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ABOUT THE FINDING OF *LEPIDOCHITONA CINEREA* (LINNAEUS, 1767) IN THE TSEMES BAY (THE BLACK SEA)

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Chitons inhabiting natural hard substrates in the Tsemes Bay pseudolittoral from the central beach of Novorossiysk to the Cape Khako were investigated in summer and winter periods of 2022–2023. For the first time in the Tsemes Bay, a local population of *Lepidochitona cinerea* (Linnaeus, 1767) (Polyplacophora, Tonicellidae) was recorded on substrates of sedimentary origin. It is a rare species, and over the past 70 years, it was found in waters of the North Caucasus only three times. We registered 34 *L. cinerea* specimens with a maximum shell length of 8 mm. The age of the largest individuals (three years) was determined by the annual rings of the apex of the first shell shield. The species is distributed in the upper horizon of the Cape of Love pseudolittoral and is confined to supralittoral baths. A similar biotope, where the chiton was found as well, was discovered in 50 km from the Tsemes Bay. As assumed, the occurrence of the mollusc in the water area is precisely due to the presence of this bionomic type of habitat – supralittoral baths which are not expressed in other study sites of the bay. The aim of the research is to describe *L. cinerea* populations in a previously unspecified biotope for this species and to identify the features of this biotope and its possible effect on the chiton occurrence. Information on the geographic distribution and biotopic confinement of the species was updated. The effect of ecological, hydrochemical, and geomorphological features of the biotope on *L. cinerea* occurrence was considered.

Keywords: *Lepidochitona cinerea*, pseudolittoral, supralittoral baths, Tsemes Bay, Black Sea

Lepidochitona cinerea (Linnaeus, 1767) (Polyplacophora, Tonicellidae) is a chiton with a body length of up to 15 mm. This amphiboreal species is known for the northern Atlantic Ocean from the coast of Norway to the Mediterranean and Marmara seas; in the Pacific Ocean, it was recorded only off the coast of North America [Yakovleva, 1952]. Off the Black Sea shores, *L. cinerea* inhabits rocky and pebble soils, shell rocks, and upper horizons of the sublittoral at depths of down to 30 m [Anistratenko V., Anistratenko O., 2001]. Also, it is registered in sandy biotopes [Sinegub, 2004] and in fouling of breakwaters [Grintsov et al., 2004; Scherbina, 2010]. This species is closely related to organisms of benthic communities: it is a consort of *Rapana venosa* (Valenciennes, 1846) [Bondarev, Revkov, 2017]. Like most chitons, it is a phytophage and feeds mainly on phytoperiphyton [Currie, 1984]. In the Black Sea, the species is distributed off the coast of Crimea and Caucasus (up to Batumi) [Yakovleva, 1952]. However, in the North Caucasus coastal waters, findings of *L. cinerea* are single [Makarov, 2018; Scherbina, 2010]. Mostly, those occur in water areas of the Crimean Peninsula [Bondarev, Revkov, 2017; Khajlenko, 2019; Kovaleva, 2012, 2020; Kovalyova et al., 2016; Losovskaya, 1984;

Makarov, 2018, 2020; Sinegub, 2001; Viter, 2013] and the Kerch Strait [Biryukova et al., 2016; Terentyev, 2008, 2017]. Off the coast of the North Caucasus, this chiton was recorded only three times over the past 70 years; therefore, its finding in the supralittoral biotope is of certain interest.

Despite the wide distribution of *L. cinerea* in various spots of the Black Sea, the species was registered in the biotope of supralittoral baths for the first time. Chitons are well adapted to unfavorable conditions of the littoral zone [Yakovleva, 1952] and are important for many littoral biocenoses regulating periphyton productivity [Aguilera et al., 2013].

In inland seas, such as the Black Sea, due to the absence of tidal phenomena, the littoral is replaced by the pseudolittoral which exists due to sea-level fluctuations [Agarkova-Lyakh, Lyakh, 2022]. According to the classification of O. Kusakin [1961], littoral and supralittoral baths are distinguished as a separate bionomic type of the littoral zone; importantly, their features are the constant presence of water there, weakened effect of the surf, and sharp shifts in salinity and temperature [Butov, 2016]. In accordance with I. Butov [2016], baths are reservoirs formed in the littoral zone and can be completely or partially isolated from the sea. These include potholes, puddles, depressions on rocks, and depressions between blocks and boulders.

