Original paper

Distribution of Bottom Vegetation in the Eastern Part of Sevastopol Bay

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Abstract
The paper studies the current state of macrophytobenthos in the eastern part of Sevastopol Bay. The study collected information on the distribution of key macrophyte species and compared changes in their contribution for over 40 years. Hydrobotanical surveys were performed using standard methodology on the same profiles during the summers of 1977, 2017, and 2024. *Gongolaria barbata* and *Ericaria crinita* were found to dominate the bottom vegetation composition at present (2017 and 2024), and green algae (*Cladophora laetevirens, Ulva intestinalis, U. rigida*) were also abundant. In 2024, almost all profiles at 0.5 m depth showed a decrease in total macrophyte biomass and the proportion of *G. barbata* and *E. crinita* due to the damaging effects of the extreme storm. However, at depths of 1 and 3 m, quantitative macrophytobenthos biomass values were about twice as high as those in 2017. A comparative analysis of macrophytobenthos distribution for almost half a century showed that the most significant transformation of the vegetation component was observed in the eastern part of the bay, where higher aquatic vegetation (*Zostera marina, Z. noltei, Stuckenia pectinata, Zannichellia* sp., *Ruppia* sp.) was replaced by thickets of perennial algae (*G. barbata* and *E. crinita*). These changes are probably due to increase in water salinity in the Chyornaya River estuarine zone and changes in the intensity of longshore sediment fluxes in the water area. In the eastern part of the bay, a change in the predominance of *Ulva species* to *G. barbata* and *E. crinita* was recorded during this period, possibly indicating some improvement in environmental quality. The study results can be applied during monitoring of the marine environment state in the bay, as well as for developing coastal protection measures.

Keywords: macrophytobenthos, *Gongolaria barbata*, *Ericaria crinita*, *Ulva rigida*, *Cladophora laetevirens*, Black Sea, Sevastopol

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Распределение донной растительности в восточной части Севастопольской бухты

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Аннотация

Представлены результаты исследования современного состояния макрофитобентоса в восточной части б. Севастопольской. В ходе изучения собраны сведения о распределении ключевых видов макрофитов и проведен сравнительный анализ изменений их вклада в общую биомассу макрофитобентоса за период более 40 лет. Гидроботанические исследования выполняли согласно стандартной методики по одним и тем же разрезам в летний период 1977, 2017 и 2024 гг. Выявлено, что в настоящее время (2017 и 2024 гг.) в составе донной растительности доминируют *Gongolaria barbata* и *Ericaria crinita*, также обильно представлены зеленые водоросли (*Cladophora laetevirens, Ulva intestinalis, U. rigida*). В 2024 г. почти на всех разрезах на глубине 0.5 м отмечено снижение общей биомассы макрофитов, доли *G. barbata* и *E. crinita* вследствие разрушительного воздействия экстремального шторма. При этом на глубине 1 и 3 м количественные показатели биомассы макрофитобентоса были примерно вдвое выше, чем в 2017 г. Сравнительный анализ распределения макрофитобентоса за почти полувековой период показал, что наиболее существенная трансформация растительной компоненты произошла в кутовой части бухты, где произрастающая здесь ранее высшая водная растительность (*Zostera marina, Z. noltei, Stuckenia pectinata, Zannichellia* sp., *Ruppia* sp.) сменилась зарослями многолетних водорослей (*G. barbata* и *E. crinita*). Эти изменения, вероятно, можно объяснить повышением солености воды в приустьевой зоне р. Черной, а также изменением интенсивности вдольбереговых потоков наносов в акватории. В восточной части бухты за этот период зарегистрирована смена доминантных видов водорослей: вместо представителей рода *Ulva* начали преобладать виды *G. barbata* и *E. crinita*, что, возможно, свидетельствует об улучшении качества среды. Результаты работы могут быть применены при мониторинге состояния морской среды в бухте, а также при планировании охранных мероприятий прибрежной зоны моря.

