Study of ecosystem of the Sukhum Bay with emphasis anthropogenic impact, Abkhazian Black Sea coast

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Abstract

For the first time in thirty years, baseline comprehensive studies plankton and zoobenthos of the Sukhum Bay were conducted and an assessment of its current environmental status was given. The summer phytoplankton abundance of the port of Sukhum was represented mainly by coccolithophorids Emiliania huxleyi and diatoms algae, among the latter, the common species in polluted or eutrophic brackish waters were recorded. The presence of euglenic algae and cyanobacteria indicates a higher nutrient status, pollution and desalination of the sea area. The alien species Peridinium quinquecorne Abé (Dinophyceae) was recorded in the Abkhazian coastal waters for the first time. Totally, 7 species of tintinnids belonging to 3 genera Favella, Tintinnopsis, Eutintinnus were established from the Sukhum Bay. Among them, the non-indigenous species Eutintinnus tubulosus and E. apertus were noticed. Tintinnid ciliates accounted for ca. 5% of total ciliates abundance. The values of the abundance of aloricated ciliates were comparable to the values obtained from offshore of bays and ports of the northeastern Black Sea. As the pressure of predators is reduced the well-pronounced peaks of holo- and meroplankton biomass were recorded in the last summer – early autumn. A significant part of total holoplankton biomass – 66.5 % (up to 1.1 g/m³) was composed of cladocerans Penilia avirostris. The meroplankton was dominated by larvae of bivalve mollusks Mytilaster lineatus, polychaetes Polydora cornuta and cirripede barnacle Amphibalanus improvisus. The number of meroplankton in the open Sukhum port was 10–15 times lower above than a level of values obtained for ports and bays of the northeastern Black Sea. Among ichthyoplankton, the dominant species were Mullus barbatus ponticus, Diplodus annularis, Trachurus mediterraneus, Engraulis encrasicolus and Sciens umbra. Mean abundance of ichthyoplankton in vertical catches was 5–10 times lower than in offshore of Anapa and Gelendzhik of the northeastern Black Sea. And the proportion of dead eggs was 2 – 3 times higher than areas of these resort cities. The composition of macrozoobenthos was drastically depleted and resembled that of the polluted port complexes of the northeastern Black Sea. Heteromastus association dominated in mud bottom sediments. Among spionid polychaetes, the worst invaders Sirelospio gynobranchiata and Polydora cornuta have been recorded in soft bottom communities. Depletion of benthic communities, loss from the structure of the trophic web of the macrophyte community and appearance of cyanobacteria and a new alien species in the planktonic and benthic communities leads inevitably to imbalance of the structure of the Sukhum port ecosystem.

Key words: phytoplankton, ciliates, holoplankton, meroplankton, ichthyoplankton, macrozoobenthos, Sukhum Bay, Black Sea.
Introduction

Research studies on the Abkhazian Black Sea shelf of the have been carried out until the mid-1980s and they were discontinued completely in early 1990s due to USSR collapse and Georgian-Abkhazian war. Nowadays, separate sets of data on several hydrophysical, hydrochemical and hydrobiological parameters on along deep-water shelf of the Republic of Abkhazia by various scientific bodies (Matishov et al., 2014; Kostianoy et al., 2017; Lebedev et al., 2017) show many gaps, and still do not give a definite holistic evaluation of real ecological status of the most polluted port and recreational tourist coastal areas. Sukhum is the capital of the Republic of Abkhazia, which is known as an important seaport, a world-famous resort and one of the most popular tourist cities of ex-USSR. The Sukhum Bay is one of the three largest gulfs of the Eastern Black Sea region (along with gulfs Pitsunda and Batumi). Bay is separated by the Sukhumi Cape (Red lighthouse) on the NW and the Kodor Cape on the SE. Maximal depths in the Sukhum Bay are over 400 m, port depths range between 3 and 5 m. During our survey of the Sukhum port (2016–2017) we recorded four non-indigenous species of spionid polychaetes and tintinnid ciliates (Selifonova & Bartsits, 2018; Selifonova & Makarevich, 2018). However, in spite of significant efforts by researchers, the general picture of the structure and functioning of the Sukhum port ecosystem still remains unclear.

It aimed to study the taxonomic composition and abundance of phytoplankton, ciliates, holoplankton, meroplankton, ichthyoplankton and macrozoobenthos of sediment bottom of the open port of Sukhum and to analyze ecological status its ecosystem.

