ISSN 2413-5577, Ecological Safety of Coastal and Shelf Zones of Sea, 2025, No. 3, pp. 54–66.

Original paper

The Tier Structure of the *Ericaria–Gongolaria* Phytocenosis in the Coastal Zone of Protected Areas of Sevastopol

D. A. Kandaurova *, N. A.Milchakova

A. O. Kovalevsky Institute of Biology of the Southern Seas of RAS, Sevastopol, Russia

* *e-mail: dkandaurova@ibss-ras.ru*

Abstract

The paper describes the taxonomic diversity of the *Ericaria–Gongolaria* phytocenosis (*Ericaria crinita + Gongolaria barbata – Cladostephus spongiosus – Ellisolandia elongata*), which is the key part of the coastal ecosystems of specially protected natural areas of Sevastopol. The material was collected according to a standard procedure in the waters of six protected sites at depths of 1–5 m in summers from 2016 to 2021 during the peak of the macrophyte growing season. When analyzing the samples, we considered the species composition of the phytocenosis, the duration of life cycle of macroalgae, and their distribution by tiers and depths. The phytocenosis structure was found to be characterized by a high phytodiversity. Totally, 34 species of macroalgae were recorded. Two of them were found in the first tier, seven species were included in the second tier, and 25 taxa were represented in the third tier. The greatest diversity was found in red (Rhodophyta) algae: their share accounted for 52% of the total number of species. The contribution of brown (Ochrophyta) and green (Chlorophyta) macroalgae was 2.2 times less (24% each). In terms of life cycle, perennial and annual algae predominated: their share was 44 and 38%, respectively. The largest contribution of perennial species (70%) was registered near Cape Aya and Cape Sarych. In general, *Ericaria–Gongolaria* phytocenosis of different specially protected natural areas was characterized by low floral similarity: the values of the Jacquard coefficient (*Kj*) ranged from 7.1 to 66.7% and the average value was 21%. The taxonomic diversity, full tier structure and the predominance of perennial species indicate the stability of the key phytocenosis in specially protected natural areas of Sevastopol and effectiveness of their environmental regime.

Keywords: macrophytobenthos, *Ericaria crinita*, *Gongolaria barbata*, phytocenosis, phytocenosis vertical structure, species composition, marine protected areas, southwestern Crimea, Black Sea

Acknowledgements: This work was carried out within the framework of IBSS state research assignment “Biodiversity as the basis for the sustainable functioning of marine ecosystems, criteria and scientific principles for its conservation” (no. 124022400148-4). The authors sincerely thank the staff of the Laboratory of Phytoresources of the Department of Biotechnology and Phytoresources of A.O. Kovalevsky Institute of Biology of the Southern Seas of RAS for their assistance in processing samples of macrophytobenthos.

For citation: Kandaurova, D.A. and Milchakova, N.A., 2025. The Tier Structure of the *Ericaria–Gongolaria* Phytocenosis in the Coastal Zone of Protected Areas of Sevastopol. *Ecological Safety of Coastal and Shelf Zones of Sea*, (3), pp. 54–66.

Ярусная структура эрикариево-гонголяриевого фитоценоза в прибрежной зоне особо охраняемых природных территорий Севастополя

Д. А. Кандаурова *, Н. А. Мильчакова

ФГБУН ФИЦ «Институт биологии южных морей им. А. О. Ковалевского РАН», Севастополь, Россия

* *e-mail: dkandaurova@ibss-ras.ru*

Аннотация

Дана характеристика таксономического разнообразия эрикариево-гонголяриевого фитоценоза (*Ericaria crinita + Gongolaria barbata – Cladostephus spongiosus – Ellisolandia elongata*), ключевого в составе макрофитобентоса особо охраняемых природных территорий г. Севастополя. Материал отбирали по стандартной методике в акваториях шести заповедных объектов на глубинах от 1 до 5 м в летний сезон с 2016 по 2021 г. в пик вегетационного периода макрофитов. При анализе проб учитывали видовой состав фитоценоза, продолжительность жизненного цикла макроводорослей, их распределение по ярусам и глубинам. Установлено, что ярусная структура фитоценоза характеризуется высоким разнообразием таксонов видового ранга. Из 34 выявленных видов макроводорослей в первом ярусе встречались два, во втором – семь и в третьем – 25 видов. Наибольшим разнообразием характеризовались красные (Rhodophyta) водоросли, на долю которых приходилось 52 % общего количества таксонов, вклад бурых (Ochrophyta) и зеленых (Chlorophyta) был меньше почти в 2.2 раза (по 24 %). По продолжительности жизненного цикла преобладали многолетние и однолетние водоросли, доля которых составляла 44 и 38 % соответственно, максимальный вклад многолетних видов (70 %) зарегистрирован у м. Айя и м. Сарыч. Показано, что на разных участках особо охраняемых природных территорий эрикариево-гонголяриевый фитоценоз характеризовался низким флористическим сходством, значения коэффициента Жаккара (*Kj*) варьировали от 7.1 до 66.7 % при среднем значении 21 %. Таксономическое разнообразие, полночленная ярусная структура и преобладание многолетних видов отражают устойчивость ключевого фитоценоза и могут свидетельствовать об эффективности действующего природоохранного режима на особо охраняемых природных территориях г. Севастополя.