Ключевые слова: макрофитобентос, *Gongolaria barbata, Ericaria crinita, Ulva rigida, Cladophora laetevirens,* Черное море, Севастополь

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Introduction

Macrophytobenthos plays a leading role in the stabilization of coastal geosystems by providing a range of ecosystem functions and services [1–3]. It is well established that benthic vegetation actively responds to environmental changes. Consequently, changes in the species composition and abundance of macrophytes enable phytobenthos to serve as a unique indicator of the ecological condition of coastal waters.

The depth distribution of benthic vegetation is determined by the photic zone's boundary, where algal photosynthesis takes place, primarily influenced by water clarity. Consequently, investigating macrophytobenthos is increasingly critical in waters heavily affected by economic activities.

The eastern part of Sevastopol Bay, subjected to long-term anthropogenic impact, was selected as a model region. Notably, significant volumes of wastewater are discharged into the bay [4–6]. The studied water area experiences active shipping, dredging, and other hydraulic engineering activities, leading to elevated pollutant levels in the water [7, 8]. Numerous contemporary studies have focused on this part of the bay, examining its hydrological and hydrochemical parameters [9, 10], the lithological composition of bottom sediments [11–14], and the quantitative characteristics of meio- and macrozoobenthos communities [15–18]. However, research on benthic vegetation remains limited [19–22].

This study aims to evaluate the current state of macrophytobenthos in the eastern part of Sevastopol Bay and to characterize the interannual dynamics of the distribution of dominant macrophyte species from 1977 to 2024.

Materials and methods of research

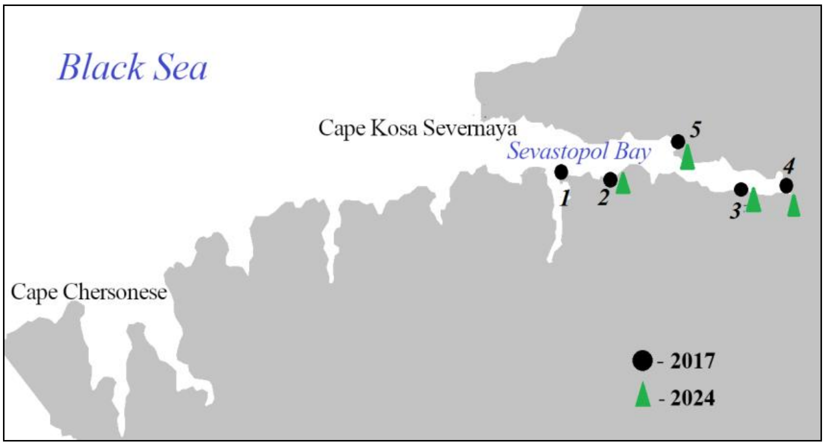
The eastern part of Sevastopol Bay has an average depth of 13.1 m, with maximum depths along the fairway reaching 19.5 m. The sea area is characterized by a complex hydrodynamic regime driven by two opposing currents: one flowing westward from the Chyornaya River and another eastwards from the open sea. The ecological condition of the waters in this region is further influenced by water exchange with Yuzhnaya Bay [4, 6, 23].

The apex of the bay is shallow, with an average depth of 4.7 m and a maximum depth of 10.8 m [7]. This semi-enclosed region of the bay is influenced by the Chyornaya River, which causes desalination of surface waters and delivers significant amounts of allochthonous organic and mineral substances, including nutrients and pollutants, through river runoff [23].

In recent decades, the area along the eastern shore of the bay has undergone significant transformation. Coastal fortifications, breakwaters, and piers have been constructed, altering the landscape. The mouth of the Chyornaya River has been modified to accomodate the Sevastopol seaport basin, while the floodplain now hosts a pier and the Chyornaya River shipping canal [24].

Phytobenthos samples were collected in Sevastopol Bay in July 2017 and 2024 and were used as study material. The samples were obtained using vertical profiles by a diver at depths of 0.5, 1, 3 and 5 m, up to the boundary of macrophyte distribution, with quadruplicate sampling conducted within 25 × 25 cm survey plots [1]. A total of 96 quantitative samples were collected and analysed (Table 1). The aim of the work was to study the distribution and biomass of macrophytobenthos in the coastal zone of the eastern part of the bay (profiles *1*–*5*) (Fig. 1). A portable Oregon 650 GPS receiver was used to determine the coordinates of the profiles. The results are presented in Table 1.

