Iranian Journal of Animal Biosystematics (IJAB)
Vol.17, No.2, 102-114, 2021
DOI: 10.22067/ijab.2021.63432.0

IJAB
ISSN: 1735-434X (print); 2423-4222 (online)

RESEARCH ARTICLE Open access

Morphometric variations in the genus *Chrotogonus* Serville, 1838 (Orthoptera: Pyrgomorphidae) from Sindh, Pakistan

Samiullah Soomro* and Riffat Sultana

Department of Zoology, University of Sindh, Jamshoro, Sindh-Pakistan

(Received: *14 April 2021*; Accepted: 6 *August 2021*)

Abstract
We studied inter and intra-specific morphometrical variability across six species/subspecies of *Chrotogonus* Serville, 1838 (Orthoptera: Pyrgomorphidae) consisting on *Chrotogonus homalodemus homalodemus* (Blanchard, 1836), *C. homalodemus* (Blanchard, 1836), *C. trachypterus trachypterus* (Blanchard, 1836), *C. trachypterus robertsi* Kirby, 1914, *C. trachypterus* (Blanchard, 1836), and *C. turanicus* Kuthy, 1905 from Sindh, Pakistan. The investigation was based on a comparative study of external morphological measurements of the six major body parts including: Antennal segments, length of head, length of pronotum, length of tegmina, length of wings, and total body length. Interspecific morphometric variation showed highest variation as 16.00 ± 04.33mm in the length of tegmina of *C. homalodemus* and lowest variation 01.98 ± 00.05mm in length of pronotum of *C. trachypterus robertsi* while intraspecific morphometric variation amongst females was highest than males. The species of *Chrotogonus* are closely similar and no satisfactory field characters exist by which may be distinguished. This study will fill the specific identification gap amongst this taxon.

Key words: *Chrotogonus*, interspecific, intraspecific, variations, dimorphism.

INTRODUCTION

Members of family Pyrgomorphidae, the shorthorned grasshoppers, show great morphological diversity between genera and species (COPR 1982). In this family genus *Chrotogonus* Serville, 1838 is readily recognized by its squat shape, brown, earthy coloration and dull appearance, strongly rugose integument and extremely slant-faced head. Its species are closely similar with each other (Meena, 2020), so, it was very essential to carry its morphometric analysis which is useful tool for the separation and identification of many groups of insects (Daly, 1985; Baylac et al., 2003; Azrizal et al., 2016). Morphometric techniques have been used to assist quantitative measurement and analysis of morphological variation in size and shape of the organisms such as: (Kundu & Mathur, 1963; Chohan, 1960; Digo et al., 2015; Jat et al., 2007; Samejo & Riffat, 2019; Raghavender & Vastrad, 2017; Riffat et al., 2020). Morphometric characters also represent one of the major keys for determining systematic and growth variability (Kovac et al., 1999). The morphological shape and size of the body and wing of insects comprehensively studied to clarify the relationship between closely related taxa and to help in identifying population within and between species of insects (Riva et al., 2001; Villegas et al., 2002; Aytekin et al., 2007; Tuzun, 2009; Riffat et al., 2019). It is reported that the variation in body size is an element of natural populations and has vital

Corresponding Author: samiqau373@gmail.com
©2021 FERDOWSI UNIVERSITY OF MASHHAD, IRAN

THIS WORK IS LICENSED UNDER A CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENSE.

implications for the understanding of the population dynamics and stability of ecological systems (Roonwal, 1981; Filin & Ovadia, 2007). A number of other studies have reported the use of morphometry on Acridoidea for the description of new species using a low number of specimens (Blackith & Albrecht, 1960; Descamps, 1977; Chapman et al., 1977; Amedegnato & Descamps, 1978; Amedegnato & Descamps, 1979; Ademolu & Idown, 2013; Tajamul & Ahmad, 2016; Tabikha & Adss, 2017). Little is known about morphometric variation in the *Chrotogonus*, therefore this study is designed to determine the difference in various body parts of this group in order to recognize it as correct taxon. It was assumed that increasing wing length and body size are indicative increasing dispersal and reproductive capability respectively. During this study significant variations were noticed.

MATERIAL AND METHODS

Field work

During present study a total of 570 mature *Chrotogonus* Serville, 1838 were collected from Sindh, Pakistan. Sample collections were done using random sampling technique based on Guibord, 1969; Riffat & Wagan, 2015. Collected specimens were narcotized with menthol (naphthalene) crystals. All samples deposited in the Entomology and Bio-Control Research Lab, Department of Zoology, University of Sindh, Pakistan.

Morphometric analysis of samples

Morphometric analysis was based on six parameters including length of antennal (LA) and total number of segments (present in an antennae), length of head (LH) (the distance from fastigium of vertex to the posterior end of head), length of pronotum (LP) (the distance from the anterior end to the posterior end of the pronotum, measured along the medial pronotal carina), length of tegmina (LT) (the distance from the base of radius and media to the apex of the tegmina), length of wing (LW) (The distance from axial region to the apex of the wing) and total body length (TBL) (the distance from front of head to terminal region of abdomen) (Figure 1).

Data Analysis

Measurements were arranged in tabular form. Charts Excel (MS Office 2007) has been used to show the variation. Standard deviation error bar charts have been made. To calculate the average of measured values (mm) of different body parameters of different species mean (μ) formula has been applied:

$\mu = \frac{\sum x}{N}$ and the amount of dispersion of values of mean (μ) was calculated by:

$$\sigma = \sqrt{\frac{\sum (x - \mu)^2}{N}}$$

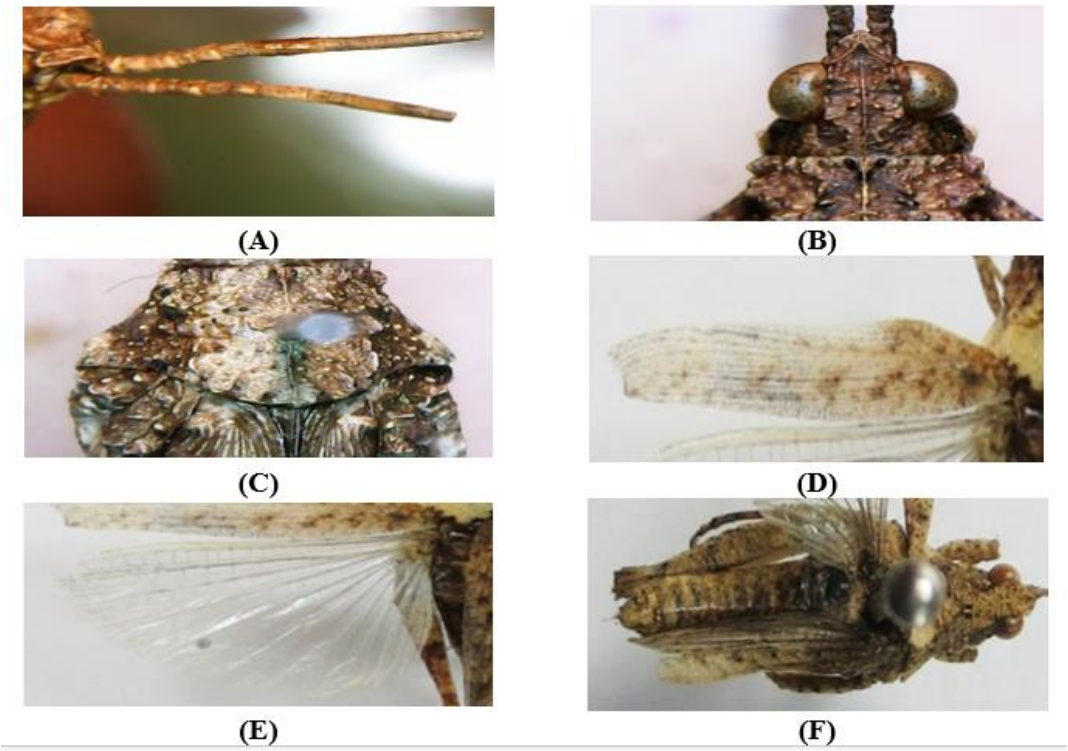

FIGURE 1. Morphometric analysis of various body parts. A) Length of antenna: Total number of segments present in an antenna B) Length of head: The distance from fastigium of vertex to the posterior end of head C) Length of pronotum: The distance from the anterior end to the posterior end of the pronotum, measured along the medial pronotal carina D) Length of tegmina: the distance from the base of radius and media to the apex of the tegmina E) Length of wing: The distance from axial region to the apex of the wing F) Total body length: The distance from front of head to terminal region of abdomen.

RESULTS

These characters were measured in six *Chrotogonus* species consisting: *C. homalodemus homalodemus*, *C. homalodemus*, *C. trachypterus trachypterus*, *C. trachypterus robertsi*, *C. trachypterus*, and *C. turanicus* (Figure 2).

Interspecific variation analyses

Morphometric variations of different body parts were calculated and mean values with standard deviations has shown in Table 1 and 2. Mean and standard deviations of 10 females and 10 males of each species were taken and numbers of antennal segments were also counted. The highest numbers of antennal segments were counted 16 in each antenna of *C. homalodemus homalodemus* and *C. homalodemus* and lowest number of antennal segments were counted 12 in each antenna of *C. turanicus* while *C. trachypterus trachypterus, C. trachypterus robertsi* and *C. trachypterus* shows 13 antennal segments in each antenna. Length of head: *C. turanicus* showed the highest variation 01.86±00.66mm in size of LH whereas *C. trachypterus robertsi* showed the lowest variation 01.77±00.07mm in size of LH. Length of pronotum: *C. homalodemus homalodemus* showed the highest variation 01.82±00.51mm in size of pronotum although *C. trachypterus robertsi* showed the lowest variation 01.98±00.05mm in size of LP. Length of tegmina: *C. homalodemus* showed the highest variation 16.00±04.33mm in size of LT while in *C. trachypterus robertsi* it was lowest 09.23± 00.12mm in size of LT. Length of Wing: *C. homalodemus homalodemus* showed the highest variation

14.60 ± 03.28mm in size of LW whereas *C. trachypterus robertsi* showed the lowest variation 11.62±00.10mm in size of LW. Total body length: *C. turanicus* showed the highest variation 15.50±02.11mm in size of body whereas *C. trachypterus* showed the lowest variation 14.10 ± 00.59mm in size of body Table 1 and 2.

Intraspecific variation analyses

Among members of same species of both sexes, comparative morphometric statistical analysis of various body parameters has been observed in Figure 3 and 4.

***Chrotogonus homalodemus homalodemus* (♂♀)**: Length of head (00.91±00.19 ♂; 01.26±00.19 ♀) in both sex analyzed as have discrete mean value and identical variability. ♀ has greater mean value than ♂ whereas variability was analyzed in ♂ and ♀ indistinguishable. Length of pronotum (01.40±00.17 ♂; 01.82±00.51 ♀) in both sexes analyzed as have discrete mean value as well as variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating pronotum as distinguishable characteristic. Length of tegmina (15.60±01.14 ♂; 16.15±03.46 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating tegmina as distinguishable characteristic. Length of wings (14.60±01.14 ♂; 14.60±03.28 ♀) in both sexes analyzed as have identical mean value and discrete variability. ♀ has greater variability than ♂ whereas mean value was analyzed in ♂ and ♀ indistinguishable. Total body length (17.30±00.83 ♂; 20.60±01.14 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating body length as distinguishable characteristic (Fig. 3a-b).

***Chrotogonus homalodemus* (♂♀)**: Length of head (00.93±00.21 ♂; 01.43±00.20 ♀) in both sex analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value than ♂ whereas variability recorded as minutely smaller in ♀ as compared to ♂. Length of pronotum (01.44±00.12 ♂; 01.85±00.49 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating pronotum as distinguishable characteristic. Length of tegmina (16.06±01.17 ♂; 16.00± 04.33 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has minutely smaller mean value than ♂ whereas variability recorded as greater in ♀ as compared to ♂. Length of wing (14.60±01.22 ♂; 14.66±03.04 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has minutely greater mean value whereas variability significantly greater in ♀ as compared to ♂. Total body length (18.22±00.91 ♂; 21.71±01.03 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ indicating body length as distinguishable characteristic (Fig. 3c-d).

***Chrotogonus trachypterus trachypterus* (♂♀)**: Length of head (02.06±00.08 ♂; 02.41±00.31 ♀) in both sex analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating head as distinguishable characteristic. Length of pronotum (02.62±00.17 ♂; 03.67±00.17 ♀) in both sexes analyzed as have discrete mean value and identical variability. ♀ has greater mean value than ♂ whereas variability was analyzed in ♂ and ♀ indistinguishable. Length of tegmina (12.40±00.54 ♂; 16.90±01.34 ♀) in

both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating tegmina as distinguishable characteristic. Length of wing (11.40±00.54 ♂; 16.00±01.41 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating wing as distinguishable characteristic. Total body Length (14.00± 00.61 ♂; 20.40±01.51 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating body length as distinguishable characteristic (Fig. 3e-f).

***Chrotogonus trachypterus robertsi* (♂♀)**: Length of head (01.05±00.11 ♂; 01.77±00.07 ♀) in both sex analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value than ♂ whereas variability recorded as smaller in ♀ as compared to ♂. Length of pronotum (01.55±00.11 ♂; 01.98±00.05♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value than ♂ whereas variability recorded as smaller in ♀ as compared to ♂. Length of tegmina (09.23±00.12 ♂; 12.86±00.24 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value than ♂ whereas variability recorded as minutely smaller in ♂ as compared to ♀. Length of Wings (08.15± 00.11 ♂; 11.62±00.10 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value than ♂ whereas variability recorded as minutely smaller in ♀ as compared to ♂. Total body length (13.40±01.25 ♂; 17.30±01.72 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating body length as distinguishable characteristic (Fig. 4a-b).

***Chrotogonus trachypterus* (♂♀)**: Length of head (01.12±00.08 ♂; 01.92±00.31 ♀) in both sex analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating head as distinguishable characteristic. Length of pronotum (01.99±00.18 ♂; 02.07±00.18 ♀) in both sexes analyzed as have discrete mean value and identical variability. ♀ has greater mean value than ♂ whereas variability was analyzed in ♂ and ♀ indistinguishable. Length of tegmina (09.80±00.61 ♂; 12.90±01.34 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating tegmina as distinguishable characteristic. Length of Wings (09.01±00.49 ♂; 11.01±01.23 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating wing as distinguishable characteristic. Total body Length (14.10±00.59 ♂; 17.80±01.23 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating body length as distinguishable characteristic (Fig. 4c-d).

***Chrotogonus turanicus* (♂♀)**: Length of head (01.71±00.51 ♂; 01.86±00.66 ♀) in both sex analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating head as distinguishable characteristic. Length of pronotum (01.92±00.21 ♂; 02.39±00.44 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating pronotum as distinguishable characteristic. Length of tegmina (08.98±00.90 ♂; 09.54±01.12 ♀) in

both sexes analyzed as have discrete mean value and variability. It has been analyzed

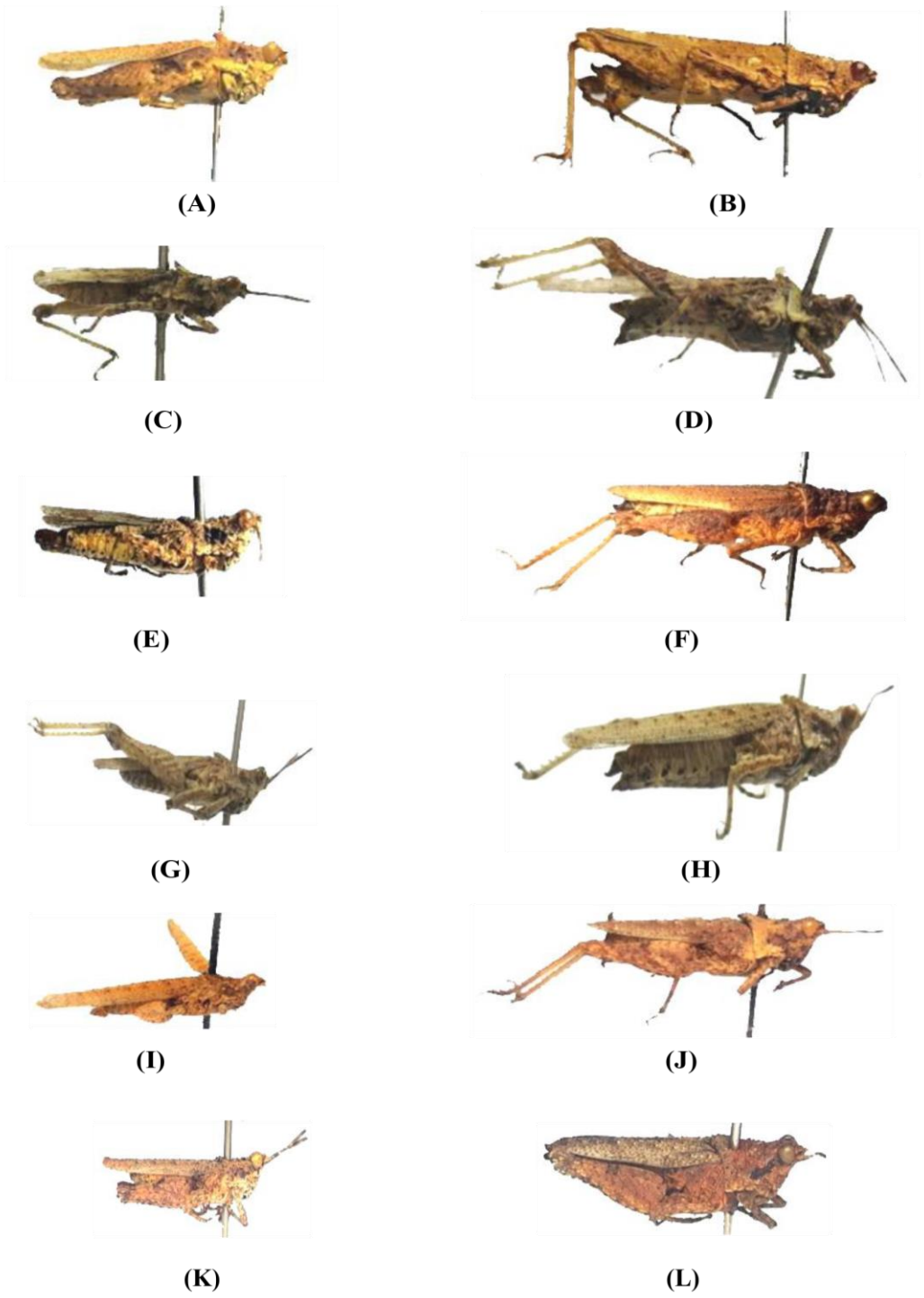

FIGURE 2. *C.* (*Chrotogonus*) *homalodemus* (A) ♂ (B) ♀, *C. (Chrotogonus) h. homalodemus* (C) ♂ (D) ♀, *C.* (*Chrotogonus*) *trachypterus robertsi* (E) ♂ (F) ♀, *C.* (*Chrotogonus*) *trachypterus trachypterus*

(G) ♂ (H) ♀, *Chrotogonus* (*Chrotogonus*) *trachypterus* (I) ♂ (J) ♀, *Chrotogonus* (*Chrotogonus*) *turanicus*: (K) ♂ (L) ♀

TABLE 1. Morphological trails and measurement (mm) for wild-caught 2019) *Chrotogonus* spp.

BP	Mean ± S.D (mm)					
	C. homalodemus homalodemus		*C. homalodemus*		*C. trachypterus trachypterus*	
	♂ (n=05)	♀ (n=05)	♂ (n=05)	♀ (n=05)	♂ (n=05)	♀ (n=05)
AS	16.00 ± 00.00	16.00 ± 00.00	16.60 ± 00.89	16.80 ± 00.83	13.00 ± 00.00	13.00 ± 00.00
LH	00.91 ± 00.19	01.26 ± 00.19	00.91 ± 00.19	01.26 ± 00.19	02.06 ± 00.08	02.41 ± 00.31
LP	01.40 ± 00.00	01.82 ± 00.51	01.40 ± 00.00	01.82 ± 00.51	02.62 ± 00.17	03.67 ± 00.17
LT	15.60 ± 01.14	16.00 ± 03.46	15.60 ± 01.14	16.00 ± 03.46	12.40 ± 00.54	16.90 ± 01.34
LW	14.60 ± 01.14	14.60 ± 03.28	14.60 ± 01.14	14.60 ± 03.28	11.40 ± 00.54	16.00 ± 01.41
TBL	17.30 ± 00.83	20.60 ± 01.14	17.30 ± 00.83	20.60 ± 01.14	14.00 ± 00.61	20.40 ± 01.51

TABLE 2. Morphological trails and measurement (mm) for wild-caught 2019) *Chrotogonus* spp.

BP	Mean ± S.D (mm)					
	C. trachypterus robertsi		*C. trachypterus*		*C. turanicus*	
	♂ (n=05)	♀ (n=05)	♂ (n=05)	♀ (n=05)	♂ (n=05)	♀ (n=05)
AS	13.00 ± 00.00	13.00 ± 00.00	13.00 ± 00.00	13.00 ± 00.00	12.00 ± 00.00	12.00 ± 00.00
LH	00.84 ± 00.09	01.24 ± 00.07	02.12 ± 00.08	02.41 ± 00.31	02.81 ± 00.51	03.17 ± 00.66
LP	10.30 ± 00.11	13.26 ± 00.05	02.52 ± 00.18	03.52 ± 00.18	03.22 ± 00.21	03.97 ± 00.44
LT	09.23 ± 00.12	12.86 ± 00.24	11.80 ± 00.61	15.90 ± 01.34	08.21 ± 00.90	09.24 ± 01.12
LW	07.15 ± 00.11	08.62 ± 00.10	11.01 ± 00.49	15.01 ± 01.23	07.19 ± 00.39	08.01 ± 01.52
TBL	13.00 ± 00.00	13.00 ± 00.00	13.50 ± 00.59	17.80 ± 01.23	12.70 ± 00.81	16.20 ± 02.11

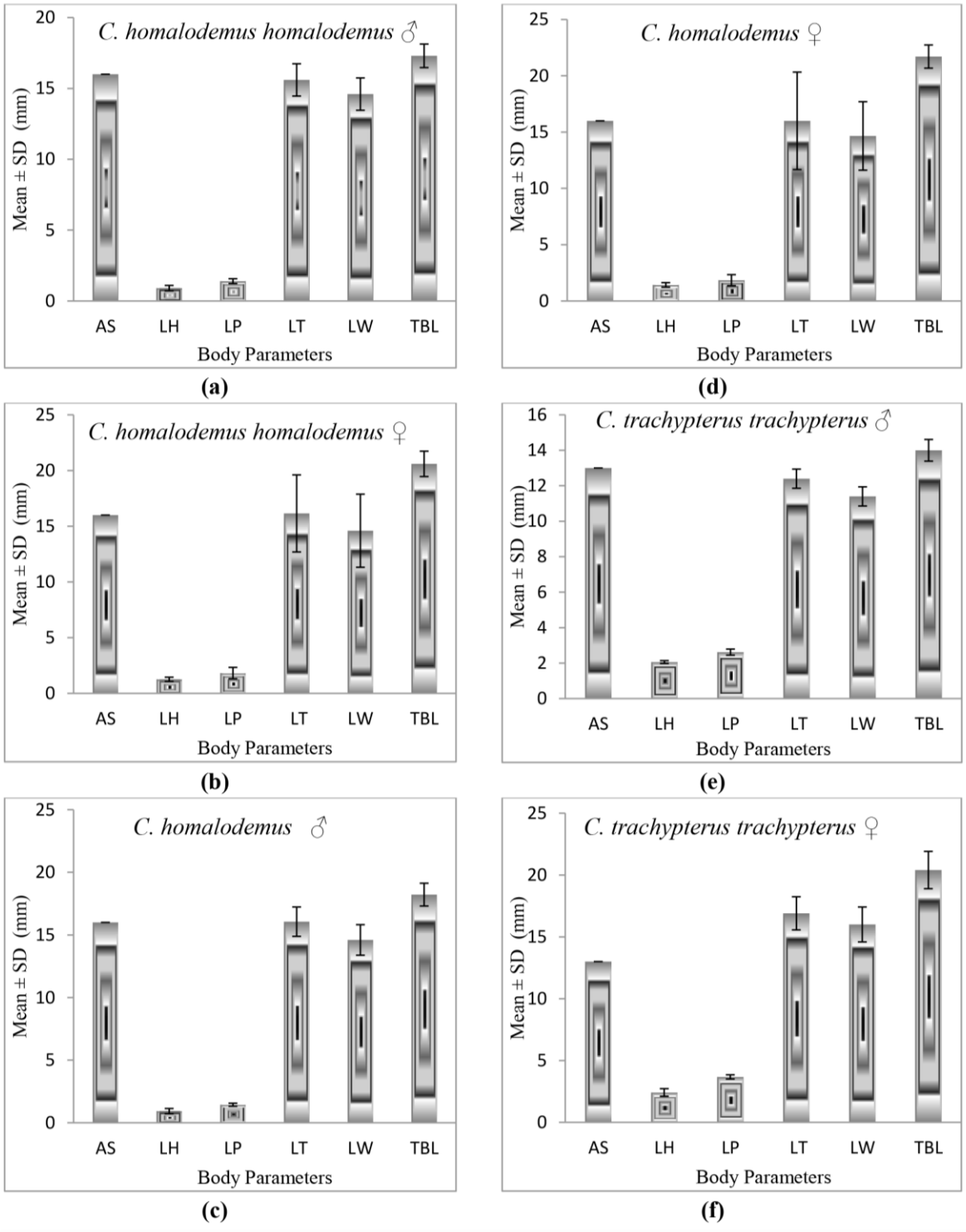

FIGURE 3. (a) *C. homalodemus homalodemus* ♂ (b) *C. homalodemus homalodemus* ♀ (c) C. *homalodemus* ♂ (d) *C. homalodemus* ♀ (e) *C. trachypterus trachypterus* ♂ (f) *C. trachypterus trachypterus* ♀.

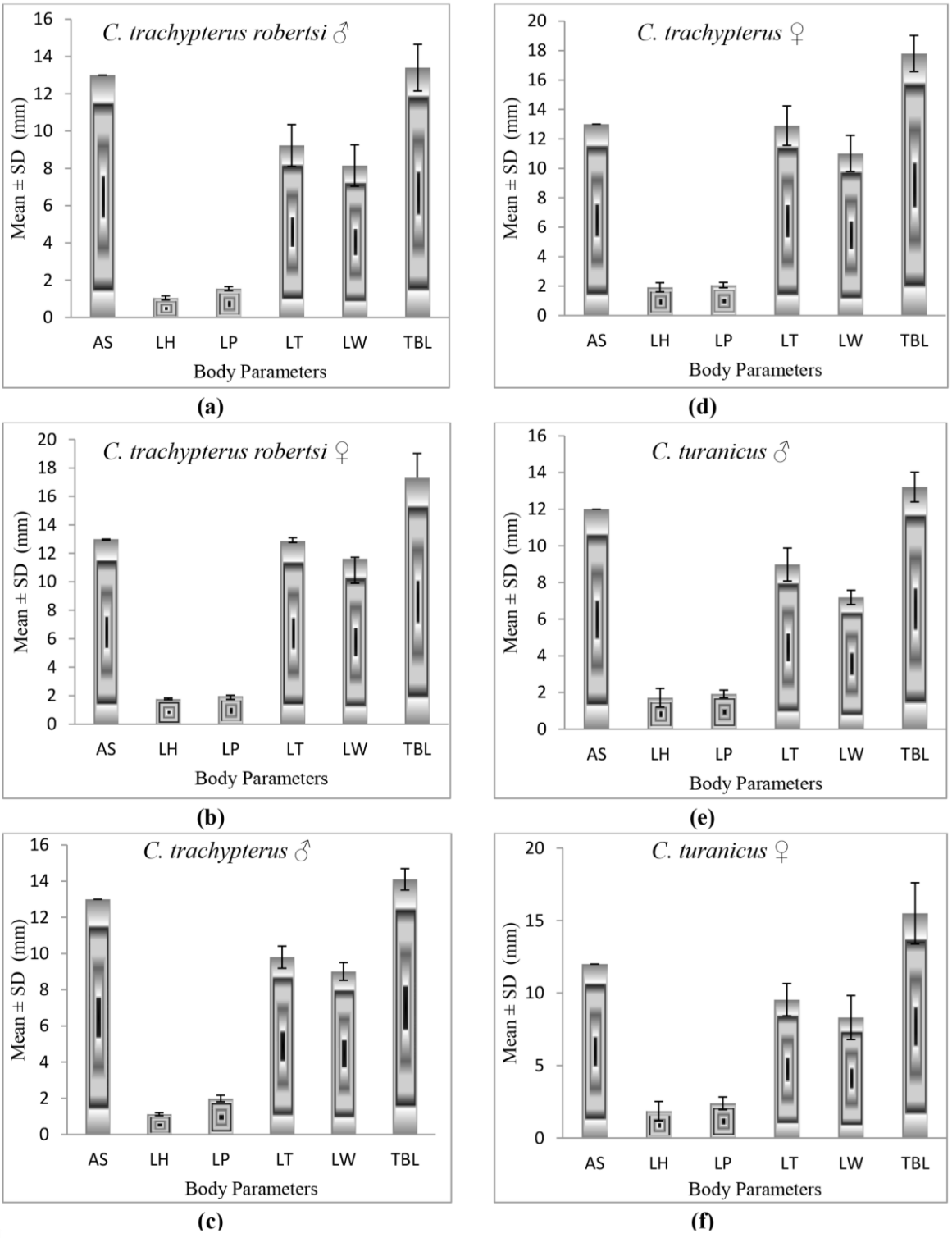

FIGURE 4. (a) *C. trachypterus robertsi* ♂ (b) *C. trachypterus roberstsi* ♀ (c) *C. trachypterus* ♂ (d) *C. trachypterus* ♀ (e) *C. turanicus* ♂ (f) *C. turanicus* ♀

that ♀ has greater mean value as well as variability than ♂ that indicating tegmina as distinguishable characteristic. Length of wings (07.19 ± 00.39 ♂; 08.31 ± 01.52 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating wing as distinguishable characteristic. Total body length (13.21 ± 00.81 ♂; 15.50 ± 02.11 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating body length as distinguishable characteristic (Fig. 4e-f).

DISCUSSION

Statistical analysis of the morphometry in the size of the different body parts of *Chrotogonus* species revealed significant differences in studied species. Significant highest variation was seen in the length of tegmina of *C. homalodemus* and lowest variation in length of pronotum of *C. trachypterus robertsi.* Present study suggests adult body size is affected by seasonality, temperature, and food availability. Food availability for primary consumers in food webs relies on plant primary production, which strongly depends on precipitation regimens (Gibert, 2019). Other studies recommend that changes in phenotipic characters and food web connectance may decrease in the number of trophic levels and impacts on feeding interactions respectively (Brose, 2012; Petchey, 2010). Bai et al. (2016) carried work on geometric morphometric differences in wing shape and size of *Trilophidia annulata* among 39 geographical populations in China and suggested that the size of the forewing and hind-wing were significantly different among populations; the shape of the forewing among populations can be divided into geographical groups, however hind-wing shape are geographical overlapped, and populations cannot be divided into geographical groups. During this study we have found that total body length of *C. trachypterus robertsi* female indicated the largest and Length of pronotum of *C. trachypterus robertsi* ♀ smallest morphometric variation in different specimens of both sexes of the same species. Length of tegmina of *C. trachypterus* female indicated the largest and Length of pronotum of *C. trachypterus* male smallest morphometric variation in different specimens of both sexes of the same species. Total body length of *C. turanicus* female indicated the largest and Length of pronotum of *C. turanicus* male smallest morphometric variation in different specimens of both sexes of the same species. Body size testified by Whitman (2008) relates to many aspects of an organism's biology, such as local adaptations to different climatic conditions, female fecundity and male mating success. Present study also agreed with Whitman (2008) observation. However, Yom-Tov & Geffen (2006) and Brandt & Navas (2011) described that morphology of *C. aquaticum* varies with sex, geography, host plant, and isolation. Sex interacts with geography and with host plant to influence body size. The sub-species *C. h. somalicus* Kevan 1959 the only one overlapping *C. hemipterus* or *C. senegalensis* in distribution usually has lightly infuscate hind wings and tegmina at least as long as the femora. The nominate sub-species over most of its range does not overlap other species and always has clear hind wings. *Chrotogonus trachypterus* distinguished from other *Chrotogonus* species which it overlaps in central and E. India by the wings being always developed and longer than the hind femur and the hind wing hyaline of fecintly tinged yellow.

The present finding provides morphometrical evidences for phenotypic interspecific and intraspecific variation among *Chrotogonus* species. Quantitative analysis of wing variation/ body length in grasshoppers can help us to understand how environmental heterogeneity affects the phenotypic patterns of insects. Nevertheless, further studies are needed to answers the following questions: (1) how do the size and shape of wings change in *Chrotogonus*, (2) does the morphological variation of *Chrotogonus* along an environmental gradient meet certain eco-geographical rules; and (3) which environmental factors may contribute to the variations in wings would be study in detail. This study has significant valued to differentiate the various pest species of *Chrotogonus.* It may inflict damage on cotton, frequently causing such heavy damage to seedling

that the crop has to be resown (Pruthi 1969). Many of the records of damage to other plants recorded below refer to attack on seedling or young plants, attack on older plants being less common or less important. In field trails, cowpea was found to be very susceptible, cluster bean almost as much, and pearl (bulrush) millet not attacked.

ACKNOWLEDGMENT
We are indebted to Higher Education Commission, Islamabad, Pakistan for funding Project No. 6737 SINDH /NRPU /R&D/ HEC.

LITERATURE CITED

Ademolu, K.O., Idowu A.B., 2013. Life cycle and Morphometric studies of variegated grasshopper *Zonocerus variegates* (Linnaeus, 1758). Munis Entomology & Zoology 8, 375-381.

Amedegnato, C., Descamps, M., 1978. Diagnoses et signalisations d'acridiens neotropicaux (Orth., Acridoidea). Acrida 7, 29-53.

Amedegnato, C., Descamps, M., 1979. Diagnoses generiques et affinittes phyletiques d'acridoidea neotropicaux recoltes por le Dr. Campos Seabra et. Descamps M. (Orthoptera*).* Annales de la Societe Entomologique de France 15, 423- 487.

Aytekin, M.A., Terzo, M., Rasmont, P., Çağatay, N., 2007. Landmark based geometric morphometric analysis of wing shape in *Sibirico bombus* Vogt (Hymenoptera: Apidae: *Bombus* Latreille). Annales de la Société Entomologique de France (n.s.) 43, 95-102.

Azrizal, W.N., Sofian, A.M., Rizman, I.M., 2016. The significance of wing and body morphometry in discriminating six species of *Eurema* butterflies (Lepidoptera: Pieridae) of peninsular Malaysia. Sains Malaysiana 45, 1413–1422.

Bai, Y., Dong, J.J., Guan, D.L., Xie, J.Y., Xu, S.Q., 2016. Geographic variation in wing size and shape of the grasshopper *Trilophidia annulata* (Orthoptera: Oedipodidae): morphological trait variations follow an ecogeographical rule. Scientific Report 6(1), 1–15. DOI: https://doi.org/10.1038/srep32680

Baylac, M., Villemant, C., Simbolotti, G., 2003. Combining geometric morphometric with pattern recognition for the investigation of species complexes. Biological Journal of Linnean Society 80, 89–98.

Blackith, R.E., Albrecht, F.D., 1960. Quelques nouvelles techniques utilisables en analyse morphométrique chez les Acridiens; I nouveaux appareils de mesure des petites dimensions. Bulletin de la Société Entomologique de France 65: 257-260

Brandt, R., Navas, C.A., 2011. Life-history evolution on tropidurinae lizards: Influence of lineage, body size and climate. PLoS ONE 6(5), e20040. DOI: https://doi.org/10.1371/journal.pone.0020040.

Brose, U., Dunne, J.A., Montoya, J.M., Petchey, O.L., Schneider, F.D., Jacob, U., 2012. Climate change in size-structured ecosystems. Philosophical Transactions of the Royal Society B: Biological Sciences 367, 2903–12. DOI: https://doi.org/10.1098/rstb.2012.0232

Chapman, R.F., Cook, A.G., Mitchell, G.M., Page, W.W., 1977. Description and morphometrics of the nymphs of *Zonocerus variegatus* (Orthoptera: Pygomorphidae). Bulletin of entomological research 67, 422–437.

Chohan, M.S., 1960. Studies on hopper stages in *Aiolopus* and *Chrotogonus* grasshoppers. M.Sc. Thesis, Agri., Punjab University, Lahore (Pakistan).

Copr. 1982. The locust and grasshopper Agricultural Manual. Centre for oversea pest Research London Bull. De'I Institue foundation d' Afrique Noire 43: 275-410.

Daly, H.V., 1985. Insect morphometrics. Annual Review of Zoology 30, 415–438.

Descamps, M., 1977. M. Étude des écosystémes guyanais I – Eumastacoidea & Acridoidea dendrophiles (Orthoptera). Annales de la Société Entomologique de France 13: 193-236.

Digo, E.O., Abad, K.L.M., Guino, I.J.B., Samillano, L.K.C, Eduque, J.R.M., Torres, M.A.J., Requieron, E.A., 2015. Application of geometric morphometrics in the body shapes of flying fish (*Parexocoetus brachypterus*) in Maitum, Sarangani Province. Aquaculture, Aquarium, Conservation & Legislation, International Journal of the Bioflux Society 8, 1027–1030.

Filin, I., Ovadia, O., 2007. Individual size variation and population stability in a seasonal environment: a discrete-time model and its calibration using grasshoppers. The American Naturalist 170, 719–733.

Gibert, J.P., 2019. Temperature directly and indirectly infuences food web structure. Scientific Report 9(1), 1–8.DOI: https://doi.org/10.1038/s41598-019-41783-0

Guibord, M.O.C., 1969. A study of the immature stages of some grasshoppers (Orthoptera: Acriddoidea) in Quebec. Master Thesis, McGill University, Montreal, Canada.

Jat, S.L., Swaminathan, R., Lekha, 2007. Morphometric variations in the local populations of *Chrotogonus trachypterus* (Blanchard). International Journal of tropical Agriculture 25, 689–694.

Kevan, D.K.Mc.E., 1959. A study of genus *Chrotogonus* Audinet servile 1839 (Orthoptera: Acridoidea: Pyrgomorphidae) V. A. revisional monograph to the Chrotogoniai. Public. Cult. Coms. Diam. Angola 43, 11-299.

Kovac, V., Copp, G., Francis, M., 1999. Morphometry of the stone loach, *Barbatula barbatula*: Do mensural characters reflect the species' life history thresholds? Environmental Biology of Fishes 56, 105–115.

Kundu, H.L., Mathur, L.M.L., 1963. Morphometric studies on certain Acridids. Indian Journal of Entomology 25, 160–171.

Meena, S., Kumari, V., 2020. Deltamethrin induced histolopathogy in male reproductive organ of *Chrotogonus Trachypterus* Blanchard (Orthoptera; Acrididae). International Journal of Entomology Research 5(3), 195–206.

Petchey, O.L., Brose, U., Rall, B.C., 2010. Predicting the effects of temperature on food web connectance. Philosophical Transactions of the Royal Society B: Biological Sciences 365, 2081–2091.

DOI: https://doi.org/10.1098/rstb.2010.0011

Pruthi, H.S., 1969. Textbook on Agricultural Entomology, Indian Council of Agricultural Research, New Delhi, 977 pp.

Raghavender, B., Vastrad, A.S., 2017. Diversity of shorthorned grasshopper in five different ecosystems. Bulletin of Environment, Pharmacology and Life Sciences 6, 486–489.

Riffat, S., Wagan, M.S., 2015. Grasshoppers and locusts of Pakistan. Higher Education Commission, Islamabad, Pakistan, 1–180.

Riffat, S., Lal, M., Wagan, M.S., 2019. An Orthoptera of the district Umerkot Sindh. International Journal of Entomology Research 4(1), 65–68.

Riffat, S., Soomro, N., Kumar, S., Samejo, S.S., Samiullah, S., 2020. Comparative Study of Egg-pod Morphology in Two Genera of Oxyinae (Acrididae: Orthoptera). Pakistan Journal of Zoology 52(4), 1327–1332. DOI: https://dx.doi.org/10.17582/journal.pjz/20190523070550.

Riva, J.D.L., Pont, F.L., Ali, V., Matias, A., Mollinedo, S., Dujardin, J.P., 2001. Wing geometry as a tool for studying the *Lutzumyia longipalpis* (Diptera: Psychodidae) complex. Memorias do Instituto Oswaldo Cruz 96, 1089–1094.

Roonwal, M.L., 1981. Field bioecology and morphometry of some central Indian grasshoppers (Acridoidea), with notes on a swimming species (Tetrigoidea). Proceedings of the Zoological Society 32, 97–106.

Samejo, A.A., Riffat, S., 2019. Morphology of Immature Stages of *Schistocerca gregaria* with Special References to its Size Variations. Pakistan Journal of Zoology 51, 1221–1226.

Tabikha, R.M., Adss, I.A., 2017. Genetic and morphological variations among geographical populations of *Rhopalosiphum padi* (L.) (Hemiptera: Aphididae) in Egypt, using Rapd and Issr markers. Munis Entomology and Zoology 12, 263–276.

Tajamul, M., Ahmad, S.T., 2016. Life history statistics and comparative morphometric assessment of rice grasshopper, *Oxya japonica* (Orthoptera: Acrididae). International Journal of Pure and Applied Zoology 4, 92–98.

Tuzun, A., 2009. Significance of wing morphometry in distinguishing some of the Hymenoptera species. African Journal of Biotechnology 8, 3353–3363.

Villegas, J., Feliciangeli, M.D., Dujardin, J.P., 2002. Wing shape divergence between *Rhodnius prolixus* from Cojedes (Venezuela) and *Rhodnius robustus*from Merida (Venezuela). Infection, Genetics and Evolution 2, 121–128.

Whitman, D.W., 2008. The significance of body size in the Orthoptera: a review. Journal of Orthoptera Research 17, 117–134. DOI: https://doi.org/10.1665/1082-6467-17.2.117.

