

Phenetic relationships and diagnostic features of sculpins of the genus *Asprocottus* (Scorpaeniformes: Cottoidea)

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ABSTRACT. Aimed at the study of phenetic and taxonomic relationships of Baikal endemic sculpins of the genus *Asprocottus* Berg 1906, the author has carried out a morphometric investigations by 11 meristic and 29 plastic characters as well as analyzed nonmetric features: coloration peculiarities of specimens, form and location of bony spinelets on the integuments, morphology of the sensory system organs and the number of preopercular spines. The results of the study have confirmed the validity of seven species: *A. herzensteini*, *A. abyssalis*, *A. intermedius*, *A. korjakovi*, *A. parmiferus*, *A. platycephalus*, and *A. pulcher*. Based on the revision of the diagnostic features, the author proposes the new key to determine species.

Keywords: *Asprocottus*, systematics, morphology, phenetic relationships, diagnostic features, Lake Baikal

1. Introduction

The genus *Asprocottus* established by L.S. Berg (Berg, 1906), and originally included only one species: *A. herzensteini* (Berg, 1906; 1907; 1933; 1949). Then, D.N. Taliev (1955) extended its composition by moving the species from other genera *A. gibbosus* (from the genus *Abyssocottus*), *A. pulcher* (from *Cottinella*) and *A. megalops* with subspecies *A. m. eurystomus* and *A. kozovi* (from *Limnocottus*). Moreover, representatives of *A. herzensteini*: *A. herzensteini abyssalis*, *A. herzensteini intermedius*, *A. herzensteini parmiferus*, and *A. herzensteini platycephalus* were described as subspecies, but later this status was elevated to species (Sideleva, 1982). Subsequently, new species *A. korjakovi* and *A. korjakovi minor* were described, and *A. intermedius* was indicated as a synonym of *A. herzensteini* (Sideleva, 2001).

Currently, the genus is usually considered to consist of eight species: *A. herzensteini*, *A. abyssalis*, *A. intermedius*, *A. korjakovi*, *A. minor*, *A. parmiferus*, *A. platycephalus*, and *A. pulcher* (Bogutskaya and Naseka, 2004; Eschmeyer et al., 2018). However, there are doubts about the validity of *A. intermedius* and the taxonomic rank of *A. minor* / *A. korjakovi minor*. In this regard, it is necessary to conduct a study aimed at clarifying the taxonomic boundaries of species and the development of a new key for their determination.

2. Material and methods

The study was carried out on the material collected by the author in 2000 – 2004 as well as

archival materials of Laboratory of ichthyology of LIN SB RAS collected by V.G. Sidelyova, A.N. Telpukhovskiy, P.N. Anoshko, I.V. Khanaev, and S.V. Kirilshik in 1977 – 2009. Fishes were caught with gill nets and beam-trawl. In total, we examined 22 specimens of *A. herzensteini*, 14 – *A. abyssalis*, 17 – *A. intermedius*, 20 – *A. korjakovi*, 38 – *A. minor*, 14 – *A. parmiferus*, 68 – *A. platycephalus*, and 30 – *A. pulcher*. Species were identified by meristic features, peculiarities of coloration and morphology of the seismosensory system organs specified in the original descriptions and subsequent revisions (Berg, 1906; 1949; Taliev, 1955; Sideleva, 1982; 2001; 2003). The nomenclature is shown in accordance with the provisions of the International Code of Zoological Nomenclature (1999).

The morphometric examination was carried out by 11 meristic and 28 plastic characters. We analyzed: number of neuromasts in the lateral (*ll.*), supraorbital (*lso*), infraorbital (*lio*), temporal (*lt*), preopercular-mandibular (*lpm*) and occipital (*lo*) sensory lines; number of rays in the first (D_1) and second (D_2) dorsal, pectoral (*P*), and anal (*A*) fins, number of gill rakers (*sp.br*); head length (*c*), length (*l*), height (*H*) and width (*w*) of the trunk; length (*lpc*) and height (*h*) of caudal peduncle; antedorsal (*aD*), postdorsal (*pD*), anteventral (*aV*), anteanal (*aA*), pectroventral (*P-V*) and ventroanal (*V-A*) distances; length of insertions of the first (ID_1) and second (ID_2) dorsal and anal (*IA*) fins; length of maximum rays in the first (hD_1) and second (hD_2) dorsal, anal (*hA*), pectoral (*IP*), and ventral (*IV*) fins; snout length (*ao*); longitudinal eye diameter (*o*); postorbital distance (*po*); head height near occiput (*ch*) and

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near vertical of the eye middle (*ch*); interorbital distance (*io*); and length of upper (*l_{mx}*) and lower (*l_{md}*) jaws. Statistical processing of the material was performed by the generally accepted methods (Plokhinskiy, 1980). Table 1 shows the variability of meristic and plastic characters. Selections were compared by factor analysis methods (PCA) using SPSS 8.0 software. For assessment of the degree of differences, *CD* coefficient was used (Mayr, 1969).

3. Results and discussion

The following features characterize sculpins of the genus *Asprocottus*. Each pelvic fin has three soft rays. The anal fin is equal or slightly shorter than the second dorsal one. The pectoral fins are fan-shaped with a wide base. The dorsal fins are located separately or adjoin the bases. The eyes are round, and their diameter coincides with or slightly smaller than the size of the orbit.

There are crests on the infraorbital and supraorbital bones. A degree of their development in different species is unequal. On *preoperculum* there are 4-5 spines, of which the first three, rarely two, upper ones are well developed, and the lower ones can be rudimentary.

The body is completely or partially covered with bony spinelets. They can be seated separately or accreted at the base.

The external neuromasts located on the skin processes, papillae, represent the sensory system. Normally, there is an additional row of neuromasts on the body above the lateral line reaching the vertical of the posterior margin or the middle of the second dorsal fin. In the anterior part of the body, groups of neuromasts, rudiments of the second and third additional rows, can be located above or below the lateral line.

Analysis of differences by *CD* (Table 2) showed taxonomically significant differences between all species, except for *A. korjakovi* and *A. minor*. Discrete differences were determined in 13 of 27 pairwise comparisons by one – four characteristics. *A. parmiferus* having discrete differences with all other species differed the most.

Multidimensional analysis (PCA) of the variability of the meristic and plastic characters of all eight species indicated that the first and second principal components explain 34.9% of total dispersion. The maximum positive loads on the first principal component yield the number of neuromasts in supraorbital, infraorbital and preopercular-mandibular lines, and the negative one – interorbital distance. The maximum positive load on the second principal component is the head length, and the negative one – the number of neuromasts in the lateral line.

