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MORPHOMETRIC VARIABILITY IN THE ROUND GOBY *NEOGOBIUS MELANOSTOMUS* (PALLAS, 1814) (ACTINOPTERYGII, GOBIIDAE) OF THE SEA OF AZOV–BLACK SEA BASIN

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The variability of external morphological characters (36 morphometric and 6 meristic ones) of the round goby *Neogobius melanostomus* (Pallas, 1814) from seven regions of the Sea of Azov–Black Sea Basin is considered: the northwestern and southwestern Black Sea coast of the Crimean Peninsula (the Karkinitsky Bay, Donuzlav Liman, and Streletskaya Bay of Sevastopol), the Kazantip Bay of the Sea of Azov, and the Salgir River in the central Crimean Peninsula. As established, the round goby from different catch regions at the age of 2+…3 has different body sizes: the maximum in individuals from the Streletskaya Bay, SL_{av} (136.2 ± 1.97) mm; the minimum in individuals from the Salgir River, SL_{av} (66.8 ± 2.28) mm. With the Mann–Whitney test, statistically significant differences were found between the samples for most morphometric characters. In terms of meristic characters, there were no differences. The greatest contributors to the discrimination of *N. melanostomus* samples were morphometric characters related to the location of fins. According to the results of cluster analysis, based on the totality of all the studied characters of the round goby of the Sea of Azov–Black Sea Basin, the samples from the Karkinitsky Bay (Samarchik Bay and Yarylgachskaya Bay, D = 28.6) and from the Bakalskaya Spit water area had the highest similarity. At the level of divergence D = 47.3, groups of the round goby from the Streletskaya Bay and Kazantip Bay were united; then, a sample from the Donuzlav Liman adjoined them at the level D = 215. The sample from the Salgir River had the most isolated position: the level of divergence was about 475. As found according to the discriminant analysis, the round goby from the Sea of Azov–Black Sea Basin was differentiated into at least three spatial groups: the first one, from the western coast of the Crimean Peninsula (the Karkinitsky Bay and Donuzlav Liman) and the Sevastopol area (the Streletskaya Bay); the second one, from the Kazantip Bay (the Sea of Azov); and the third one, from the Salgir River. The following characters made the greatest contribution to the discrimination of spatial groupings (with the correlation coefficient between characters and coordinate values along the second canonical axis being higher than 0.75): maximum body depth, caudal peduncle depth and width, predorsal and prepelvic distances, and width of pectoral and pelvic fin base. The revealed heterogeneity shows a high paratypical variability of morphometric characters; under different environmental conditions, individuals of the same species form a specific phenotype.

Keywords: round goby, Sea of Azov–Black Sea Basin, morphometric and meristic characters, variability, population

The round goby *Neogobius melanostomus* (Pallas, 1814) is a Ponto-Caspian endemic species with a natural range that includes water areas of the Black, Marmara, and Caspian seas and the Sea of Azov [Boltachev, Karpova, 2017; Manilo, 2014; Pinchuk, Miller, 2003; Smirnov, 1986; Svetovidov, 1964; Vasileva, 2007]. In almost its entire natural range, the round goby is one of the important commercial fish species [Boltachev, Karpova, 2017].

N. melanostomus is a bottom-dwelling fish preferring brackish-water coastal areas of seas and river mouths and one of the widespread goby species off the coast of the Crimean Peninsula [Boltachev, Karpova, 2017; Manilo, 2014]. According to numerous literature data, this species is characterized by high ecological plasticity and invasive potential; it actively spreads in new habitats outside the Ponto-Caspian Basin. Specifically, the round goby penetrated upstream of large European rivers and formed stable freshwater populations in new areas; moreover, the fish was transported with ballast waters into the Baltic Sea Basin and the Great Lakes of North America [Buřič et al., 2015; Crossman et al., 1992; Nyeste et al., 2017; Piria et al., 2011; Roche et al., 2015; Simonović et al., 2001; Skóra, Rzeźnik, 2001; Smirnov, 2001; Stráňai, Andreji, 2004; van Beek, 2006; Verreycken et al., 2011; Ĉolić et al., 2018].

Gobies are known as low-migratory fish, capable of forming local groups differing morphologically [Manilo, 2014]. Certain publications are focused on the study of intraspecific variability of *N. melanostomus* both in its natural range and under new conditions [Demchenko, Tkachenko, 2017; Diripasko, Zabroda, 2017; Kodukhova et al., 2017; Smirnov, 1986, 2001; Tkachenko, 2012]. However, the morphological structure of the round goby in the coastal area of the Crimea has been poorly studied, while in its inland water bodies, it has generally not been investigated.

The ecological conditions of water bodies and water areas off the Crimean Peninsula are very diverse. On average, the salinity of the Black Sea is 17–18‰, and that of the Sea of Azov is 10–11‰. Anthropogenic load on some areas of the Sea of Azov–Black Sea Basin over the past half century caused changes in both hydrochemical characteristics and composition of the fish fauna. The ichthyofauna of the Karkinitsky Bay and inland water bodies of the Crimea has long been affected by the North Crimean Canal; accordingly, in these areas, representatives of the Dnieper ichthyofauna were recorded [Belogurova et al., 2020; Karpova, 2016; Karpova, Boltachev, 2012]. In the Donuzlav Liman, the modern ichthyofauna has been formed over the past 35 years: since a canal was dug on the Belyaus Spit that separates one of the saltiest Crimean lakes from the Black Sea [Zuev, Boltachev, 1999].

Under different environmental conditions, for example, hydrochemical regime or current speed, in fish of the same species, variations in morphological characters are developed. Studying their variability, one can assess the scale of adaptation of the species to the environmental conditions.

Considering that the round goby actively spreads in new water bodies and is capable of forming local groups which differ morphologically within the area depending on the environmental conditions, the aim of the work was to assess the variability of external morphological characters of *Neogobius melanostomus* from various water areas of the Sea of Azov–Black Sea Basin based on morphometric and meristic characters.

