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TO THE STUDY OF MACROPHYTOBENTHOS OF COASTAL WATERS OF KARADZHINSKY PLOT ON TARKHANKUT PENINSULA (CRIMEA, BLACK SEA)

© 2020 **S. Ye. Sadogurskiy**

Nikitsky Botanical Gardens – National Scientific Center of RAS, Yalta, Russian Federation
E-mail: *ssadogurskij@yandex.ru*

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Composition and distribution of seaweeds in coastal waters of the Karadzhinskaya Bay, adjacent to the southern cluster of a specially protected natural area "Tarkhankut" Nature Park (Crimea, Tarkhankut Peninsula, Black Sea), are described and discussed. Peculiarities of the coastal zone geomorphology determine structural features of macrophytobenthos and its intermediate position in relation to macrophytobentos of adjacent abrasive and accumulative coasts. Totally 57 species of seaweeds were identified (Chlorophyta – 12, Ochrophyta (cl. Phaeophyceae) – 12, Rhodophyta – 33); 21 of them occur in pseudolittoral, and 56 – in sublittoral. Biomass ranges from 0.5 kg per m^2 in pseudolittoral to 4.5 kg per m^2 in sublittoral. Nature and quantity of benthic vegetation, flora composition, and ratio of main ecological-floristic groups of macrophytobenthos are generally characteristic for the Tarkhankut-Sevastopol hydrobotanical region of the Black Sea. A rare fraction of flora includes 14 taxa listed in nature conservation lists of various ranks. The biotope subjects to special protection according to the EU Habitats Directive (Directive 92/43/EEC). The territorial-aquatic complex is important both from nature protection and recreation points of view. Its conservation will contribute to structural and functional integrity of Black Sea coastal zone ecosystem.

Keywords: Black Sea, Crimea, Tarkhankut Peninsula, macrophytobenthos, species composition, biomass, distribution

The Tarkhankut Peninsula of Crimea has a dynamic geological past and is characterized with a variety of geomorphologic structures, which, along with weak anthropogenic transformation, determine a high level of both landscape and biological diversity [17]. As part of specially protected natural areas, unique areas of true sod-cereal (poor-forbs) and desert (wormwood-cereal) steppes are preserved here [12]. Biological and landscape diversity is also characteristic of Black Sea waters washing Tarkhankut Peninsula coast. This determines the sozological significance of the region and its potential for optimizing protected areas and ecological networks of various types. On the other hand, it makes the area attractive to adherents of unorganized and extreme tourism. They are usually followed by "traditional" recreants, and it means that infrastructure is inevitably formed. Some areas in a sea coastal zone, transformed (recreational) ones, as well as priority areas for biodiversity conservation (including existing and planned protected objects), have already become closely adjacent and alternating. Taking into consideration dynamics of coastal development, including plans for construction of large-scale recreational complexes, a yacht marina, etc., it can be concluded that the area biological diversity is under threat. Allocation of sites for conservation or limited ecological tourism requires special comprehensive studies. Integral territorial-aquatic complexes of the sea coastal zone with preserved natural or quasi-natural vegetation are of the greatest significance [15]. At the same time, both water areas off Tarkhankut Peninsula coast and macrophytobenthos forming the foundation of coastal marine biotopes have been poorly studied. To fill this gap, we characterized bottom vegetation cover on abrasive and accumulative coast within the boundaries of the vast Karadzhinsky Plot located in the far west of Tarkhankut [13, 28, 29]. At this stage, we set an aim: within the framework of a comprehensive hydrobotanical survey of the Karadzhinsky Plot, to give both a detailed description of marine phytobenthos at the abrasive and accumulative coast and recommendations for their effective use.

Research area. The Tarkhankut Peninsula is of tectonic origin and is a gently sloping rampart formed by tertiary limestones of pontic tier [4]. The Karadzhinskaya Bay is located in the central part characterized by a diverse geomorphological structure of the coast and limited by Karamrun and Tarkhankut capes (Fig. 1).

The bay depression is continued by a lagoon salt Karadzha Lake (Tarkhankut group of lakes), separated by above water sandbar, and a broad arroyo of the same name [5]. Northern and southern coasts of the bay are abrasive, composed of dense upper sarmatian limestones, with their retreat not exceeding 0.1–0.2 m per year and bottom abrasion being the main source of sediment supply [2, 3, 17]. Limestones at Karamrun Cape form high cliffs while at the Cape Tarkhankut they have only a small storm berm. Correspondingly, at the northern shallow-bay coast, bottom is steep covered with block and block-boulder bulk; the southern coast is bordered by a strip of flat limestone bench, forming a number of wide steps under water. In shallow water, a boulder bulk is not observed, while at depths of 4–7 m it can be recorded fragmentary. At a distance of about 1.5–2 km from the coast at depths of 15–20 m, there is a side face of the rock plate, and at its foot at depths of 35–40 m, there is a shelf plain covered with loose sediments [5]. At the adjoining points of the sandbar, the limestones are covered with clays; a dead cliff can be observed here, and it indicates that sandbar body had previously been at a longer distance off the sea coast. In the area surveyed, cliff height does not exceed 1–1.5 m. The sandbar itself, now having a length of about 1 km, a width of up to 400 m, and a height of up to 1.5 m, is composed of oolitic limestone sands with an admixture of broken shells, with the same sediments covering shallow bottom of the bay.