Ключевые слова: макрофитобентос, *Ericaria crinita, Gongolaria barbata,* фитоценоз, вертикальная структура фитоценоза, видовой состав, охраняемые акватории, Юго-Западный Крым, Черное море

Благодарности: работа выполнена в рамках государственного задания ФИЦ ИнБЮМ по теме «Биоразнообразие как основа устойчивого функционирования морских экосистем, критерии и научные принципы его сохранения» (№ гос. регистрации 124022400148-4). Авторы приносят искреннюю благодарность коллективу лаборатории фиторесурсов отдела биотехнологий и фиторесурсов ФИЦ ИнБЮМ за помощь в проведении экспедиционных исследований и обработке проб макрофитобентоса.

Для цитирования: *Кандаурова Д. А., Мильчакова Н. А.* Ярусная структура эрикариево-гонголяриевого фитоценоза в прибрежной зоне особо охраняемых природных территорий Севастополя // Экологическая безопасность прибрежной и шельфовой зон моря. 2025. № 3. С. 54–66.

Introduction

The nature conservation network of Specially Protected Natural Areas (SPNAs) in the city of Sevastopol comprises 19 sites, covering a total area of 23,768 km^2 (30% of the city's territory). This represents one of the highest figures among the subjects of the Russian Federation [1)]. Although Marine Protected Areas (MPAs) account for only 3% of the total area of these protected sites, they play a significant role in conserving the biodiversity of coastal ecosystems. According to various estimates [2)], the proportion of protected macrophyte species within the waters of SPNAs ranges from 18.2 to 45.5% of the species listed in the Red Book of Sevastopol [3)].

The benthic vegetation of the MPA is dominated by the *Ericaria–Gongolaria* phytocenosis, comprising *Ericaria crinita* + *Gongolaria barbata – Cladostephus spongiosus – Ellisolandia elongata*, which is one of the key ecosystems for the Black Sea coastal ecosystems and is protected at the international level [4), 5)]. The coenosis-forming species, *Ericaria crinita* (Duby) Molinari & Guiry and *Gongolaria barbata* (Stackhouse) Kuntze, also hold protected status [6), 7)]. Along the open shores of southwestern Crimea, the *Ericaria–Gongolaria* phytocenosis forms a belt type [8)] vegetation structure [1], with maximum productivity and the ecological-phytocenotic optimum of *E. crinita* and *G. barbata* recorded at depths from 1 to 5 m [8)], where the influence of factors driving the transformation of benthic communities is most pronounced. The primary factor is anthropogenic impact, which leads to biotope degradation, pollution from inadequately treated or untreated domestic wastewater, etc. [2, 3].

---

1) Sevastopol City Administration, 2023. [*Annual Report on State and Protection of Environment of the City of Sevastopol in 2023*]. Sevastopol: Main Department of Natural Resources and Ecology of the City of Sevastopol. Part 1, 194 p. (in Russian).

2) Milchakova, N.A., ed., 2015. [*Marine Protected Areas of Crimea. Scientific Reference Book*]. Sevastopol, Simferopol: N. Orianda, 300 p. (in Russian).

3) Dovgal, I.V. and Korzhenevskiy, V.V., eds., 2018. *The Red Data Book of Sevastopol.* Sevastopol: ROST-DOAFK, 432 p. (in Russian).

4) EEC Council, 1992. *Habitats Directive 92/43/EEC*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri= CELEX:31992L0043 [Accessed: 22 August 2025].

5) Gubbay, S., Rodwell, J.R., Garcia Criado, M., Borg. J., Otero, M., Janssen, J.A.M., Haynes, T., Beal, S., Nieto, A. [et al.], 2016. *European Red List of Habitats. Part 1. Marine habitats*. Luxembourg: Publications Office of the European Union, 2016. 52 p. https://doi.org/10.2779/032638

6) Ena, A.V. and Fateryga, A.V., eds., 2015. *Red Book of the Republic of Crimea. Plants, algae and fungi*. Simferopol: ARIAL, 480 p. (in Russian).

7) Dumont, H.J., ed., 1999. *Black Sea Red Data Book.* New York: United Nations Office for Project Services, 413 p.

8) Kalugina-Gutnik, A.A., 1975. [*Phytobenthos of the Black Sea*]. Kiev: Naukova Dumka, 246 p. (in Russian).

Over the past two decades, negative anthropogenic factors have impacted the coastal waters of Crimea and Black Sea regions, including protected areas, leading to a decline in macrophyte diversity, a shift in their lower growth boundary toward the shore, reduced productivity of macrophytobenthos, and alterations in the spatial distribution and vertical structure of phytocenoses [2, 4–6]. Under conditions of high anthropogenic pressure and coastal water pollution, macrophytobenthos transformation has been marked by outbreaks of short-cycle and epiphytic algae, changes in the tiered structure of benthic phytocenoses, reduced ecosystem stability, and a consequent decline in the self-purification capacity of coastal ecosystems [4, 5, 7–12]. As a result of anthropogenic succession, *E. crinita* and *G. barbata* have lost their dominant positions in many areas of the coastal zone along the Caucasian shelf, as well as off the coasts of Romania, Bulgaria and Turkey, including MPAs [11, 13, 14]. Similarly, in the Mediterranean Sea, their phytocenoses, particularly in the lower tiers, have experienced a replacement of perennial species with short-cycle or ephemeral species, predominantly green and calciphilic red algae [6, 15–20]. Concurrently, in many Mediterranean MPAs, the area occupied by phytocenoses of perennial brown algae, including species of the genera *Ericaria* and *Gongolaria*, has significantly decreased, largely due to biotope degradation resulting from inadequate regulation of fishing in protected areas [19–22].