Yom-Tov, Y., Geffen, E., 2006. Geographic variation in body size: The effects of ambient temperature and precipitation. Oecologia 148, 213–218. DOI: https://doi.org/10.1007/s00442-006-0364-9

Iranian Journal of Animal Biosystematics (IJAB)
Vol.17, No.2, 115-129, 2021
DOI: 10.22067/ijab.2021.69752.1007

IJAB
ISSN: 1735-434X (print); 2423-4222 (online)

RESEARCH ARTICLE Open access

Systematics and distribution of the genus *Ablepharus* Fitzinger, 1823 (Sauria, Scincidae): A review

Rasoul Karamiani[1,*], Nasrullah Rastegar-Pouyani[1], and Eskandar Rastegar-Pouyani[2]

[1] *Department of Biology, Faculty of Science, Razi University, 6714967346 Kermanshah, Iran*
[2] *Department of Biology, Faculty of Science, Hakim Sabzevari University, Sabzevar, Iran*

(Received: *13 April 2021*; Accepted: 11 *December 2021*)

Abstract
A review of the Snake-eyed Skink *Ablepharus* Fitzinger, 1823 is presented. The specific character of *Ablepharus* involves a lack of movable eyelids, with the lower eyelid fused to the upper one, forming a transparent spectacle covering the eye. The genus *Ablepharus* occurs in southeastern Europe, southwest Asia, and Central Asian Republics (from the Mediterranean Sea coasts to northwest India), including 11 valid species: *A. anatolicus* Schmidtler, 1997, *A. bivittatus* (Ménétries, 1832), *A. budaki* Göçmen, Kumlutas & Tosunoglu, 1996, *A. chernovi* Darevsky, 1953, *A. darvazi* Eremchenko & Panfilov, 1990, *A. deserti* Strauch, 1868, *A. grayanus* (Stoliczka, 1872), *A. kitaibelii* Bibron & Bory St-Vincent, 1833, *A. lindbergi* Wettstein, 1960, *A. pannonicus* (Lichtenstein, 1823), and *A. rueppellii* (Gray, 1839). For identification of species of *Ablepharus*, we used additional scalation and molecular features, used anatomical survey (e.g. osteological and hemipenial characters), and species distribution models. Of the genus *Ablepharus*, *A. bivittatus*, *A. chernovi*, *A. grayanus*, and *A. pannonicus* occur in Iran.

Key words: *Ablepharus*, Scincidae, Systematics, Distribution, Iran.

INTRODUCTION

The family Scincidae Oppel (1811) encompasses more than 25% (1,579 species) of all living genera and species of lizards (Uetz et al., 2021) with a nearly worldwide distribution (Vitt and Caldwell, 2013). Based on morphological characteristics the family Scincidae consists of four subfamilies Acontinae, Feylininae, Lygosominae, and Scincinae (Greer, 1970), but based on molecular analysis it only includes three subfamilies Acontiinae, Scincinae, and Lygosominae (Pyron et al., 2013). According to main evidence from molecular phylogenies and morphological characters the Scincomorpha consist of nine families as follows: Acontidae (26 spp.), Ateuchosauridae (2 spp.) Egerniidae (58 spp.), Eugongylidae (418 spp.), Lygosomidae (52 spp.), Mabuyidae (190 spp.), Ristellidae (14 spp.), Sphenomorphidae (546 spp.), and Scincidae (273 spp.), but usually grouped in a single family, Scincidae (Hedges, 2014).

According to a molecular phylogenic study the genus *Ablepharus* is nested within Lygosominae and is the sister taxon of the central and East Asian *Asymblepharus* (Pyron et al., 2013). The genus *Ablepharus* Fitzinger, 1823 contains 11 valid species: *A. anatolicus* Schmidtler,

Corresponding Author: rasoul.karamiani@gmail.com
©2021 FERDOWSI UNIVERSITY OF MASHHAD, IRAN

THIS WORK IS LICENSED UNDER A CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENSE.

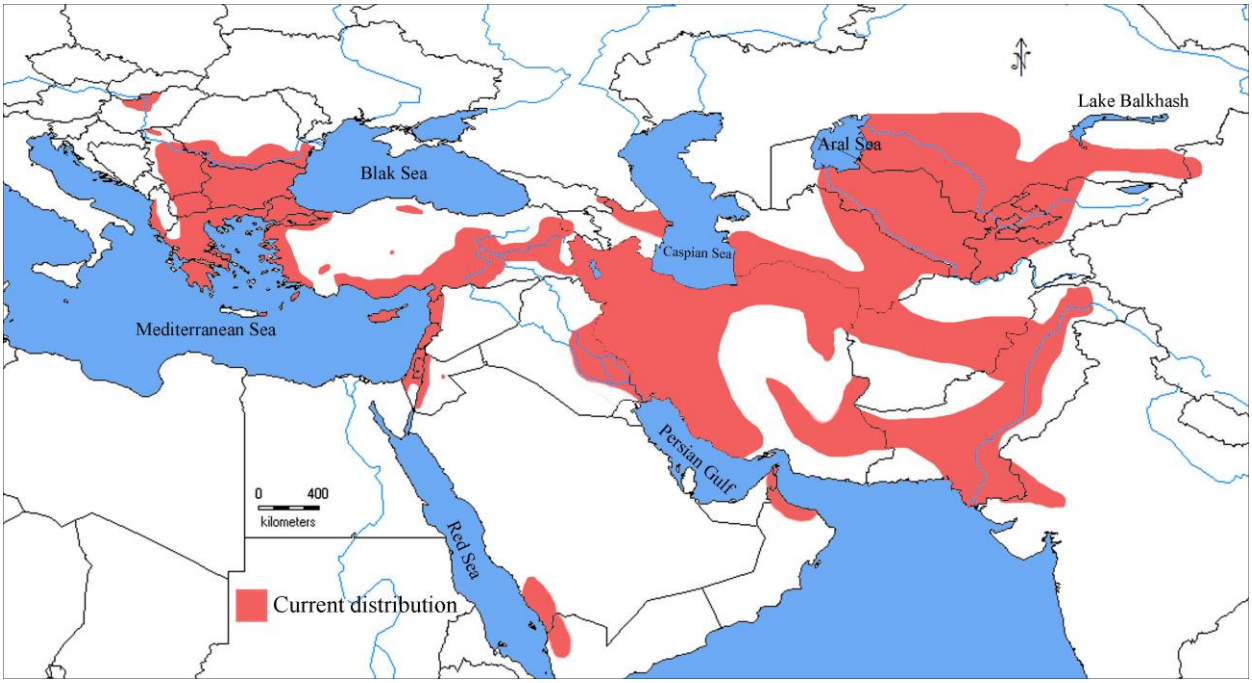

FIGURE 1. Distribution of the genus *Ablepharus*.

1997, *A. bivittatus* (Ménétries, 1832), *A. budaki* Göçmen, Kumlutas & Tosunoglu, 1996, *A. chernovi* Darevsky, 1953, *A. darvazi* Eremchenko & Panfilov, 1990, *A. deserti* Strauch, 1868, *A. grayanus* (Stoliczka, 1872), *A. kitaibelii* Bibron & Bory St-Vincent, 1833, *A. lindbergi* Wettstein, 1960, *A. pannonicus* (Lichtenstein, 1823), and *A. rueppellii* (Gray, 1839) which are distributed in southern Europe, Transcaucasia (Armenia, south-east Azerbaijan), Turkey, Syria to Egypt, Tajikistan, Kazakhstan, Kyrgyzstan, Uzbekistan, Turkmenistan, Afghanistan, Iran, Iraq, United Arab Emirates, Pakistan and NW India (Fühn, 1969a, b; Anderson, 1999; Khan, 2002; Ananjeva et al., 2006; Vyas, 2011; Rastegar-Pouyani et al., 2008; Šmíd et al., 2014) (Fig. 1).

The morphological characteristics in the genus *Ablepharus* are as follows: small lizards; pentadactyl limbs relatively weakly developed. immovable eyelids, lower eyelid is fused with upper, forming transparent membrane covering eye; outer ear opening small or hidden under the skin; supranasal scales absent; 18-26 rows of smooth scales around middle of body; oviparous (Fühn 1969b; Eremchencko and Szczebak, 1986; Anderson 1999; Ananjeva et al., 2006). Also, the genus *Ablepharus* has particular elements in the cranial osteology as following: no posterior projecting process of palatines separating pterygoids bone; pterygoids not in contact; no recurved process of pterygoids; nine pleurodont teeth on premaxillary bone (Fig. 2) (Fühn, 1969a).

In his monograph on the genus *Ablepharus*, Strauch (1868) mentioned nine pentadactyle species (*A. pannonicus*, *A. bivittatus*, *A. brantii*, *A. deserti*, *A. nigropunctatus*, *A. wahlbergi*, *A. boutonii*, *A. lineo-ocellatus*, *A. anornalus*) distributed in Africa, Eurasia, East Indies, Australia and Polynesia as belonging to a single genus, *Ablepharus* Fitzinger, 1823, and allotted the forms with reduced fingers to other genera. Boulenger (1887), based on the reduction of digits and toes grouped eight genera (*Lerista* Bell, 1833; *Cryptoblepharus* Wiegmann, 1834; *Menetia* Gray, 1844; *Miculia* Gray, 1844; *Morethia* Gray, 1844; *Panaspis* Cope, 1868; *Blepharosteres* Stoliczka, 1872; *Phaneropsis* Fischer, 1881) and 16 species in the genus *Ablepharus*, characterized by having immovable eyelids, and a transparent shield covering eyes. Smith (1937) showed that transparent disc on the eyes of *Ablepharus* is not intact, having a small palpebral slit hidden under the supercilium or the vestige of the upper lid, while several genera of Scincidae have a transparent window in the lower eyelid.

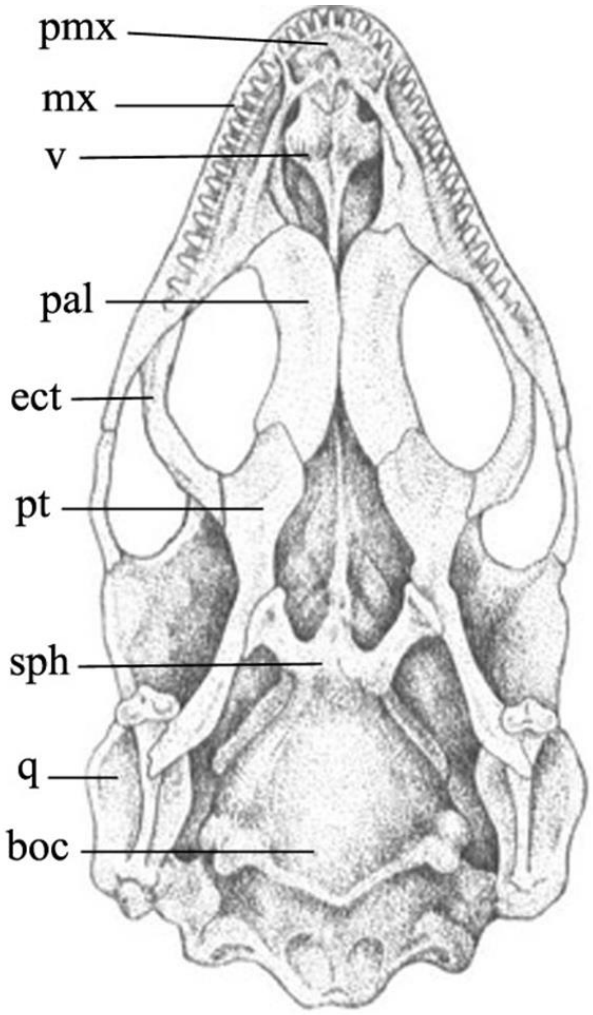

FIGURE 2. Ventral view of skull of *Ablepharus kitaibelii*. Abbreviations: boc, basioccipital; ect, ectopterygoid; mx, maxilla; pal, palatine; pmx, premaxilla; pt, pterygoid; q, quadrate; sph, sphenoid; v, vomer (modified from Fühn, 1969a).

Smith's opinion was accepted by De Witte (1936), and Mittleman (1952). Fühn (1969b) in the revision of the genus *Ablepharus*, based mainly on osteology of the skull (absence of recurved process of the pterygoids, and of posterior projecting process of the palatines) restricted the genus *Ablepharus* only to Eurasian species (i.e., *bivittatus* (*A. b. bivittatus*, *A. b. linddbergi*, *A. b. alaicus*), *deserti*, *kitaibelii* (*A. kitaibelii fitzingeri*, *A. k. kitaibelii, A. k. stepaneki*, *A. k. fabichi*, *A. k. chernovi*), and *pannonicus* (*A. p. pannonicus*, *A. p. grayanus*)). Subsequently, based on detailed morphological and molecular analyses, some modifications have occurred in the taxonomic rank of each species and subspecies (Poulakakis et al., 2005). A comprehensive morphological revision of all Snake-eyed Skinks is needed because these fundamental studies were carried out some decades ago. In this study systematics and distribution of the genus *Ablepharus* are discussed.

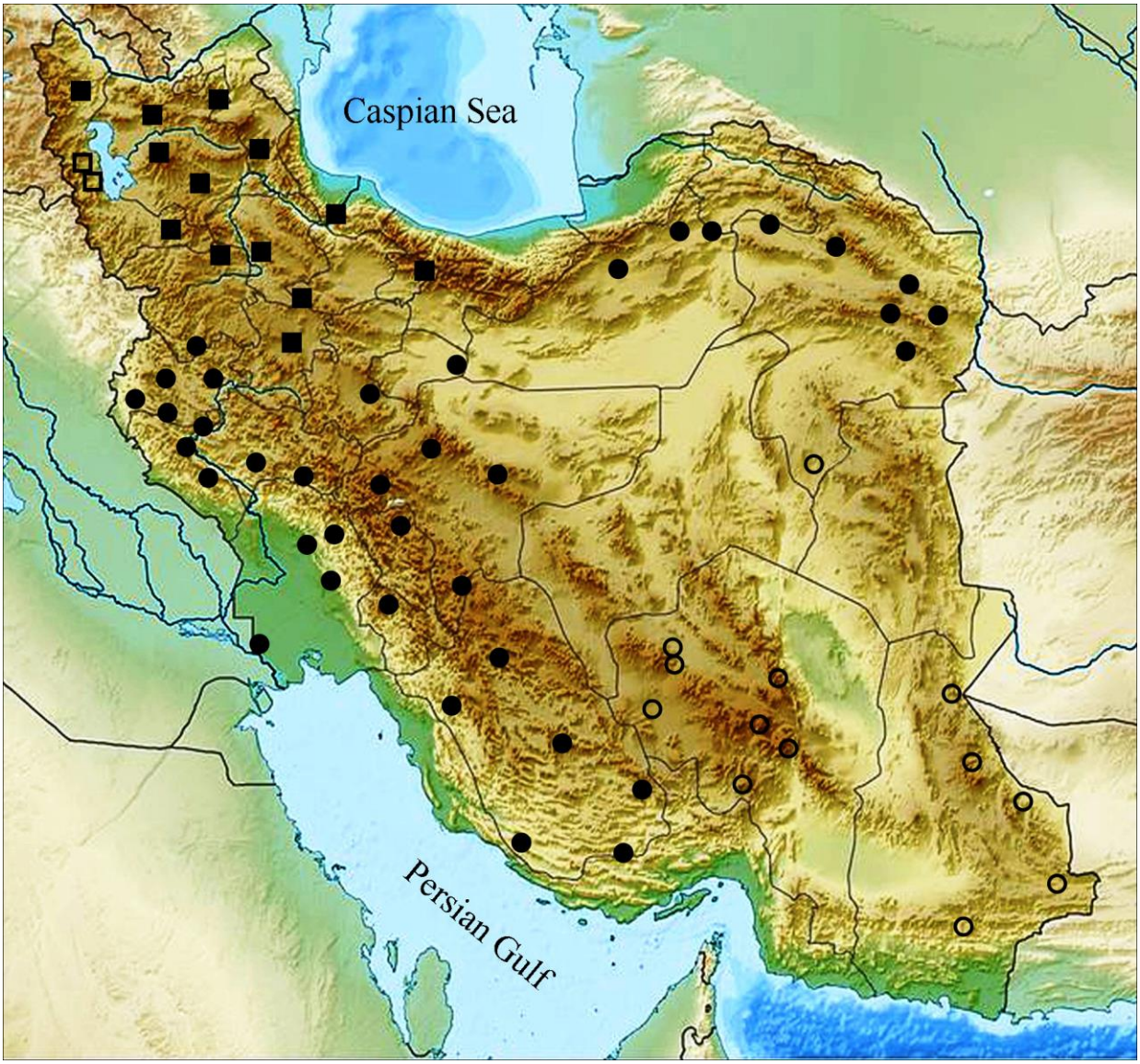

FIGURE 3. Distribution of the genus *Ablepharus* in Iran: solid square = *Ablepharus bivittatus* (Ménétries, 1832), hollow square = *A. chernovi* Darevsky, 1953, solid circle = *A. pannonicus* (Lichtenstein, 1823) and hollow circle = *A. grayanus* (Stoliczka, 1872).

***Ablepharus* Fitzinger, 1823**

The Snake-eyed Skinks of the genus *Ablepharus* Fitzinger, 1823 occur in southeastern Europe, southwest Asia, and Central Asian Republics (Anderson, 1999). These skinks lack movable eyelids, with the lower eyelid fused to the upper, thereby forming a transparent spectacle covering the eye. The genus *Ablepharus* based on scalation characters consists of 11 recognized species as follows: *A. anatolicus*, *A. bivittatus*, *A. budaki*, *A. chernovi*, *A. darvazi*, *A. deserti*, *A. grayanus*, *A. kitaibelii*, *A. lindbergi*, *A. pannonicus*, *A. rueppellii*, of which *A. bivittatus*, *A. chernovi*, *A. grayanus*, and *A. pannonicus* occur in Iran (Anderson, 1999; Sindaco and Jeremčenko 2008; Karamiani et al., 2015; Karamiani et al., 2018a) (Fig. 3). Recently Vergilov et al. (2017) used anatomical hemipenial characters for recognition of some species of *Ablepharus* (i.e. *A. kitaibelii* and *A. budaki*).

Systematic Account

Ablepharus anatolicus Schmidtler, 1997

Ablepharus anatolicus was regarded as a subspecies of *A. budaki* from southern Anatolia by Schmidtler (1997). *Ablepharus budaki anatolicus* was elevated to species level as *A. anatolicus* based on morphological and genetic data (Skourtanioti et al., 2016; Bozkurt and Olgun 2020).

Ablepharus bivittatus (Ménétriés, 1832)

The Two-streaked Snake-eyed Skink, *Ablepharus bivittatus* was described as *Scincus bivittatus* from Perimbal, Talysch Mountains, Azerbaijan by Ménétriés 1832. Wettenstein (1960) described a subspecies of ablepharine skink from upland Afghanistan and Punjab as *A. bivittatus lindenbergi*. Eremchencko and Szczerbak (1986) reviewed the genus *Ablepharus* and regarded *A. lindbergi* as a distinct full species. Elpatjevsky (1901) described a new ablepharine skink from Kirghiz, northeastern Tadjikistan, southeastern Kazakhstan, and western Xinjiang, China as *A. alaicus*. Later on, this species was regarded as a subspecies of *Ablepharus bivittatus* by researchers (e.g., Wettenstein, 1960; Fühn, 1969b). Eremchencko and Szczerbak (1986) assigned *alaicus* to a new genus *Asymblepharus*. The two-streaked snake-eyed skink *A. bivittatus* (Fig. 4A) is distributed in Azerbaijan, Armenia, eastern Turkey, and northwestern Iran (Baran and Atatür, 1998; Anderson, 1999; Ilgaz et al., 2007). Based on morphological characters, females are larger than males. In the other words, sexual differences are female-biased (Karamiani et al., 2017). Conservation status in the IUCN Red List categories and criteria for the species is Least Concern (IUCN, 2021).

Ablepharus budaki Göçmen, Kumlutas & Tosunoglu, 1996

The Budak's snake-eyed Skink, *Ablepharus budaki* was introduced from Northern Cyprus as a subspecies of *A. kitaibelii* based on morphological characters as follows: the ventral side coloration of the trunk and tail, the number of the vertical rows of scales between the masseteric and ear opening, and the size of the ear openings (Göçmen et al., 1996). Poulakakis et al., (2005), based on molecular data, changed its taxonomic status into a distinct species from *A. kitaibelii*. *Ablepharus budaki* is distributed in Turkey, Cyprus, Syria, Lebanon (Hraoui-Bloquet et al., 2002; Baier et al., 2009; Özkan et al., 2019). According to anatomical investigation hemipenis is leaf-shaped in *A. budaki,* folds are also deeply bilobed and the two branches of each hemipenis are equally long and symmetrical, with thick labia surrounding the sulci (Fig. 5; Vergilov et al., 2017). Conservation status in the IUCN Red List categories and criteria for the species is Least Concern.

Ablepharus chernovi Darevsky, 1953

The Chernov's Skink, *Ablepharus chernovi* Darevsky, 1953, was regarded as a subspecies of *Ablepharus kitaibelii* Bibron & Bory St-Vincent, 1833 from the vicinity of the settlement Tkhit, Ashtarak region, middle current of the river Razdan, Armenia. *Ablepharus chernovi* (Fig. 4B), which had previously been accepted as a subspecies (Fühn, 1969b; Baran, 1977), is considered a species. A molecular phylogenetic study confirmed *A. chernovi* to represent a genetically distinct species (Poulakakis et al., 2005). *Ablepharus chernovi* is distinguished based on having a hidden tympanum (versus ear-opening visible in *Ablepharus kitaibellii*) and having two supraocular scales, without supraciliary granular scales between eye and supraocular scales (versus three supraocular scales, a row of supraciliary granular scales between eye and supraocular scales in *Ablepharus bivittatus*) (Arakelyan et al., 2011; Karamiani et al., 2018a) (Fig. 6). *Ablepharus chernovi* is distributed in Razan River valley Armenia, northern Syria and southern and central parts of Anatolian Turkey, and Urmia of West Azerbaijan Province, Iran (Baran & Atatür 1998; Ananjeva et al. 2006; Sindaco & Jeremčenko 2008; Arakelyan et al., 2011; Karamiani et al., 2015). Of the four described subspecies, *A. c. chernovi* occurs in Armenia, *A. c. eiselti* (Adana province), *A. c. isauriensis*, and *A. c. ressli* (Mersin Province) described by Schmidtler 1997 are from southern Turkey (Gemel et al., 2019). Conservation status in the IUCN Red List categories and criteria for the species is Least Concern.

FIGURE 4. Adult specimen of (**A**) *Ablepharus bivittatus* (Ménétriés, 1832), (**B**) *A. chernovi* Darevsky, 1953, (**C**) *A. grayanus* (Stoliczka, 1872), and (**D**) *A. pannonicus* (Lichtenstein, 1823).

***Ablepharus darvazi* Eremchenko & Panfilov, 1990**

The Darvaz Snake-eyed Skink, *Ablepharus darvazi* was described from Darvaz mountain range, Tadzhikistan by Eremchenko & Panfilov (1990). So far, the species is known only in Darvaz and Khozratishoh mountains and inhabits bushes and montane forest habitats. In other words, it is endemic to the Badakshan Mountains but it is likely to occur in nearby regions of Afghanistan, Pakistan, and northwestern India (Ananjeva et al., 2006; Sindaco and Jeremčenko 2008). Conservation status in the IUCN Red List categories and criteria for the species is Data Deficient.

***Ablepharus deserti* Strauch, 1868**

The Desert Lidless Skink, *Ablepharus deserti* was described from Settlement Ak-Mechet, Kazakhstan by Strauch (1868). The desert snake-eyed skink is distributed in southern Kazakhstan, Kyrgyzstan, northern Tajikistan, Uzbekistan, and eastern Turkmenistan. As well, isolated populations occur in southern Turkmenistan, central Tien Shan, and southeastern Kazakhstan (Kolbintzev et al., 1999; Ananjeva et al., 2006). Conservation status in the IUCN Red List categories and criteria for the species is Least Concern.

***Ablepharus grayanus* (Stoliczka, 1872)**

The Minor Snake-eyed Skink, *Ablepharus grayanus* was first described as *Blepharosteres grayanus* from Waggur District, northeast Kutch, India (Stoliczka, 1872). Later, it was regarded as a subspecies of *A. pannonicus* (Fühn, 1969b). *Ablepharus grayanus* (Stoliczka, 1872) (Fig. 4C) is distinguished based on having a hidden tympanum and 18-20 scales around midbody (versus a small ear opening and 20-22 scales around midbody in *A. pannonicus*), which is distributed in north and west India, through Pakistan, Afghanistan, and Iran (Leviton and Anderson, 1970; Khan, 2002; Venugopal, 2010; Vyas, 2011; Rais et al., 1997; Karamiani et al., 2015). Conservation status in the IUCN Red List categories and criteria for the species is "Not Listed".

***Ablepharus kitaibelii* Bibron & Bory St-Vincent, 1833**

The Snake-eyed Skink, *A. kitaibelii,* distributed in southeastern Europe and west and central Turkey (Schmidtler, 1997), is represented by four subspecies as follows: *A. k. fitzingeri* Mertens, 1952 in southern Slovakia, northern Serbia, and Hungary, *A. k. stepaneki* Fühn, 1970 in Romania, Bulgaria, Serbia, Bosnia, and Albania, *A. k. kitaibelii* (Bibron & Bory, 1833) in Greece, including the Ionian and Aegean islands and *A. k. fabichi* Stepànek, 1937 in the Greek islands of Mikronisi, Amathia, Kasos, and Karpathos (Fühn 1969b; Pasuljević, 1977; Göçmen et al., 1996; Gruber, 1981; Tomović et al., 2001; Ljubisvljevic et al., 2002; Herczeg et al., 2004; Kumlutas et al., 2005). Poulakakis et al. (2005) inferred phylogenetic relationships between populations of the *A. kitaibelii* indicated that *A. kitaibelii* is paraphyletic, as the populations on the Kastelorizo Archipelago (Greece, off the Lycian coast of southwestern Turkey) is distinct, nesting at the base of the ingroup. Moreover, the remaining populations of *A. kitaibelii* consist of two clades, one involving the populations inhabiting continental Greece and the west Aegean (the Cyclades and Kithira) and Ionian (Leukada) islands, and the other including populations that inhabit the East Aegean Islands and Turkey. Conservation status in the IUCN Red List categories and criteria for the species is Least Concern.

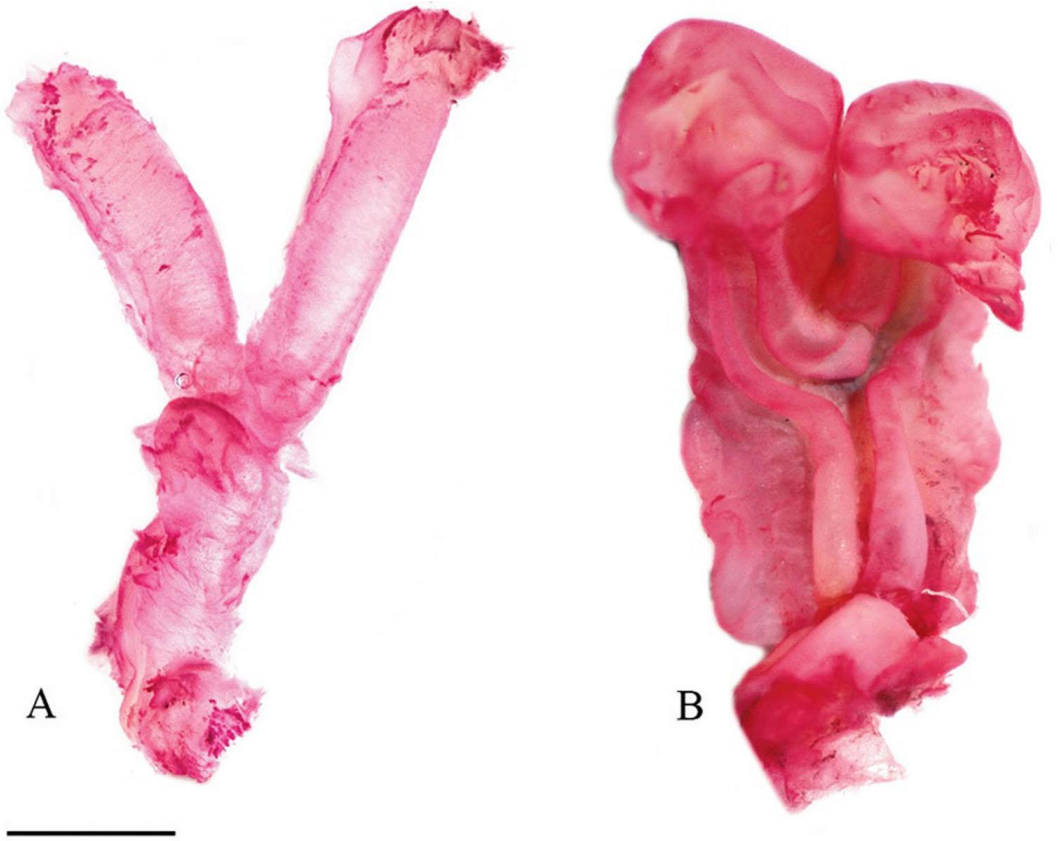

FIGURE 5. Inflated hemipenes of (A) *Ablepharus budaki* Göçmen, Kumlutaş & Tosunoğlu, 1996 and (B) *A. kitaibelii* (Bibron & Bory Saint-Vincent, 1833); Scale bar = 1 mm (Vergilov et al., 2017).

***Ablepharus lindbergi* Wettstein, 1960**

The Lindberg's Twin-striped Skink, *Ablepharus lindbergi* Wettstein, 1960, was regarded as a subspecies of *A. bivittatus* (Ménétries, 1832) from the steppes east of Herat, western Afghanistan. Having a widespread distribution within the Hindu Kush Mountains (Wagner et al., 2016), it is endemic to Afghanistan (Sindaco and Jeremčenko 2008), Conservation status in the IUCN Red List categories and criteria for the species is Least Concern.

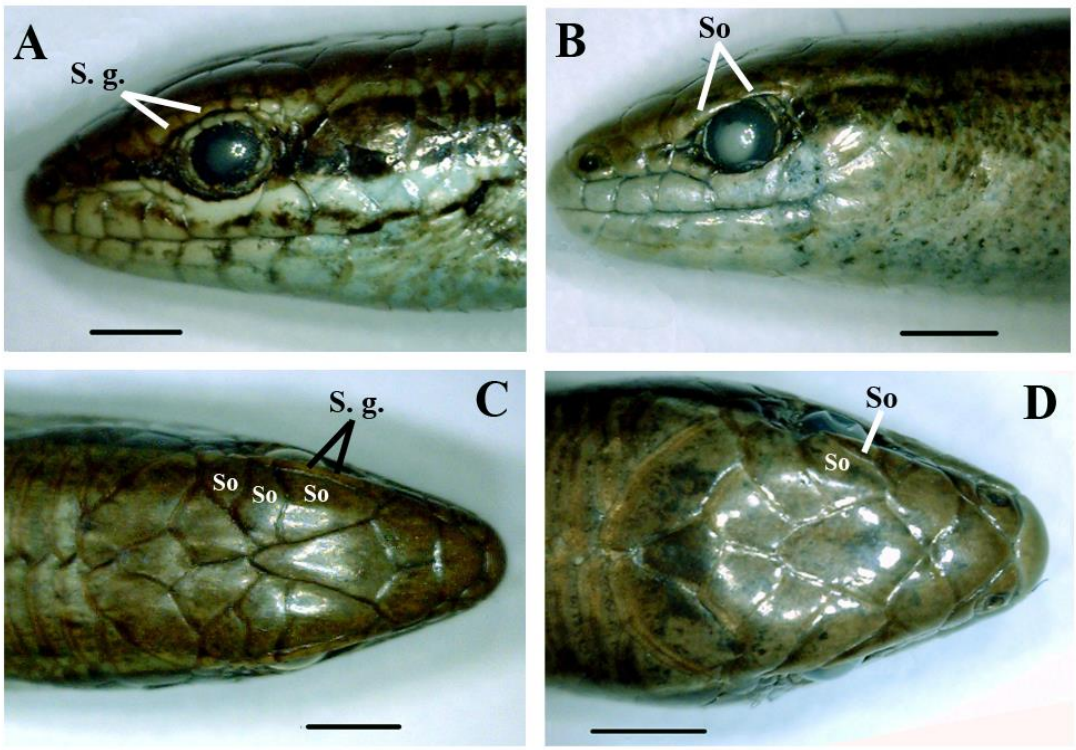

Fig. 6. Lateral (A) and dorsal (C) views of the head scalation of *Ablepharus bivittatus* (Ménétriés, 1832), (RUZM SA10.5, from near Tabriz, East Azerbaijan Province, NW Iran), and lateral (B) and dorsal (D) views of the head scalation of *A. chernovi* Darevsky, 1953, (RUZM SA30.2, from near Urmia, West Azerbaijan Province, NW Iran); So: Supraocular scales, S.g: Supraciliary granules (Karamiani et al., 2018a).

***Ablepharus pannonicus* (Lichtenstein, 1823)**

The Asian Snake-eyed Skink, *Ablepharus pannonicus* was initially described as *Scincus pannonicus* by Lichtenstein (1823) from Bukhara Province, Uzbekistan. During 1868 to 1907 some species including *A. brandtii* Strauch 1868 (Samarkand, Turkestan), *A. pusillus* Blanford 1874 (Bussora = Basra, Iraq), *A. brandti* var. *brevipes* Nikolsky 1907 (Dech-i-Diz and Karun River, Iran), and *A. persicus* Nikolsky 1907 (Schachrud =Shahrud, Semnan Iran) were introduced based on morphological characters which all were synonymized later with *A. pannonicus* (Fig. 4D) by Anderson (1999). The Asian Snake-eyed Skink is the most widely distributed species of the genus *Ablepharus*, occuring in Yemen, Saudi Arabia, Iraq, Syria, Iran, Afghanistan, Pakistan, south of Tajikistan, Uzbekistan, southern Turkmenistan, southeast Georgia, Azerbaijan, and northwestern India (Anderson, 1999; Ananjeva et al., 2006; Karamiani et al., 2018b). Conservation status in the IUCN Red List categories and criteria for the species is "Not Listed".

***Ablepharus rueppellii* (Gray, 1839)**

The Rüppell's Snake-eyed Skink, *Ablepharus rueppellii* was initially described as *Riopa ruppellii* by Gray (1839) from Arabia Petrea (Jordan). For a long time, it was considered to be a subspecies of *Ablepharus kitaibelii* but was raised to species rank by Schmidtler (1997). *Ablepharus rueppellii* is distributed from southern Syria and Lebanon, western Jordan to Sinai Peninsula of Egypt (Sindaco et al., 1995; Saleh, 1997; Disi et al., 2001; Modrý et al., 2004; Al-Quran, 2009; Disi, 2011; Handal et

al., 2016). Conservation status in the IUCN Red List categories and criteria for the species is Least Concern.

Key to the species of *Ablepharus* in Iran (Modified from Leviton et al., 1992; Anderson, 1999; Khan, 2002).

1a. Prefrontals usually forming a median suture; frontoparietals divided ……2
1b. Prefrontals separated; a single frontoparietal …… 3
2a. Three supraocular scales, a row of supraciliary granular scales between eye and supraocular scales (Fig. 6A & C) …… *A. bivittatus*
2b. Two supraocular scales, without supraciliary granular scales between eye and supraocular scales (Fig. 6B & D) …… *A. chernovi*
3a. Hidden tympanum; having 18-20 scales around midbody …… *A. grayanus*
3b. Small ear opening; 20-22 scales around midbody …… *A. pannonicus*

Table 1. The main morphological characters in various species of the Snake-eyed Skink *Ablepharus* Fitzinger, 1823: Number of scales around mid-body (AMS), frontoparietal scales (FS), Prefrontal scales (PS), Supraciliary granular scales (SG), Tympanum status (TS) (Strauch, 1868; Fühn 1969a; Göçmen et al., 1996; Kumlutas et al., 2005; Karamiani et al., 2015; Karamiani et al., 2018b; Özkan et al., 2019).

	AMS	FS	PS	SG	TS
A. bivittatus	22-24	paired	in contact	present	obvious
A. budaki	18-20	single	usually in contact	present	obvious
A. chernovi	18	paired	in contact	absent	obvious
A. darvazi	-	paired	in contact	-	-
A. deserti	20-22	paired	in contact	present	obvious
A. grayanus	18-20	single	separated	absent	hidden
A. kitaibelii	18-20	paired	rarely in contact	present	obvious
A. lindbergi	26-27	paired	in contact	present	obvious
A. pannonicus	20-22	single	separated	absent	obvious
A. rueppellii	18	paired	in contact	present	obvious

DISCUSSION

The genus *Ablepharus* is restricted in distribution to the western Eurasian region, encompassing the following species: *A. anatolicus*, *A. bivittatus*, *A. budaki*, *A. chernovi*, *A. darvazi*, *A. deserti*, *A. grayanus*, *A. kitaibelii*, *A. lindbergi*, *A. rueppellii*, and *A. pannonicus*. Such characters as prefrontals status, the number of frontoparietal scales, tympanum status (hidden or obvious), supraciliary granular scales (present or absent), and the number of scales around midbody are important key characters for the identification of various species within the genus (Table 1). Additional pholidosis features and anatomical survey (Vergilov et al., 2017), molecular study (Poulakakis et al., 2005), and species distribution models (Karamiani et al., 2018b) can result in delimitation of the species of *Ablepharus*. Sanchooli (2016) modeled range distribution of *A. bivittatus* and showed that it is restricted to the northwest and some isolated areas in the central Elburz and Kopet Dagh Mountains. Karamiani et al. (2017) extended the range distribution of *A. bivittatus* from northwestern regions of Iran to Hamedan Province, western Iran. In an investigation Karamiani et al., (2016) showed variations in erythrocyte and nucleus sizes among *A. bivittatus* and *A. pannonicus* with larger sizes for former species. During recent years, the range of *A. chernovi* extended from Turkey to southwestern Iran by Karamiani et al. (2018a). In another

study, Karamiani et al. (2015) rediscovered *A. grayanus* from two different localities in Sistan and Baluchestan and Kerman Provinces, southeastern Iran, formerly mentioned by Fühn (1969b), Leviton and Anderson, (1970), and Nikolsky (1900) without providing exact localities. A modeling study showed that *A. grayanus* and *A. pannonicus* are confined to specific habitats in distinct geographical areas, which can be good indicators for assessing the effects of climatic changes on the distribution range of vertebrate organisms (Karamiani et al., 2018b). Phylogenetic relationships among the Snake-eyed Skinks found in Iran (i.e., *A. bivittatus*, *A. chernovi*, *A. grayanus*, and *A. pannonicus*) need a more comprehensive survey, now being conducted by the senior author and his colleagues.

ACKNOWLEDGMENTS

The authors thank Prof. S. C. Anderson (University of the Pacific, Stockton, California, USA) for his kind support in improving the English of the manuscript, and thank Ali Bazdar, Ali Permanoon, Erfan Permanoon, Ali Gholamifard, Akbar Fattahi, Mohsen Takesh, Mosa Mahmoudi, and Morad Besharati for their valuable assistance during fieldwork. We are grateful to the authorities of Razi University (Kermanshah, Iran) for financial support to conduct the field trips.

References

Al-Quran, S. 2009. The Herpetofauna of the southern Jordan. American-Eurasian Journal Agriculture & Environmental Science 6, 385–391.

Ananjeva, N.B., Orlov, N.L., Roman, G.K., Darevsky, S.D., Ryabov, S.A., Barabanov, A.V. 2006. The reptiles of northern Eurasia-taxonomic diversity, distribution, conservation status. Sofia (Pensoft Publishers).

Anderson, S.C. 1999. The Lizards of Iran. Society for the Study of Amphibians and Reptiles, Oxford, Ohio.

Arakelyan, M.S., Danielyan, F.D., Corti, C., Sindaco, R., Leviton, A.E. 2011. The herpetofauna of Armenia and Nagorno-karabakh. Salt Lake City (SSAR - Society for the Study of Amphibians and Reptiles).

Baier, F., Sparrow, D.J., Wiedl, H.J. 2009. The Amphibians and Reptiles of Cyprus. Edition Chimaira, Frankfurt/M., ca.

Baran, İ., 1977. Türkiye'de Scincidae familyası türlerinin taksonomisi. Doğa Bilim Dergisi 1, 217–223.

Baran, Ý., Atatür, M.K. 1998. Turkish Herpetofauna. Amphibians and Reptiles, Ankara (Republic of Turkey Ministry of Environment).

Blanford, W.T. 1874. Description of new Reptilia and Amphibia from Persia and Baluchistan. Annals and Magazine of Natural History, 4, 31–35.

Boulenger, G.A. 1887. Catalogue of the lizards in the British Museum (Natural History). Vol. III. Lacertidae, Gerrhosauridae, Scincidae, Anelytropidae, Dibamidae, Chamaeleontidae. Trustees of the British Museum, London.

Bozkurt, E., Olgun, K. 2020. Taxonomic investigation of the genus *Ablepharus* (Sauria; Scincidae) with molecular and morphological methods in Anatolian populations. Turkish Journal of Zoology, 44, 134–145.

De Witte, G.F. 1936. Description d'une espèce nouvelle du genre *Ablepharus* provenant du Congo Belge, Revue de Zoologie et de Botanique Africaines 29, 29–33.

Disi, A.M. 2011. Review of the lizard fauna of Jordan: (Reptilia: Sauria). Zoology in the Middle East, 54, 89–102.

Disi, A.M., Modry, D., Necas, P., Rifai, L. 2001. Amphibians and Reptiles of the Hashemite Kingdom of Jordan: An Atlas and Field Guide. Edition Chimaira Frankfurt am Main.

Elpatjevsky, V.S. 1901. The genus *Ablepharus* Fitzinger in the collections of the Zoological Museum of Moscow University, Dnevn. Zool. Otdel. Imp. Obshch. Lyubit. Estestvozn. 3, 37–39.

Eremchencko, V.K., Szczerbak, N.N. 1986. Ablepharine lizards in the fauna of the USSR and neighbouring countries, Frunze (Akad. Nauk. Kirgis. SSR), [in Russian].