The benthic vegetation was characterized using the dominance classification proposed by A. A. Kalugina-Gutnik [2]. To analyze the structure of phytocommunities, the Shannon species diversity index (*H*) was calculated. Algal species identification followed the guide [3], incorporating the latest nomenclature revisions [4]. Data on the composition and distribution of benthic vegetation in the bay for 1977 were obtained by one of the authors, who participated in sample collection during the summer period in the study areas and analyzed them using a similar method.



F i g . 1 . Schematic map of hydrobotanical profiles in the western part of Sevastopol Bay: *1* – Cape Pavlovsky; *2* – Ushakov Beam; *3* – thermal station; *4* – Inkerman; *5* – Gollandia

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[1] Kalugina-Gutnik, A.A., 1969. [Study of the Black Sea Bottom Vegetation Using Lightweight Diving Equipment]. In: Academy of Sciences of the USSR, 1969. [*Marine Underwater Studies*]. Moscow: Nauka, pp. 105–113 (in Russian).

[2] Kalugina-Gutnik, A.A., 1975. [*Phytobenthos of the Black Sea*]. Kiev: Naukova Dumka, 248 p. (in Russian).

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[4] Available at: http://www.algaebase.org [Accessed: 22 August 2025].

T a b l e 1 . Coordinates and depth range of hydrobotanical profiles, number of sampled macrophytobenthos in Sevastopol Bay

Profile	Coordinates		Depth, m				Number of samples
	°N	°E	0.5	1	3	5	
1	44°36′57″	33°32′4″	+/0	+/0	+/0	+/0	16
2	44°36′57″	33°32′42″	+/+	+/+	+/+	+/–	28
3	44°36′37″	33°34′57″	+/+	+/+	–	–	16
4	44°36′30″	33°36′05″	+/+	+/+	–	–	16
5	44°37′23″	33°33′39″	+/+	+/+	–/+	–	20

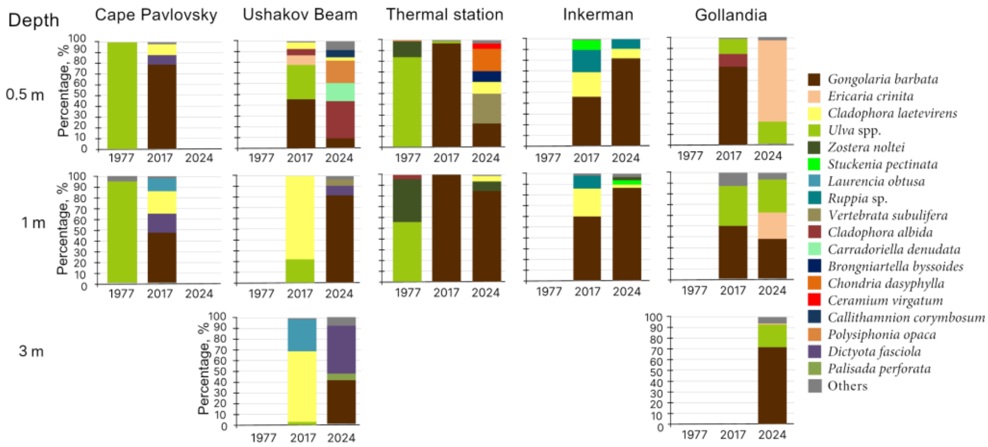
Note: Numerator – samples taken in 2017; denominator – samples taken in 2024. Symbol "+" denotes presence of bottom vegetation, and symbol "–" denotes its absence, "0" – no samples were taken.

Results and discussion

Analysis of the collected data revealed that benthic vegetation in the eastern part of Sevastopol Bay is primarily concentrated at depths of 0.5 to 3 m, and in the apex at depths of 0.5 to 1 m. In the early 2000s, O. G. Mironov and colleagues observed dark gray and black silts at depths exceeding 5 m in this region, often characterized by hydrogen sulfide and fuel oil odors [11]. Pollution of water areas with organic matter, oil and its derivatives – originating from river runoff, industrial, agricultural and domestic waste – leads to a degraded oxygen regime, significant siltation of sediments and, consequently, the decline of landscape and biological diversity [6, 13–15, 25].