MATERIAL AND METHODS

The material was fish samples fixed with a 4% formaldehyde solution which were obtained during expeditions of IBSS plankton department in 2009–2020. The study sites were several water areas of the Black Sea off the northwestern and southwestern coast of the Crimean Peninsula (the Karkinitsky Bay, 3 samples; the Donuzlav Liman, 1 sample; and the Streletskaya Bay of Sevastopol, 1 sample), the Salgir River (inland water body of the Crimean Peninsula, 1 sample), and the Kazantip Bay (the Sea of Azov, 1 sample) (Fig. 1). Ichthyological material in the Donuzlav Liman and Karkinitsky Bay was sampled with shrimp hoop nets with a mesh size of 6.5–7.5 mm. In the Salgir River (Novogrigorievka village area) and in the Kazantip Bay (the Sea of Azov), sampling was carried out with gill nets with a mesh size of 10–30 mm. In the Streletskaya Bay, a bottom trap was used with a 12-mm mesh. For morphometric analysis, 167 ind. of sexually mature male round goby aged 2+…3 were selected from seven samples. Age was determined analyzing otoliths: those were viewed under a binocular microscope at magnification 20× [Pravdin, 1966].

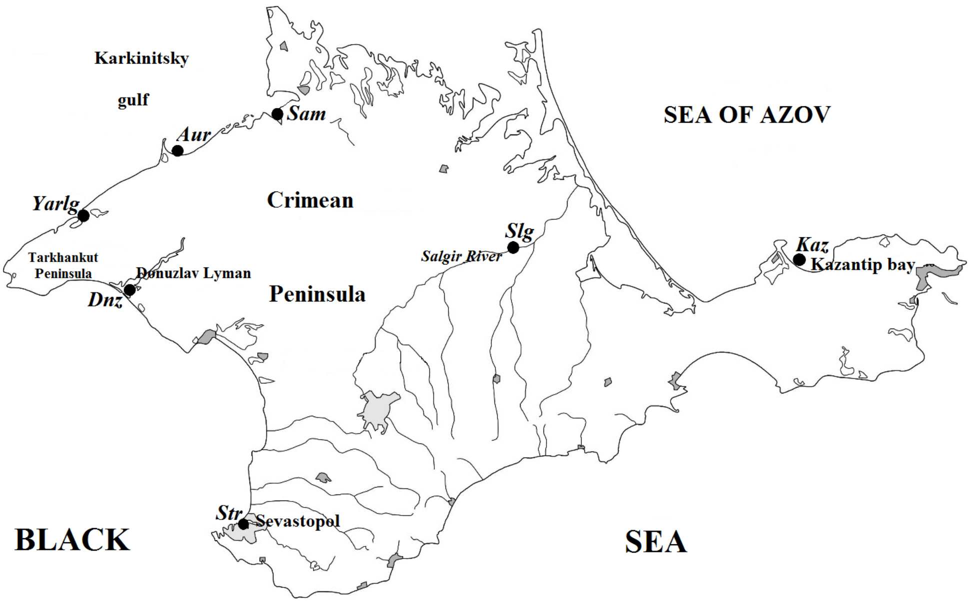

Fig. 1. Schematic map of the round goby *Neogobius melanostomus* sampling sites in the Sea of Azov–Black Sea Basin. Sam, Samarchik Bay; Aur, Bakalskaya Spit (Aurora village area); Yarlg, Yarylgachskaya Bay; Dnz, Donuzlav Liman; Str, Streletskaya Bay; Slg, Salgir River (Novogrigorievka village area); Kaz, Kazantip Bay

In total, 36 morphometric and 6 meristic characters were studied. The measurements were made using a caliper with an accuracy of 0.1 mm according to a standard scheme with additions (Fig. 2) [Pravdin, 1966; Zabroda, Diripasko, 2009]. For further processing, measurements on the body and head of the round goby were converted into character indices expressed as % of the standard length (SL) and head length (HL).

In different samples, fish length varied significantly. Therefore, to level out the factor of size variability in the absolute values of measurements, those were transformed by the Reist formula:

$$\lg \ddot{X}_i = \lg lgX_i - b(\lg SL_i - \lg SL),$$

where $\lg\ddot{X}_i$ is the transformed value of character X in the *i*-th individual;

X_i is the initial value of the character in the *i*-th individual;

SL_i is the standard length of the *i*-th individual;

SL is the mean length in the sample;

b is the allometric coefficient defined as the tangent of the slope of the regression line for logarithmic measurement values on logarithmic body length values [Reist, 1985, 1986; Thorpe, 1975].

To process the data, we used generally accepted statistical indicators calculated in MS Office Excel. To analyze differences between samples with a small number of specimens, the nonparametric Mann–Whitney test was applied at a significance level of $p \le 0.05$. The variability of characters in each sample was assessed using the coefficient of variation (*var*) – a standard deviation expressed as a percentage of the arithmetic mean. It was considered that indices varied weakly with *var* < 10% and moderately with *var* of 11–25% [Lakin, 1990]. To determine the divergence in the complexes of the studied characters between fish from different regions, the Kullback–Leibler divergence index (*D*) was used [Andreev, Reshetnikov, 1977]. Methods of univariate and multivariate statistics (discriminant and cluster analysis) were applied, with calculations performed in STATISTICA 10.0 software package [Khalafyan, 2007].