Eremchenko, V.K. Panfilov, A.M. 1990. *Ablepharus darvazi* sp. nov.—A New Lidless Skink Species (Sauria, Scincidae) from Tajikistan, Izvestia Academii Nauk Kirgizskoy SSR, Khimiko–Tekhnologicheskie I Biologicheskie Nauki 4, 56–63.

Fühn I.E. 1969a. The 'polyphyletic' origin of the genus *Ablepharus* (Reptilia: Scincidae): A case of parallel evolution, Zeit. Zool. Syst. Evolutionsforschung **7**, 67–76.

Fühn, I.E. 1969b. Revision and redefinition of the genus *Ablepharus* Lichtenstein, 1823 (Reptilia, Scincidae), Revue Roumaine de Biologie, ser. Zoology 14, 23–41.

Gemel, R., Gassner, G., Schweiger, S. 2019. Katalog der Typen der Herpetologischen Sammlung des Naturhistorischen Museums Wien–2018. Annalen des Naturhistorischen Museums in Wien. Serie B für Botanik und Zoologie 121, 33–248.

Göçmen, B., Kumlutas, Y., Tosunoglu, M. 1996. A new subspecies, *Ablepharus kitaibelii* (Bibron & Borry, 1833) *budaki* n. ssp. (Sauria: Scincidae) from the Turkish Republic of Northern Cyprus, Turkish journal of Zoology 20, 397–406.

Gray, J.E. 1839. Catalogue of the slender-tongued saurians, with descriptions of many new genera and species. Annals and Magazine of Natural History, 1, 287–293.

Greer, A.E. 1970. A subfamilial classification of scincid lizards. Bulletin of the Museum of Comparative Zoology 139, 151–183.

Gruber, U. 1981. *Ablepharus kitaibelii* (Bibron & Bory 1833) Johannisechse. Handbuch der Reptilien und Amphibien Europas 1, 297–302.

Handal, E.N., Amr, Z.S., Qumsiyeh, M.B. 2016. Some Records of Reptiles from the Palestinian Territories. Russian Journal of Herpetology 23, 261–270.

Hedges, S.B. 2014. The high–level classification of skinks (Reptilia, Squamata, Scincomorpha). Zootaxa 3765, 317–338.

Herczeg, G., Tóth, T., Kovács, T., Korsós, Z., Török, J. 2004. Distribution of *Ablepharus kitaibelii* fitzingeri Mertens, 1952 (Squamata: Scincidae) in Hungary, Russian Journal of Herpetology, 11, 99–105.

Hraoui-Bloquet, S., Sadek, R.A., Sindaco, R., Venchi, A. 2002. The herpetofauna of Lebanon: new data on distribution, Zoology in the Middle East 27, 35–46.

Ilgaz, Ç., Kumlutaş, Y., Olgun, K., Baran, İ. 2007. The morphology and distribution of *Ablepharus bivittatus* (Menetries, 1832) (Reptilia: Sauria: Scincidae) in Turkey, Russian Journal of Herpetology 14, 91–97.

International Union For Conservation Of Nature. 2021. IUCN Red List of Threatened Species. Version 2021. 3. Available from www.iucnredlist.org (Accessed on 21 October 2021)

Karamiani, R, Rastegar-Pouyani, N., Parto, P., Rastegar-Pouyani, E., Khazaii, N. 2016. Morphology of red blood cells in *Ablepharus bivittatus* and *Ablepharus pannonicus* lidless skink lizards, Online Journal of Veterinary Research 20, 307–311.

Karamiani, R., Rastegar-Pouyani, N., Rastegar-Pouyani, E., Akbarpour, M., Damadi, E. 2015. Verification of the Minor Snake-eyed Skink, *Ablepharus grayanus* (Stoliczka, 1872) (Sauria: Scincidae), from Iran, Zoology in the Middle East 61, 226–230.

Karamiani, R., Rastegar-Pouyani, N., Rastegar-Pouyani, E., Mamaghani Shishvani, M., Nilson, G. 2018a. First record of *Ablepharus chernovi* Darevsky, 1953, from Iran, Herpetozoa 31, 94–97.

Karamiani, R., Rastegar-Pouyani1, N., Rastegar-Pouyani, E. 2018b. Modeling the Past and Current Distribution and Habitat Suitability for *Ablepharus grayanus* and *A. pannonicus* (Sauria: Scincidae), Asian Herpetological Research 9, 56–64.

Karamiani, R., Rastegar-Pouyani1, N., Rastegar-Pouyani, E., Dehghani, A., Banan-Khojasteh, S. M., Mahmoodi, M. 2017. Phenotypical variation and range extension distribution of the Snake-eyed Skink, *Ablepharus bivittatus* (Sauria: Scincidae) in Iran, Iranian Journal of Animal Biosystematics (IJAB) 13, 289–294.

Khan, M. S. 2002. Key and checklist to the lizards of Pakistan (Reptilia: Squamata: Sauria), Herpetozoa 15, 99–119.

Kolbintzev, V., Miroschnichenko, L. Dujsebayeva, T. 1999. Distribution and Natural History of the Lidless Skinks, *Asymblepharus alaicus* and *Ablepharus deserti* (Sauria: Scincidae) in the Aksu-Djabagly Nature Reserve (Western Tian-Shan Mountains) Kazakstan, Asiatic Herpetological Research 8, 69–74.

Kumlutas, Y., Öz, M., Özdemir, A., Rizvan Tunc, M., Durmus, H., Düsen, S. 2005. On the populations of *Ablepharus kitaibelii* (Bibron & Bory, 1833) (Sauria: Scincidae) from South-Western Anatolia, Pakistan Journal of Biological Sciences 8, 461–465.

Leviton, A.E. Anderson, S.C. 1970. *The Amphibians and reptiles of Afghanistan, a checklist and key to the herpetofauna*. Proceedings of the California Academy of Sciences, 38, 163–206.

Leviton, A.E., Anderson, S.C. Adler, K. Minton, S.A. 1992. Handbook to Middle East amphibians and reptiles. Society for the Study of Amphibians and Reptiles, Oxford, Ohio.

Lichtenstein, M.H.C. 1823. *Verzeichniss der Doubletten des zoologischen Museums der Königlichen Universität zu Berlin nebst Beschreibung vieler bisher unbekannter Arten von Säugethieren, Vögeln, Amphibien und Fischen*. T. Trautwein, Berlin, 118 pp.

Ljubisvljevic, K., Dzukic, G. Kalezic, M.L. 2002. Morphological differentiation of the snake-eyed skink *Ablepharus kitaibellii* (Bibron and Bory, 1933), in the north-western part of the species' range: systematic implications (Squamata: Sauria: Scincidae), Herpetozoa 14, 107–121.

Ménétriés, É. 1832. Catalogue raisonne des objets de zoologie recueillis dans un voyage au Caucase et jusqu'aux frontieres actuelles de la Perse. Académie impériale des sciences St. Pétersbourg.

Mittleman, M.B. 1952. A generic synopsis of the lizard of subfamily Lygosominae. Smithsonian, Misc Coll 117, 1–35.

Modrý, P., Rifai, L., Abu Baker, M., Amr, Z. 2004. Amphibians and reptiles of the Hashemite Kingdom of Jordan, Denisia 14, 407–420.

Nikolsky, A.M. 1900. Reptiles, amphibies et poissons, recueillis pendant le voyage de Mr. N. A. Zaroudny en 1898 dans la Perse. Annuaire Musée Zoologique de l'Académie Impériale des Sciences de St.-Pétersbourg, 4,375–417.

Nikolsky, A.M. 1907. Reptiles and Amphibians collected by N.A. Zarudny in Persia 1903–1904 [in Russian]. Annuaire Musée Zoologique de l'Académie Impériale des Sciences de St.-Pétersbourg, 10, 260–301.

Özkan, H., Bülbül, U., Koç, H. 2019. New locality record of *Ablepharus budaki* (Squamata: Scincidae) in Turkey, Turkish Journal of Biodiversity 2, 48–51.

Pasuljević, G. 1977. Biogeografske karakteristike vrste *Ablepharus kitaibelii* i istorijat njenog proučavanja u Jugoslaviji, Arhiv bioloških nauka Beograd 29, 31–37.

Poulakakis, N., Lymberakis, P., Tsigenopoulos, C.S., Magoulas, A., Mylonas, M. 2005. Phylogenetic relationships and evolutionary history of snake-eyed skink *Ablepharus kitaibelii* (Sauria: Scincidae), Molecular Phylogenetics and Evolution 34, 245–256.

Pyron, R.A., Burbrink, F.T., Wiens, J.J. 2013. A phylogeny and revised classification of Squamata, including 4161 species of lizards and snakes, BMC evolutionary biology 13, 1–54.

Rais, M., Baloch, S., Rehman, J., Anwar, M., Hussain, I., Mahmood, T. 1997. Diversity and conservation of amphibians and reptiles in North Punjab, Pakistan, Bridges, 1999, 2000.

Rastegar-Pouyani, N., Kami, H.G., Rajabzadeh, M., Shafiei, S. Anderson, S.C. 2008. Annotated checklist of Amphibians and Reptiles of Iran, Iranian Journal of Animal Biosystematics 4, 43–66.

Saleh, M.A. 1997. Amphibians and reptiles of Egypt. Arab Republic of Egypt, Cabint [sic] of Ministers, Ministry of State for Environmental Affairs, Egyptian Environmental Affairs Agency.

Sanchooli, N., 2016. Modeling the potential distribution of *Ablepharus bivittatus* (Menetries, 1832), in Iran (Squamata: Sauria: Scincidae). Herpetozoa, 29, 63–68.

Schmidtler, J.F. 1997. Die *Ablepharus kitaibelii*–Gruppe in Süd–Anatolien und benachbarten Gebieten, Herpetozoa, 10, 35–63.

Sindaco, R., Fedrighini, N., Venchi, A. 1995. Contribution to the herpetology of Jordan, Bollettino–Museo Regionale Di Scienze Naturali 13, 389–405.

Sindaco, R., Jeremčenko, V.K. 2008. The reptiles of the Western Palearctic. Annotated checklist and distributional atlas of the turtles, crocodiles, amphisbaenians and lizards of Europe, North Africa, Middle East and Central Asia. Latina (Edizioni Belvedere).

Skourtanioti, E., Kapli, P., Ilgaz, C., Kumlutaş, Y., Avcı, A., Ahmadzadeh, F., Isailović, J.C.n., Gherghel, I., Lymberakis, P., Poulakakis, N. 2016. A reinvestigation of phylogeny and divergence times of the *Ablepharus kitaibelii* species complex (Sauria, Scincidae) based on mtDNA and nuDNA genes. Molecular Phylogenetics and Evolution, 103, 199–214.

Šmíd, J., Moravec, J., Kodym, P., Kratochvíl, L., Hosseinian Yousefkhani, S. S., Frynta, D. 2014. Annotated checklist and distribution of the lizards of Iran, Zootaxa 3855, 1–97.

Smith, M.A. 1937. A review of the genus Lygosoma (Scincidae: Reptilia) and its allies, Rec Indian Mus 39, 213–234.

Stoliczka, F. 1872. Notes on the Reptilian and Amphibian Fauna of Kachh, Proceedings of the Asiatic Society of Bengal 1872:71–85.

Strauch, A. 1867. Über die Arten der Eidechsengattung *Ablepharus* Fitz. Bulletin de l'Académie Impériale des Sciences de St.- Pétersbourg, 4, 553–570

Tomović, L.j., Ljubisavljević, K., Ajtić, R., Aleksić, I. Crnobrnja-Isailović, J. 2001. New records of the snake-eyed skink *Ablepharus kitaibelii* in Serbia, Biota 2, 115–117.

Uetz, P., Freed, P, Aguilar, R. & Hošek, J. 2021. The Reptile Database, http://www.reptile-database.org, (accessed 21 October 2021).

Venugopal, P.D. 2010. An updated and annotated list of Indian lizards (Reptilia: Sauria) based on a review of distribution records and checklists of Indian reptiles, Journal of Threatened Taxa 2, 725–738.

Vergilov, V.S., Zlatkov, B.P., Tzankov, N.D. 2017. Hemipenial differentiation in the closely related congeners *Ablepharus kitaibelii* (Bibron & Bory De Saint-Vincent, 1833), and *Ablepharus budaki* Göçmen, KumluTaş & ToSunoğlu, 1996, Herpetozoa 30, 39–48.

Vitt, L.J., Caldwell, J.P. 2013. Herpetology: an introductory biology of amphibians and reptiles. Academic press.

Vyas, R. 2011. Preliminary Survey on Reptiles of Jassore Wildlife Sanctuary, Gujarat State, India, Russian Journal of Herpetology 18, 210–214.

Wagner, P., Bauer, A.M., Leviton, A., Wilms, T.M. Bohme, W. 2016. A checklist of the amphibians and reptiles of Afghanistan Exploring herpetodiversity using biodiversity archives, Proceedings of the California Academy of Sciences 63, 457–565.

Wettenstein, O. 1960. Contribution a l'etude de la faune d'Afghanistan. 3. Lacertilia aus Afghanistan, Zoologischer Anzeiger 165, 58–63.

Iranian Journal of Animal Biosystematics (IJAB)
Vol.17, No.2, 131-136, 2021
DOI: 10.22067/ijab.2021.70494.1011

IJAB
ISSN: 1735-434X (print); 2423-4222 (online)

RESEARCH ARTICLE Open access

First record of the genus *Paraimene* Javed & Ahmed, 1988 (Crustacea: Isopoda: Sphaeromatidae) from Iranian coast of the Gulf of Oman, with a revised diagnosis to the genus

Arian, N. and Khalaji-pirbalouty, V.*

Department of Biology, Faculty of science, shahrekord university, Shahrekord, Iran.

(Received: *20 May 2021*; Accepted: 11 *December 2021*)

Abstract
Paraimene tuberculata Javed & Ahmed, 1988, the type species of the genus is redescribed, photographed and illustrated, based on material from the Gulf of Oman. This species is distinguished from all other species of the genus by pereonites 2–4 bearing 3 rounded tubercles, pereonites 5–7 with 3 rounded and 2 elongated tubercles, and a pleotelson with 7 elongated tubercles on dorsal surface. This species is the only known member of the genus that occurs Indian Ocean from Pakistan coasts to the Iranian coast of the Gulf of Oman. A revised generic diagnosis is provided for the genus *Paraimene.*

Key words: Isopoda, Sphaeromatidae, *Paraimene*, Gulf of Oman, Iran.

INTRODUCTION

The isopod fauna of the Gulf of Oman is poorly known. Only sporadic studies have been carried out along the Iranian coasts of the Gulf of Oman, and there are only a few records of Isopoda from this region (Hobbins & Jones, 1993; Khalaji-Pirbalouty et al., 2015; Khalaji-Pirbalouty 2016, 2018). *Paraimene* Javed & Ahmed, 1988 is a small genus of five described species (Boyko et al. 2008 onwards), known from the tropical Western Indian Ocean and North Atlantic Ocean. While the type species *Paraimene tuberculata* Javed & Ahmed, 1988 was described from the rocky intertidal zone of Cape Monze, Karachi, Pakistan (Javed and Ahmad, 1988), the remaining four species occur in the North Atlantic Ocean. Three species are known from Cuba: *P. ibarzabalae* Kensley, Ortiz & Schotte, 1997 from Punta Frances*; P. tumulus* Kensley, Ortiz & Schotte, 1997 from Cayo Frances; and *P. danieli* Ortiz, Winfield & Cházaro-Olvera, 2012 from Cojimar Bay. The last species, *P. charlesae* Kensley & Schotte, 1994, is reported from Grand Bay, Dominican. The aim of this study was to redescribe *P. tuberculata* Javed & Ahmed, 1988 from the Iranian side of the Gulf of Oman, and add an updated generic diagnosis for the genus based on all reported species.

MATERIAL AND METHODS

Specimens for this study were collected from intertidal habitats along the Iranian coastline of the Gulf of Oman during 2013–2015. The material was deposited in the Zoological Museum,

Corresponding Author: vkhalaji@sku.ac.ir
©2021 FERDOWSI UNIVERSITY OF MASHHAD, IRAN

THIS WORK IS LICENSED UNDER A CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENSE.

Shahrekord University, Shahrekord, Iran. Drawings were made using a camera lucida mounted on a compound microscope (Olympus BX 51). Line drawings were made from pencil drawings using Corel Draw (version X6) and Adobe Photoshop (version CS5). A Zeiss AxioCam ERc5s camera mounted on a Zeiss Stereomicroscope (Stemi 508) equipped with an imaging system was employed to obtain color images of the specimens.

RESULTS

Taxonomy

Family Sphaeromatidae Latreille, 1825

Genus *Paraimene* Javed & Ahmed, 1988

Abbreviated synonymy. *Paraimene* Javed & Ahmed, 1988:371.— Kensley & Schotte, 1994: 494.— Kensley, Ortiz & Schotte, 1997: 89.— Ortiz, Winfield & Cházaro-Olvera, 2012: 976.

Type species: *Paraimene tuberculata* Javed & Ahmed, 1988; by original designation.

Generic diagnosis. Body length about two times as long as greatest width. Head dorsal surface smooth; rostral point slightly visible in dorsal view; epistome anteriorly broadly rounded. Perenoite 1 smooth, longest; pereonites 2–7 without coxal plate sutures, with or without tubercles or transverse carina. Pleon posterior margin with two separate sutures on either side, smooth or with 1 or 2 pairs of rounded tubercles. Pleotelson markedly domed, with 4–8 protuberances, edges of pleotelson folding ventrally to form vertical slit. Antennula with broad basal article; flagellum of 6–10 articles. Antenna subequal in length to antennula, peduncle articles 3 and 5 shortest and longest, respectively. Maxilla with four curved pectinate robust setae on middle and lateral endites. Pereopods 1–7 increasing in length posteriorly, inferior margins of merus, carpus, and propodus bearing dense fine setae fringe. Penial processes short, separated, close together, distally rounded. Appendix masculina elongate, extending well beyond apex of endopod. Pleopod 3 exopod with transverse suture in distal fifth. Pleopods 4 and 5 rami bearing thickened transverse ridges; pleopod 5 exopod with 3 scale patches (2 distally and 1 proximal to transverse suture). Uropodal rami lamellar, subequal, and extending well beyond pleotelson apex.

Paraimene tuberculata Javed & Ahmed, 1988

Type locality: Cape Monze, Karachi, Pakistan.

Material examined: Pasabandar, Sistan and Baluchestan Province, Iran, Gulf of Oman, 25° 4'15.93"N, 61°24'32.76"E; 1 ♂ (3.5 mm); 1♀ (3.1 mm), 20 May 2013, coll. V. Khalaji-Pirbalouty (ZMSU 1048). Ramin, Sistan and Baluchestan Province, Gulf of Oman, 25°16'08.46"N, 60°45'03.83"E, 2 ♂ (3.1, 2.6 mm), 1♀ (3.1 mm), 19 May 2013, coll. V. Khalaji-Pirbalouty (ZMSU 1049). Bahl Village, near Jask, Hormuzgan Province, Iran, Gulf of Oman, 25°40'48.95"N, 57°51'13.36"E, 1 ♂ (3.2 mm); 28 June 2013, coll. V. Khalaji-Pirbalouty (ZMSU 1050).

Redescription. (Based on specimens from Gulf of Oman)

Body about 1.6 times as long as greatest width, widest at pereonite 6 (Fig. 1 A). *Head* with small rostral point. *Pereonite 1* smooth, pereonites 2–4 with 3 tubercles, *pereonites 5–7* with 3 round medial and 2 elongated lateral tubercles (Fig. 1 A, B). *Pleon* posterior margin with 2 median tubercles. *Pleotelson* about 2.3 times as long as width, markedly domed, dorsal surface bearing two pairs of elongated tubercles followed by a single median elongated tubercle on apex and flanked on either side by a single longitudinal elongated tubercle (Fig. 1 A, B). *Antennula* (Fig. 1 C) not extending to posterior of pereonite 1; first peduncle article 1.3 times as long as article 2; peduncle article 3 subequal to article 2; flagellum with 7 articles, articles 2–6 bearing aesthetascs. *Antenna* peduncular articles all collinear, articles 2 and 4subequal, article 5 longest; flagellum with 9 articles. *Pereopod 1* (Fig. 1 E) basis about 2.3 times as long as greatest width; ischium, merus, carpus, and propodus inferior margins fringed with dense fine setae; ischium superior margin with 3 long

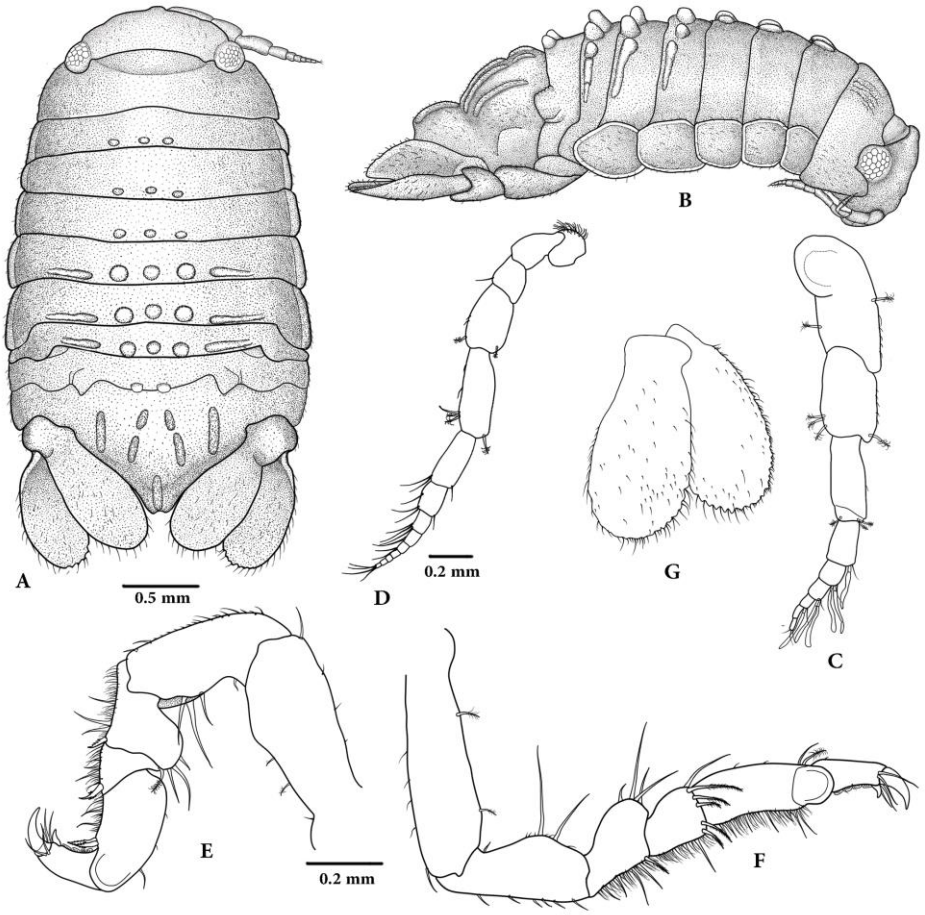

FIGURE 1. *Paraimene tuberculata* Javed & Ahmed, 1988: A. dorsal view; B. lateral view; C. antennula; D. antenna; E. pereopod 1; F. pereopod 7; G. uropod.

simple setae; inferior margin fringed with some small fine setae; merus superodistal corner with 3 long simple and 1 single sensory palmate seta, inferodistal angle with 1 biserrate robust seta; carpus triangular, inferodistal angle with 1 biserrate robust seta; propodus about 2 times as long as wide, inferodistal angle with 2 biserrate robust setae; dactylus bearing a small secondary unguis, inferior margin with cuticular scales. *Pereopod 7* (Fig. 1, F) basis about 5 times as long as greatest width, ischium, merus, carpus, and propodus inferior margins fringed with dense fine setae; ischium superior margin with 2 long simple setae; merus superodistal corner with 4 long simple setae, inferodistal angle with 1 biserrate robust seta; carpus distal angle with 5 biserrate robust setae; propodus about 2.7 times as long as wide; dactylus bearing a small secondary unguis, inferior margin with cuticular scales. *Uropodal rami* (Fig. 1, G) lamellar, subequal, extending well beyond pleotelson apex, fringed with dense small marginal setae. *Penial processes* (Fig. 2, A) smooth, unfused but close together, each about 2.4 as long as basal width**.** *Pleopod 1* (Fig. 2, B) exopod and endopod with 20 and 14 plumose marginal setae respectively, endopod shorter than exopod; sympodite mesial margin with 3 coupling hooks.

Pleopod 2 (Fig. 2, C) exopod and endopod subequal in length, with 22 and 18 plumose marginal setae respectively; *appendix masculina* arising basally, proximally slightly swollen, distally

narrowing, extending well beyond endopod by about 1.45 as long as endopod, most of surface bearing cuticular setules; sympodite mesial margin with 3 coupling hooks. Pleopod 3 (Fig. 2, D) exopod shorter than endopod, with 20 and 8 plumose marginal setae respectively; sympodite mesial margin with 3 coupling hooks. *Pleopod 4* (Fig. 2, E) both rami subequal in length, with transverse folds. *Pleopod 5* (Fig. 2, F) both rami with transverse folds, exopod with 3 scale patches (2 distally and 1 proximal to transverse suture), lateral margin with slender simple marginal setae.

Female: Similar to male with the exception of the sexual characters.

Remarks. *Paraimene tuberculata* Javed & Ahmed, 1988 is distinguished from all other species of the genus by pereonites 2–4 with 3 rounded tubercles, pereonites 5–7 with 3 rounded and 2 elongated tubercles, and a pleotelson with 7 elongated tubercles on dorsal surface. Whereas, *P. tumulus* and *P. charlesae* have no ornamentation on dorsal surface of pereonites 2–7, and *P. ibarzabalae* has low carinae on pereonites 5 and 6. *Paraimene tuberculata* is most similar to *P. danieli* from Cuba, as both species have a pleotelson with elongated tubercles. However, *P. danieli* is distinguishable by a pelon with 2 pairs of rounded tubercles on posterior margin and a pleotelson with 4 rounded and 4 elongated tubercles.

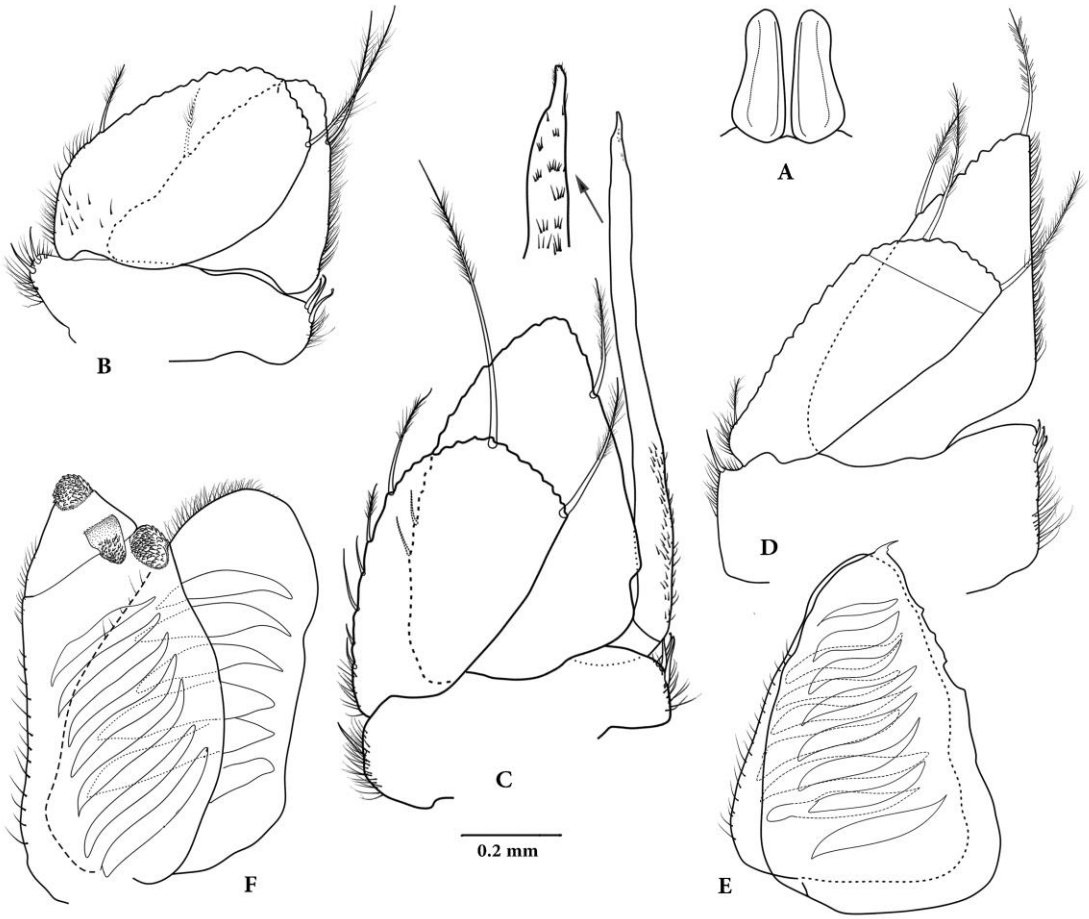

FIGURE 2. *Paraimene tuberculata* Javed & Ahmed, 1988: A. penes; B–F, pleopods 1– 5.

FIGURE 3. *Paraimene tuberculata* Javed & Ahmed, 1988: A. dorsal view; B. lateral view.

ACKNOWLEDGMENTS

This publication is part of a MSc. thesis conducted by Niloofar Arian at Shahrekord University. Dr. G. Mohammadi Kashani (Zanjan University) and anonymous referees would be appreciated for reviewing the manuscript and providing valuable comments and advises. The project was principally funded by the Iran National Science Foundation (INSF) under the grant no. 91048864 and was partly supported by the Shahrekord University.

LITERATURE CITED

Hobbins, C.C., Jones, D.A., 1993. New species of deepsea isopods from the Red Sea and North Western Indian Ocean: families Cirolanidae and Corallanidae. Senckenbergiana Maritima 23, 115-134.

Javed, W., Ahmed, R., 1988. Paraimene tuberculata, a new genus and species of Isopoda (Sphaeromatidae) from Karachi, Pakistan. Hydrobiologia 169(3), 371-378.

Kensley, B., Ortiz, M., Schotte, M., 1997. New records of marine Isopoda from Cuba (Crustacea: Peracarida). Proceedings of the Biological Society of Washington 110 (1), 74-98.

Khalaji-Pirbalouty, V., 2016. A new species of *Cymodoce* from Iran (Crustacea: Isopoda: Sphaeromatidae) with remarks on the status of *Cymodoce manorii* (Nooruddin, 1965) comb. nov. and
Cymodoce spinula Yousuf & Javed, 2001. Zootaxa 4084(2), 267-276.

Khalaji-Pirbalouty, V., 2018. Redescription of Cerceis biforamina Javed & Yousuf, 1996 from the Gulf of Oman (Crustacea: Isopoda: Sphaeromatidae) with remarks on the status of Cymodoce insolita Yousuf, 2011. Zootaxa 4472(2), 375-384.

Khalaji-pirbalouty, V., Naderloo, R., Keikhosravi, A., 2015. *Atarbolana makranensis*, a new species of Cirolanidae (Crustacea, Isopoda) from Makran, Iranian coast of the Gulf of Oman. ZooKeys 522, 129-140.

Ortiz, M., Winfield, I., Cházaro-Olvera, S., 2012. A new species of isopod (Isopoda: Flabellifera: Sphaeromatidae) from Cuba, with an identification key for the species of Paraimene. Revista Mexicana de Bioversidad 83, 976–982.

Iranian Journal of Animal Biosystematics (IJAB)
Vol.17, No.2, 137-146, 2021
DOI: 10.22067/ijab.2022.70768.1013

IJAB
ISSN: 1735-434X (print); 2423-4222 (online)

RESEARCH ARTICLE Open access

Identifying closely related species of the genus *Gammarus* (Crustacea, Amphipoda) using geometric morphometrics

Malekmohammad, K.[1], Khalaji-Pirbalouty, V.[1*], Oraei H.[1], Tabatabaei S. N.[2]

[1]*Department of Biology, Faculty of Basic Science, Shahrekord University, Shahrekord, Iran.*
[2]*Department of Biodiversity and Ecosystem Management, Environmental Sciences Research Center, Shahid Beheshti University, Tehran, Iran.*

(Received: *14 April 2021*; Accepted: 21 *October 2021*)

Abstract
Landmark-Based Geometric Morphometric Methods were used for the first time to quantitatively assess shape variations of the third epimeral plate (Ep3) of six *Gammarus* species (*G. lordeganensis, G. parthicus, G. pretzmanni, G. pseudosyriacus, Gammarus* sp1 and *Gammarus* sp2.) from five different localities in Iran. Two landmarks and 10 semi-landmarks on the posterior, anterior and inferior margins of the Ep3 were digitized on 78 adult male specimens. Shape diversity of samples and discrimination of all species were analyzed with Principal Components Analysis (PCA) and Canonical Variates Analysis (CVA). The results strongly supported the distinction in the posterior margin of Ep3 shape of the six species, while the inferior margin clearly showed similar morphological structure. A remarkable separation of *G. lordeganensis* as a distinct group from the rest of the species was found in both CVA and PCA analyses of anterior margin of Ep3 shape, while other species had overlaps with each other. Based on these findings, geometric morphometric data, could be used to identify diagnostic morphological traits. The shape of the Ep3 could be used as an appropriate character for separating closely related amphipod species of the genus *Gammarus*.

Key words: *Gammarus*, third epimeral plate, geometric morphometrics, shape variation

INTRODUCTION

Geometric morphometrics is an efficient technique to analyze the variability of the biological structures and specify the exact nature and position of the morphological shape differences since the late 1980s (Hennessy & Stringer, 2002; Rosas & Bastir, 2002). Landmark-based geometric morphometrics captures shape information and geometry of the object effectively to study population variations through a powerful and comprehensive statistical analysis (Rohlf, 1999; Cadrin, 2000). Also, semi-landmarks describe information on curves and outlines in this method (Gunz & Mitteroecker, 2013). Consequently, Geometric morphometrics provides not only large amounts of significant shape information that previously was unattainable through traditional morphometric approaches, but also is cost-effective, quick, and accurate. (Zeltdich *et al*. 2004, 2012; Grinang *et al.* 2019).

Corresponding Author: vkhalaji@sku.ac.ir
©2021 FERDOWSI UNIVERSITY OF MASHHAD, IRAN

THIS WORK IS LICENSED UNDER A CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENSE.

Crustaceans are a suitable group for using geometric morphometrics technique due to their tough integument and easily identifiable homologous landmarks (Rosenberg, 2002; Rufino *et al*. 2004; Riedlecker *et al.* 2009; Hampton *et al*. 2014). In this group, amphipods are a good model for the application of this methodology and the geometric study of the anatomical shapes (Curatolo *et al*. 2013). Among the various amphipod genera, *Gammarus* Fabricius, 1775 has the highest diversity and till now 18 valid species of genus *Gammarus* have been identified from the different freshwater regions of Iran (Zamanpoor *et al*. 2011). The Ep3 as a specific morphological characteristic of the genus *Gammarus* was selected for this analysis because this anatomical piece has various forms and consistent variations among different species, and it optimizes the taking of photographs and geometric morphometric analysis (Curatolo *et al.* 2013).

There are no studies to apply the geometric morphometrics technique as a powerful tool for examining the Ep3 shape variation and discrimination of different *Gammarus* species. So, this study aims to analyze the Ep3 shape variation as a diagnostic character using a geometric morphometric method for the first time in the genus *Gammarus* to discriminate different *Gammarus* species.

MATERIALA AND METHODS

The samples were collected from different five locations in Chaharmahal-Va-Bakhteyari, Markazi, and Fars provinces between 2016 and 2017. Characteristics of sampling areas are presented in Table 1 and figure 1. In the laboratory, the specimens were classified according to sex and maturity, and only mature and male *Gammarus* species were used in this study. Several keys to the *Gammarus* were used to identify these species (Karaman & Pinkster, 1977; Stock *et al*. 1998; Khalaji-Pirbalouty & Sari 2004, 2006).

Thirteen adult males *Gammarus* specimens from each populations were used for geometric morphometrics analysis. We examined a total of 78 Ep3s from all five locations in this study. Digital images of the Ep3s were captured using ZEISS Axiocam ERc 5s camera, mounted on a Carl ZEISS microscope. Anterior, posterior and inferior margins of Ep3s were separately analyzed through landmark-based morphometric methods. The digital images were processed with MakeFan6 software. MakeFan6 software was used to draw parallel lines at equal distances along a curve for placing semi-landmarks on digital images (Sheets, 2003; Curatolo *et al.* 2013).

Then the coordinates of two landmarks and 10 semi-landmarks were digitized separately on each of the anterior, posterior, and inferior margins of Ep3s digital images (Fig. 2A-C) using TpsDig2 v. 1.11 software (Rohlf, 2004; Curatolo *et al*. 2013). Subsequent analyses of the landmark data were conducted using Paleontological Statistics (PAST) software (Hammer *et al.* 2001). A generalized Procrustes analysis (GPA) was applied to remove the variations not related to the form such as position, orientation, rotation, and scale (Rohlf, 1999, Zelditch *et al*. 2004). Shape variation of samples was analyzed with Principal Components Analysis (PCA) followed by Canonical Variate Analysis (CVA) using the PAST v. 3.04 software for simplifying the description of differences between groups (Hammer *et al*. 2001). Also, PCA was performed to determine the variation explained by each principal component (PC). The total variability by principal component axis and canonical variate axis were included in figs. 3-5.

TABLE 1. Sampling locations of *Gammarus* species.

No	Locality	Coordinates	species
1	Charmahal va bakhteyari, Borujen, Bizhgerd spring	31°45'56.63"N, 1°10'19.76"E	*Gammarus* sp1.
2	Charmahal va bakhteyari, Farsan , Pir-Ghar spring	32°13'1.32"N, °32'38.66"E	*Gammarus* sp2.
3	Fars, Eghlid, Rasoul spring	30°53'27.61"N 52°40'18.31"E	*G. pseudosyriacus*
4	Charmahal va bakhteyari, lordegan, Barm spring	31°30'32.57"N 50°49'28.68"E	*G. lordeganensis*
5	Markazi, Shazand, Sarab abbas abad spring	33°54'37.78"N 49°25'29.82"E	*G. pretzmanni, G. parthicus*

RESULTS

The Geometric morphometrics analyses were conducted to obtain Ep3 shape variations between different species of genus *Gammarus*. The digital images of 78 third epimeral plates were compared using PCA and CVA.

The PCA performed on 13 Ep3 posterior margin shape coordinates of two landmarks and 10 semi-landmark from the six studied species resulted in 24 principal components, with the first two components explaining 94.78 % of the total variation (PC1 82.30 %, PC2 12.48 %) (Fig 3). To get a clearer picture of the segregation of species, CVA performed on the same dataset revealed that

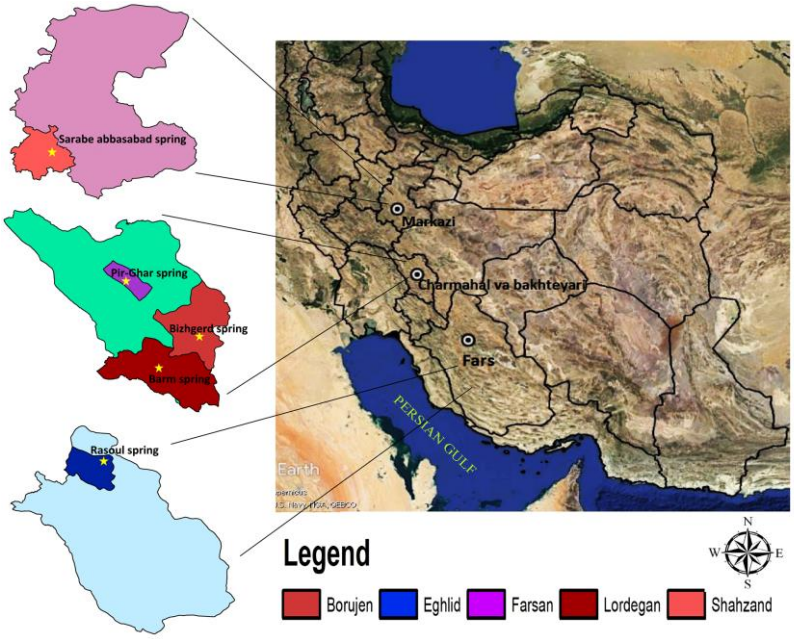

FIGURE 1. Map showing surveyed areas in Iran between 2016 and 2017.

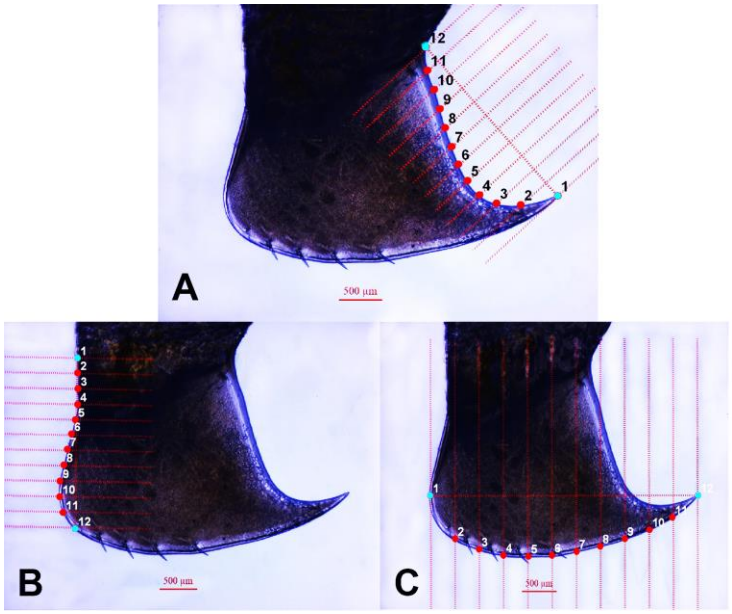

FIGURE 2. Position of the landmarks and semi-landmarks on the third epimeral plate for geometric morphometric analysis. The landmarks (points 1 and 12) and the semi-landmarks (points 2 to 11). (A) Posterior margin of third epimeral plate; (B) anterior margin of Ep3; (C) inferior margin of Ep3.