The aim of this work is to describe *Lepidochitona cinerea* population in a previously unspecified biotope for this species and to identify features of this biotope and its possible effect on the occurrence of the chiton.

MATERIAL AND METHODS

The study was carried out in the summer and winter of 2022–2023 off the coast of the Tsemes Bay (the Black Sea) (Fig. 1).

Fig. 1. The map of study areas off the Tsemes Bay (the Black Sea): black marks denote water sampling sites; orange mark denotes *Lepidochitona cinerea* finding site

The search for the mollusc was carried out by the route method from the central beach of Novorossiysk to the Cape Khako. Investigated depths varied from 0.3 to 2.0 m. *L. cinerea* was sampled by examining natural hard substrates – inspecting boulders and lifting rocky placers out of water. The age of individuals was estimated analyzing annual layers on the apex of the first shell shield according to the method of A. Yakovleva [1952]. Shell length was measured using the millimeter scale of a YAXUN YX-AK36 binocular (China). Salinity was determined with an RHS-10ATC refractometer for seawater (China) with an accuracy of 1‰. Acidity and alkalinity were established using an EcoDigital digital pH meter (China) with an accuracy of 0.1.

The nomenclature of the species is given in accordance with the current taxonomy (https://www.marinespecies.org/).

Water samples from the Tsemes Bay were studied for the content of heavy metals. Water was sampled in August 2022 from three bay sites, the Cape of Love, Cape Khako, and Sudzhuk Spit, from a 1-m depth (Table 1). In January 2023, water was sampled again from the Cape of Love where *L. cinerea* was found.

Samples were analyzed on a HACH DREL 2800 spectrophotometer (the USA). Each water sample was investigated in three analytical replicates. Content of water-soluble forms of heavy metals (copper, cadmium, cobalt, lead, manganese, and zinc) was determined. The obtained values were compared with the maximum permissible concentrations (hereinafter MPC) for fishery reservoirs [Ob utverzhdenii normativov, 2016].

Table 1. Dates, coordinates, and depth of water sampling sites in the Tsemes Bay (the Black Sea)

Bay site	Date	Coordinates		Depth, m
		N	E	
Cape of Love	21.01.2023	44°42′32.61″	37°47′20.96″	1
Cape of Love	13.08.2022	44°42′32.34″	37°47′20.93″	1
Sudzhuk Spit	13.08.2022	44°41′4.92″	37°48′12.80″	1
Cape Khako	13.08.2022	44°39′1.31″	37°44′18.34″	1

RESULTS AND DISCUSSION

Geomorphological characteristics of the studied biotopes. The Cape of Love is a continuation of the beach of the same name, along which the central embankment of Novorossiysk runs. The beach is about 100 m long and 4–5 m wide. The coast is composed of sedimentary rocks: sandstone, siltstone, quartzite [Modina, Kuznetsov, 2021], and limestone [Dembitskiy et al., 2014]. The geomorphological type of the Cape of Love coast, as well as the entire Tsemes Bay, is abrasion-bay [Dobrovolsky, Zalogin, 1982]. The cape cliff is concreted. The beach turns into a flooded abrasion-accumulative terrace (a bench), 10–12 m wide. There are similar marine terraces on many abrasion coasts, in particular, in areas adjacent to capes [Leontev, 1955]

The bench surface is almost completely surrounded by a ridge of boulders extending along the cape base. As a result of surge sea-level fluctuations, water is retained between the boulders and forms the pseudolittoral with baths of a total area of 618 m^2. There, biogenic residues actively accumulate causing siltation of the substrate. The nature of the soil is mixed; it is composed of two fractions: coarse limestone crushed stone (> 10 cm) and sharp-angled boulders (> 100 cm). In the area of the edge and below the water edge, the bottom sediments of baths are represented by rocky placers with an admixture of silt (Fig. 2).