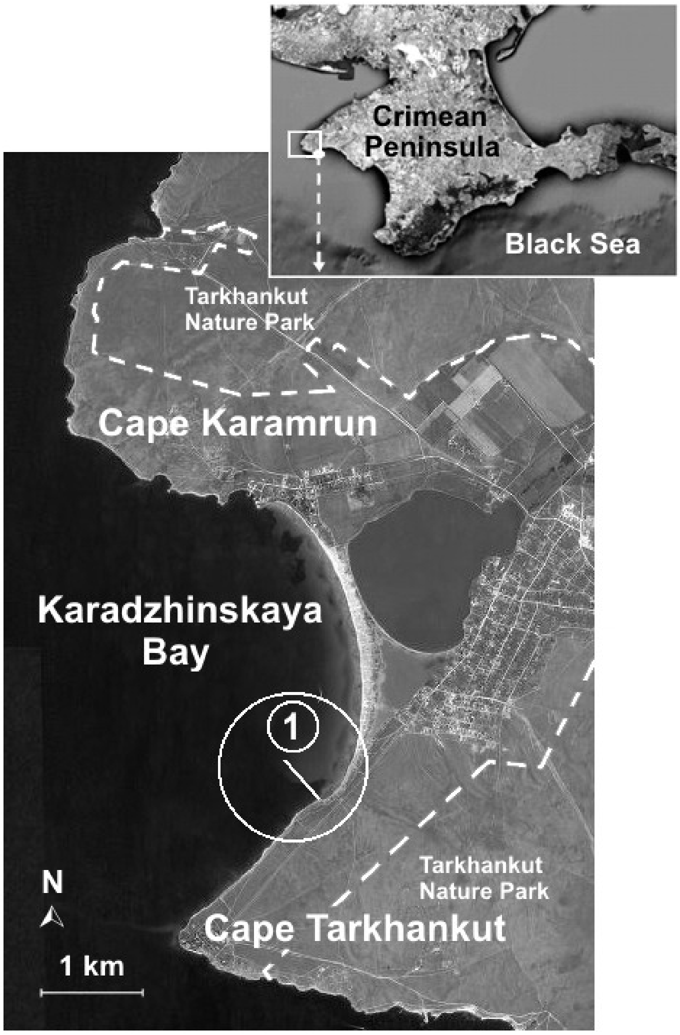

Fig. 1. Map of the Karadzhinsky Plot on the Tarkhankut Peninsula: 1 – sampling area is marked with a circle; hydrobotanical profile is in the circle center

Hydrodynamics off the coast of the Tarkhankut Peninsula is high due to intensive wave activity and alongshore currents with speeds of up to 0.25–0.30 m per s [11]. Moreover, our observations show that at the southern coast of the bay, wave deformation and burrowing of their ridges above a gently sloping bottom begin at a considerable distance off the coast. In summer, winds of the western, northern, and northwestern rhombuses dominate in this sea region. In July, average long-term values are: water temperature of +19.8 °C, mineralization of 17.47 g per L (average annual fluctuations within +4.8…+21.6 °C and 17.21–17.55 g per L, respectively) [1]. Low coastal cliff, adjoining of accumulative beach of sandbar, and availability of roads attract spontaneous recreants to this area. At the same time, the area adjoins southern cluster of protected areas ("Charivna havan" national nature park since 2009; "Tarkhankut" regional nature park since 2015).

MATERIAL AND METHODS

A survey of the coastal zone with a total length of about 1 km along water edge (Fig. 1) was carried out in summer period of 2012 by generally accepted hydrobotanical methods [7, 8]. Location of hydrobotanical profile base (at the intersection of the surf line), along which macrophytobenthos samples were taken, was 45°21′33.2″N, 32°30′35″E. Material was collected during dives using light-diving equipment: in pseudolittoral – along the water edge (station no. 1: distance from the coast $l \approx 0$ m, height above sea level – depth $h \approx \pm$ (0.05…0.15) m), and in sublittoral – along three isobaths (st. no. 2: $l \approx 25…30$ m, $h \approx 1$ m; st. no. 3: $l \approx 100…120$ m, $h \approx 3$ m; st. no. 4: $l \approx 250…300$ m, $h \approx 5$ m). Visual observation of the bottom was carried out up to a depth of 10 m. Thus, the profile covered all areas of the benthal where vegetation was recorded. Totally 10 pseudolittoral samples were taken using a frame with an area of 0.01 m^2; 5 sublittoral samples were taken at each station using a frame with an area of 0.04 m^2. During the work, at a distance of 5 m from the coast in the water surface layer, mineralization was of 17.5 g per L, temperature was of +22.5 °C.