Material and Methods

The samples collected at the sampling stations (Fig. 1) in June – September 2016–2017 have been analyzed within the period of maximal anthropogenic impact on ecosystem. Field work was accomplished during 6 field trips. During sampling the sea surface temperature varied between 22.1°C (June 2017) and 28.5°C (August 2016) (Fig. 2a).

Figure 1. The map of sampling survey in the port of Sukhum.

Phytoplankton were sampled from the surface by a plastic bucket and concentrated using an sedimentary method. Samples were fixed with neutral formalin to a final concentration of 1–2% for species identification. Living cells were also observed before sedimentation depending on the cell density (Sukhanova, 1983). A samples were analyzed in a Nageotte counting chamber under a microscope. Cells were counted in 0.1 to 0.5 of the volume of the concentrated sample depending on cell abundance. Algal
biomass was calculated by a volumetric technique based on the cell size and shapes the most similar to specific geometric shapes (Bryantseva et al., 2005).

Samples for the qualitative analysis of tintinnid ciliates were collected by towing a 40-µm mesh plankton net within the top half-meter of water. The tintinnid ciliates for the quantitative analysis were collected from the surface by a plastic bucket. The 1500 ml samples were preserved with glutaraldehyde solution (2% final concentration) and concentrated using sedimentation to 10–20 ml subsamples. For determination of abundance, the aloricated ciliates were studied alive with stereomicroscope before preservation using Sorokin’s counting chamber (Sorokin, 1999). Species were identified in vivo, in temporal preparations and preparations impregnated a protargol and a silver carbonate according to A. Kurilov & N. Gavrilova (2015). The biomass of infusorians was determined standard method as well as according to the average volume and abundance in each size group (Mamaeva, 1979, 1980; Kurilov, 2004).

Holoplankton and meroplankton (crustaceans, larvae of benthic organisms, rotifers and others organisms > 200–500 µm) was sampled throughout the water column using a medium-sized Juday net with an opening diameter of 25 cm (mesh size 120 µm) by total catch. The material was fixed by 2–4% neutral formaldehyde and processed in the laboratory by the conventional procedure. Calculations of biomass were made using Petipa’s (1957).

The fish eggs and larvae (ichthyoplankton) were sampled using Bogorov–Rass net (80/114 cm, mesh size 500 µm, mouth area 0.5 m) and horizontal 10 min trawling using neuston net MNT.

The macrozoobenthos sampling was carried out with a Petersen grab (0.04 m² capture area). Samples of sediment bottom were thoroughly washed through a sieve with the mesh size of 0.5 mm and fixed with 4% formaldehyde solution (2% final concentration) and ethanol. Laboratory, worms were sorted and identified to species under a stereomicroscope, and preserved in 70% ethanol.