On the diagram of the species dispersion in the space of the first two principal components (Fig. 1a), *A. parmiferus* and *A. platycephalus* occupied a separate position. Other species formed three pairs of phenetically similar forms: *A. herzensteini* – *A. abyssalis*, *A. intermedius* – *A. pulcher*, and *A. korjakovi* – *A. minor* (Fig. 1b). The multidimensional analysis of these pairs

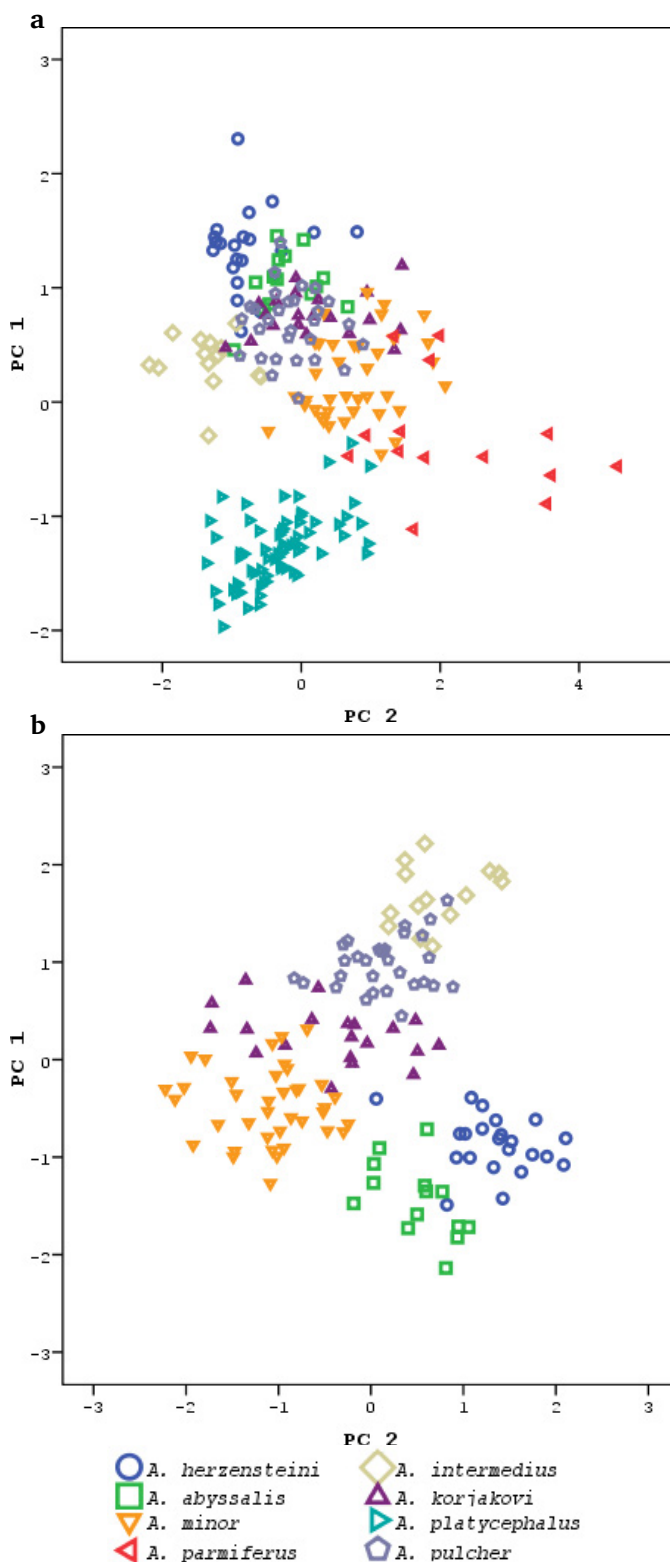


Fig. 1. Distribution of species of genus *Asprocottus* in the space of a first (PC1) and second (PC2) principals components by meristic and plastic characters: a – all species; b – the same thing, without *A. parmiferus* and *A. platycephalus*

(Fig. 2), like the analysis of the differences by *CD* (Table 2), has shown that in the pairs *A. herzensteini* – *A. abyssalis* and *A. intermedius* – *A. pulcher* the compared forms belong to different population sets, in this case – to different species, even though they do not have discrete differences. In the pair *A. korjakovi* – *A. minor*, such differences have not been identified, which indicates the conspecificity of these forms.

Table 1. The total length (TL), standard length (SL) and morphometric characters of the species of the genus *Asprocottus*