Benthic macrophytes were studied. Nomenclature of macroalgae of phylum Chlorophyta, Ochrophyta (class Phaeophyceae), and Rhodophyta is given according to AlgaeBase [22]; taxa authors names are in the standard abbreviation in accordance with the recommendations of IPNI [23]. If necessary, nomenclature combinations are given in addition according to A. D. Zinova ([6] is used as a basic guide for identifying taxa). Ecological and floristic characteristics of algae are given according to A. A. Kalugina-Gutnik [8]; saprobiological and halobility characteristics – according to data unpublished by A. A. Kalugina-Gutnik and T. I. Eremenko (provided by the authors to Nikitsky Botanical Gardens staff). The projective cover (hereinafter PC) was set visually; average biomass values (wet weight) of macrophytes ($\bar{x}$) and error of the mean ($\pm S_{\bar{x}}$) were determined by statistical processing.

RESULTS AND DISCUSSION

Depending on intensity of wind surge of sea level fluctuations, pseudolittoral vegetation in the Sea of Azov – Black Sea region exhibits various structural features [27]. *Cladophora sericea* + *Ulva linza* community (station no. 1) develops in the pseudolittoral of the area surveyed on a solid substrate, represented by fragmented wave-breaking niche and individual clusters of boulder bulk, in form of narrow, 0.1–0.3 m wide belt undifferentiated into subzones. Totally 21 macrophyte species with biomass of about 490 g per m^2 and PC of up to 75 % were identified (Table 1, Fig. 2). In general, the vegetation cover of the pseudolittoral zone resembles that of the Cape Tarkhankut [29]; however, in the area surveyed, the zone is wider and somewhat less fragmented; therefore, the quantitative values are higher (though they are significantly lower than in Cape Karamrun area [28], while at the top of the bay on loose sediments the pseudolittoral is not observed at all [16]).

Table 1. List and biomass of macrophytobenthos species in the water area surveyed

Taxa	Biomass, g per m^2 (stations no. 1–4)			
	PSL (± 0.15 m)	SBL (−0.5…5 m)		
	no. 1	no. 2	no. 3	no. 4
Chlorophyta				
Bolbocoleon piliferum Pringsh.		L	L	
Chaetomorpha aërea (Dillwyn) Kütz. [*Chaetomorpha chlorotica* (Mont.) Kütz., *Chaetomorpha crassa* (C. Agardh) Kütz.]		L	L	L
Chaetophora pisiformis (Roth) C. Agardh		L	L	
Cladophora albida (Nees) Kütz. [*C. albida* (Huds.) Kütz.]	33.33 ± 25.17	0.42	L	1.22 ± 1.01
Cladophora sericea (Huds.) Kütz.	300.00 ± 55.68	4.50	2.92 ± 1.91	16.51 ± 3.15
Cladophora vagabunda (L.) C. Hoek	5.00	0.67	L	
Ulva intestinalis L. [*Enteromorpha intestinalis* (L.) Link nom. illeg.?]	2.33 ± 1.89	2.50		
Ulva linza L. [*Enteromorpha linza* (L.) J. Agardh, *Enteromorpha ahlneriana* Bliding nom. illeg.]	111.67 ± 41.93	97.08 ± 42.74	12.46	39.87 ± 3.02
Ulva prolifera O. F. Müll. [*Enteromorpha prolifera* (O. F. Müll.) J. Agardh]	L	12.50 ± 9.92		
Ulvella lens P. Crouan et H. Crouan	L			L
Ulvella leptochaete (Huber) R. Nielsen, O'Kelly & B. Wysor [*Ectochaete leptochaete* (Huber) Wille]	L	L	L	
Ulvella viridis (Reinke) R. Nielsen, O'Kelly & B. Wysor [*Entocladia viridis* Reinke] ✪		L	L	
Ochrophyta (кл. Phaeophyceae)				
Cladostephus spongiosum f. *verticillatum* (Lightf.) Prud'homme [*Cladostephus verticillatus* (Lightf.) C. Agardh nom. illeg.?] ✱		32.92 ± 18.93	850.00 ± 143.16	
Corynophlaea umbellata (C. Agardh) Kütz.		L	L	
Cystoseira crinita Duby [*C. crinita* (Desf.) Bory] ★✪▲○		1683.33 ± 95.93	3042.50 ± 415.02	
Dictyota fasciola (Roth) J. V. Lamour. [*Dilophus fasciola* (Roth) M. Howe]	1.35	31.25 ± 28.26		
Ectocarpus siliculosus (Dillwyn) Lyngbye [*E. confervoides* (Roth) Le Jolis]	L	L	L	
Feldmannia irregularis (Kütz.) Hamel [*Ectocarpus arabicus* Fig. et De Not.]				L
Myriactula rivulariae (Suhr ex Aresch.) Feldmann		L	L	
Myrionema seriatum (Reinke) Kylin		L	L	