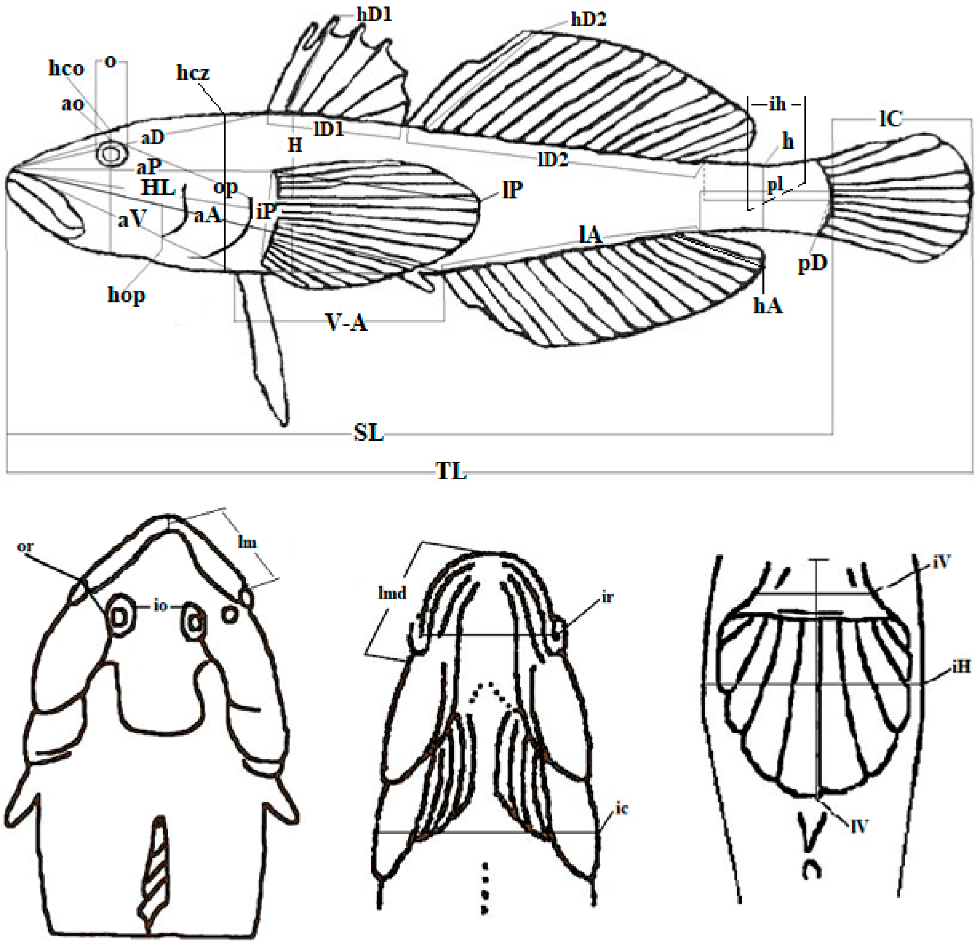

Fig. 2. Scheme of morphometric measurements of the round goby *Neogobius melanostomus*. TL, total length; SL, standard length. Morphometric characters as % of SL: H, maximum body depth; h, minimum body depth (caudal peduncle depth); iH, maximum body width; ih, minimum body width (caudal peduncle width); aD, predorsal distance; pD, postdorsal distance; aP, prepectoral distance; aV, prepelvic distance; aA, preanal distance; V-A, pelvic-anal distance; pl, caudal peduncle length; lD1, length of the first dorsal fin base; hD1, first dorsal fin depth; lD2, length of the second dorsal fin base; hD2, the second dorsal fin depth; lA, length of anal fin base; hA, anal fin depth; lP, pectoral fin length; iP, width of pectoral fin base; lV, pelvic fin length; iV, width of pelvic fin base; lC, caudal fin length; HL, head length. Morphometric characters as % of HL: ic, head width; ao, preorbital distance; o, horizontal eye diameter; op, postorbital distance; io, interorbital distance; lm, upper jaw length; lmd, lower jaw length; or, distance between eye and corner of mouth; hop, cheek depth; ir, mouth width; hco, head depth through middle of eye. Meristic characters: D1, the first dorsal fin spines number; Dr2, the second dorsal fin rays number; Ar, anal fin rays number; P, pectoral fin rays number; V, pelvic fin rays number; C, caudal fin rays number

RESULTS

The results of the morphometric analysis of the round goby from seven study regions of the Sea of Azov–Black Sea basin are given in Table 1.

N. melanostomus from the Streletskaya Bay turned out to be larger on average than specimens from other water areas, SL_{av} was (136.2 ± 1.97) mm. This is likely to result from selectivity of the fishing gear used there. However, the round goby individuals can be large in the bays of Sevastopol because of their low density in the coastal area, and, consequently, better conditions for growth and feeding.

Table 1. Morphometric characters of the male round goby *Neogobius melanostomus* from seven regions of the Sea of Azov–Black Sea Basin, mm (the names of the study regions correspond to those in Fig. 1)

Character	Sam, *n* = 21	Aur, *n* = 32	Yarlg, *n* = 23	Dnz, *n* = 22	Slg, *n* = 19	Kaz, *n* = 23	Str, *n* = 27
SL	99.0–129.5 111.0 ± 1.87	100.7–123.1 109.2 ± 0.90	91.9–124.1 105.0 ± 1.42	80.5–107.2 87.6 ± 1.27	55.5–90.8 66.8 ± 2.28	81.0–136.9 96.6 ± 3.37	**108.7–153.4** **136.2 ± 1.97**
Morphometric characters as % of SL							
H	20.5–24.9 22.2 ± 0.25	**20.8–26.5** **23.6 ± 0.24**	19.2–25.1 22.2 ± 0.25	18.0–22.6 19.9 ± 0.28	19.3–24.8 21.9 ± 0.36	18.4–23.4 20.3 ± 0.27	18.8–24.0 21.2 ± 0.29
h	10.3–12.4 11.1 ± 0.14	**10.4–13.4** **11.7 ± 0.11**	10.7–12.5 11.5 ± 0.11	9.8–11.5 10.5 ± 0.11	9.4–12.1 10.6 ± 0.17	8.8–11.4 10.5 ± 2.28	9.3–11.6 10.5 ± 0.11
iH	16.2–20.2 18.0 ± 0.25	18.7–22.0 20.2 ± 0.14	16.7–20.3 18.4 ± 0.22	14.4–19.5 16.4 ± 0.32	**17.7–24.4** **20.3 ± 0.45**	13.5–17.8 16.1 ± 0.27	16.8–21.6 18.3 ± 0.24
ih	5.0–8.0 6.2 ± 0.19	**7.0–9.3** **8.3 ± 0.09**	6.4–10.3 7.9 ± 0.18	6.4–8.2 7.2 ± 0.10	4.0–5.8 4.8 ± 0.28	4.2–6.1 5.2 ± 0.10	4.5–6.1 5.3 ± 0.09
aD	33.7–38.7 35.8 ± 0.29	**34.7–38.7** **36.2 ± 0.16**	26.5–39.2 35.4 ± 0.55	32.6–38.1 35.6 ± 0.30	34.0–37.5 35.9 ± 0.30	32.6–38.3 35.0 ± 0.36	31.4–36.9 34.5 ± 0.27
pD	12.2–16.9 14.7 ± 0.25	12.1–18.5 15.5 ± 0.24	12.8–16.8 15.1 ± 0.24	14.5–18.8 16.4 ± 0.18	13.3–18.4 15.4 ± 0.33	**14.6–19.0** **16.6 ± 0.25**	13.7–17.0 15.7 ± 0.19
aP	27.8–33.5 31.6 ± 0.28	29.4–32.9 31.1 ± 0.12	30.2–32.9 31.3 ± 0.15	26.8–30.8 28.7 ± 0.22	**30.9–34.9** **32.8 ± 0.23**	29.2–33.3 31.5 ± 0.18	29.3–34.8 32.0 ± 0.26
aV	**31.0–35.9** **32.9 ± 0.25**	31.3–34.9 32.8 ± 0.15	30.0–35.3 32.7 ± 0.25	27.8–32.4 30.5 ± 0.27	26.5–32.6 30.0 ± 0.37	29.6–34.7 32.2 ± 0.26	29.1–34.8 32.1 ± 0.27
aA	**56.1–63.8** **60.9 ± 0.39**	31.5–62.6 58.7 ± 0.96	55.0–64.0 59.6 ± 0.46	52.1–61.0 56.6 ± 0.41	54.7–62.2 57.0 ± 0.51	54.1–63.1 58.1 ± 0.53	54.1–64.6 59.1 ± 0.52
V-A	22.6–32.5 29.5 ± 0.49	**25.3–32.9** **29.6 ± 0.32**	26.0–33.4 29.0 ± 0.45	22.0–31.9 27.4 ± 0.55	23.5–30.4 27.1 ± 0.44	24.2–30.9 26.8 ± 0.39	24.7–35.9 28.8 ± 0.54
pl	13.6–17.6 16.1 ± 0.24	12.1–24.4 16.7 ± 0.40	14.2–18.1 16.0 ± 0.22	15.5–24.1 18.3 ± 0.35	13.2–20.1 17.5 ± 0.41	**14.8–25.0** **18.3 ± 0.55**	14.7–19.6 16.9 ± 0.26
lD1	15.4–20.4 17.9 ± 0.31	**15.1–21.3** **18.5 ± 0.24**	16.2–19.5 18.1 ± 0.18	15.3–19.9 18.1 ± 0.28	15.5–20.9 18.4 ± 0.29	14.5–21.4 17.6 ± 0.36	15.6–20.9 18.3 ± 0.36
hD1	12.9–17.1 15.3 ± 0.26	13.7–17.0 15.8 ± 0.12	13.2–18.2 15.5 ± 0.26	14.2–18.2 16.3 ± 0.25	**15.0–21.2** **17.9 ± 0.45**	12.1–18.3 15.0 ± 0.31	14.0–19.4 16.1 ± 0.25
lD2	30.2–35.8 32.3 ± 0.32	18.8–35.1 32.2 ± 0.49	28.9–36.6 32.3 ± 0.36	28.9–36.5 32.3 ± 0.46	30.6–35.3 32.9 ± 0.34	**31.1–36.2** **33.7 ± 0.29**	26.3–38.1 33.4 ± 0.42