Distribution of benthic vegetation in the eastern part of the bay in 2017 and 2024

Profile *1*. In 2017, the total macrophyte biomass (TMB) along this profile decreased by 1.5 times as depth increased from 0.5 to 1 m, while the proportion of the dominant species declined by approximately half (Table 2). At these depths, *Gongolaria barbata* (Stackhouse) Kuntze (= *Cystoseira barbata*) was the dominant species (Fig. 2). The macrophytobenthos at these depths included *Dictyota fasciola* (Roth) Howe (9–18% of TMB) and *Cladophora laetevirens* (Dillw.) Kütz. (10–21% of TMB) (Fig. 2). The contribution of epiphytes at depths of 0.5–1 m was minimal (Table 2). Notably, at a depth of 5 m, benthic vegetation was nearly absent, with *C. laetevirens* (60%) and *Ulva rigida L*. (17%) as the primary contributors to TMB. *Zostera marina* L. was occasionally observed within the community at this depth. The species diversity index increased with depth from 1.07 to 2.07, indicating a more complex community structure.



F i g. 2. Interannual and spatial dynamics of species composition of dominant macrophytes

Profile *2.* In 2017, at a depth of 0.5 m in this profile, over 50% of the TMB was contributed by *G. barbata* and *Ericaria crinita* (Duby) Molinari & Guiry (= *Cystoseira crinita*) (Table 2). At this depth, green algae were abundant within the microphytobenthos, including *U. rigida* (32%), *C. laetevirens* (6%), *C. albida* (Nees) Kütz. (6% of TMB) (Fig. 2). At depths of 1–3 m, *C. laetevirens* was dominant (Fig. 2). Within this depth range, TMB decreased by 1.4 times, while the proportion of the dominant species increased to 66–78% (Table 2). *U. rigida* was also present in the community at these depths (3–22% of TMB) (Fig. 2). Notably, at a depth of 3 m, the lithophytic form *Laurencia obtusa* (Huds.) J. V. Lamour was abundant, contributing 30% of TMB (Fig. 2). At a depth of 5 m, TMB was low, with *C. albida* dominating among the algae, accounting for 94% of TMB (Table 2). At this depth, *C. laetevirens* was recorded within the microphytobenthos, contributing 3% of TMB (Fig. 2). The contribution of epiphytic algae to TMB along profile 2 was minimal, ranging from 0 to 5% (Table 2). The species diversity index decreased approximately fivefold with increasing depth, from 2.00 to 0.43 (Table 2).

In 2024, benthic vegetation was recorded at a depth of up to 3 m along profile *2*. At a depth of 0.5 m, the TMB was nearly an order of magnitude lower than in 2017 (Table 2). At this depth, only seedlings of *G. barbata* and *E. crinita* were observed, replacing their previously dominant thickets and contributing just 9% of the TMB (Fig. 2). The microphytobenthos was dominated by *C. albida* (35%), *Polysiphonia opaca* (C. Ag.) Moris et De Notaris (21%), *Carradoriella denudata* (Dillwyn) Savoie et G. W. Saunders (17%), *Callithamnion corymbosum* (Smith) Lyngb. (7% of TMB) (Fig. 2). No epiphytic algae were recorded. At depths of 1–3 m, TMB was two to three times higher than in 2017 (Table 2). *G. barbata* dominated at these depths, although its proportion decreased by half from 1 to 3 m, while the contribution of *D. fasciola* increased from 9 to 45% of TMB (Fig. 2). The contribution of epiphytes ranged from 6 to 7% of TMB. Notably, during the study period, T a b l e 2. Distribution of dominant macrophyte and epiphyte species and diversity index *H* in Sevastopol Bay in 1977, 2017 and 2024 (by depths)