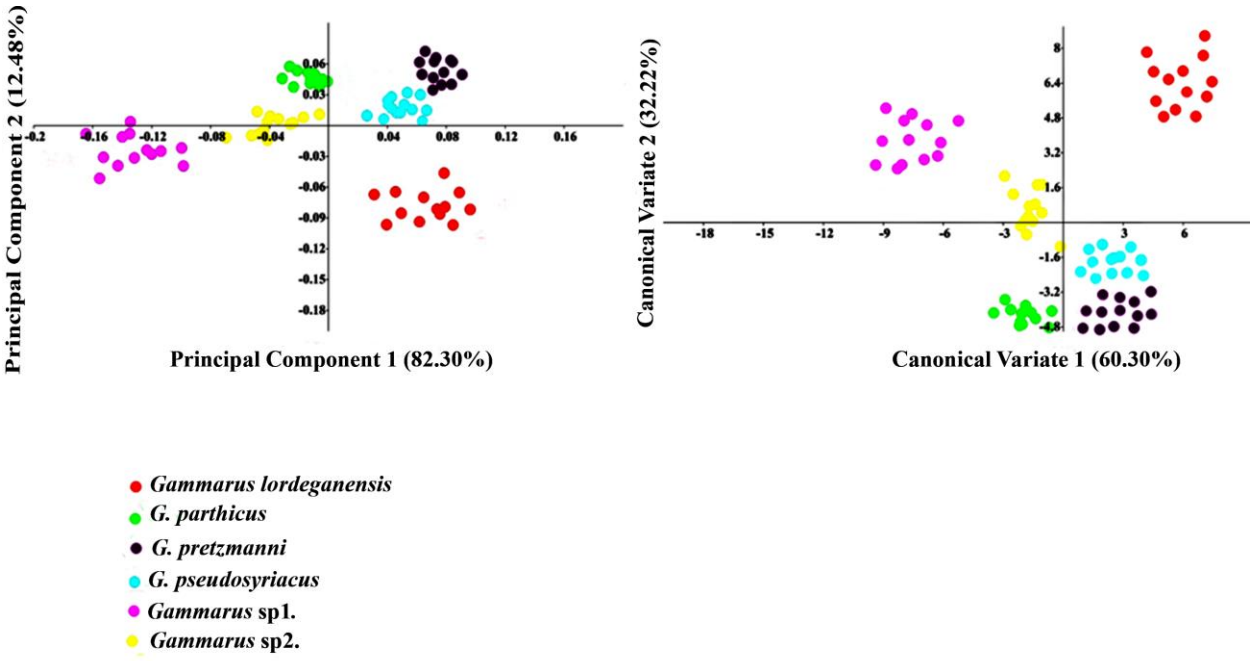

FIGURE 3. PCA and CVA showing significant difference in the shape of the posterior margin of Ep3 between different species of genus *Gammarus.*

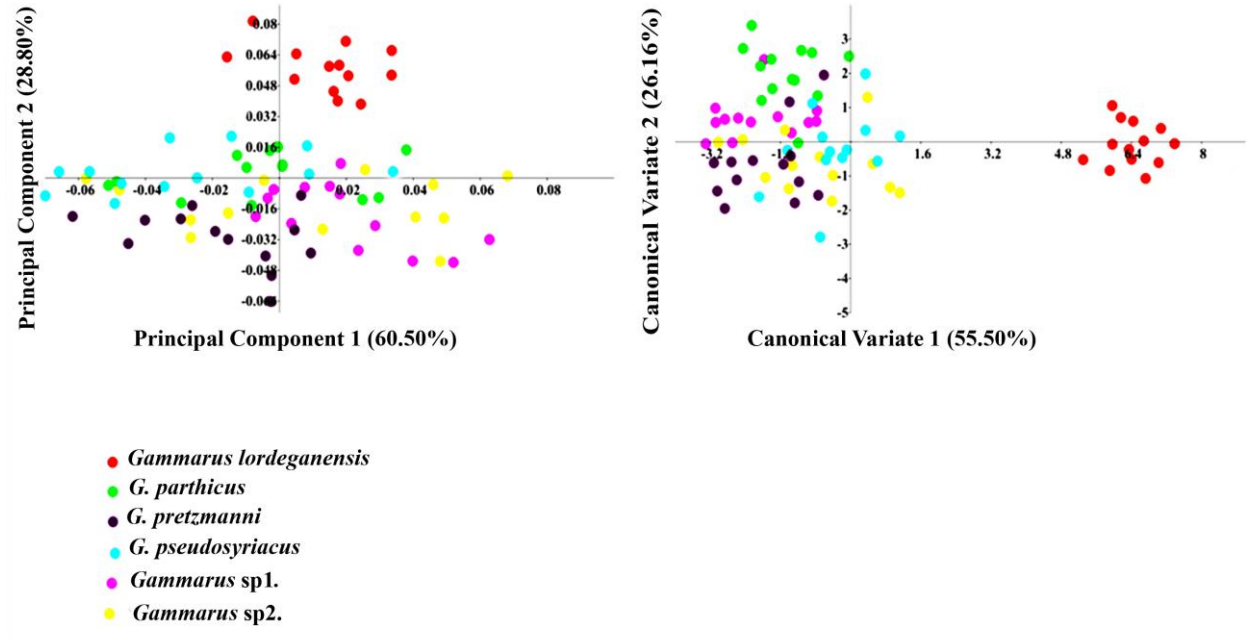

FIGURE 4. PCA and CVA showing insignificant variations in the shape of the anterior margin of Ep3 between different species of genus *Gammarus* except *G. lordeganensis* that is clearly distincted from the rest species.

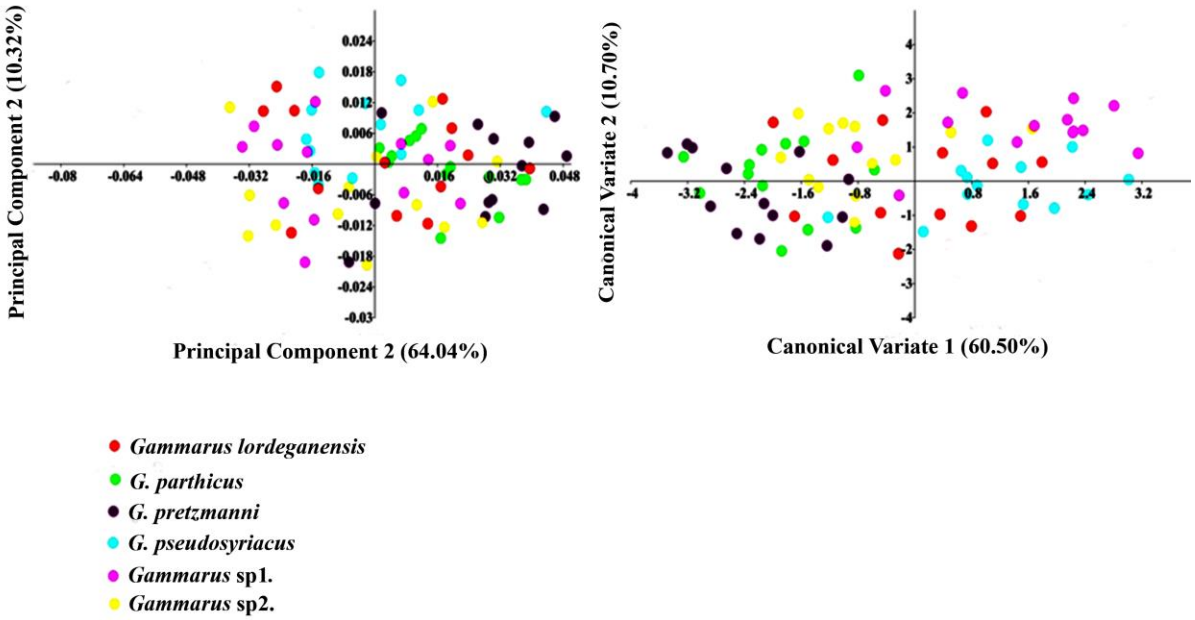

FIGURE 5. PCA and CVA showing insignificant variations in the shape of the inferior margin of Ep3 between different species of genus *Gammarus*.

the first two Canonical Variates (CV1 60.30 %, CV2 32.22 %) explained 92.52 % of the total variation (Fig. 3). So, significant morphometric differentiation in the posterior margin of Ep3 shape between different species of genus *Gammarus* were evident. These populations were completely separate and no overlap occurred among them. Over 88% of the anterior margin of Ep3 shape variation was described by principal components 1 and 2. PC1 and PC2 represent 60.5% and 28.8% of the variation, respectively (Fig. 4). This result is confirmed by CVA. The two first Canonical Variates (CV1 and CV2) explained 81.66 % of the total variation. The CV1 and CV2 explained 55.5% and 26.16% of the total variation between the groups, respectively (Fig 4). Results of the multivariate analyses clearly show that variation in the anterior margin of Ep3 shape is insignificant ($P>0.05$). There is only a significant difference between *G. lordeganensis* with other groups ($P<0.05$). A remarkable separation of *G. lordeganensis* as a distinct group from the rest of the species was found in both CVA and PCA analyses. Other species have overlap with each other.

PC1 and PC2 depict 64.04% and 10.32% of the variance in the shape of the Ep3 inferior margin between the groups, respectively. Results of PCA are supported by CVA. The first canonical axis and the second canonical axis explained 60.5% and 10.7% of the total variation between the groups, respectively (Fig. 5). Multivariate analyses clearly show that variation in the inferior margin of Ep3 shape is insignificant ($P>0.05$). All specimens were widely overlapped in the scatter plots.

DISCUSSION

This investigation is the first study to utilize the geometric morphometric technique to quantify Ep3s morphological variation for differentiation of *Gammarus* species. In our study, landmark-based geometric morphometric technique has been used to analyze differences in the posterior, anterior, and inferior margins of Ep3 shape of six *Gammarus* species and species discrimination. The results of the posterior margin of Ep3 shape analyses clearly showed that all species were completely distinct and different from each other. The posterior margins of the Ep3 shape of each species have different and various forms. The posterior margin of the Ep3 of *Gammarus* sp1 is very acuminate. The form of the Ep3 of the *G. lordeganensis* is convex posteromedially, while the shape of Ep3 of *G. parthicus* is weakly pointed posteroventrally. Ep3 shape of the *G. pretzmanni* has a

rectangular posteroventral corner. The posterodistal corner of *G. pseudosyriacus* Ep3 is slightly pointed and the Ep3 posterodistal corner of *Gammarus* sp2. is sharply pointed.

These results confirm previous studies on the Ep3 posterior margin shape of the genus *Bathyporeia* (Amphipoda, Bathyporeiidae). The Ep3 shape especially the postero-ventral tooth of the Ep3 was used as a diagnostic character to identify *Bathyporeia* species (Bellan-Santini, 1989; d'Udekem d'Acoz & Vader, 2005). The geometric morphometrics technique has also been conducted on the Ep3s of the Mediterranean *Bathyporeia guilliamsoniana* (Spence Bate, 1857) to assess intra-specific variations (Curatolo *et al*. 2013). It was found that *B. sunnivae* and *B. megalops* are morphotypes with *B. guilliamsoniana* and that the geometric morphometrics method helps to identify and discriminate species (Curatolo *et al*. 2013).

A considerable separation of *G. lordeganensis* as a distinct group from the rest of the species was observed in both CVA and PCA analyses of Ep3 anterior margin shape. The differentiation of *G. lordeganensis* from the other species is due to the different form of the anterior margin of Ep3 shape which is lobbed antero-inferiorly. Other species overlapped with each other due to having similar forms of the anterior margins of Ep3s which are not lobbed antero-inferiorly. Geometric morphometrics analysis of the inferior margin of Ep3 clearly shows that all specimens were entirely overlapped in the scatter plots due to their same morphological structure. These findings revealed that the shape of the third epimeral plate, particularly its posterior margin, is a better characteristic to diagnose species in the genus *Gammarus* (Fig 6).

This technique was used successfully in amphipods by Riedlecker *et al* (2009) on the second gnathopod propodus to discriminate native and non-native species of Caprellidae. Moreover, the geometric morphometric technique was effectively performed on species of the genus *Bathyporeiidae*, to assess the 'cryptic' variation in the Ep3 shape and species identification (Curatolo *et al*. 2013). In addition, this method was used in another group of amphipods by Layeghi *et al* (2019) for investigating of sexual dimorphism of taxonomic characters. In their study, sexual dimorphism of gnathopods 1 and 2 and uropod 3' shapes in *Parhyale darvishi* was successfully described using geometric morphometric method (Layeghi *et al.* 2019). Application of geometric morphometrics in the present study proved to be a very valuable tool for shape analysis, separating species and studying morphological variation in this group of amphipods. Ep3 shape makes amphipods, especially those of the genus *Gammarus* good models for identifying species using the geometric morphometrics method.

Several previous studies have confirmed the applicability of the geometric morphometric technique in crustaceans to identify species and morphological discrimination of various species, differences of anatomical shapes, revealing sexual dimorphism, shape and size variation, and identifying taxonomic key characteristics of species (Giri & Collins, 2004; Zimmermann *et al*. 2012; Ligios & Gliozzi, 2012; Bissaro *et al.* 2013; Marchiori *et al*. 2014; Diawol *et al*. 2015; Karanovic *et al*. 2016; Grinang *et al.* 2019). Research by Bagheri et al (2020) confirmed that geometric morphometric technique combined with statistical methods on the variation of carapace shape of blue swimming crab *Portunus segnis* (Forskal, 1775) along the Iranian coasts of the Persian Gulf and Oman Sea are useful in separating *Portunus* species (Bagheri *et al*. 2020). Recent studies on pattern of shape variation in isopods have received much attention. A landmark geometric morphometric approach was applied on dactylus shape of cymothoid isopods to investigate size algometry and shape variations. The results revealed that geometric morphometric method is an effective tool for uncovering complex patterns from simple outline shapes like dactyli (Baillie *et al.* 2019). Geometric morphometric method was able to show the seasonal shape variations in terrestrial isopod *Porcellionides pruinosus* as well as shape sexual dimorphism (Ismail, 2021). 2D landmark-based geometric morphometrics was effectively applied to study of interpopulation size of a Microcerberid Isopod and pleon sensilla, and male pleopod II endopodite shape variations. It was

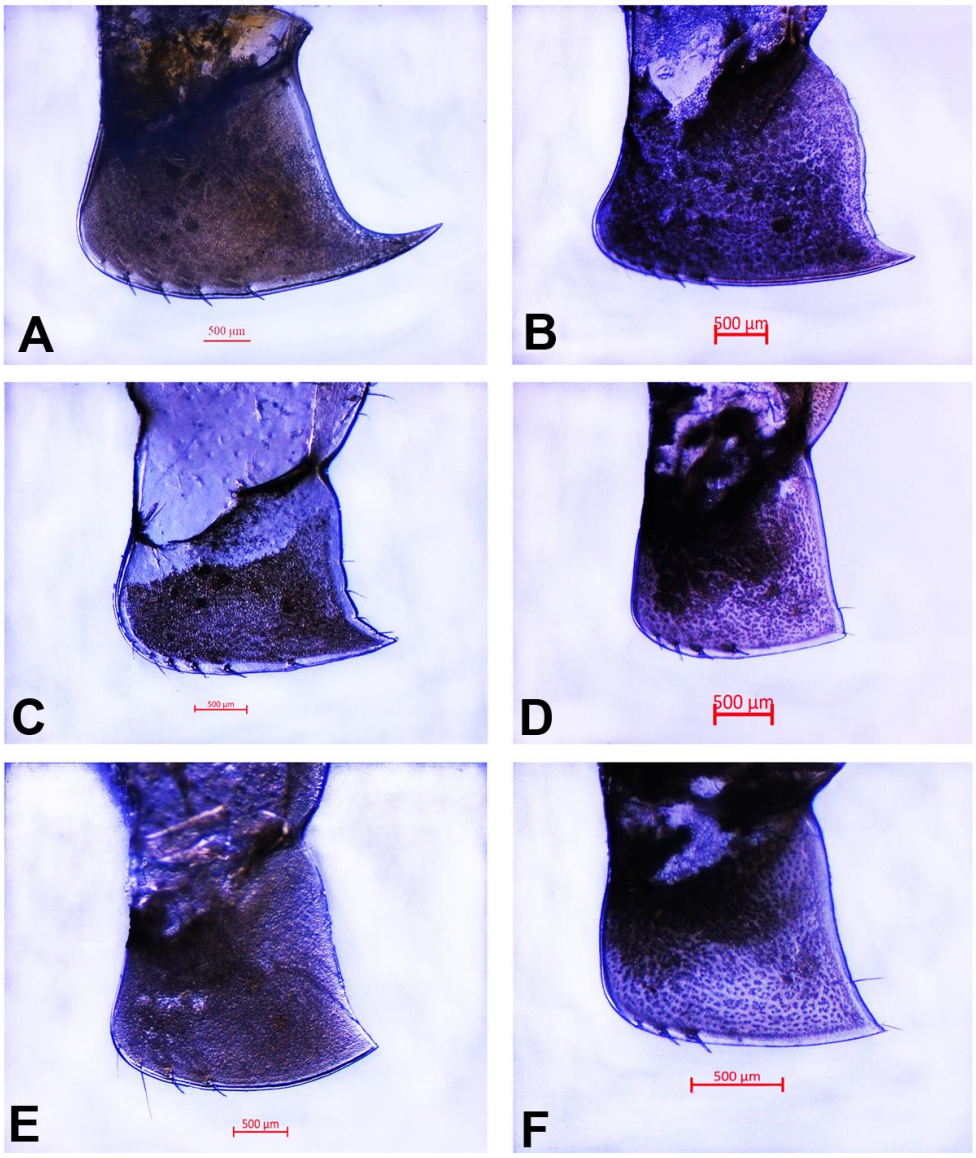

FIGURE 6. The third epimeral plates of different species of genus *Gammarus*. A. *Gammarus* sp1. B. *G. lordeganensis*, C. *Gammarus* sp2. D. *G. pretzmanni*, E. *G. pseudosyriacus*, F. *G. parthicus*

found that this method as a novel approach provides new insight to intrapopulation shape variations and ontogenetic variation (Kim *et al.* 2021).

All of the above studies in different groups of crustaceans as well as this research confirmed that 2D landmark-based geometric morphometric method is able to show shape variations and species discrimination

CONCLUSION

This study represents the first attempt to utilize the geometric morphometrics method for morphological analysis of the third epimeral plates in the genus *Gammarus*. Based on our geometric morphometrics analyses, Ep3 shape particularly its posterior margin across the species can be the best characteristic for species discrimination in the genus *Gammarus*. Thus, the geometric morphometrics method can be a precise tool for shape analysis of *Gammarus* species. Moreover,

Amphipods especially those of the genus *Gammarus* are appropriate for the geometric study of the anatomical shapes.

ACKNOELDGMENTS
We express our thanks to Sayyed Vahid Hosseini and Mohammad Khodabakhshi for assistance during the field trips. This study was financially supported by the Shahrekord University, Iran.

LITERATURE CITED

Bagheri, D., Farhadi, A., Bargahi, A., Nabipour, I., Sharif, S.R.A. and Jeffs, A.G., 2020. Morphometric and genetic characterizations of blue swimming crab *Portunus segnis*, (Forskal, 1775) along the Iranian coasts of the Persian Gulf and Oman Sea. Regional Studies in Marine Science, **34**, 101091.

Baillie, C., Welicky, R.L., Hadfield, K.A., Smit, N.J., Mariani, S. and Beck, R.M., 2019. Hooked on you: shape of attachment structures in cymothoid isopods reflects parasitic strategy. BMC evolutionary biology, 19, 1-11.

Bissaro, F.G., Gomes-Jr, J.L., Di Beneditto, A.P.M., 2013. Morphometric variation in the shape of the cephalothorax of shrimp *Xiphopenaeus kroyeri* on the east coast of Brazil. Journal of the Marine Biological Association of the United Kingdom **93,** 683–691.

Bellan-Santini, D., 1989. Genus *Bathyporeia*. In: S. RUFFO (ed.). The Amphipoda of the Mediterranean, 2, Gammaridea (Haustoriidae to Lysianassidae). Mémoires de l'institut Océanographique, Monaco **13,** 365–380.

Cadrin, S.X., 2000. Advances in morphometric identification of fishery stock. Review of Fish Biology and Fisheries **10**, 91–112.

Curatolo, T., Calvaruso, C., Galil, B.S., Brutto, S.L., 2013. Geometric morphometry supports a taxonomic revision of the Mediterranean *Bathyporeia guilliamsoniana* (Spence Bate, 1857) (Amphipoda, Bathyporeiidae). Crustaceana **86,** 820–828.

D'udekem D'acoz, C., Echchaoui, H.M., Menioui, M., 2005. Further Observations on North African and South Iberian *Bathyporeia* (Crustacea, Amphipoda), With the Description of a New Species. Contributions to Zoology **74,** 279–300.

Diawol, V.P., Giri, F., Collins, P.A., 2015. Shape and size variations of *Aegla uruguayana* (Anomura, Aeglidae) under laboratory conditions: A geometric morphometric approach to the growth. Iheringia. Série Zoologia **105,** 76–83.

Grinang, J., Das, I., Ng, P.K.L., 2019. Geometric morphometric analysis in female freshwater crabs of Sarawak (Borneo) permits addressing taxonomy-related problems. PeerJ **7,** e6205.

Gunz, P., Mitteroecker, P., 2013. Semilandmarks: A method for quantifying curves and surfaces. Hystrix **24,** 103–109.

Giri, F., Collins, P.A., 2004. A geometric morphometric analysis of two sympatric species of the family Aeglidae (Crustacea, Decapoda, Anomura) from the La Plata basin. Italian Journal of Zoology **71,** 85–88.

Hampton, K.R., Hopkins, M.J., McNamara, J.C., Thurman, C.L., 2014. Intraspecific variation in carapace morphology among fiddler crabs (genus *Uca*) from the Atlantic coast of Brazil. Aquatic Biology **20,** 53–67.

Hennessy, R.J., Stringer, C.B., 2002. Geometric morphometric study of the regional variation of modern human craniofacial form. American Journal of Physical Anthropology **117,** 37– 48.

Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001. PAST: paleontological statistics software package for education and data analysis. Palaeontologia Electronica **4**, 1–9.

Ismail, T.G., 2021. Seasonal shape variations, ontogenetic shape changes, and sexual dimorphism in a population of land isopod *Porcellionides pruinosus*: a geometric morphometric study. The Journal of Basic and Applied Zoology, **82**, 1-15.

Karanovic, T., Djurakic, M., Eberhard, S.M. 2016. Cryptic species or inadequate taxonomy? Implementation of 2D geometric morphometrics based on integumental organs as landmarks for delimitation and description of copepod taxa. Systematic Biology **65,** 304–327

Karaman, G.S., Pinkster, S., 1977. Freshwater *Gammarus* species from Europe, North Africa and adjacent regions of Asia (Crustacea - Amphipoda) part I. Gammarus pulex-group and related species. Bijdragen Tot De Dierkunde **47,** 1–97.

Khalaji-Pirbalouty, V., Sari, A., 2004. Biogeography of amphipods (Crustacea: Amphipoda: Gammaridae) from the central Zagros Mountains, Iran, with descriptions of two new species. Journal of Natural History **38,** 2425–2445.

Khalaji-Pirbalouty, V., Sari, A., 2006. Description of *Gammarus balutchi* spec. nov. (Amphipoda: Gammaridae) from Iran, based on light and electron microscopy. Zoologische Mededelingen Leiden **80,** 91–100.

Kim, J., Kim, J., Lee, W. and Karanovic, I., 2021. The first insight into the patterns of size and shape variation of a microcerberid isopod. Water **13**, 515-532.

Layeghi, Y., Bagherian Yazdi, A.A. and Momtazi, F., 2019. Sexual dimorphism of gnathopods 1 and 2 and uropod 3'shapes in *Parhyale darvishi* (Momtazi and Maghsoudlou, 2016) based on geometric morphometric methods. Applied Biology **33**, 111-122.

Ligios, S., Gliozzi, E., 2012. The genus *Cyprideis* Jones, 1857 (Crustacea, Ostracoda) in the Neogene of Italy: A geometric morphometric approach. Revue de micropaléontologie **55,** 171–207.

Marchiori, A.B., Bartholomei-Santos, M.L., Santos, S., 2014. Intraspecific variation in *Aegla longirostri* (Crustacea: Decapoda: Anomura) revealed by geometric morphometrics: evidence for ongoing speciation? Biological Journal of the Linnean Society **112,** 31–39.

Riedlecker, E., Ashton, G., Ruiz, G., 2009. Geometric morphometric analysis discriminates native and non-native species of Caprellidae in Western North America. Journal of the Marine Biological Association of the United Kingdom **89,** 535–542.

Rohlf, F.J., 1999. Shape statistics: procrustes superimpositions and tangent spaces. Journal of Classification **16,** 197–223

Rohlf, F.J., 2004. TpsDig. Stony Brook, NY: Department of Ecology and Evolution, State University of New York. Available at http://life.bio.sunysb.edu/morph.

Rosenberg, M.S., 2002. Fiddler crab claw shape variation: a geometric morphometric analysis across the genus *Uca* (Crustacea: Brachyura: Ocypodidae). Biological Journal of the Linnean Society **75,** 147–162.

Rosas, A., Bastir, M., 2002. Thin-plate spline analysis of allometry and sexual dimorphism in the human craniofacial complex. American Journal of Physical Anthropology **117,** 236–245.

Rufino, M., Abelló, P., Yule, A.B., 2004. Male and female carapace shape differences in Liocarcinus depurator (Decapoda, Brachyura): an application of geometric morphometric analysis to crustaceans. Italian Journal of Zoology **71,** 79–83.

Sheets, H.D., 2003. MakeFan6 software, IMP software series, available online at http://www. canisius.edu/sheets/morphsoft.html/, Accessed 15 March. 2016.

Stock, J.H., Mirzajani, A.R., Vonk, R., Naderi, S., Kiabi, B. 1998. Limnic and brackish water Amphipoda from Iran. Beaufortia **48,** 173–234.

Zamanpoore, M., Grabowski, M., Poeckl, M., Schiemer, F., 2011. Taxonomic review of freshwater Gammarus (Crustacea: Amphipoda) from Iran. ZooTaxa **3140,** 1–14.

Zelditch, M.L., Swiderski, D.L., Sheets, D.H., Fink, W.L., 2004. Geometric morphometrics for biologists: A primer. Amsterdam: Elsevier Academic Press, London.

Zelditch, M.L., Swiderski, D.L., Sheets, H.D., 2012. Geometric Morphometrics for biologists: a primer. Elsevier Academic Press, London.

Zimmermann, G., Bosc, P., Valade, P., Cornette, R., Améziane, N., Debat, V., 2012. Geometric morphometrics of carapace of *Macrobrachium australe* (Crustacea: Palaemonidae) from Reunion Island. Acta Zoologica **93,** 492–500.

Iranian Journal of Animal Biosystematics (IJAB)
Vol.17, No.2, 147-155, 2021
DOI: 10.22067/ijab.2022.69956.1014

IJAB
ISSN: 1735-434X (print); 2423-4222 (online)

RESEARCH ARTICLE Open access

Evaluation ecological niche between *Platyceps rhodorachis* and *P. karelini* (Serpentes: Colubridae) in Iran

Seyed Hassan Moradi[1], Eskandar Rastegar-Pouyani[1,*], Seyyed Saeed Hosseinian Yousefkhani[2,3], Jamil Zargan[4]

[1]*Department of Biology, Faculty of Science, Hakim Sabzevari University, Sabzevar, Iran*
[2]*Department of Animal Science, School of Biology, Damghan University, Damghan, Iran*
[3]*Institute of Biological Science, School of Biology, Damghan University, Damghan, Iran*
[4]*Faculty of Basic Science, Imam Hossien comprehensive university, Tehran, Iran*

(Received: *14 June 2021*; Accepted: 30 *December 2021*)

Abstract
Platyceps rhodorachis (JAN, 1863) and *P. karelini* (BRANDT, 1838) are both members of the *P. rhodorachis* complex species, which is widely distributed in Iran and includes many local populations in the country. These two species are molecularly and to some extent morphologically valid. However, hybrids between *P. karelini* and *P. rhodorachis* have been described, but so far their ecological differentiation have not been evaluated. In this study, the ecological niche models was predicted for these two members of the *P. rhodorachis* complex using bioclimatic layers and geographical coordinates. Possible habitat models show the distribution density of these two species in the southern (including some islands in the Persian Gulf) regions, and some areas in northeastern Iran. The results of niche similarity tests (identity and niche overlap tests) based on the criteria of environmental species, in order to assess the degree of species differentiation, indicate the degree of differentiation between these two sister species and raises the possibility of a hybrid belt in southern Iran.

Key words: *Platyceps,* Common Cliff Racer, Ecological niche modeling, Niche differentiation, Snake.

INTRODUCTION

The issue of species delimitation has become a contentious issue over the last half century (De Queiroz, 2007). Biologists believe that the delimitation of species depends on the identification of biological diversity at the species level (Carstens *et al.,* 2013). Numerous operational techniques based on molecular or phenotypic data have been designed to aid the understanding of biological species, however in some cases post- or pre-zygotic barriers are broken (Mayr 1978; Tobias *et al.,* 2010). Because selection acts on phenotypes and any mutualistic units, the concept of ecological species is proposed as a solution to describe species boundaries (Van Valen, 1976). Interest in describing, understanding, and predicting geographic and environmental distributions of species is very old (Grinnell, 1917; Wallace, 2016). According to Dobson (1995), "Biodiversity is the diversity and variability of living organisms and ecological complexes and the sum of the different types of organisms that inherit an area". Understanding how climate change affects the distribution of different animal species has always been one of the main challenges for conservation biologists (Root

Corresponding Author: rastegarpouyani45@gmail.com
©2021 FERDOWSI UNIVERSITY OF MASHHAD, IRAN

THIS WORK IS LICENSED UNDER A CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENSE.

& Schneider, 2006). A set of techniques commonly called species distribution model (SDM) (Guisan & Zimmermann, 2000; Guisan & Thuiller, 2005), and the related Ecological Niche Modeling has experienced significant growth over the past decade and serves as one of the fundamental strategies for determining potential species habitats (Peterson, 2006). The fundamental importance of identifying species distribution areas as a biogeographical and ecological concept and the myriad applications that can be used through these methods explain the growing interest in this field (Peterson *et al*., 2011). Bioclimatic envelope models is one of the neutral terms that has been developed to use these models (Araújo & Peterson, 2012).

The concept of ecological species, as mentioned before, has a lot to do with the climate and ecosystem of the species distribution region, so the study of species biodiversity in Iran is very important due to the existence of different formations in geological, climatic and soil arrangement (Agapow *et al*., 2004; Jowkar *et al*., 2016). Habitat loss is the greatest threat to reptile and amphibian populations, and climate change due to human activities is exacerbating it (Fisher *et al*., 1968; Devos & Wiles, 1973; Ashrafzadeh *et al*., 2019). Detection of the protective status of reptiles is faced with a lack of information for various reasons. Modern computer processing and modeling methods with the integration of mechanical models and distribution data of the target species make it possible to gain a better understanding of species limiting factors(Root & Schneider, 2006; Yousefkhani, 2019; Ghelichy Salakh *et al*., 2020). The MaxEnt principle is one of the most popular methods for modeling species distribution, which is based on ecosystem data and species presence area. The high power of presence prediction, low cost and ease of use have attracted many researchers to use the method (Hijmans *et al*., 2005; Warren & Seifert, 2011).

Colubrid Snakes make up about two-thirds of the world's snakes (Dessauer, 1967). Racer snakes of the genus *Platyceps* distributed from SW Croatia to Central Asia (Kyrgyzstan), Himalayas (probably westernmost Nepal) and parts of North and Northeast Africa (Schaetti *et al*., 2014; Sinaiko *et al*., 2018). So far, 29 species of this genus have been described, of which six species are distributed in Iran (Schaetti *et al*., 2014; Rajabizadeh, 2018). Among Iranian representatives, *P. karelini*, *P.ventromaculatus* and *P. rhodorachis* are defined as complex species (Schätti & Mccarthy, 2004). *Platyceps ventromaculatus* (Gray, 1834) is somewhat isolated from *P. rhodorachis* complex in terms of distribution range, but the separation of the distribution range of the other two species has not been considered so far (Yildiz, 2011). All research on *P. rhodorachis* complex has so far focused on taxonomic and phenotypic studies and no study has been done on the extent of distribution and habitat suitability (Perry, 1985; Khan, 1997; Schätti & McCarthy, 2004; Schaetti *et al*., 2014; Sinaiko *et al*., 2018).

In this study, we examined the current distribution of two species (*P .rhodorachis* and *P. karelini*) using ecological niche criterion, to examine the degree of ecological differentiation between the two sister species. Also, modeling was used to predict the potential distribution of both species in Iran and the degree of niche space overlap between them. Finally, it is predicted that despite the overlap in the distribution range, the focus area of these two species are different from each other and we will discuss the effect of non-living environmental factors (temperature, precipitation, altitude and slope) on the extent of this separation. Also, we will determine the potential hybridization region by using niche modeling.

MATERIAL AND METHODS

More of the occurrence records are related to the field studies of the research team of Imam Hossein University and Hakim Sabzevari University between 2003 and 2008, which include 126 points. Otherwise, the rest are obtained from the literatures (Schätti *et al*., 2012; Schaetti *et al*., 2014). In total, 158 records of presence belonging to both species (50 records for *P. karelini* and 108 records for *P. rhodorachis*) (Appendix 1) were used in this study. The current 19 bioclimatic variables were loaded from WorldClim (www.worldclim.org) with an accuracy of 30 seconds and used to model both

species (Fick & Hijmans, 2017). The slope layer was created using ArcGIS 10.6.1 from the original altitude layer in 30 arc-second resolution and all layers were cut using ArcGIS 10.6.1 for Iran. Correlation matrix for bioclimatic variables was obtained using ENMtools v1.3 software and Pearson correlation coefficient was obtained using ENMTools V 1.3 software and variables with Pearson correlation coefficient higher than 0.75 were removed due to high correlation. (Benesty *et al*., 2009; Warren *et al*., 2010). Finally, three bioclimatic variables and two geographical variables were selected for analysis as follows: BIO6 (Min temperature of coldest month of the year (°C), BIO11 (Mean temperature of coldest quarter of the year (°C), BIO18 (Precipitation of warmest quarter of the year (mm), altitude and slope.

The species potential distribution model was implemented using the maximum entropy method in Maxent v3.4.4 (Elith *et al*., 2011). The ENMeval package in R v4.0.4 was used to obtain the optimal Maxent settings (Muscarella *et al*., 2014). Maximum 500 iterations, convergence threshold was set to the lowest (0.01) due to the wide range of species distribution, regularization multiplier 0.5 and 15 replicates with cross-validation method (Heidari, 2019). The area under receiver operating characteristic curve (AUC) were considered as accuracy criteria between 0 and 1, the amount of lower than 0.5 represents the random model, and a value closer to 1.0 shows high accuracy of the predicted model (Townsend Peterson *et al*., 2007).

To measure habitat differentiation between species, niche overlap and identity test were measured using ASCII files on ENMTools 1.3 (Nakazato *et al*., 2010). In these tests, two required criteria were measured, namely Schoener's D (Giannini & Goloboff, 2010), and Hellinger's-based I (Schoener & Gorman, 1968). Schoener's D calculates the suitable range based on the probability of occupied grid cells, whereas Hellinger's-based I refers to the probability of ecological niche models (Warren *et al*., 2010). Identity tests were conducted for each species based on 100 pseudoreplicates. Finally, Schoener's D and Hellinger's-based I indices of true calculated niche were compared with the null distribution of 100 pseudoreplicates (Warren *et al*., 2008; Gholipur, 2018). These indices ranged between 0 (no overlap) and 1 (complete overlap).

RESULTS

Ecological niche modeling results

Based on the literature and records, the distribution range of both species; *P. karelini* and *P. rhodorachis* overlaps, and there are reports of hybridization among their different populations (Туниев, 2000; Schätti *et al*., 2012). To evaluate the performance of the Maxent model, the area under the curve (AUC) was used. The area under the curve (AUC) is a quantitative indicator to show the efficiency and accuracy of the model prediction (Elith *et al*., 2006). The AUC values for *P. karelini* and *P. rhodorachis* are 0.812±0.166 (mean ± standard deviation) and 0.845±0.255 respectively, which is acceptable considering the occurrence records. The potential distribution model for *P. karelini* shows the high distribution suitability of this species throughout Iran, except the Zagros and northwestern heights of the country; The main distribution for *P. karelini* is in the southeastern in Sistan and Baluchestan Province and to some extent eastern and northeastern of Iran (Figure 1: A). For *P. rhodorachis*, the Niche distribution model shows a high density in the southern coast strip of Iran, Khuzestan and western Golestan province (Figure 1: B); both species are mainly distributed in coastal strip in the south. BIO6 (Min Temperature of Coldest Month) in *P. karelini* and altitude in *P. rhodorachis* are the most important factors determining the forecasting model (Table 1).

Niche overlap between *P. karelini* and *P. rhodorachis* indicated that their niche similarity was upper than 0.5 (Hellinger's-based I = 0.89 and Schoener's D = 0.65) however, due to the hybridization between these two sister species, this amount is a significant difference. Identity test showed the expected ecological niche interference between two sister species. The results are visible in the diagram in Figure 2. The results of the identity test (i = 0.89, D = 0.65) show the relative separation of the distribution for these two species, this separation can also be seen in the range of the obtained prediction model (Figure 1).

TABLE 1. Permutation importance and Percent contribution of variables used in MaxEnt model for two species of *P. karelini* and *P. rhodorachis*.

Variables	Description of variables	Percent contribution		Permutation importance	
		P. karelini	*P. rhodorachis*	*P. karelini*	*P. rhodorachis*
BIO6	Min Temperature of Coldest Month of the year (°C)	51.8	20.00	37.4	7.30
BIO11	Mean Temperature of Coldest Quarter of the year (°C)	19.7	32.4	45.7	32.1
BIO18	Precipitation of Warmest Quarter of the year (mm)	0.40	0.50	0.00	1.70
Altitude	Height above sea level (m)	26.5	45.6	16.9	58.8
Slope	Land slope	1.60	1.50	0.00	0.00

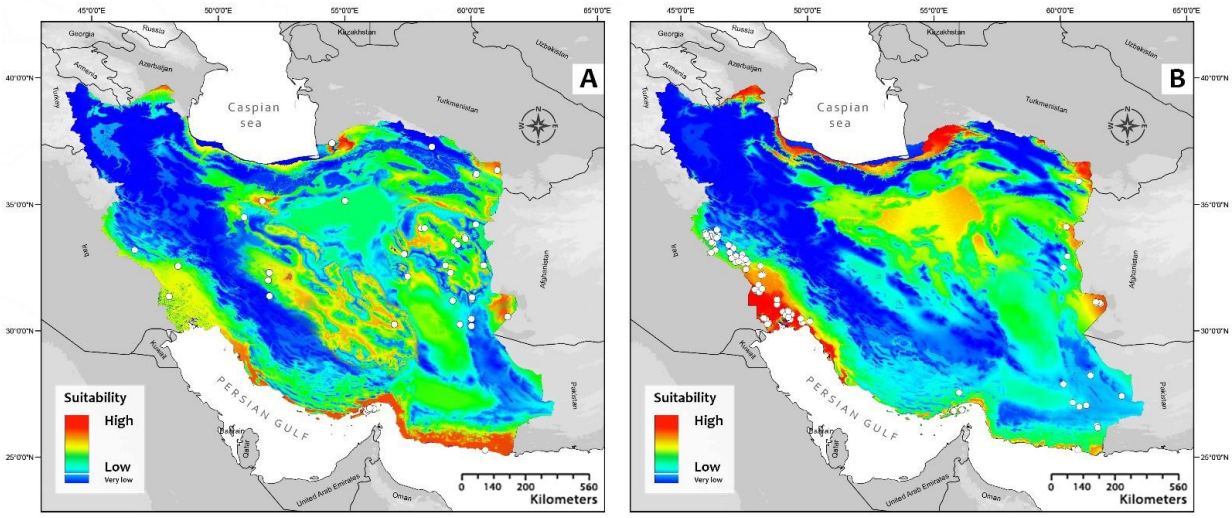

FIGURE 1. Predicted potential distributions of *P. karelini* (A) and *P. rhodorachis* (B) using MaxEnt, Habitat suitability is shown on the map using a gradient and the white circles indicate specimens collecting sites.

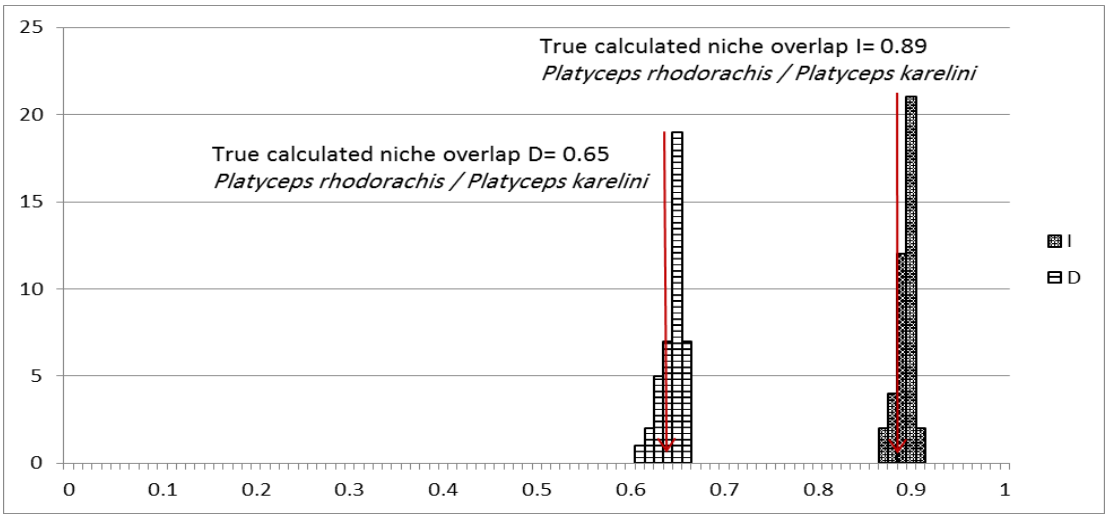

FIGURE 2. Results of the identity test. Red arrows refer to the actual niche overlap as calculated by ENMTools (D and I). The bars (with two different patterns) are calculated by replicates with identity test mode.