Considering the role of key brown algae phytocenoses – the primary producers in the coastal ecosystems of southwestern Crimea – and the limited research on their structure, the objective of this study was to characterize the species composition and tiered structure of the *Ericaria–Gongolaria* phytocenosis and to evaluate its stability in the waters of SPNAs of Sevastopol.

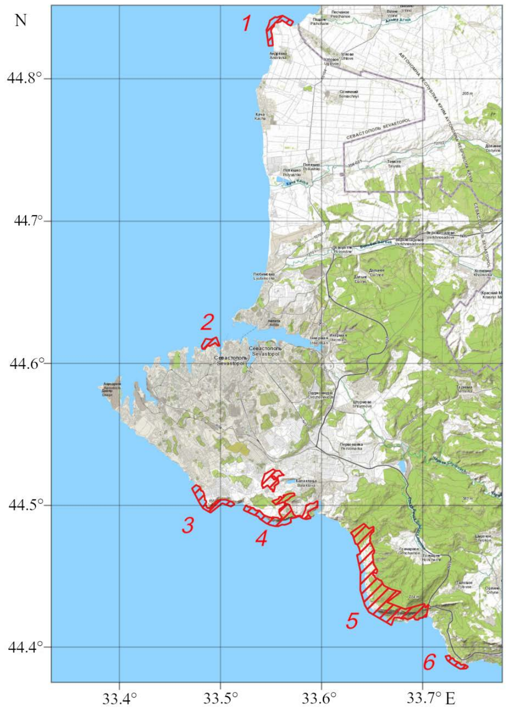
Materials and methods of research

The vertical tiered structure of the *Ericaria–Gongolaria* phytocenosis was investigated in six SPNAs in Sevastopol, including two State Natural Preserves (SNPs) – *Cape Aya* and *Karansky* – and four Natural Monuments (NMs): the *Coastal Aquatic Complex* (CAC) *at Cape Sarych*, *CAC at Cape Fiolent*, *CAC at Tauric Chersonese*, and *CAC at Cape Lukull* (Fig. 1). In the coastal zones of these protected areas, this phytocenosis occurs on rocky-block substrates at depths ranging from 0.5 to 10 m.

The study focuses on lithophytic macroalgae of the *Ericaria–Gongolaria* phytocenosis, a key component of the Black Sea macrophytobenthos [8)].

Material was collected at depths of 1, 3 and 5 m, corresponding to the ecological-phytocenotic optimum for *E. crinita* and *G. barbata*, during the summer periods of 2016–2021. Quantitative samples of macrophytes were collected using a standard method [8)], employing a 25 × 25 cm sampling frame at each depth horizon in four replicates. To assess the species diversity across tiers, qualitative samples were gathered at various horizons within the phytocenosis distribution zone.

When processing the samples, the species composition, biomass of macrophytes by vertical tiers, the number of cenosis-forming lithophytic macroalgae, and



F i g . 1 . The map of specially protected natural areas of Sevastopol: *1* – Natural Monument at Cape Lukull, *2* – Natural Monument at Tauric Chersonese, *3* – Natural Monument at Cape Fiolent, *4* – State Nature Preserve Karansky, *5* – State Nature Preserve Cape Aya, *6* – Natural Monument at Cape Sarych (the borders of objects are highlighted in red colour)

total projective cover of the phytocenosis were evaluated. A total of 93 quantitative and 20 qualitative samples of macrophytobenthos were collected and analyzed along six vertical transects located in the central part of SPNAs.

To characterize the vertical tiered structure of the *Ericaria–Gongolaria* phytocenosis, we analyzed the species composition of lithophytes in the 1st–3rd tiers. For the 4th tier, comprising crustose lithophytes, only the presence or absence of species was recorded using the underwater photofixation method [6].

A comparative analysis of the diversity of lithophytic synusiae was conducted across three vertical tiers, evaluating the proportion of species by division (Chlorophyta, Ochrophyta, Rhodophyta) and life cycle duration. For each species, the coefficient of occurrence Po (%) was calculated using the formula:

$$P_o = P\frac{a}{n}100,$$

where *a* represents the number of sites where the species was recorded; and *n* is the total number of surveyed sites [9].

The similarity of the species composition of the phytocenosis across the water areas of the SPNAs was assessed using the Jaccard coefficient *Kj* (%) [9]

$$Kj = 100\frac{c}{a+b-c},$$

where *a* is the number of species in one site; *b* is the number of species in another site; and *c* is the number of species common to both sites.

---

[9] Pesenko, Yu.A., 1982. [*Principles and Methods of Quantitative Analysis in Fauna Studies*]. Moscow: Nauka, 287 p. (in Russian).

To evaluate the similarity of the vertical tier structure of the *Ericaria–Gongolaria* phytocenosis in SPNAs, a cluster analysis was performed using data on species occurrence and presence or absence [10)]. Macroalgal names were updated to reflect recent taxonomic revisions and nomenclature changes [11)].