Profile	Depth, m	Year	Total biomass of macrophytes, $g \cdot m^{-2}$	Proportion, %		*H*
				Gongolaria barbata, *Ericaria crinita*	Epiphytic	
1	0.5	1977	858.3 ± 45.7	0	0	0.67
		2017	1783.8 ± 837.9	79	1	1.07
	1	1977	1171.7 ± 207.8	0	0	1.18
		2017	1192.5 ± 189.9	47	2	1.96
	3	1977	145.2 ± 37.9	0	0	0
	5	2017	16.1 ± 2.5	0	5	2.07
2	0.5	2017	3333.2 ± 603.6	55	5	2.00
		2024	357.2 ± 93.5	9	0	2.91
	1	2017	1332.3 ± 192.3	0	0	0.77
		2024	3782.4 ± 786.9	82	7	1.05
	3	2017	980.0 ± 326.9	0	2	1.13
		2024	1834.6 ± 247.2	41	6	1.77
	5	2017	49.5 ± 5.16	0	0	0.43
3	0.5	1977	231.6 ± 55.8	0	0	1.42
		2017	4042.8 ± 1738.5	97	0	0.24
		2024	1394.8 ± 198.5	22	0	2.60
	1	1977	353.8 ± 96.2	0	0	1.74
		2017	1957.4 ± 665.0	100	0	0.05
		2024	3308.8 ± 976.9	85	5	0.80
4	0.5	2017	1738.0 ± 540.5	46	1	4.27
		2024	4340.7 ± 1067.3	82	0	0.89
	1	2017	1467.4 ± 493.8	60	5	1.03
		2024	2811.4 ± 273.5	87	0	0.88
5	0.5	2017	4532.2 ± 456.7	73	14	1.23
		2024	3888.4 ± 1158.5	76	1	1.09
	1	2017	3146.3 ± 336.9	92	5	0.69
		2024	7307.7 ± 1754.1	94	0	0.68
	3	2024	1647.8 ± 583.2	73	4	1.48

Note: Data for 1977 are taken from the article by A. A. Kalugina-Gutnik [26].

the species diversity index increased across all studied depths, indicating a more complex algal community structure (Table 2).

Profile *3.* In 2017, the TMB decreased twofold as depth increased from 0.5 to 1 m (Table 2). At these depths, *G. barbata* was dominant, with its proportion reaching maximum values (Fig. 2). U. *rigida* and C. *laetevirens* were observed sporadically within the phytocommunity. No epiphytic algae were recorded. Low values of the species diversity index *H* indicated a homogeneous phytocommunity structure, dominated by the primary species (Table 2).

In 2024, along profile *3,* the TMB at a depth of 0.5 m decreased threefold, while at a depth of 1 m, it doubled compared to 2017 values (Table 2). *G. barbata* remained dominant at these depths, although its proportion decreased, particularly at 0.5 m, where lithophytic forms, including *Vertebrata subulifera* (C. Ag.) Kütz. (28%), *Brongniartella byssoides* (Good. et Wood.) F. Schmitz (10%), *Chondria dasyphylla (*Woodw.) C. Ag. (21%), *C. laetevirens* (11%), and *Ceramium virgatum* Roth (5% of TMB), were prominent (Fig. 2). Notably, at a depth of 1 m, where *G. barbata* dominated, *Zostera noltei* Hornem. (9% of TMB) was observed in patches with a silty-sandy substrate. Epiphytic algae were represented by *C. laetevirens.* A simplification of the algal community structure with increasing depth was confirmed by a more than threefold decrease in the species diversity index (Table 2).

Profile *4.* In 2017, along this section, the TMB decreased slightly as depth increased from 0.5 to 1 m, while the proportion of the dominant species (*G. barbata*) increased (Table 2). At these depths, the microphytobenthos included green algae (*C. laetevirens* (23–26%) and *U. rigida* (1–2%)) and higher aquatic vegetation represented by the genera *Ruppia, Stuckenia, and Zannichellia* (12–30% of the TMB) (Fig. 2). The contribution of epiphytes increased with depth from 1 to 5% of TMB. Notably, the species diversity index reached its maximum at a depth of 0.5 m, indicating a polydominant community structure (Table 2).