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Padina pavonica (L.) Thivy [*Padina pavonia* (L.) Gaill. nom. illeg.?] ◻		3.75		
Spermatochnus paradoxus (Roth) Kütz. ✱		4.58		
Sphacelaria cirrosa [cirrhosa] (Roth) C. Agardh	L	L	L	L
Stilophora tenella (Esper) P. C. Silva [*Stilophora rhizodes* (Ehrh.) J. Agardh nom. illeg.?] ✱✚▲		5.00		
Rhodophyta				
Acrochaetium parvulum (Kylin) Hoyt [*Kylinia parvula* (Kylin) Kylin]			L	L
Acrochaetium secundatum (Lyngb.) Nägeli [*Kylinia virgatula* (Harv.) Papenf., *K. secundata* (Lyngb.) Papenf.]	L	L	L	
Apoglossum ruscifolium (Turner) J. Agardh			1.00	
Callithamnion granulatum (Ducluz.) C. Agardh ✱	28.33 ± 10.41	4.67		
Choreonema thuretii (Bornet) F. Schmitz			L	
Ceramium ciliatum (J. Ellis) Ducluz.	6.43 ± 4.97	0.83	0.92	L
Ceramium diaphanum (Lightf.) Roth. [*Ceramium tenuissimum* (Lyngbye) J. Agardh]		9.82 ± 3.15	L	L
Ceramium virgatum Roth [*Ceramium pedicellatum* (Duby) J. Agardh nom. illeg.?; *Ceramium rubrum* (Huds.) C. Agardh nom. illeg.?]		12.92 ± 3.15	1.42 ± 1.01	
Chondria capillaris (Huds.) M. J. Wynne [*Ch. tenuissima* (Gooden. et Woodw.) C. Agardh]		10.83 ± 4.39	6.08	0.42
Chroodactylon ornatum (C. Agardh) Basson [*Asterocytis ramosa* (Thwaites) Gobi ex F. Schmitz]	L	L	L	
Colaconema savianum (Menegh.) R. Nielsen [*Acrochaetium savianum* (Menegh.) Nägeli]	L	L	L	
Gelidium crinale (Hare ex Turner) Gaillon [*G. crinale* (Turner) J. V. Lamour.]		L	L	
Gelidium spinosum (S. G. Gmel.) P. C. Silva [*G. latifolium* (Grev.) Bornet et Thur.] ✪	L			
Hydrolithon farinosum (J. V. Lamour.) Penrose & Y. M. Chamb. [*Melobesia farinosa* J. V. Lamour.]			L	
Jania rubens (L.) J. V. Lamour.		L	13.75 ± 11.92	
Jania virgata (Zanardini) Mont. [*Corallina granifera* J. Ellis et Soland.]			8.33 ± 0.72	
Laurencia coronopus J. Agardh ✱▲		4.17		
Laurencia obtusa (Huds.) J. V. Lamour. ✪		47.08 ± 18.30	200.83 ± 61.71	
Lomentaria firma (J. Agardh) Falkenb. [*L. firma* (J. Agardh) Kylin nom. illeg.?]		0.17		
Lophosiphonia obscura (C. Agardh) Falkenb.			L	L

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Peyssonnelia rubra (Grev.) J. Agardh			L	
Phyllophora crispa (Huds.) P. S. Dixon [*Ph. nervosa* (DC.) Grev.] ★✪✚▲	4.25			
Pneophyllum confervicola (Kütz.) Y. M. Chamb. [*Melobesia minutula* Foslie]	L	L	L	
Polysiphonia denudata (Dillwyn) Grev. ex Harv. [*P. denudata* (Dillwyn) Kütz. nom. illeg.?]	1.67	11.67 ± 8.78	0.50	1.34
Polysiphonia elongata (Huds.) Spreng. [*P. elongata* (Huds.) Harv. nom. illeg.?]				1.58
Vertebrata fucoides (Huds.) Kuntze [*Polysiphonia fucoides* (Huds.) Grev., *Polysiphonia nigrescens* (Dillwyn) Grev. nom. illeg.?]	0.67	7.50 ± 2.50		
Polysiphonia opaca (C. Agardh) Moris et De Not. [*P. opaca* (C. Agardh) Zanardini nom. illeg.?]				0.20
Polysiphonia subulata (Ducluz.) Kütz. [*Polysiphonia violacea* var. *subulata* (Ducluz.) L. Batten] ✪	L	82.50 ± 47.70	0.83	
Vertebrata subulifera (C. Agardh) Kuntze [*Polysiphonia subulifera* (C. Agardh) Harvey]		500.83 ± 77.51	310.83 ± 146.49	
Rhodochorton purpureum (Lightf.) Rosenv. ✱			0.08	0.02
Sahlingia subintegra (Rosenv.) Kornmann [*Erythrocladia subintegra* Rosenv.]			L	
Stylonema alsidii (Zanardini) K. M. Drew [*Goniotrichum elegans* (Chauv.) Zanardini] ✱✪		L	L	
Titanoderma pustulatum (J. V. Lamour.) Nägeli [*Dermatolithon pustulatum* (J. V. Lamour.) Foslie]			L	