	<i>A. herzensteini</i> (n=22)	<i>A. abyssalis</i> (n=14)	<i>A. intermedius</i> (n=17)	<i>A. korjakovi</i> (n=20)	<i>A. minor</i> (n=38)	<i>A. platycephalus</i> (n=68)	<i>A. parmiferus</i> (n=14)	<i>A. pulcher</i> (n=29)
TL (mm)	100.9 77.9-116.0	66.4 61.0-71.9	80.8 73.6-87.2	104.8 86.2-123.2	75.5 68.3-87.7	94.3 80.2-109.5	63.2 44.2-77.1	96.9 86.7-108.3
SL (mm)	84.8 65.3-98.2	54.7 51.2-60.3	69.1 62.4-75.0	89.2 72.7-104.6	62.6 55.5-74.0	80.0 65.9-93.0	52.3 35.9-64.8	80.6 71.6-90.9
Meristic characters								
<i>D</i> ₁	$\frac{6.4 \pm 0.10}{6-7; 0.49}$	$\frac{6.5 \pm 0.20}{5-8; 0.73}$	$\frac{6.1 \pm 0.10}{5-7; 0.42}$	$\frac{5.0 \pm 0.15}{3-6; 0.67}$	$\frac{5.2 \pm 0.08}{4-6; 0.49}$	$\frac{6.1 \pm 0.07}{5-7; 0.60}$	$\frac{5.4 \pm 0.19}{4-7; 0.73}$	$\frac{6.0 \pm 0.12}{5-7; 0.64}$
<i>D</i> ₂	$\frac{15.4 \pm 0.14}{14-16; 0.64}$	$\frac{14.6 \pm 0.17}{14-16; 0.62}$	$\frac{16.3 \pm 0.16}{15-17; 0.67}$	$\frac{14.9 \pm 0.13}{14-16; 0.57}$	$\frac{14.7 \pm 0.14}{13-17; 0.88}$	$\frac{15.6 \pm 0.10}{14-17; 0.84}$	$\frac{14.6 \pm 0.22}{13-16; 0.82}$	$\frac{16.1 \pm 0.11}{15-17; 0.57}$
<i>P</i>	$\frac{15.9 \pm 0.11}{15-17; 0.51}$	$\frac{14.1 \pm 0.21}{13-15; 0.80}$	$\frac{13.7 \pm 0.18}{13-16; 0.75}$	$\frac{15.0 \pm 0.05}{14-15; 0.22}$	$\frac{14.9 \pm 0.08}{13-16; 0.52}$	$\frac{14.5 \pm 0.07}{13-15; 0.55}$	$\frac{15.4 \pm 0.28}{14-17; 1.05}$	$\frac{14.8 \pm 0.11}{14-16; 0.59}$
<i>A</i>	$\frac{13.5 \pm 0.15}{12-15; 0.72}$	$\frac{13.1 \pm 0.17}{12-14; 0.64}$	$\frac{15.5 \pm 0.17}{14-17; 0.70}$	$\frac{14.8 \pm 0.09}{14-15; 0.40}$	$\frac{14.4 \pm 0.13}{13-16; 0.81}$	$\frac{15.1 \pm 0.09}{14-17; 0.73}$	$\frac{13.6 \pm 0.31}{12-15; 1.18}$	$\frac{14.8 \pm 0.13}{14-16; 0.73}$
<i>sp.br.</i>	$\frac{6.5 \pm 0.17}{5-8; 0.78}$	$\frac{7.0 \pm 0.23}{6-8; 0.85}$	$\frac{5.4 \pm 0.20}{4-7; 0.84}$	$\frac{6.2 \pm 0.09}{6-7; 0.40}$	$\frac{5.9 \pm 0.12}{4-7; 0.72}$	$\frac{5.8 \pm 0.08}{4-8; 0.69}$	$\frac{5.1 \pm 0.22}{4-6; 0.83}$	$\frac{6.1 \pm 0.15}{5-9; 0.83}$
<i>Lso.</i>	$\frac{10.4 \pm 0.15}{9-12; 0.98}$	$\frac{9.5 \pm 0.15}{8-12; 0.78}$	$\frac{10.4 \pm 0.26}{9-12; 0.98}$	$\frac{9.6 \pm 0.16}{8-12; 1.02}$	$\frac{7.8 \pm 0.10}{6-11; 0.87}$	$\frac{7.4 \pm 0.15}{6-10; 0.94}$	$\frac{7.5 \pm 0.20}{6-10; 1.01}$	$\frac{9.7 \pm 0.13}{8-12; 0.98}$
<i>Lio.</i>	$\frac{19.7 \pm 0.16}{17-22; 1.04}$	$\frac{17.1 \pm 0.25}{14-20; 1.33}$	$\frac{16.1 \pm 0.22}{14-18; 0.83}$	$\frac{17.9 \pm 0.16}{16-20; 1.03}$	$\frac{16.5 \pm 0.16}{14-20; 1.35}$	$\frac{14.6 \pm 0.14}{13-17; 0.86}$	$\frac{13.7 \pm 0.37}{11-19; 1.87}$	$\frac{17.8 \pm 0.16}{15-20; 1.22}$
<i>Lt.</i>	$\frac{3.3 \pm 0.10}{2-4; 0.62}$	$\frac{4.3 \pm 0.10}{4-6; 0.51}$	$\frac{4.6 \pm 0.19}{4-6; 0.73}$	$\frac{2.4 \pm 0.11}{1-5; 0.70}$	$\frac{2.3 \pm 0.11}{1-4; 0.91}$	$\frac{3.1 \pm 0.10}{2-4; 0.56}$	$\frac{3.4 \pm 0.14}{2-4; 0.69}$	$\frac{4.6 \pm 0.08}{4-6; 0.65}$
<i>Loc.</i>	$\frac{1.8 \pm 0.08}{1-3; 0.53}$	$\frac{1.6 \pm 0.19}{1-4; 0.88}$	$\frac{2.1 \pm 0.16}{1-3; 0.59}$	$\frac{1.2 \pm 0.07}{1-2; 0.42}$	$\frac{1.1 \pm 0.04}{1-3; 0.33}$	$\frac{1.0 \pm 0.03}{1-2; 0.18}$	$\frac{1.3 \pm 0.11}{1-3; 0.55}$	$\frac{1.3 \pm 0.07}{1-3; 0.53}$
<i>Lpn.</i>	$\frac{22.0 \pm 0.23}{19-25; 1.52}$	$\frac{20.7 \pm 0.28}{18-23; 1.47}$	$\frac{21.9 \pm 0.53}{19-26; 1.99}$	$\frac{21.8 \pm 0.22}{19-24; 1.37}$	$\frac{19.3 \pm 0.16}{16-23; 1.43}$	$\frac{16.7 \pm 0.17}{15-19; 0.99}$	$\frac{15.8 \pm 0.54}{11-21; 2.78}$	$\frac{21.8 \pm 0.24}{17-26; 1.83}$
<i>Ll.</i>	$\frac{41.2 \pm 0.62}{34-50; 4.04}$	$\frac{36.5 \pm 0.59}{31-43; 3.10}$	$\frac{51.0 \pm 2.52}{42-61; 6.65}$	$\frac{40.4 \pm 0.54}{34-48; 3.29}$	$\frac{34.8 \pm 0.22}{31-42; 1.95}$	$\frac{35.8 \pm 0.43}{32-42; 2.30}$	$\frac{31.7 \pm 1.10}{20-38; 5.59}$	$\frac{43.6 \pm 0.61}{37-58; 4.62}$
Plastic characters in % SL								
<i>c</i>	$\frac{31.7 \pm 0.22}{29.9-33.9; 1.04}$	$\frac{32.1 \pm 0.31}{29.3-33.9; 1.16}$	$\frac{31.0 \pm 0.27}{29.2-33.0; 1.13}$	$\frac{33.0 \pm 0.30}{30.2-35.5; 1.35}$	$\frac{33.9 \pm 0.16}{32.3-36.9; 1.01}$	$\frac{32.7 \pm 0.13}{30.4-36.3; 1.11}$	$\frac{35.7 \pm 0.35}{33.6-38.7; 1.31}$	$\frac{34.0 \pm 0.20}{31.2-36.7; 1.06}$
<i>L</i>	$\frac{71.2 \pm 0.34}{68.6-74.3; 1.59}$	$\frac{71.8 \pm 0.35}{67.6-73.8; 1.33}$	$\frac{72.9 \pm 0.35}{69.9-75.7; 1.45}$	$\frac{71.9 \pm 0.32}{69.7-74.8; 1.41}$	$\frac{70.9 \pm 0.25}{67.4-74.7; 1.56}$	$\frac{69.9 \pm 0.18}{65.7-72.8; 1.47}$	$\frac{69.3 \pm 0.67}{64.3-73.0; 2.49}$	$\frac{70.5 \pm 0.36}{65.8-73.7; 1.92}$

