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Original paper

Distribution of the Chestnut Goby *Chromogobius quadrivittatus* (Steindachner, 1863) in the Black Sea and the Problem of its Range Expansion

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Abstract
Under climate change and increasing anthropogenic pressure, rare species with unique ecosystem functions are particularly vulnerable. One of these species is the chestnut goby *Chromogobius quadrivittatus*, whose presence in the Black Sea has long been considered occasional. The study aims to specify the range, abundance and ecological peculiarities of this species. For this purpose, underwater observations and captures were carried out from 2012 to 2022 near the Crimean and the Caucasian coasts using the apnoea diving method, photosurvey and artificial habitat traps. Four stationary habitats of the species were recorded in the mentioned area predominantly in rocky and stony biotopes in shallow waters. The populations showed mosaic distribution and significant inter-annual fluctuations in abundance. Maximum abundance was recorded in 2016–2018 in Kazachya Bay (Sevastopol) and was up to 3 individuals per square metre. No such concentrations of the species have been noted since 2020. It is presumably due to increased abundance of the rock bass *Serranus scriba*. In the Black Sea populations, the size characteristics of fish were close to the maximum known and positive allometry was observed. Fish matured at SL 45.5 mm, and the male-to-female ratio in the sample was 1:1. These findings add to the data on species characteristics of the chestnut goby in the Black Sea and indicate the need for a more accurate assessment of its conservation status given limited information on the population abundance and dynamics.

Keywords: chestnut goby, *Chromogobius quadrivittatus*, Black Sea, cryptobenthic species, length-weight relationships, species distribution

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Распространение четырехполосого бычка *Chromogobius quadrivittatus* (Steindachner, 1863) в Черном море и проблема расширения его ареала

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Аннотация

В условиях климатических изменений и нарастающего антропогенного давления редкие виды, обладающие уникальными экосистемными функциями, оказываются особенно уязвимыми. Одним из таких видов является четырехполосый хромогобиус *Chromogobius quadrivittatus*, чье присутствие в Черном море долгое время считалось эпизодическим. Настоящее исследование направлено на уточнение ареала, численности и экологических особенностей этого вида. Для этого с 2012 по 2022 г. проводились подводные наблюдения и отлов у побережья Крыма и Кавказа с применением техники апноэ, фотофиксации и ловушек – искусственных биотопов. Были зафиксированы четыре устойчивых местообитания вида у берегов Крыма и Кавказа, преимущественно в скально-каменистых биотопах на мелководье. Популяции демонстрировали мозаичное распределение и значительные межгодовые колебания численности. Максимальное обилие было зарегистрировано в 2016–2018 гг. в б. Казачьей (Севастополь) и составляло до трех особей на квадратный метр. С 2020 г. таких концентраций вида не отмечается. Предположительно, это результат увеличения численности каменного окуня *Serranus scriba*. В черноморских популяциях размерные характеристики рыб были близки к максимально известным, наблюдалась положительная аллометрия, созревали рыбы при достижении стандартной длины 45.5 мм, соотношение самцов и самок в выборке составляло 1:1. Полученные данные дополняют сведения о видовых характеристиках хромогобиуса в Черном море и указывают на необходимость более точной оценки его охранного статуса в условиях ограниченной информации о численности и динамике популяций.

Ключевые слова: четырехполосый хромогобиус, *Chromogobius quadrivittatus*, Черное море, криптобентический вид, линейно-весовые соотношения, распространение вида

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Introduction

The ongoing degradation of ecosystems precipitated by climatic changes and increasing anthropogenic impact has led to a marked decline in biodiversity, with numerous species facing extinction. It is a well-documented fact that rare and small species are often the first to disappear. Despite the extensive research that has been conducted on the significance of biodiversity in ensuring ecosystem functionality, the role of these species remains a subject of debate. It is acknowledged that a limited number of species are capable of performing essential functions in a variety of transformative systems [1, 2]. The results obtained by these authors emphasize the importance of conserving rare species even in ecosystems with high diversity, which are thought to exhibit high functional redundancy. The hypothesis that common species can compensate for the loss of functions in ecosystems maintained by rare species has not been demonstrated. The role of rare and low abundance species extends beyond the aesthetic or taxonomic value of diversity; these species augment significantly the potential breadth of functions provided by ecosystems. Consequently, they are likely to ensure biodiversity against uncertainty arising from ecological restructuring due to climate change and ever-increasing anthropogenic pressure on ecosystems.

This is particularly evident in ecosystems characterised by low species diversity, a category that encompasses the Black Sea. In contrast, other ecosystems are likely to exhibit high functional redundancy. To illustrate this point, the number of fish species in the region is considerably lower than in the neighbouring Mediterranean basin, with only approximately 40 species being common and widespread. For rare species, data are definitely insufficient and often limited to records of isolated finds.