Note: PSL – pseudolittoral; SBL – sublittoral. Empty cellsindicate absence of the species in the samples; L – little (less than 0.01 g in the sample). Standard error of the mean (± $S_{\bar{x}}$) is indicated for cases where v < 100 % (v is coefficient of variation). There is an opinion that *Cystoseira crinita* is Mediterranean endemic and does not occur in the Black Sea, and specimens identified as *C. crinita* f. *crinita* and *C. crinita* f. *bosphorica* actually refer to *Cystoseira bosphorica* Sauv. [19]. This issue requires a special study, with Crimean coast including. The conservation status of taxa in the Sea of Azov – Black Sea region: ✚ – Red Book of the Russian Federation [10]; □ – Red Data Book of the Republic of Bulgaria [26]; ✱ – Red Data Book of Ukraine [18]; ★ – Black Sea Red Data Book [20]; ✪ – Black Sea Red Data List [21]; ○ – Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention, 1976) [25], ▲ – Red Book of the Republic of Crimea [9].

In shallow water of the sublittoral, surf waves transform when interacting with a gentle bottom, and their kinetic energy increases. As a result, macroscopic vegetation is damaged on a hard-flat surface of a rocky bench, and during storms it is actually abraded by pebbles, gravel, etc. Therefore, the bench up to a depth of 0.3–0.4 (0.5) m is almost devoid of macroscopic vegetation. Moreover, here and below (even under canopy of vegetation), it is more or less covered with a thin layer of sand brought from the bay (it was not observed south to the Cape Tarkhankut). At some distance off the coast multi-tiered (PC of 90–100 %), well developed, having no signs of mechanical damage "*Cystoseira* belt" communities were registered on hard, even ground. At shallow depths (station no. 2), *Cystoseira crinita* + *Vertebrata subulifera* community develops, with 42 macroalgae taxa recorded with biomass of a little over 2.5 kg per m^2 (Table 1, Fig. 2). *V. subulifera* develops abundantly over almost the entire spectrum of depths, and it dominates in the epiphyton at the distal ends of the branches of the largest *Cystoseira* specimens. Deeper (station no. 3)

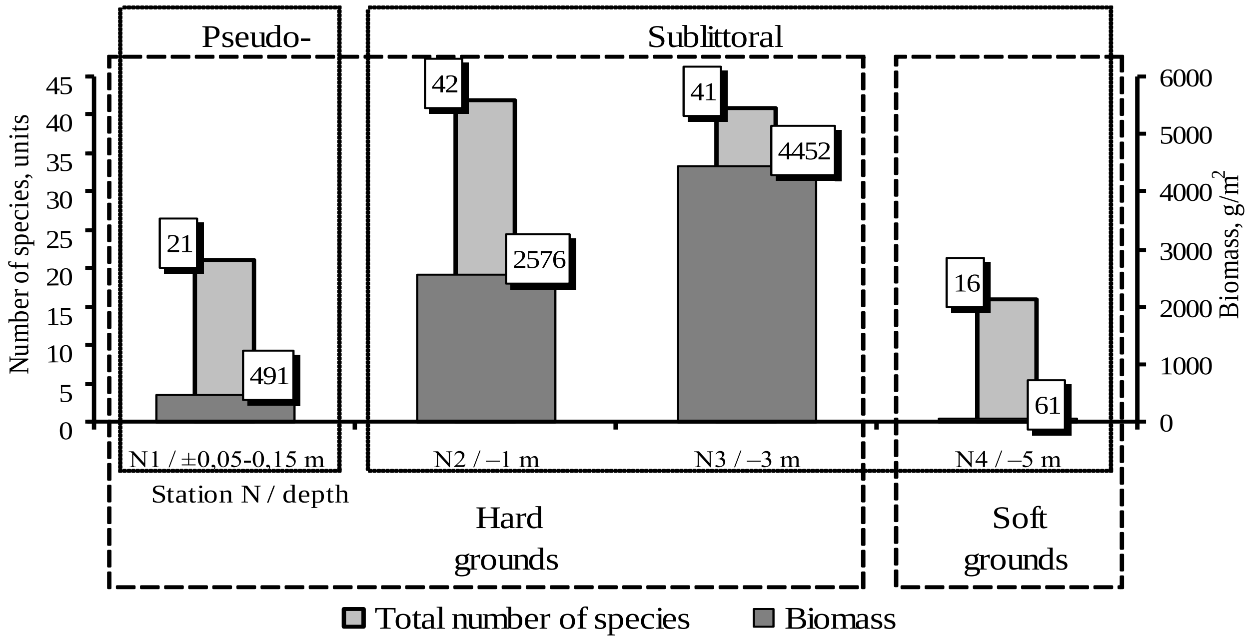

Fig. 2. Changes in total number of species and average biomass of macrophytobenthos with depth change in the water area surveyed

up to the lower boundary of distribution of solid grounds, at a depth of about 4 m at a distance of 190–200 m off the coast, a flat bottom is covered with *Cystoseira crinita* + *Vertebrata subulifera* – *Cladostephus spongiosum* community with biomass of about 4.5 kg per m^2 and PC of 90–95 %, and in this community 41 taxa were identified. Up to this point, picture in general terms was similar to that registered at the Cape Tarkhankut [29]. However, at the Cape Tarkhankut, a deeper flat bench is covered with a block bulk of *Cystoseira* thickets, and in the area surveyed it plunges gradually into loose sediments (there is no clear line between rocks and sand).