In 2024, along profile *4,* the depth distribution of macrophytobenthos remained consistent with previous years. The TMB decreased by 1.5 times as depth increased from 0.5 to 1 m, while its values were approximately twice as high as in 2017 (Table 2). *G. barbata* dominated at these depths. The macrophytobenthos included *C. laetevirens* (3–9%) and the seagrasses *Ruppia spiralis L*., *Stuckenia pectinate* (L.) Börner (formerly *Potamogeton pectinatus),* and Z. *noltei* (7–9% of TMB) (Fig. 2). No epiphytic algae were recorded. The species diversity index varies within a narrow range (Table 2).

Profile *5.* In 2017, along this profile, the TMB decreased by 1.4 times as depth increased from 0.5 to 1 m (Table 2). *G. barbata* dominated at these depths, contributing 73 to 92% of the TMB. *U. rigida* and *C. albida* were also present, with their contribution decreasing with depth from 14 to 6% and from 12 to 1% of the TMB, respectively (Fig. 2). Notably, as depth increased, the proportion of epiphytes decreased nearly threefold, the phytocommunity structure simplified, and the species diversity index decreased by half (Table 2).

In 2024, along profile *5*, benthic vegetation was recorded at depths up to 3 m. The highest TMB was observed at a depth of 1 m; at 0.5 m, TMB was approximately half as high, and at 3 m, it was four times lower (Table 2). *E. crinita* and *G. barbata* dominated at all studied depths, contributing 73 to 94% of the TMB. The remaining TMB was mainly attributed to species of the genus *Ulva* (Fig. 2). Notably, at a depth of 0.5 m, the TMB values and the proportions of dominant species were comparable to those in 2017, while at 1 m, TMB in 2024 was twice as high as in 2017, although the proportion of dominant species remained similar (Table 2). Epiphytic algae were minimally represented (0–4% of the TMB). The species diversity index ranged from 0.68 to 1.48, indicative of an algal community dominated by a few key species.

Over the past seven years (from 2017 to 2024), the depth distribution of macrophytobenthos in the eastern part of Sevastopol Bay underwent changes, while the species composition of dominant macrophytes remained relatively stable. Notably, in 2024, at all profiles except profile *4*, the TMB at a depth of 0.5 m was lower, while at depths of 1 and 3 m, it was approximately twice as high as in 2017. The significant decrease in TMB at 0.5 m can probably be explained by the destructive impact of an extreme storm in autumn 2023 [27]. Specifically, at profile *2* in 2024, TMB was nearly ten times lower than in 2017 (Table 2). At this depth, only seedlings of *G. barbata* and *E. crinita* were observed, with their proportion decreasing from 55 to 9% of TMB over the study period (Fig. 2). At profile *3*, at a depth of 0.5 m, TMB decreased threefold compared to 2017 values (Table 2). Here, isolated thalli of *G. barbata* were recorded, with its proportion decreasing from 97 to 22% of TMB during this period (Fig. 2). At profile *5*, over the seven-year period, the decrease in TMB at 0.5 m was minimal, while the proportion of *G. barbata* ranged from 73 to 76% of TMB (Table 2). Notably, in 2024, at all studied profiles at a depth of 0.5 m, the benthic vegetation was dominated by annual algae (*Cladophora albida*, *Carradoriella denudata*, *Callithamnion corymbosum, Vertebrata subulifera, Brongniartella byssoides, Chondria dasyphylla, Ceramium virgatum),* further indicating the influence of the autumn storm.

A comparative analysis of the composition and quantitative indicators of macrophytobenthos for 2017–2024 at depths of 1 and 3 m revealed several differences. At profile *2* in 2017, *C. laetevirens* dominated the 1–3 m depth range, contributing from 66 to 78% of the TMB, while *G. barbata* and *E. crinita* were absent. In contrast, in 2024, *G. barbata* contributed 41–82% of TMB at these depths (Fig. 2). At profile *3*, at a depth of 1 m, the proportion of *G. barbata* was consistently high, ranging from 85 to 100% of TMB (Fig. 2). At profile *4*, the contribution of *G. barbata* increased from 46–60 to 82–87%, while the proportion of seagrasses decreased from 12–30 to 7–9% of TMB during this period (Fig. 2). Notably, at profile *5* in 2024, benthic vegetation was recorded up to a depth of 3 m, whereas in 2017, macrophytobenthos was observed only up to 1 m (Table 2). During the study period, the combined proportion of *G. barbata* and *E. crinita* at a depth of 1 m remained high, varying slightly from 92 to 94% of TMB (Fig. 2).