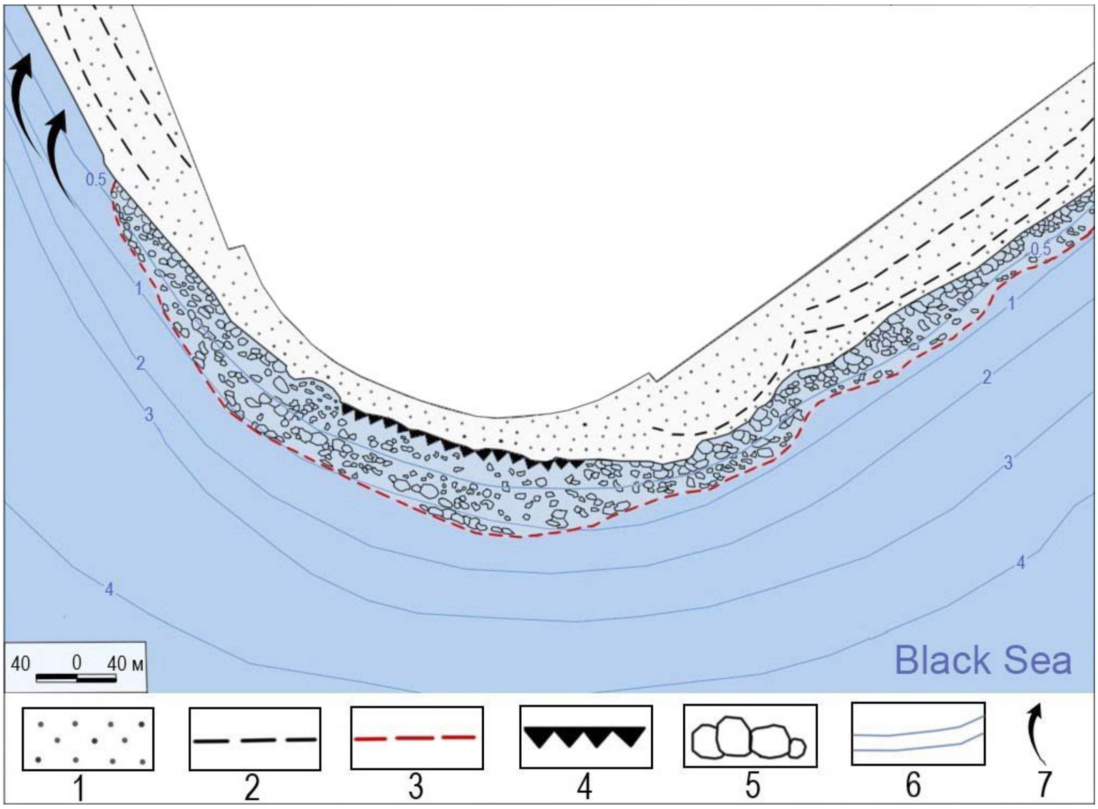

Fig. 2. Geomorphological map of the Cape Love: 1, accumulative form; 2, beach ridges; 3, conditional boundary of supralittoral baths; 4, ancient bench; 5, boulders; 6, isobaths; 7, direction of sediment

A biotope of a similar type is located in the Dzhankhot area. This is the closest site to the Cape of Love, where *L. cinerea* was registered (coordinates according to [GBIF, 2023] are 44°27′28.9″N, 38°9′27.7″E), with an abrasion cliff along the coastline. As a result of ongoing abrasion and denudation, blocky and boulder-blocky piles were formed on a pebble beach [Nikiforov, Shevchenko, 2015] similar to supralittoral baths of the Cape of Love.

In the study sites where the mollusc was not recorded, the mineral composition of the rocky soil did not differ much from that at the Cape of Love [Dembitskiy et al., 2014]. From the central beach of Novorossiysk to the Cape Khako, a noticeable difference in the size and roundness of the soil was observed. Specifically, the Cape Khako and Sudzhuk Spit coasts are represented mainly by large pebbles, while the Cape of Love coast is composed of coarse rubble and boulders.

At the Cape Khako, a dead cliff with exposed bench ridges and an adjacent accumulative terrace are clearly visible. Coastal ridges are composed of coarse pebbles, and there are depressions between them.

The Sudzhuk Spit is composed of sediments. This coastal bar is 10–15 m wide.