Results and discussion

Phytoplankton. Totally, 55 taxa were found in the phytoplankton from the Sukhum Bay, including 21 – Bacillariophyta, 28 – Dinophyta, 2 – Cyanophyta, 1 – Cryptophyta, 2 – Euglenophyta, 1 – Chrysophyta. The mean values of phytoplankton abundance during study period were 234±67.9×10⁶ cells./m³, biomass – 471±141.2 mg/m³. The maximal abundance (582×10⁶ cells./m³) was observed in July, maximal biomass (658–1120 mg/m³) – in August (see fig. 2a). The summer phytoplankton (June – July) was represented mainly by coccolithophorids (Chrysophyta) Emiliania huxleyi (Lohmann) W.W.Hay et H.P.Mohler, constituted 80–96 % of the total phytoplankton abundance (200–558×10⁶ cells/m³). Diatoms algae (Bacillariophyta) were dominant in the last of summer – early autumn (82–94 % of the total phytoplankton abundance). In August phytoplankton abundance (155×10⁶ cells/m³) was due to diatoms algae, such as Dactyliosolen fragilissimus (Bergon) Hasle, Pseudosolenia calcis-avis (Schultze) B.G. Sundström, Pseudonitzschia pseudodelicatissima (Hasle) Hasle, Talassiosira sp., Skeletonema costatum (Greville) Cleve and in September (122×10⁶ cells/m³) – Cylindrotheca closterium (Ehrenberg) Reimann & J.C. Lewin respectively. Among of them C. closterium is common species in polluted or eutrophic brackish waters (Konovalova et al., 1989). In September its biomass in the Sukhum Bay varied from 99 to 110 mg/m³. The large diatoms Pseudosolenia calcis-avis occurred with maxima biomass (1020 mg/m³) in August (91 % of the total phytoplankton biomass). The share of dinoflagellates of the total biomass of phytoplankton varied in June – July from 65 to 48 % (300–130 mg/m³ respectively). Among the dinoflagellates noted Prorocentrum micans Ehrenberg, Scrippsiella trochoidea (Stein) Loeblich III, Dinophysis rotundata Claràpede & Lachmann, species of genera Protoperidinium, Gyrodinium, Glenodinium, Gymnodinium and other species. The alien Mediterranean species Peridinium quinquecorne Abé (Dinophyceae) was recorded in the Abkhazian coastal waters for the first time (Gomez, 2003) (fig. 3). This is the second report in the northeastern Black Sea after its first finding in Novorossiysk Bay (Yasakova & Makarevich, 2017). Its mean abundance was 0.76×10⁶ cells/m³. This species is common for estuaries and brackish waters (Konovalova et al., 1989). During the course of the study, 2–8 % of the total phytoplankton abundance was formed by euglenic algae and cyanobacteria genera Eutreptia, Euglena (Euglenophyta), Oscillatoria, Lyngbya (Cyanophyta). The presence of these species indicates a higher nutrient status, pollution and desalinization of the sea area.
Ciliates. The abundance of aloricated ciliates varied between $18 - 39 \times 10^6$ cells/m$^3$, biomass – $100$–$260$ mg/m$^3$ (average abundance $29.4 \pm 3.0 \times 10^6$ cells/m$^3$, biomass $158 \pm 32.4$ mg/m$^3$) (see fig. 2b). The most common genera were *Strombidium, Tontonia, Tiarina* and species *Mesodinium pulex* Claparède & Lachmann and *M. rubrum* (Lohmann). Aloricated ciliates were most abundant in August–September at a temperature of seawater $25$–$28.5$ °C. Totally, 7 species of tintinnids belonging to 3 genera *Favella ehrenbergii* Claparede et Lachmann, *Tintinnopsis campanula* Ehrenberg, *T. davidovi* Daday, *T. minuta* Wailes, *T. tubulosa* Levander, *Eutintinnus tubulosus* Ostenfeld and *E. apertus* Kofoid and Campbel were established from the Sukhum Bay. Among tintinnids species two new to the region were recorded, *E. tubulosus* and *E. apertus* (Selifonova & Makarevich, 2018). A average density of these tintinnids, did not exceed $0.001$–$0.05 \times 10^6$ cells/m$^3$. High sum abundance of tintinnids was recorded in the last of summer – early autumn. They accounted for ca. 5% of total ciliates abundance. It should be mentioned that values of the abundance of infusorians from the open port of Sukhum were comparable to the values obtained from offshore of bays and ports of the northeastern and the northwestern Black Sea (Kurilov, 2010; Selifonova, 2012).