Analysis of spatio-temporal changes in macrophytobenthos over nearly half a century revealed significant transformations. According to the hydrobotanical survey of Sevastopol Bay conducted in 1977 by A. A. Kalugina-Gutnik, species of the genus *Ulva* dominated on hard substrates at depths of 0.5–5 m in the eastern part of the bay, while *G. barbata* and *E. crinita* were present in the macrophytobenthos at greater depths [26]. Notably, at the beginning of the 20th century, S.A. Zernov (1913) reported "pure" thickets of *G. barbata* and *E. crinita* in this region [5)]. According to a number of authors, for over a century, clusters of eelgrass (*Zostera marina* and *Z. noltei)* have been observed on soft substrates at the apex of the bay (its top) [5), 6)]. In 1977, species of the genus *Ulva* were also recorded as part of the higher aquatic vegetation in this area [26].

According to A. A. Kalugina-Gutnik's 1977 survey, along the coastline at profiles *1–3* at a depth of 0.5 m, species of the genus *Ulva* dominated, contributing 85–100% of the TMB (Fig. 2) [26]. Subsequently, I. K. Evstigneeva and I. N. Tankovskaya reported that in 2003–2005 *G. barbata* and *E. crinita* began to appear at this depth in the waters of profile *2* [21]. Studies conducted in 2017 at profiles *1–3* at a depth of 0.5 m confirmed the dominance of *G. barbata* and *E. crinita*, with biomasses of 1412.4 ± 543.9, 1818.9 ± 476.2, and 3921.9 ± 776.2 $g \cdot m^{-2}$, respectively (79, 55, and 97% of the TMB).

At profile *1* in 1977, benthic vegetation extended to a depth of 3 m, with macrophytobenthos consisting almost entirely of species of the genus *Ulva* (95–100% of the TMB). By 2017, the vertical distribution of macrophytes had expanded to a depth of 5 m, with *G. barbata* dominating at 1 m (47%) and species of the genus *Cladophora* predominating at depths of 3–5 m (60% of the TMB) (Fig. 2).

At profile *3* in 1977, *Zostera noltei* was noted at a depth of 1 m, in addition to species of the genus *Ulva*. It is notable that, with an increase in depth from 0.5 to 1 m, the proportion of *Ulva* species decreased from 85 to 56 %, while the proportion *of Z. noltei* increased from 15 to 40% of the TBM (Fig. 2) [26]. In 2017, the TBM index significantly exceeded the 1977 values, which is associated with the formation of nearly monodominant stands *of G. barbata* (97–100% of the TBM) (Fig. 2).

Thus, an analysis of literary sources and our own data on the distribution of macrophytobenthos in the eastern part of Sevastopol Bay over nearly half a century shows that its distribution and composition have changed significantly. The most significant transformation of the plant component occured in the corner of the bay, where higher aquatic vegetation (*Zostera marina*, *Z. noltei*, *Stuckenia pectinata*, *Zannichellia* sp., *Ruppia* sp.) previously grew, but was replaced by thickets of perennial algae (*G. barbata* and *E. crinita)*. These changes can probably be explained by an increase in water salinity in the estuary zone of the Chernaya River [23].

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5) Zernov, S.A., 1913. [On Studying Life of the Black Sea]. In: IAS, 1913. *Zapiski Imperatorskoy Akademii Nauk*. Saint Petersburg: Imperatorskaya Akademiya Nauk. Vol. 32, iss. 1, 304 p. (in Russian).

6) Kalugina-Gutnik, A.A., 1974. [Bottom Vegetation of Sevastopol Bay]. In: AS USSR, 1974. *Biologiya Morya*. Kiev: Naukova Dumka. Iss. 32, pp. 133–164 (in Russian).