Results and discussion

The phytodiversity of the tiered structure of the *Ericaria–Gongolaria* phytocenosis in the coastal zone of Sevastopol's SPNAs exhibited high species richness, comprising 34 species. These were distributed as follows: 2 species in the 1st tier, 7 in the 2nd tier, and 25 in the 3rd tier. The 1st tier was dominated by the coenosis-forming species *Ericaria crinita* and *Gongolaria barbata*, the second was dominated by *Phyllophora crispa* (Hudson) P. S. Dixon, *Cladostephus spongiosus* (Hudson) C. Agardh and *Ulva rigida* C. Agardh, the third by *Apoglossum ruscifolium* (Turner) J. Agardh, *Chondria da-syphylla* (Woodward) C. Agardh, *Dictyota fasciola* (Roth) J. V. Lamouroux, *Ellisolandia elongata* (J. Ellis & Solander) K. R. Hind & G. W. Saunders, *Gelidium crinale* (Hare ex Turner) Gaillon, *G. spinosum* (S. G. Gmelin) P. C. Silva, *Jania rubens* (Linnaeus) J. V. Lamouroux, *J. virgata* (Zanardini) Montagne, *Laurencia coronopus* J. Agardh and *Vertebrata subulifera* (C. Agardh) Kuntze.

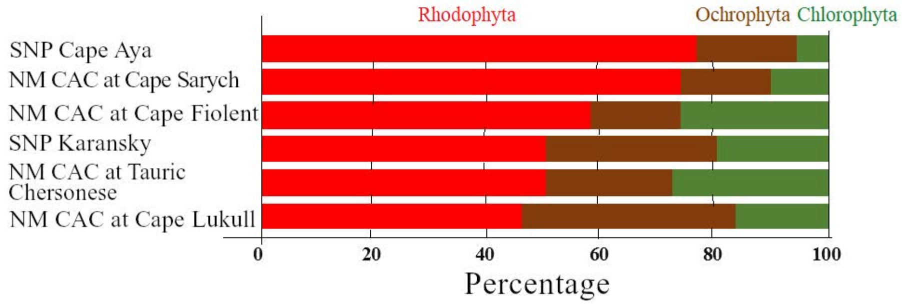
Analysis of the species composition by taxonomic division revealed that red algae (Rhodophyta) contributed the largest proportion, accounting for 52% of the total species, while brown algae (Ochrophyta) and green algae (Chlorophyta) each represented 24%. Notably, species proportions varied significantly across vertical tiers. In the 2nd tier, brown algae comprised 57% of the species, seven times higher than in the 3rd tier (8%). Conversely, green and red algae were 2–2.2 times less (29% and 64%, and 14% and 28%, respectively).

The number of species in SPNAs varied significantly across vertical tiers, ranging from one to five species in the 2nd tier and from one to eight in the 3rd tier. In the 2nd tier, the highest frequency of occurrence (*P*o = 75–100%) was recorded for *C. spongiosus*, *Ph. crispa*, and *U. rigida*. In the 3rd tier, high occurrence frequencies (from 50 to 75%) were noted for *A. ruscifolium*, *D. fasciola*, *E. elongata*, *G. crinale*, *G. spinosum*, *J. rubens*, *J. virgata*, *C. dasyphylla*, *L. coronopus*, and *V. subulifera*.

The highest species richness of lithophytes in the 2nd and 3rd tiers was observed in the waters of the NM *CAC at Cape Fiolent*, while the lowest was recorded in the *Karansky SNP* (Fig. 2). The greatest proportion of red algae was found in the coastal zones of the *Cape Aya SNP* and the NM *CAC at Cape Sarych*, accounting for 67% and 80% of the total species, respectively [8)]. Brown algae contributed 23% in the NM *CAC at Cape Lukull*, indicating relatively clean water conditions in these areas [2]. A high proportion of green algae (38%) was recorded in the *CAC at Cape Fiolent*, likely due to elevated recreational pressure in the coastal zone during spring and summer.

10) Zaytsev, G.N., 1990. [*Mathematics in Experimental Botany*]. Moscow: Nauka, 296 p. (in Russian).

11) Algaebase Team. Algaebase. 2025. [online] Available at: http://www:algaebase.org [Accessed: 22 August 2025].



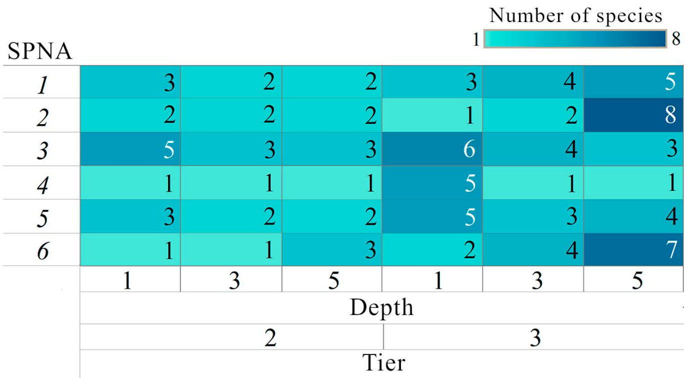
F i g . 2 . Ratio of green, brown and red algae of the *Ericaria–Gongolaria* phytocenosis in the marine area of specially protected natural areas of Sevastopol

Analysis of species richness across the tiers in SPNAs of Sevastopol revealed slight variations with depth. The 1st tier, dominated by *E. crinita* and *G. barbata*, occurs at depths of 1 to 5 m and 3 to 5 m, respectively. In the 2nd and 3rd tiers, the highest number of species was recorded at depths of 1 and 5 m (22 species each), while diversity was lower at 3 m (15 species). The proportion of species by taxonomic division also varied slightly with depth; across all sites, red algae contributed twice as much to species richness as green and brown algae. In the 3rd tier, the proportion of Rhodophyta was three times higher than that of Ochrophyta and Chlorophyta, whereas no such pattern was observed in the 2nd tier.