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Character	Sam, n = 21	Aur, n = 32	Yarlg, n = 23	Dnz, n = 22	Slg, n = 19	Kaz, n = 23	Str, n = 27
hD2	13.5–18.6 / 15.7 ± 0.33	14.0–18.1 / 16.0 ± 0.17	13.2–17.3 / 15.7 ± 0.22	13.4–18.7 / 16.2 ± 0.31	**14.9–23.2 / 18.3 ± 0.52**	14.5–18.3 / 15.9 ± 0.21	12.2–17.3 / 14.7 ± 0.25
lA	20.7–27.1 / 24.5 ± 0.37	20.2–28.7 / 25.3 ± 0.25	**23.5–29.1 / 26.8 ± 0.27**	21.1–28.8 / 25.6 ± 0.34	21.6–28.7 / 25.8 ± 0.45	22.3–28.6 / 26.0 ± 0.37	20.8–29.6 / 25.9 ± 0.38
hA	11.7–16.1 / 13.5 ± 0.25	11.1–16.2 / 14.2 ± 0.20	12.9–17.1 / 14.4 ± 0.25	12.1–15.4 / 14.2 ± 0.16	**13.2–21.9 / 16.1 ± 0.56**	12.6–18.8 / 14.7 ± 0.34	11.1–15.5 / 12.9 ± 0.20
lP	21.9–28.5 / 25.4 ± 0.33	24.0–30.0 / 27.1 ± 0.23	22.4–29.1 / 25.8 ± 0.34	23.5–30.3 / 27.5 ± 0.36	20.2–26.9 / 24.4 ± 0.31	**27.8–33.0 / 30.2 ± 0.30**	22.4–30.2 / 26.2 ± 0.32
iP	12.5–18.4 / 13.6 ± 0.27	12.4–14.3 / 13.2 ± 0.08	**13.0–15.4 / 13.8 ± 0.12**	11.0–13.2 / 12.1 ± 0.14	9.0–12.1 / 10.7 ± 0.18	11.7–15.2 / 13.0 ± 0.15	11.8–14.3 / 12.9 ± 0.11
lV	17.0–20.8 / 19.0 ± 0.23	19.0–22.0 / 19.9 ± 0.13	18.1–21.8 / 19.5 ± 0.22	18.7–23.0 / 20.4 ± 0.25	**20.7–24.2 / 22.4 ± 0.23**	19.2–24.0 / 21.3 ± 0.26	15.5–20.5 / 18.5 ± 0.24
iV	7.1–8.9 / 8.0 ± 0.09	7.2–8.7 / 7.9 ± 0.07	**7.3–9.2 / 8.2 ± 0.08**	6.6–8.0 / 7.3 ± 0.09	6.1–8.0 / 7.2 ± 0.13	6.6–8.9 / 7.6 ± 0.09	6.6–8.9 / 7.6 ± 0.10
lC	19.8–24.6 / 22.7 ± 0.32	19.0–25.0 / 22.7 ± 0.22	20.2–26.7 / 22.3 ± 0.29	21.6–25.5 / 23.5 ± 0.22	21.7–27.0 / 24.2 ± 0.33	**23.0–27.8 / 25.4 ± 0.27**	19.1–25.4 / 22.8 ± 0.30
HL	27.9–31.5 / 29.7 ± 0.21	28.0–30.4 / 29.2 ± 0.10	28.9–31.3 / 30.0 ± 0.15	26.7–29.0 / 27.8 ± 0.15	**27.6–33.7 / 30.6 ± 0.35**	27.0–31.0 / 28.8 ± 0.20	27.8–31.8 / 29.3 ± 0.19
Morphometric characters as % of HL							
hcz	71.6–82.8 / 77.3 ± 0.73	**72.9–88.4 / 81.7 ± 0.65**	69.6–87.3 / 78.8 ± 0.91	64.6–84.6 / 76.2 ± 1.19	65.2–79.1 / 72.1 ± 0.84	64.2–79.9 / 73.2 ± 0.81	67.4–82.6 / 74.8 ± 0.76
ic	52.2–61.3 / 56.3 ± 0.54	51.4–61.0 / 56.2 ± 0.43	49.4–59.6 / 55.7 ± 0.57	50.2–57.8 / 53.9 ± 0.51	**69.8–81.2 / 76.1 ± 0.75**	49.8–60.2 / 54.5 ± 0.56	50.8–60.3 / 55.0 ± 0.48
ao	34.2–39.1 / 36.6 ± 0.29	**34.1–40.3 / 38.2 ± 0.24**	32.4–40.1 / 36.4 ± 0.41	34.2–39.6 / 36.1 ± 0.27	28.1–39.6 / 34.0 ± 0.54	31.1–38.5 / 34.9 ± 0.39	32.2–39.8 / 36.3 ± 0.33
o	17.8–22.3 / 20.2 ± 0.25	18.4–22.6 / 20.3 ± 0.22	18.7–23.7 / 21.3 ± 0.30	19.2–24.0 / 21.6 ± 0.31	**20.8–30.6 / 24.9 ± 0.64**	16.9–25.9 / 22.4 ± 0.53	14.6–21.8 / 18.6 ± 0.32
op	52.7–58.5 / 55.3 ± 0.37	**54.6–60.7 / 57.5 ± 0.26**	53.9–59.0 / 56.4 ± 0.33	52.8–60.4 / 56.5 ± 0.36	50.5–62.1 / 56.3 ± 0.76	52.4–57.9 / 55.3 ± 0.34	53.2–59.3 / 55.5 ± 0.31
io	12.7–16.7 / 14.5 ± 0.23	11.1–18.1 / 15.2 ± 0.31	8.7–15.8 / 13.5 ± 0.34	9.6–15.4 / 12.5 ± 0.34	10.7–20.3 / 14.9 ± 0.53	12.2–18.8 / 15.3 ± 0.37	**12.8–19.0 / 16.0 ± 0.30**
lm	30.3–36.2 / 32.5 ± 0.37	25.8–32.5 / 29.8 ± 0.30	25.3–34.9 / 30.8 ± 0.50	24.4–31.3 / 27.8 ± 0.38	22.3–30.4 / 26.6 ± 0.47	28.5–39.7 / 32.7 ± 0.58	**30.4–36.9 / 33.1 ± 0.30**
lmd	38.6–48.6 / 43.9 ± 0.50	35.7–45.4 / 42.1 ± 0.46	36.9–48.5 / 41.7 ± 0.60	37.3–44.1 / 40.5 ± 0.36	30.1–36.7 / 33.5 ± 0.42	**40.4–54.8 / 45.7 ± 0.65**	37.7–47.5 / 43.3 ± 0.48
or	23.8–33.6 / 27.4 ± 0.56	23.8–30.6 / 27.3 ± 0.31	22.5–32.4 / 26.8 ± 0.46	21.3–29.3 / 24.7 ± 0.43	16.7–23.9 / 27.5 ± 0.53	23.5–33.7 / 27.5 ± 0.53	**26.6–35.8 / 31.0 ± 0.38**
hop	40.4–47.4 / 43.1 ± 0.42	40.7–47.4 / 43.6 ± 0.30	**40.6–48.7 / 44.1 ± 0.43**	40.6–45.8 / 43.3 ± 0.29	31.9–46.4 / 39.9 ± 0.72	34.8–50.5 / 42.1 ± 0.73	37.4–45.2 / 42.3 ± 0.32
ir	39.1–49.0 / 43.8 ± 0.57	34.6–46.2 / 41.9 ± 0.43	35.6–51.9 / 41.9 ± 0.81	31.8–42.5 / 36.7 ± 0.59	31.4–45.8 / 39.2 ± 0.86	38.3–55.3 / 44.3 ± 0.90	**38.7–52.1 / 44.4 ± 0.65**