DISCUSSION

Review of recent papers suggests that ecological theory is rarely explicitly considered (Austin 2007). Species distribution models (SDMs), which are commonly used to obtain hypotheses about the distribution or realization of species potential, has grown significantly since 1995, when this field came into focus. Current linkages between SDM practice and ecological theory are often weak, hindering progress. What is clear is that the use of SDM is essential for applications such as bioprotection planning and uncertainty in SDMs arises from data deficiencies (eg, samples of species occurrences that are small, biased or lacking absences) (Barry & Elith, 2006). Although the conservation status of Colubrid snakes has not been studied due to their widespread distribution and the least concern for this group has been predicted, but due to the overlap of the distribution range in the most suitable habitats of this group with human activities, this group may considered as "endangered" in the not too distant future (Petros Lymberakis *et al*., 2009). Recently, new studies have been performed on the *P. rhodorachis* complex and this group was revised and new species recommended (Perry, 2012; Schaetti *et al*., 2014). *Platyceps rhodorachis* (Jan, 1865) has the highest range of distribution in this genus and overlaps with most congeners and there are significant cases of crossbreeding with them, especially with *P. karelini* (Khan, 1997; Туниев, 2000; Sinaiko *et al*., 2018). Based on the literature and records, the distribution range of both species; *P. karelini* and *P. rhodorachis* overlaps, and there are reports of hybridization among their different populations (Туниев, 2000; Schätti *et al*., 2012), our results confirm this and the range of distribution obtained is very similar to reports and literatures. *Platyceps karelini* (BRANDT, 1838) has three subspecies, all three of which are distributed in Iran. There is no report in the literature on the distribution of this species in southern Iran and no comprehensive study of the distribution of this species has been done so far in Iran. The available studies are limited to the initial faunistic studies and checklists of snakes in this area, which due to the observed variations in this genus, there is a possibility of misidentification of the species (Rastegar-Pouyani *et al*., 2011). Comparison of ecological niches among different populations can show the niche differentiation and also detect distinct groups along the whole distribution range within the species complex (Cayuela *et al*., 2009; Guisan *et al*., 2013). The predicted distribution pattern in both species has a high overlap with their reported distribution range, however areas of the predicted model are reported for the first time. In *P. karelini*, Ardabil and Hormozgan provinces, and especially Sistan and Baluchestan, have been identified as compatible areas for the distribution of this species (Figure 1: A). In *P. rhodorachis*, Ardabil province and southwest of Khuzestan province have been identified as areas with high compatibility for distribution that Ardabil province had not been reported before (Figure 1: B). Altitude is the most important factor determining the likely distribution of *P. rhodorachis*, while in *P. karelini* the minimum temperature of the coldest month has the greatest effect on the prediction model (Table 1).

In the coastal areas of Sistan and Baluchestan province, the temperature is always above zero and due to the high evaporation volume is always sultry and higher than the temperature of the province. The same situation is observed in the coastal areas of Hormozgan province, but due to less monsoon winds, its intensity has decreased. These conditions justify the desirability of *P. karelini* distribution in these areas (Figure 1) (Chaichitehrani & Allahdadi, 2018). *Platyceps rhodorachis* distribution prediction model indicates the high importance of altitude factor, according to the prediction model, this species has the highest distribution merit at low altitudes and close to sea level. The precipitation seasonality in Hormozgan province affects the type of vegetation in the region (Abolhasan & Maryam, 2013; Nohegar *et al*., 2015), and this issue directly affects the distribution of this species in this area. Probably the distribution of this species in this area is seasonal and reports of hybrids between *P. rhodorachis* and *P. karelini* in this area confirms this argument (Schätti *et al*., 2012).

The general rule is that the new application of ecological niche modeling greatly facilitates species identification, and thus helps to identify additional species diversity and newer species

speciation events, it also provides a way to identify the possible hybridization region between the two sister species and to explain overlapping distribution patterns. We expect this approach to create new opportunities to identify potential distribution areas and protected areas.

ACKNOWLEDGMENTS
It is an honor to thank Imam Hussein University for providing the coordinates for collecting snakes in this study.

LITERATURE CITED

Abolhasan, G., N. Maryam. Case study: Enso events, rainfall variability and the potential of soi for the seasonal precipitation predictions in Iran.

Agapow, P.-M., O. R. Bininda-Emonds, K. A. Crandall, J. L. Gittleman, G. M. Mace, J. C. Marshall and A. Purvis, 2004. The impact of species concept on biodiversity studies. The Quarterly Review of Biology 79, 161-179.

Araújo, M. B., A. T. Peterson, 2012. Uses and misuses of bioclimatic envelope modeling. Ecology 93, 1527-1539.

Ashrafzadeh, M. R., A. A. Naghipour, M. Haidarian, S. Kusza, D. S. Pilliod, 2019. Effects of climate change on habitat and connectivity for populations of a vulnerable, endemic salamander in iran. Global Ecology Conservation 19, E00637.

Austin, M, 2007. Species distribution models and ecological theory: A critical assessment and some possible new approaches. Ecological Modelling 200, 1-19.

Barry, S., J. Elith, 2006. Error and uncertainty in habitat models. Journal of Applied Ecology 43, 413-423.

Benesty, J., J. Chen, Y. Huang, I. Cohen, 2009. Pearson correlation coefficient. Noise Reduction in Speech Processing, Springer 1-4.

Carstens, B. C., T. A. Pelletier, N. M. Reid, J. D. Satler, 2013. How to fail at species delimitation. Molecular Ecology 22, 4369-4383.

Cayuela, L., D. Golicher, A. Newton, M. Kolb, F. De Alburquerque, E. Arets, J. Alkemade, A. Pérez, 2009. Species distribution modeling in the tropics: problems, potentialities, and the role of biological data for effective species conservation. Tropical Conservation Science 2, 319-352.

Chaichitehrani, N, M. N. Allahdadi, 2018. Overview of wind climatology for the gulf of oman and the northern arabian sea. American Journal of Fluid Dynamics 8, 1-9.

De Queiroz, K, 2007. Species concepts and species delimitation. Systematic Biology 56, 879-886.

Dessauer, H. C, 1967. Molecular approach to the taxonomy of Colubrid snakes. Herpetologica 23, 148-155.

Devos, A, J. Wiles, 1973. International experience with national parks and related reserves. University of Waterloo, Faculty Of Environmental Studies.

Dobson, A. P, 1996. Conservation And Biodiversity. Wh Freeman And Co.

Elith, J., C. H. Graham, R. P. Anderson, M. Dudík, S. Ferrier, A. Guisan, R. J. Hijmans, F. Huettmann, J. R. Leathwick, A. Lehmann, 2006. Novel methods improve prediction of species' distributions from occurrence data. Ecography 29, 129-151.

Elith, J., S. J. Phillips, T. Hastie, M. Dudík, Y. E. Chee, C. J. Yates, 2011. A statistical explanation of maxent for ecologists. Diversity Distributions 17, 43-57.

Fick, S. E, R. J. Hijmans, 2017. Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37, 4302-4315.

Fisher, W. B., J. A. Boyle, J. A. Boyle, I. Gershevitch, E. Yarshater, R. N. Frye, 1968. The cambridge history of Iran. Cambridge University Press.

Ghelichy Salakh, A., H. Kami, M. Rajabizadeh, 2020. Modeling the species distribution of Caucasian Pit Viper (*Gloydius halys caucasicus*) (Viperidae: Crotalinae) under the influence of climate change. Caspian Journal of Environmental Sciences 18, 217-226.

Gholipur, B, 2018. Statistical errors may taint as many as half of mouse studies, Tillgänglig.

Giannini, N. P, P. A. Goloboff, 2010. Delayed-response phylogenetic correlation: An optimization-based method to test covariation of continuous characters. Evolution: International Journal of Organic Evolution 64, 1885-1898.

Grinnell, J, 1917. Field tests of theories concerning distributional control. The American Naturalist 51, 115-128.

Guisan, A, W. Thuiller, 2005. Predicting species distribution: Offering more than simple habitat models. Ecology Letters 8, 993-1009.

Guisan, A., R. Tingley, J. B. Baumgartner, I. Naujokaitis-Lewis, P. R. Sutcliffe, A. I. Tulloch, T. J. Regan, L. Brotons, E. Mcdonald-Madden, C. Mantyka-Pringle, 2013. Predicting species distributions for conservation decisions. Ecology Letters 16, 1424-1435.

Guisan, A, N. E. Zimmermann, 2000. Predictive habitat distribution models in ecology. Ecological Modelling 135, 147-186.

Heidari, N, 2019. Ecological niche differentiation between *Acanthodactylus micropholis* and *A. Khamirensis* (Sauria: Lacertidae) in southern Iran. Zoologia 36.

Hijmans, R. J., S. E. Cameron, J. L. Parra, P. G. Jones, A. Jarvis, 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology: A Journal of The Royal Meteorological Society 25, 1965-1978.

Jowkar, H., S. Ostrowski, M. Tahbaz, P. Zahle, 2016. The conservation of biodiversity in Iran: Threats, Challenges and Hopes. Iranian Studies 49, 1065-1077.

Khan, M. S, 1997. Taxonomic notes on pakistani snakes of the *Coluber karelini-rhodorachis-ventromaculatus* species complex: a new approach to the problem. Asiatic Herpetological Research 7, 51-60.

Mayr, E, 1978. Origin and history of some terms in systematic and evolutionary biology. Systematic Zoology 27, 83-88.

Muscarella, R., P. J. Galante, M. Soley-Guardia, R. A. Boria, J. M. Kass, M. Uriarte, R. P. Anderson., 2014. Enm eval: An R package for conducting spatially independent evaluations and estimating optimal model complexity for maxent ecological niche models. Methods in ecology evolution evolution 5, 1198-1205.

Nakazato, T., D. L. Warren, L. C. Moyle, 2010. Ecological and geographic modes of species divergence in wild tomatoes. American Journal of Botany 97, 680-693.

Nohegar, A., S. Mahmoodabadi, A. Norouzi, 2015. Comparison the suitability of spi, Pni and di drought index in kahurestan watershed (Hormozgan Province/South of Iran). Journal of Environment Earth Science 5, 71-76.

Perry, G, 1985. A new subspecies of *Coluber-rhodorachis* (Ophidia, Colubridae) from Israel. Israel Journal of Zoology, Laser Pages Publ Ltd Po Box 50257, Jerusalem 91502, Israel.

Perry, G, 2012. On the appropriate names for snakes usually identified as *Coluber rhodorachis* (Jan, 1865) or why ecologists should approach the forest of taxonomy with great care. Reptiles Amphibians 19, 90-100.

Peterson, A. T, 2006. Uses and requirements of ecological niche models and related distributional models.

Peterson, A. T., J. Soberón, R. G. Pearson, R. P. Anderson, E. Martínez-Meyer, M. Nakamura, M. B. Araújo, 2011. Ecological niches and geographic distributions (Mpb-49). Princeton University Press.

Petros Lymberakis, Rastko Ajtic, Varol Tok, Ismail H. Ugurtas, Murat Sevinç, Pierre-André Crochet, Ahmad Mohammed Mousa Disi, Souad Hraoui-Bloquet, I. H. Riyad Sadek, Wolfgang Böhme, Aram Agasyan, Boris Tuniyev, Natalia Ananjeva, N. Orlov, 2009. "*Platyceps najadum*. The Iucn Red List of Threatened Species."

Rajabizadeh, M. K, 2018. Snakes of iran. Tehran, Iran Shenasi 1, 245-263. In Persian.

Rastegar-Pouyani, N., H. G. Kami, M. Rajabzadeh, S. Shafiei, S. C. Anderson, 2011. Annotated checklist of amphibians and reptiles of iran. Iranian Journal of Animal Biosystematics 4, 30.

Root, T. L, S. H. Schneider, 2006. Conservation and climate change: the challenges ahead. Conservation Biology 20, 706-708.

Schaetti, B., F. Tillack, C. Kucharzewski, 2014. *Platyceps rhodorachis* (Jan, 1863)-A study of the racer genus *Platyceps* Blyth, 1860 east of the Tigris (Reptilia: Squamata: Colubridae). Vertebrate Zoology 64, 297-405.

Schätti, B., C. Kucharzewski, R. Masroor, E. Rastegar Pouyani, 2012. *Platyceps karelini* (Brandt, 1838) from iran to pakistan and revalidation of *Coluber chesneii martin*, 1838 (Reptilia: Squamata: Colubrinae). Revue Suisse De Zoologie; Annales De La Société Zoologique Suisse Et Du Muséum D'histoire Naturelle De Genève 119, 441-483.

Schätti, B, C. Mccarthy, 2004. Saharo-arabian racers of the *Platyceps rhodorachis* complex: description of a new species (Reptilia: Squamata: Colubrinae). Revue Suisse De Zoologie 111, 691-705.

Schoener, T. W, G. C. Gorman, 1968. Some niche differences in three lesser antillean lizards of the genus *Anolis*. Ecology 49, 819-830.

Sinaiko, G., T. Magory-Cohen, S. Meiri, R. Dor, 2018. Taxonomic revision of israeli snakes belonging to the *Platyceps rhodorachis* species complex (Reptilia: Squamata: Colubridae). Zootaxa 4379, 301-346.

Tobias, J. A., N. Seddon, C. N. Spottiswoode, J. D. Pilgrim, L. D. Fishpool and N. J. Collar, 2010. Quantitative criteria for species delimitation. Ibis 152, 724-746.

Townsend Peterson, A., M. Papeş, M. Eaton, 2007. Transferability and model evaluation in ecological niche modeling: A comparison of garp and maxent. Ecography 30, 550-560.

Van Valen, L, 1976. Ecological species, multispecies, and oaks. Taxon: 233-239.

Wallace, A. R, 2016. On the zoological geography of the malay archipelago. Read Books Ltd.

Warren, D. L., R. E. Glor, M. Turelli, 2008. Environmental niche equivalency versus conservatism: Quantitative approaches to niche evolution. Evolution: International Journal of Organic Evolution 62, 2868-2883.

Warren, D. L., R. E. Glor, M. Turelli, 2010. Enmtools: A toolbox for comparative studies of environmental niche models. Ecography 33, 607-611.

Warren, D. L, S. N. Seifert, 2011. Ecological niche modeling in maxent: The importance of model complexity and the performance of model selection criteria. Ecological Applications 21, 335-342.

Yildiz, M. Z, 2011. Distribution and morphology of *Platyceps ventromaculatus* (gray, 1834) (serpentes: colubridae) in south-eastern Anatolia, Turkey. North-Western Journal of Zoology 7.

Yousefkhani, S. S. H, 2019. Review to the last ecological niche modelling studies on iranian herpetofauna and their importance for species conservation. Journal of Biological Studies 1, 165-167.

Туниев, Б, 2000. К вопросу о внутривидовой систематике и гибридизации *Coluber rhodorachis* И *Coluber karelini* (Ophidia: Colubridae). Современная Герпетология 1.

Iranian Journal of Animal Biosystematics (IJAB)
Vol.17, No.2, 157-167, 2021
DOI: 10.22067/ijab.2022.69007.1004

IJAB
ISSN: 1735-434X (print); 2423-4222 (online)

RESEARCH ARTICLE Open access

Male and female genital allometry in *Habrobracon hebetor* (Hymenoptera: Braconidae)

Mohammad Mahdi Rabieh[1,*] and Farzaneh Afkhami[2]

[1]*Department of Plant Protection, Faculty of Agriculture, University of Birjand, Birjand, Iran.*
[2]*Department of Plant Protection, Faculty of Agriculture, Institute of Higher Education Jahad Daneshgahi, Kashmar, Iran.*

(Received: *22 February 2021*; Accepted: 10 *December 2021*)

Abstract
This is particularly apparent within the insects that show high variations in genitalic form between closely related species. Static allometry is one of the effective approaches for quantification of such variation. Despite the crucial roles of the parasitic Hymenoptera in the ecosystems, little is known about the sexual selection in this order, compared with other insect orders. We examined the allometry of different morphological traits in 35 males and 35 females of *Habrobracon hebetor* (Say, 1836) (Hymenoptera: Braconidae) from a laboratory colony reared in Mashhad city, for the first time. The aim was the investigation of allometric relationships of different body traits as a way for quantification of the natural selection impacts on the different body parts. 12 genitalic and non-genitalic body parts of *H. hebetor* males and females were photographed and measured. Principal Component Analysis (PCA) was used to explore the variance of the traits and two regression analysis methods to obtain the allometric slopes. All the non-genitalic traits in male and female wasps showed isometry except pterostigma width in male wasps which showed positive allometry. In male genitalia, two traits showed strong negative allometry and one trait showed isometry. Our findings showed that in this species males with an average size of genitalia were more successful in generating viable offspring than males with relatively smaller or larger genitalia sizes and this is irrespective of the overall body size. Our results showed for the first time that such stabilizing sexual selection might operate on genital size in the braconid wasps.

Key words: Insect's evolution, Sexual selection, *Habrobracon hebetor*, Intraspecific variety, Morphology.

INTRODUCTION

Extraordinary variation of genitalia structures in animals and its function in the natural selection and speciation is highly considered and discussed, lately. Sexual selection is discussed as the primary force driving such enormous variation (Leonard & Córdoba-Aguilar, 2010; Cao et al. 2019). Static allometry, which is defined as the size relationship of a specific body part with the whole body in a population of a particular species, is one of the effective approaches for quantification of the natural selection impacts on the different body parts and their performance in an organism (Hosken, & Stockley, 2004; Ohno et al. 2003). This relationship is revealed by the slope attained in log-log regression of the size of a given body trait on an indicator of total body size (Eberhard, 1985). According to the selection hypotheses, relative size of different body parts is

Corresponding Author: *mmrabie@birjand.ac.ir*
©2021 FERDOWSI UNIVERSITY OF MASHHAD, IRAN

THIS WORK IS LICENSED UNDER A CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENSE.

examined by using an index for the overall body size. Several studies on genital allometry used a single somatic trait as the indicator of body size (e.g. pronotum length, elytra length and head width), although the use of a different body-size indicator may give rise to different results (Green, 1999). A slope over 1.0 (positive allometry) indicates advantage of relatively larger traits in the larger individuals of the population. Slope around 1.0 (isometry) shows relatively constant size of the trait across the population. Allometric slopes lower than 1.0 (negative allometry) are the indicator of relatively smaller trait expression in larger individuals (Eberhard, 2009).

Presumably, natural selection can adjust allometric slopes and consequently, affects the traits performance (Eberhard et al. 1998). Stabilizing selection is one of the main ways that selection can affects animals. In this type of selection, individuals with intermediate trait size will be favored in the population instead of exaggerated trait size which will be favored in the disruptive selection phenomena (Hosken & Stockley, 2004).

According to the selection hypotheses, when trait size increases faster than overall body size, there is a positive allometric relationship, as seen in insect's weapons. An isometric relationship exists when selection pressure is equal on the trait and overall body size, like most somatic traits in insects (Eberhard et al. 1998). If the selection pressure favors intermediate values of the trait regardless of body size, it causes negative allometry (Hosken & Stockley, 2004). Apparently, this relationship is common in male genital structures of insects and spiders (Eberhard et al. 1998; Eberhard, 2009). Conversely, Bolanos et al. (2014) found an exception to the previous findings. They interpreted isometric relationship of some genital traits in the damselflies as effect of sexual conflict situation that could change scaling pattern of genitalia in these insects. Also, some similar exceptions to the general pattern proposed by Eberhard et al. (1998) were previously found (Johnson, 1995; Cayetano et al. 2011). These findings showed that genital traits may evolve under different kinds of scaling patterns in different species. Moreover, different selective pressures which genitalia may confront during different sexual selection mechanisms need further investigations.

Eberhard et al. (1998) proposed the one-size-fits-all hypothesis based on their study of allometric relationships of genital and non-genital morphological traits in many species of arthropods including insects. They indicated that all morphological traits in the male genitalia have allometric slopes significantly lower than 1.0 and lower than the slopes for non-genitalic body traits. Their finding means that sexual selection within the arthropod populations acts through stabilizing selection and males with the average genital sizes are more favored for gene transfer to the next generations. According to this hypothesis, female morphology is relatively invariable so that the consistency of male genital morphology is an adaptation to this situation. Subsequently, several studies on different orders of insects and spiders have confirmed their findings for male genital size (e.g., Schmitz et al. 2000; Iwahashi, 2001; Tatsuta et al. 2001; Eberhard, 2002; Tschinkel et al. 2003; Hosken et al. 2005; Mutanen & Kaitala, 2006; Rabieh et al. 2015; Cao & Hayashi, 2019).
Eberhard et al. (1998) found that genitalia traits of the studied females have lower allometric slopes than the median allometric slope for non-genitalic traits but this difference was not significant. According to these results, they proposed that female genitalia may show the same patterns of variation as male genitalia. But they reported less variability for female genitalia than those of non-genitalic traits (Eberhard et al. 1998; Eberhard, 2009). Afterward, a few studies (e.g., Funke & Huber, 2005; Rabieh et al. 2015; Cao & Hayashi, 2019) confirmed their findings. Although, Nava-Bolaños et al. (2012) found that genital traits did not show negative allometry in two Odonata species, in both sexes.

Despite the crucial roles of the parasitic Hymenoptera in the ecosystems and the high diversity of mating systems, little is known about sexual selection and sexual conflict in this order, compared with other insect orders. Although, the mating systems of this diverse taxonomic group are studied in-sight of how population structure influences sex allocation strategies and how to

encourage their attack and control of pest populations as one of the main groups of biological control agents in the applied research (West, 2009; Boulton et al. 2015).

Allometric relationships of different body traits including genitalic parts are poorly studied in the Hymenoptera species and most allometry studies are focused on allometric relationships of non-genitalic traits, especially in the case of sexual dimorphisms investigations (e.g., Perrard et al. 2012; Benítez et al. 2013; Polilov & Makarova, 2017; Quezada-Euán et al. 2019). To determine whether genitalic parts are coordinating with the stabilizing selection prediction of strong negative allometry of genitalic structures, in Braconid wasps, this paper examined the allometry of different genitalic and non-genitalic morphological traits in males and females of *Habrobracon hebetor* (Say, 1836) (Hymenoptera: Braconidae). This species is a polyphagous and gregarious ectoparasitoid wasp which is widely used in integrated pest management programs. This species is mass-reared for control of the larvae of some important and well-known Lepidoptera pest species (Borzoui et al. 2016). The present paper also examined CV (coefficient of variation), CV´ (degree of dispersion of points around the allometric line) and SEE (standard error of estimate) that are other sources of information about the trait's variation. The results are discussed in evolutionary frameworks.

Material and Methods

Insects

A laboratory stock colony of *Habrobracon hebetor* was established from individuals collected from tomato fields during spring 2018 around Mashhad, Khorasan-e Razavi province of Iran. Rearing was done in the laboratory conditions at 25±1 ºC, 65±5 % RH, and a photoperiod of 16:8 (L:D) on fifth-stage larvae of *Ephestia kuehniella* for at least 10 generations for obtain to adequate population reared on the host at these conditions (Borzoui et al. 2016). 35 adult males and 35 adult females of *H. hebetor* were selected, randomly, from the laboratory stock colony and killed in Ethanol 70% solution.

E. kuehniella, were provided according to Borzoui et al. (2016) at the above-mentioned laboratory conditions. Examined materials were deposited in the Insect Collection of Birjand, Plant Protection Department, Faculty of Agriculture, University of Birjand, Iran.

Preparation and Measurements

Body parts of *H. hebetor* males and females were dissected. In each individual, the antenna, forewing, foreleg and hind leg were removed and cleaned to eliminate redundant tissues. Genitalia of both sexes were removed from the softened surrounding tissues of the abdomen and preserved in Ethanol 70% solution for only some minutes prior mounting. All mentioned parts were mounted on Canada balsam fixative. After preparation, all body parts were photographed through a microscope using a C-5050ZOOM digital camera (Olympus). 15 (three genitalic and 12 non-genitalic) traits in males and females were examined. For prevention of errors due to body asymmetry, only the right body parts were examined in all traits. The 12 measured non-genitalic traits in both sexes were the lengths of the following body parts: forewing, pterostigma, fore femur, fore tibia, spine of fore tibia, mid femur, mid tibia, hind femur, hind tibia, pedicel and the width of forewing and pterostigma (Fig. 1). The lengths of valva and ovipositor and the width of valva in the females and the lengths of the gonoforcep and penisvalva and the width of penisvalva in the males, were the measured genitalic traits (Fig. 1). TPSDIG, version 2.16 (Rohlf, 2015) was used for all the measurements. To minimize the measurement error, each trait was measured by the same person three times. Estimated measurement error for all studied traits showed relatively repeatable measurements (Table 1). Therefore, the average of the three measurements was used for further analyses.

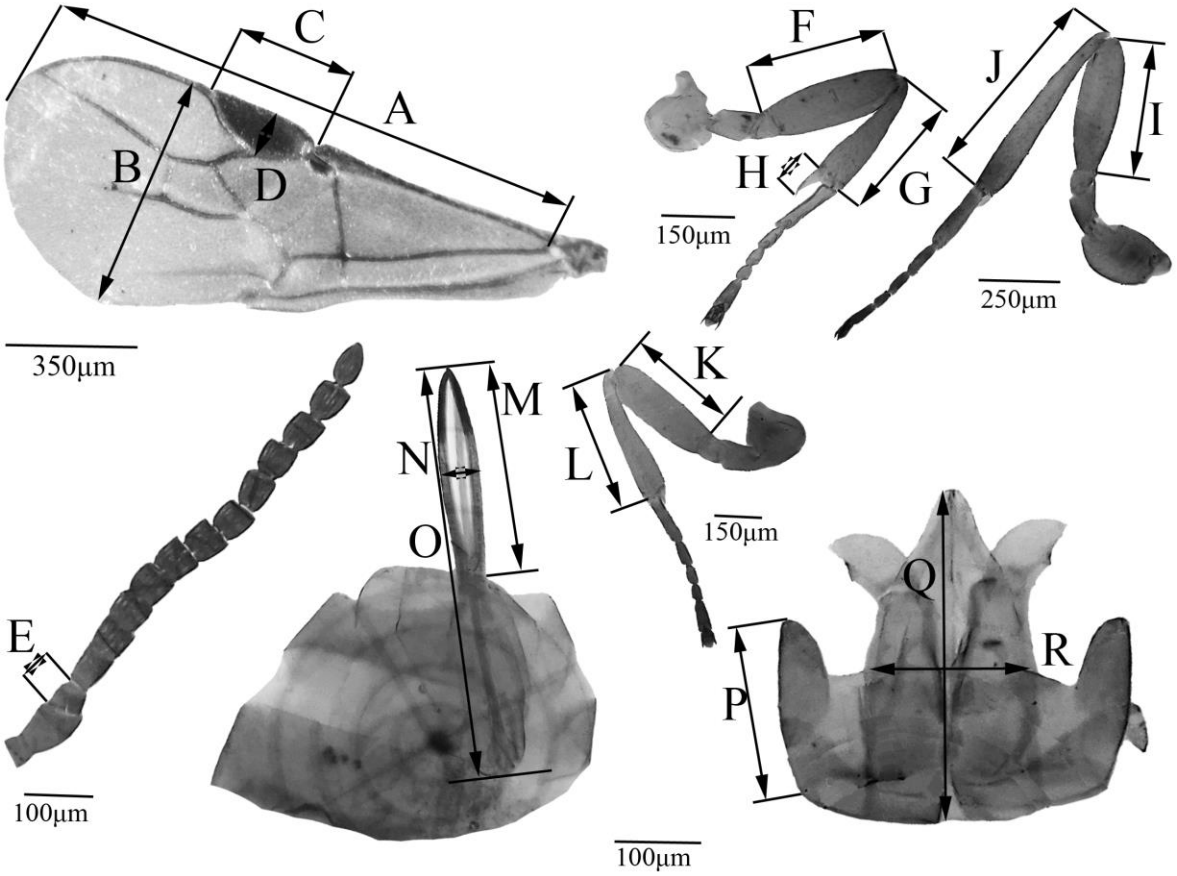

FIGURE 1. Genitalic and non-genitalic traits in male and female *Habrobracon hebetor*. A: Forewing length; B: Forewing width; C: Pterostigma length; D: Pterostigma width; E: Pedicel length; F: Fore femur length; G: Fore tibia length; H, Fore tibia spine length; I: Hind tibia length; J: Hind femur length; K: Mid femur length; L: Mid tibia length; M: Valva length; N: Valva width; O: Ovipositor length; P: Gonoforcep length; Q: Penisvalva length; R: Penisvalva width.

Data analysis

We used Principal Component Analysis (PCA), conducted separately for each sex, to obtain the best component explaining the variance of the traits. We selected forewing as the indicator of body size for allometry studies in male and female wasps. Loading all the measured traits on PC1, this trait showed the strongest correlation among other traits. Then, Pearson's product–moment correlation coefficient was calculated for the correlation between all other morphological traits and the body size indicator.

To estimate the allometric slopes, RMA and SMA regression analysis method was performed for log10-transformed values of the traits on log10-transformed forewing length in each sex according to Rabieh et al. (2015) (Table 2)

Also, CV (coefficient of variation), CV´ (degree of dispersion of points around the allometric line) and SEE (standard error of estimate) that are other sources of information about the trait's variation were calculated (Rabieh et al. 2015). The estimated components were compared between genitalic vs. non-genitalic traits by Mann–Whitney U-tests within each species. All statistical data analyses were performed using SPSS version 19.0 (IBM Corp, 2010).

TABLE 1. Measurement error and coefficients of variation (CV) evaluation for all male and female traits in *Habrobracon hebetor*

Trait		Measurement Error (%)	CV (%)
ɔn-genitalic			
	Forewing length	0.78	2.11
	Forewing width	1.16	2.66
	Pterostigma length	1.25	1.93
	Pterostigma width	0.99	3.23
	Fore femur length	0.27	2.19
	Fore tibia length	0.82	1.5
	Fore tibia spine length	2.13	2.31
	Mid femur length	1.17	1.64
	Mid tibia length	1.4	2.47
	Hind femur length	1.55	2.43
	Hind tibia length	0.94	1.72
	Pedicel	2.21	2.13
Genitalic			
	Valva length	1.82	2.25
	Valva width	2.01	1.3
	Ovipositor length	1.96	2.32
	Penisvalva length	2.52	1.68
	Penisvalva width	2.71	1.21
	Gonoforcep length	2.3	1.12

TABLE 2. Allometry of evaluated morphometric traits in *Habrobracon hebetor* males.

Trait		r(p)	RMA slope	*p*-Value	SMA slope	SMA slope CI	CV′	SEE
Non-genitalic								
	Forewing width	0.92(0.0008)	0.88	< 0.001	0.85	0.74-1.02	1.04	0.0137
	Pterostigma length	0.88(0.0001)	0.83	< 0.001	0.77	0.67-1.00	0.92	0.0159
	Pterostigma width	0.89(0.005)	1.21	< 0.001	1.03	1.01-2.13	1.35	0.0217
	Fore femur length	0.85(0.0001)	0.67	< 0.001	0.89	0.52-1.01	1.15	0.0145
	Fore tibia length	0.86(0.004)	0.77	< 0.001	0.81	0.61-1.04	0.77	0.0167
	Fore tibia spine length	0.73(0.001)	0.78	< 0.001	0.73	0.52-1.03	1.26	0.0181
	Mid femur length	0.92(0.007)	0.74	< 0.001	0.65	0.63-1.22	0.64	0.0117
	Mid tibia length	0.87(0.0001)	0.75	< 0.001	0.82	0.6-1.16	1.22	0.0151
	Hind femur length	0.90(0.013)	0.84	< 0.001	0.79	0.7-1.31	1.06	0.0145
	Hind tibia length	0.83(0.012)	0.75	< 0.001	0.69	0.57-1.12	0.96	0.0178
	Pedicel	0.71(0.005)	0.89	< 0.001	0.81	0.57-1.21	1.50	0.0212
Genitalic								
	Penisvalva length	0.55(0.003)	0.2	0.006	0.18	0.06-0.34	1.04	0.0141
	Penisvalva width	0.42(0.006)	0.61	0.012	0.66	0.14-1.05	1.1	0.0157
	Gonoforcep length	0.53(0.05)	0.09	0.46	0.11	-0.16-0.34	0.94	0.0227

-The table shows Pearson correlation coefficient (r) and its *p*-value, ranged major regressions allometric coefficient (RMA slope), the *p*-value obtained from permutations to test if the allometric coefficients differed from zero, standardized major axis allometric coefficients (SMA slope), and their confidence intervals (SMA slope CI), degree of dispersion of points around the allometric line (CV′) and standard error of estimate (SEE).

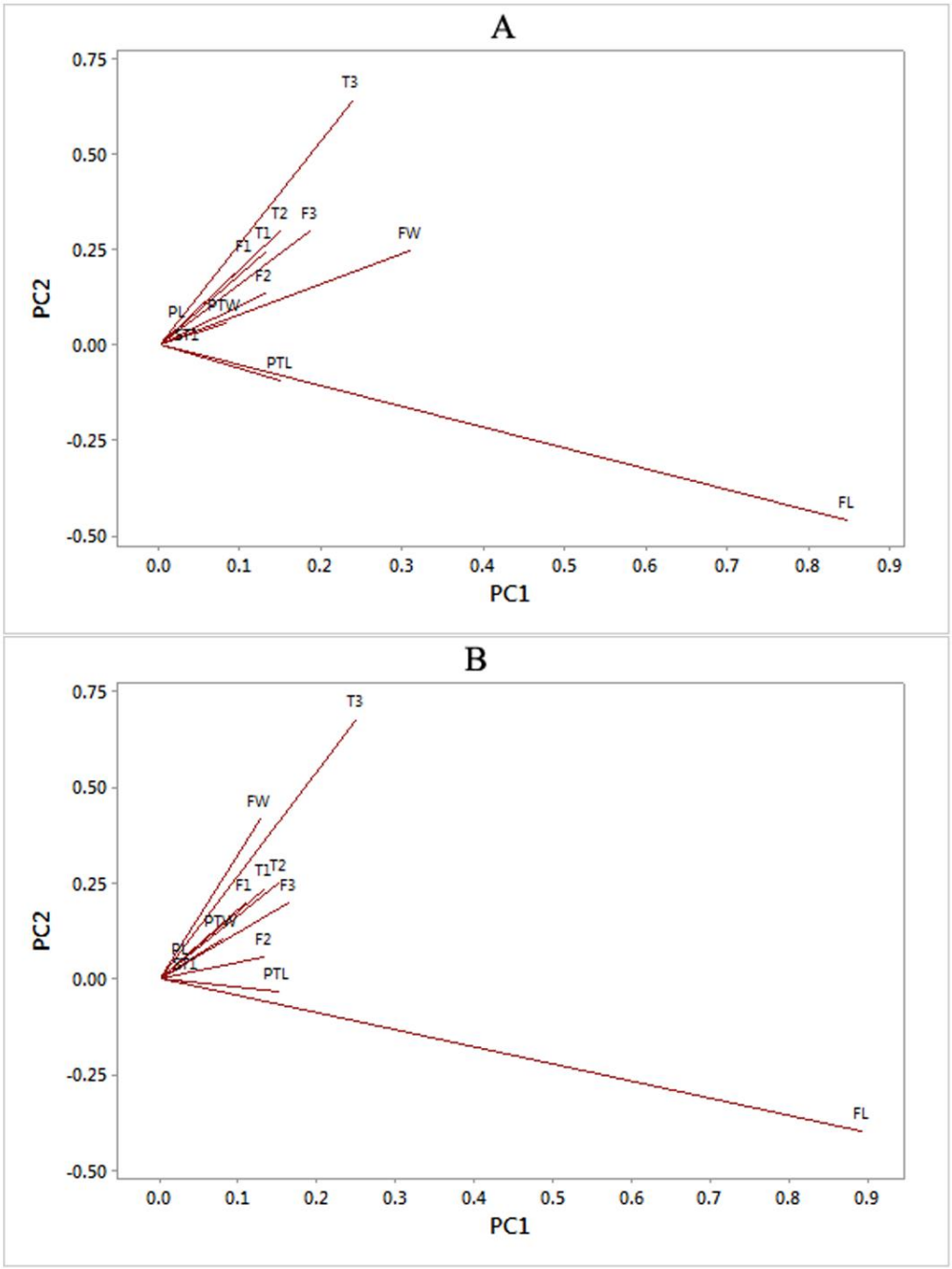

FIGURE 2. Principal component analysis (PCA) plots of trait loadings on PC1 vs. PC2 showing the covariation structure in the trait matrix of the males and females. A: *Habrobracon hebetor* male. B: *H. hebetor* female. FW: forewing width; FL: forewing length; F1: Fore femur length; F2: Mid femur length; F3: hind femur length; T1: Fore tibia length; T2: mid tibia length; T3: hind tibia length; ST1: Fore tibia spine length; PL; length of the pedicel; PTL: pterostigma length; PTW: pterostigma width.

TABLE 3. Allometry of evaluated morphometric traits in *Habrobracon hebetor* females.

Trait		r (p)	RMA slope	*p*-Value	SMA slope	SMA slope CI	CV′	SEE
Non-genitalic								
	Forewing width	0.94(0.0002)	0.84	< 0.001	0.89	0.72-1.00	0.91	0.0142
	Pterostigma length	0.89(0.0004)	0.81	< 0.001	0.79	0.71-1.01	0.88	0.0161
	Pterostigma width	0.84(0.001)	0.92	< 0.001	0.81	0.55-1.13	1.75	0.0188
	Fore femur length	0.79(0.0001)	0.61	< 0.001	0.69	0.63-1.05	1.34	0.0154
	Fore tibia length	0.81(0.002)	0.87	< 0.001	0.75	0.58-1.03	0.87	0.0173
	Fore tibia spine length	0.82(0.001)	0.6	< 0.001	0.68	0.57-1.01	1.32	0.0189
	Mid femur length	0.84(0.003)	0.53	< 0.001	0.52	0.43-1.00	0.88	0.0126
	Mid tibia length	0.88(0.0001)	0.68	< 0.001	0.83	0.62-1.12	1.17	0.0132
	Hind femur length	0.88(0.001)	0.82	< 0.001	0.77	0.7-1.25	1.15	0.0152
	Hind tibia length	0.9(0.002)	0.59	< 0.001	0.64	0.58-1.02	0.74	0.0138
	Pedicel	0.81(0.004)	0.79	< 0.001	0.85	0.67-1.19	1.2	0.0205
Genitalic								
	Valva length	0.48(0.05)	0.47	0.27	0.39	0.1-0.54	1.97	0.0311
	Valva width	0.69(0.01)	0.59	0.31	0.65	0.49-1.00	0.94	0.0251
	Ovipositor length	0.52(0.002)	0.62	0.01	0.8	0.53-1.01	1.98	0.0323

- The table shows Pearson correlation coefficient (r) and its *p*-value, ranged major regressions allometric coefficient (RMA slope), the *p*-value obtained from permutations to test if the allometric coefficients differed from zero, standardized major axis allometric coefficients (SMA slope), and their confidence intervals (SMA slope CI), degree of dispersion of points around the allometric line (CV´) and standard error of estimate (SEE).

DISCUSSION

This study is a comprehensive static allometry investigation on external genitalia and non-genitalic traits within both sexes of a Hymenopteran species. Although, most studies on insect's allometry usually focus on male genitalia traits and lay conspecific female genitalia away from their deduction.

In our results, almost all non-genitalia traits in both sexes of *Habrobracon hebetor* showed isometry (greater than 1.0 in pterostigma width in males). On the other hand, male genitalia traits of *H. hebetor* showed negative allometry except for Penisvalva width which showed isometry. This information confirms that, in *H. hebetor* male genitalia and non-genitalia traits reveal coordination with the one-size-fits-all hypothesis proposed by Eberhard et al. (1998) and further explained in Eberhard (2009). This means that in a given population of this species male individuals with average size of genitalia are more successful in generating surviving offspring than males with relatively smaller or larger genitalia sizes and this is irrespective of the overall body size of them. Our results in terms of the negative allometry of genitalia traits vs. isometry of non-genitalic traits, is in coordinate with the results of other works evaluated static allometry in male genitalia of different insect orders (e.g., Schmitz et al. 2000; Iwahashi, 2001; Tatsuta et al. 2001; Eberhard, 2002; Tschinkel et al. 2003; Hosken et al. 2005; Mutanen & Kaitala, 2006; Rabieh et al. 2015; Cao & Hayashi, 2019). Although, some studies found different results which do not support one-size-fits-all hypothesis, recently (e.g., Nava-Bolanos et al. 2012; Nava-Bolanos et al. 2014). These findings offer consideration on different functions of genitalia parts during copulation and sexual conflicts through different sexual selection mechanisms. For example, male genitalia parts may evolve to access stored sperm of females which leads to positive allometry of aedeagus in males of *Protoneura cara* (Odonata: Protoneuridae) (Nava-Bolanos et al. 2012).

According to our results, there is no significant difference between genitalic and non-genitalic traits in female wasps. This finding is another confirmation for the claim that the shallow

static allometry slopes of male genitalic traits reflect functional roles associated with mating and sexual competition.

In a given species population, larger CV of a specified trait may be due to a higher allometric value or a greater dispersion of points around the allometric line (CV′). The allometric slope is related to genetic structure of the organism which evolves under different selection pressures but the degree of dispersion may be related not only to genetic structure but also to other environmental and internal causes (Eberhard, 1998). In our results, CV′ and SEE of genitalic traits have values less than those for non-genitalic traits, in the male wasps. Although, their difference was not significant, this result means that in *H. hebetor* the size of male genitalia is more stable than that of non-genitalic parts against changes in the body size, and the difference in the degree of phenotypic variation between genitalic and non-genitalic morphometric feature is related to the difference in allometric slopes. These findings are consistent with those of previous studies which investigated the allometric slope and the dispersion of points around the allometric line, separately, for male genitalia traits and other body parts (e.g., Eberhard et al. 1998; Ohno et al. 2003; Rabieh et al. 2015; Cao & Hayashi, 2019). It is assumed that sexual selection in arthropods may favor a particular scaling relationship for male genitalia under a developmental-genetic program which appears as allometric slope (Eberhard et al. 1998). Our results showed that such stabilizing sexual selection may also operate on genital size in braconid wasps.