This also applies to one of the members of the Gobiidae family – the chestnut goby *Chromogobius quadrivittatus* (Steindachner, 1863). Based on isolated, generally few finds, its range includes the Eastern Atlantic, the Mediterranean, Aegean, Marmara and Black seas [1), 2), 3)] [3–7]. The history of findings of this species in the Black Sea is complex and long. It was first found in 1939 [8] in a salt lake near Novorossiysk, then in the coastal lagoons of Abrau and Sochi, and it was defined as a new scientific species and genus – *Relictogobius kryzanovskii* Ptschelina. Much later, the specimens were redefined as *Ch. quadrivittatus* [9] and the species has been granted the status of a Mediterranean alien. The following finds were discovered on the coast of the Gulf of Varna (Bulgaria) in 1957 [1)] and in coastal lakes between capes Bolshoi and Maly Utrish in 1971 [10]. Further attempts to find the goby in its former habitats on the Caucasian coast were unsuccessful [11], and

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[1)] Georgiev, Z.M., 1961. [An Unknown Goby of Bulgarian Ichthyofauna – *Relictogobius kryzanowskii*]. *Izvestia na Tsentralniya Nauchnoizsledovatelski Institut po Ribovodstvo i Ribolov – Varna*, 1, pp. 141–145 (in Bulgarian).

[2)] Svetovidov, A.N., 1964. [*Fishes of the Black Sea*]. Moscow, Leningrad: Nauka, 551 p. (in Russian).

[3)] Vassilev, M., Apostolou, A., Velkov, B., Dobrev, D. and Zarev, V., 2012. *Atlas of Gobies (Gobiidae) in Bulgaria*. Sophia: IBER-BAS, 112 p.

it was concluded that the population had disappeared due to habitat degradation. However, the fish were soon found along the entire Black Sea coast of Turkey [7].

The goby was first recorded off the Crimean coast in 2012 in the underwater caves of the Tarkhankut Peninsula, and in subsequent years it was repeated in these habitats [12], with no fish observed near the open coast in this area. A few years later, the species was also identified in the vicinity of Sevastopol [4)] [13].

It is evident that the species under consideration is present in a relatively consistent manner along various sections of the Black Sea coast. However, it is noteworthy that the presence of the species has been documented in areas where it has not been previously recorded. Conversely, the occurrences of the species are sporadic and often do not recur in the same location. This species belongs to the group of cryptobenthic species, for which it is rather difficult to establish the naturalization status in different habitats. Furthermore, anthropogenic impact is considered to be the presumed cause of the species rarity [11].

The aim of this study is to obtain new data on the distribution and some ecological and ethological peculiarities of a rare species, the chestnut goby, and to specify the current status of the Black Sea population of this species.

Materials and methods

Observations were conducted as part of the monitoring program for ichthyofauna in the coastal zone of the Black Sea. The fish searches in the coastal water area were conducted through the utilization of diving techniques, specifically the apnoea method. Stony coastal substrates of the Crimean coast from the Tarkhankut Peninsula in the area of Mezhvodnoye village to Cape Opuk and near the Caucasian coast in the area of the *Utrish* Nature Reserve were surveyed. The transect method was used, with a transect length of 10 m and width of 1 m, running parallel to the shore at depths of 1.0, 1.0–2.0 and 2.0–3.0 m. When on the transect, both free bottom areas and rocks located on it, including their underside, were examined. Surveys were conducted regularly since 2013 on the same transects in Kazachya Bay (Sevastopol), in 2016–2019 – in the area of the *Utrish* State Nature Reserve, in the rest of the water area – episodically, once in 2–4 years. When possible, detected fish were caught with a hand net (hoop diameter 30 cm, mesh pitch 3 mm) or recorded with Nikon D800 (Taiwan) photographic equipment. In Sevastopol, in Kazachya and Karantinnaya bays and at berth No. 164, surveys were also carried out with the use of a trap – an artificial habitat (Patent No. 2624417) (Sevastopol). The traps were made according to the scheme of the utility model (Patent No. 162868). A total of 38 specimens of gobies were caught and examined by different methods.

Captured individuals were transported alive to the laboratory where biological analyses, including measurements (total TL and standard SL length, weight W), visual gender determination, were performed. Furthermore, the behaviour of the fish under aquarium conditions was observed after undergoing adaptation.

[4)] Boltachev, A.R., Karpova, E.P. and Pashkov, A.N., 2018. [Chestnut Goby *Chromogobius quadrivittatus* (Steindachner, 1863)]. In: I. V. Dovgal and V. V. Korzhenevskiy, eds., 2018. *The Red Data Book of Sevastopol*. Kaliningrad, Sevastopol: ROST-DOAFK, p. 368 (in Russian).