Across SPNAs, the number of macroalgal species in the tiers also varied slightly with depth (Fig. 3). The highest phytodiversity was observed in the NM *CAC at Cape Fiolent* at a depth of 1 m. In the 2nd tier, the greatest species richness (five species) was recorded in the phytocenosis of the NM *CAC at Cape Fiolent* at 1 m, while the lowest (one species) was recorded in the *Karansky SNP* and the NM *CAC at Cape Sarych* at 3 m. Near Cape Lukull, species richness in the 2nd tier increased slightly with depth, reaching a maximum at 5 m.

In the 3rd tier, the highest species richness was observed in the waters of the NM *CAC at Tauric Chersonese* and the NM *CAC at Cape Sarych* at a depth of 5 m (7 and 8 species, respectively). The lowest species richness was recorded at depths of 3 and 5 m in the *Karansky SNP* and at 1 m in the NM *CAC at Tauric Chersonese* (one species each). Notably, in certain areas of the *Cape Aya* and *Karansky SNPs*, as well as the NM *CAC at Cape Fiolent*, at depths from 3 to 5 m within the ecological-phytocenotic optimum of the phytocenosis [8)], no algae were found in the 2nd and 3rd tiers, which is probably due to the high density of coenosis-forming species in the 1st tier [1].

Comparative analysis of the phytodiversity across the three tiers of the *Ericaria – Gongolaria* phytocenosis revealed that the total species richness in SPNAs of Sevastopol was 1.3 times higher (34 species) than in other areas of the Crimean and Caucasian coasts (27 species) [1, 2, 5, 8, 10, 11, 13, 14, 23]. However, within protected waters, the number of taxa in the tiers ranged from 8 to 17 species, compared to 6 to 27 species in other areas of the Russian Black Sea shelf.

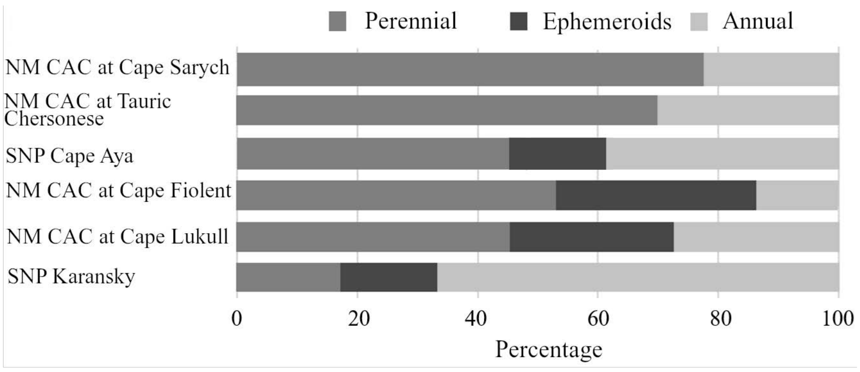


F i g . 3 . The change in the number of species in the 2nd and 3rd tiers of the *Ericaria–Gongolaria* phytocenosis at depths of 1, 3 and 5 m in the marine area of specially protected natural areas of Sevastopol (see Fig. 1)

In the phytocenoses of protected areas, the 2nd tier contained 7 species, 1.6 times fewer than the 11 species reported elsewhere, while the 3rd tier exhibited 1.5 times greater species richness (21 species) compared to other studies (14 species). The increased diversity in the 3rd tier may be attributed to the presence of certain macroalgae, specifically *A. ruscifolium*, *C. dasyphylla*, *L. coronopus*, *L. obtusa* and *V. subulifera*, which were identified as lithophytic in this study but are typically epiphytic in other regions [8].

Analysis of the proportion of macroalgal species with varying life cycle durations in the tiers of the *Ericaria–Gongolaria* phytocenosis in SPNTs of Sevastopol revealed that perennial algae accounted for 44%, annual algae for 38%, and ephemeroids for 18% of the total species identified. Among brown algae, perennial and short-cycle species predominated; among red algae, perennial and annual species were prevalent; and among green algae, annual species dominated. The 1st tier consisted exclusively of perennial species, while in the 2nd and 3rd tiers, perennial species contributed 43% and 40%, respectively, and short-cycle species accounted for 57% and 52%, respectively. The highest proportion of perennial species (78%) was recorded in the waters of the NM *CAC at Cape Sarych* (Fig. 4), while the lowest (18%) was found in the *Karansky SNP*. The predominance of annual species (67%) in the *Karansky SNP* is likely associated with the influx of domestic and industrial wastewater from the Balaklava collector under specific synoptic conditions [24, 25].

The greatest proportion of perennial algae, ranging from 50 to 70%, was observed in the waters of the NM *CAC at Tauric Chersonese* (depth 1 m), the NM *CAC at Cape Sarych* and the *Cape Aya SNP* (depth 3 and 5 m). No seasonal or ephemeral species were recorded in the phytocenosis of the latter two sites.