In bays in summer period, which is relatively windless, on molluscs shells and on other solid objects located on loose grounds surface, at a depth of not lower than 3 m, an ephemeral vegetation cover develops predominantly from green and, to a lesser extent, red algae [14]. We previously showed that in the central part of the Karadzhinskaya Bay under conditions of reduced hydrodynamics at a certain distance off the surf zone with its increased hydrodynamics (and with lots of recreants, who also have a mechanical effect on the ground and vegetation), *Ulva linza* + *Cladophora sericea* community develops [16]. It was registered in the area surveyed under similar conditions (station no. 4). With biomass of more than 60 g per m^2 and PC of 10–15 %, 16 macrophyte species were recorded there (Table 1, Fig. 2). That is, during the period of research throughout the bay (visually to a depth of at least 8 m), a fairly uniform ephemeral vegetation cover of the same composition and structure developed on loose grounds. Empirically, it can be concluded that its density (and biomass) depends on the amount of shells on the ground surface and on the duration of relatively windless period, since damage is usually observed even after short storms.

Totally 57 macroalgae species were observed within the boundaries of the area surveyed (Table 1): Chlorophyta – 12 (21.05 %), Ochrophyta (Phaeophyceae) – 12 (21.05 %), and Rhodophyta – 33 (57.9 %). At the same time, 56 taxa were registered in the sublittoral, and it is comparable with the values obtained for other points of the Karadzhinsky Plot. In the pseudolittoral, there were 21 taxa, and is not much more than on the Cape Tarkhankut (where the coast structure is similar to that of the area under discussion), but 1.5 times less than in Cape Karamrun area (coast is deep there, and bench is not expressed) [13, 28, 29].

In a range of depths of 1–3 m in the sublittoral *Cystoseira* communities, values of species diversity and phytobenthos biomass are the highest (Table 2). In terms of biomass, share of Phaeophyceae in these communities is within 68–87 %, and share of epiphyton decreases with depth while total values increase. Contribution of Chlorophyta to formation of the biomass of these communities is minimal, while in pseudolittoral and on loose grounds in the sublittoral they form more than 90 % of the biomass. Over the entire spectrum of the depths surveyed, in the ratio of systematic groups by the species number, the share of Rhodophyta is half or more.

In general, oligosaprobic macroalgae dominate the area (Table 2). Their share in terms of the species number (61–64 %) and biomass (94–99 %) is maximal in *Cystoseira* communities, while in pseudolittoral and on loose grounds in the sublittoral, almost the entire biomass is formed by mesosaprobionts. By the species number, their share is also the highest (33–43 %).

By the species number, short vegetation algae dominate in the area surveyed, but with an increase in depth, share of perennial taxa increases (Table 2). They form 69 to 92 % of the biomass in *Cystoseira* communities, while in pseudolittoral and on loose grounds in the sublittoral, up to 100 % is formed by short vegetation taxa.

The analysis of halobility groups ratio shows that marine macroalgae dominate by the species number, with a tendency to increase their share with depth increase (Table 2). Representatives of this group form 94–99 % of the biomass of *Cystoseira* communities, but in pseudolittoral and on loose grounds in the sublittoral, this result is shown by brackish-marine taxa. It should be noted that composition of marine groups varies greatly from station to station, while brackish-marine and brackish groups taxa are actually the same at all stations (Table 1).

In general, representatives of warm-water complex dominate over the area, as well as at some stations, especially by biomass. With depth increase, share of warm-water macroalgae in the total number of species increases, but their contribution to biomass formation decreases (the latter is true for the sublittoral) (Table 2). On the whole, the picture resembles that previously recorded at the Cape Tarkhankut [29].

Macrophytobenthos of the area surveyed has 14 rare taxa (taking into consideration relatively small size of the water body and international cooperation of the Black Sea states in the field of protection of the sea, all published national and international phytososological lists, as well as the regional Red Book, are taken into account) (Table 1). Biotope based on macrophyte communities falls under the EU Directive on the conservation of natural habitats and wild fauna and flora (Directive 92/43/EEC; code 1170 – Reefs) [24].