Results and discussion

From 2012 to 2022, four mosaic habitats of the chestnut goby were found near the Crimean and Caucasian coasts – in the vicinity of Cape Tarkhankut, in Sevastopol bays, in Laspinskaya Bay and in the area of Cape Bolshoi Utrish (Fig. 1).

In August 2013, during an expedition to the Tarkhankut Peninsula (western coast of Crimea), 15 individuals of the goby were found indicating that a population had been established there. The species inhabited underwater caves and grottoes, including small openings located on vertical walls in the lower part of caves, with the depth reaching up to 5–6 m.

The next finding was made in 2015 at berth No. 164 (Sevastopol) where traps simulating an artificial habitat were set in March after the end of winter storms. Mussel and oyster shells were used as filler. Traps were placed at 2–5 m depths along the berth and concrete tetrapod-shaped breakwaters. Three months later, in June, the traps were lifted and their contents were thoroughly searched resulting in the finding of several extremely rare species in the Black Sea including two individuals of *Ch. quadrivittatus*.

In Sevastopol, in Kazachya and Karantinnaya bays, the gobies were found during visual survey among limestone rubble piled on shell sand as well as in gaps between concrete blocks of hydraulic structures. Fish were usually found in depressions and holes leading under fairly large stones and sometimes on the sand next to their shelter – in calm conditions. All individuals were recorded in shallow water, at a depth of 0.5–1.5 m. Near the open coast in Laspinskaya Bay and in the area

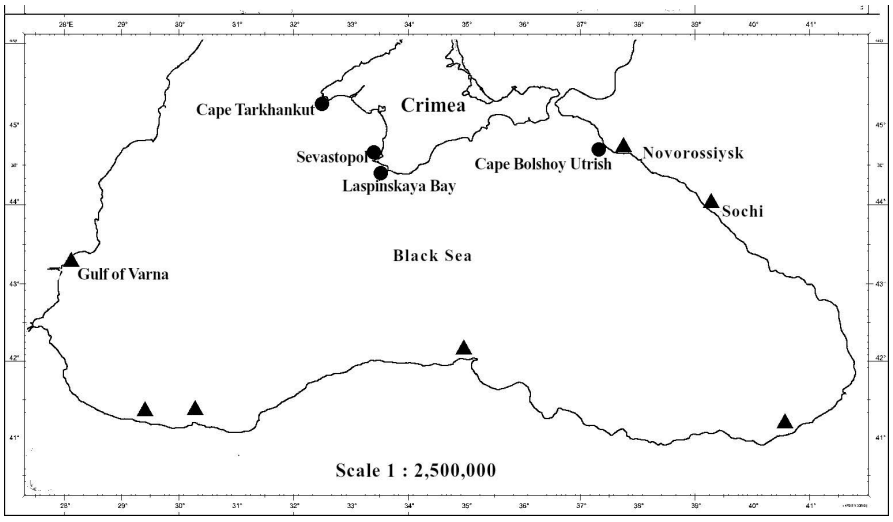

Fig. 1. The scheme of the locations of the chestnut goby finds in the Black Sea. Round markers are our findings, triangular markers are literary data

of Cape Bolshoi Utrish, fish were found in clumps of large rocks at the foot of boulders not subject to wave shear at 0.7–1.5 m depths in 2017 and 2018.

The maximum fish concentration was recorded in Kazachya Bay in 2016–2018 and reached 3 ind./m^2 and up to 10 individuals per transect. Fish were distributed very unevenly and could congregate in one small area and be absent from the rest of the transect. The gobies were predominantly recorded at shallow depths (0.5–0.8 m) in May and early June. Later, in July–October, fish were encountered at the same locations much less frequently and in numbers not exceeding 0.1 ind./m^2. Probably, as the water warmed up, they gradually migrated to deeper waters where it is much more difficult to detect them. Probably, therefore, the gobies were observed rarely and sporadically near the open shore, which does not make it possible to estimate the size of their populations.

Negative phototaxis associated with residence in darkened and twilight habitats was hypothesised for the gobies [11, 14]. However, according to our observations, fish are quite active also in sunlit areas and in calm conditions do not hurry to leave them. Probably, the behaviour noted by the researchers was more related to the general sensitivity of the species to stress factors and to the presence of observers. Most researchers classify the species as cryptobenthic [5, 7, 13], whose strategy is to hide and conceal themselves when any threatening factor (visual stimuli, water movement, etc.) appears.