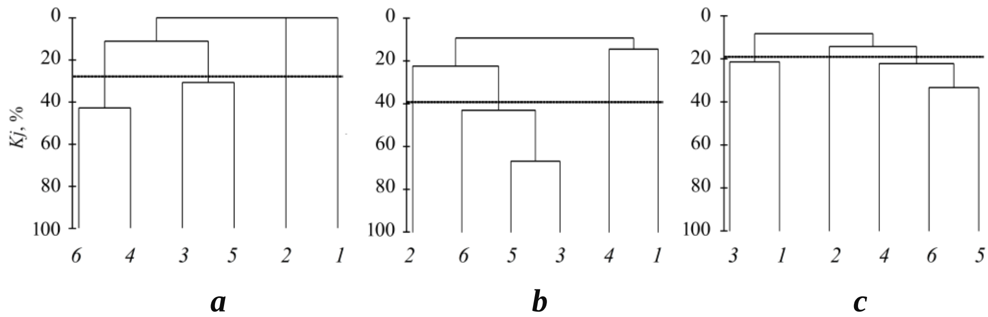
F i g . 4 . The ratio of *Ericaria–Gongolaria* phytocenosis species by their life history in the marine area of specially protected natural areas of Sevastopol

The proportion of species with different vegetation periods reflects both the condition of benthic phytocenoses and their resilience to adverse environmental factors [8)] [4, 18]. The predominance of perennial species in the *Ericaria–Gongolaria* phytocenosis (Fig. 4) suggests favorable conditions for macrophytobenthos in the coastal zone of Sevastopol's SPNAs, which is confirmed by evidence of improved environmental quality in these protected waters over recent decades [12, 24–26].

Previous studies have demonstrated that increased domestic pollution and eutrophication result in reduced species richness in perennial brown algae phytocenoses of the Black Sea, decreased biomass of coenosis-forming species in the 1st and 2nd tiers, and an increase in coralline calciphilic macroalgae in the 3rd tier [1, 2, 4, 8, 11, 13, 16]. Under the influence of these adverse factors, some key phytocenoses in the Mediterranean Sea have exhibited a replacement of perennial brown algae in the 1st tier with red coralline algae, such as *Corallina officinalis* Linnaeus, *E. elongata*, *J. rubens*, and others. This shift has led to significant structural transformation and a decline in the productivity of macrophytobenthos [17–20].

Analysis of the species diversity across the tiers of the *Ericaria–Gongolaria* phytocenosis in SPNAs revealed low structural similarity. The average value of *Kj* between sites did not exceed 21% (Fig. 5), compared to 56–62% in other areas of the coastal zone of Crimea [8)]. The highest number of shared species was observed between the phytocenoses of the *Cape Aya SNP* and the NM *CAC at Cape Sarych* (*Kj* from 33.3 to 46.2%). In other sites, *Kj* values were 3–5 times lower.

Significant variation in *Kj* was observed across depths. The highest species similarity was recorded in the phytocenoses near Cape Aya and Cape Fiolent at a depth of 3 m (*Kj* = 66.7%), while the lowest was found near the *Karansky SNP* and the NM *CAC at Cape Lukull* at depths of 3 and 5 m (*Kj* = 7.1%).



F i g . 5 . Dendrogram of similarity in species composition of *Ericaria–Gongolaria* phytocenosis in the specially protected natural areas of Sevastopol (see Fig. 1): *a* – depth of 1 m, *b* – 3 m, *c* – 5 m

Conclusion

The *Ericaria–Gongolaria* phytocenosis (*Ericaria crinita* + *Gongolaria barbata – Cladostephus spongiosus – Ellisolandia elongata*) is a key component of the Black Sea macrophytobenthos, exhibiting high taxonomic diversity in the coastal SPNAs of Sevastopol. Thirty-four macroalgal species were identified in the lithophytic synusiae across three tiers, of which Chlorophyta and Ochrophyta each contributed 24% to the total species richness, while Rhodophyta accounted for 52%. The 1st tier was dominated by coenosis-forming brown algae (Ochrophyta), in the 2nd and 3rd tiers, their proportions were 57% and 28%, red algae (Rhodophyta) – 29% and 64%, green algae (Chlorophyta) – 14% and 8%, respectively. The proportion of species across taxonomic divisions varied slightly across regions and depths, with brown and red algae consistently 2–3 times more abundant than green algae.

Perennial species predominated in the composition of the tiered synusiae of the phytocenosis, with their highest proportion (53–78%) recorded in the phytocenoses of the NM *CAC at Cape Fiolent*, the NM *CAC at Cape Sarych*, and the *Cape Aya SNP*. In other protected waters of SPNAs of Sevastopol, the proportion ranged from 17 to 46%. The floristic similarity of the species composition across the tiers in these protected areas was low, with the highest number of shared species observed among the phytocenoses of the *Cape Aya SNP*, the NM *CAC at Cape Sarych*, and the NM *CAC at Cape Fiolent*.

Elements of restorative succession, indicative of ecological stability, were identified in the *Ericaria–Gongolaria* phytocoenosis within the coastal zone of SPNAs of Sevastopol. These include a well-developed structure, high floristic diversity across tiers, and the predominance of perennial brown and red algae. The ecological and phytocoenotic characteristics of this phytocoenosis suggest that the protected waters of Sevastopol can be classified as relatively clean. However, due to significant fuel oil inputs into the waters of the *Cape Aya SNP* and the NM *CAC at Cape Fiolent*, regular monitoring of key benthic phytocoenoses, which are critical for the self-purification of coastal waters, remains an essential conservation priority.