Our results, presented another confirmation of the previous studies which showed that genitalia traits of females have lower allometric slopes than the median allometric slope for non-genitalic traits but this difference was not significant (e.g., Eberhard et al. 1998; Funke & Huber, 2005; Rabieh et al. 2015; Cao & Hayashi, 2019). We found that genitalia traits in *H. hebetor* females have lower allometric slope, CV, CV′ and SEE than those for non-genitalic traits which for two last components, the differences were significant. Our findings showed similar allometric patterns among the male and female traits measured. Consequently, as male genitalia parts showed negative allometry and female genitalia, on the other hand displayed isometric relationship, we predict relatively invariability in female morphology of *H. hebetor* so that male wasp could adapt to this by being consistent in genital morphology. While our evidences do suggest the possibility of stabilizing selection in *H. hebetor*, additional experiments would be required to reinforce these claims.

If a non-genitalic trait of a male individual attends as a secondary sexual trait during sexual selection mechanism, it may produce higher mating success when has a larger relative size, conversely, in small individuals, viability costs may limit the size of this trait, resulting in positive allometry (Bonduriansky, 2007). This will be much distinctive when a large number of competitive males exist or the trait produces resolutely more advantage in competitive interactions (Fromhage & Kokko, 2014). In our results, the pterostigma width in *H. hebetor* males showed positive allometry in relation to body size. Conversely, this trait in *H. hebetor* females showed an isometric relationship with body size. This suggests selection for larger pterostigma in large *H. hebetor* males and/or relatively smaller ones in small *H*. *hebetor* males. Therefore, positive allometry of the pterostigma width in *H. hebetor* may be a result of secondary sexual function. This possibility deserves further investigations.

RESULTS

The first and second components of the PCA explained 94.8% and 3.4% of the total variance in the males and 91.1% and 3.7% in the females, respectively. Therefore, PC1 chose as the best component explaining the variance of the traits for both sexes. Plots of trait loadings on PC1 vs. PC2 showing the covariation structure in the trait matrix of the males and females are presented (Fig. 2). Loading all the measured traits on PC1, forewing length showed the strongest correlation among other traits (Males: r = 0.989, p-value < 0.001; Females: r = 0.977, p-value < 0.001). All the measured traits were significantly related to the overall body size for male and female wasps

(Tables 2 and 3). In most traits, a highly significant relationship (p-value<0.01) was observed in both sexes (Tables 2 and 3). All the non-genitalic traits in male and female wasps showed isometric relationship with the body size indicator (Tables 2 and 3) except pterostigma width in male wasps which showed positive allometric relationship with body size (Table 2). In females, valva length showed strongly negative allometric relationship with body size and valva width and ovipositor length showed isometry (Tables 3). In male wasps, length of penisvalva and gonoforcep have strong negative allometry in relation to body size indicator and penisvalva width showed values which did not differ significantly from one (isometry) (Table 2).

The mean slope for the measured genitalic traits of males was significantly lower than one's for the non-genitalic traits (Mann–Whitney U-test, P < 0.01). In female wasps, there is no significant difference (Mann–Whitney U-test, P = 0.097) but the mean slope of genital traits was lower than the mean slope for non-genitalic traits. There is no significant difference between results of allometric slopes in the RMA and SMA regression methods (Mann–Whitney U-test, P < 0.01).

Genitalic traits of male wasps showed significantly lower CV than non-genitalic traits (Mann–Whitney U-test, P < 0.01). Despite the lower mean value for genitalic traits, there was no significant difference between CV for genitalic and non-genitalic traits, in female wasps (Tables 3). Conversely, CV′ showed no significant difference between genitalic and non-genitalic traits in male wasps (Mann–Whitney U-test, P = 0.361) and it was significantly lower for non-genitalic than genitalic traits in female wasps. Similar situation was seen for SEE which only female wasps have significantly lower non-genitalic traits than genitalic traits (Tables 2 and 3).

Acknowledgments
We sincerely thank Dr. Javad Noei for his kind helps in the laboratory affairs. This study was supported by the grant, number 21833, from university of Birjand, Birjand, Iran.

LITERATURE CITED

Andersson, M., 1994. Sexual Selection. Princeton University Press, Chichester, UK.

Benítez, H.A., Bravi, R., Parra, L.E., Sanzana, M-J., Sepúlveda-Zúñiga, E., 2013. Allometric and non-allometric patterns in sexual dimorphism discrimination of wing shape in *Ophion intricatus*: Might two male morphotypes coexist? Journal of Insect Science 13, 143.

Bonduriansky, R., 2007. Sexual selection and allometry: a critical reappraisal of the evidence and ideas. Evolution 61, 838–849.

Boulton, R.A., Collins, L.A., Shuker, D.M., 2015. Beyond sex allocation: the role of mating systems in sexual selection in parasitoid wasps. Biological Reviews of the Cambridge Philosophical Society 90, 599–627.

Borzoui, E., Naseri, B., Mohammadzadeh-Bidarani, M., 2016. Adaptation of *Habrobracon hebetor* (Hymenoptera: Braconidae) to rearing on *Ephestia kuehniella* (Lepidoptera: Pyralidae) and *Helicoverpa armigera* (Lepidoptera: Noctuidae). Journal of insect science 16, 1–12.

Cao, C., Yu, P., Hayashi, F., 2019. Allometry and morphological trait relationship in the sexually dimorphic Chinese dobsonfly, *Acanthacorydalis asiatica* (Wood-Mason, 1884) (Megaloptera, Corydalidae). ZooKeys 854, 119–129.

Cayetano, L., Maklakov, A.A., Brooks, R.C., Bonduriansky, R., 2011. Evolution of male and female genitalia following release from sexual selection. Evolution 65, 2171–2183.

Eberhard, W.G., 1985. Sexual selection and animal genitalia. Harvard University Press. Cambridge, UK.

Eberhard, W.G., 2002. The relation between aggressive and sexual behavior and allometry in *Palaeosepsis dentatiformis* flies (Diptera: Sepsidae). Journal of the Kansas Entomological Society 75, 317–332.

Eberhard, W.G., 2009. Static allometry and animal genitalia. Evolution 63, 48–66.

Eberhard, W.G., Huber, B.A., Rodriguez, R.L., Briceno, R.D., Salas, I., Rodriguez, V., 1998. One size fits all? Relationships between the size and degree of variation in genitalia and other body parts in twenty species of insects and spiders. Evolution 52, 415–431.

Fromhage, L., Kokko, H., 2014. Sexually selected traits evolve positive allometry when some matings occur irrespective of the trait. Evolution 68(5), 1332–1338.

Funke, S., Huber, B.A., 2005. Allometry of genitalia and fighting structures in *Linyphia Triangularis* (Araneae, Linyphiidae). The Journal of Arachnology 33, 870–872.

Green AJ. 1999. Allometry of genitalia in insects and spiders: one size does not fit all. Evolution 53: 1621–1624.

Hosken, D.J., Stockley, P., 2004. Sexual selection and genital evolution. Trends in Ecology and Evolution 19, 87–93.

Hosken, D.J., Minder, A.M., Ward, P.I., 2005. Male genital allometry in Scathophagidae (Diptera). Evolutionary Ecology 19(5), 501–515.

Iwahashi, O., 2001. Aedeagal length of the Oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae), and its sympatric species in Thailand and the evolution of a longer and shorter aedeagus in the parapatric species of *B*. *dorsalis*. Applied Entomology and Zoology 36, 289–297.

International Business Machines Corporation, 2010. IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY.

Johnson, N.F., 1995. Variation in male genitalia of Merope tuber Newman Mecoptera: Meropeidae. Journal of the Kansas Entomological Society 682, 224–233.

Leonard, J., Cordoba-Aguilar, A., 2010. The evolution of primary sexual characters in animals. Oxford University Press, NY.

Mutanen, M., Kaitala, A., 2006. Genital variation in a dimorphic moth *Selenia tetralunaria* (Lepidoptera, Geometridae). Biological Journal of the Linnean Society 87, 297–307.

Nava-Bolanos, A., Mungua-Steyer, R., Cordoba-Aguilar, A., 2012. A test of genital allometry using two damselfly species does not produce hypoallometric patterns. Ethology 118, 203–213.

Nava-Bolanos, A., Sanchez-Guillen, R.A., Mungua-Steyer, R., Cordoba-Aguilar, A., 2014 Isometric patterns for male genital allometry in four damselfly species. Acta Ethologica 17, 47–52.

Ohno, S., Hoshizaki, S., Ishikawa, Y., Tatsuki, S., Akimoto, S., 2003. Allometry of male genitalia in a Lepidopteran species, *Ostrinia latipennis* (Lepidoptera: Crambidae). Applied Entomology and Zoology
38: 313–319.

Perrard, A., Villemant, C., Carpenter, J.M., Baylac, M. 2012. Differences in caste dimorphism among three hornet species (Hymenoptera: Vespidae): forewing size, shape and allometry. Journal of Evolutionary Biology 25, 1389–1398.

Polilov, A.A., Makarova, A.A., 2017. The scaling and allometry of organ size associated with miniaturization in insects: A case study for Coleoptera and Hymenoptera. Scientific Reports 7, 43095.

Quezada-Euán, J.G., Corey, S., Raúl, S., Castillo, C., 2019. Patterns of sexual size dimorphism in stingless bees: Testing Rensch's rule and potential causes in highly eusocial bees (Hymenoptera: Apidae, Meliponini). Ecology and Evolution 9, 2688–2698.

Rabieh, M.M., Esfandiari, M., Seraj, A.A., Bonduriansky, R., 2015. Genital and body allometry in two species of noctuid moths (Lepidoptera: Noctuidae). Biological Journal of the Linnean Society 116, 183–196.

Rohlf, F.J. 2015. TPSDIG, version 2.16. Department of Anthropology, Stony Brook University, Stony Brook, USA, Available online at: http://life.bio.sunysb.edu/morph/.

Schmitz, G., Reinhold, K., Wagner, P., 2000. Allometric relationship between genitalic size and body size in two species of mordellid beetles (Coleoptera: Mordellidae). Annals of the Entomological Society of America 9(3), 637–639.

Tatsuta, H., Mizota, K., Akimoto, S.I., 2001. Allometric patterns of heads and genitalia in the stag beetle *Lucanus maculifemoratus* (Coleoptera: Lucanidae). Annals of the Entomological Society of America 94, 462–466.

Tschinkel, W.R., Mikheyev, A.S., Storz, S.R., 2003. Allometry of workers of the fire ant, *Solenopsis invicta*. 11pp. Journal of Insect Science 3, 2.

West, S.A., 2009. Sex allocation. Princeton University Press, Woodstock, UK.

Iranian Journal of Animal Biosystematics (IJAB)
Vol.17, No. 2, 169-178, 2021
DOI: 10.22067/ijab.2022.63444.0

IJAB
ISSN: 1735-434X (print); 2423-4222 (online)

RESEARCH ARTICLE Open access

Shell and Radula Morphology of land snails in Urmia city, North-west of Iran

Shamsi, L.[1], Tavassoli, M.[1*], Naem, S.[1], Mahmoudian, A.[2], and Ahmadi, E.[3]

[1]*Department of Pathobiology, Faculty of Veterinary Medicine, Urmia University, PO Box 165, Urmia, Iran,*
[2]*Department of Microbiology, Faculty of Veterinary Medicine, Urmia University, Urmia, Iran*
[3]*Iranian Research Institute of Plant Protection (IRIPP) Research Department of Agricultural Zoology. Agricultural Zoology Museum P O Box 1454, Tehran, Iran*

(Received: *14 April 2021*; Accepted: 21 *October 2021*)

Abstract
Mollusca are the second-largest phylum of invertebrates after Arthropoda and may play a role as an intermediate host for parasites. To determine the morphological features of land snails (including *Assyriella ceratomma*, *Jaminia isseliana*, *Helix lucorum* and *Euomphalia pisiformis*) from North-west of Iran (Urmia city), the specimens were collected during 2015-2017. After extraction, the radulas were stained using Mallory II and the shell morphology and teeth formula were studied.
A significant correlation was found between the mean length of radula and their body size. In addition, snails with bigger shell size, had a larger teeth size and more lateral teeth. The longest and the shortest central tooth belonged to *Helix lucorum* and *Jaminia isseliana*, respectively. The length of the central teeth in the *Helix lucorum* and *Assyriella ceratomma* differed significantly from other species. Furthermore, the shape of the central tooth in all examined snails was triangular. The lateral teeth in the *Helix lucorum* and *Assyriella ceratomma* species had one mushroom-like cusp with two short sharp cusps. The lateral teeth in *Jaminia isseliana* contained blade like cusps at the middle. *Helix lucorum* snails had more marginal teeth compared to others.

Key words: Iran, Land snails, Morphology, Radula, Shell, Urmia

INTRODUCTION

Both aquatic (freshwater and marine) and terrestrial snails belong to the Pulmonata subclass of Gastropoda, contain a variety of aquatic (freshwater and marine) snails and terrestrial snails (Morton, 1979). Despite the development of molecular biomarkers for identification of different species in recent years (Stothard & Rollinson 1996; Hebert *et al*., 2003; Akinwale *et al*., 2015), the morphological features, including shell and radula structure are still widely used to characterize them (Schander & Willassen, 2005). The shape of radula teeth, which composed of a long ribbon of tissue and repeated rows of teeth, is unique to a genus or species (Rumam & Thornton, 1967). Radula teeth consists of transverse rows and one central (C), one lateral (L), and one marginal teeth (M) (Mansourian, 2005). The teeth formula (Ponder & Lindberg, 1996) as well as shape, size and structure of the cusps (Kilburn, 1988; Monzon *et al*., 1993) of radula as well as shell morphological characters are used to differentiate different snail species (Oso & Odaibo, 2018). In this current study we sought to determine the differences in the shell and radula morphology of four land snail species collected from Urmia city in North-west of Iran.

Corresponding Author: m.tavassoli@urmia.ac.ir
©2021 FERDOWSI UNIVERSITY OF MASHHAD, IRAN

THIS WORK IS LICENSED UNDER A CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENSE.

MATERIAL AND METHODS

Study area

City of Urmia (Fig. 1) is the capital of West Azarbaijan province in North-west of the country, with an area of approximately 5895 square kilometers and an altitude of about 1312 meters above sea level (longitude of 45 00′ to 45 07′ E and latitude of 37 29′ to 37 34′N). Urmia's climate is temperate with a maximum of 34 °C in August and a minimum of 6.1 °C in January (an average of 8.9 °C). The average annual rainfall is about 370 mm, and its relative humidity sometimes can reach 50%.

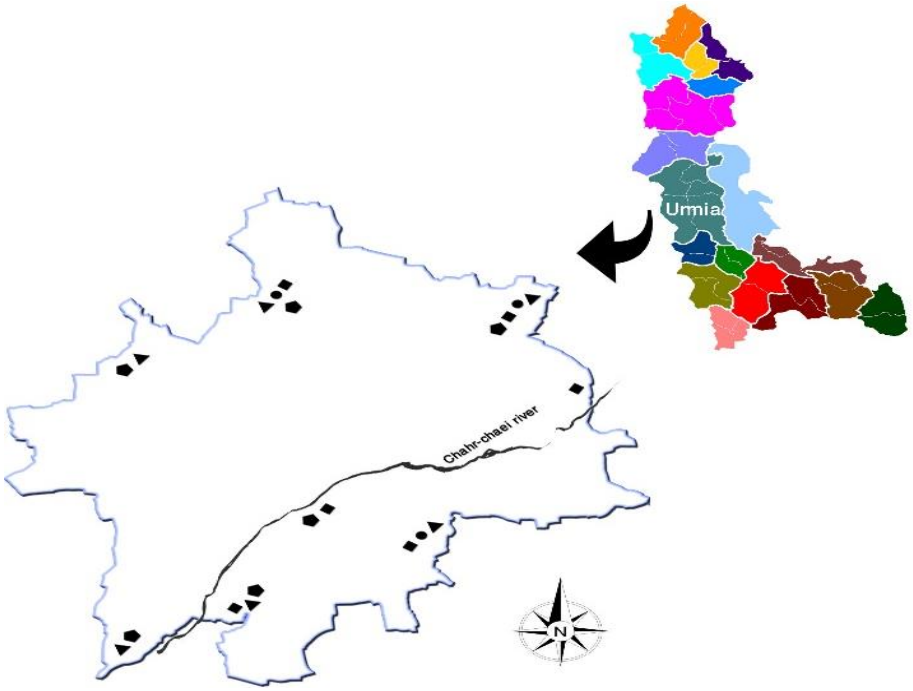

FIGURE 1. Sampling areas in Urmia, west Azerbaijan province, Iran (Trapezius: *Assyriella ceratomma*, Circle: *Jaminia isseliana*; Triangular: *Helix lucorum*; Square: *Euomphalia pisiformis*).

Collection and identification of land snails

A total of 260 snails were collected from soil and subsoil, forage, rock from different parts of Urmia during 2015 – 2017 (Fig 1). In the lab, the specimens were preserved in 70% ethanol and the length of the shells (the distance from the apex to the base of the aperture) were measured before dissection. For morphology examinations, the criteria described somewhere else were used (Burch & Van Devender, 1980; Cameron & Riley, 2008; Cameron & Redfern, 2009).

Firstly, the buccal mass was completely removed as explained previously (Kristensen, 1984) and the surrounding tissues of radulas were dissolved using 7.5% KOH for 24 hours and then stained using Mallory II solution (Mansourian, 1986). To determine the teeth configuration, radulas were mounted on slides using a mounting medium (Canada Balsam). The length of central (C), lateral (L), and marginal (M) radular teeth were measured from apical cusp to the base using an optic microscope. To determine the tooth formulas, the number of rows and the teeth within each row were counted.

Statistical analysis

The Variance (ANOVA) analysis was performed using SPSS v. 21, and the *P values* less than 0.05 were statistically considered significant.

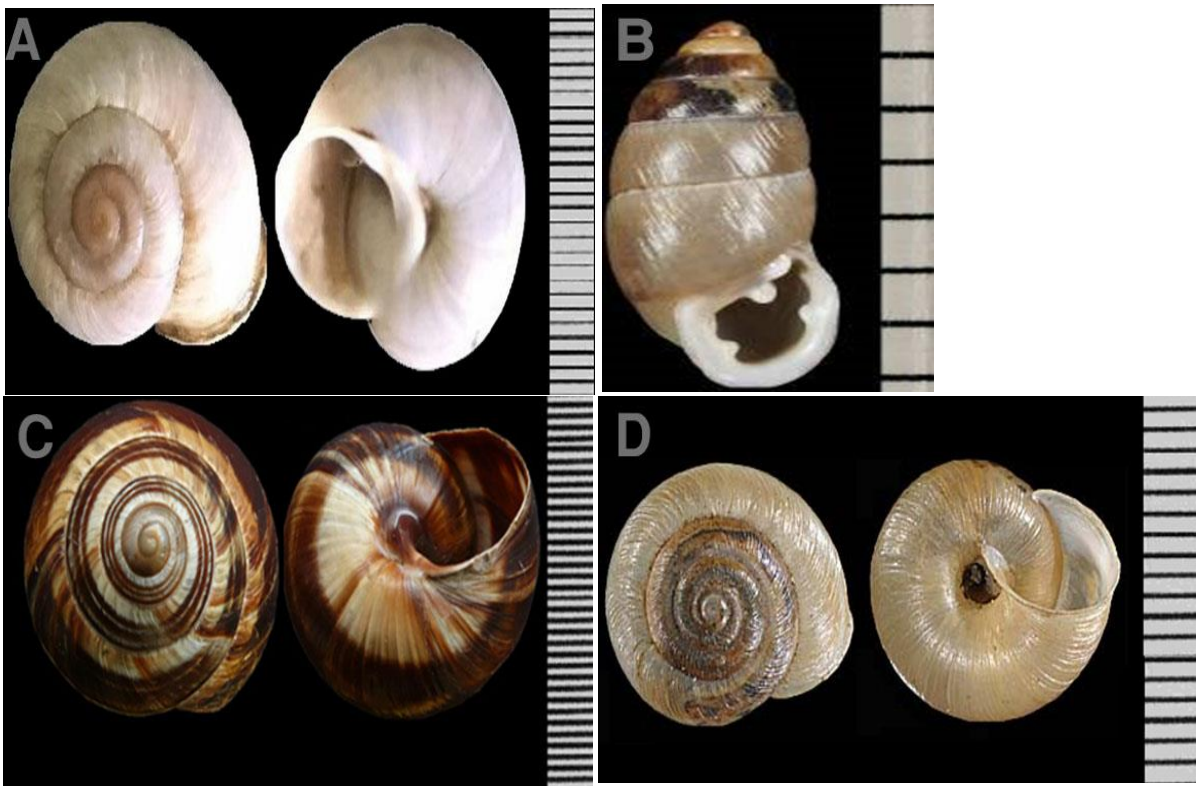

FIGURE 2. Examined Snails: A, *Assyriella ceratomma*; B, *Jaminia isseliana*; C, *Helix lucorum*; D, *Euomphalia pisiformis*.

Results

Morphology of snails

***Assyriella ceratomma* (Pfeiffer, 1856)** (Fig. 2A)

The discus shell large, white, matte, and hard with five whorls. The umbilicus unclear. Shell valve thick, rounded and elliptical. The shell height more than 20 mm.

***Jaminia isseliana* (Issel, 1865)** (Fig. 2B)

A conical cylinder with seven to eight slightly twisted turns. The end twist with a white stripe on the back and slightly raised towards the aperture. Oval Aperture short, almost vertical. The edges of the aperture white and thick.

***Helix lucorum* (Linnaeus, 1758)** (Fig. 2C)

The shell thick, spherical, compact and round. With 4.5 to 5 rounded whorls, last whorl wide. The first whorl lined with distinct spiral striae. The white background irregular with dark brown intersections stripes. Aperture small, oval-shaped with sharply upper edge.

***Euomphalia pisiformis* (Pfeiffer, 1852)** (Fig. 2D)
With discus shell. Shell color white with a brown stripe on the surface of the whorls. With 5.5 to 6 whorls. With small needle-shaped patterns on its surface. The tip sharp, and the spire equal or slightly higher than the valve. The valve rounded. The edge of the valve sharp and thin, partially turned. Shells with narrow umbilicus, partially covered by columella.

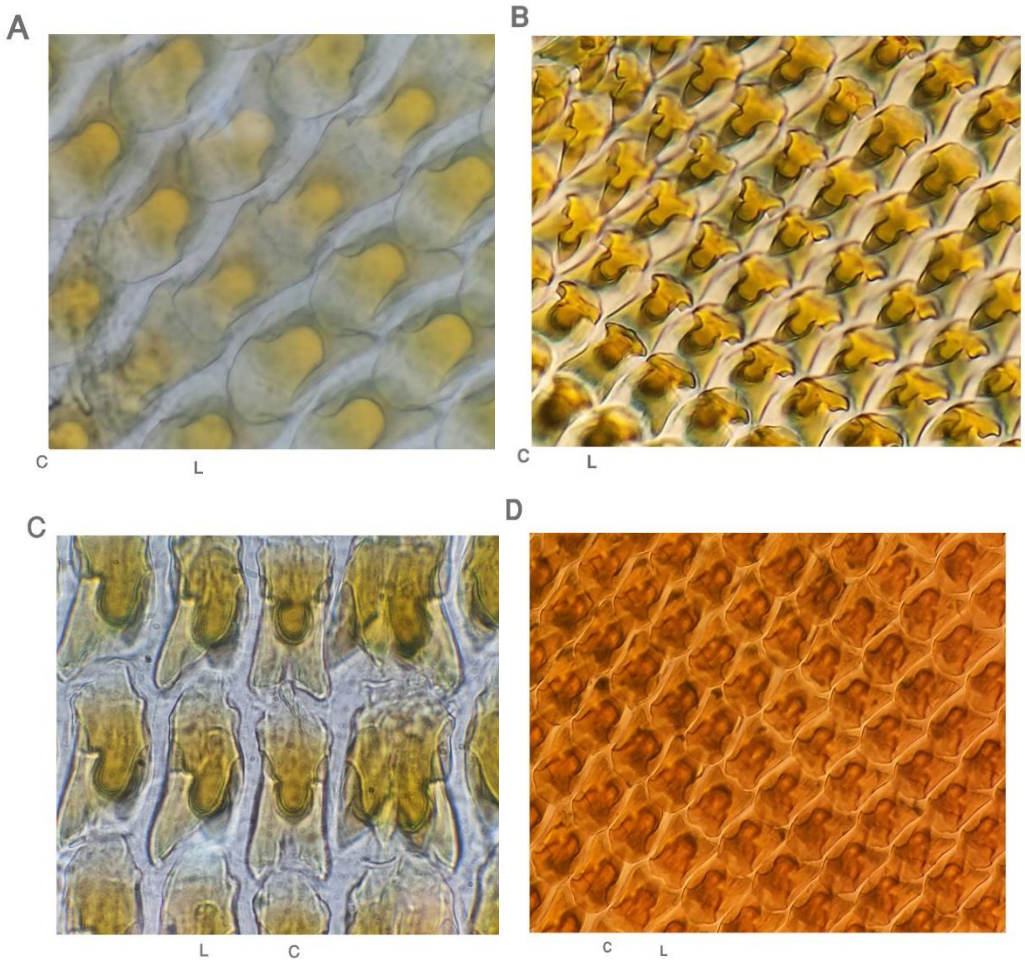

FIGURE 3. The radular central (C) and lateral (L) teeth of: A, *Assyriella ceratomma*, 100×; B, *Jaminia isseliana* 100×; C, *Helix lucorum* 100×; D, *Euomphalia pisiformis* 100×. (Stained by Mallory II).

Description of radular teeth structures
The morphological differences of radula between different species are shown in Figure 3 (A–D). As shown in Table 1, the land snails with larger shell size had larger teeth size. Accordingly, the mean length of radular teeth increased with increasing of the body size in all examined specimens. The number of lateral teeth was greater in larger snails. The longest central tooth belonged to *H. lucorum* snail (33.34±0.9) and the smallest was found in *J. isseliana* (15.46±0.68). The length of the central teeth in *H. lucorum* and *A. ceratomma* differed significantly from other species ($p<0.05$). There was an association between the number of teeth rows and the size of the examined snails. *H. lucorum* had the highest numbers of teeth rows (154.69±4.62; $P<0.05$). The number of marginal teeth was higher in *H. lucorum* snails compared to the other species. Interestingly, the teeth formula of *J. isseliana* were found to be almost the same *as E. pisiformis* (Table 1).

TABLE 1. Means and standard deviation (Mean ± SD) for radular teeth measurements and Radula formula of Land snails in Urmia city, Iran.

Snail species	Radular teeth*						Teeth rows	Shell length	Radula Formula
	Length of Central teeth	Width of Central teeth	Length of Lateral teeth	Width of Lateral teeth	Length of Marginal teeth	Width of Marginal teeth			
A. ceratomma	29.64±1.86^{b}	15.93±0.45^{b}	31.87±1.66^{a}	17.99±0.42^{b}	21.82±0.92^{a}	15.43±0.51^{a}	142.08±5.60^{ab}	26.70±0.75^{b}	1,17,18
H. lucorum	33.34±0.90^{a}	17.05±0.55^{a}	33.45±1.22^{a}	21.10±0.57^{a}	22.75±1.87^{a}	14.36±0.65^{a}	154.69±4.62^{a}	39.30±0.13^{a}	1,19,24
E. pisiformis	15.52±0.65^{d}	7.52±0.24^{f}	15.50±0.39^{c}	8.67±0.49^{f}	9.20±0.63^{c}	8.93±0.27^{c}	107.00±1.81^{c}	13.52±0.38^{d}	1,12,15
J. isseliana	15.46±0.68^{d}	11.29±0.26^{de}	15.37±0.54^{c}	11.34±0.19^{e}	10.51±0.65^{bc}	10.93±0.4^{b}	107.31±5.10^{c}	7.28±0.56^{e}	1,11,15

The middle of each row of the radula (the C tooth) is almost triangular with specific cusp shape. The size of lateral teeth was the same as central teeth in all species. The L teeth in *H. lucorum* and *A. ceratomma* species had a mushroom like cusp with two short sharp cusps. The L teeth of *J. isseliana* had the blade like cusps in the middle.

DISCUSSION

Generally, study of shells in snails can provide important taxonomic information. The radular shape and size are used to differentiate the genus or species of Mollusca (Franklin *et al*., 2007). The radula in each species of Mollusca has a unique morphology and structure (Yakhchali & Jamshidi Deillami, 2012). In several studies have been shown the importance of radula for discriminating of different species (Matthews-Cascon *et al*., 2005; Haijirawowg *et al*., 2008; Yakhchali & Jamshidi Deillami, 2012; Tumpeesuwan & Tumpeesuwan, 2015; Medina *et al*., 2016).

For the first time, the current study used the morphological carateristics to differentiate different radula of land snails in Iran. Consistent with other studies, it has shown that snails with larger shell sizes had larger teeth sizes (Howe 1930; Barker, 2001; Yakhchali & Jamshidi Deilami, 2012; Yakhchali *et al*., 2013).

The number of cusps were found to be different between species. In our study, the radula of all four land snails were tricuspid as shown previously on *Zidona dufresnei* (Medina *et al*. (2016). In our study, two cusps on outer lateral teeth of studied land snails were found, but in another study, four cusps were reported in *Pterocyclos diluvium* and *Pearsonia lamphunensis* (Tumpeesuwan & Tumpeesuwan, 2015). In addition, A pantacuspid radula has been found in *Thais bronni* and *T. clavigera* (Fujioka, 1985). Similar to other studies, we also found that the central cusp of radular teeth is longer than the lateral cusps (Harasewych & Kantor, 1991; Harasewych & Marshall, 1995).

The median teeth of giant African land snails (Odaibo & Olayinka, 2019) and freshwater snails (Yakhchali & Jamshidi Deilami, 2012) are smaller compared to lateral and marginal teeth, but the size of the lateral and central teeth in all species were found to be the same in our study. As shown by others and in this current study, snails with larger shell size had more teeth rows (Ferreira, 1977; Ocanˇa *et al.*, 2004; Yakhchali *et al*., 2013). Snails with larger shell size also had more marginal teeth. The shell of *H .lucorum* was larger than other species and had the highest marginal teeth too, as shown by another study in *lymnaeid* snails (Yakhchali & Jamshidi Deillami, 2012).

CONCLUSION

The findings from our study demonstrates that morphological characteristics of shells and radulas were useful to differentiate different snail species.

Literature cited

Akinwale, O.P., Oso, O.G., Salawu, O.T., Odaibo, A.B., Chen, P.T., Gyang, P.V., 2015. Molecular Characterization of BulinusSnails Intermediate Hosts of Schistosomes in Ogun State, South West Nigeria. Folia Malacologia 23, 1-11.

Barker, G.M., 2001. The biology of terrestrial molluscs: Radular structure and function (Mackenstedt U and Markel K). CABI Publishers, Wallingford, London, UK.

Burch, J. B., and Van Devender, A. S., 1980. Identification of eastern North American land snails. Society for experimental and descriptive malacology, 50 p.

Cameron, R., Riley, G., 2008. Land snails in the British Isles. FSC Publications, 234 p.

Cameron, R., Redfern, M., 2009. British land snails: Mollusca, Gastropoda: keys and notes for the identification of the species. Linnean Society of London by Academic Press, 64 p.

Ferreira, A. J., 1977. A review of the genus *Triopha* (Mollusca: Nudibranchia). The Veliger 19, 387–402.

Franklin, J.B., Fernando, S.A., Chalke, B.A., Krishnan, K.S., 2007. Radular morphology of Conus (Gastropoda: Caenogastropoda: Conidae) from India. Molluscan Research 27(3), 111–22.

Fujiok, Y., 1985. Seasonal aberrant radular formation in *Thais bronni* (dunker) and *T. clavigera* (kuster) (gastropoda: muricidae). Journal of Experimental Marine Biology and Ecology 90, 43-54

Harasewych, M.G., Kantor, Y.I., 1991. Tenebrincola frigida, a new genus and species of abyssal volute from the northern Pacific Ocean (Gastropoda: Volutidae). Nemouria 38, 1–11.

Harasewych, M.G., Marshall, B.A., 1995. Zygomelon zodion, a new genus and species of bathyal volute from New Zealand. The Veliger 38, 145–51.

Hebert, D.N., Cywinska, A., Ball, S.L., de Waard, J.R., 2003. Biological Identifications through DNA Barcodes. Proceedings of the Royal Society of London 270, 313-321.

Howe, S.W., 1930. A study of the variations in the radula of a snail with particular reference to the size of the median teeth. Nautilus 44, 53-63.

Kilburn, R.N., 1988. Turridae (Mollusca: Gastropoda) of southern Africa and Mozambique. Part 4. Subfamilies Drilliinae, Crassispirinae and Strictispirinae. Annals of the Natal. Museum 29, 167-320.

Kristensen, T. K., 1984. Methodology for Snail Dissection and Preparation. Danish Bilharziasis Laboratory. Charlottenland, Copenhagen, Denmark.

Mansourian, A., 2005. Terrestrial mollusces of Golestan, and Mazandaran provinces, northern Iran.Journal of Veterinary Research 60(1), 316.

Mansourian, A. 1986. A practical guidline for identification of Iranian freshwater snails. Iranian Journal of Public Health 15, 41–53.

Matthews-Cascon, H.R., Pereira, A.H.A., Guimaraes, R.S., Mota, R.M.S., 2005. Sexual dimorphism in the radula of Pisaniapusio (Linnaeus, 1758) (Mollusca, Gastropoda, Buccinidae). Thalassas 21,29-33.

Medina, A.I., Romero M.A, Narvarte M.A., 2016. Radular morphology of *Zidona dufresnei* (Neogastropoda: Volutidae) and an analysis of its variability along the distributional range. Marine biology research 12, 211-220

Monzon, R.B., Kitikoon, V., Thammapalerd, N., Temcharoen, P., Sornmani, S., Viyanant, V., 1993. Comparative shell morphology of Lymnaea (Bullastra) cumingiana (Pulmonata: Lymnaeidae) and related taxa in the Indo-Pacific region. Southeast Asian Journal of Tropical Medicine and Public Health 24(3), 554-562.

Morton, B., 1979. The population dynamics and expression sexuality in Balcis schaplandi and Mocronalia fulvescens (Mollusca: Gastropoda: Aglosa) parasitic upon Archaster typicus (Echinodermata: Asteroidea). Malacologia 18, 327–346.

Oca ñ a, A., Sánchez-tocíno, L., García, F.G., 2004. Ontogenetic radular variation in species of Tambja Burn, 1952 (Gastropoda, Opistobranchia, Polyceratidae), from the eastern Atlantic Ocean and Mediterranean Sea. Scientia Marina 68, 205–210.

Odaibo, A.B., Olayinka, S.O., 2019.Shell Morphology, Radula and Genital Structures of New Invasive Giant African Land 2 Snail Species, Achatina fulica Bowdich, 1822, Achatina albopicta E.A. Smith (1878) and 3 Achatina reticulata Pfeiffer 1845 (Gastropoda: Achatinidae) in Southwest Nigeria. bioRxiv 1-19.

Oso, O.G., Odaibo, A.B., 2018. Shell morphology and the radula structure of two closely related bulinid snail intermediate host of Schistosoma haematobium in Nigeria. African Journal of Biotechnology 17(9), 269-278.

Ponder, W.F., Lindberg, D.R., 1996. Gastropod phylogeny: challenges for the 90s. In: Taylor JD, ed. Origin and evolutionary radiation of the Mollusca. OU Press, New York, pp. 135-154.

Ruham, N.W., Thornton, P.R., 1967. Mechanical wear of the gastropod radula: Scanning electron microscope study. Journal of the Zoological Society of London 153, 445–452.

Schander, C., Willassen, E., 2005. What can a biological barcoding do for marine biology. Marine Biology Research 1, 79-83.

Stothard, J.R., Rollinson, D., 1996. An evaluation of random amplified polymorphic DNA for identification and phylogeny of freshwater snails of the genus *Bulinus* (Gastropoda: Planorbidae). Journal of Molluscan Studies 62,165-176.

Tumpeesuwan, S., Tumpeesuwa, C.H., 2015. First record and description of a new species of the land snail genus Pearsonia Kobelt, 1902 (Cyclophoridae: Pterocyclinae) from Thailand, with a note on radula morphology. Raffles Bulletin of Zoology 63, 287–292.

Yakhchali, M., Jamshidi Deilamy, L., 2012. Radular variations in freshwater snails of the family Lymnaeidae (Mollusca: Gastropoda: Basommatophora) from northwestern Iran. American Malacological Bulletin 30(2), 323–32.

Yakhchali, M., Gorgani-firuzjaei, T., Baghri K., 2013. Radular Teeth Morphology in *Limax* (*Caspilimax*) *keyserlingi* (Martens, 1880) and *Parmacella ibera* (Eichwald, 1841) from Northern Iran. Iranian Journal of Parasitology 8(2), 256-263.

Iranian Journal of Animal Biosystematics (IJAB)
Vol.17, No.2, 179-207, 2021
DOI: 10.22067/ijab.2022.67343.1000

IJAB
ISSN: 1735-434X (print); 2423-4222 (online)

RESEARCH ARTICLE Open access

A checklist of the ants (Insecta, Formicidae) of Azerbaijan Republic

Nataly Snegovaya[1] and Chingiz Shigayev[2]

[1]*Institute of Zoology, National Academy of Science of Azerbaijan (IZB), A. Abbaszade st.115, pr.1128, bl.504, Az 1004, Baku, Azerbaijan*
[2]*Aliyar Aliyev 25/29, Az 1033, Baku, Azerbaijan*

(Received: *2 December 2020*; Accepted: 15 *December 2021*)

Abstract
In this checklist 128 ant species belonging to 28 genera that have been recorded from Azerbaijan are presented. Data on distribution around the world and in Azerbaijan are given. This study is based on a generalization of all available literature data. *Messor laboriosus* Santschi, 1927 is recorded for the first time for Azerbaijan.

Key words: fauna, *Messor laboriosus, new record, Azerbaijan*

INTRODUCTION

The myrmecofauna of Azerbaijan is not studied well enough. Coverage on this family of insects is very few and far between. Most thoroughly studied are the ants of Talysh (Arnol'di, 1948). Information on some species can be found in the works of Ruzsky (1902, 1905), Karavaiev (1926a, 1926b, 1929a, 1929b, 1932), Arnol'di (1930, 1964, 1968, 1970, 1977a, 1977b), Radchenko (1997). The catalog of Borowiec (2014) contains generalized data on Azerbaijan and lists 70 species of ants for Azerbaijan in his catalog. Some data may also be gathered from the catalog of Dubovikoff & Yusupov (2017), where 4 species are noted directly for Azerbaijan and 79 species for the Caucasus (including Azerbaijan). New information on the ants of Azerbaijan was revealed by Bračko (2019), with data provided on 73 species of ants, 30 of which are new to the fauna of Azerbaijan. The list was provided here is a general checklist of the ants of Azerbaijan, based on all available information. *Messor laboriosus* Santschi, 1927, found by the second author in Absheron, is recorded for the first time for Azerbaijan.

MATERIAL AND METHODS

The first checklist of the Azerbaijanian ants was assembled using published records. For each species country distribution and spread around the world is indicated (Fig. 1).

RESULTS

As a result of our work on the checklist of the ants of Azerbaijan, we have revealed the full species composition, summarized information on its distribution within the republic, and have given data on their distribution worldwide.

Corresponding Author: snegovaya@yahoo.com
©2021 FERDOWSI UNIVERSITY OF MASHHAD, IRAN

THIS WORK IS LICENSED UNDER A CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENSE.

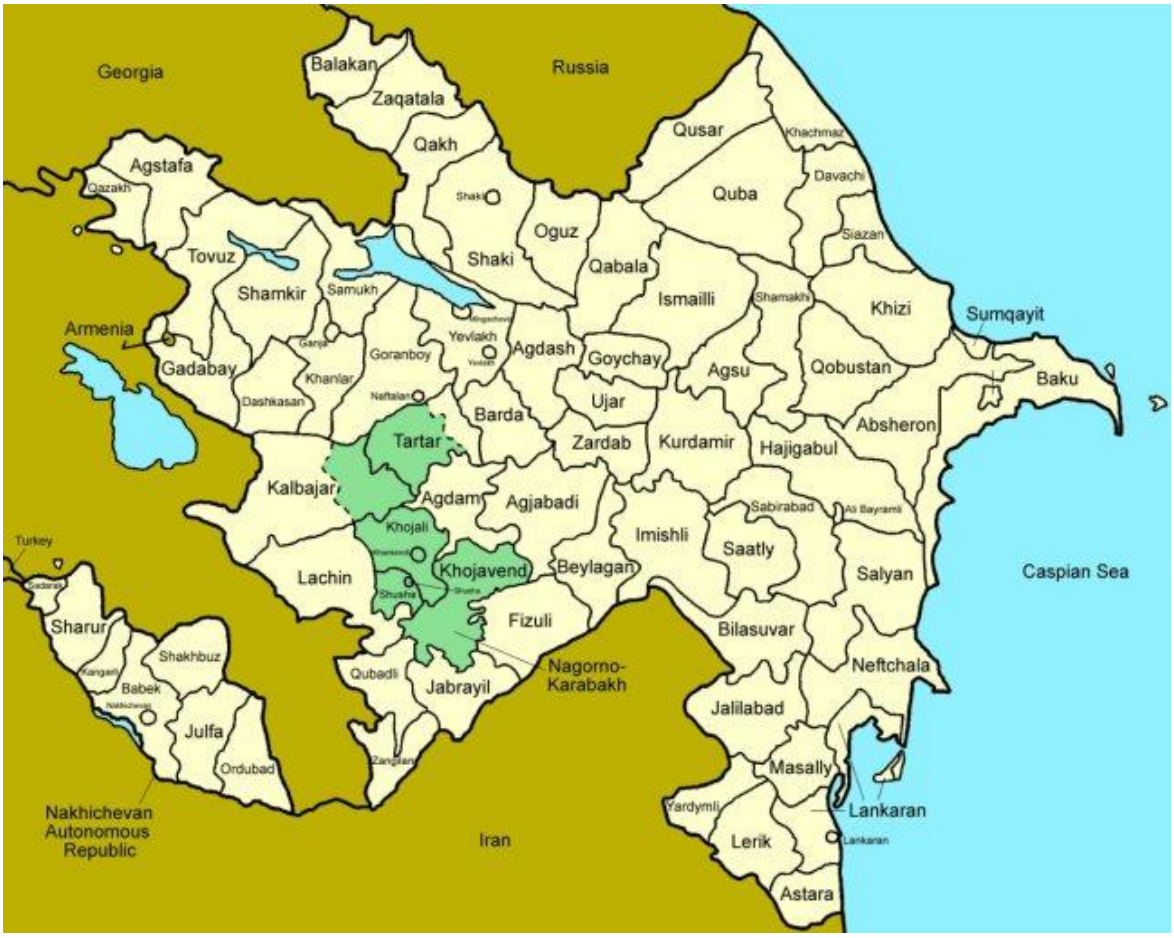

FIGURE 1. Map of regions of the Azerbaijan Republic (ref.).