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H	16.3 ± 0.30 14.5-21.0; 1.39	17.3 ± 0.34 15.4-19.2; 1.29	17.4 ± 0.33 13.9-19.4; 1.37	20.4 ± 0.46 15.9-23.4; 2.05	19.4 ± 0.27 15.5-22.7; 1.69	15.8 ± 0.22 12.4-20.3; 1.82	22.1 ± 0.55 18.3-25.6; 2.07	18.9 ± 0.22 16.5-21.3; 1.18
h	5.7 ± 0.08 5.1-6.9; 0.36	6.5 ± 0.09 6.1-7.3; 0.32	5.4 ± 0.11 4.5-6.2; 0.44	6.0 ± 0.13 5.3-7.4; 0.57	6.1 ± 0.08 5.2-7.2; 0.48	5.6 ± 0.06 4.6-6.9; 0.53	6.7 ± 0.21 5.2-8.2; 0.78	5.9 ± 0.07 5.0-6.8; 0.38
w	15.2 ± 0.29 12.4-18.4; 1.35	15.8 ± 0.36 13.4-18.3; 1.34	16.7 ± 0.26 14.9-18.4; 1.09	18.3 ± 0.37 14.3-21.2; 1.68	15.6 ± 0.21 13.3-18.9; 1.28	15.2 ± 0.15 12.5-17.7; 1.20	18.1 ± 0.44 14.8-20.4; 1.66	15.8 ± 0.15 14.0-17.2; 0.79
aD	36.7 ± 0.31 32.0-39.5; 1.43	36.3 ± 0.41 33.3-38.7; 1.54	37.4 ± 0.41 34.3-40.7; 1.68	38.4 ± 0.32 35.2-40.4; 1.44	39.8 ± 0.34 32.2-42.7; 2.07	37.9 ± 0.25 29.8-40.9; 2.08	41.6 ± 0.51 40.0-46.2; 1.91	39.2 ± 0.40 31.1-42.8; 2.14
pD	15.0 ± 0.26 12.2-17.6; 1.20	15.5 ± 0.64 11.3-20.2; 2.39	12.9 ± 0.33 10.2-15.1; 1.35	13.5 ± 0.24 11.7-15.5; 1.09	13.4 ± 0.22 10.1-16.1; 1.37	11.9 ± 0.17 8.3-15.2; 1.40	11.7 ± 0.41 8.9-14.6; 1.54	11.4 ± 0.23 8.7-14.9; 1.26
aV	28.2 ± 0.23 26.4-31.0; 1.08	27.3 ± 0.39 25.0-29.6; 1.47	29.7 ± 0.28 27.5-32.2; 1.16	30.5 ± 0.39 27.3-33.9; 1.73	29.3 ± 0.30 26.6-37.0; 1.87	28.7 ± 0.18 25.3-31.9; 1.52	29.7 ± 0.52 26.5-33.4; 1.95	30.8 ± 0.22 28.3-32.8; 1.19
aA	56.5 ± 0.32 54.4-60.0; 1.52	54.7 ± 0.34 52.8-57.1; 1.27	54.6 ± 0.36 52.5-58.5; 1.50	55.8 ± 0.40 53.0-59.3; 1.81	55.0 ± 0.21 51.7-58.4; 1.28	54.6 ± 0.19 50.8-58.2; 1.60	57.0 ± 0.67 52.7-62.1; 2.51	56.2 ± 0.26 53.9-59.7; 1.39
lpc	16.1 ± 0.33 13.4-19.8; 1.56	16.9 ± 0.24 15.4-18.5; 0.88	12.5 ± 0.29 10.3-14.5; 1.19	12.7 ± 0.24 10.2-14.1; 1.07	13.3 ± 0.29 9.4-16.5; 1.77	11.6 ± 0.14 8.9-13.5; 1.14	11.5 ± 0.60 7.8-16.6; 2.26	12.3 ± 0.28 9.9-15.5; 1.50
PV	4.3 ± 0.14 3.2-5.7; 0.66	4.2 ± 0.18 3.0-5.4; 0.68	5.6 ± 0.16 4.5-6.8; 0.66	5.9 ± 0.19 4.3-7.5; 0.83	5.0 ± 0.09 3.9-6.2; 0.58	5.0 ± 0.08 3.6-6.4; 0.70	4.9 ± 0.14 4.1-5.9; 0.54	5.2 ± 0.15 3.7-6.8; 0.80
VA	28.1 ± 0.35 25.2-32.5; 1.63	27.6 ± 0.47 24.4-30.5; 1.77	25.7 ± 0.65 19.0-30.3; 2.68	27.0 ± 0.57 22.6-31.5; 2.55	25.6 ± 0.30 21.7-30.5; 1.87	26.3 ± 0.25 22.1-31.2; 2.08	27.6 ± 0.59 22.3-31.7; 2.20	27.3 ± 0.37 23.9-30.9; 2.00
ID ₁	17.6 ± 0.25 15.5-20.1; 1.19	18.2 ± 0.45 15.4-21.1; 1.68	17.1 ± 0.29 15.2-19.7; 1.22	18.5 ± 0.27 16.5-20.6; 1.21	17.4 ± 0.25 14.0-20.3; 1.54	16.2 ± 0.18 12.9-20.2; 1.51	16.8 ± 0.42 14.3-19.9; 1.56	17.1 ± 0.32 13.3-20.7; 1.71
ID ₂	30.7 ± 0.42 25.5-33.7; 1.96	31.6 ± 0.42 28.6-35.0; 1.57	33.6 ± 0.44 29.6-36.5; 1.83	29.3 ± 0.32 26.9-31.8; 1.45	30.7 ± 0.29 27.1-34.1; 1.81	32.7 ± 0.21 27.3-36.1; 1.73	32.6 ± 0.63 27.8-36.5; 2.37	32.2 ± 0.34 27.9-37.5; 1.84
hD ₁	8.2 ± 0.17 6.8-10.1; 0.78	9.6 ± 0.25 7.8-11.3; 0.95	7.7 ± 0.18 6.5-9.3; 0.73	7.5 ± 0.17 6.3-9.6; 0.76	8.4 ± 0.15 6.9-10.2; 0.92	8.1 ± 0.13 5.1-11.2; 1.06	8.3 ± 0.37 6.4-10.9; 1.39	7.4 ± 0.16 5.9-9.1; 0.86
hD ₂	13.0 ± 0.23 11.5-15.7; 1.07	13.1 ± 0.33 10.4-15.0; 1.25	10.1 ± 0.23 8.4-11.6; 0.93	11.2 ± 0.20 9.8-13.8; 0.92	12.2 ± 0.21 9.8-15.8; 1.27	10.3 ± 0.17 8.0-14.9; 1.40	11.6 ± 0.42 9.3-15.3; 1.56	11.9 ± 0.28 9.7-14.7; 1.51
IA	27.1 ± 0.54 16.6-29.9; 2.55	28.4 ± 0.57 24.6-33.3; 2.13	34.4 ± 0.47 30.8-39.4; 1.94	31.2 ± 0.46 27.4-34.9; 2.04	31.6 ± 0.27 28.6-35.0; 1.67	33.8 ± 0.26 29.1-39.9; 2.16	32.7 ± 1.02 23.2-39.0; 3.80	32.3 ± 0.34 27.6-35.2; 1.81
hA	10.9 ± 0.18 9.3-13.3; 0.85	11.0 ± 0.38 7.2-13.1; 1.41	7.8 ± 0.12 6.7-8.7; 0.49	9.5 ± 0.22 7.7-11.9; 1.00	10.7 ± 0.21 8.0-13.9; 1.32	9.5 ± 0.17 7.3-13.3; 1.40	11.9 ± 0.32 10.0-15.2; 1.21	10.0 ± 0.22 8.2-13.3; 1.19
IP	23.4 ± 0.34 19.1-26.2; 1.61	22.3 ± 0.40 18.0-24.9; 1.51	22.1 ± 0.41 17.5-24.4; 1.69	21.2 ± 0.37 17.8-23.9; 1.65	23.1 ± 0.26 20.4-26.8; 1.59	19.6 ± 0.20 15.4-23.2; 1.64	24.5 ± 0.55 20.7-28.1; 2.07	23.5 ± 0.20 20.5-25.5; 1.06