General characteristics of the habitat of benthic mollusc communities. The boulders are dominated by the phytocenoses of *Cladophora laetevirens* (Dillwyn) Kützing, 1843 and *Ulva rigida* C. Agardh, 1823 + *Ulva intestinalis* Linnaeus, 1753, where the species diversity of invertebrate communities is chiefly formed by crustaceans and gastropods. The lower layers of phytocenoses are represented by crusts of coralline algae. Earlier, the macrophytobenthos of the Cape of Love was fully studied at the phytocenotic level by V. Teyubova [2010]. According to her observations, the pseudolittoral is formed by five monodominant phytocenoses: *C. laetevirens*, *U. intestinalis*, *Porphyra leucosticta* Thuret, 1863, *Scytosiphon simplicissimus* (Clemente) Cremades 1990, and *Urospora peniciliformis* (Roth) Areschoug, 1866. The mollusc was not found outside surf baths, at a depth of 1.5–2.0 m. There, the bench turns into an underwater slope, and the phytocenoses of *Cystoseira barbata* (Stackhouse) C. Agardh, 1820 + *Cystoseira crinita* Duby, 1830 dominate rounded sedimentary debris.

In the Dzhankhot area, the bottom vegetation of the pseudolittoral is represented by three phytocenoses: *Dilophus fasciola* (Roth) M. A. Howe, 1914 + *Padina pavonica* (Linnaeus) Thivy, 1960, *C. barbata*, and *C. laetevirens*. These algocenoses are characteristic of the pseudolittoral of the Cape Khako and differ from the communities of the supralittoral baths of the Cape of Love.

Hydrological features of the studied biotopes. At the time of sampling, the water temperature reached +28 °C (August) and +9 °C (January). In baths having a constant connection with the sea, the salinity is about 17‰. In supralittoral baths, the value decreases to 16‰. These fluctuations fit into the range of variability of salinity in the Tsemes Bay (16.15–18.57‰) [Kachestvo morskih vod, 2020].

In the pseudolittoral, a slightly alkaline reaction of the environment is registered. The pH value is almost constant and amounts to 7.5–7.6.

Baths as a bionomic type of the littoral (pseudolittoral) are characterized by the lack of surf or its weakening while maintaining most of its aerating effect [Butov, 2016]. Chitons are sensitive to low levels of oxygen dissolved in water [Yakovleva, 1952]. The boulders are located in the constant surf zone and serve as breakwaters protecting baths from wind and wave action. At the same time, the level of water aeration increases which is necessary for chitons.

Characteristics of *Lepidochitona cinerea* population. The mollusc was recorded on sedimentary rocks at a depth of 0.3–1 m. A total of 34 ind. were found (Fig. 3). The average shell length is 6.2 mm, the maximum one is 8.0 mm. The age of *L. cinerea* individuals with a shell length of 6–8 mm is three years. Most often, the chiton was registered on solid substrates covered with microperiphyton and in synusia of crustose coralline algae, which, according to D. Currie [1984], are directly included in the species diet. Two epibionts were noted on *L. cinerea* shells: the polychaete tubeworm *Spirorbis* sp. was recorded on plates of nine chitons and *C. laetevirens* was registered on three individuals.

Fig. 3. *Lepidochitona cinerea* on hard substrates in the Cape of Love pseudolittoral (the Black Sea)

Level of water pollution with heavy metal ions. The results of the study are provided in Table 2. To compare the data obtained with MPC for fishery purposes, we used averaged values for the Cape of Love (for summer and winter periods).

Table 2. Heavy metal content ($mg \cdot L^{-1}$) in waters of the study sites off the Tsemes Bay (the Black Sea)

Heavy metal	Bay site				MPC_f
	Cape of Love		Sudzhuk Spit	Cape Khako	
	August	January			
Cd	0.0049 ± 0.0001*	0.0043 ± 0.0001*	0.0039 ± 0.0001*	0.0046 ± 0.0001*	0.01
Pb	0.011 ± 0.0001*	0.01 ± 0.0001*	0.01 ± 0.0001*	0.011 ± 0.0001*	0.01
Co	0.07 ± 0.0001*	0.07 ± 0.0001*	0.06 ± 0.0001*	0.08 ± 0.0001*	0.005
Mn	0.429 ± 0.061	0.419 ± 0.007	0.402 ± 0.017	0.407 ± 0.021	0.05
Cu	0.069 ± 0.001	0.062 ± 0.005	0.056 ± 0.003	0.063 ± 0.003	0.005
Zn	0.07 ± 0.006	0.06 ± 0.005	0.06 ± 0.005	0.07 ± 0.005	0.05

Note: MPC_f denotes maximum permissible concentration for fishery reservoirs; * indicates instrument error.