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Character	Sam, n = 21	Aur, n = 32	Yarlg, n = 23	Dnz, n = 22	Slg, n = 19	Kaz, n = 23	Str, n = 27
hco	58.0–69.0 / 61.2 ± 0.60	54.5–64.2 / 60.1 ± 0.41	51.4–61.2 / 56.5 ± 0.50	51.3–59.0 / 54.6 ± 0.35	47.7–58.8 / 52.1 ± 0.77	54.7–69.8 / 58.5 ± 0.81	**57.5–68.8 / 61.9 ± 0.55**
Meristic characters							
D1	5.0–7.0 / 6.1 ± 0.08	6.0	**6.0–7.0 / 6.1 ± 0.07**	6.0	6.0	5.0–6.0 / 6.0 ± 0.04	6.0
Dr2	14.0–15.0 / 14.5 ± 0.11	14.0–15.0 / 14.8 ± 0.08	14.0–16.0 / 14.9 ± 0.09	13.0–16.0 / 15.1 ± 0.13	15.0–16.0 / 15.8 ± 0.09	14.0–16.0 / 14.9 ± 0.14	**15.0–16.0 / 15.5 ± 0.10**
Ar	11.0–12.0 / 11.6 ± 0.11	11.0–13.0 / 11.8 ± 0.10	12.0–13.0 / 12.6 ± 0.09	11.0–13.0 / 12.2 ± 0.11	11.0–13.0 / 12.0 ± 0.09	11.0–13.0 / 12.0 ± 0.13	**11.0–13.0 / 12.5 ± 0.12**
P	**18.0–20.0 / 19.1 ± 0.14**	17.0–20.0 / 18.6 ± 0.16	18.0–20.0 / 18.6 ± 0.15	17.0–20.0 / 18.6 ± 0.14	17.0–18.0 / 17.7 ± 0.11	17.0–19.0 / 17.9 ± 0.10	18.0–20.0 / 18.8 ± 0.13
V	12.0	12.0	12.0	12.0	12.0	12.0	12.0
C	23.0–25.0 / 23.7 ± 0.16	23.0–26.0 / 24.2 ± 0.15	23.0–26.0 / 24.6 ± 0.20	23.0–25.0 / 24.1 ± 0.14	22.0–24.0 / 23.2 ± 0.20	24.0–27.0 / 25.5 ± 0.19	**25.0–28.0 / 26.2 ± 0.16**

Note: the numerator denotes the limiting values of the characters; the denominator, the mean ± standard error of the mean. Characters for which the value of the coefficient of variation *var* > 10% is recorded are highlighted in color. Indicators with mean values being the highest in samples from seven regions are highlighted in bold.