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IV	<u>15.0 ± 0.24</u> 13.7-17.1; 1.11	<u>16.1 ± 0.43</u> 13.7-20.1; 1.62	<u>13.0 ± 0.14</u> 11.6-13.7; 0.56	<u>14.3 ± 0.17</u> 12.9-15.8; 0.78	<u>15.0 ± 0.19</u> 11.8-18.0; 1.18	<u>12.5 ± 0.14</u> 10.0-15.7; 1.12	<u>15.7 ± 0.60</u> 11.1-19.8; 2.24	<u>15.1 ± 0.17</u> 13.2-17.1; 0.90
Plastic characters in % c								
ao	<u>26.5 ± 0.17</u> 25.4-28.3; 0.79	<u>25.2 ± 0.52</u> 22.2-28.8; 1.94	<u>26.4 ± 0.34</u> 24.4-29.5; 1.39	<u>26.4 ± 0.29</u> 24.0-28.7; 1.30	<u>26.9 ± 0.30</u> 21.7-30.0; 1.84	<u>25.5 ± 0.15</u> 22.1-28.7; 1.23	<u>29.5 ± 0.42</u> 26.7-32.5; 1.58	<u>28.1 ± 0.24</u> 26.3-30.7; 1.31
o	<u>23.4 ± 0.32</u> 20.5-26.2; 1.52	<u>26.9 ± 0.53</u> 24.3-31.3; 2.00	<u>22.6 ± 0.33</u> 20.4-24.8; 1.38	<u>21.0 ± 0.35</u> 17.4-23.9; 1.58	<u>24.1 ± 0.30</u> 20.9-29.1; 1.87	<u>19.5 ± 0.20</u> 15.1-23.4; 1.68	<u>21.9 ± 0.59</u> 18.0-26.6; 2.20	<u>20.9 ± 0.17</u> 19.2-23.3; 0.94
op	<u>43.7 ± 0.37</u> 39.6-46.7; 1.71	<u>43.0 ± 0.37</u> 40.0-45.1; 1.40	<u>46.4 ± 0.46</u> 41.6-49.4; 1.92	<u>45.3 ± 0.64</u> 41.1-49.8; 2.88	<u>45.1 ± 0.26</u> 41.3-50.5; 1.62	<u>44.9 ± 0.20</u> 40.1-48.5; 1.63	<u>47.1 ± 0.68</u> 44.0-53.8; 2.56	<u>46.7 ± 0.32</u> 42.6-50.5; 1.70
cH	<u>47.9 ± 0.70</u> 42.4-55.3; 3.27	<u>51.0 ± 0.94</u> 44.3-56.9; 3.52	<u>51.8 ± 0.73</u> 47.3-59.3; 3.02	<u>55.4 ± 0.93</u> 46.6-61.5; 4.16	<u>53.0 ± 0.53</u> 45.8-61.0; 3.25	<u>44.8 ± 0.41</u> 37.6-52.0; 3.39	<u>56.1 ± 1.20</u> 47.5-66.2; 4.48	<u>75.9 ± 0.68</u> 70.2-83.0; 3.66
ch	<u>34.5 ± 0.52</u> 28.5-39.1; 2.44	<u>37.6 ± 0.74</u> 33.2-42.6; 2.77	<u>34.8 ± 0.37</u> 30.4-36.7; 1.51	<u>38.6 ± 0.57</u> 33.2-43.5; 2.57	<u>37.0 ± 0.48</u> 30.7-42.4; 2.94	<u>30.7 ± 0.27</u> 25.6-36.3; 2.20	<u>39.5 ± 0.50</u> 37.3-42.1; 1.86	<u>51.1 ± 0.60</u> 44.4-59.8; 3.21
io	<u>14.4 ± 0.29</u> 12.1-17.2; 1.38	<u>17.3 ± 0.29</u> 15.6-19.4; 1.09	<u>9.4 ± 0.34</u> 6.7-13.2; 1.39	<u>14.1 ± 0.31</u> 12.1-17.7; 1.41	<u>13.0 ± 0.27</u> 8.5-15.9; 1.66	<u>17.0 ± 0.14</u> 14.4-19.7; 1.14	<u>20.4 ± 0.45</u> 18.2-24.4; 1.67	<u>36.7 ± 0.41</u> 29.0-41.0; 2.21
lmx	<u>35.8 ± 0.32</u> 33.2-38.6; 1.49	<u>35.1 ± 0.52</u> 30.6-38.8; 1.94	<u>42.6 ± 0.44</u> 39.0-47.0; 1.81	<u>37.5 ± 0.26</u> 34.2-39.7; 1.17	<u>36.3 ± 0.23</u> 33.0-39.0; 1.44	<u>38.3 ± 0.18</u> 34.8-41.3; 1.47	<u>41.9 ± 0.95</u> 35.7-47.4; 3.55	<u>11.5 ± 0.28</u> 8.9-15.1; 1.48
lmd	<u>46.4 ± 0.31</u> 43.5-49.3; 1.47	<u>46.4 ± 0.39</u> 43.0-49.3; 1.45	<u>48.7 ± 0.38</u> 46.4-52.0; 1.59	<u>48.2 ± 0.42</u> 43.3-51.1; 1.87	<u>48.0 ± 0.26</u> 43.0-51.2; 1.62	<u>49.2 ± 0.29</u> 38.8-54.6; 2.39	<u>49.2 ± 0.59</u> 45.2-52.4; 2.19	<u>42.3 ± 0.33</u> 38.9-46.1; 1.78

Note: Above the line – mean value and its error; under the line – limits of variation of character and mean square deviation.

Table 2. Differences in the morphometric characters of species of the genus *Asprocottus* reaching a taxonomically significant level (CD > 1.28)

	<i>A. herzensteini</i>	<i>A. abyssalis</i>	<i>A. intermedius</i>	<i>A. korjakovi</i>	<i>A. minor</i>	<i>A. parmiferus</i>	<i>A. platycephalus</i>
<i>A. abyssalis</i>	<i>P</i>						
<i>A. intermedius</i>	<i>P, A, l.io, lpc, hD₂ *IA, *hA, io, *lmx</i>	<i>D₂ A, lL, *lpc, hD₁ lA, hA, IV, *io, *lmx</i>					
<i>A. korjakovi</i>	<i>P, lpc</i>	<i>A, l.t, *lpc, *o, io</i>	<i>P, l.t, lD₂ io, lmx</i>				
<i>A. minor</i>	<i>D₂, Lso., l.io.</i>	<i>l.t, lpc, io</i>	<i>l.so., l.t., l.L, c, hA, lmx</i>				
<i>A. parmiferus</i>	<i>l.so., l.io. l.pm., c, H, *aD₁, *io</i>	<i>c, H, *aD, lpc</i>	<i>l.so., l.pm., *l.L, *c, H, *hA, *io</i>	<i>l.io. l.pm., *io</i>	<i>*io</i>		
<i>A. platycephalus</i>	<i>P, l.so., l.io, l.pm., lpc, lA</i>	<i>A, l.pm., *pl, lA, lV, *o, cH</i>	<i>l.so., l.oc., l.pm., l.L, *io, lmx</i>	<i>l.io, l.pm., cH, ch</i>	<i>o, io</i>	<i>H, lP, cH, *ch</i>	
<i>A. pulcher</i>	<i>lP, lD, *lmx</i>	<i>D₂ aV, lpc, o, *io, *lmx</i>	<i>c, lA, lV</i>	<i>l.t., lmx</i>	<i>l.t., l.L, lmx</i>	<i>l.io., l.pm., *io</i>	<i>l.io, l.pm., lP, ch, io</i>

Note: * - characters for which there is hiatus.