Superfamily Formicoidea
Family **Formicidae**
Subfamily Dolichoderinae Forel, 1878
Genus *Dolichoderus* Lund, 1831

1. *D. quadripunctatus* (Linnaeus, 1771)
Karawajew**,** 1926b**:** *Dolichoderus (Hypoclinea) quadripunctatus* L.: 187
Arnoldi, 1948: *Dolichoderus (Hypoclinea) quadripunctatus* (Linnaeus, 1771): 212
Bračko, 2019: *Dolichoderus quadripunctatus* (Linnaeus, 1771): 170

Records: Aresh (now Agdash), Nukha (now Sheki), Lankaran (Karawajew**,** 1926), Lerik (Arnol'di, 1948)*,* Khachmaz, Agsu, Ismailly, Zagatala, Gakh and Lankaran (Bračko, 2019*).*
Distribution: Albania, Andorra, Armenia, Austria, Belarus, Belgium, Bulgaria, Croatia, Czech Republic, France (type locality), Georgia, Germany, Gibraltar, Greece, Hungary, Iberian Peninsula, Iran, Liechtenstein, Lithuania, Luxembourg, Monaco, Montenegro, Norway, Poland, Portugal, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Switzerland, Turkey, Ukraine (https://www.antwiki.org).

Genus *Tapinoma* Förster, 1850

2. *T. erraticum* (Latreille, 1798)
Arnoldi, 1948: *Tapinoma erraticum* Ltr.: 212

Borowiec, 2014: *Tapinoma erraticum* (Latreille, 1798): 167
Dubovikoff, Yusupov, 2017: *Tapinoma erraticum* (Latreille, 1798): 198
Bračko, 2019: *Tapinoma erraticum* (Latreille, 1798): 173
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017), Guba, Samukh, Astara (Bračko, 2019*).*
Distribution: Albania, Andorra, Armenia, Austria, Balearic Islands, Belarus, Belgium, Bulgaria, Canary Islands, Channel Islands, Croatia, Czech Republic, France (type locality), Georgia, Germany, Gibraltar, Greece, Hungary, Iberian Peninsula, Iran, Israel, Italy, Kazakhstan, Kyrgyzstan, Liechtenstein, Lithuania, Luxembourg, Malta, Monaco, Montenegro, Netherlands, Poland, Portugal, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Turkmenistan, Ukraine, United Kingdom of Great Britain and Northern Ireland, Aland Islands (https://www.antwiki.org).

3. *T. karavaievi* Emery, 1925
Karavayev, 1932: *Tapinoma simrothi* subsp. *azerbeidzhanica* Karavaiev, 1932: 248.
Borowiec, 2014: *Tapinoma karavaievi* Emery, 1925: 167
Bračko, 2019: *Tapinoma karavaievi* Emery, 1925: 173
Records: Ganja (Karavayev, 1932), Azerbaijan (Borowiec, 2014), Guba, Ismailly, Gakh, Sabirabad (Bračko, 2019*).*
Distribution: Afghanistan, Armenia, Azerbaijan, Georgia, Iran, Kazakhstan (type locality), Turkmenistan (https://www.antwiki.org).

4. *T. magnum* Mayr, 1861
Bračko, 2019: *Tapinoma magnum* Mayr, 1861: 173
Records: Absheron (Bračko, 2019*).*
Distribution in the Palaearctic Region: Algeria, Belgium, France, Germany, Greece, Italy (type locality), Morocco, Netherlands, Spain, Tunisia (https://www.antwiki.org).

Subfamily Formicinae
Genus *Camponotus* Mayr, 1861

5. *C.* (*Camponotus*) *herculeanus* (Linnaeus, 1758)
Ruzsky, 1902: *Camponotus herculeanus,* Lin.: 5
Records: Lankaran (Ruzsky, 1902*).*
Distribution : Andorra, Armenia, Austria, Belarus, Belgium, Bulgaria, China, Croatia, Czech Republic, Denmark, Estonia, Finland, Georgia, Germany, Greece, Hungary, Iberian Peninsula, Italy, Kazakhstan, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Netherlands, Norway, Poland, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation (type locality), Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, North America, Alaska (https://www.antwiki.org).

6. *C. (Myrmentoma) atricolor* (Nylander, 1849)
Bračko, 2019: *Camponotus atricolor* (Nylander, 1849): 169
Records: Guba, Khachmaz, Gusar, Khizi, Evlakh, Agstafa, Samukh, Agjabedi, Bilyasuvar, Lankaran, Lerik (Bračko, 2019*).*
Distribution: Austria, Bulgaria, Greece, Hungary, Romania, Russian Federation (type locality) (https://www.antwiki.org).

7. *C.* (*Myrmentoma*) *candiotes* Emery, 1894
Borowiec, 2014: *Camponotus* (*Myrmentoma*) *candiotes* Emery, 1894: 28
Records: Azerbaijan (Borowiec, 2014).

Distribution: Greece (type locality), Turkey. (https://www.antwiki.org).

8. *C. (Myrmentoma) interjectus* Mayr, 1877
Arnoldi, 1948: *Camponotus interjectus* subsp. *transcaucasicus* Arnoldi, 1948: 212
Borowiec, 2014: *Camponotus* (*Myrmentoma*) *interjectus* Mayr, 1877: 34
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014).
Distribution: Afghanistan, China, Iran, Iraq, Israel, Jordan, Kazakhstan (type locality), Kyrgyzstan, Russian Federation, Turkmenistan (https://www.antwiki.org).

9. *C. (Myrmentoma) fallax* (Nylander, 1856)
Borowiec, 2014: *Camponotus* (*Myrmentoma*) *fallax* (Nylander, 1856): 30
Bračko, 2019: *Camponotus fallax* (Nylander, 1856): 169
Records: Azerbaijan (Borowiec, 2014), Guba, Ismailly, Gakh, Zagatala (Bračko, 2019*)*.
Distribution: Albania, Andorra, Armenia, Austria, Balearic Islands, Belarus, Belgium, Bulgaria, Croatia, Czech Republic, Finland, France (type locality), Georgia, Germany, Greece, Hungary, Iberian Peninsula, Iran, Liechtenstein, Lithuania, Luxembourg, Malta, Montenegro, Netherlands, Poland, Portugal, Republic of Korea, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraines://www.antwiki.org).

10. *C.* (*Myrmentoma*) *kurdistanicus* Emery, 1898
Borowiec, 2014: *Camponotus* (*Myrmentoma*) *kurdistanicus* Emery, 1898: 35
Records: Azerbaijan (Borowiec, 2014).
Distribution: China, Iran, Iraq, Israel, Russian Federation (type locality), Turkey. (https://www.antwiki.org).

11. *C. (Myrmentoma) lateralis* (Olivier, 1792)
Bračko, 2019: *Camponotus lateralis* (Olivier, 1792): 169
Records: Khizi, Khachmaz, Agsu, Ismailly, Balaken, Lankaran (Bračko, 2019*).*
Distribution: Albania, Algeria (type locality), Andorra, Armenia, Azerbaijan, Balearic Islands, Bulgaria, Croatia, Cyprus, France (type locality), Georgia, Germany, Gibraltar, Greece, Hungary, Iberian Peninsula, Iran, Israel, Italy, Malta, Monaco, Montenegro, Morocco, Portugal, Republic of Macedonia, Romania, Russian Federation, Slovakia, Slovenia, Spain, Switzerland, Turkey, Turkmenistan, Ukraine (https://www.antwiki.org).

12. *C. (Tanaemyrmex) turkestanicus* Emery, 1887
Bračko, 2019: *Camponotus turkestanicus* Emery, 1887: 169
Records: Evlakh, Samukh, Salyan, Absheron, Sabirabad (Bračko, 2019).
Distribution: Afghanistan, China, Georgia, Iran, Kazakhstan (type locality), Kyrgyzstan, Russian Federation, Turkmenistan (https://www.antwiki.org).

13. *C. (Tanaemyrmex) aethiops* (Latreille, 1798)
Arnoldi, 1948: *C. (Tanaemyrmex) aethiops* Latr: 212
Borowiec, 2014: *Camponotus* (*Tanaemyrmex*) *aethiops* (Latreille, 1798): 25
Dubovikoff, Yusupov, 2017: *C. (Tanaemyrmex) aethiops* (Latreille, 1798): 199
Bračko, 2019: *Camponotus aethiops* (Latreille, 1798): 169
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017), Guba, Ismailly, Evlakh, Bilyasuvar, Lerik, Salyan (Bračko, 2019*)*.
Distribution: Albania, Andorra, Armenia, Austria, Balearic Islands, Bulgaria, China, Croatia, Czech Republic, France (type locality), Georgia, Germany, Gibraltar, Greece, Hungary, Iberian Peninsula,

Iran, Israel, Italy, Malta, Montenegro, Portugal, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Switzerland, Turkey, Turkmenistan, Ukraine (https://www.antwiki.org).

14. *C. (Tanaemyrmex) fedtschenkoi* Mayr, 1877
Karavayev, 1932: *Camponotus (Tanaemyrmex*) *maculatus* F. susp. *fedtschenkoi* Mayr: 191
Dubovikoff, Yusupov, 2017: *C. (Tanaemyrmex) fedtschenkoi* Mayr, 1877: 199
Records: Aresh (now Agdash), Geoktapa (near Ganja), Pirsagat, Aresh (now Agdash) (Karawajev, 1926), Azerbaijan (Dubovikoff, Yusupov, 2017).
Distribution: South Caucasus, Middle Asia, Kazakhstan, Iran (Radchenko, 1997).

Genus *Cataglyphis* Förster, 1850

15. *C. aenescens* (Nylander, 1849)
Ruzsky, 1902 b: *Myrmecocystus cursor* var. *caspius* Ruzsky, 1902 b: 470
Arnoldi, 1948: *Cataglyphis* (*Monocombus*) *cursor*. a*enescens Nyl.*: 212
Borowiec, 2014: *Cataglyphis aenescens* (Nylander, 1849): 50
Dubovikoff, Yusupov, 2017: Cataglyphis aenescens (Nylander, 1849): 199
Bračko, 2019: *Cataglyphis aenescens* (Nylander, 1849): 170
Records: Mugan steppe and Araks, Salyan, Lankaran (Ruzsky, 1902), Lerik (Arnol'di, 1948*)*, Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017), Gusar, Samukh, Lerik, Bilyasuvar, Salyan, Gobustan (Bračko, 2019*)*.
Distribution: Afghanistan, Armenia, Bulgaria, China, Croatia, Georgia, Greece, Hungary, Iran, Kazakhstan (type locality), Kyrgyzstan, Mongolia, Republic of Macedonia, Romania, Russian Federation (type locality), Slovakia, Turkey, Turkmenistan, Ukraine (https://www.antwiki.org).

16. *C. cuneinodis* Arnoldi, 1964
Arnoldi, 1964: Cataglyphis viaticoides ssp. cuneinodis Arnoldi: 1810
Borowiec, 2014: *Cataglyphis cuneinodis* Arnoldi, 1964: 53
Records: Ordubad, Nakhichevan (Arnoldi, 1964), Azerbaijan (Borowiec, 2014).
Distribution: Azerbaijan, Iran (https://www.antwiki.org).

17. *C. nodus* (Brullé, 1833)
Arnoldi, 1948: *Cataglyphis bicolor nobus* Brulle: 212
Arnoldi, 1964: *Cataglyphis nodus* subsp. *causcasicola* Arnoldi, 1964: 1803
Borowiec, 2014: *Cataglyphis nodus* (Brullé, 1833): 58
Dubovikoff, Yusupov, 2017: *Cataglyphis nodus* (Brullé, 1833): 199
Bračko, 2019: *Cataglyphis nodus* (Brullé, 1833): 170
Records: Lerik (Arnol'di, 1948*)*, Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017), Khizi, Evlakh, Agstafa, Samukh, Agjabedi, Absheron, Sabirabad (Bračko, 2019*)*.
Distribution: Albania, Armenia, Bulgaria, Croatia, Georgia, Greece (type locality), Hungary, Iran, Israel, Jordan, Montenegro, Republic of Macedonia, Romania, Russian Federation, Slovakia, Turkey, Turkmenistan, Uzbekistan (https://www.antwiki.org).

18. *C. setipes* (Forel, 1894)
Ruzsky, 1902: *Myrmecocystus viaticus* subsp. *Setipes,* For.: Ruzsky, 1902
Records: Baku, Murovdag, Kelbajar, Kura, Araks (Ruzsky, 1902*).*
Distribution: Iran (https://www.antwiki.org).

Genus *Colobopsis* Mayr, 1861

19. *C. truncatus* (Spinola, 1808)

Arnoldi, 1948: *Camponotus* (*Colobopsis*) *truncatus* Spin.: 212
Borowiec, 2014: *Camponotus* (*Colobopsis*) *truncatus* (Spinola 1808): 44
Bračko, 2019: *Colobopsis truncata* (Spinola, 1808): 170
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017), Khachmaz, Oguz, Zagatala, Balaken (Bračko, 2019*).*
Distribution: Albania, Algeria, Andorra, Armenia, Austria, Balearic Islands, Bulgaria, Croatia, Cyprus, Czech Republic, Finland, France, Georgia, Germany, Greece, Hungary, Iberian Peninsula, Israel, Italy (type locality), Jordan, Malta, Montenegro, Netherlands, Poland, Portugal, Republic of Macedonia, Republic of Moldova, Romania, Slovakia, Slovenia, Spain, Switzerland, Turkey, Turkmenistan, Ukraine (https://www.antwiki.org).

Genus *Formica* Linnaeus, 1758

20. *F.* (*Coptoformica*) *fennica* Seifert, 2000
Records: Azerbaijan (Seifert (2019).
Distribution in the Palaearctic Region: Azerbaijan, Finland (type locality), Georgia (https://www.antwiki.org).

21. *F.* (*Serviformica*) *georgica* Seifert, 2002
Bračko, 2019: *Formica georgica* Seifert, 2002: 170
Records: Guba, Ismailly, Sheki, Balaken, Gakh, Goygel, Dashkesan (Bračko, 2019*).*
Distribution: Azerbaijan, Georgia (type locality), Turkey (https://www.antwiki.org).

22. *F.* (*Raptiformica*) *sanguinea* Latreille, 1798
Arnoldi, 1948: *Formica* (*Raptiformica*) *sanguinea clarior* Ruz: 212
Borowiec, 2014: *Formica* (*Raptiformica*) *sanguinea* Latreille, 1798: 79
Dubovikoff, Yusupov, 2017: Formica (Raptiformica) sanguinea Latreille, 1798: 200
Bračko, 2019: *Formica sanguinea* Latreille, 1798: 170
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017), Khachmaz, Ismailly, Evlakh, Lerik (Bračko, 2019*),*
Distribution: Afghanistan, Albania, Andorra, Armenia, Austria, Balearic Islands, Belarus, Belgium, Bulgaria, Canary Islands, China, Croatia, Czech Republic, Democratic Peoples Republic of Korea, Denmark, Estonia, Finland, France (type locality), Georgia, Germany, Gibraltar, Greece, Hungary, Iberian Peninsula, Iran, Japan, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Mongolia, Netherlands, Norway, Poland, Portugal, Republic of Korea, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

23. *F.* (*Serviformica*) *clara* Forel, 1886
Borowiec, 2014: *Formica* (*Serviformica*) *clara* Forel, 1886: 73
Bračko, 2019: *Formica clara* Forel, 1886: 170
Records: Azerbaijan (Borowiec, 2014), Absheron, Guba, Khachmaz, Ismailly, Gabala, Zagatala, Gakh, Evlakh, Samukh, Lankaran Lerik (Bračko, 2019*),* Azerbaijan
(AntWiki: https://www.antwiki.org/wiki/Formica_clara).
Distribution: Afghanistan, Austria, Azerbaijan, Belgium, Bulgaria, China, Croatia, Czech Republic, Georgia, Germany, Greece, Hungary, Iran, Israel, Italy, Kyrgyzstan, Mongolia, Netherlands, Poland, Romania, Russian Federation (type locality), Slovakia, Slovenia, Spain, Switzerland, Turkey, Turkmenistan, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

24. *F.* (*Serviformica*) *cunicularia* Latreille, 1798

Bračko, 2019: *Formica cunicularia* Latreille, 1798: 170
Records: Ismailly (Bračko, 2019*).*
Distribution: Albania, Andorra, Armenia, Austria, Belarus, Belgium, Bulgaria, Channel Islands, China, Croatia, Czech Republic, Denmark, Estonia, Finland, France (type locality), Georgia, Germany, Greece, Hungary, Iberian Peninsula, Iran, Italy, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Mongolia, Montenegro, Morocco, Netherlands, Norway, Poland, Portugal, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

25. *F.* (*Serviformica*) *cinereofusca* Karawajew, 1929
Karawajew**,** 1929**:** *Formica cinerea var. cinereofusca* Karawajew, 1929: 214
Dubovikoff, Yusupov, 2017: *Formica (Serviformica) cinereofusca* Karawajew, 1929: 200
Records: Kelbajar (Karawajev 1929), Caucasus (Dubovikoff, Yusupov, 2017).
Distribution: Armenia, Azerbaijan, China, Georgia, Russian Federation, Ukraine (https://www.antwiki.org).

26. *F.* (*Serviformica*) *fusca* Linnaeus, 1758
Arnoldi, 1948: *Formica* (*Serviformica*) *fusca hyrcana* K. Arn: 212
Arnoldi, 1968: *Formica* (*Serviformica*) *fusca* subsp. *Hyrcana* Arnoldi, 1968: 1821.
Borowiec, 2014: *Formica* (*Serviformica*) *fusca* Linnaeus, 1758: 74
Dubovikoff, Yusupov, 2017: *Formica (Serviformica) fusca* Linnaeus, 1758: 200
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017).
Distribution: Albania, Andorra, Armenia, Austria, Belarus, Belgium, Bulgaria, Channel Islands, China, Croatia, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iberian Peninsula, Isle of Man, Latvia, Lithuania, Luxembourg, Malta, Montenegro, Netherlands, Norway, Poland, Portugal, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

27. *F.* (*Serviformica*) *gagates* Latreille, 1798
Ruzsky, 1902: *Formica gagates,* Latr.: 13
Records: Murovdag, Kelbajar (Ruzsky, 1902*)*.
Distribution: Albania, Austria, Bulgaria, China, Croatia, Czech Republic, France (type locality), Germany, Greece, Hungary, Iberian Peninsula, Montenegro, Poland, Portugal, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Switzerland, Turkey, Ukraine (https://www.antwiki.org).

28. *F.* (*Serviformica*) *picea* Nylander, 1846
Karawajew**,** 1926b**:** *Formica. (Serviformica) picea* Nyl: 196
Bračko, 2019: *Formica picea* Nylander, 1846: 170
Records: Istisu, Kelbajar (Karawajev, 1926), Gusar (Bračko, 2019*).*
Distribution: Andorra, Belgium, Bulgaria, China, Czech Republic, Finland (type locality), Georgia, Greece, Iberian Peninsula, Italy, Kazakhstan, Poland, Russian Federation, Spain, Turkey, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

29. *F.* (*Serviformica*) *rufibarbis* Fabricius, 1793
Ruzsky, 1902: *Formica* (*Serviformica*) *rufibarbis,* F: 11
Arnoldi, 1948: *F. (Serviformica) rufibarbis* F.: 212
Borowiec, 2014: *Formica* (*Serviformica*) *rufibarbis* Fabricius, 1793: 78

Dubovikoff, Yusupov, 2017: *Formica (Serviformica) rufibarbis* Fabricius, 1793: 201
Records: Gusar (Ruzsky, 1902), Lerik (Arnol'di, 1948*),* Caucasus (Dubovikoff, Yusupov, 2017), Azerbaijan (Borowiec, 2014).
Distribution: Albania, Andorra, Armenia, Austria, Balearic Islands, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, China, Croatia, Czech Republic, Denmark, Estonia, Finland, France (type locality), Georgia, Germany, Greece, Hungary, Iberian Peninsula, Iran, Italy, Latvia, Lithuania, Luxembourg, Montenegro, Netherlands, Norway, Poland, Portugal, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Turkmenistan, Ukraine, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

30. *F.* (*Serviformica*) *subpilosa* Ruzsky, 1902
Karawajew, 1926b: *Formica cinera* var. *bipilosa* Karavaiev 1926: 199
Borowiec, 2014: *Formica* (*Serviformica*) *subpilosa* Ruzsky, 1902: 79
Dubovikoff, Yusupov, 2017: *Formica (Serviformica) subpilosa* Ruzsky, 1902: 201
Bračko, 2019: *Formica subpilosa* Ruzsky, 1902: 170
Records: Salyan (Karavayev, 1926), Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017), Sabirabad (Bračko, 2019*)*.
Distribution: Afghanistan, Armenia, Azerbaijan, China, Georgia, Kyrgyzstan, Russian Federation (type locality), Turkey, Turkmenistan, Uzbekistan (https://www.antwiki.org).

Genus *Lasius* Fabricius, 1804

31. *L. bombycina* Seifert et Galkowski, 2016
Bračko, 2019: *Lasius bombycina* Seifert et Galkowski, 2016: 170
Records: Guba (Bračko, 2019*).*
Distribution: Austria, Azerbaijan, Bulgaria, Greece, Hungary, Slovenia, Turkey (type locality) (https://www.antwiki.org).

32. *L. illyricus* Zimmermann, 1935
Bračko, 2019: *Lasius illyricus* Zimmermann, 1935: 170
Records: Ismailly, Zagatala, Gakh, Goygel (Bračko, 2019*).*
Distribution: Armenia, Austria, Azerbaijan, Croatia (type locality), Greece, Montenegro, Republic of Macedonia, Russian Federation, Serbia, Turkey, Ukraine (https://www.antwiki.org).

33. *L.* (*Lasius*) *platythorax* Seifert, 1991
Bračko, 2019: *Lasius platythorax* Seifert, 1991: 170
Records: Gakh (Bračko, 2019*).*
Distribution: Andorra, Austria, Belarus, Belgium, Bulgaria, Croatia, Czech Republic, Estonia, Finland, Germany (type locality), Greece, Hungary, Iberian Peninsula, Iran, Ireland, Italy, Montenegro, Netherlands, Norway, Poland, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

34. *L.* (*Lasius*) *alienus* (Förster, 1850)
Arnoldi, 1948: *Lasius alienus Forst.*: 212
Borowiec, 2014: *Lasius* (*Lasius*) *alienus* (Förster 1850): 83
Dubovikoff, Yusupov, 2017: *Lasius (Lasius) alienus* (Förster, 1850): 202
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017).

Distribution: Albania, Andorra, Armenia, Austria, Belarus, Belgium, Bulgaria, Channel Islands, China, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany (type locality), Greece, Hungary, Iberian Peninsula, Iran, Israel, Italy, Japan, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Malta, Mongolia, Montenegro, Netherlands, Poland, Portugal, Republic of Korea, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Turkmenistan, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

35. *L.* (*Lasius*) *brunneus* (Latreille, 1798)
Arnoldi, 1948: *Lasius brunneus* Latr.: 212
Borowiec, 2014: *Lasius* (*Lasius*) *brunneus* (Latreille, 1798): 84
Dubovikoff, Yusupov, 2017: *Lasius (Lasius) brunneus* (Latreille, 1798): 202
Bračko, 2019: *Lasius brunneus* (Latreille, 1798): 170
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017), Khachmaz (Bračko, 2019*).*
Distribution: Albania, Andorra, Armenia, Austria, Belarus, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Finland, France (type locality), Georgia, Germany, Greece, Hungary, Iberian Peninsula, Iran, Israel, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Republic of Korea, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

36. *L.* (*Lasius*) *emarginatus* (Olivier, 1792)
Arnoldi, 1948: *Lasius emarginatus* Ol.: 212
Borowiec, 2014: *Lasius* (*Lasius*) *emarginatus* (Olivier, 1792): 85
Dubovikoff, Yusupov, 2017: *Lasius (Lasius) emarginatus* (Olivier, 1792): 202
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017).
Distribution: Albania, Andorra, Armenia, Austria, Azerbaijan, Balearic Islands, Belarus, Belgium, Bulgaria, Canary Islands, Channel Islands, China, Croatia, Czech Republic, France (type locality), Georgia, Germany, Gibraltar, Greece, Hungary, Iberian Peninsula, Iran, Israel, Italy, Luxembourg, Malta, Monaco, Montenegro, Poland, Portugal, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Switzerland (type locality), Turkey, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

37. *L. (Lasius) lasioides* (Emery, 1869)
Arnoldi, 1948: *Lasius lasioides elegantulus* K. Arn: 212
Borowiec, 2014: *Lasius* (*Lasius*) *lasioides* (Emery, 1869): 87
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014).
Distribution: Albania, Balearic Islands, Croatia, France, Georgia, Greece, Iberian Peninsula, Iran, Israel, Italy (type locality), Malta, Montenegro, Morocco, Portugal, Republic of Macedonia, Spain, Turkey (https://www.antwiki.org).

38. *L.* (*Lasius*) *obscuratus* Stitz, 1930
Bračko, 2019: *Lasius obscuratus* Stitz, 1930: 170
Records: Khizi, Guba, Gusar, Ismailly, Lerik (Bračko, 2019*).*
Distribution: Azerbaijan, China, Georgia, Mongolia, Russian Federation (https://www.antwiki.org).

39. *L.* (*Cautolasius*) *flavus* (Fabricius, 1782)
Arnoldi, 1948: *Lasius flavus* F.:212

Borowiec, 2014: *Lasius* (*Cautolasius*) *flavus* (Fabricius, 1782): 86
Dubovikoff, Yusupov, 2017: *Lasius (Cautolasius) flavus* (Fabricius, 1782): 201
Bračko, 2019: *Lasius flavus* (Fabricius, 1782): 170
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017), Guba, Gusar, Ismailly, Gakh, Goygel (Bračko, 2019*)*.
Distribution: Albania, Andorra, Armenia, Austria, Azerbaijan, Balearic Islands, Belarus, Belgium, Bulgaria, Canary Islands, Channel Islands, China, Croatia, Czech Republic, Democratic Peoples Republic of Korea, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iberian Peninsula, Iran, Italy, Japan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Mongolia, Montenegro, Netherlands, Norway, Poland, Portugal, Republic of Korea, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Turkmenistan, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

40. *L.* (*Cautolasius*) *myops* Forel, 1894
Borowiec, 2014: *Lasius* (*Cautolasius*) *myops* Forel, 1894: 86
Bračko, 2019: *Lasius myops* Forel, 1894: 170
Records: Azerbaijan (Borowiec, 2014), Lerik (Bračko, 2019*)*.
Distribution: Algeria (type locality), Austria, Azerbaijan, Belgium, Bulgaria, Croatia, Democratic Peoples Republic of Korea, France, Georgia, Germany, Greece, Hungary, Iberian Peninsula, Kyrgyzstan, Montenegro, Morocco, Netherlands, Portugal, Republic of Macedonia, Slovakia, Slovenia, Spain, Switzerland, Turkey, Ukraine (https://www.antwiki.org).

41. *L.* (*Chthonolasius*) *bicornis* (Förster, 1850)
Karawajew**,** 1926b**:** *Lasius* (*Chthonolasius*) *bicornis* Foerster: 1905:195
Dubovikoff, Yusupov, 2017: *Lasius (Chthonolasius) bicornis* (Förster, 1850): 201
Records: Caucasus (Dubovikoff, Yusupov, 2017).
Distribution: Armenia, Austria, Azerbaijan, Belgium, Bulgaria, Croatia, Czech Republic, France, Georgia, Germany (type locality), Greece, Hungary, Iberian Peninsula, Italy, Netherlands, Norway, Poland, Romania, Russian Federation, Slovenia, Spain, Sweden, Switzerland, Turkey (https://www.antwiki.org).

42. *L.* (*Chthonolasius*) *citrinus* Emery, 1922
Borowiec, 2014: *Lasius* (*Chthonolasius*) *citrinus* Emery, 1922: 85
Dubovikoff, Yusupov, 2017: *Lasius (Chthonolasius) citrinus* Emery, 1922: 201
Records: Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017).
Distribution: Austria, Azerbaijan, Belarus, Belgium, Bulgaria, Czech Republic, Democratic Peoples Republic of Korea, Georgia, Greece, Hungary, Iberian Peninsula, Italy (type locality), Netherlands, Norway, Poland, Russian Federation, Slovakia, Slovenia, Spain, Switzerland (https://www.antwiki.org).

43. *L.* (*Chthonolasius*) *mixtus* (Nylander, 1846)
Arnoldi, 1948: *Lasius* (*Chthonolasius*) *mixtus* Nyl.: 212
Borowiec, 2014: *Lasius* (*Chthonolasius*) *mixtus*: 87
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014).
Distribution: Albania, Andorra, Austria, Azerbaijan, Belarus, Belgium, Bulgaria, Channel Islands, Croatia, Czech Republic, Democratic Peoples Republic of Korea, Denmark, Estonia, Finland (type locality), Georgia, Germany, Greece, Hungary, Iberian Peninsula, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Republic of Macedonia, Republic of Moldova, Romania, Russian

Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

44. *L.* (*Dendrolasius*) *fuliginosus* (Latreille, 1798)
Arnoldi, 1948: *Lasius* (*Dendrolasius*) *fuliginosus* Latr.: 212
Borowiec, 2014: *Lasius* (*Dendrolasius*) *fuliginosus* (Latreille, 1798): 86
Dubovikoff, Yusupov, 2017: *Lasius (Dendrolasius) fuliginosus* (Latreille, 1798): 201
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014) Caucasus (Dubovikoff, Yusupov, 2017).
Distribution: Albania, Andorra, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bulgaria, Channel Islands, Croatia, Czech Republic, Denmark, Estonia, Finland, France (type locality), Georgia, Germany, Greece, Hungary, Iberian Peninsula, Isle of Man, Italy, Latvia, Liechtenstein, Luxembourg, Montenegro, Netherlands, Norway, Poland, Portugal, Republic of Korea, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

Genus *Lepisiota* Santschi, 1926

45. *L. caucasica* (Santschi, 1917)
Bračko, 2019: *Lepisiota caucasica* (Santschi, 1917): 170
Records: Khizi, Oguz, Evlakh, Samukh, Absheron (Bračko, 2019*).*
Distribution: Caucasus (type locality) (https://www.antwiki.org).

46. *L. frauenfeldi* (Mayr, 1855)
Arnoldi, 1948: *Acantholepis frauenfeldi* Mayr: 212
Borowiec, 2014: *Lepisiota frauenfeldi* (Mayr, 1855): 93
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014).
Distribution: Afghanistan, Albania, Armenia, Azerbaijan, Balearic Islands, Bulgaria, Croatia, Georgia, Greece, Iran, Israel, Malta, Montenegro, Republic of Macedonia, Spain, Turkey (https://www.antwiki.org).

47. *L. syriaca* (André, 1881)
Bračko, 2019: *Lepisiota syriaca* (André, 1881): 172
Records: Khizi (Bračko, 2019*).*
Distribution: Armenia, Azerbaijan, Iraq, Israel, Syrian Arab Republic, Turkey (https://www.antwiki.org).

Genus *Plagiolepis* Mayr, 1861

48. *P. arnoldii* Dlussky, Soyunov et Zabelin, 1990
Bračko, 2019: *Plagiolepis arnoldii* Dlussky, Soyunov et Zabelin, 1990: 172
Records: Khizi, Khachmaz, Ismailly, Oguz, Sabirabad (Bračko, 2019*).*
Distribution: Azerbaijan, Turkmenistan (type locality). (https://www.antwiki.org).

49. *P. karawajewi* Radchenko, 1989
Borowiec, 2014: *Plagiolepis karawajewi* Radchenko, 1989: 146
Records: Azerbaijan (Borowiec, 2014).
Distribution: Azerbaijan, Greece, Russian Federation, Ukraine (type locality) (https://www.antwiki.org).

50. *P. pallescens* Forel, 1889
Karawajew**,** 1926 b**:** *Plagiolepis (Plagiolepis) pallescens* For.: 188

Arnoldi, 1948: *Plagiolepis pallescens* For.: 212
Borowiec, 2014: *Plagiolepis pallescens* Forel, 1889: 146
Dubovikoff, Yusupov, 2017: *Plagiolepis pallescens* Forel, 1889: 202
Bračko, 2019: *Plagiolepis pallescens* Forel, 1889: 172
Records: Lankaran (Karawajew**,** 1926), Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017), Guba, Gusar, Ismailly, Gabala, Agstafa, Agjabedi, Lerik (Bračko, 2019).
Distribution: Albania, Armenia, Austria (type locality), Azerbaijan, Belgium, Bulgaria, Channel Islands, China, Croatia, Czech Republic, Democratic Peoples Republic of Korea, France, Germany, Greece (type locality), Hungary, Iran, Israel, Kyrgyzstan, Mongolia, Montenegro, Republic of Korea, Romania, Russian Federation, Slovenia, Spain, Switzerland, Turkey (type locality), Ukraine (type locality), United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

51. *P. perperamus* Salata, Borowiec et Radchenko, 2018
Bračko, 2019: *Plagiolepis perperamus* Salata, Borowiec et Radchenko, 2018: 172
Records: Absheron, Khizi, Agstafa, Lankaran, Astara (Bračko, 2019*).*
Distribution: Greece, Iran, Turkey (Salata et al., 2018).

52. *P. pygmaea* (Latreille, 1798)
Ruzsky, 1902: *Plagiolepis pygmaea* Latr.: 18
Records: Baku, Lankaran, Mugan steppe (Ruzsky, 1902*).*
Distribution: Afghanistan, Andorra, Armenia, Austria, Balearic Islands, Belgium, Bulgaria, Canary Islands, China, Croatia, Czech Republic, France (type locality), Georgia, Germany, Gibraltar, Greece, Hungary, Iberian Peninsula, Iran, Israel, Italy, Malta, Montenegro, Morocco, Portugal, Republic of Macedonia, Romania, Slovakia, Slovenia, Spain, Switzerland, Turkey (https://www.antwiki.org).

53. *P. regis* Karavaiev, 1931
Arnoldi, 1948: *Plagiolepis regis* Kar.: 212
Borowiec, 2014: *Plagiolepis regis* Karavaiev, 1931: 146
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014).
Distribution: Kazakhstan (type locality) (https://www.antwiki.org).

Genus *Proformica* Ruzsky, 1902

54. *P. epinotalis* Kuznetsov-Ugamsky, 1927
Bračko, 2019: *Proformica epinotalis* Kuznetsov-Ugamsky, 1927: 172
Records: Gusar, Lerik (Bračko, 2019*).*
Distribution: China, Iran, Kazakhstan (type locality), Kyrgyzstan, Republic of Moldova, Romania, Russian Federation, Turkmenistan (https://www.antwiki.org).

55. *P. nasuta* (Nylander, 1856)
Ruzsky, 1902: *Formica* (*Proformica*) *nasuta,* Nyl.: 13
Borowiec, 2014: *Proformica nasuta* (Nylander, 1856): 151
Records: Lankaran (Ruzsky, 1902), Azerbaijan (Borowiec, 2014).
Distribution: Bulgaria, Canary Islands, China, France (type locality), Georgia, Iberian Peninsula, Portugal, Republic of Macedonia, Romania, Spain, Turkey (https://www.antwiki.org).

56. *P. pilosiscapa* Dlussky, 1969
Dlussky, 1969: *Proformica pilosiscapa* Dlussky, 1969: 228
Borowiec, 2014: *Proformica pilosiscapa* Dlussky, 1969: 151

Records: Talysh (Dlussky, 1969), Azerbaijan (Borowiec, 2014).
Distribution: Armenia (type locality), Bulgaria, China, Georgia, Iran, Turkey (https://www.antwiki.org).

Subfamily Myrmicinae
Genus *Aphaenogaster* Mayr, 1853

57. *A. muschtaidica* Emery, 1908
Bračko, 2019: *Aphaenogaster muschtaidica* Emery, 1908: 169
Records*:* Khachmaz, Agsu, Zagatala, Evlakh (Bračko, 2019*).*
Distribution: Georgia (type locality) (https://www.antwiki.org).

58. *A. subterranea* (Latreille, 1798)
Arnoldi, 1948: *Aphaenogaster* (*Attomyrma*) *subterranea* Ltr: 211
Borowiec, 2014: *Aphaenogaster subterranea* (Latreille, 1798): 19
Dubovikoff, Yusupov, 2017: *Aphaenogaster subterranea* (Latreille, 1798): 203
Bračko, 2019: *Aphaenogaster subterranea* (Latreille, 1798): 169
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017), Khizi, Guba, Khachmaz, Aghsu, Ismailly, Sheki, Balaken, Gakh, Zagatala (Bračko, 2019).
Distribution: Albania, Algeria, Andorra, Armenia, Austria, Balearic Islands, Belgium, Bulgaria, Channel Islands, China, Croatia, Czech Republic, France (type locality), Georgia, Germany, Gibraltar, Greece, Hungary, Iberian Peninsula, Iran, Italy, Malta, Montenegro, Poland, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Switzerland, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

59. *A. georgica* Arnoldi, 1968
Arnoldi, 1968: *Aphaenogaster* (*Attomyrma*) *georgica* Arnoldi, 1968: 1804
Borowiec, 2014: *Aphaenogaster georgica* Arnoldi, 1968: 12
Records: Gazakh (Alnoldi, 1968), Azerbaijan (Borowiec, 2014).
Distribution: Georgia (type locality) (https://www.antwiki.org).

60. *A. gibbosa* (Latreille, 1798)
Arnoldi, 1948: *Aphaenogaster* (*Attomyrma*) *gibbosa muschtaidica* Ruz.: 211
Borowiec, 2014: *Aphaenogaster gibbosa* (Latreille, 1798): 12
Dubovikoff, Yusupov, 2017: *Aphaenogaster gibbosa* (Latreille, 1798): 203
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017).
Distribution: Algeria, Andorra, Armenia, Bulgaria, France (type locality), Georgia, Gibraltar, Greece, Iberian Peninsula, Iran, Israel, Montenegro, Portugal, Republic of Macedonia, Russian Federation, Spain, Switzerland, Turkey, Turkmenistan (https://www.antwiki.org).

61. *A. splendida* (Roger, 1859)
Arnoldi, 1948: *Aphaenogaster* (*Attomyrma*) *splendida* var. *transcaucasica* Kar.: 211
Borowiec, 2014: *Aphaenogaster splendida* (Roger, 1859): 19
Dubovikoff, Yusupov, 2017: *Aphaenogaster splendida* (Roger, 1859): 203
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Azerbaijan (Dubovikoff, Yusupov, 2017).
Distribution: Algeria, Armenia, Croatia, Greece (type locality), Iberian Peninsula, Iran, Israel, Malta, Occupied Palestinian Territory, Republic of Macedonia, Russian Federation, Spain, Turkey (https://www.antwiki.org).

62. *A. kurdica* Ruzsky, 1905
Arnoldi, 1948: *Aphaenogaster* (*Attomyrma*) *kurdica Ruz*.: 211
Borowiec, 2014: *Aphaenogaster kurdica* Ruzsky, 1905: 14
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014).
Distribution: Armenia, Georgia, Iran, Russian Federation (type locality) (https://www.antwiki.org).

Genus *Aulacopone* Arnol'di, 1930

63. *A. relicta* Arnol'di, 1930
Arnoldi, 1930: *Aulacopone relicta* Arnoldi, 1930 c: 140
Arnoldi, 1948: *Aulacopone relicta* K. Arn.: 211
Borowiec, 2014: *Aulacopone relicta* Arnoldi, 1930: 21
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014).
Distribution: Azerbaijan (type locality) (https://www.antwiki.org).

Genus *Cardiocondyla* Emery, 1869

64. *C. brachyceps* Seifert, 2003
Bračko, 2019: *Cardiocondyla brachyceps* Seifert, 2003: 170
Records: Samukh (Bračko, 2019*).*
Distribution: Afghanistan, Iran (type locality), Turkey (https://www.antwiki.org).

65. *C. elegans* Emery, 1869
Arnoldi, 1948: *Cardiocondyla elegans caucasica* K. Arn.: 211
Borowiec, 2014: *Cardiocondyla elegans* Emery, 1869: 46
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014).
Distribution: Armenia, Bulgaria, China, France, Georgia, Greece, Hungary, Iberian Peninsula, Iran, Israel, Italy (type locality), Montenegro, Republic of Macedonia, Romania, Slovenia, Spain, Turkey, Turkmenistan, Ukraine (https://www.antwiki.org).

66. *C. sahlbergi* Forel, 1913
Borowiec, 2014: *Cardiocondyla sahlbergi* Forel, 1913: 48
Dubovikoff, Yusupov, 2017: *Cardiocondyla sahlbergi* Forel, 1913: 203
Bračko, 2019: *Cardiocondyla sahlbergi* Forel, 1913: 170
Records: Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017), Gabala, Balaken, Oguz, Gakh, Evlakh, Agjabedi, Lankaran, Astara, Lerik, Gobustan (Bračko, 2019*)*.
Distribution: Armenia, Georgia, Iran, Israel (type locality), Kazakhstan, Russian Federation, Tunisia, Turkey, Uzbekistan (https://www.antwiki.org).

67. *C. stambuloffii* Forel, 1892
Bračko, 2019: *Cardiocondyla stambuloffii* Forel, 1892: 170
Records: Agstafa, Agjabedi (Bračko, 2019*).*
Distribution: Armenia, Bulgaria (type locality), China, Georgia, Greece, Iran, Republic of Moldova, Romania, Russian Federation, Turkey, Ukraine (https://www.antwiki.org).

68. *C. ulianini* Emery, 1889
Borowiec, 2014: *Cardiocondyla ulianini* Emery, 1889: 49
Dubovikoff, Yusupov, 2017: *Cardiocondyla ulianini* Emery, 1889: 203
Records: Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017).