REFERENCES

1. Milchakova, N.A., 2003. Macrophytobenthos. In: V. N. Eremeev and A. V. Gaevskaya, eds., 2003. *Modern Condition of Biological Diversity in Near-Shore Zone of Crimea (the Black Sea Sector)*. Sevastopol: ECOSI-Gidrofizika, pp. 152–208 (in Russian).
2. Milchakova, N.A. and Petrov, A.N., 2003 Morphofunctional Analysis of Long-Term Changes of the Structure of *Cystoseira* Phytocenoses (Laspi Bay, the Black Sea). *International Journal of Algae*, 5(3), pp. 47–63. https://doi.org/10.1615/InterJAlgae.v5.i3.40
3. Milchakova, N.A., Alexandrov, V.V. and Ryabogina, V.G., 2019. State of Key Phytocenoses of Marine Protected Areas and Problems Their Conservation (Southwestern Crimea, Black Sea). *Plant Biology and Horticulture: Theory, Innovation*, (149), pp. 113–123 (in Russian).
4. Milchakova, N.A., 2015. Current State of Macrophytobenthos in Karadag Nature Reserve and Adjacent Objects of the Marine Protected Area (Crimea, the Black Sea). In: A. V. Gayevskaya and A. L. Morozova, eds., 2015. *100 Years of the T.I. Vyazemsky's Karadag Scientific Station*. Simferopol: N. Orianda, pp. 506–523 (in Russian).
5. Evstigneeva, I.K. and Tankovskaya, I.N., 2021. Hydro-Botanical Studies of the Protected Water Area of the Western Crimea (Black Sea). *Phytodiversity of Eastern Europe*, 15(4), pp. 16–33 (in Russian).
6. Berov, D., Todorova, V., Dimitrov, L., Rinde, E. and Karamfilov, V., 2018. Distribution and Abundance of Phytobenthic Communities: Implications for Connectivity and Ecosystem Functioning in a Black Sea Marine Protected Area. *Estuarine, Coastal and Shelf Science*, 200, pp. 234–247. https://doi.org/10.1016/j.ecss.2017.11.020
7. Minicheva, G.G., Bolshakov, V.N., Kalashnik, E.S., Zotov, A.B. and Marinets, A.V., 2018. Assessment of the Reactions of the Black Sea Ecosystem's Algaecommunities to Influence of Climatic Factors. *International Journal of Algae*, 28(2), pp. 121–135. https://doi.org/10.15407/alg28.02.121
8. Cernysheva, E.B., 2019. Changes in the Structure of Cystoseira Communities in Various Environmental Conditions (the Black Sea, Sevastopol). *Ecological Safety of Coastal and Shelf Zones of Sea*, (3), pp. 72–81. https://doi.org/10.22449/2413-5577-2019-3-72-81 (in Russian).
9. Kovardakov, S.A. and Prazukin, A.V., 2012. Structural and functional characteristics of the bottom seaweeds community in Kruglaya bay (Sevastopol). In: TNU, 2012. *Optimization and Protection of Ecosystems*. Simferopol: TNU. Iss. 7, pp. 138–148 (in Russian).
10. Kostenko, N.S., Evstigneeva, I.K. and Tankovskaya, I.N., 2018. Phytobenthos. In: N. S. Kostenko, ed., 2018. *The Biology of the Black Sea Offshore Area at the South-Eastern Crimea*. Simferopol: ARIAL, pp. 172–233. https://doi.org/10.21072/978-5-907032-04-0 (in Russian).
11. Lisovskaya, O.A and Nikitina, V.N., 2007. Macrophytobenthos of Caucasus Coast of Black Sea near Tuapse and Big Sochi. *Vestnik of Saint-Petersburg University. Series 3. Biology*, (2), pp. 22–33 (in Russian).
12. Milchakova, N.A., Alexandrov, V.V., Kovardakov, S.A. and Pavshenko, D.A., 2023. Macrophytobenthos of the Natural Monument "Coastal Aquatic Complex at Cape Fiolent" (Sevastopol). In: N. A. Bagrikova, ed., 2023. *Scientific Notes of the «Cape Martyan» Nature Reserve*. Simferopol: ARIAL, Iss. 14, pp. 183–188. https://doi.org/10.25684/2413-3019-2023-14-183-188 (in Russian).

13. Simakova, U.V., Smirnov, I.A., Shabalin, N.V. and Papunov, V.G., 2017. [Macroalgae Community of Utrish Natural Reserve]. In: R. V. Gorbunov, ed., 2017. *All-Russian Scientific Conference «Scientific Researches on the Reserve Territories», devoted to the 160th anniversary of the birth of the Karadag scientific station founder, doctor of medicine, privat-docent of the Moscow University Terenty Ivanovich Vyazemsky, as well as the Year of Specially Protected Natural Territories and the Year of Ecology in Russia, Kurortnoe, October 9–14, 2017*. Simferopol: ARIAL, pp. 47 (in Russian).

14. Afanasyev, D.F., Kamnev, A.N. and Sushkova E.G., 2018. Structure and Seasonal Dynamics of *Cystoseira Crinita* (Fucales, Phaeophyceae) Dominated Communities from the North-Eastern Black Sea. In: A. L. Budantsev, ed., 2018. [*Botany in the Modern World. Proceedings of the XIV Congress of the Russian Botanical Society and the Conference "Botany in the Modern World" (Makhachkala, 18−23 June 2018). Vol. 3: Spore Plants. Mycology. Structural Botany. Plant Physiology and Biochemistry. Plant Embryology*]. Makhachkala: ALEF, pp. 14−16 (in Russian).