Comparison of the results of this survey with the data obtained earlier for other points of the Karadzhinsky Plot shows that the vegetation cover of this area has an intermediate position. It reveals features typical for the Cape Tarkhankut: in the pseudolittoral zone it shows relatively weak development and some fragmentation of the vegetation cover; in the sublittoral zone it is absent in the shallowest part, while monotonous *Cystoseira* thickets with lower biomass and relatively simplified vertical structure (two tiers) develop up to the lower boundary of hard ground (for example, at the Cape Karamrun with longer thalli and larger *Cystoseira* biomass, three tiers are formed in communities). As we indicated earlier, this is due to the peculiarities of the geomorphological structure of the coastal zone: at the Cape Karamrun, the narrow coastal bottom strip covered with block-boulder and (deeper) with block bulk has a significant slope angle, while both the area surveyed and the Cape Tarkhankut are characterized by extensive shallow rocky bench, almost devoid of block clusters. Above its surface, an early transformation of surf waves occurs, when oscillatory motion of water mass is converted into translational one. This enhances the mechanical effect on the coastal *Cystoseira* thickets resulting in not only reduced production values, but also in eliminating

Table 2. Distribution of the species number and biomass of macrophytes in ecological-floristic groups in the water area surveyed

GR	Species number, units / % (stations no. 1–4)					Biomass, g per m^2 / % (stations no. 1–4)				
	PSL	SBL			**total**	PSL	SBL			**mean**
	no. 1	no. 2	no. 3	no. 4		no. 1	no. 2	no. 3	no. 4	
Chl	8 / 38.10	11 / 26.19	9 / 21.95	5 / 31.25	**12 / 21.05**	452.33 / 92.17	117.67 / 4.57	15.38 / 0.35	57.60 / 94.18	**160.74 / 8.48**
Oh	3 / 14.29	11 / 26.19	7 / 17.07	2 / 12.25	**12 / 21.05**	1.35 / 0.28	1760.83 / 68.36	3892.50 / 87.42	L / 0	**1413.67 / 74.60**
Rh	10 / 47.62	20 / 47.62	25 / 60.98	9 / 56.25	**33 / 57.89**	37.10 / 7.56	697.24 / 27.10	544.57 / 12.23	3.56 / 5.82	**320.62 / 16.92**
Os	10 / 47.62	27 / 64.29	25 / 60.98	8 / 50.00	**37 / 64.91**	36.78 / 7.49	2423.66 / 94.10	4435.15 / 99.61	2.02 / 3.30	1724.40 / 91.00
Ms	7 / 33.33	8 / 19.05	11 / 26.83	7 / 43.75	**13 / 22.81**	446.67 / 91.01	113.67 / 4.41	15.88 / 0.36	59.14 / 96.70	158.84 / 8.38
Ps	4 / 19.05	7 / 16.67	5 / 12.20	1 / 6.25	**7 / 12.28**	7.33 / 1.50	38.41 / 1.49	1.42 / 0.03	L / 0	11.79 / 0.62
Pr	2 / 9.52	8 / 19.05	11 / 26.83	4 / 25.00	**16 / 28.07**	L / 0	1770.74 / 68.75	4116.49 / 92.45	1.80 / 2.94	**1472.25 / 77.70**
Sh	19 / 90.48	33 / 78.57	28 / 68.29	12 / 75.00	**39 / 68.42**	490.78 / 100	805.00 / 31.25	335.96 / 7.55	59.36 / 97.06	422.78 / 22.31
?	0 / 0	1 / 2.38	2 / 4.88	0 / 0	**2 / 3.51**	0 / 0	L / 0	L / 0	0 / 0	**L / 0**
Cl	8 / 38.10	15 / 35.71	15 / 36.59	6 / 37.50	**19 / 33.33**	339.00 / 69.07	138.09 / 5.36	854.83 / 19.20	19.33 / 31.61	**337.81 / 17.83**
Wr	10 / 47.62	21 / 50.00	23 / 56.10	10 / 62.50	**32 / 56.14**	149.45 / 39.45	2405.56 / 93.39	3596.20 / 80.77	41.83 / 68.39	**1548.26 / 81.70**
Cs	3 / 14.29	5 / 11.90	3 / 7.32	0 / 0	**5 / 8.77**	2.33 / 0.47	27.92 / 1.08	1.42 / 0.03	0 / 0	**7.92 / 0.42**
En	0 / 0	1 / 2.38	0 / 0	0 / 0	**1 / 1.75**	0 / 0	4.17 / 0.16	0 / 0	0 / 0	**1.04 / 0.05**
Mr	11 / 52.38	28 / 66.67	29 / 70.73	10 / 62.50	**43 / 75.44**	36.78 / 7.49	2423.66 / 94.10	4435.15 / 99.61	2.22 / 3.63	**1724.45 / 91.00**
Bm	6 / 28.57	10 / 23.81	10 / 24.39	6 / 37.50	**10 / 17.54**	446.67 / 91.01	136.41 / 5.30	17.30 / 0.40	58.94 / 96.37	**164.83 / 8.70**
Br	4 / 19.05	4 / 9.52	2 / 4.88	0 / 0	**4 / 7.02**	7.33 / 1.49	15.67 / 0.61	L / 0	0 / 0	**5.75 / 0.30**
Σ	**1 / 100**	**2 / 100**	**1 / 100**	**6 / 100**	**7 / 100**	**90.78 / 100**	**575.74 / 100**	**452.45 / 100**	**1.16 / 100**	**1895.03 / 100**