Distribution: Afghanistan, China, Iran, Kazakhstan, Kyrgyzstan, Russian Federation (type locality), Ukraine (https://www.antwiki.org).

Genus *Chalepoxenus* Menozzi, 1923

69. *C. hyrcanus* Dubovikoff et Radchenko, 2010
Dubovikoff, Radchenko, 2010: *Chalepoxenus hyrcanus* Dubovikoff et Radchenko, 2010: 207-208
Borowiec, 2014: *Chalepoxenus hyrcanus* Dubovikoff et Radchenko, 2010: 63
Records: Lankaran, Talysh (Dubovikoff, Radchenko, 2010), Azerbaijan (Borowiec, 2014).
Distribution: France, Gibraltar, Iberian Peninsula, Morocco, Portugal, Spain (type locality) (https://www.antwiki.org).

Genus *Crematogaster* Lund, 1831

70. *C. schmidti* (Mayr, 1853)
Arnoldi, 1948: *Crematogaster (Arcoelia) scutellaris schmidti* Mayr: 211
Borowiec, 2014: *Crematogaster schmidti* (Mayr, 1853): 68
Dubovikoff, Yusupov, 2017: *Crematogaster schmidti* (Mayr, 1853): 204
Bračko, 2019: *Crematogaster schmidti* (Mayr, 1853): 170
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017), Khizi, Khachmaz, Aghsu, Ismailli, Oguz, Balaken, Zagatala, Agstafa, Samukh, Lankaran (Bračko, 2019*)*.
Distribution: Armenia, Austria (type locality), Bulgaria, Georgia, Greece, Hungary, Iran, Italy, Montenegro, Republic of Macedonia, Romania, Russian Federation, Slovenia, Turkey, Turkmenistan, Ukraine (https://www.antwiki.org).

71. *C. scutellaris* (Olivier 1792)
Ruzsky, 1902: *Crematogaster scutellaris,* Oliv.: 31
Records: Garabakh, Murovdag, Kelbajar, Lankaran, Talysh (Ruzsky, 1902*)*.
Distribution: Andorra, Austria, Balearic Islands, Bulgaria, Croatia, Denmark, France (type locality), Georgia, Germany, Gibraltar, Greece, Hungary, Iberian Peninsula, Israel, Italy, Malta, Montenegro, Portugal, Republic of Macedonia, Romania, Slovenia, Spain, Switzerland, Tunisia, Turkey, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

72. *C. subdentata* Mayr, 1877
Bračko, 2019: *Crematogaster subdentata* Mayr, 1877: 170
Records: Absheron, Evlakh, Agjabedi, Bilasuvar (Bračko, 2019*)*.
Distribution: Afghanistan, Armenia, China, Georgia, Iran, Kazakhstan (type locality), Kyrgyzstan, Mongolia, Russian Federation, Turkmenistan (type locality), Ukraine (https://www.antwiki.org).

73. *C. sordidula* (Nylander, 1849)
Ruzsky, 1902: *Crematogaster sordidula,* Nyl.: 31
Arnoldi, 1948: *Crematogaster (Orhtocrema*) *sordidula mayri Mayr v. costi Ruz.*: 211
Borowiec, 2014: *Crematogaster sordidula* (Nylander, 1849): 69
Dubovikoff, Yusupov, 2017: *Crematogaster sordidula* (Nylander, 1849): 204
Records: Jebrail (Ruzsky, 1902), Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017).
Distribution: Albania, Balearic Islands, Bulgaria, Croatia, France, Georgia, Gibraltar, Greece, Hungary, Iberian Peninsula, Israel, Italy (type locality), Montenegro, Portugal, Republic of Macedonia, Romania, Russian Federation, Slovenia, Spain, Switzerland, Turkey (https://www.antwiki.org).

Genus *Messor* Forel, 1890

74. *M. caducus* (Victor, 1839)
Arnoldi, 1977: *Messor caducus* (Victor, 1839): 4638
Bračko, 2019: *Messor caducus* (Victor, 1839): 172
Records: Nakhichevan, Ordubad (Arnoldi, 1977), Gusar, Evlakh, Samukh, Agjabedi, Bilasuvar, Salyan, Sabirabad (Bračko, 2019*).*
Distribution: Albania, Armenia, Bulgaria, Georgia, Greece, Iran, Malta, Republic of Macedonia, Romania, Russian Federation (type locality), Slovakia, Turkey (https://www.antwiki.org).

75. *M. diabarensis* Arnoldi, 1970
Arnoldi, 1948: *Messor structor diabarensis* K. Arn.: 211
Arnoldi, 1970: *Messor diabarensis* Arnol'di, 1970: 75
Arnoldi, 1977: *Messor diabarensis* Arnol'di, 1977b: 1643
Records: Lerik (Arnol'di, 1948, 1970, 1977*).*
Distribution: Azerbaijan (Arnol'di, 1948, 1970, 1977).

76. *M. laboriosus* Santschi, 1927 (Figs. 2-4)
Material: 5 workers, 1 queen, Absheron, 40.40442,49.87619, leg. C.Shigayev, 14.11.2020.
Distribution: China, Greece, Iran, Israel, Kazakhstan (type locality), Kyrgyzstan, Montenegro, Republic of Macedonia, Russian Federation, Turkey, Turkmenistan (https://www.antwiki.org). This species is indicated for the first time for the fauna of Azerbaijan.

77. *M. melancholicus* Arnol'di, 1977
Karavaiev, 1926a: *Messor structor* ssp. *striaticeps* var. *melancholica* Karavaiev, 1926: 104
Borowiec, 2014: *Messor melancholicus* Arnoldi, 1977: 109
Bračko, 2019: *Messor melancholicus* Arnol'di, 1977: 172
Records: Mugan steppe, Ordubad, Nakhichevan (Karavaiev, 1926), Azerbaijan (Borowiec, 2014), Lerik (Bračko, 2019*)*.
Distribution: Armenia, Georgia, Iran, Kazakhstan (https://www.antwiki.org).

78. *M. minor* (André, 1883)
Arnoldi, 1948: *Messor minor meridionalis* André: 211
Records: Lerik (Arnol'di, 1948*).*
Distribution: Canary Islands, Iran, Iraq, Israel, Italy (type locality), Kuwait, Montenegro, Morocco (https://www.antwiki.org).

79. *M. muticus* (Nylander, 1849)
Bračko, 2019: *Messor muticus* (Nylander, 1849): 172
Records: Guba, Ismailly, Balaken, Gakh, Agstafa, Dashkesan, Samukh, Agjabedi, Lankaran, Astara, Bilasuvar, Sabirabad (Bračko, 2019*).*
Distribution: Armenia, Kazakhstan, Kyrgyzstan, Romania, Russian Federation (type locality), Ukraine (https://www.antwiki.org).

80. *M. semirufus* (André, 1883)
Ruzsky 1905: Aphaenogaster barbara var. semirufa André, 1883: Ruzsky,1905b: 750
Records: Fizuli (Ruzsky 1905), Lankaran (Karavayev 1926).
Distribution: Afghanistan, Iran, Iraq, Israel, Italy, Turkey (https://www.antwiki.org).

81. *M. structor* (Latreille, 1798)

Borowiec, 2014: *Messor structor* (Latreille, 1798): 112
Dubovikoff, Yusupov, 2017: *Messor structor* (Latreille, 1798): 204
Records: Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017).
Distribution: Austria, Bulgaria, Czech Republic, France (type locality), Hungary, Romania, Slovenia (https://www.antwiki.org).

FIGURE 2. *Messor laboriosus* Santschi, 1927: lateral view of the body, worker

FIGURE 3. *Messor laboriosus* Santschi, 1927: face, dorsal view.

FIGURE 4. *Messor laboriosus* Santschi, 1927: alitrunk on the top.

Genus *Monomorium* Mayr, 1855

82. *M. ruzskyi* Dlussky et Zabelin, 1985
Bračko, 2019: *Monomorium ruzskyi* Dlussky et Zabelin, 1985: 172
Records: Khizi, Evlakh, Samukh, Agjabedi, Salyan, Absheron (Bračko, 2019*).*
Distribution: South Caucasus, Turkmenistan, Uzbekistan (Dlussky, Soyunov, Zabelin, 1989).

Genus *Myrmica* Latreille, 1804

83. *M. bergi* Ruzsky, 1902
Arnoldi, 1948: *Myrmica bergi iranica* K. Arn: 211
Borowiec, 2014: *Myrmica bergi* Ruzsky, 1902: 129
Dubovikoff, Yusupov, 2017: *Myrmica bergi* Ruzsky, 1902: 205
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Azerbaijan (Dubovikoff, Yusupov, 2017).
Distribution: Austria, Balearic Islands, Belgium, Finland, Germany, Gibraltar, Iran, Kazakhstan (type locality), Kyrgyzstan, Romania, Russian Federation, Switzerland (https://www.antwiki.org).

84. *M. caucasicola* Arnol'di, 1934
Arnoldi, 1948: *Myrmica schencki* nat. *caucasicola* K. Arn: 211
Borowiec, 2014: *Myrmica caucasicola* Arnoldi, 1934: 129
Bračko, 2019: *Myrmica caucasicola* Arnol'di, 1934: 172
Records: Lerik, Talysh (Arnol'di, 1934), Azerbaijan (Borowiec, 2014), Guba (Bračko, 2019*)*.
Distribution: Armenia, Azerbaijan, Georgia (https://www.antwiki.org).

85. *M. deplanata* Emery, 1921
Arnoldi, 1948: *Myrmica deplanata lulakeranica* K. Arn: 211
Borowiec, 2014: *Myrmica deplanata* Emery, 1921: 129
Dubovikoff, Yusupov, 2017: *Myrmica deplanata* Emery, 1921: 205

Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014). Caucasus (Dubovikoff, Yusupov, 2017).
Distribution: Austria, Bulgaria, China, Czech Republic, Georgia (type locality), Hungary, Iran, Kazakhstan, Poland, Romania, Russian Federation (type locality), Slovakia, Turkmenistan, Ukraine (type locality) (https://www.antwiki.org).

86. *M. hellenica* Finzi, 1926
Arnol'di, 1948: *Myrmica rugulosa caucasica* K. Arn, 1934: 165
Borowiec, 2014: *Myrmica hellenica* Finzi, 1926: 130
Bračko, 2019: *Myrmica hellenica* Finzi, 1926: 172
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Ismailly, Zagatala, Gakh, Goygel, Lerik (Bračko, 2019*)*.
Distribution: Armenia, Austria, Bulgaria, Croatia, Finland, Georgia, Germany, Greece (type locality), Iran, Italy, Montenegro, Poland, Romania, Russian Federation, Serbia, Slovenia, Switzerland, Ukraine (https://www.antwiki.org).

87. *M. lobicornis* Nylander, 1846
Karawajev, 1926a: *Myrmica (Myrmica) lobicornis* Nyl.: 95
Bračko, 2019: *Myrmica lobicornis* Nylander, 1846: 172
Records: Kelbajar (Karawajev, 1926), Gusar (Bračko, 2019*).*
Distribution: Albania, Armenia, Austria, Belarus, Belgium, Bulgaria, Canary Islands, Croatia, Czech Republic, Denmark, Estonia, Finland (type locality), France, Georgia, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Luxembourg, Mongolia, Netherlands, Norway, Poland, Republic of Korea, Romania, Russian Federation, Slovakia, Slovenia, Sweden, Switzerland, Ukraine, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

88. *M. ruginodis* Nylander, 1846
Arnol'di, 1948: *Myrmica ruginodis* Nyl.: 211
Borowiec, 2014: *Myrmica ruginodis* Nylander, 1846: 133
Dubovikoff, Yusupov, 2017: *Myrmica ruginodis* Nylander, 1846: 206
Bračko, 2019: *Myrmica ruginodis* Nylander, 1846: 172
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017), Guba, Gusal, Goygel (Bračko, 2019*)*.
Distribution: Albania, Andorra, Armenia, Austria, Belarus, Belgium, Bulgaria, Channel Islands, China, Croatia, Czech Republic, Democratic Peoples Republic of Korea, Denmark, Estonia, Finland (type locality), Georgia, Germany, Greece, Hungary, Iberian Peninsula, Latvia, Lithuania, Luxembourg, Mongolia, Netherlands, Norway, Poland, Portugal, Republic of Korea, Republic of Macedonia, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

89. *M. rugulosa* Nylander, 1849
Ruzsky, 1902: *Myrmica rugulosa* Nyl.: 30
Records: Lankaran (Ruzsky, 1902).
Distribution: Austria, Belarus, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland (type locality), Georgia, Germany, Greece, Hungary, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Romania, Russian Federation, Slovakia, Slovenia, Sweden, Switzerland, Ukraine (https://www.antwiki.org).

90. *M. salina* Ruzsky, 1905
Bračko, 2019: *Myrmica salina* Ruzsky, 1905: 172

Records: Gabala, Evlakh, Agstafa (Bračko, 2019*).*
Distribution: Austria, Croatia, Czech Republic, Georgia, Kazakhstan (type locality), Kyrgyzstan, Romania, Russian Federation, Slovenia (https://www.antwiki.org).

91. *M. specioides* Bondroit, 1918
Bračko, 2019: *Myrmica specioides* Bondroit, 1918: 172
Records: Guba, Khachmaz, Ismailly, Astara, Lerik (Bračko, 2019*).*
Distribution: Andorra, Armenia, Austria, Belgium (type locality), Bulgaria, Croatia, Czech Republic, Denmark, Finland, France, Georgia, Germany, Greece, Hungary, Iberian Peninsula, Iran, Italy, Montenegro, Netherlands, Norway, Poland, Romania, Russian Federation, Slovenia, Spain, Turkey, Turkmenistan, Ukraine, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

92. *M. scabrinodis* Nylander, 1846
Ruzsky, 1902: Myrmica scabrinodis, Nyl.: Ruzsky, 1902: 30
Karawajev, 1926a: *Myrmica (Myrmica) scabrinodis* Nyl.: 95
Records: Gusar (Ruzsky, 1902), Nukha (now Sheki), Agsu (Karawajev, 1926).
Distribution: Albania, Andorra, Armenia, Austria, Balearic Islands, Belarus, Belgium, Bulgaria, Channel Islands, China, Croatia, Czech Republic, Denmark, Estonia, Finland (type locality), France, Georgia, Germany, Greece, Hungary, Iberian Peninsula, Italy, Jersey, Kazakhstan, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Montenegro, Netherlands, Norway, Poland, Portugal, Republic of Korea, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

93. *M. rubra* (Linnaeus, 1758)
Ruzsky, 1902: *Myrmica laevinodis* Nyl.: 29
Dubovikoff, Yusupov, 2017: *Myrmica rubra* (Linnaeus, 1758): 206
Records: Lankaran (Ruzsky, 1902), Caucasus (Dubovikoff, Yusupov, 2017).
Distribution: Andorra, Armenia, Austria, Belarus, Belgium, Bulgaria, China, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iberian Peninsula, Japan, Jersey, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Mongolia, Montenegro, Netherlands, Norway, Poland, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

Genus *Myrmecina* Curtis, 1829

94. *M. graminicola* (Latreille, 1802)
Arnol'di**,** 1948**:** *Myrmecina graminicola striatula* Nyl.: 211
Borowiec, 2014: *Myrmecina graminicola* (Latreille, 1802): 128
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014).
Distribution: Albania, Andorra, Armenia, Austria, Balearic Islands, Belarus, Belgium, Bulgaria, Channel Islands, China, Croatia, Czech Republic, Democratic Peoples Republic of Korea, Denmark (type locality), France, Georgia, Germany, Gibraltar, Greece, Hungary, Iberian Peninsula, Israel, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Montenegro, Netherlands, Norway, Poland, Portugal, Republic of Korea, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tunisia, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

Genus *Pheidole* Westwood, 1839

95. *P. koshewnikovi* Ruzsky, 1905
Bračko, 2019: *Pheidole koshewnikovi* Ruzsky, 1905: 172
Records: Khachmaz, Gusar, Ismailly, Oguz, Balaken, Evlakh, Samukh, Lankaran, Astara, Lerik, Bilasuvar, Sabirabad (Bračko, 2019*).*
Distribution: Azerbaijan, Cyprus, Greece, Iran, Kazakhstan (type locality), Kyrgyzstan, Montenegro, Russian Federation, Turkey, Uzbekistan (type locality) (https://www.antwiki.org).

96. *P. pallidula* (Nylander, 1849)
Arnol'di**,** 1948**:** *Pheidole pallidula orientalis* Em., 1923: 211
Borowiec, 2014: *Pheidole pallidula* (Nylander, 1849): 143
Dubovikoff, Yusupov, 2017: *Pheidole pallidula* (Nylander, 1849): 207
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017).
Distribution: Afghanistan, Albania, Algeria, Andorra, Armenia, Austria, Balearic Islands, Bulgaria, Canary Islands, Croatia, France, Georgia, Gibraltar, Greece, Iberian Peninsula, Iran, Israel, Italy (type locality), Kazakhstan, Kyrgyzstan, Malta, Monaco, Montenegro, Portugal (type locality), Republic of Macedonia, Romania, Russian Federation, Slovenia, Spain, Turkey, Turkmenistan (https://www.antwiki.org).

Genus *Solenopsis* Westwood, 1840

97. *S. fugax* (Latreille, 1798)
Ruzsky, 1902: *Solenopsis fugax,* Latr.: 31
Borowiec, 2014: *Solenopsis fugax* Latreille, 1798: 155
Dubovikoff, Yusupov, 2017: *Solenopsis fugax* (Latreille, 1798): 207
Bračko, 2019: *Solenopsis fugax* (Latreille, 1798): 172
Records: Talysh (Ruzsky, 1902), Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017), Guba, Oguz, Zagatala, Lankaran (Bračko, 2019*)*.
Distribution: Afghanistan, Albania, Armenia, Austria, Balearic Islands, Belarus, Belgium, Bulgaria, Channel Islands, China, Croatia, Czech Republic, Denmark, France (type locality), Georgia (type locality), Germany, Gibraltar, Greece, Hungary, Iberian Peninsula, Iran, Israel, Italy, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Malta, Montenegro, Netherlands, Poland, Republic of Korea, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, San Marino, Slovenia, Spain, Sweden, Switzerland, Turkmenistan, Ukraine (type locality), United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

98. *S. deserticola* Ruzsky, 1905
Karawajev, 1926b**:** *Solenopsis orbula* subsp. *oblongior* Karavaiev, 1926 b: 161
Borowiec, 2014: *Solenopsis deserticola* Ruzsky, 1905: 154
Dubovikoff, Yusupov, 2017: *Solenopsis deserticola* Ruzsky, 1905: 207
Records: Hajigabul (Karawajev, 1926b), Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017).
Distribution: Armenia, Kazakhstan (type locality), Russian Federation, Turkmenistan (https://www.antwiki.org).

99. *S. ilinei* Santschi, 1936
Karawajev, 1926c**:** *Solenopsis orbula* var. *oculata* Karavaiev, 1926 b: 162
Dlussky, Radchenko, 1994: *Diplorhoptrum ilinei (*Santschi, 1936): 103
Borowiec, 2014: *Solenopsis deserticola* Ruzsky, 1905: 154
Dubovikoff, Yusupov, 2017: *Solenopsis ilinei* Santschi, 1936: 207

Records: Shemakha (Karawajev, 1926b, Dlussky, Radchenko, 1994), Azerbaijan (Dubovikoff, Yusupov, 2017).
Distribution: Georgia, Russian Federation (https://www.antwiki.org).

Genus *Stenamma* Westwood, 1839

100. *S. lippulum* (Nylander, 1849)
Arnol'di**,** 1948**:** *Stenamma hirtulum* Em.: 211
Borowiec, 2014: *Stenamma lippulum* (Nylander, 1849): 160
Dubovikoff, Yusupov, 2017: *Stenamma lippulum* (Nylander, 1849): 207
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Azerbaijan (Dubovikoff, Yusupov, 2017).
Distribution: Israel, Russian Federation (type locality) (https://www.antwiki.org).

Genus *Strongylognathus* Mayr, 1853

101. *S. rehbinderi* Forel, 1904
Arnol'di, 1948: *Strongylognathus rehbinderi hyrcanus* K. Arn: 211
Arnol'di, 1948: *Strongylognathus rehbinderi diabarensis* K. Arn: 211
Borowiec, 2014: *Strongylognathus rehbinderi* Forel, 1904: 164
Bračko, 2019: *Strongylognathus rehbinderi* Forel, 1904: 173
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Astara (Bračko, 2019*)*.
Distribution: Armenia, Georgia, Russian Federation (https://www.antwiki.org).

102. *S. testaceus* (Schenck, 1852)
Arnol'di, 1948: *Strongylognathus testaceus barnassarensis* K. Arn: 211
Dubovikoff, Yusupov, 2017: *Strongylognathus testaceus* (Schenck, 1852): 207
Records: Lerik (Arnol'di, 1948*),* Caucasus (Dubovikoff, Yusupov, 2017).
Distribution: Andorra, Austria, Belarus, Belgium, Bulgaria, Croatia, Czech Republic, Georgia, Germany (type locality), Greece, Hungary, Iberian Peninsula, Lithuania, Netherlands, Poland, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkmenistan, Ukraine, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

Genus *Strumigenys* Smith, 1860

103. *S. argiola* (Emery, 1869)
Arnol'di**,** 1948**:** *Epitritus argiolus* Em.: 211
Borowiec, 2014: *Strumigenys argiola* (Emery, 1869): 165
Dubovikoff, Yusupov, 2017: *Strumigenys argiola* (Emery, 1869): 207
Records: Lerik (Arnol'di, 1948*),* Caucasus (Dubovikoff, Yusupov, 2017), Azerbaijan (Borowiec, 2014).
Distribution: Austria, Azerbaijan, Balearic Islands, Bulgaria, Croatia, France, Greece, Hungary, Iberian Peninsula, Israel, Italy (type locality), Portugal, Russian Federation, Slovakia, Spain, Switzerland, Tunisia (https://www.antwiki.org).

Genus *Temnothorax* Mayr, 1861

104. *T. crasecundus* Seifert et Csősz, 2015
Borowiec, 2014: *Temnothorax crassispinus* (Karavaiev, 1926): 176
Bračko, 2019: *Strongylognathus rehbinderi* Forel, 1904: 173
Records: Azerbaijan (Borowiec, 2014), Guba, Agsu, Ismailly, Zagatala, Gakh (Bračko, 2019*)*.

Distribution: Armenia, Bulgaria (type locality), Georgia, Greece, Romania, Russian Federation, Turkey, Ukraine (https://www.antwiki.org).

105. *T. interruptus* (Schenck, 1852)
Bračko, 2019: *Temnothorax interruptus* (Schenck, 1852): 173
Records: Guba, Khachmaz, Gakh (Bračko, 2019*).*
Distribution: Armenia, Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Finland, France, Germany (type locality), Hungary, Iberian Peninsula, Montenegro, Netherlands, Norway, Poland, Republic of Macedonia, Romania, Russian Federation, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine (type locality), United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

106. *T. korbi* (Emery, 1924)
Arnol'di**,** 1948**:** *Leptothorax korbi Em.*: 211
Borowiec, 2014: *Temnothorax korbi* (Emery, 1924): 180
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014).
Distribution: Azerbaijan, Georgia, Turkey (Borowiec, 2014).

107. *T. nylanderi* (FOERSTER, 1850)
Arnol'di**,** 1948**:** *Leptothorax nylanderi Foerst.*: 211
Records: Lerik (Arnol'di, 1948*).*
Distribution: Andorra, Armenia, Austria, Belgium, Bulgaria, Denmark, France, Georgia, Germany (type locality), Iberian Peninsula, Jersey, Montenegro, Netherlands, Norway, Poland, Portugal, Republic of Macedonia, Russian Federation, Spain, Sweden, Switzerland, Ukraine, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

108. *T. parvulus* (Schenck, 1852)
Bračko, 2019: *Temnothorax parvulus* (Schenck, 1852): 173
Records: Khizi, Khachmaz, Goygel, Lankaran (Bračko, 2019*)*.
Distribution: Andorra, Armenia, Austria, Belgium, Bulgaria, Croatia, Czech Republic, Georgia, Germany (type locality), Gibraltar, Greece, Hungary, Iberian Peninsula, Iran, Italy, Montenegro, Poland, Portugal, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Turkey, Turkmenistan (https://www.antwiki.org).

109. *T. shelkovnikovi* (Karavaiev, 1926)
Karavaiev, 1926c: *Leptothorax* (*Leptothorax*) *shekkovnikovi* Karavaiev, 1926 b: 166
Borowiec, 2014: *Temnothorax shelkovnikovi* (Karavaiev, 1926): 189
Bračko, 2019: *Temnothorax shelkovnikovi* (Karavaiev, 1926): 173
Records: Aresh (now Agdash) (Karavaiev, 1926), Evlakh (Bračko, 2019*),* Azerbaijan (Borowiec, 2014).
Distributionn (Borowiec, 2014).

110. *T. tauricus* (Ruzsky, 1902)
Bračko, 2019: *Temnothorax tauricus* (Ruzsky, 1902): 173
Records: Guba, Ismailly, Balaken, Gakh, Dashkesan (Bračko, 2019*).*
Distribution: Armenia, Bulgaria, Greece, Russia (Causcasus), Ukraine (Borowiec, 2014).

111. *T. tuberum* (Fabricius, 1775)
Arnol'di**,** 1948**:** *Leptothorax tuberum* F.: 211
Arnol'di**,** 1948**:** *Leptothorax tuberum acutinodis* K. Arn: 211

Borowiec, 2014: *Temnothorax tuberum* (Fabricius, 1775): 192
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014).
Distribution: Andorra, Armenia, Austria, Belarus, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, France (type locality), Georgia, Germany, Hungary, Iberian Peninsula, Iran, Jersey, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Montenegro, Netherlands, Norway, Poland, Portugal, Republic of Korea, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden (type locality), Switzerland (https://www.antwiki.org).

112. *T. unifasciatus* (Latreille, 1798)
Arnol'di**,** 1948**:** *Leptothorax unifasciatus* Latr.: 211
Borowiec, 2014: *Temnothorax unifasciatus* (Latreille, 1798): 192
Dubovikoff, Yusupov, 2017: *Temnothorax unifasciatus* (Latreille, 1798): 209
Records: Lerik (Arnol'di, 1948*),* Caucasus (Dubovikoff, Yusupov, 2017), Azerbaijan (Borowiec, 2014).
Distribution: Albania, Andorra, Armenia, Austria, Belarus, Belgium, Bulgaria, Channel Islands, Croatia, Czech Republic, Denmark, France (type locality), Georgia, Germany, Greece, Hungary, Iberian Peninsula, Israel, Italy, Jersey, Kazakhstan, Liechtenstein, Lithuania, Luxembourg, Malta, Montenegro, Morocco, Netherlands, Poland, Portugal, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Turkmenistan, Ukraine, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

Genus *Tetramorium* Mayr, 1855

113. *T. aegeum* Radchenko, 1992
Arnol'di**,** 1948**:** *Tetramorium inerme laevigatum* Kar., 1948: 211
Borowiec, 2014: *Tetramorium aegeum* Radchenko, 1992: 193
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014).
Distribution: Azerbaijan, Russian Federation (https://www.antwiki.org).

114. *T. caespitum* (Linnaeus, 1758)
Arnol'di**,** 1948**:** *Tetramorium caespitum* L: 211
Borowiec, 2014: *Tetramorium caespitum* (Linnaeus, 1758): 195
Dubovikoff, Yusupov, 2017: *Tetramorium caespitum* (Linnaeus, 1758): 209
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017).
Distribution: Afghanistan, Albania, Armenia, Austria, Balearic Islands, Belarus, Belgium, Bulgaria, Canary Islands, Channel Islands, China, Croatia, Democratic Peoples Republic of Korea, Denmark, Estonia, Finland, France, Georgia, Germany, Gibraltar, Hungary, Iberian Peninsula, Iran, Israel, Italy, Jersey, Kazakhstan, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Monaco, Montenegro, Netherlands, Norway, Poland, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Spain, Sweden, Switzerland, Turkmenistan, Ukraine, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

115. *T. caucasicum* Wagner, Arthofer, Seifert, Muster, Steiner et Schlick-Steiner, 2017
Bračko, 2019: *Tetramorium caucasicum* Wagner, Arthofer, Seifert, Muster, Steiner et Schlick-Steiner, 2017: 173
Records: Lerik (Bračko, 2019*).*

Distribution: Armenia (type locality), Georgia (type locality), Russian Federation (https://www.antwiki.org).

116. *T. chefketi* Forel, 1911
Bračko, 2019: *Tetramorium chefketi* Forel, 1911: 173
Records: Gusar (Bračko, 2019*)*.
Distribution: Armenia, Bulgaria, China, Georgia, Greece, Iran, Kyrgyzstan, Republic of Macedonia, Russian Federation, Turkey (type locality), Ukraine (https://www.antwiki.org).

117. *T. immigrans* Santschi, 1927
Bračko, 2019: *Tetramorium immigrans* Santschi, 1927: 173
Records: Absheron, Guba, Khachmaz, Agsu, Ismailly, Gabala, Sheki, Balaken, Zagatala, Gakh, Evlakh, Agstafa, Dashkesan, Samukh, Lankaran, Astara, Lerik, Salyan, Sabirabad (Bračko, 2019*).*
Distribution: Bulgaria, Turkey (https://www.antwiki.org).

118. *T. indocile* Santschi, 1927
Bračko, 2019: *Tetramorium indocile* Santschi, 1927: 173
Records: Guba, Lerik (Bračko, 2019*).*
Distribution: Armenia, Bulgaria, France, Hungary, Iran, Kyrgyzstan (type locality), Russian Federation, Spain, Switzerland (type locality), Ukraine (https://www.antwiki.org).

119. *T. inerme* Mayr, 1877
Borowiec, 2014: *Tetramorium inerme* Mayr, 1877: 199
Records: Azerbaijan (Borowiec, 2014).
Distribution: Armenia, China, Iran, Kazakhstan (type locality), Kyrgyzstan, Mongolia, Russian Federation, Turkmenistan (https://www.antwiki.org).

120. *T. ferox* Ruzsky, 1903
Arnol'di**,** 1948**:** *Tetramorium ferox* Ruz.: 211
Borowiec, 2014: *Tetramorium ferox* Ruzsky, 1903: 198
Dubovikoff, Yusupov, 2017: *Tetramorium ferox* Ruzsky, 1903: 209
Records: Lerik (Arnol'di, 1948*),* Caucasus (Dubovikoff, Yusupov, 2017), Azerbaijan (Borowiec, 2014).
Distribution: Armenia, Bulgaria, China, Croatia, Czech Republic, Georgia, Greece, Hungary, Iran, Kyrgyzstan, Malta, Montenegro, Republic of Macedonia, Romania, Russian Federation (type locality), Turkmenistan (https://www.antwiki.org).

121. *T. moravicum* Novák et Sadil, 1941
Bračko, 2019: *Tetramorium moravicum* Novák et Sadil, 1941: 173
Records: Guba, Ismailly (Bračko, 2019*)*.
Distribution: Austria, Bulgaria, Croatia, Czech Republic, France, Germany, Greece, Hungary, Iran, Italy, Montenegro, Poland, Romania, Russian Federation, Serbia, Slovenia, Turkey, Ukraine (https://www.antwiki.org).

122. *T. punicum* (Smith, F., 1861)
Arnol'di**,** 1948**:** *Tetramorium punicum caspium* K. Arn: 211
Borowiec, 2014: *Tetramorium punicum* (F. Smith, 1861): 202
Records: Lerik (Arnol'di, 1948*),* Azerbaijan (Borowiec, 2014).
Distribution: Canary Islands, Georgia, Greece, Iran, Israel (type locality) (https://www.antwiki.org).

123. *T. semilaeve* André, 1883
Arnol'di, 1948: *Tetramorium semilaeve schmidti For.*: 211
Arnol'di, 1948: *Tetramorium semilaeve kosmalianicum* K. Arn: 211
Borowiec, 2014: *Tetramorium semilaeve* André, 1883: 203
Records: Lerik (Arnol'di, 1948), Azerbaijan (Borowiec, 2014).
Distribution: France (type locality), Iberian Peninsula, Italy, Malta, Spain (https://www.antwiki.org).

124. *T. sulcinode* Santschi, 1927
Bračko, 2019: *Tetramorium sulcinode* Santschi, 1927: 173
Records: Gusar, Evlakh (Bračko, 2019).
Distribution: Afghanistan, Kazakhstan (type locality), Kyrgyzstan, Russian Federation, Turkey, Turkmenistan, Turkmenistan (https://www.antwiki.org).

Genus *Trichomyrmex* Mayr, 1865

125. *T. dentigera* (Roger, 1862)
Arnoldi, 1948: *Monomorium* (*Holcomyrmex*) *dentigerum* Rog.: 211
Borowiec, 2014: *Monomorium dentigerum* (Roger, 1862): 118
Records: Lerik (Arnol'di, 1948), Azerbaijan (Borowiec, 2014).
Distribution: Armenia, Georgia, Iran, Israel, Israel, Oman, Syrian Arab Republic, Turkey, Turkmenistan (https://www.antwiki.org).

126. *T. perplexus* (Radchenko, 1997)
Radchenko, 1997: *Monomorium perplexum* Radchenko, 1997: 213
Bračko, 2019: *Trichomyrmex perplexus* (Radchenko, 1997)
Dubovikoff, Yusupov, 2017: *Trichomyrmex perplexus* (Radchenko, 1997): 209
Records: Eldar plane (Samukh) (Radchenko, 1997), Caucasus (Dubovikoff, Yusupov, 2017), Evlakh (Bračko, 2019).
Distribution: Armenia (type locality), Greece, Iran, Russian Federation (https://www.antwiki.org).

Subfamily Ponerinae

Genus *Ponera* Latreille, 1804

127. *P. coarctata* (Latreille, 1802)
Ruzsky, 1905: *Ponera coarctata lucida* Em.
Arnol'di, 1948: *Ponera coarctata lucida* Em.: 211
Borowiec, 2014: *Ponera coarctata* (Latreille, 1802): 148
Dubovikoff, Yusupov, 2017: Ponera coarctata (Latreille, 1802): 209
Bračko, 2019: *Ponera coarctata* (Latreille, 1802): 172
Records: Lankaran (Ruzsky, 1905), Lerik (Arnol'di, 1948), Azerbaijan (Borowiec, 2014), Caucasus (Dubovikoff, Yusupov, 2017), Sheki, Dashkesan (Bračko, 2019).
Distribution: Albania, Andorra, Armenia, Austria, Balearic Islands, Belgium, Bulgaria, Channel Islands, Croatia, Czech Republic, France, Georgia, Germany, Gibraltar, Greece, Hungary, Iberian Peninsula, Israel, Italy, Kazakhstan, Kyrgyzstan, Luxembourg (type locality), Montenegro, Morocco, Netherlands, Poland, Portugal, Republic of Macedonia, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, Spain, Switzerland, Tunisia, Ukraine, United Kingdom of Great Britain and Northern Ireland. (https://www.antwiki.org).

128. *P. testacea* Emery, 1895
Bračko, 2019: *Ponera testacea* Emery, 1895: 172

Records: Guba (Bračko, 2019*).*
Distribution: Austria, Balearic Islands, Belgium, Bulgaria, Croatia, Czech Republic, France (type locality), Germany, Greece, Hungary, Iberian Peninsula, Italy, Montenegro, Morocco, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Switzerland, United Kingdom of Great Britain and Northern Ireland (https://www.antwiki.org).

DISCUSSION

As mentioned above, the myrmecophauna of Azerbaijan is currently comprised of 128 species in 28 genera. Considering the physiographic location of the republic and the wide variety of physiogeographic zones, a much higher number of species is to be expected, including species new to science. For comparison, the ant fauna of Georgia consists of 142 species from 35 genera (Gratiashvili, Barjadze, 2008), the fauna of Armenia - 119 species in 32 genera (Arakelyan, 1994, Borowiec, 2014). Of the endemics of Azerbaijan, two species should be noted - *Aulacopone relicta* Arnol'di, 1930 and *Messor diabarensis* Arnol'di, 1970 (Both found in Lerik). Thus, the provided checklist will be the start of systematic research into the ants of Azerbaijan.

Literature cited

Arakelian, G. R. 1994. Fauna of the Republic of Armenia. Hymenopterous insects. Ants (Formicidae). Erevan: Gitutium, 153 pp.

Arnoldi (Arnol'di), K. V. 1930. Studien über die Systematik der Ameisen. IV. Aulacopone, eine neue Ponerinengattung (Formicidae) in Russland. *Zoologischer Anzeiger,* 89: 139-144.

Arnol'di, K. V. 1948. Ants of Talysh and the Diabar depression. Their importance for the characterization of communities of terrestrial invertebrates and for historical analysis of the fauna. *Tr. Zool. Inst. Akad. Nauk SSSR,* 7(2): 206-262.

Arnoldi, K. V. 1964. Higher and specialized representatives of the ant genus *Cataglyphis* (Hymenoptera, Formicidae) in the fauna of the USSR. *Zoologicheskii Zhurnal*, 4(43): 1800-1815.

Arnoldi (Arnol'di), K. V. 1968. Important additions to the myrmecofauna (Hymenoptera, Formicidae) of the USS R, and descriptions of new forms. *Zoologicheskii Zhurnal,* (4)47: 1800-1822.

Arnoldi (Arnol'di), K. V. 1970. Review of the ant genus *Myrmica* (Hymenoptera, Formicidae) in the European part of the USSR. *Zoologicheskii Zhurnal*, 49: 1829-1844.

Arnoldi, K. V. 1977a. New and little known ant species of the genus *Leptothorax* Mayr, (Hymenoptera, Formicidae) in the European USSR and the Caucasus. *Entomologicheskoe Obozrenie*, 56: 198-204.

Arnoldi (Arnol'di), K. V. 1977b. Review of the harvester ants of the genus *Messor* (Hymenoptera, Formicidae) in the fauna of the USSR. *Zoologicheskii Zhurnal,* 56: 1637-1648.

Borowiec, L. 2014. Catalogue of ants of Europe, the Mediterranean Basin and adjacent regions (Hymenoptera: Formicidae). *Biologica silesiae*, 25(1-2).

Bračko G. 2019. New data on the ant fauna (Hymenoptera: Formicidae) of Azerbaijan. *Caucasian Entomological Bulletin*, 15(1): 165–175.

Dlussky, G.M., Soyunov, O.S., Zabelin, S.I. 1989. Ants of Turkmenistan. *Akhshkhabad: Ilim*, 273 p.

Dlussky, G. M., Radchenko, A. G. 1994. Ants of the genus *Diplorhoptrum* (Hymenoptera, Formicidae) from the central Palearctic. *Zoologicheskii Zhurnal* 73(2): 102-111.

Dubovikoff, D.A. & Radchenko, A.G. 2010. *Chalepoxenus hyrcanus* – a new ant species from Azerbaijan. *Caucasian Entomological Bulletin*, 6(2):207-208.

Dubovikoff, D. A., & Yusupov, Z. M. 2017. Family Formicidae - Ants. In Belokobylskij S. A. and A. S. Lelej: Annotated catalogue of the Hymenoptera of Russia. *Proceedingss of the Zoological Institute of the Russian Academy of Sciences,* 6: 197-210.

Gratiashvili, N.; Barjadze, S. 2008. Checklist of the ants (Formicidae Latreille, 1809) of Georgia. Proceedings of the Institute of Zoology (Tbilisi) 23:130-146.

Seifert, B. 2019. The Rubens morph of Formica exsecta Nylander, 1846 and its separation from Formica fennica Seifert, 2000 (Hymenoptera, Formicidae). *Deutsche Entomologische Zeitschrift,* 66: 55-61.

Karavaiev, V. 1926a. Beiträge zur Ameisenfauna des Kaukasus, nebst einigen Bemerkungen über andere palaearktische Formen. Konowia 5: 93-109.

Karavaiev V. 1926b. Beiträge zur Ameisenfauna des Kaukasus, nebst einigen Bemerkungen über andere palaearktische Formen. (Schluss). *Konowia* 5: 187-199.

Karavaiev V. 1926c. Beiträge zur Ameisenfauna des Kaukasus, nebst einigen Bemerkungen über andere palaearktische Formen. (Fortsetzung). *Konowia* 5: 161-169.

Karavaiev, V. 1929a. Myrmekologische Fragmente. II. *Zbirnyk Prats' Zoolohichnoho Muzeyu* 7: 205-220 [=Trudy. Ukrains'ka Akademiya Nauk. Fizichno-Matematichnoho Viddilu 13: 203-218].

Karavaiev, V. 1929b. Beitrag zur Ameisenfauna der Wälder in der Umgegend von Brjansk. *Zbirnyk Prats' Zoolohichnoho Muzeyu* 7: 59-63 [=Trudy. Ukrains'ka Akademiya Nauk. Fizichno-Matematichnoho Viddilu 13: 57-61].

Karavaiev, V. 1932. Zwei neue Ameisen aus Aserbeidschan (Transkaukasien). *Zoologischer Anzeiger,* 98: 248-250.

Radchenko, A. G. 1997. Review of the ants of scabriceps group of the genus *Monomorium* Mayr, (Hymenoptera, Formicidae). *Annales Zoologici* (Warsaw), 46: 211-224.

Ruzsky, M. 1902. Material on the ant fauna of the Caucasus and the Crimea. *Protokoly Obshchestva Estestvoispytatelei pri Imperatorskom Kazanskom Universitete,* 206: 1-33.

Ruzsky, M. 1905. The ants of Russia. (Formicariae Imperii Rossici). Systematics, geography and data on the biology of Russian ants. Part I. *Trudy Obshchestva Estestvoispytatelei pri Imperatorskom Kazanskom Universitete,* 38(4-6): 1-800.

Salata, S., Borowiec, L. Radchenko, A.G. 2018. Description of *Plagiolepis perperamus*, a new species from East-Mediterranean and redescription of *Plagiolepis pallescens* Forel, 1889 (Hymenoptera: Formicidae). *Annales Zoologici*. 68(4): 809–824.

DOI: 10.3161/00034541ANZ2018.68.4.005

Seifert, B. 2019. The Rubens morph of *Formica exsecta* Nylander, 1846 and its separation from *Formica fennica* Seifert, 2000 (Hymenoptera, Formicidae). *Deutsche Entomologische Zeitschrift*, 66: 55-61.

AnWiki: https://www.antwiki.org