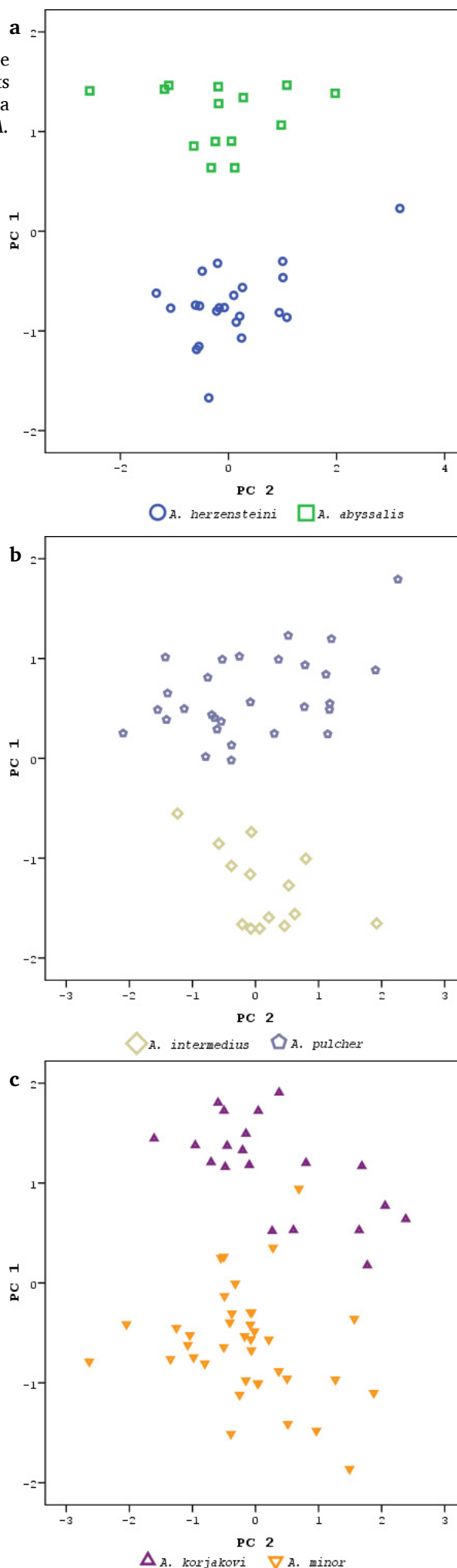
Fig. 2. Distribution of species of genus *Asprocottus* in the space of a first (PC1) and second (PC2) principals components by meristic and plastic characters in pairwise comparison: a – *A. herzensteini* and *A. abyssalis*; b – *A. intermedius* and *A. pulcher*; c – *A. korjakovi* and *A. minor*

Therefore, the genus *Asprocottus* includes seven valid species, *A. herzensteini*, *A. abyssalis*, *A. intermedius*, *A. korjakovi*, *A. parmiferus*, *A. platycephalus*, and *A. pulcher*, that are characterized by the following features.

Asprocottus herzensteini: (Fig 3a, 4a); D_1 6–7; D_2 13–16; P 15–17; VI 3; A 12–15; *sp.br.* 5–8, *l.so.* 9–12, *l.io.* 17–22, *l.t.* 2–4, *Loc.* 1–3, *Lpm.* 19–25, *ll.* 34–50. Body oblong. Back slightly raised above the nape. Dorsal fins separated by a small gap. Pelvic fins short, approximately half the distance to the anus. Head moderately flattened. Eyes large, oval, occupy all or most of the orbit. Interorbital distance narrow, two-three times less than the diameter of the eye. Well-defined crests on the infraorbital and frontal bones are. Four well-developed spines on *preoperculum*. Neuromasts of the sensory lines of the head are located on high papillae. Papillae of the truncal lines short. As a rule, there is one additional row above the lateral line. In addition, separate neuromasts may be located above or below the main row. Body completely covered with needle-shaped spinelets not aggregated into plates. Coloration pale yellow of grey; juveniles are pale yellow or pink. The upper part of the body and head darker; belly and fins lighter.

Asprocottus abyssalis: (Fig 3b, 4b); D_1 5–8; D_2 13–16; P 13–16; VI 3; A 12–14; *sp.br.* 6–8, *l.so.* 8–12, *l.io.* 14–20, *l.t.* 4–6, *Loc.* 1–4 (or absent), *Lpm.* 18–23, *ll.* 31–46. Body oblong. Back slightly raised above the nape. Dorsal fins separated by a small gap. Pelvic fins short, approximately half the distance to the anus. Head moderately flattened. Eyes large, oval, occupy all or most of the orbit. Interorbital distance narrow, two-three times less than the diameter of the eye. Crests on the infraorbital and front bones are not defined. Two well-developed spines on *preoperculum*. Neuromasts of the sensory lines are located on high papillae. Papillae of the truncal lines short. As a rule, there is one additional row above the lateral line. In addition, separate neuromasts may be located above or below the main row. Body completely covered with needle-shaped spinelets not aggregated into plates. Coloration pale yellow or pink. The upper part of the body and head darker; belly and fins are lighter.

Asprocottus intermedius: (Fig 3c, 4c); D_1 5–7; D_2 15–17; P 13–17; VI 3; A 14–17; *sp.br.* 4–7, *l.so.* 9–12, *l.io.* 14–18, *l.t.* 6–6, *Loc.* 1–3, *Lpm.* 19–26, *ll.* 42–61. Body oblong. Back slightly raised above the nape. Dorsal fins separated by a small gap. Pelvic fins short, approximately half the distance to the anus. Head flattened. Eyes large, oval, occupy the entire orbit. Interorbital distance narrow, two-tree times less than the diameter of the eye. Infraorbital and front bones have crests. Neuromasts of the sensory and truncal lines are located on short papillae. As a rule, there is one additional row above the lateral line. In addition, separate neuromasts



may be located above or below the main row, which are rudiments of the second and third additional rows. Spinelets on the body rudimentary, separately seated or accreted into the plates. They are located behind the nape and at the base of dorsal and anal fins. The separately located spinelets can be also found on the sides. The upper part of the body and head pale yellow or grey. Belly and fins light.

Asprocottus korjakovi: (Fig 3d, 4d); D_1 3–7; D_2 13–17; P 13–16; VI 3; A 13–16; *sp.br.* 4–7, *l.so.* 6–12, *l.io.* 14–20, *l.t.* 1–5, *loc.* 1–3, *l.pm.* 16–24, *l.l.* 31–48. Body short. Back raised above the nape. Dorsal fins separated by a small gap. Pelvic fins short, approximately half the distance to the anus. Head large, moderately flattened. Eyes round, of medium size, occupy the entire orbit. Interorbital distance narrow, twice less than the diameter of the eye. Well-defined crests on the infraorbital and front bones. Neuromasts of the sensory lines of the head are located on high papillae. Papillae of the truncal lines short. As a rule, there is one additional row above the lateral line. In addition, separate neuromasts may be located above or below the main row. The body completely covered with spinelets accreted into bony plates on the back and nape. The upper part of the body and head pale yellow or grey, with dark spots on the sides. The belly and fins light.

Asprocottus parmiferus: (Fig 3e, 4e); D_1 4–7; D_2 13–16; P 14–17; VI 3; A 12–15; *sp.br.* 4–6, *l.so.* 6–10, *l.io.* 11–19, *l.t.* 2–4, *loc.* 1–3, *l.pm.* 11–21, *l.l.* 20–40. Body short. Back raised above the nape. Dorsal fins separated by a small gap. Pelvic fins short, less than half the distance to the anus. Head large, slightly flattened. Eyes round, of medium size, occupy the entire orbit. Interorbital distance wide, approximately equal to the diameter of the eye. Crests on the infraorbital and front bones. Neuromasts of the sensory lines of the head are located on high papillae. Papillae on the body short. There is one additional row above the lateral line. Sides, back and nape completely covered with bony plates of accreted spinelets. The upper part of the body and head as well as fins are of red and brown colors. Sides, back and fins have numerous dark spots. Belly light.