In catches from the Streletskaya Bay of Sevastopol, the round goby, unlike other fish species, is rare, while in the Karkinitsky Bay and Donuzlav Liman, the population density of all gobies is quite high. For example, in 2017, in Samarchik Bay, the abundance of *N. melanostomus* in catches amounted to 42% of the total abundance of gobies [Prishchepa et al., 2018].

In general, characters in the round goby samples varied slightly. The highest variability (*var* > 10%) was recorded in the caudal peduncle width in fish from Samarchik Bay and Yarylgachskaya Bay and the caudal peduncle length in individuals from the Bakalskaya Spit water area, the Salgir River, and the Kazantip Bay. The anal fin depth was the most variable in fish from the Salgir River and Kazantip Bay. Also, in the round goby from the Salgir River, the first dorsal fin depth and second dorsal fin depth were the most variable characters. Out of head measurements, the most variable in the samples from six regions (except for Samarchik Bay) was the interorbital distance; for *N. melanostomus* from the Salgir River and Kazantip Bay, the most variable characters were the eye diameter and distance between eye and corner of mouth. The Streletskaya Bay was the region for which *var* > 10% were recorded only for the first dorsal fin depth.

The meristic characters of the round goby in the studied samples turned out to be the least variable of all the analyzed characters.

According to the results of comparison with the nonparametric Mann–Whitney test, the indices of morphometric characters of *N. melanostomus* from seven regions of the Sea of Azov–Black Sea Basin significantly differed from each other. Table 2 provides the number of characters studied in the round goby for which noticeable differences were revealed. In meristic characters, there were no significant differences.

In all morphometric characters (24 on the body and 12 on the head), differences were observed between the fish from the Streletskaya Bay and other six regions. Apparently, this is due to the larger size of the round goby from the bay. Differences in the smallest number of characters were recorded between *N. melanostomus* from three areas of the Karkinitsky Bay, probably due to the significant similarity of conditions because of the geographical proximity of these water areas. Differences were also noted in most of the studied characters between the round goby from three areas of the Karkinitsky Bay and other regions.

Table 2. Results of assessing differences between samples of the round goby *Neogobius melanostomus* from seven regions of the Black Sea by morphometric characters (the names of the study regions correspond to those in Fig. 1)

Region	Sam	Aur	Yarlg	Dnz	Slg	Kaz	Str
Sam		3	6	12	12	12	12
Aur	3		4	12	12	12	12
Yarlg	9	17		12	12	10	12
Dnz	23	24	24		9	8	12
Slg	24	24	24	24		11	12
Kaz	19	21	19	14	24		12
Str	24	24	24	24	24	24	

Note: differences are observed at a significance level of $p \leq 0.05$. Below the diagonal, the number of significantly different measurements on the body of the round goby is indicated; above the diagonal, on its head.

The degree of similarity of *N. melanostomus* from seven regions of the Sea of Azov–Black Sea Basin for all analyzed characters is shown in the dendrogram (Fig. 3). It is built using cluster analysis according to Kullback–Leibler divergence index (*D*) in different patterns of combining characters.

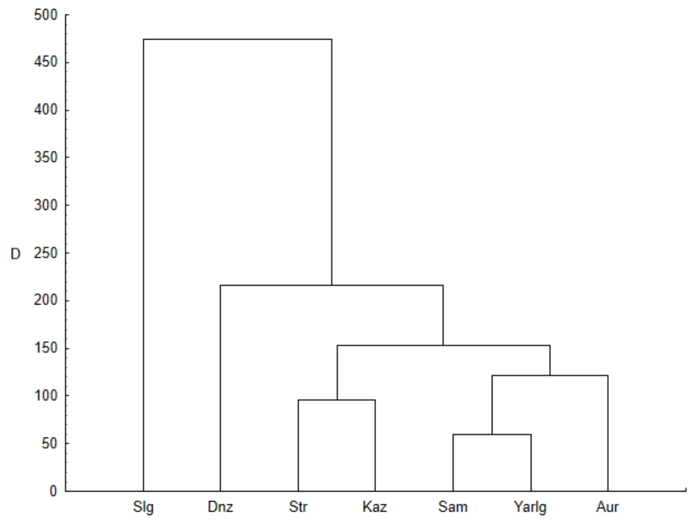

Fig. 3. Similarity dendrogram of all studied characters of samples of the round goby *Neogobius melanostomus* from seven regions of the Sea of Azov–Black Sea Basin (the names of the study regions correspond to those in Fig. 1)

Similarity of the round goby samples from Samarchik Bay and Yarylgachskaya Bay is observed at the lowest level of divergence ($D = 28.6$). These samples are adjoined by a group from the Bakalskaya Spit water area. At the level of divergence $D = 47.3$, groups of the fish from the Streletskaya Bay and Kazantip Bay are united. These groups form a cluster with a group of *N. melanostomus* from three areas of the Karkinitsky Bay, and a sample from the Donuzlav Liman adjoins them. The sample from the Salgir River adjoins these groups at the highest level of divergence, about 475. It can be tentatively concluded that such differences are related to the hydrochemical parameters of the studied water bodies. Specifically, fish from marine water areas (bays and bights of the Black Sea and Sea of Azov) form a separate group adjoined by a group of fish from the Donuzlav Liman with a higher salinity; the last in the dendrogram is a group of the round goby from a freshwater basin (the Salgir River).

The divergence of *N. melanostomus* samples from seven regions of the Sea of Azov–Black Sea Basin according to a complex of morphometric characters was obtained by the results of discriminant analysis. Thus, there were 99% of correct classifications of individuals according to catch areas. The studied characters in the samples form clouds of points in the space of two roots of the discriminant functions (Fig. 4A, B).