![Figure 2. Dynamics of phytoplankton (a): numerical abundance ($N$, $10^6$ cell/m$^3$), biomass ($B$, mg/m$^3$), temperature of seawater (°C) and planktonic ciliates (b): numerical abundance ($N$, $10^6$·ind./m$^3$), biomass ($B$, mg/m$^3$)](image-url)
**Holoplankton.** Totally, 20 taxa were found in the holoplankton, including 10 – Copepoda, 4 – Cladocera, 1 – Rotifera, 2 – Ctenophora, 1 – Dinophyceae (*Noctiluca scintillans* (Macartney) Kofoid & Swezy), 1 – Chaetognatha, 1 – Appendicularia. The average abundance ranged from 1.8 to 73.2×10^3 ind./m^3 and biomass ranged from 28 to 1164.8 mg/m^3 (fig. 4a). The number of holoplankton during research period averaged 31.1±9.2×10^3 ind./m^3, biomass 663.8±167.3 mg/m^3. Three peaks in the dynamics of biomass were registered in June, August, and September. In June, 86% total holoplankton abundance and 96.7% of biomass composed heterotrophic dinoflagellats *N. scintillans* (13.2±1.2×10^3 ind./m^3, biomass 858±98.4 mg/m^3). The quota of holoplankton crustaceans was negligible. Among their were noted cladoceran *Pleopsis polyphemoides* Leuckart, calanoid copepods *Centropages ponticus* Karavaev, *Acartia tonsa* Dana, *Paracalanus parvus* (Claus), cyclopoid copepods *Oithona davisa* Ferrari F.D. & Orsi and other species. In July, the abundance of sharply dropped up to 1.8±0.5×10^3 ind./m^3, biomass 28±1.6 mg/m^3. Such changes in the structure of holoplankton took place owing to consumption of zooplankton by comb jelly *Mnemiopsis leidyi* A. Agassiz, which peaks in July (Vinogradov et al., 2005). Comb jelly is a predator with a wide feeding spectrum (zooplankton, fish eggs, and larvae) (Tsikhon-Lukanina, Reznichenko, 1991). In August, with appearance in the plankton of ctenophore *Beroe ovata* Bruguière feeding mainly on *M. leidyi*, the abundance of holoplankton started to recover. Its average number increased to maximum 73.2±7.9×10^3 ind./m^3, biomass 1164.8±78 mg/m^3. High abundance of holoplankton was determined by considerable density of cladocerans *Penilia avirostris* Dana (28.6% of the total number), copepods *C. ponticus* (39.8%) and copepods *O. davisa* (26.3%). A significant part of total biomass holoplankton (66.5%) was composed of cladocerans *P. avirostris*. This biomass (≤2–6%) was also represented by species of cladoceran *Evadne spinifera* Müller and *E. tergestina* Claus. In September, *P. avirostris* along with predatory chaetognaths *Parasagitta setosa* (Müller) comprised from 31 to 51% respectively of the total holoplankton biomass.

**Meroplankton.** The larvae of bottom invertebrates comprised 24 taxa, including 6 taxa of Polychaeta, 2 – Cirripedia, 1 – Phorona, 6 – Decapoda, 4 – Bivalvia, 4 – Gastropoda, and 1 – taxa of Hydrozoa. The number of meroplankton during research period averaged 1.8±0.45×10^3 ind./m^3, biomass 18.9±4.8 mg/m^3. The density of the meroplankton ranged from 0.09–3.7×10^3 ind./m^3, biomass 0.45–37 mg/m^3 (see fig. 4b). The contribution of meroplankton to the overall zooplankton density averaged 2.7–16.5%. Well-pronounced peaks of meroplankton density (2–3.7×10^3 ind./m^3) were recorded in August – September 2016. The density of the meroplankton was the lowest in July (0.09×10^3 ind./m^3), when larvae of bottom invertebrates was sharply reduced by predation pressure from the pelagic ctenophore *M. leidyi*. The summer plankton was dominated by larvae of bivalve mollusks *Mytilaster lineatus* (Gmelin), polychaetes *Polydora cornuta* Bosc and cirripede barnacle *Amphibalanus improvisus* (Darwin). In late summer – early autumn the meroplankton mostly consisted of the larvae of bivalve mollusks *Anadara kagoshimensis*.
(Tokunaga), *Chamelea gallina* (Linnaeus) and hydroid *Sarsia tubulosa* (M. Sars) (their overall density was $1.3\sim1.5 \times 10^3$ ind./m$^3$). During research period we observed the larvae of polychaetes *Alitta succinea* (Leuckart), *Malacoceros fuliginosus* (Claparède), *Nephtys hombergii* Savigny in Larnack and *Prionospio* sp. in the plankton; however, the densities of these species were rather low. Larvae of decapods were represented *Diogenes pugilator* (Roux), *Upogebia pusilla* (Petagna), *Pilumnus hirtellus* (Linnaeus), *Athanass nitescens* (Leach), *Brachynotus sexdentatus* (Risso), *Rhitropancheus harrisi tridentatus* Maitland and larvae of gastropod mollusk – *Bittium reticulatum* (da Costa), *Rissoa* sp., *Tritia reticulata* (Linnaeus), *Rapana venosa* (Valencienne). Among them, the most common were *D. pugilator*, *U. pusilla* and *B. reticulatum*. According to presented data taxonomic composition of meroplankton in the open port of Sukhum was 2–3 times lower than in areas of ports and bays of the northeastern Black Sea (Selifonova, 2018). The number of meroplankton was 10–15 times lower above a level of values obtained for these areas.