Asprocottus platycephalus: (Fig 3f, 4f); D_1 4–7; D_2 13–17; P 13–15; VI 3; A 12–17; *sp.br.* 4–8, *l.so.* 6–10, *l.io.* 13–17, *l.t.* 2–4, *loc.* 1–2 (or absent), *l.pm.* 15–19, *l.l.* (30) 32–42. Body oblong. Back slightly raised over the nape. Dorsal fins separated by a small gap. Pelvic fins short, approximately half the distance to the anus. Head much

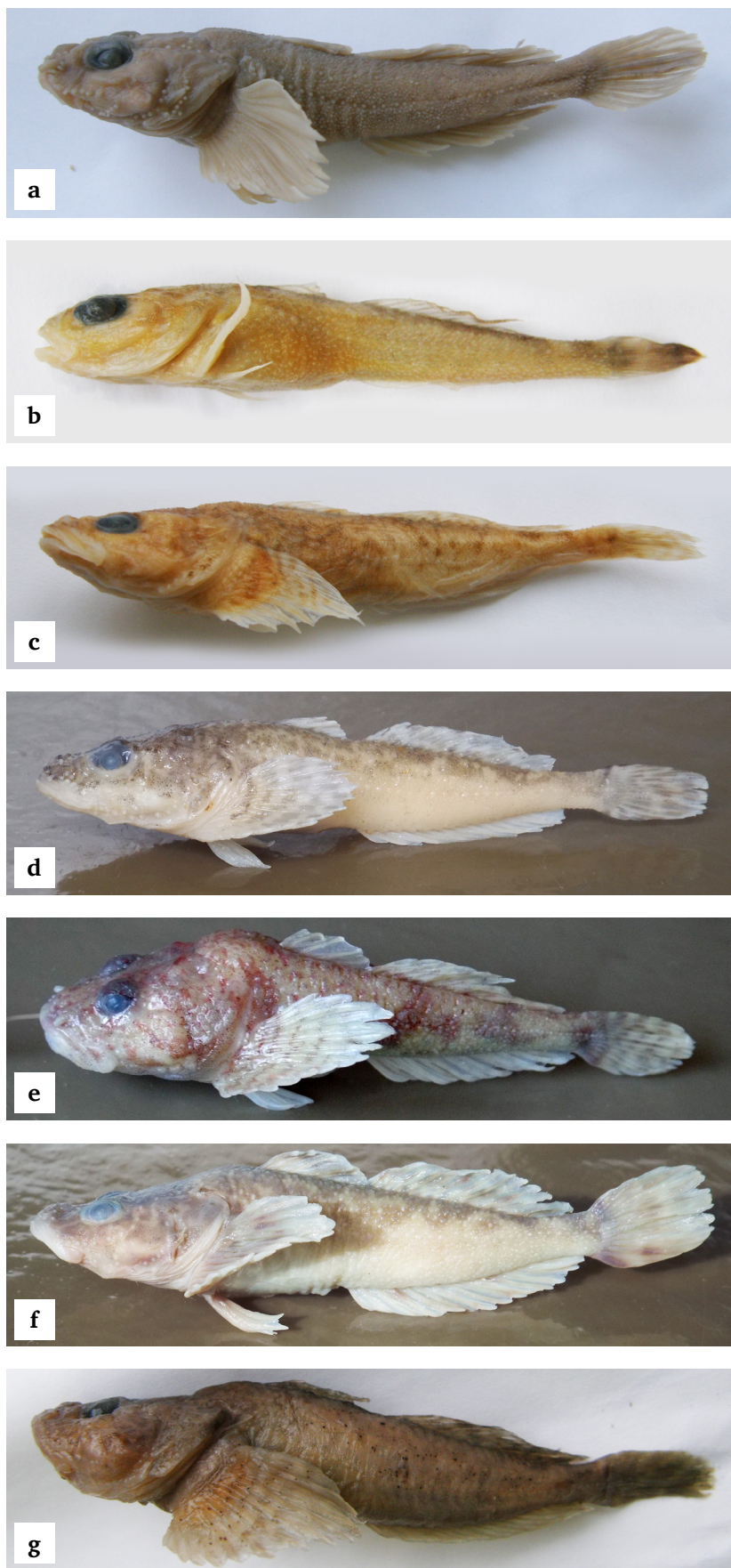


Fig. 3. The appearance (lateral) of sculpins of genus *Asprocottus*: a – *A. herzensteini*, b – *A. abyssalis*, c – *A. intermedius*, d – *A. korjakovi*, e – *A. parmiferus*, f – *A. platycephalus*, g – *A. pulcher*

