve and “Karkinitsky” nature reserve (Sadogurskiy, 2009, 2010 ; Sadogurskiy et al., 2009). The national natural park was expected to be one of the key objects of ecological networks of various ranks in the Northern Black Sea Region: it was supposed to increase the area of absolutely protected territories and ensure the continuity of the international Sea of Azov–Black Sea eco-corridor. Unfortunately, these recommendations have not been implemented, but it is gratifying that those were updated (Milchakova & Alexandrov, 2018). Considering the anthropogenic disturbance of the lithodynamic balance which, apparently, resulted in the transformation of all the components of the protected territorial-aquatic complex,

it is necessary to carry out a new comprehensive survey, *inter alia* a large-scale hydrobotanical study, with re-sampling at previously investigated points (at least, at those preserved on the map). But even in its current state, with the available level of information, the object meets the criteria and deserves to be included in the Emerald Network – as part of the Pan-European Ecological Network. It is aimed at uniting and effective management of the spots that are of particular value for the conservation of biota species and natural biotopes (Area of Special Conservation Interest, ASCI) in Eastern Europe.

Conclusion. After the nomenclatural and taxonomic revision, 64 macrophyte species were recorded in the marine and lagoonal water areas of the protected territorial-aquatic complex of the Bakalskaya Spit: Chlorophyta, 23; Ochrophyta, 5; Rhodophyta, 31; and Tracheophyta, 5. The taxonomic structure of the macrophyte flora includes 5 classes, 16 orders, 26 families, and 37 genera. Almost one third of the floristic list belongs to the rare fraction, and biotopes formed by macroalgae and seagrasses are subject to special protection in accordance with international environmental documents. Considering high sozological significance of the territorial-aquatic complex and accelerating degradation of the spit, urgent measures are required. First of all, it is necessary to eliminate one of the key threats – to stop sand mining. It would be relevant to expand the area of the territorial-aquatic complex and to raise its conservation status – either as an independent object or as part of a larger object in the rank of a national park or reserve, since those have real management and security structures. Moreover, it is advisable to include the area in the Emerald Network, since this will provide new opportunities and additional arguments for its protection and preservation. The results of this publication are the basis for further hydrobotanical studies with re-sampling: this will help in revealing the scale and vector of alterations in the composition and structure of macrophytobenthos and the entire ecosystem.

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РЕВИЗИЯ МАКРОФИТОБЕНТОСА ЗАПОВЕДНОГО ТЕРРИТОРИАЛЬНО-АКВАЛЬНОГО КОМПЛЕКСА БАКАЛЬСКОЙ КОСЫ (ЧЁРНОЕ МОРЕ)

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Территориально-аквальный комплекс Бакальской косы, расположенной на северо-западе Крымского полуострова, представляет собой уникальный природный объект, который отличается высоким разнообразием биоты и ландшафтов. Несмотря на то, что он имеет статус ландшафтного парка, его компоненты претерпевают существенную антропогенную трансформацию. Структурный и функциональный фундамент большинства прибрежно-морских и лагунных биотопов комплекса формирует макрофитобентос. Однако информация о видовом составе и систематической структуре их флоры была неполной и не учитывала номенклатурно-таксономические изменения, принятые в фикологии в последние годы. В связи с этим по результатам собственных исследований выполнена ревизия флоры макрофитов морских и лагунных акваторий в границах заповедного территориально-аквального комплекса. Установлено, что она включает 64 вида: Chlorophyta — 23, Ochrophyta — 5, Rhodophyta — 31, Tracheophyta — 5. Таксономическая структура включает 5 классов, 16 порядков, 26 семейств, 37 родов. Анализ соотношения эколого-флористических группировок показал, что 51,6 % составляют олигосапробы. Преобладают коротковегетирующие виды (68,7 %). Среди галобных группировок доминируют морские и солоноватоводно-морские виды (суммарно 90,7 %). Преобладает тепловодный комплекс (45,3 %), но достаточно велик вклад видов-космополитов, отличающихся эврибионтностью (15,6 %). Раритетная фракция насчитывает 21 вид (32,8 %); макрофиты формируют основу биотопов, подлежащих особой охране согласно Директиве ЕС о местообитаниях (Council Directive 92/43/EEC; коды 1110, 1150 и 1160). С учётом высокого созологического значения территориально-аквального комплекса необходимо прекратить промышленную

добычу песка (она представляет основную угрозу и является трансформирующим фактором), а также увеличить площадь комплекса и повысить заповедный статус (либо как самостоятельного объекта, либо в составе крупного национального парка). Целесообразно включение территориально-аквального комплекса в структуру экологической сети Emerald для получения дополнительных возможностей для его защиты и сохранения. Представленные результаты являются основой для повторных гидроботанических исследований, которые позволят выявить масштаб и вектор изменений в составе и структуре макрофитобентоса и экосистемы в целом.

Ключевые слова: Чёрное море, Крымский полуостров, Бакальская коса, макрофитобентос, видовой состав, ревизия