**Ichthyoplankton.** The eggs and larvae of 7 migrating, such as *Engraulis encrasicholus* (Linnaeus), *Mullus barbatus ponticus* Essipov, *Trachurus mediterraneus* (Steindachner), *Diplodus annularis* (Linnaeus), *Pomatomus saltatrix* (Linnaeus), *Chelon saliens* (Risso), *Sciena umbra* Linnaeus and 5 settled fish species, such as *Syngnathus* sp., *Symphodus mediterraneus* (Linnaeus), *Scorpaena porcus* Linnaeus, *Serranus scriba* (Linnaeus), *Gobius niger* Linnaeus were found in this area. Among them, the dominant species were goatfish *M. barbatus ponticus*, annular sea bream *D. annularis*, horse mackerel *T. mediterraneus*, anchovy *E. encrasicholus* and corr *S. umbra*. The eggs of the rare Red Data Book species of fishes *S. scriba* are noted in the horizontal catches only. The share of larvae in the ichthyoplankton ranged from $\leq 4$ to 8 %. The density of ichthyoplankton in the vertical catches varied from 2 to 24 ind./m$^2$, averaging 12.6±8.5 ind./m$^2$ (fig. 5). In horizontal catches, the average was 70.6±52.4 ind./100 m$^3$. The number of ichthyoplankton ranged from 16 to 130 ind./100 m$^3$. The highest concentration of the ichthyoplankton was found in June and August, when their number in the vertical catches was 21–24 ind./m$^2$ and in the horizontal catches was 116–130 ind./100 m$^3$. The lowest concentration of ichthyoplankton was recorded in July (9 ind./m$^2$ and 49 ind./100 m$^3$ respectively). These changes in ichthyoplankton abundance coincide with mass development of the pelagic predator *M. leidyi*. At this time, the fish eggs and larvae of goatfish, horse mackerel, sea bream were the most abundant. Along with them, eggs of anchovy prevailed in June. High abundance of ichthyoplankton in August was determined by considerable density of the eggs of black umber (52 % of the total number) and goatfish (21 %). In September, the number of species of ichthyoplankton decreased to 2–6 ind./m$^2$ and 16–18 ind./100 m$^3$. It was represented by larvae of sea bream only. At this time, the reproduction of most fishes ceased and a decline occurs their eggs and larvae in plankton. In general, the share of dead and abnormally developing eggs during research period reached 30 – 45 %. Oil stains on the water surface are common phenomenon in the port of Sukhum. Mean abundance of ichthyoplankton in vertical catches in the port of Sukhum was 5–10 times lower than in offshore of resort cities of the northeastern Black Sea, such as Anapa, Gelendzhik (Selifonova, 2018). And the proportion of dead eggs was 2 – 3 times higher than areas of these resort cities.

![Figure 5](image_url) **Figure 5.** Numerical density of ichthyoplankton in vertical catches, ind./m$^2$ (a) and horizontal catches, ind./100 m$^3$ (b): 1 – goatfish, 2 – horse mackerel, 3 – annular sea bream, 4 – anchovy, 5 – corb

**Macrozoobenthos.** 13 taxa of benthic invertebrates were found in September 2016: 1 – Nemertea, 8 – Polychaeta, 1 – Cirripedia, 1 – Bivalvia, 2 – Gastropoda. The abundance of macrozoobenthos varied in the range of 1600–3400 ind./m$^2$ (mean $2325\pm949.6$ ind./m$^2$), biomass – 59.9–99.6 g/m$^2$ (mean $77.9\pm20.1$ g/m$^2$).
Heteromastus association dominated in mud bottom sediments. The population density of capitellid polychaetes Heteromastus filiformis (Claparède) averaged 2141±714.7 ind./m² (range 1550–2950), biomass – mean 7.9±1.1 g/m² (range 6.8–9 g/m²). The contribution of H. filiformis to the overall macrozoobenthos density and biomass averaged 92% and 10.1% respectively. Heteromastus association was represented by such taxa as Streblospio gynobranchiata Rice & Levin, Polydora cornuta Bosc, Capitella capitata (Fabricius), Notomastus sp., N. hombergii, Micronephthys sp., A. succinea (Polychaeta), A. improvisis (Cirripedia), M. lineatus (Bivalvia), B. reticulatum, R. venosa (Gastropoda). Among polychaetes species two new to the region were recorded, spionid S. gynobranchiata, P. cornuta (Selifonova, Bartsits, 2018). Population density of S. gynobranchiata varied from 25 to 400 ind./m², at the average values 150±10.8 ind./m². Maximal density of species recorded at station 1, located near of estuary river Basla. They inhabit the upper layer of muddy sediments containing hydrogen sulphide (Radashevsky & Selifonova, 2013). Population density of P. cornuta varied from 25 to 50 ind./m², at the average values 25±11.1 ind./m². At sampling stations there were the specimens in muddy tubes. P. cornuta and S. gynobranchiata have been classified as the worst invaders in soft bottom communities in the Mediterranean Sea (Zenetos et al., 2005). These polychaetes are capable of fast growth and possess high genetic variability providing advantages in the survival in organic pollution of mud bottom sediments above a critical level.