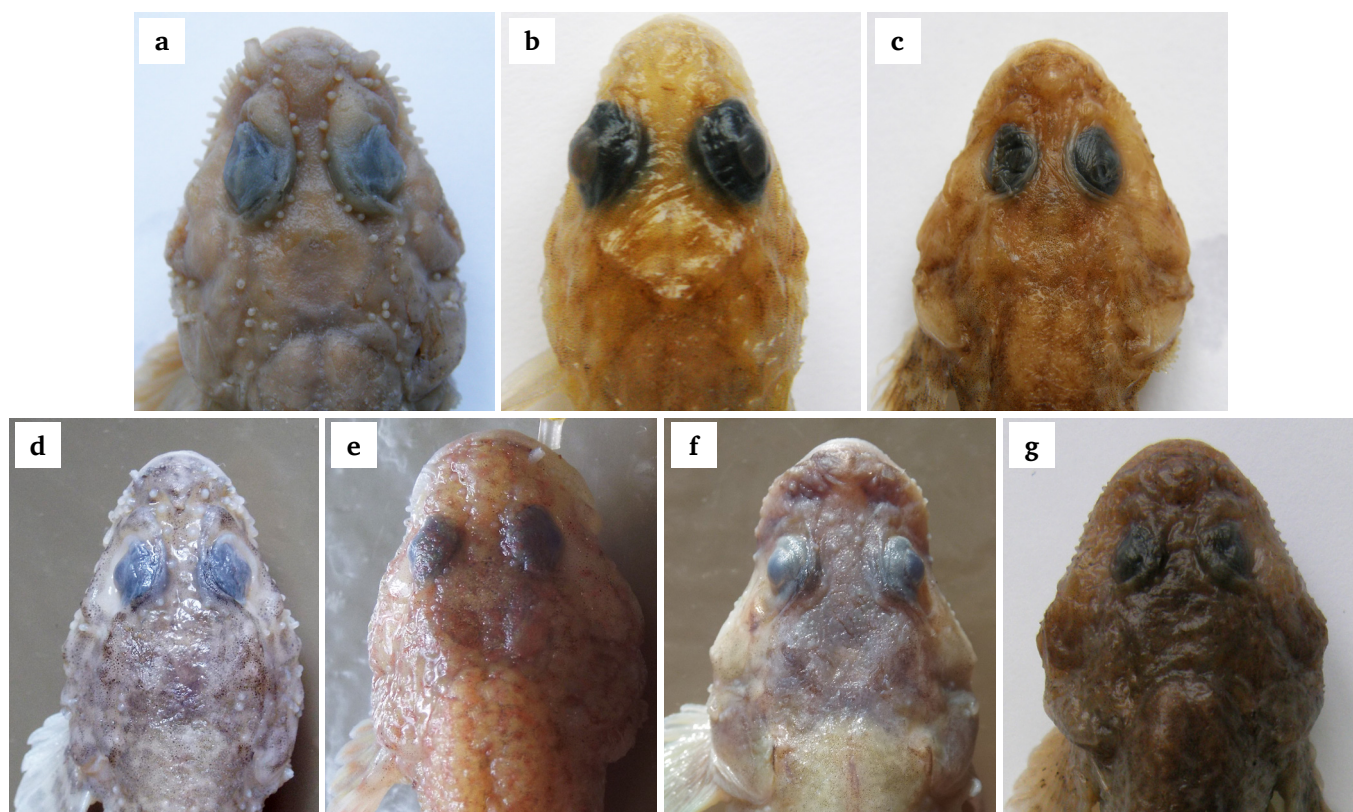


Fig. 4. The head appearance (dorsal) of sculpins of genus *Asprocottus*: a – *A. herzensteini*, b – *A. abyssalis*, c – *A. intermedius*, d – *A. korjakovi*, e – *A. parmiferus*, f – *A. platycephalus*, g – *A. pulcher*

flattened. Eyes round, small, substantially smaller than the orbit. Interorbital distance approximately equal to the diameter of the eye. Poorly defined crests on the infraorbital and front bones. Neuromasts of the sensory lines of the head and body are located on short papillae. On the body, as a rule, there is one additional row of the lateral line. In addition, separate neuromasts may be located above or below the main row, which are rudiments of the second and third additional rows. Body completely covered with small needle-shaped spinelets. The upper part of the body and head pale yellow or grey. Belly and fins light.

Asprocottus pulcher: (Fig 3g, 4g); D_1 5–7; D_2 15–17; P 14–16; VI 3; A 14–16; *sp.br.* 5–9, *l.so.* 8–12, *lio.* 15–20, *lt.* 4–6, *loc.* 1–3 (or absent), *lpm.* 17–26, *ll.* 32–67. Body short. Back behind the nape is sharply raised in the form of a hump. Dorsal fins adjoin or are separated by a small gap. Pelvic fins short, approximately half the distance to the anus. Head moderately flattened. Eyes large, oval, occupy all or most of the orbit. Interorbital distance narrow, twice smaller than the diameter of the eye. Poorly defined crests on the infraorbital and front bones. Neuromasts of the sensory lines of the head and body are located on short papillae. There are three additional rows on the body. Body is bare or looks like bare. Bony needle-shaped spinelets rudimentary, located at the base of the dorsal and pectoral fins. Coloration spotty. Belly light. Fins have rows of dark stripes.

4. Conclusion

Results of the study have confirmed the phenotypic isolation and diagnosability of seven species in the genus *Asprocottus*: *A. herzensteini*, *A. abyssalis*, *A. intermedius*, *A. korjakovi*, *A. parmiferus*, *A. platycephalus*, and *A. pulcher*. It seems appropriate to consider *A. minor* as a small form of *A. korjakovi*. Both, the external similarity and vicarious nature of these forms, indicate this fact. Revision of diagnostic features suggests the following key to determine the species:

1(10) Body is completely or partially covered with well-developed bony spinelets or plates. On the body, as a rule, there is one additional row of the lateral line. In addition, separate neuromasts can be located above or below the main row, which are rudiments of the second and third additional rows.

2(5) Spinelets are needle-shaped, not accreted by bases.

3(4) Head is moderately flattened; the size of the eye corresponds to the size of the orbit, and its diameter is approximately equal to the length of the snout and two-three times more than the interorbital distance.

Infraorbital and supraorbital crests are well developed. There are four well-developed spines on preoperculum: *A. herzensteini*

Infraorbital and supraorbital crests are not developed. There are two well-developed spines on preoperculum: *A. abyssalis*

4(3) Head is very flattened; eye is substantially less than the orbit, its diameter is less than the length

of the snout, and it is approximately equal to the inter-orbital distance: *A. platycephalus*

5(2) Spines are short with a thickened base, single or accreted into plates.

6(7) Body is completely covered with plates from the accreted spinelets: *A. parmiferus*

7(6) Plates are located only behind the nape and at the base of dorsal fins; the rest of the integument has singly located spines.

8(9) Spinelets are well developed and cover the whole body and the top of the head: *A. korjakovi*

9(8) Spinelets and bony plates are rudimentary, located mainly behind the nape and at the base of the dorsal and anal fins: *A. intermedius*

10(1) Bony spinelets are rudimentary, invisible with the naked eye, simple, needle-like, and located at the base of the dorsal and pectoral fins. There are three additional rows of the lateral line on the body: *A. pulcher*

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References

Berg L.S. 1906. Overview of Cataphracti (Fam. Cottidae, Cottocomphoridae and Comephoridae) of Lake Baikal. Zoologischer Anzeiger [Zoological Bulletin]. 30: 906–911. (in German)

Berg L.S. 1907. The Cataphracti of Lake Baikal (Fam. Cottidae, Cottocomphoridae and Comephoridae). Contributions to the osteology and systematics. In: Scientific results of the zoological expedition to Lake Baikal under the direction of professor Alexis Korotneff in 1900-1902. 3rd ed. St. Petersburg and Berlin, pp. 1–75. (in German)

Berg L.S. 1933. Freshwater fishes of the USSR and adjacent countries. V. 2. Leningrad: Academy of Sciences USSR Publ. (in Russian)

Berg L.S. 1949. Freshwater fishes of the USSR and adjacent countries. V. 3. Moscow, Leningrad: Academy of Sciences USSR Publ. (in Russian)

Bogutskaya N.G., Naseka A.M. 2004. Catalogue of agnathans and fishes of fresh and brackish waters of Russia with comments on nomenclature and taxonomy. Moscow: KMK Scientific Press Ltd. (in Russian)

Catalog of fishes: genera, species, references. 2018. In: Fricke R., Eschmeyer W. N., van der Laan R. (Eds.). [<http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp>]

International code of zoological nomenclature: fourth edition. 1999. In: Ride W.D.L., Cogger H.G., Dupuis C. et al. (Eds.). [<http://www.iczn.org/iczn/index.jsp>]

Mayr E. 1969. Principles of systematic zoology. New York: McGraw-Hill.

Plokhinskiy N.A. 1980. Biometric algorithms. Moscow: Moscow University Press. (in Russian)

Sideleva V.G. 1982. Sensory systems and ecology of the Baikal sculpins (Cottoidei). Novosibirsk: Nauka. (in Russian)

Sideleva V.G. 2001. List of fishes from Lake Baikal with descriptions of new taxa of cottoid fishes. Proceedings of the Zoological Institute 287: 45–79.

Sideleva V.G. 2003. The endemic fishes of Lake Baikal. Leiden: Backhuys Publishers.

Taliev D.N. 1955. Sculpin fishes of Lake Baikal (Cottoidei). Moscow, Leningrad: Nauka. (in Russian)