We noted pronounced fluctuations in the abundance of this species. Fish were regularly recorded in the same habitat for 2–3 years, after which no individuals were found there. In the last 3–4 years, the gobies have become much rarer everywhere. Probably, one of the reasons for this was a sharp increase in the abundance of the rock bass *Serranus scriba* [14, 15] which occurs in various locations in large numbers including at shallow depths near the shore. At the same time, one large boulder can be used as a shelter by two to three rock bass individuals, which makes it unlikely that gobies live under such conditions as predators stalk their prey and do not let small fish leave their shelters in search of food. Negative impact of hydraulic construction on this species is unlikely as, according to our observations, the fish successfully exploit cracks between concrete blocks of berths and breakwaters made of artificial materials. The combination of factors such as cryptobenthic lifestyle, low abundance subject to sharp fluctuations and isolated finds in most Black Sea littoral countries can indicate that the range of the species covers the entire coastal part of the Black Sea where rocky and stony biotopes necessary for its successful survival are available and the lack of finds is mainly of a methodological nature.

It is possible to find little or no data on the biological and ecological characteristics of this species. Those papers where a maximum SL [5] of 66 mm is given for *Ch. quadrivittatus* [16], refer to a single study by P. J. Miller [3]. Individuals with sizes TL 35.0–71.1 mm, SL 28.7–60.3 and W 0.41–3.97 g were present in our findings. Consequently, the maximum sizes of the species in the Black Sea populations are close to those observed in the Mediterranean Sea. The relationship between total and standard fish length is described by the following equation: TL = 1.1427SL + 1.9413 with a high degree of approximation ($R^2 = 0.9938$) and length-weight relationships of the gobies (both genders) were expressed as follows: $W = SL^{3.11} \cdot 10^{-5}$ ($R^2 = 0.9772$). Fish exhibited positive allometry, which can be indicative of both species-specific traits and good feeding conditions. Fish matured at SL 45.5 mm, and the male-to-female ratio in the sample was 1:1.

As the fish matured, their colouration changed. In juvenile subjects with SL under 50 mm, the general body tone was olive with darker vertical stripes. The marble-like patterns on the head were bright, dark brown, the band at the base

Fig. 2. Specimens of *Ch. quadrivittatus* from Kazachya Bay (Sevastopol) with *TL* 42.5 mm (*a*) and 71.1 mm (*b*)

[5] Vasil'eva, E.D., 2007. *Fish of the Black Sea. Key to Marine, Brakish-Water, Euryhaline, and Anadromous Species with Color Illustration Collected by S. V. Bogorodsky*. Moscow: VNIRO Publishing, 238 p. (in Russian).

of the pectoral fin rays was dark, almost black, and the fins were yellow-olive in colour (Fig. 2, *a*). In larger individuals, the general body tone became brown, with very faint vertical stripes. The patterns on the head lost brightness and dark tone, and the fins also became lighter, up to the complete loss of the dark band on the pectoral fin, which is one of the defining characteristics of the species (Fig. 2, *b*).

The International Union for Conservation of Nature and Natural Resources has given this species LC (Least Concern) status. The question of whether this is appropriate, in the opinion of the authors of the article, is relevant in this case. As the chestnut goby leads a secretive way of life, it is extremely difficult to establish its number and population status. A more thorough evaluation can be found in the Red Data Book of Krasnodar Krai, where the species is categorized as Insufficiently Studied. This designation signifies that the reasons for its rarity have not been unequivocally determined, consequently precluding an accurate assessment of its extinction risk. The species is also included in the Red Data Book of the Republic of Crimea and the Red Data Book of the City of Sevastopol where it is assigned the 3rd category (rare species).

Conclusion

The conducted studies enabled to specify the current distribution and some features of the ecology of the chestnut goby *Chromogobius quadrivittatus* in the Black Sea. The species populations show mosaic distribution, predominantly in specific shelters in rocky and shaded habitats. Observed sharp fluctuations in abundance, limited number of finds and widespread fragmentation of the range indicate the potential vulnerability of the population. It has been found that despite its ability to master artificial structures, the species is under pressure from more abundant and aggressive inhabitants such as *Serranus scriba*, which may limit its distribution and maintenance of a stable population status. The contradiction between international Least Concern status and actual rarity in the Black Sea necessitates a reassessment of the level of threats and increased protection measures. These findings emphasize the importance of further monitoring and study of rare species that play a unique role in maintaining the sustainability and functional diversity of the regional marine ecosystems.

Compliance with ethical standards

In conducting this study, the authors claim to have adhered to all international, national or institutional guidelines relevant to the care and utilization of animals.

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Ernes R. Abliazov − processing of the material, analysis and discussion of the results, manuscript editing

All the authors have read and approved the final manuscript.