During our survey of port we revealed sediments consisted of black and dark gray silted sand strong smelling of hydrogen sulphide, as they were under considerable anthropogenic load. Such sediments are formed by the decomposition of organic matter, coming to the shelf owing of municipal sewage discharge. This process is accompanied by movement of free hydrogen sulphide towards the bottom surface, resulting build-up of sulphides and its toxic impact on zoobenthos up to its extinction and promoting development of cyanobacteria (Sorokin & Zakuskina, 2008). The current situation is worrisome, in view of evident signs of anoxia in bottom layers of the port of Sukhum. It is known that under the influence of environmental conditions in such areas the biodiversity of ecosystems and their resistance to external influences decrease, and new ecological niches are occupied by invasions (Selifonova, 2015). The presence of introduced species in communities, even if their taxonomic structure and biomass are insignificant, is a serious risk factor for the ecosystem especially during the periods of reduced stability and structural changes in the communities.

Conclusions

1. The summer phytoplankton abundance of the port of Sukhum was represented mainly by coccolithophorids Emiliania huxleyi and diatoms algae, among the latter, the common species in polluted or eutrophic brackish waters were recorded. A significant part of sum phytoplankton biomass was composed of large diatoms Pseudosolenia calcar-avis. The presence of euglenic algae and cyanobacteria was indicated a higher nutrient status, pollution and desalination of the sea area.

2. The present study reports on the occurrence of the alien Mediterranean species Peridinium quinquecorne Abé (Dinophyceae), in Sukhum Bay. This finding enhances its distributional pattern within the Black Sea.

3. Totally, 7 species of tintinnids belonging to 3 genera Favella, Tintinnopsis, Eutintinnus were established from the Sukhum Bay. Among them, the non-indigenous species Eutintinnus tubulosus and E. apertus were noticed. Tintinnid ciliates accounted for ca. 5% of total ciliates abundance. The values of the abundance of aloricated ciliates were comparable to the values obtained from offshore of bays and ports of the northeastern Black Sea.

4. As the pressure of predators is reduced the well-pronounced peaks of holoplankton and meroplankton density and biomass were recorded in the last summer – early autumn. A significant part of total holoplankton biomass – 66.5% (up to 1.1 g/m³) was composed of cladocerans Penilia avirostris. The meroplankton was dominated by larvae of bivalve mollusks Mytilaster lineatus, polychaetes Polydora cornuta and cirripede barnacle Amphibalanus improvisus. The number of meroplankton in the open Sukhum port was 10–15 times lower above than a level of values obtained for ports and bays of the northeastern Black Sea.

5. Among ichthyoplankton, the dominant species were Mullus barbatus ponticus, Diplodus annularis, Trachurus mediterraneus, Engraulis encrasicholus and Sciena umbra. Mean abundance of ichthyoplankton in vertical catches was 5–10 times lower than in offshore of Anapa and Gelendzhik of the northeastern Black Sea. And the proportion of dead eggs was 2 – 3 times higher than areas of these resort cities.
The composition of macrozoobenthos was drastically depleted and resembled that of the polluted port complexes of the northeastern Black Sea. The contribution of capitellid polychaetes *Heteromastus* association dominated in mud bottom sediments. Among spionid polychaetes, the worst invaders *Streblospio gynobranchiata* and *Polydora cornuta* have been recorded in soft bottom communities.

Depletion of benthic communities, loss from the structure of the trophic web of the macrophyte community and appearance of cyanobacteria and a new alien species in the planktonic and benthic communities leads inevitably to imbalance of the structure of the Sukhum port ecosystem.

This work represents a first attempt at a holistic approach to the problems of coastal marine ecosystems of recreational, tourist and protected areas of the Caucasus and may be a basis for future research in order to fill in present gaps in Abkhazian sector of the Black Sea.

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