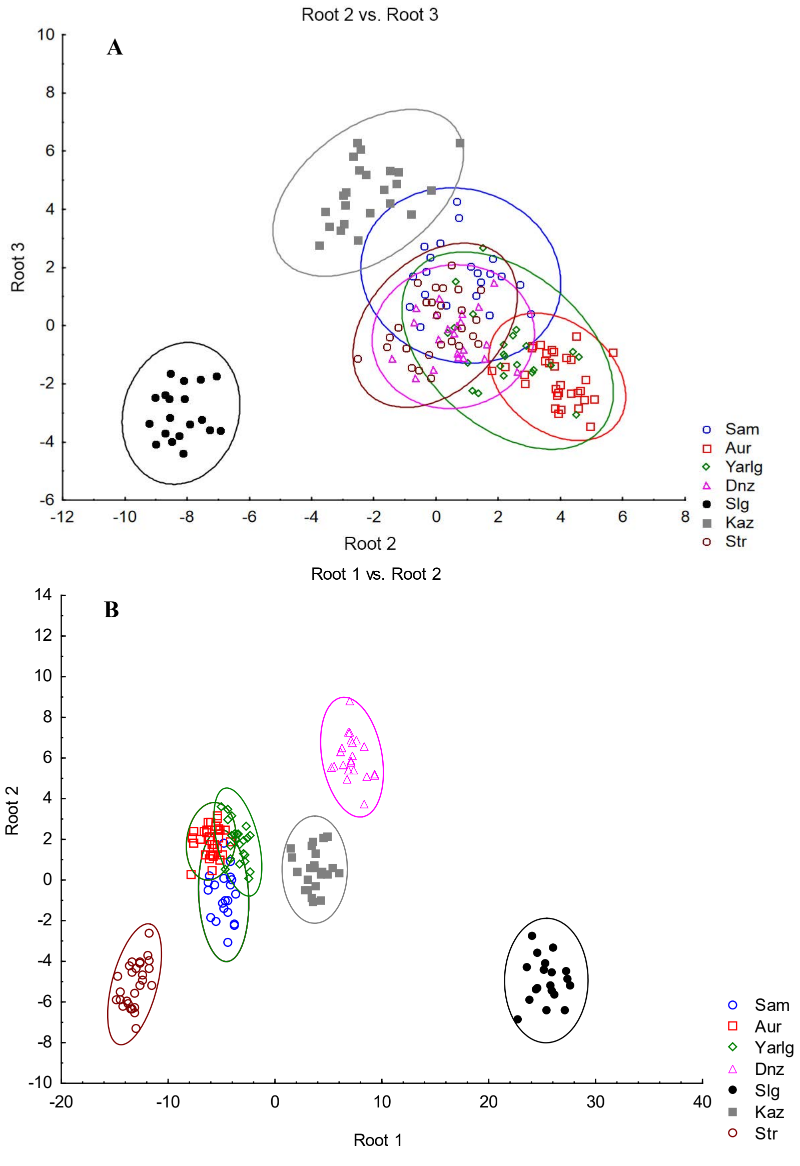

Fig. 4. Scattering diagram of canonical estimates of the indices of morphometric characters of the round goby *Neogobius melanostomus* from seven regions of the Sea of Azov–Black Sea Basin (A) and the values of characters transformed by the Reist formula (B) (results of discriminant analysis) (the names of the study regions correspond to those in Fig. 1)

According to the discriminant analysis, the round goby in the Sea of Azov–Black Sea Basin is differentiated into at least three spatial groupings. The first one is formed by fish from the western coast of the Crimean Peninsula (the Karkinitsky Bay and Donuzlav Liman) and the Sevastopol area (the Streletskaya Bay); the second one is formed by *N. melanostomus* from the Salgir River; and the third one is formed by the round goby from the Kazantip Bay (the Sea of Azov). Analysis using measurement values transformed by the Reist formula showed a clearer isolation of the samples.

Specifically, fish from geographically close areas of the Karkinitsky Bay form a separate group in the space of the roots of discriminant functions, while *N. melanostomus* from water areas differing in the environmental conditions [from a freshwater basin (the Salgir River) and the Streletskaya Bay] are isolated from the rest in terms of both canonical variables (Fig. 4B).

Analysis of the correlations of the studied characters of the round goby with the values of canonical variables revealed as follows: the divergence of samples along two axes is ensured by almost all indices of fish body measurements (Table 3) when the correlation coefficient between the characters and coordinate values along the second canonical axis exceeds 0.50. The greatest contributors to discrimination along the first canonical axis (root 2) with correlation coefficients exceeding 0.75 are the characters H, h, ih, aD, aV, iP, and iV.

Thus, the identified differences between the round goby individuals from the studied water areas are determined by the local environmental conditions of fish habitats.

Table 3. Correlations between the characters and coordinate values of two canonical variables for the round goby *Neogobius melanostomus* from seven regions of the Sea of Azov–Black Sea Basin

Character	Root 2	Root 3	Character	Root 2	Root 3
SL	**0.56**	**0.20**	lD2	**0.66**	**0.31**
H	**0.75**	0.04	hD2	**0.61**	0.14
h	**0.78**	0.10	lA	**0.60**	**0.24**
iH	**0.68**	–0.12	hA	**0.51**	**0.19**
ih	**0.88**	**–0.19**	lP	**0.68**	**0.46**
aD	**0.77**	**0.21**	iP	**0.77**	**0.29**
pD	**0.70**	**0.35**	lV	**0.64**	**0.31**
aP	**0.67**	**0.26**	iV	**0.75**	**0.22**
aV	**0.76**	**0.27**	lC	**0.63**	**0.45**
aA	**0.72**	**0.25**	HL	**0.70**	**0.20**
V-A	**0.74**	0.13	hcz	**0.17**	0.02
pl	**0.54**	**0.35**	ic	0.05	–0.01
lD1	**0.70**	**0.16**	ao	**0.15**	0.03
hD1	**0,62**	0,07			

Note: significant correlation coefficients are highlighted in bold.

DISCUSSION

Differences in the morphology of populations of invasive species may reflect the processes of adaptive phenotypic change and a unique history of a population [Langerhans, DeWitt, 2004]. At the same time, such differences occur within the native range of the species as well. According to [Smirnov, 1986], in the "Sea of Azov" population of the round goby, compared to the "Black Sea" one, the pectoral and pelvic fin length and the anal fin depth are higher, while the body width and length are lower; this can result from feeding and movement patterns. The round goby from the Dnieper River possesses rheophilic characters: the caudal section of the body is elongated, and the interorbital distance is increased [Smirnov, 1986]. In the Kakhovka Reservoir, *N. melanostomus* has an increased dorsal fin length compared to fish inhabiting bays of the Sea of Azov, while pelvic fin length and width, as well as pectoral, anal, and caudal fin length, are lower, which is related to inhabiting stagnant water [Demchenko, Tkachenko, 2017; Tkachenko, 2012]. The round goby from the Southeastern Baltic population is characterized by a reduced number of fin rays and number of vertebrae, compared to fish from the native range [Kodukhova et al., 2017]. In *N. melanostomus* from the Great Lakes of North America (an invasive population), a decrease in meristic characters was also revealed: these individuals have reduced number of rays in the second dorsal and caudal fins [Smirnov, 2001].