Concentration of heavy metal compounds in the study sites of the bay was characterized by little variability. Cadmium content in all water samples did not exceed the standard one, but was close to its upper limit. Copper, manganese, and cobalt occurred in water in fairly high concentrations: the values exceeded MPC by 13.1, 9.0, and 14.0 times, respectively. Concentrations of lead and zinc slightly exceeded MPC, by 1.1 and 1.3 times, respectively.

At the Cape of Love, water was sampled for the second time – to analyze hydrochemical indicators and reveal the correlation between them and occurrence of the mollusc. The values for summer and winter samples differed slightly. During winter sampling, five adult *L. cinerea* specimens were found.

To date, the Cape of Love is the only *L. cinerea* habitat recorded in the Tsemes Bay. Compared to the Cape Khako and Sudzhuk Spit biotopes, where the species was not registered, the Cape of Love biotope is subject to greater pollution.

The obtained increased values of the content of heavy metal ions can be associated with the fact that the Cape of Love is a drainage area for urban wastewater and stormwater [Teyubova, 2010]. Novorossiysk is among key transport centers of the Krasnodar Krai. There, one of the largest ports in the country operates, and it poses an environmental hazard to the bay area [Tekhnogennoe zagryaznenie, 1996]. In 2000 alone, 46 cases of emergency oil spills were recorded in the port [Fashchuk, 2019]. Other sources of pollution are oil platforms, specifically Sheskharis oil terminal [Dinamicheskie processy, 2003], and cement plants (*e. g.*, Novoroscement), machine-building enterprises (Krasny Dvigatel and Molot), and other factories [Mamas et al., 2012].

However, exceeding MPC for copper, manganese, and cobalt in water, apparently, was not a limiting factor for *L. cinerea* development in the Tsemes Bay.

Conclusion:

1. During the study carried out in 2022–2023 in the coastal zone of the Tsemes Bay (in supralittoral baths of the pseudolittoral and among rocky placers and boulders of the Cape of Love), a local population of *Lepidochitona cinerea* (34 ind.) was registered for the first time.
2. Apparently, the complex of biotopic conditions of supralittoral baths provides the formation of optimal trophic and edaphic factors for the development of this chiton.
3. Increased concentrations of several heavy metal ions (copper, manganese, lead, cobalt, and zinc) in the Cape of Love waters seem to have little effect on *L. cinerea*.
4. It is necessary to monitor the state of the environment of the chiton habitat, to search for similar biotopes in other areas of the shore, and to study coastal communities of the Cape of Love.

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О НАХОДКЕ *LEPIDOCHITONA CINEREA* (LINNAEUS, 1767) В ЦЕМЕССКОЙ БУХТЕ (ЧЁРНОЕ МОРЕ)

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Проведены исследования панцирных моллюсков, обитающих на естественных твёрдых субстратах в псевдолиторальной зоне Цемесской бухты от центрального пляжа города Новороссийска до мыса Хако, в летний и зимний периоды 2022–2023 гг. На субстратах осадочного происхождения впервые в Цемесской бухте обнаружена локальная популяция *Lepidochitona cinerea* (Linnaeus, 1767) (Polyplacophora, Tonicellidae). Это редкий вид, и за последние 70 лет он был встречен в водах Северного Кавказа лишь трижды. Найдено 34 экз. *L. cinerea* с максимальной длиной раковины 8 мм. Возраст наиболее крупных особей (три года) определён по годовым кольцам апекса первого щитка раковины. Вид распространён в верхнем горизонте псевдолиторали мыса Любви и приурочен к супралиторальным ваннам. Схожий биотоп, в котором также встречен панцирный моллюск, был обнаружен в 50 км от Цемесской бухты. Предположено, что присутствие *L. cinerea* в акватории обусловлено именно наличием данного биономического типа местообитаний — супралиторальных ванн, которые не выражены на других изученных участках бухты. Цель исследования — описать популяции *L. cinerea* в ранее не указанном для этого вида биотопе, а также выявить особенности данного биотопа и его возможного влияния на присутствие панцирного моллюска. Пополнены сведения о географическом распространении и биотопической приуроченности вида. Рассмотрено влияние экологических, гидрохимических и геоморфологических особенностей биотопа на присутствие *L. cinerea*.

Ключевые слова: *Lepidochitona cinerea*, псевдолитораль, супралиторальные ванны, Цемесская бухта, Чёрное море