Note: GR – groups. Systematical: Ch – Chlorophyta; Oh – Ochrophyta (cl. Phaeophyceae); Rh – Rhodophyta. Saprobiological: Os – oligosaprobes; Ms – mesosaprobes; Ps – polysaprobes. By the duration of the vegetation period: Pr – perennial; Sh – short-vegetating; ? – no data. Phytogeographical: Cl – cold-water; Wr – warm-water; Cs – cosmopolitans; En – endemics. In relation to halobility: Mr – marine; Bm – brackish-marine; Br – brackish.

quantitative differences between stations [29]. At the same time, an ephemeral vegetation cover develops deeper on a loose substrate, which is similar in composition and structure to that of the central part of the Karadzhinskaya Bay [13, 16].

Conclusion. As a result of hydrobotanical survey carried out in the coastal water area near the Cape Tarkhankut, it has been revealed that macrophytobenthos develops on a solid substrate (class of formations of hard grounds community is Thalassophycion sclerochthonophytia) and on a loose substrate (class of formations of soft grounds community is Thalassophycion malacochthonophytia), and it determines the common nature of vegetation cover. At the same time, A. A. Kalugina-Gutnik when classifying Black Sea benthic vegetation referred to the last class of formations only communities of char algae developing on silty sediments. Our observations show that development of ephemeral communities of green algae in summer (often with a significant share of red algae) is characteristic of soft (sandy, admixture of shells) grounds localized in vast bays at the Black Sea and the Sea of Azov coasts. Nature and quantity of benthic vegetation, flora composition, and ratio of ecological-floristic groups are generally characteristic for the Tarkhankut-Sevastopol hydrobotanical region of the Black Sea. Specific features of geomorphological structure of the coastal zone of the area surveyed determine certain structural characteristics of macrophytobenthos and its intermediate position concerning vegetation cover of adjacent abrasive and accumulative coastal areas. At the same time, vegetation cover demonstrates quite a high level of preservation; taxa and biotopes, that are of particular value in the framework of regional and international legislation, are registered within its borders. Previously, we recommended absolutely reserved status for the waters adjacent at the Tarkhankut and Karamrun capes. However, taking into account the recreational use of the area surveyed, in the future it can be included in the zones of regulated recreation of the nature park covering regime marine water areas, at least along the contour of distribution of solid grounds occupied by *Cystoseira* thickets. We would like to emphasize that we are discussing not only some protected water areas, but also the whole territorial-aquatic complex of the Cape Tarkhankut. Such an approach will make it possible to control and regulate anthropogenic load from full preservation to limited recreation and ecotourism in certain areas, which is to slow down (and even to prevent) structural and functional transformation of one of few preserved territorial-aquatic complexes in the Steppe Crimea.

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К ИЗУЧЕНИЮ МАКРОФИТОБЕНТОСА ПРИБРЕЖНОЙ АКВАТОРИИ КАРАДЖИНСКОГО УЧАСТКА ПОЛУОСТРОВА ТАРХАНКУТ (КРЫМ, ЧЁРНОЕ МОРЕ)

С. Е. Садогурский

Никитский ботанический сад – Национальный научный центр РАН, Ялта, Российская Федерация
E-mail: *ssadogurskij@yandex.ru*

Приведены сведения о составе и распределении макроводорослей в прибрежной акватории Караджинской бухты, примыкающей к южному кластеру особо охраняемой природной территории Национальный природный парк «Тарханкутский» (Крым, п-ов Тарханкут, Чёрное море). Специфика геоморфологического строения береговой зоны обусловливает структурные особенности макрофитобентоса и его промежуточное положение по отношению к макрофитобентосу прилегающих абразионных и аккумулятивных участков берега. Всего зарегистрировано 57 видов макроводорослей (Chlorophyta — 12, Ochrophyta (кл. Phaeophyceae) — 12, Rhodophyta — 33), из них 21 — в псевдолиторали и 56 — в сублиторали. Биомасса колеблется от 0,5 кг·м$^{-2}$ в псевдолиторали до 4,5 кг·м$^{-2}$ в сублиторали. Характер и количественные показатели бентосной растительности, состав флоры и соотношение эколого-флористических группировок макрофитобентоса в целом характерны для Тарханкутско-Севастопольского гидроботанического района Чёрного моря. Раритетная фракция включает 14 таксонов, занесённых в природоохранные списки различного ранга. Биотоп подлежит особой охране согласно Директиве ЕС о местообитаниях (Directive 92/43/EEC). Территориально-аквальный комплекс имеет созологическую и рекреационную ценность, его сохранение необходимо для обеспечения структурно-функциональной целостности экосистемы береговой зоны моря.

Ключевые слова: Чёрное море, Крым, полуостров Тарханкут, макрофитобентос, видовой состав, биомасса, распределение