15. Sava, D., Doroftei, E. and Arcuş, M., 2011. Ecology and Distribution of Macrophytic Red Algae from the Romanian Black Sea Coast. *Botanica Serbica*, 35(1), pp. 37–41.

16. Birben, Ü., 2020. The Effectiveness of Protected Areas in Biodiversity Conservation: The Case of Turkey. *Cerne*, 25(4), pp. 424–438. https://doi.org/10.1590/01047760201925042644

17. Boudouresque, C.-F., Blanfune, A., Changeux, T., Pergent, G., Perret-Boudouresque, M., Ruitton, S. and Thibaut, T., 2024. Marine Biodiversity in the Mediterranean in the Era of Global Warming. *La Mer*, 61(3–4), pp. 189–231. https://doi.org/10.32211/lamer.61.3-4_189

18. Thibaut, T., Blanfune, A., Boudouresque, C.-F. and Verlaque, M., 2015. Decline and Local Extinction of Fucales in French Riviera: The Harbinger of Future Extinctions? *Mediterranean Marine Science*, 16(1), pp. 206–224. https://doi.org/10.12681/mms.1032

19. Coleman, M.A. and Wernberg, T., 2017. Forgotten Underwater Forests: The Key Role of Fucoids on Australian Temperate Reefs. *Ecology and Evolution*, 7(20), pp. 8406–8418. https://doi.org/10.1002/ece3.3279

20. Rindi, F., Vergés, A., Zuchegna, I., Bianchelli, S., de Caralt, S., Galobart, C., Santamaría, J., Martini, F., Monserrat, M. [et al.], 2023. Standardized Protocol for Reproductive Phenology Monitoring of Fucalean Algae of the Genus *Cystoseira* s.l. with Potential for Restoration. *Frontiers in Marine Science*, 10, 1250642. https://doi.org/10.3389/fmars.2023.1250642

21. Verdura, J., de Caralt, S., Santamaria, J., Vergés, A., Mangialajo, L., Ivesa, L., Farina, S., Cefalí, M.E., Fraschetti, S. [et al.], 2018. Regional Environmental Conditions Determine Tolerance to Future Warming of a Marine Macroalgae Forests. *PeerJ PrePrints*, 2 p. https://doi.org/10.7287/peerj.preprints.26766v1

22. Rendina, F., Falace, A., Alongi, G., Buia, M.C., Neiva, J., Appolloni, L., Marletta, G. and Russo, G.F., 2023. The Lush Fucales Underwater Forests off the Cilento Coast: An Overlooked Mediterranean Biodiversity Hotspot. *Plants*, 12(7), 1497. https://doi.org/10.3390/plants12071497

23. Pavshenko, D.A., 2023. Application of Geobotanical Methods for Studying the Benthic Vegetation of the Black Sea. *Ekosistemy*, (36), pp. 18–29 (in Russian).

24. Kuftarkova, E.A., Rodionova, N.Yu., Gubanov, V.I. and Bobko, N.I., 2008. Hydrochemical Characteristics of Several Bays of Sevastopol Coast. In: YugNIRO, 2008. *Trudy YUGNIRO = YugNIRO Proceedings*. Kerch: YugNIRO Publishers. Vol. 46, pp. 110–111 (in Russian).

25. Gruzinov, V.M., Dyakov, N.N., Mezenceva, I.V., Malchenko, Y.A., Zhohova, N.V. and Korshenko, A.N., 2019. Sources of Coastal Water Pollution near Sevastopol. *Oceanology*, 59(4), pp. 523–532. https://doi.org/10.1134/S0001437019040076

26. Shchurov, S.V., Kovrigina, N.P. and Ladygina, L.V., 2019. Seasonal Variation of Abiotic Factors of Environment and Phytoplankton in the Laspi Bay Mussel Farm Area (2010–2011). *Scientific Notes of V.I. Vernadsky Crimean Federal University. Geography. Geology*, 5(2), pp. 184–201 (in Russian).

Submitted 09.04.2025; accepted after review 01.06.2025;
revised 24.06.2025; published 30.09.2025

About the authors:

Daria A. Kandaurova, Postgraduate Student, Junior Research Associate, A. O. Kovalevsky Institute of Biology of the Southern Seas of RAS (2 Nakhimov Av., Sevastopol, 299011, Russian Federation), **ORCID ID: 0009-0009-2966-6811**, *dkandaurova@ibss-ras.ru*

Nataliya A. Milchakova, Leading Research Associate, Head of Phytoresources Laboratory, A. O. Kovalevsky Institute of Biology of the Southern Seas of RAS (2 Nakhimov Av., Sevastopol, 299011, Russian Federation), PhD (Biol.), **ORCID ID: 0000-0001-5407-7706, ResearcherID: I-1280-2016**, *nmilchakova@ibss-ras.ru*

Contribution of the authors:

Daria A. Kandaurova – processing of macrophytobenthos samples, analysis of the study results, preparation of the article text

Nataliya A. Milchakova – problem statement, determination of the macrophytobenthos species composition, analysis of the study results, preparation of the article text

All the authors have read and approved the final version of the manuscript.