According to the discriminant analysis, the greatest contribution to the discrimination of the round goby samples from seven areas of the Sea of Azov–Black Sea Basin is made by the maximum body depth, caudal peduncle depth and width, predorsal and prepelvic distance, and width of pectoral and pelvic fin base (the correlation coefficient between these characters and coordinate values along the second canonical axis exceeds 0.75). In fish from the Bakalskaya Spit area, the anterior part of the body and caudal fin length and width are increased. *N. melanostomus* inhabiting areas exposed to strong surf is likely to have a more massive anterior part of the body. The round goby from the Salgir River has higher values of fin depth (the first and second dorsal fins and the anal one) and pelvic fin length, compared to fish from other areas; it is an adaptation for inhabiting spots with constant current.

The indices of head characters turned out to be higher in fish from the Bakalskaya Spit area and Streletskaya Bay. In the first region, compared to other ones, the round goby had a longer preorbital and postorbital distance; in the second, the upper jaw and head were more massive (the interorbital distance, upper jaw length, distance between eye and corner of mouth, mouth width, and head width through middle of eye were the highest). Apparently, the food spectrum of *N. melanostomus* from the Streletskaya Bay includes larger food objects than that of fish from other regions. As shown in [Bogachik, 1967], the structure of the jaw apparatus in the round goby depends on the nature of its feeding. Its food mostly consists of molluscs of the genera *Mytilus* Linnaeus, 1758, *Mytilaster* Monterosato, 1884, *Balanus* Costa, 1778, and *Dreissena* Van Beneden, 1835. *N. melanostomus* has developed specific muscles on the upper jaw allowing it to consume attached forms of molluscs, which are rarely consumed by other fish species.

Conclusion. A significant morphological heterogeneity of *Neogobius melanostomus* groups from different water areas of the Sea of Azov–Black Sea Basin is revealed. The results of the discriminant analysis showed that the spatial groupings of the round goby are combined into at least three groups. The first one is formed by fish from the western coast of the Crimean Peninsula (the Karkinitsky Bay and Donuzlav Liman) and the Sevastopol area (the Streletskaya Bay); the second one, by *N. melanostomus* from the Salgir River; and the third one, by the round goby from the Kazantip Bay (the Sea of Azov). According to the obtained data and analysis of literature, the differences between local groups based on external morphology may be due to various reasons: hydrological, hydrochemical, and environmental, including trophic conditions in certain water areas of the Sea of Azov–Black Sea Basin. Moreover, such differences may be related to the history of formation of the fish population in the studied water areas. In the inland water bodies of the Crimean Peninsula (in particular, the Salgir River), *N. melanostomus* was formed from the ichthyofauna of the Dnieper River Basin, distributing during the period of the North Crimean Canal operation. It is likely to determine the morphological isolation of this local group.

Thus, the round goby within the Sea of Azov–Black Sea Basin has formed morphologically different spatial groupings corresponding to the environmental conditions in this area. The revealed heterogeneity shows high paratypical variability of morphometric characters and the fact that under different environmental conditions, individuals of the same species develop a specific phenotype.

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МОРФОЛОГИЧЕСКАЯ ИЗМЕНЧИВОСТЬ БЫЧКА-КРУГЛЯКА *NEOGOBIUS MELANOSTOMUS* (PALLAS, 1814) (ACTINOPTERYGII, GOBIIDAE) АЗОВО-ЧЕРНОМОРСКОГО БАССЕЙНА

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Рассмотрена изменчивость признаков внешней морфологии (36 пластических и 6 меристических) бычка-кругляка *Neogobius melanostomus* (Pallas, 1814) из семи районов Азово-Черноморского бассейна: северо-западного и юго-западного черноморского побережья Крымского полуострова (Каркинитский залив, лиман Донузлав, Стрелецкая бухта Севастополя), Казантипского залива Азовского моря, а также реки Салгир в центральной части Крымского полуострова. Установлено, что бычок-кругляк из разных районов вылова в возрасте 2+…3 имеет разные размеры тела: наибольшие у особей из Стрелецкой бухты, $SL_{\text{ср}}$ (136,2 ± 1,97) мм; наименьшие у особей из реки Салгир, $SL_{\text{ср}}$ (66,8 ± 2,28) мм. С помощью критерия Манна — Уитни между выборками установлены статистически достоверные различия по большинству пластических признаков. По меристическим признакам они отсутствуют. Наибольший вклад в дискриминацию выборок *N. melanostomus* вносят пластические признаки, связанные с расположением плавников. Согласно результатам кластерного анализа, по совокупности всех изученных признаков у бычка-кругляка Азово-Черноморского бассейна наибольшим сходством обладают выборки из Каркинитского залива (залив Самарчик и Ярылгачская бухта, $D = 28{,}6$) и из акватории Бакальской косы. На уровне дивергенции $D = 47{,}3$ объединяются группы бычков из Стрелецкой бухты и Казантипского залива, а затем к ним на уровне $D = 215$ примыкает выборка из лимана Донузлав. Выборка бычка из реки Салгир занимает наиболее обособленное положение: уровень дивергенции составляет около 475. По данным дискриминантного анализа установлено, что бычок-кругляк из Азово-Черноморского бассейна дифференцирован как минимум на три пространственные группировки: первая — из района западного побережья Крымского полуострова (Каркинитский залив и лиман Донузлав) и района Севастополя (бухта Стрелецкая); вторая — из Казантипского залива (Азовское море); третья — из реки Салгир. Наибольший вклад в дискриминацию пространственных группировок (при коэффициенте корреляции между признаками и значениями координат по второй канонической оси больше 0,75) внесли следующие признаки: высота тела, высота и толщина хвостового стебля, антедорсальное и антевентральное расстояния и ширина грудных и брюшных плавников. Выявленная неоднородность показывает высокую паратипическую изменчивость пластических признаков; в различных экологических условиях у особей одного вида формируется специфический фенотип.

Ключевые слова: бычок-кругляк, Азово-Черноморский бассейн, пластические и меристические признаки, изменчивость, популяция