It was concluded in [23] that there has been a steady trend toward increased water salinity in both the surface and bottom waters in the eastern part of the bay in recent decades. At a distance of about 1000 m from the river mouth, the salinity of the water was 17 ‰, during the low-water period, this figure reached 17.6–17.9 ‰ throughout the entire corner of the bay [23]. Second, the construction of the northern and southern parts of the pier, piers and berths, as well as intensive dredging, caused changes in coastal sediment flows and decreased the degree of abrasion throughout the bay [28]. This may have led to a change in the composition of bottom sediments. In the corner part of the bay, at profiles *3* and *4*, where seagrasses previously grew on soft substrates, bedrock has become exposed, providing a substrate for algae attachment.

The transformation of the macrophytobenthos in the eastern part of the bay is characterized by a change in dominant species. The *Ulva* genus, which was previously predominant, is being replaced by *G. barbata* and *E. crinita*, whose population continues to grow.

Over the past two centuries, Sevastopol Bay has experienced intense anthropogenic impact, evidenced by increased concentrations of nutrients in the water, reaching levels 1–2 orders of magnitude higher than in the open waters of the Black Sea [4–6, 10, 23]. The elevated concentrations of pollutants in the bay, including its eastern sector, have significantly impacted biotic components, particularly the structure of benthic phytocenoses. At all profiles of the eastern part of the bay, green algae were abundant, particularly *C. laetevirens*, *Ulva intestinalis L.*, and *U. rigida*. These algae are indicators of eutrophication in the water. These algae, as well as *Callithamnion corymbosum* and *Ceramium virgatum*, grow in polluted water from domestic and industrial wastewater.

In recent years, considerable attention has been given to environmental protection measures aimed at reducing the inflow of pollutants into Sevastopol Bay. These measures undoubtedly impact the ecological situation in the bay. For example, L. V. Malakhova with colleagues demonstrated that under current conditions, lower concentrations of polychlorinated biphenyls (PCB 5) were found in the top layer of bottom sediments than at depths of 5 to 20 cm, indicating a decrease in anthropogenic pollution of the bay [12]. Perhaps the improvement in environmental quality has manifested itself in a change in the dominant macrophyte species. Thus, in 2024, *G. barbata* and *E. crinita* experienced mass growth in the studied part of the bay alongside *Dictyota fasciola*, *Laurencia obtusa*, *Palisada perforata* (Bory) K.W. Nam., and *Vertebrata subulifera*. These species usually inhabit areas with a relatively low degree of eutrophication [2)].

Conclusions

1. Hydrobotanical studies conducted in the eastern sector of Sevastopol Bay in 2017 and 2024 revealed significant changes in the vertical distribution of microphytobenthos, alongside relative stability in the species composition of the dominant macrophytes. Currently, *Gongolaria barbata* and *Ericaria crinita* dominate the benthic vegetation, and green algae (*Cladophora laetevirens*, *Ulva intestinalis*,

U. rigida) are also abundant. Notably, during this period, an increase in the contribution of *G. barbata* (from 46–60 to 82–87%) was recorded, while the proportion of seagrasses decreased (from 12–30 to 7–9% of the TBM).

2. Notably, in 2024, there was a decrease in TBM and the proportion of *G. barbata* and *E. crinita* in almost all profiles at a depth of 0.5 m due to the destructive impact of an extreme storm that occurred in the autumn 2023. Meanwhile, at depths of 1 and 3 m, the quantitative indicators of macrophytobenthos biomass were approximately twice as high as in 2017.

3. A comparative analysis of the spatial distribution of macrophytobenthos for 1977–2024 revealed a significant changes in the plant composition, particularly in the corner of the bay, where the communities of higher aquatic vegetation (*Zostera marina, Z. noltei, Stuckenia pectinata, Zannichellia* sp., *Ruppia* sp.) completely changed to perennial macrophytes (*G. barbata* and *E. crinita)*. These changes can probably be explained by an increase in water salinity in the estuary zone of the Chyornaya River, as well as changes in coastal sediment flow dynamics. In the eastern part of the bay, *Ulva* species were replaced by *G. barbata* and *E. crinita* during this period, which may indicate a trend toward improvement in environmental conditions.

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